ENERGY TRANSFER

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Structure to Electrolyte Potential Measurement

Code Reference:	**Procedure No.: HLD.03**	
49 CFR: 195.567, 195.571, 195.573	***Effective Date: 04/01/18***	**Page 1 of 11**

1.0 Purpose

This Standard Operating Procedure (SOP) describes how to take voltage measurements of the electrochemical potential of the pipe or other metallic structures in an electrolyte such as soil or water.

2.0 Scope

This SOP describes how to perform basic structure-to-electrolyte potential measurements.

3.0 Applicability

Pipe to Soil Voltage Potential Measurements (P/S) are used to evaluate the level of cathodic protection on a pipe or metallic structure with respect to a standard reference electrode. The test procedures and techniques described apply to all structure-to-electrolyte potential measurements regardless of the type of corrosion potential survey being conducted.

4.0 Frequency

As required when performing all corrosion control surveys required to monitor or troubleshoot.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Vice President of Operations

6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

Terms	**Definitions**
Structure-to-electrolyte potential	The potential difference between the structure of a buried or a submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.
Reference Electrode	An electrode whose open circuit potential is constant under similar conditions of measurement, which is used for measuring the relative potentials of other electrodes.
Half Cell	Pure metal in contact with a solution of known concentration of its own ion, at a specific temperature develops a potential, which is characteristic and reproducible. One half of a corrosion cell.
IR Drop	The voltage across the resistance, in accordance with Ohm's Law.

7.0 Structure to Electrolyte Potential Measurement

To measure the potential difference between the structure and the electrolyte, the operations personnel uses the following:

- Voltmeter
- Reference electrodes
- Test leads
- Maintenance of instrumentation and equipment
- Instrument connections
- Reference cell location
- Voltmeter data and determining voltage drops

NOTE: The following SOPs reference D.03 and provide the documentation and reporting requirements:

- *SOP HLD.20 Annual Corrosion Control Survey*
- *SOP HLD.15 Close Interval Survey*
- *SOP HLD.19 Critical Bond Inspection*

7.1 Voltmeter

Follow the procedure below for proper voltmeter usage.

Step	Activity
1	**PERFORM** the structure-to-electrolyte measurements using a high impedance digital voltmeter with appropriate ranges.
2	**VERIFY** the instrument impedance value is high enough to avoid errors due to the impedance of external circuit components; typically, a minimum value of 10 mega ohms is sufficient.

NOTE: Analog to digital converters are used in instruments and, in these cases, it should be understood that the speed at which the readings are captured sometimes results in the recording of only a portion of the waveform.

7.2 Reference Electrodes

Use the following procedure for reference electrodes. A saturated copper-copper sulfate electrode is the most common reference electrode used. A typical copper/copper sulfate electrode (CSE) is shown in Figure 1.

Step	Activity
1	**USE** a saturated copper/copper sulfate electrode (CSE) for onshore corrosion control survey work.

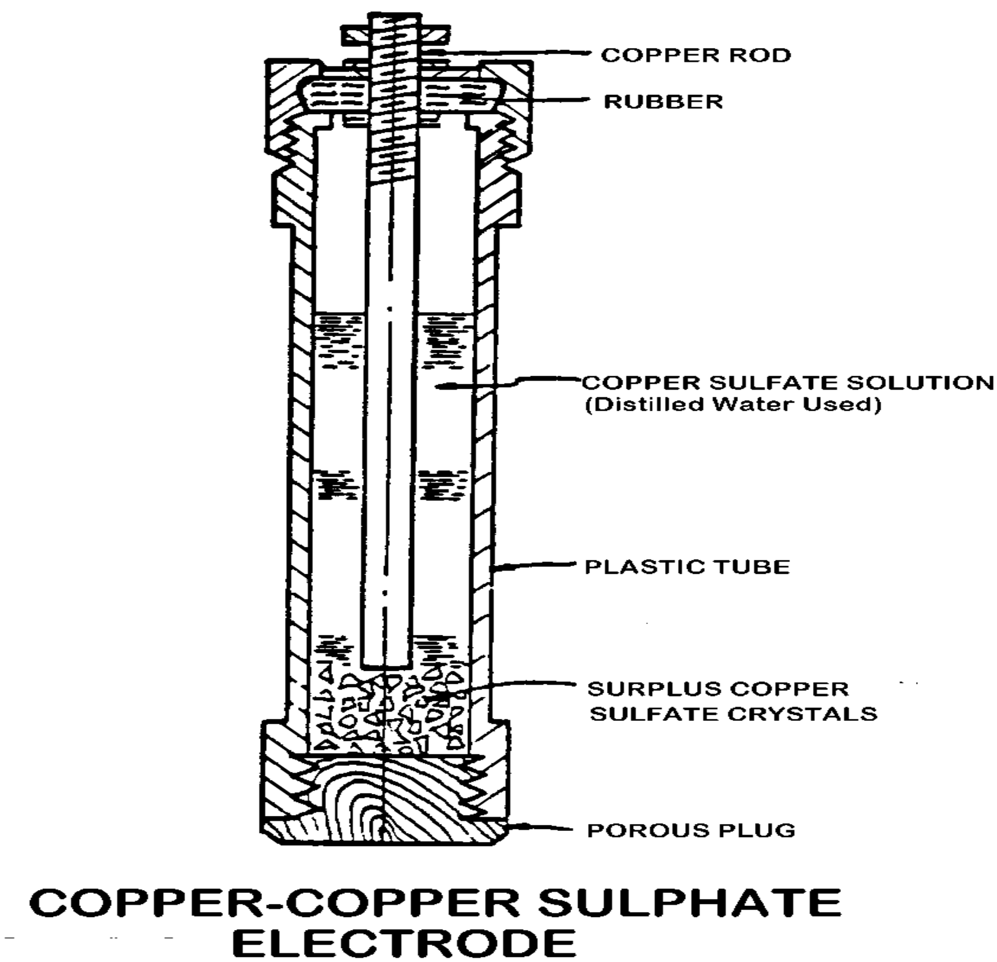

Figure 1: Copper-Copper Sulfate Electrode

Step	Activity
2	**USE** the silver/silver chloride reference for environments with salt or brackish water.
3	If necessary, **USE** a zinc electrode as the reference electrode. **CONSULT** the Corrosion Specialist prior to use.

NOTE:

- The Zinc reference electrode does not have the stability levels of the above mentioned reference electrodes.
- The reference electrode becomes a half-cell of a measurement circuit when inserted into the electrolyte. The other half-cell is the structure being tested. Refer to Figure 2.

VOLTAGE EQUIVALENTS:

Voltage equivalents to CSE value of -850mV at 25°C (77°F) are:

- Silver/silver chloride electrode in 25 ohm-cm water -800mV
- Zinc reference electrode +250mV

To convert the silver/chloride potential value to the equivalent CSE value, add -0.05 volts to the silver/silver chloride potential value. To convert the zinc potential value to the equivalent copper sulfate electrode value, add -1.1 volts to the zinc electrode potential value.

Example:

-0.800v vs Ag/AgCl

+ -0.050v Conversion factor for CSE

= -0.850v Corrected to CSE

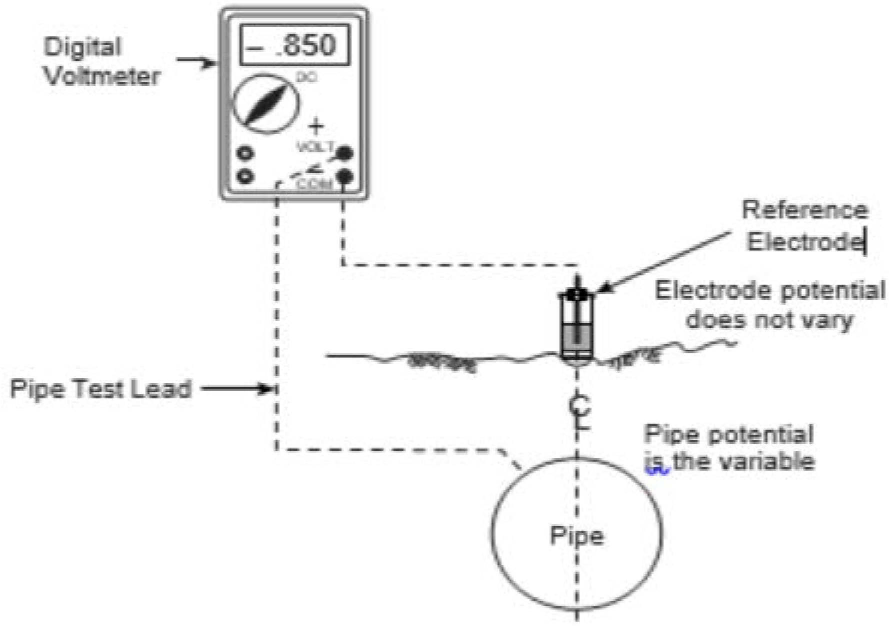

Figure 2: Typical Pipe-to-Soil Potential Measurement

7.3
Test Leads

Follow the procedure below for test leads.

Step	Activity
1	**VERIFY** test leads are of sufficient wire size and length, which helps avoid any significant voltage drop due to the current flowing in the circuit.
2	**VERIFY** test leads are flexible for convenience of use, but strong enough to resist breakage that could result in an open circuit.
3	**VERIFY** leads are covered with an electrically insulating material, which helps prevent electrical contact with structures external to the measuring circuit.

4	**VERIFY** test lead ends are fitted with clips or fittings that allow good low resistance connection to the circuit connection points.

7.4 Maintenance of Instrument - ation and Equipment

Follow the procedure below for the maintenance of instrumentation and equipment.

Step	Activity
1	**CONDUCT** calibration checks on voltmeters to confirm their readings are within the tolerances in the instrument specifications, in accordance with *BP B.02 Certification and Calibration of Test Equipment*.
2	**MAINTAIN** copper/copper sulfate reference electrodes on a regular basis.
3	**REMOVE** the copper rod and clean it with a non-metallic, abrasive material to maintain a bright surface. **NEVER USE** any type of metal oxide emery cloth or sand paper.
4	**REPLACE** the copper sulfate solution with distilled water (pH 7.0) and fresh copper sulfate crystals or pre-mixed copper sulfate solutions at least annually or whenever the electrolyte is suspected to be contaminated.
5	**CONFIRM** the saturated condition of the electrolyte by the presence of un-dissolved copper sulfate crystals visible in the solution.
6	**CHECK** the reference electrodes for accuracy prior to their use. **TEST** them against a standard electrode or by checking two electrodes against each other. **DO NOT CHECK** two references with different temperatures.

NOTE: A standard electrode should be a new electrode, not previously used in the field and retained for testing other electrodes. Measure the potential difference between the two electrodes, placed side by side, in a plastic tub with tap water filled to above the top of the porous plug. Calibration of an electrode in the field when a calibration issue is suspected can be done by placing two reference electrodes close to each other in soil and measuring the potential difference between the two electrodes. The potential difference should not exceed ten millivolts between the two electrodes. If the difference is excessive, then either one or both of the electrodes have become contaminated.

Step	Activity
7	**MAINTAIN** test leads in good condition.
8	**REPAIR** any breaks in cable insulation and/or frayed wire ends.
9	**REPLACE** clips and connecting fittings if there is potential for them to present a high resistant connection.
10	**STORE** test leads in such a way as to prevent kinks that may develop into cable discontinuities.

7.5 Instrument Connections

Follow the procedure below for instrument connections.

Step	Activity
1	**PERFORM** cathodic protection pipe-to-soil (structure to electrolyte) potential measurements.
2	**CONNECT** the instrument positive terminal to the structure. **CONNECT** the instrument negative terminal to the reference electrode.

CAUTION: Serious errors can occur if the polarity of the reading taken is misinterpreted. Make sure the connection is as described above.

NOTE: The reading taken with this connection indicates, under normal conditions, that the reference electrode is negative with respect to the pipe.

7.6 Reference Cell Location

Verify the placement of the reference cell for a structure-to-soil potential measurement is as close to the metal/soil boundary as possible.

NOTE:

- The most practical placement of is to place the electrode at the surface of the soil directly over the structure. If placement over the pipeline is not practical, an offset placement of half-cell is permitted but the offset must be documented in remarks in corrosion database.
- Certain structures or situations, such as tank bottoms, foreign line crossings, and voltage controlled rectifiers, may require the installation of a permanently buried reference electrode.

CAUTION: Take care to avoid errors in measurement. Do not place reference electrodes in the following locations:

- Locations contaminated by oil, chemicals, or other foreign matter
- High-resistance contact locations due to frozen or dry soil conditions, rock, or sealed pavement areas
- Locations within the voltage gradient of anodes or foreign structures

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7.7 Voltmeter Data and Determining Voltage Drops

Follow the procedure below for voltmeter and voltage drop considerations.

Step	Activity
1	**SELECT** the voltmeter range for the best accuracy.
2	**EVALUATE** voltage drops (IR) other than those across the pipe to electrolyte boundary, for valid interpretation of the pipe-to-soil voltage measurement. **REFER** to *SOP HLD.22 Application of Cathodic Protection Criteria* for more details. The preferred method to evaluate IR drop is the Instant Off Method. Consult the Manager of Corrosion Services before utilizing an alternative method.
3	**TAKE** readings with instruments that are clean and properly adjusted. **OBTAIN** good electrical contacts between the half-cell and the soil. If the soil is dry, water may be added to improve soil contact resistance.
4	When taking the reading, and there is an odd reading or the meter will not give a steady reading, **STOP** and **VERIFY** that the correct meter function is selected and the following contacts are good: • Meter to test lead • Test lead to reference cell • Test lead to structure • Reference cell to electrolyte

8.0

Documentation Requirements

Record data in corrosion database or utilize the following form(s) as applicable:

9.0 References

Best Practice B.02 Certification and Calibration of Test Equipment

*HL*D.15 Close Interval Survey

*HL*D.19 Critical Bond Inspection

*HL*D.20 Annual Corrosion Control Survey

*HL*D.22 Application of Cathodic Protection Criteria

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	OQ Task
Measure Structure-to-electrolyte Potential – AC / DC	PLOQ406
Conduct Close Interval Survey	PLOQ407A
Annual Test Point Survey	PLOQ419

ENERGY TRANSFER

Soil Resistivity Measurement

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.06**	
49 CFR 195.588	***Effective Date: 04/01/18***	**Page 1 of 10**

1.0 Purpose

This Standard Operating Procedure (SOP) describes the determination of soil resistivity at various depths or at specific points, depending on the method used.

2.0 Scope

Soil resistivity measurements are used for anode bed design, location of corrosion areas on bare pipe, and evaluating the corrosivity of the soil.

3.0 Applicability

This SOP applies when soil resistivity measurements are to be determined.

4.0 Frequency

As required.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	**Responsibility**	**Accountability**	**Authority**
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0
Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP* HL*A.01 Glossary and Acronyms*.

Terms	Definitions
Wenner Four-Pin Method	Provides an average soil resistivity from the surface to the greatest depth measured. This is the most common method used for soil resistivity measurement and generally provides the most accurate data.
Barnes Layer Method	Analyzes the four-pin resistivity data derived from the Wenner Four-Pin Method to provide the resistivity of the various layers.
Single Probe Method	Uses a single probe where the tip and the shank of the probe are two electrodes that are electrically isolated.
Soil Box Measurement Method	Utilizes the Wenner Four Pin Method while a soil sample is contained in a clear, plastic box.

7.0
Soil Resistivity Measurement

Use the methods in this SOP to determine soil resistivity. The following procedures are described in this section:

- Wenner Four-Pin Method
- Barnes Layer Method
- Single Probe Method
- Soil Box Measurement Method
- Additional Considerations for ECDA

The soil resistivity is the measured resistance value in ohm-cm.

7.1 Wenner Four-Pin Method

The Operations Personnel follows the steps and activities below prior to tests, inspections, and overhauls.

Step	Activity
1	**USE** the following equipment for this test: • Soil resistivity test instrument that includes: o An alternator or vibrator current source o Galvanometer o Resistance bridge measuring circuit in one unit o Four (4) metal pins • Wiring to make the connections
2	**SELECT** the alignment of the measurement so the pins are in a straight line. If the measurements are made near the pipeline, **VERIFY** that the pins are perpendicular to the pipeline.
3	**DO NOT INCLUDE** large non-conducting bodies, such as boulders, concrete foundations, etc., which are not representative of the soil of interest.
4	**VERIFY** that conductive structures, such as pipe and cables, are not within fifteen (15) feet of the nearest pin unless they are at right angles to the measurement span.
5	**SELECT** pin spacing with regard to the depth of interest.

NOTE: Pin spacing of 2.5, 5, 10, 15, and 20 feet are commonly used.

Step	Activity
6	**LAY OUT** the pins in a selected configuration (straight line) and **DRIVE** each into the ground.

NOTE: Pin depth should not exceed one-fifth the spacing selected.

Step	Activity
7	**CONNECT** the pins to the soil resistivity test instrument.

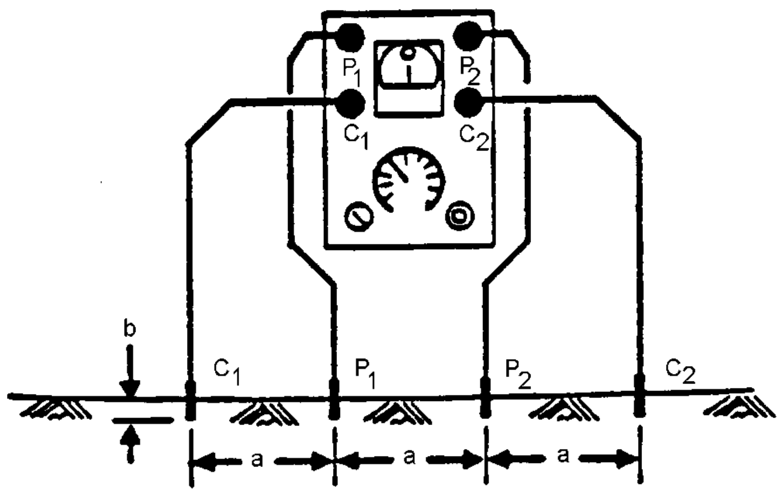


Figure 1: 4-Pin Method

Step	Activity
8	**ENERGIZE** the equipment measuring system. **WATER** the pin/soil contact point, if necessary, to obtain meaningful readings.
9	**COMPLETE** the applicable form(s) for *Four-Pin Soil Resistivity Test.* **RECORD** pin spacing, resistance or amperes and volts, date, weather, type of soil, etc.
10	**CALCULATE** the apparent soil resistivity as follows: (ohm-cm) = 191.5 aR

	Where: a = pin spacing in feet R = resistance in ohms
11	**RECORD** the soil resistivity on the applicable form(s) for *Four-Pin Soil Resistivity Test*.

7.2 Barnes Layer Method

Operations Personnel uses this method to determine the incremental soil layer resistivity.

Step	Activity
1	**CALCULATE** the following from the data recorded on the applicable form(s) for *Four-Pin Soil Resistivity Test*.: • Column I: the reciprocal of measured 4-pin test resistance. • Column II: the arithmetic difference between the Column I conductivities for adjacent pin spacing pin measurements. • Column III: the reciprocal of values in Column II. • Column IV: the soil resistivity factors.
2	**MULTIPLY** Column III times Column IV and **ENTER** in the layer resistivity Column V.
3	**RECORD** the soil resistivity on the applicable form(s) for *Four-Pin Soil Resistivity Test*.

NOTE:	This method is not fail-safe because it assumes uniform thickness of soil layers that must be parallel to the surface. A negative value may indicate a non-uniform layer.

7.3 Single Probe Method

Operations Personnel uses the single probe method when spot measurements are desired.

NOTE: A limitation of this method is that it only measures the resistivity of a small sphere (6-8 inch diameter) of the soil immediately surrounding the tip of the rod.

Step	Activity
1	**VERIFY** that both the tip and shank have good contact with the soil in order to obtain accurate measurements.
2	**MAKE** the necessary connections. **LOCATE** probe in the soil to be tested.
3	**MEASURE** the resistance between the two terminals at the top of the probe.
4	**CALCULATE** the soil resistivity as follows: (ohm-cm) = CR Where: C = probe constant R = measured resistance
5	**CHECK** the probe constant by immersion in a known resistivity environment.
6	**RECORD** the soil resistivity on the applicable form(s) for *Resistance Probe/Soil Box Resistivity Measurement*.

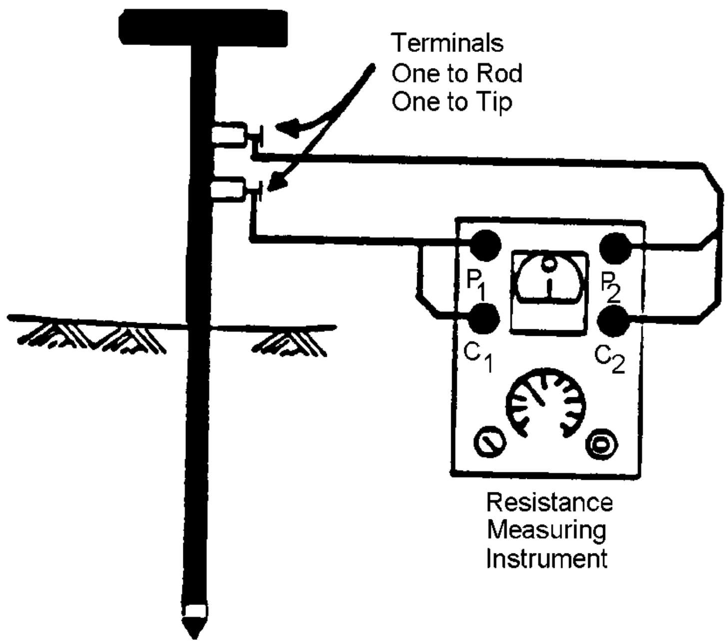


Figure 2: Single-Probe Soil Resistivity Device

7.4 Soil Box Measurement Method

Operations Personnel uses the following procedure for the soil box measurement method.

Step	Activity
1	**VERIFY** that the following equipment is available for taking soil box resistivity measurements: • A soil resistivity test instrument, or one with a separate AC current source • A voltmeter unit • An ammeter unit • A specially constructed soil box

Code Reference:	**Procedure No.: HLD.06**	
49 CFR 195.588	***Effective Date: 04/01/18***	**Page 8 of 10**

Step	Activity
2	**VERIFY** that soil samples are representative of the area or stratum of interest.
3	**FILL** the box flush to the top and **COMPACT** the soil in layers to eliminate air spaces as much as possible.
4	**TAKE** a measurement with a soil resistivity test instrument.
5	**RECORD** the soil resistivity on the applicable *form(s)* for *Resistance Probe/Soil Box Resistivity Measurement*.

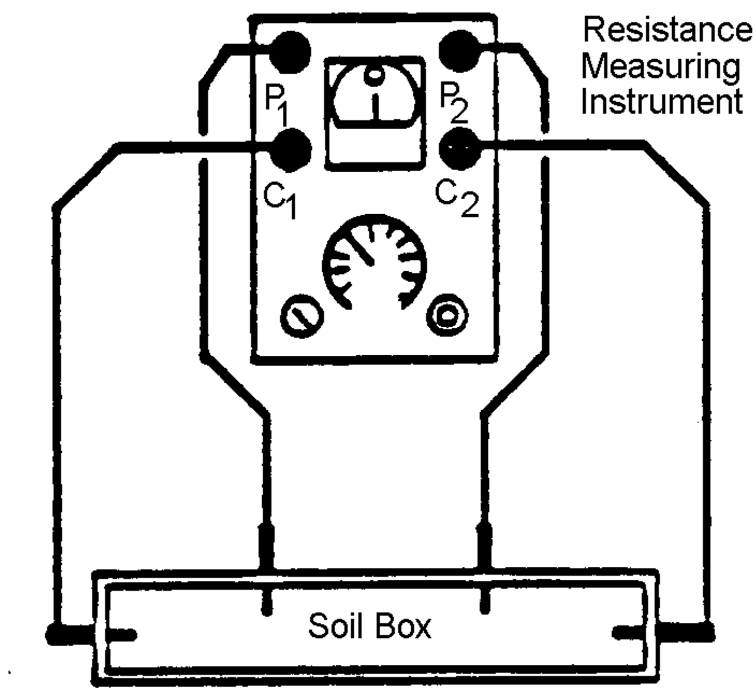


Figure 3: Soil Box Measurement

7.5
Soil Box

Operations Personnel uses the following additional procedures when soil resistivity is utilized as an Indirect Inspection Tool during an External Corrosion Direct Assessment.

Measurement Method

Step	Activity
1	**MEAURE** soil resistivity at uniform intervals throughout the DA Region using any of the methods detailed in this Procedure.

NOTE:	The maximum soil resistivity measurement interval for a DA should not exceed 100 feet.

Step	Activity
2	**MEASURE** soil resistivity at each ECDA Direct Examination location using any of the methods detailed in this Procedure.
3	**RECORD** the soil resistivity on the applicable form(s) for Resistance Probe/Soil Box Resistivity Measurement. . **SCAN** and **SAVE** a copy of this form to a secure network drive on the pipeline integrity drive.

8.0 Documentation Requirements

Record data in the electronic database or utilize the following form(s) as applicable:

- D.06.A Four-Pin Soil Resistivity
- D.06.B Resistance Probe/Soil Box Resistivity Measurement

9.0 References

There are no additional references for this SOP.

Appendix A: OQ Task Requirements

The table below identifies any Operator Qualification (OQ) task requirements for this SOP.

Task Description	OQ Task
Measure Soil Resistivity	PLOQ420

ENERGY TRANSFER

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.08**	
49 CFR 195.567	***Effective Date: 04/01/18***	

1.0 Purpose

This Standard Operating Procedure (SOP) describes the requirements to perform an exothermic weld.

2.0 Scope

This SOP describes how to perform an exothermic weld to attach a test lead wire or cathodic cable to a metallic structure.

3.0 Applicability

This SOP applies to pipelines and pipeline segments where cathodic protection is utilized.

4.0 Frequency

As needed: any time a test lead wire, bond wire or cathodic cable needs to be attached to a metallic structure for cathodic protection continuity, or testing.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0 Terms and Definitions

For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

7.0 Exothermic Weld

Operations Personnel follows these procedures in this section:

- Application
- Inspection
- Re-coating of Connection
- Database Record Updates

NOTE:
- For pipe having nominal wall thickness of 0.218" or less, conductors shall be attached by silver soldering, or Pin-Brazing.
- For pipe having nominal wall thickness greater than 0.218", conductors shall be attached by either silver soldering, or Thermite welding, or Pin-Brazing.
- For Dresser-coupled pipelines only, steel patches may be electric arc welded onto the pipe for the purpose of connecting heavy-duty bonding jumpers across the Dresser couplings. See Company welding procedures for welding on pressure or liquid containing facilities.
- See Engineering Standard 6.0211 Connection of Conductors *to Pipelines*

7.1 Application

The procedure below describes how to apply the exothermic weld.

Step	Activity
1	**DO NOT UTILIZE** a charge greater than 15grams charge.
2	For cable sizes larger than AWG #4, **APPLY** a crow foot design described in **Appendix B:** Allowable Strands per Exothermic Weld. For Large Cable Connections, **REFER** to Appendix C: Standard Drawing SF-007-TG.

NOTE: For rectifier negatives and pipeline interconnect cables, a weld pad per Appendix C: *Standard Drawing SF-9017* can be used in lieu of the crows foot connection.

Step	Activity
3	**CLEAN** the pipe surface where the test wire is to be attached.
4	**USE** a rasp or powered sanding disc to **CLEAN** the surface to a bright metal free of all mill scale, dirt, paint or coating. **DO NOT USE** a wire brush.

NOTE: The pipe coating is removed over an area of approximately 4”x 4”. The clean surface should not be wiped by hand, as this often leaves a grease film that will prevent effective welding. Prior to performing an exothermic weld an ultrasonic thickness inspection should be performed Refer to I.34 Use of Ultrasonic Thickness Equipment for Measurement of Wall Thickness. Check for gas or other flammable vapors prior to igniting the weld material in accordance with *SOP I.22 Gas Leakage Survey*

Step	Activity
5	**REMOVE** grease with a safety solvent.
6	If the steel is moist, **DRY** the surface.
7	If applicable, **USE** a torch to **DRY** the surface. **REMOVE** any carbon deposit prior to application of the weld.
8	**SELECT** the graphite mold suitable for the particular situation.
9	**REMOVE** enough insulation from the test wire to **INSERT** a length of bare copper wire into the center of the weld cavity of the graphite mold.

10	**EXTEND** the bare wire approximately ¼” beyond the outside of the mold. For AWG #10 or smaller test wire, **POSITION** a copper sleeve over the length of bare copper wire before it is positioned into the mold. **REFER** Appendix C: Standard Drawing SF-008-TG.
11	**PLACE** a metal disk into the mold to cover the weld cavity and **FILL** the mold with the powder from a 15-gram charge.
12	As the powder transfers from the charge container to the mold, **VERIFY** that the starting powder remains at the top of the mold.
13	**POSITION** the filled mold over the test wire on the prepared surface of the pipe.
14	**CLOSE** the cover on the mold, and **IGNITE** the powder, using a flint igniter.

CAUTION: Keep the mold dry at all times. Refer to the *Safety Procedure S-310 Personal Protective Equipment* to protect yourself when performing this task.

Step	Activity
15	During the melting period, following the powder ignition, **HOLD** the mold firmly in place.

NOTE: Gentle tapping on the side of the mold can be helpful in obtaining a good weld form.

Step	Activity
16	When the metal has solidified, **LIFT** the mold from the pipe.
17	**REMOVE** the aluminum oxide slag from the mold and the test wire connection and **INSPECT** the connection.

7.2 Inspection

Follow this procedure for inspecting the weld.

Step	Activity
1	**INSPECT** each welded wire or cable connection.
2	**TEST** strength of weld by tapping finished weld with a hammer.
3	**REMOVE** all weld slag, spatter, sharp edges, and burs from the metal surface.
4	**REJECT** any loose or obviously unacceptable installations.
5	If the weld is not successful, **DO NOT ATTEMPT** a second weld on the same spot. **PREPARE** a new surface a minimum of 3 inches away.

CAUTION: Multiple attempts in the same location can lead to material degradation and possible loss of pressure carrying capacity. Relocating the charge after a failed attempt will minimize this potential.

NOTE:	If after the first attempt an arc burn or hard spot has been created, remove the affected area with a soft-back sanding disc and verify remaining strength of material after defect removal. Refer to HLD.47 Evaluation of Remaining Strength of Pipeline Metal Loss

Step	Activity
6	**DO NOT ACCEPT** any portion of the test wire being exposed within the confines of the weld.
7	On horizontal connections **VERIFY** the maximum depression of the weld (after removal of the slag) is no lower than the top of the test wire.

NOTE: A low fill indicates one of the following:

- Insufficient weld metal was used.
- There is excessive leakage of molten metal from the mold.
- The test wire is positioned improperly inside the mold.
- The test wire or mold moved during installation.

Step	Activity
8	**INSPECT** the surface of the weld connection for finish that is: • Smooth • Free of major slag deposits • Free of pin holes • Porosity
9	**INSPECT** the weld to verify that the wire and weld are tight and the weld remains fixed to the pipe.

NOTE:	Porosity is normally caused by contaminants (water, oil, dirt, etc.) on the test wire, pipe, or weld mold.

7.3
Re-Coating of Connection

After inspection and acceptance of the connection, perform a coating repair in accordance with the company's Engineering Standard HL6.0306 Coating Of Field Joints, Valves, Tie-Ins, Girth Welds, and Short Sections of Pipe Using Two Part Epoxy.

7.4
Database Record Updates

Operations Personnel updates the appropriate database as follows.

Step	Activity
1	**COMPLETE** a Pipe Inspection per *SOP HLD.35 Pipe Inspection and Evaluation*.
2	**UPDATE** the Corrosion Database for any new test points

Code Reference :	**Procedure No.: HLD.08**	
49 CFR 195.567	***Effective Date: 03/01/14***	**Page 5 of 6**

8.0 Documentation Requirements

Record data in the electronic database or utilize the following form(s) as applicable:

- Pipe Inspection Database
- Corrosion Database

9.0 References

Small Cable Connection – Standard Drawing SF-008-TG
Large Cable Connection – Standard Drawing SF-007-TG
Weld Pad Installation/Cable Connection - Standard Drawing SF-9017
SOP D.35 Pipe Inspection and Evaluation
ES 6.0306 Coating of Field Joints, Valves, Tie-Ins, Girth Welds, Tanks and Short Sections of Pipe Using Two Part Epoxy
D.47 Evaluation of Remaining Strength of Pipeline Metal Loss
I.34 Use of Ultrasonic Thickness Equipment for Measurement of Wall Thickness
SOP I.22 Gas Leakage Survey
SOP HLD.35 Pipe Inspection and Evaluation

Contact the Corrosion Specialist for locating the Engineering Standard HL6.0306. Coating of Field Joints, Valves, Tie-Ins, Girth Welds, Tanks and Short Sections of Pipe Using Two Part Epoxy and Standard Drawings

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	OQ Task
Installation of exothermic electrical Connections	PLOQ412
Demonstrate how to Repair Small Holidays on New or Existing Coatings (above or below grade)	PLOQ403
Commission and Maintain Cathodic Protection Systems with AC Power Sources	PLOQ1801

Appendix B: Allowable Cable Strands per Exothermic Weld

Cable Size	Numbers of Strands	Number of Groups/ Cable Connections	Cable Strands per Group
12	7 or Solid	1	1 7

8	19	1	19
6	7 or 19	1	7 19
4	7 or 19	2	3-4 10-9
2	7 or 19	3	3-2-2 7-6-6
1/0	19 or 37	4	5-5-4 10-9-9-9
2/0	19 or 37	5	4-4-4-4-3 8-8-7-7-7
4/0	19 or 37	7	3-3-3-3-3-2-2 5-5-5-5-5-4-4-4

Appendix C: Standard Drawings

Standard Drawing SF-007 TG
Standard Drawing SF-9017
Standard Drawing SF-008 TG

ENERGY TRANSFER

Standard Operating Procedures
Applicable to Hazardous Liquids Pipelines and Related Facilities

CP Current Source System Installation and Inspection

Code Reference:	**Procedure No.: HLD.09**	
49 CFR 195.573	***Effective Date: 04/01/18***	

1.0 Purpose

This Standard Operating Procedure (SOP) establishes the requirements for installing and inspecting impressed current Cathodic Protection (CP) systems and documenting results.

2.0 Scope

These various devices provide cathodic protection to underground metallic structures.

- Rectifier units that contain:
  - A step-down voltage transformer with an adjustable secondary winding
  - A rectification element to convert alternating current to direct current
- Generators:
  - Thermoelectric
  - Gas turbine
  - Wind
  - Fuel cells
- Solar Devices

3.0 Applicability

This SOP applies to company facilities where impressed current cathodic protection systems are utilized.

4.0 Frequency

As required:

- Initial inspection: routine maintenance, or rectifier efficiency.
- Operational inspection: Six (6) times per calendar year with intervals not to exceed two and one-half months.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

Terms	Definitions
Rectifier	A device that converts alternating current to direct current.

7.0
CP Current Source System Installation and Inspection

The procedures in this SOP describe how to install and inspect CP current sources. This section contains the following procedures:

- Safety Considerations and PPE
- Rectifier Installation Procedures
- Initial Test and Inspection
- Annual Maintenance Inspection
- Operational Inspection
- Scheduled Activities

7.1
Safety Considerations and PPE

Personnel must follow the safety procedures below prior to installation, inspection, and maintenance of CP current sources.

WARNING:

- Maintenance and installation of system components upstream of the secondary side of the AC disconnect switch, with the exception of changing service fuses using appropriate tools and Personal Protective Equipment (PPE), must be performed by either a licensed, company approved electrical contractor or a company employee licensed in accordance with local and/or state regulations.
- Specialized PPE may be required prior to obtaining voltage measurements.

Step	Activity
1	**VERIFY** that personnel responsible for rectifier inspection, installation, and maintenance are properly trained and equipped with applicable PPE.
2	**DETERMINE** appropriate PPE required to complete the task prior to approaching the rectifier. **REFER** to *Safety Procedure S-090, Electrical Safety*, for PPE requirements.
3	**MAINTAIN** approach and protection boundaries when working on or near exposed energized electrical parts. **REFER** to *Safety Procedure S-090, Electrical Safety*, contains procedures for determining approach and protection boundaries.
4	**MEASURE** AC and DC potentials between the rectifier case and ground or **USE** an electronic voltage detection meter.
5	If the case to ground potential is greater than fifteen (15) volts, **OR** if non-contact voltage detector alarms, **DE-ENERGIZE** rectifier at the upstream disconnect switch. **INSPECT** rectifier for defective components, evidence of arcing / overheating, or a defective grounding system.

WARNING:

1. Electrical PPE rated for full AC input voltage is required for any energized troubleshooting when AC potentials >15 volts are measured on the rectifier case or if the non-contact voltage detector alarms.
2. A broken conductor or faulty component could energize the metallic case of the rectifier.
3. Grounding systems are designed to provide a direct metallic path to ground during such conditions; however, the breaker will only trip if current flow to ground exceeds the rated capacity of the input breaker.
4. Non-contact voltage detectors must have a lower detection threshold of <15 Volts AC.

7.2 Rectifier Installation Procedures

Operations Personnel follows the procedure below when installing rectifiers.

Step	Activity
1	Prior to installation, **REVIEW** drawings and maps. **SURVEY** the power pole location and trench route with pipe and cable locators to **DETERMINE** location of underground piping, cable, or other objects. **COMPLETE** Environmental Matrix. **INVESTIGATE** disposal options for cuttings and drilling fluids.
2	**VERIFY** Right-Of-Way (ROW) agreements are in place for the installation of the rectifier/groundbed.
3	**CONTACT** local electrical utility to verity that AC service is available at the proposed rectifier location and **OBTAIN** local requirements and cost estimates for the proposed service.
4	**MAKE** all appropriate One-Call notifications.
5	**FLAG** the location of underground objects crossing the cable trench. **REFER** to the current company procedure HLI.10 Excavation and Backfill regarding excavation and backfill.
6	**DIG** the trench with a minimum clearance of 1 ft. between cables and foreign structures.

NOTE: Unless otherwise specified, depth of cable trench should be 24 inches.

Step	Activity
7	**VERIFY** the trench is free of objects that may damage the cable, such as sharp rocks.

7.2.1 Installation of DC Cable

Follow the steps below for installation of DC cable.

Step	Activity
1	**INSTALL** DC cable so that it is not twisted or kinked and has sufficient slack to allow for future shifting of the soil.
2	**VERIFY** that cables installed underground are suitable for direct burial. If required, **INSTALL** the cable between the rectifier and the junction box in conduit.
3	If required by local regulation, **ENCASE** the cable in conduit and/or concrete.
4	**INSPECT** the cable to ensure it is free of cuts or nicks.
5	**INSTALL "Cathodic Protection Cable"** plastic warning tape 6 inches above the cable in congested areas.
6	**INSTALL** aboveground wiring in conduit. **VERIFY** conduit is free of burrs or other foreign materials.
7	**VERIFY** that the design and installation of the rectifier assembly is in accordance with *National Electric Code* and applicable local regulations.

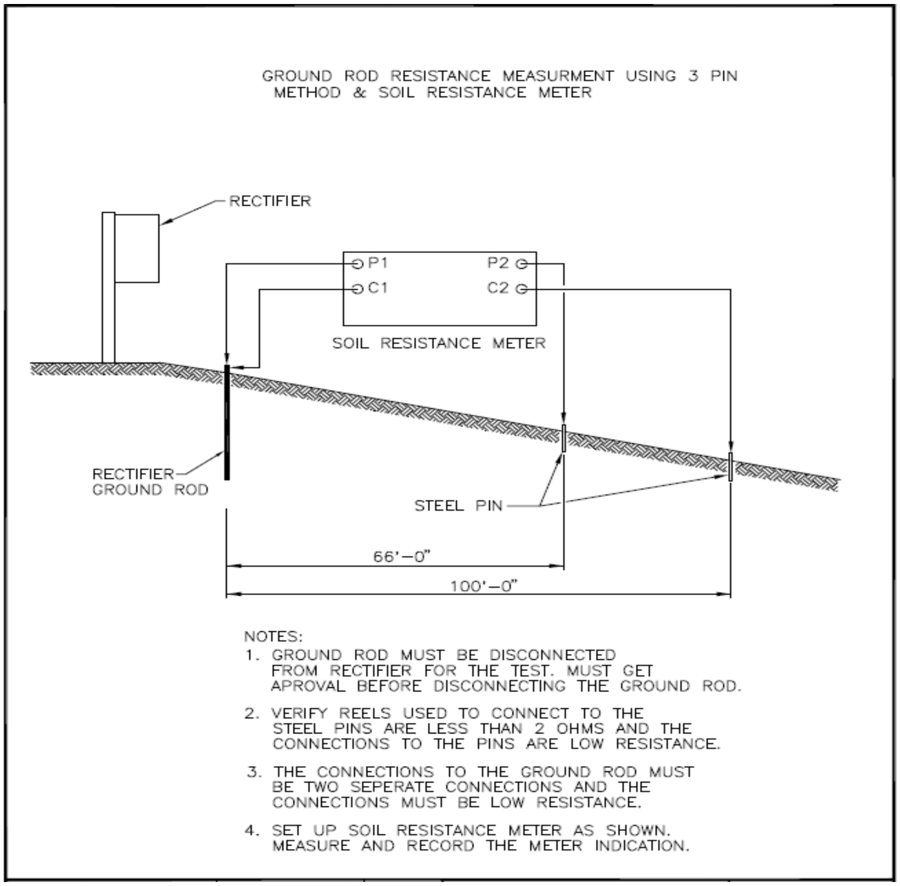
7.3 Initial Test and Inspection

Operations Personnel performs an initial test and inspection as a final checkpoint prior to energizing a new rectifier. Recording initial conditions and pertinent rectifier data serves as the basis for monitoring rectifier and anode bed performance.

7.3.1 Grounding System

Operations Personnel tests the grounding system using the procedure below.

Step	Activity
1	**TEST** the electrical resistance to earth of the rectifier and electrical service grounding system.
2	**USE** a clamp on ground resistance tester, the three-pin method, or the fall of potential method.



NOTE:
- The maximum resistance to earth for a new grounding system is 25 Ohms.
- The Corrosion Specialist may increase (or decrease) the maximum rectifier to ground resistance based on site conditions.

7.3.2 Electrical Power Supply

Operational Personnel inspects and tests the electrical power supply as follows.

Step	Activity
1	**CONDUCT** a visual examination of the AC supply assembly. **REPAIR** any visual defects including loose connections, broken or corroded conduit fittings, exposed conductors, broken insulation, and missing face plates prior to energizing the rectifier.
2	**VERIFY** that AC disconnect switches, breakers, and/or fuse boxes upstream of the rectifier are operational.

Step	Activity
3	**VERIFY** that the rectifier input circuit breaker is off and that the rectifier AC input is rated and configured to accept line voltage.

NOTE: Most rectifiers can be configured for 110 or 220 volt input.

Step	Activity
4	**DISCONNECT** the transformer secondary from the rectifier stack by removing the shorting bars. **TURN ON** the AC power to the unit at the line power disconnect switch/breaker. **VERIFY** that the rectifier input circuit breaker remains in the OFF position.
5	**MEASURE** voltage to the rectifier AC input terminals. **VERIFY** that the line voltage matches the rectifier input voltage rating and configuration.

7.3.3 Transformer

Operations Personnel inspect and tests transformers using the procedure below.

Step	Activity
1	**TURN ON** the rectifier input circuit breaker. **MEASURE** the AC voltages between: • Adjacent fine taps • Adjacent coarse taps • Low fine and the low coarse taps • High fine and the high coarse taps
2	**Clean** coarse and fine tap bars before reinstallation

NOTE: Taking measurements between adjacent coarse or fine taps should yield equal increments. Any readings not equal to the other adjacent readings indicate problems with the transformer windings. Readings taken between the lowest coarse and lowest fine should yield the lowest possible voltage output of the unit. Measurements taken between the highest coarse and highest fine should yield the highest possible voltage output of the unit.

Step	Activity
3	**TURN OFF** the AC power and **VERIFY** circuit is de-energized. **REPLACE** the shorting bars to connect rectifier stack to transformer secondary. **ADJUST** rectifier coarse and fine tap settings to the lowest output.

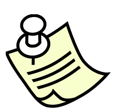
7.3.4 DC Output

The Operations Personnel inspects and tests the DC output using the procedure below.

Step	Activity
1	**VERIFY** that the positive DC terminal of the rectifier is the anode bed and the negative DC terminal of the rectifier is connected to the structure (pipeline).
2	**MAKE** a final confirmation of correct rectifier DC output connections by measuring structure-to-electrolyte potentials at a location in close proximity to the rectifier, but electrically remote from the anodic gradient of the groundbed. **USE** a current interrupter or manual switching for this test.
3	**RECORD** potentials with the rectifier output cycled ON and OFF. Structure-to-electrolyte potentials should increase (become more negative) when the rectifier is switched ON.

CAUTION: Reversing rectifier outputs leads will cause metal loss at the structure (pipeline) and can cause structure failure.

Step	Activity
4	**OBSERVE** cathodic potential deflections when the rectifier is switched ON. **RECORD** potentials at the closest upstream and downstream test stations.
5	**TURN OFF** the AC power supply before adjusting tap settings. **INCREASE** rectifier tap settings incrementally until the desired DC current output is reached. **ADJUST** the output of the rectifier to provide sufficient current to meet the selected cathodic protection criterion.
6	**MEASURE** structure-to-electrolyte potentials of the AC ground / neutral with the rectifier ON and OFF.



NOTE:
- Consult Corrosion Specialist if operation of the impressed current rectifier / groundbed shifts the AC ground / neutral in a positive direction.
- Consider a resistance bond between the rectifier negative terminal and the AC ground / neutral if cathodic interference is confirmed.

Step	Activity
7	**RECORD** results in the Corrosion Database.

7.3.5 Circuit Resistance

Operations Personnel inspect and test the circuit resistance using the procedure below.

Step	Activity
1	**MEASURE** the output voltage and current with the rectifier on and off. **USE** Ohms Law to **DETERMINE** the groundbed resistance value.
2	**REPEAT** measurements for several different rectifier output settings and **RECORD** the average of the calculated groundbed resistance values.

NOTE:
Output circuit resistance = Change in ON/OFF voltage (volts) / Change in ON/OFF current (amps)

Step	Activity
3	For new construction, **REPEAT** circuit resistance measurements during the next scheduled rectifier inspection to provide adequate time for backfill consolidation and moisture absorption around the anodes.
4	**REPEAT** structure-to-soil potential measurements at the closest upstream and downstream test stations at earliest convenience after energizing the rectifier.

NOTE: Adjustments to the rectifier output may be required at this time due to polarization of the line.

7.3.6 Records and Reporting

Operations Personnel records and reports findings using the procedure below.

Step	Activity
1	**RECORD** initial rectifier commissioning data on the applicable form(s) for *Rectifier/Groundbed Installation Data* including most of the information contained on the manufacturer's nameplate and instruction booklet. **ATTACH** an "as built" drawing.
2	**NOTIFY** neighboring utilities as required using the applicable form(s) for D.09.B *Cathodic Unit Installation Notice* when cathodic interference could result. Contact area-coordinating committees, if they exist, to advice of a proposed/new cathodic protection installations.
3	**COMPLETE** recording requirements in the Corrosion Database.

7.4 Annual Maintenance Inspection

Operations Personnel performs annual inspections of cathodic protection systems. Refer to Section 7.1 for safety requirements prior to inspection or maintenance.

Step	Activity
1	**VISUALLY** inspect all above grade components of the cathodic protection system for damage and housekeeping problems including: • Third party damage from farm or mowing equipment • Dirt, insect, or rodent infiltration • Condition of hinges, hasps, conduits, cables, boxes, etc.
2	**CLEAN, TREAT,** and/or **REPAIR** cathodic protection systems as required to maintain operational status.

NOTE: Newer installations may be equipped with digital display power meters.

7.4.1 Grounding System

The maximum test interval for grounding systems is five (5) years. Record testing of the Grounding System in the applicable electronic database. Operations test the electrical resistance to earth of the rectifier and electrical service grounding system using:

- A clamp on ground resistance tester
- The three-pin method
- The fall of potential method
- Report deficiencies to company Corrosion Specialist

NOTE:
- The maximum resistance to earth for an existing grounding system is 25 Ohms.
- The Corrosion Specialist may increase (or decrease) the maximum rectifier to ground resistance based on site conditions.

7.4.2 AC Breaker Inspection

Operations Personnel follows the procedure below when conducting an annual inspection of AC breakers.

Step	Activity
1	**VERIFY** operation of the AC disconnects switch/breaker and the rectifier input circuit breaker.
2	Visually **INSPECT** for the presence of corroded or faulty connections, evidence of excessive heat or arcing, inoperative meters, cracked insulation, bare wires, etc.

NOTE: Maintenance of electrical components is performed by qualified personnel only.

7.4.3 Neutral Bonds

Operations Personnel follows the procedure below when conducting an annual inspection to determine the potential for cathodic interference of AC ground / neutral systems.

Step	Activity
1	**MEASURE** structure-to-electrolyte potentials of the AC ground / neutral with the rectifier ON and OFF.

NOTE:

- Consult Corrosion Specialist if operation of the impressed current rectifier / groundbed shifts the AC ground / neutral in a positive direction.
- Consider a resistance bond between the rectifier negative terminal and the AC ground / neutral if cathodic interference is confirmed.

Step	Activity
2	**MEAURE** the amperage flowing through the resistance bond on all rectifiers equipped with an AC ground / neutral bond.
3	**RECORD** results in the Corrosion Database.

7.4.4 Meter Calibration

Operations Personnel follows the procedure below for calibrating meters during the annual inspection.

Step	Activity
1	**READ** the panel instruments and remote monitoring instrumentation, if equipped, in the rectifier and **COMPARE** with a calibrated field meter for accuracy.
2	**ADJUST** panel instruments, if possible, to match calibrated field meter readings.
3	**PERFORM** testing with the rectifier ON and OFF.

7.4.5 Groundbed Inspection

Operations Personnel inspects ground beds by following the procedure below during the annual inspection.

Step	Activity
1	Visually **INSPECT** the groundbed site to determine if there has been any evidence of disturbances over the anodes or cables that may have resulted in damage. Possible causes that should be of concern are: • Soil erosion • Rodent activity • Washout • Construction activities
2	**NOTE** and **INVESTIGATE** recent installations of underground utility structures for possible interference problems.

7.4.6 Groundbed Resistance

Operations Personnel measures groundbed resistance as follows during the annual inspection.

Step	Activity
1	**MEASURE** the rectifier output voltage and current across the positive and negative output terminals with the rectifier on and off. Use these readings to **CALCULATE** groundbed resistance.
2	**MEASURE** current output to individual groundbed legs or anodes, as applicable.

NOTE:
- Output current is calculated from the voltage drop across a calibrated shunt. Refer to Best Practice HL*D.05 Shunt Current Flow Measurement*.
- Many rectifiers are equipped with dedicated shunts to measure current flow to individual anodes or legs of a distributed anode bed.
- Groundbed watering may be required in dry areas to maintain required outputs

Step	Activity
3	**REVIEW** output values to **DETERMINE** that the rectifier is operating within manufacturers rated capacity.
4	**RECORD** results in the Corrosion Database.

7.4.7 Efficiency Test

Operations Personnel follows these procedures to conduct an efficiency test during the annual inspection.

Step	Activity
1	**PERFORM** an efficiency test as deemed necessary by the Corrosion Specialist.
2	**COUNT** the revolutions of the kilowatt-hour meter disc and **USE** with the meter constant in the calculation below.
3	Percent efficiency (%) = $\frac{\text{DC volts x DC amps x seconds}}{\text{Kh Factor x 3600 x Disc revolutions}} \times 100$ Where: Seconds = time in seconds for disc revolutions counted. A minimum time of 60 seconds should be used. Kh Factor = power meter kilowatt-hour factor as indicated on the power meter. Revolutions = number of disc revolutions counted.
4	**RECORD** results in the corrosion database.

NOTE:
- This test is not required for rectifiers equipped with silicon diode stacks.
- This test is not accurate for very low output rectifiers (<50 Amperes DC) due to the low speed of the kilowatt-hour meter disc.
- This test requires a spinning disc style power meter.

7.4.8 Potential Verification

Operations Personnel follows the procedure below during the annual test point survey.

Step	Activity
1	**MEASURE** structure-to-electrolyte potentials at the nearest upstream and downstream pipeline test stations.
2	**DO NOT USE** the rectifier negative (-) load connection for the measurement of pipe-to-soil potential.
3	**ADJUST** rectifier as required to maintain selected cathodic protection criterion.
4	If immediate repairs are not possible, **RESTORE** or have a plan in place for repair or replacement by the next bi-monthly operational inspection. **For intrastate pipelines regulated by state agencies,** follow specific state regulatory guidance. Example: Louisiana requires restoration within 90 days.
5	**DOCUMENT** proposed remedial action in accordance with SOP HL*D.40 Corrosion Control Remedial Action*. **DOCUMENT** readings, maintenance, adjustments and testing in the Corrosion Database.

7.4.9 Records and Reporting

Operations Personnel records and reports findings using the procedure below.

Step	Activity
1	**GRAPH** and **REVIEW** rectifier output voltage, current, and groundbed resistance trends with the Corrosion Specialist.
2	**INVESTIGATE** any significant changes in historic rectifier output, groundbed resistance, or efficiency to verify that adequate cathodic protection is being provided to all assets in the area.
3	**ADJUST** taps, as required, to maintain historic rectifier output. **TROUBLESHOOT** groundbed in accordance with SOP HLD.10, *Anode Bed Inspection and Installation*.

NOTE:

1. Groundbeds should be recommended for replacement when output trends indicate the system is no longer capable of providing historic cathodic protection output current levels.
2. Consideration should be given to extreme weather events that can limit groundbed output (and may not be corrected by installation of a new groundbed). In such cases, a higher output voltage rectifiers should be evaluated for effectiveness.
3. Consideration may be given to further testing to evaluate whether historic current output levels are required to maintain adequate levels of cathodic protection. Close interval surveys are recommended in such cases across all areas influenced by the rectifier / groundbed in question. Refer to SOP HL*D.15 Close Interval Surveys* for guidance.

Step	Activity
4	**DOCUMENT** proposed remedial action in accordance with SOP HL*D.40 Corrosion Control Remedial Action*. **DOCUMENT** readings, maintenance, adjustments and testing in the Corrosion Database.

7.5 Operational Inspection

Operations Personnel performs an operational inspection six (6) times each calendar year, but at intervals not exceeding two and one half months as follows. Refer to Section 7.1 for safety requirements prior to inspection or maintenance.

Step	Activity
1	**PERFORM** operational rectifier inspections to ensure the continuous and effective operation of the impressed current cathodic protection systems connected to company underground structures.
2	Visually **INSPECT** all above grade components of the cathodic protection system for damage and housekeeping problems, including: • Third party damage from farm or mowing equipment • Dirt, insect, or rodent infiltration • Condition of hinges, hasps, conduits, cables, boxes, etc.
3	**CLEAN, MODIFY,** and/or **REPAIR** cathodic protection systems as required to maintain operational status.
4	**MEASURE** the current and voltage output of the rectifier.

NOTE: Rectifier output voltage is measured across the positive and negative output terminals of the rectifier. Output current is calculated from the voltage drop across a calibrated shunt or measured using a calibrated ammeter.

Step	Activity
5	**OBTAIN** compliance measurements using either a calibrated field meter or a calibrated electronic remote monitoring device.

NOTE: Only use panel meters to verify rectifier operation following a maintenance outage, electrical storm, etc.

Step	Activity
6	If any improper conditions are found, **MAKE** corrections before proceeding with the inspection.
7	If immediate repairs are not possible, **RESTORE** or have a plan in place for repair or replacement by the next bi-monthly operational inspection. **For intrastate pipelines regulated by state agencies,** follow specific state regulatory guidance. Example: Louisiana requires restoration within 90 days.
8	**MEASURE** on and off potential readings by cycling rectifier, near the pipe negative cable connection. **VERIFY** that potentials shift in the negative direction when rectifier is energized.
9	**COMPARE** current readings with previous readings and **INVESTIGATE** discrepancies.
10	**ADJUST** taps, as required, to maintain historic rectifier output. **TROUBLESHOOT** groundbed, as required to restore historic output, in accordance with SOP HLD.10, *Anode Bed Inspection and Installation*.
11	**INVESTIGATE** the impact of any rectifier outage and/or decline in rectifier output. **REVIEW** historic levels of cathodic protection and **VERIFY** potentials upstream and downstream of the depleting / problematic current source.

NOTE:

1. Utilize historic CIS, if available, to identify the lowest potentials areas upstream and downstream of the depleting / problematic current source. These areas should be monitored to verify potentials.
2. Conduct CIS upstream and downstream of the depleting / problematic current source if no historic CIS data is available for potential verification. Consult the Corrosion Specialist to determine required distances.
3. Current distribution to parallel lines can be impacted by changes in rectifier output. Verify that potentials on parallel lines and investigate any discrepancies.
4. Only use panel meters to verify rectifier operation following a maintenance outage, electrical storm, etc.

Step	Activity
12	**DOCUMENT** proposed remedial action in accordance with SOP HL*D.40 Corrosion Control Remedial Action*. **DOCUMENT** readings, maintenance, adjustments and testing in the Corrosion Database.

NOTE:

1. Groundbeds should be recommended for replacement when output trends indicate the system is no longer capable of providing historic cathodic protection output current levels.
2. Consideration should be given to extreme weather events that can limit groundbed output (and may not be corrected by installation of a new groundbed). In such cases, a higher output voltage rectifiers should be evaluated for effectiveness.
3. Consideration may be given to further testing to evaluate whether historic current output levels are required to maintain adequate levels of cathodic protection. Close interval surveys are recommended in such cases across all areas influenced by the rectifier / groundbed in question. Refer to SOP HL*D.15 Close Interval Surveys* for guidance.

7.6 Rectifier Efficiency Test

Operations Personnel performs an optional rectifier efficiency test using the procedure below.

Step	Activity
1	**PERFORM** a rectifier efficiency test, as directed by Corrosion Specialist if rectifier output has significantly dropped off without a change in settings or circuit resistance. **REFER** to Section 7.4.7 of this SOP for test procedures to perform rectifier efficiency test.
2	**DOCUMENT** Efficiency Test results in the Corrosion Database.

8.0

Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

- D.09.A Rectifier/Groundbed Installation Data
- D.09.B Cathodic Unit Installation Notice
- D.40.A Corrosion Control Remedial Action Report
- Corrosion Database

9.0
References

Best Practice D.05 Shunt Current Flow Measurement
HLSOP D.10 Anode Bed Inspection and Installation
HLSOP D.15 Close Interval Surveys
HLSOP D.40 Corrosion Control Remedial Action
S-310 Personal Protective Equipment
S-090 Electrical Safety
National Electric Code
HLSOP I.10 Excavation and Backfill
HLSOP H.21 Low Voltage (<600V) Electrical Equipment Inspection and Maintenance

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Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	**OQ Task**
Inspect Rectifier and Obtain Readings	PLOQ408
Commission and maintain Cathodic Protection Bonds	PLOQ409
Commission and Maintain Cathodic Protection Systems with AC Power Sources	PLOQ1801

ENERGY TRANSFER

Anode Bed Inspection and Installation

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.10**	
	Effective Date: 04/01/18	

1.0 Procedure Description

This Standard Operating Procedure (SOP) describes the inspection of impressed current cathodic protection anode beds.

2.0 Scope

This SOP covers the testing and inspection of impressed current cathodic protection anode beds.

3.0 Applicability

This SOP applies to remote and/or distributed impressed current anode beds used for applying cathodic protection to buried or submerged steel pipelines.

4.0 Frequency

As needed

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

Terms	**Definitions**
Conventional Anode Bed	An anode bed that is augured or trenched in place, where the anodes are placed either vertically or horizontally at a depth from 5 to 50 feet
Distributed Anode Bed	An anode bed that is augured or trenched in place, and located near the piping or structure that is being protected. The anodes are placed in a non-geometric pattern, and distributed as needed to overcome shielding effects, such as those found in station yards.
Deep Anode Bed	An anode bed that is drilled into place vertically to a depth greater than 50 feet

Terms	Definitions
Remote Anode Bed	A conventional or deep anode bed that is located a distance from the piping or structure being protected. The nearest anode is usually 200 to 500 feet or more from the protected structure.

7.0
Anode Bed Inspection and Installation

The following procedures are described in this section:

- Inspection
- Anode Cable Tracing
- Anode Profile Test
- Deep Anode Bed Testing

7.1
Inspection

Operations Personnel follows the procedure below for inspection.

Step	Activity
1	If the anode bed is found to not be discharging current or discharging current at a reduced rate, **TAKE** remedial measures to identify the problem and correct the situation.
2	**SELECT** the proper procedure for inspection based on the particular situation, such as described below.
3	**DOCUMENT** results in the Corrosion Database.

NOTE: If there is no current output, the apparent cause is a break in the header cable before the first anode or the negative cable for a single negative rectifier. A reduced current output may be due to anode depletion, anode cable failure within the anode bed, a break in a negative cable if there are multiple cables, or very dry conditions causing unusually high soil resistivity.

7.2
Anode Cable Tracing

Operations Personnel follows the procedure below for anode cable tracing.

Step	Activity
1	**USE** a pipe/cable locator instrument to trace positive and negative cables. Refer to *SOP HLB.04 Pipe Location and Marking*
2	**TURN OFF** the rectifier, and **DISCONNECT** the anode cable to be tested from the positive output terminal of the rectifier. If more than one anode header cable is connected to the rectifier, **TEST** only the circuit of no current output.
3	**USE** the anode installation drawing as a guide, and **TRACE** the signal along the header cable until the signal is lost.

NOTE: This may indicate a broken cable, be sure to mark the spot where the signal abruptly drops off.

Step	Activity
4	**PINPOINT** the cable break location as closely as possible to minimize the excavation necessary to find the break.
5	**MARK** the cable break location as accurately as possible on the drawings, sketches, and applicable forms. **FLAG** the location for repairs.
6	**COMPLETE** repairs as soon as possible for resumption of normal rectifier operation. If immediate repairs are not possible, **RESTORE** or have a plan in place for repair or replacement by the next bi-monthly operational inspection. **For intrastate pipelines regulated by state agencies,** follow specific state regulatory guidance. Example: Louisiana requires restoration within 90 days
7	**DOCUMENT** results in the Corrosion Database.

7.3 Anode Profile Test

Operations Personnel uses the procedure below for anode profile testing.

Step	Activity
1	**USE** a copper/copper sulfate reference electrode to obtain ground surface potential measurements over anode bed installation areas. **REFER** to Figure 1.

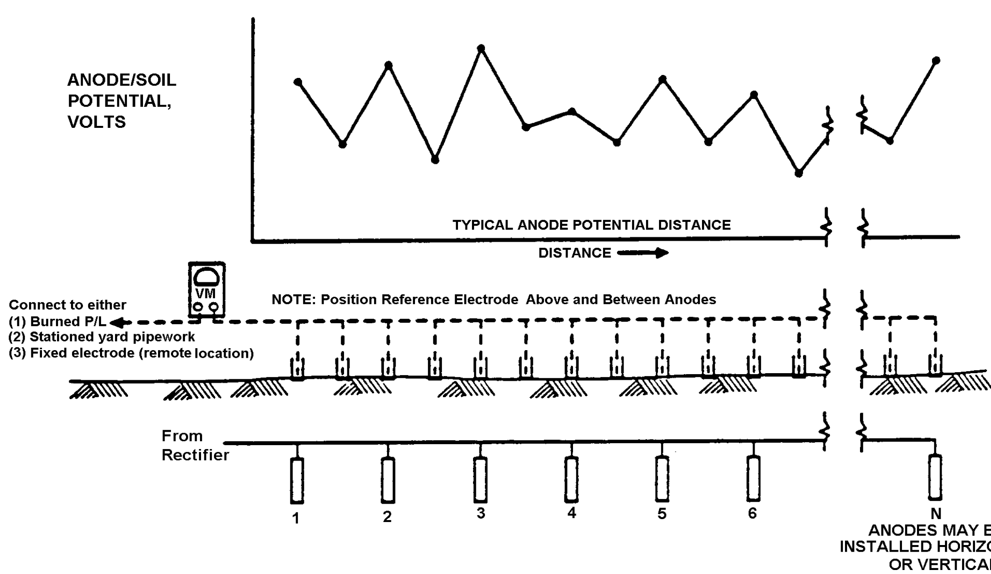

Figure 1: Anode/Soil Potential Volts

Step	Activity
2	**REVIEW** anode bed installation drawings for anode spacing and anode bed configuration.
3	**CONNECT** the negative lead of voltmeter to either: • The rectifier negative terminal • A buried pipeline test lead • The station yard piping at the closest convenient point • Another electrode at a remote location(s)
4	**ATTACH** the positive lead of the voltmeter to a copper/copper sulfate reference electrode.
5	**TAKE** and **RECORD** voltage readings over each anode and between each anode. **TRY** to be as accurate as possible with location of measurement points. **RECORD** these measurements on regular graph paper.

NOTE: The pattern of readings will show a positive potential peak for each actively working anode. The absence of a potential peak over an anode will indicate a non-working or depleted anode. Analysis of the anode bed profile will determine whether or not the anode bed or anode bed cables have been damaged and are in need of repair.

Step	Activity
6	If excavation is necessary, **FLAG** the area for repair or anode replacement.
7	**DOCUMENT** results on the applicable form(s) for *Anode Bed Profile.*

7.4 Deep Anode Bed Testing

Operations Personnel uses this procedure only for the measurements described below.

NOTE: Anode bed potential profiles cannot be conducted with deep anode beds.

Step	Activity
1	**MEASURE** individual anode current outputs where separate anode leads have been brought to the surface and placed in a junction box.
2	**RAISE** anodes for visual inspection or replacement, where possible and as required.
3	**ANALYZE** the data collected and **DETERMINE** if repairs or replacement are necessary.
4	**DOCUMENT** results in the Corrosion Database.

7.5 Evaluation of Anode Bed Inspections

Operations Personnel references *SOP HLD.40 Corrosion Control Remedial Action* to correct any deficiencies found.

8.0 Documentation Requirements

Record data in the electronic database or utilize the following form(s) as applicable:

- D.10.A Anode Bed Profile
- Corrosion Database

9.0 References

HLB.04 Pipe Location and Marking
HLD.40 Corrosion Control Remedial Action

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	**OQ Task**
Ground-bed Maintenance and Troubleshooting	PLOQ1800

ENERGY TRANSFER

Casing Isolation Testing

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.12**	
49 CFR 195.575	***Effective Date: 04/01/18***	**Page 1 of 11**

1.0 Purpose

This Standard Operating Procedure (SOP) describes tests to identify and locate an electrical short circuit between casing and carrier pipe at cased pipeline locations.

2.0 Scope

Electrical isolation is used to maintain adequate Cathodic Protection (CP) levels by isolating the protected structure from all foreign or unprotected structures, such as casings.

The first indication of a possible electrical short between the casing and carrier pipe is usually found during the Annual Corrosion Control Survey, where identical or near identical structure-to-electrolyte (pipe-to-soil) potentials are measured for both the casing and carrier pipe.

Casing and carrier potentials within ±100 mV indicate a possible shorted casing. Further testing is required to investigate these situations.

3.0 Applicability

This SOP applies to all company liquid pressurized piping installed within a casing.

4.0 Frequency

As required.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0 Terms and Definitions

For general terms, refer to *SOP* HL*A.01 Glossary and Acronyms*.

7.0 Casing Isolation Testing

Operations Personnel follow these procedures to identify and test potentially shorted casings:

- Identify shorted casings
- Panhandle Eastern test
- Polarization test
- Battery test
- Locating short circuits
- Remedial action

7.1 Identify Shorted Casings

Follow the procedures below to identity potential shorted casings.

Step	Activity
1	**IDENTIFY** all cased pipeline locations where the carrier pipe-to-soil potential (P/S) is within ±100 mV of the casing-to-soil potential (C/S).

NOTE: Casing and carrier pipe potentials within ±100mV are indications of a possible shorted casing.

Step	Activity
2	**DETERMINE** whether a casing isolation test has been performed. **VERIFY** that records are available to document the test.
3	If documentation of a previous casing isolation test is not available **OR** if conditions have changed to warrant additional testing, **PERFORM** the casing isolation test.

7.2 Panhandle Eastern Test

Follow the procedures below to conduct the Panhandle Eastern test.

Step	Activity
1	**CONDUCT** this test with the negative terminal of a DC power source connected to a temporary anode bed and the positive terminal connected to the casing, as shown in Figure 1.

NOTE: The anode bed must be at least 50 feet from the pipeline. Greater separation may be required when pipeline potentials are affected by the anodic gradient.

Step	Activity
2	**MEASURE** initial pipe-to-soil, casing-to-soil potentials. (See *SOP HLD.03 Pipe to Soil Potential Surveys*~~)~~ **VERIFY** placement of electrode is as near to over the top of the casing end and the carrier pipe as practical. **VERIFY** Electrode placement does not change during the test procedure. **RECORD** data on the applicable form *D.12.A Panhandle Eastern Test Maintenance Record.xls).*
3	**CONNECT** the circuit, and **ADJUST** the current output to provide approximately one (1) Amp of current to the casing. To control DC current output, **USE** either a variable resistor in series with the power supply, or a variable current output power supply.
4	**MEASURE** and **RECORD** pipe-to-soil potential, casing-to-soil potential, applied DC voltage, and applied DC current. **VERIFY** electrode placement does not change during the test procedure.
5	**INCREASE** current flow by approximately one (1) Amp, and **RECORD** current applied potentials. **REPEAT** in one (1) Amp increments for a minimum of five current applied test cycles. For each test cycle, **MEASURE** and **RECORD** P/S, C/S, applied DC voltage, and applied DC current cycle. Normally 5 – 7 test cycles (5 – 7 Amps) are sufficient. When using the Panhandle Eastern Test, **CONSIDER** a casing resistance of 0.08 ohms and above as insulated.

NOTE: If the pipeline is shorted to the casing, the pipe-to-soil and the casing-to-soil potentials will be essentially the same before the battery is connected, and will polarize to nearly the same potential when the battery is energized.

Step	Activity
6	**CALCULATE** the casing to carrier resistance as follows: $R = [[P/S_{initial} - C/S_{initial}] - [P/S_{current\ applied} - C/S_{current\ applied}]] / I$ Where: R = Casing to Pipe Resistance (Ohms) $P/S_{initial}$ = Pipe to Soil Potential (Volts) $C/S_{initial}$ = Casing to Soil Potential (Volts) $P/S_{current\ applied}$ = Pipe to Soil Potential with Test Current Applied (Volts) $C/S_{current\ applied}$ = Casing to Soil Potential with Test Current Applied (Volts) I = test current (Amperes)
7	**DOCUMENT** test results on the applicable form (*D.12.A Panhandle Eastern Test Maintenance Record*). **RECORD** status of casing insulation (shorted or not shorted) in the Corrosion Database.
8	**NOTIFY** Area Management and Corrosion Specialist if test results confirm a shorted casing.

NOTE: the location of the reference is at the casing end and over the pipeline/casing interface

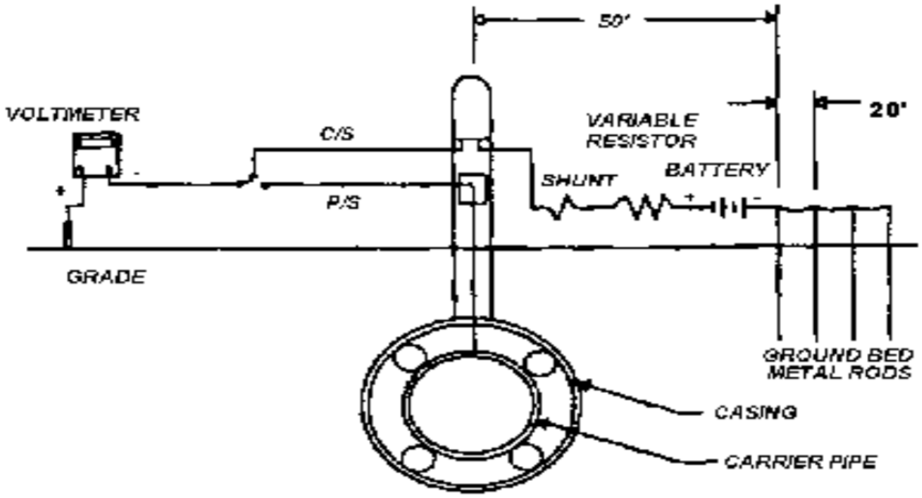

Figure 1: Panhandle Eastern Test Diagram

7.2.1 Polarization Test Method

Follow the procedures below to conduct the Polarization test.

This test method is based on the theory of polarization in a galvanic cell:

- When a current is applied across two structures electrically isolated within a common electrolyte, polarization will occur and polarization decay can be observed.
- When a current is applied across two structures electrically continuous within a common electrolyte, polarization will not occur.

Step	Activity
1	**CONDUCT** this test with the positive terminal of a battery or portable DC power supply connected the casing, and the negative terminal connected to the pipeline, as shown in Figure 2. **INCLUDE** an ammeter and a current-limiting resistor in the test circuit. (See Figure 2 below) **UTILIZE** the applicable form *(D.12.B Polarization Test Record.xlsx)*
2	**INCLUDE** a current-limiting resistor in the test circuit to limit current flow to less than 10 Amps.

WARNING: Connection of a wet cell battery between a shorted casing and carrier pipe could result in excessive current flow and can cause the battery to explode.

NOTE: A 500' roll of #12 wire can often be used as a current-limiting resistor in the test circuit.

Code Reference :	Procedure No.: HLD.12	
49 CFR 195.575	*Effective Date: 04/01/18*	Page 5 of 11

Step	Activity
3	**MEASURE** initial pipe-to-soil potential and casing-to-soil potential. **VERIFY** electrode placement is as near to over the top of the casing end and the carrier pipe as practical. **RECORD** test data on the applicable form D.12.B *Polarization Test Record).*
4	**MEASURE** the potential difference between the pipe and casing using a high impedance voltmeter.
5	**ENERGIZE** the test circuit, **MEASURE** the test current, and **ALLOW** current to flow for two minutes.
6	**MEASURE** the potential difference between the pipe and casing as in Step 4.
7	**DE-ENERGIZE** the test circuit and **MONITOR** the potential difference between pipe and casing as the casing depolarizes.
8	**RECORD** the depolarization time in seconds and the depolarized potential difference between pipe and casing on the applicable form D.12.B *Polarization Test Record.*

NOTE:

- Depolarization time is the time required for the potential between the pipe and casing to return within ±10 millivolts of the initial value measured in Step 5.
- If the pipe immediately depolarizes (within the time it takes a digital meter to react), the casing is considered to be metallically shorted.

Step	Activity
9	**DOCUMENT** test results and pipe information on the applicable form(s) for *Polarization Test* and **INDICATE** “Shorted” or “Not Shorted.”
10	**NOTIFY** Area Management and the Corrosion Specialist when test results confirm a shorted casing.

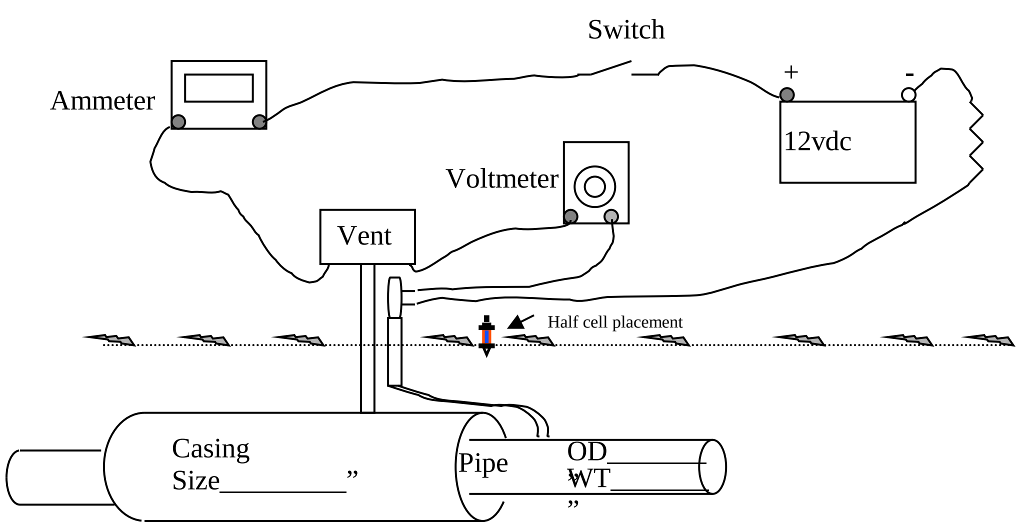

Figure 2: Polarization Test Method

7.3 Battery Test

Follow the following procedure below to conduct the battery test.

Step	Activity
1	**CONDUCT** this test with the positive terminal of a battery or portable DC power supply connected the casing, and the negative terminal connected to the pipeline as shown in Figure 3.
2	**INCLUDE** a variable resistor in the test circuit to limit current flow to less than 5 Amps.

WARNING: Connection of a wet cell battery between a shorted casing and carrier pipe could result in excessive current flow and can cause the battery to explode.

Step	Activity
3	**MEASURE** initial pipe-to-soil potential and casing-to-soil potential in accordance with *SOP HLD.03 Structure-to-Electrolyte Potential Measurement*. **VERIFY** electrode placement is as near to over the top of the casing end and the carrier pipe as practical. **RECORD** test data on the applicable form *D.12.D Battery Test Maintenance Record.*
4	**ENERGIZE** the circuit. **MEASURE** and **RECORD:** • Pipe-to-soil potential • Casing-to-soil potential • Applied DC voltage • Applied DC current **VERIFY** electrode placement does not change during the test procedure. **TAKE** readings as soon as possible after energizing circuit to reduce heat in the variable resistor.

NOTE: If the pipeline is shorted to the casing, the pipe-to-soil and the casing-to-soil potentials will be essentially the same before the battery is connected, and will polarize to nearly the same potential when the circuit is energized.

Step	Activity
5	**CALCULATE** the casing to carrier resistance as follows: $R = [[P/S_{initial} - C/S_{initial}] - [P/S_{current\ applied} - C/S_{current\ applied}]] / I$ Where: R = Casing to Pipe Resistance (Ohms) $P/S_{initial}$ = Pipe to Soil Potential (Volts) $C/S_{initial}$ = Casing to Soil Potential (Volts) $P/S_{current\ applied}$ = Pipe to Soil Potential with Test Current Applied (Volts) $C/S_{current\ applied}$ = Casing to Soil Potential with Test Current Applied (Volts) I = test current (Amperes) **CONSIDER** a casing resistance of 0.08 ohms and above as insulated.

Step	Activity
6	**DOCUMENT** test results on the applicable form(s) *for Battery Test Maintenance*. **RECORD** status of casing insulation (shorted or not shorted) in the Corrosion Database
7	**NOTIFY** the Area Management and Corrosion Specialist when test results confirm a shorted casing.

NOTE: The location of the reference is at the casing end and over the pipeline/casing interface.

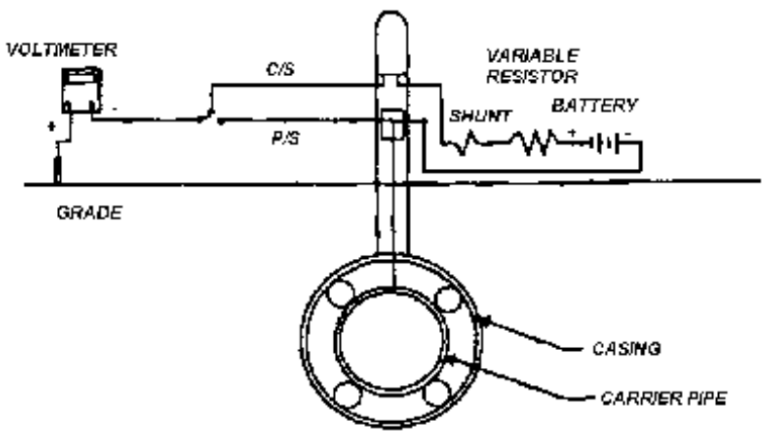

Figure 3: Battery Test Diagram

7.4 Locating Short Circuits

Follow the procedures below to locate short circuits in casings.

Step	Activity
1	**DETERMINE** the location of a single shorted condition by measuring battery current as it flows between the pipe and casing. **REFER** to Figure 4.
2	**MEASURE** the distance between connections on the ends of the casing. **DESIGNATE** the connections as L1 and L2 and the distance as “D”. **USE** a probe bar if test leads or casing vents are not available.
3	**MEASURE** and **RECORD** the voltage drop and polarity between L1 and L2 with no current flowing. **IDENTIFY** this voltage drop as V1.

WARNING: Connection of a wet cell battery between a shorted casing and carrier pipe results in excessive current flow and can cause the battery to explode.

Step	Activity
4	**CONNECT** the negative terminal of a test battery to the pipeline test lead.

Step	Activity
5	**CONNECT** the positive terminal through an ammeter to the casing vent (or probe bar connected to casing). **APPLY** about 5 amps of current and **IDENTIFY** this as C1.
6	As battery circuit is energized, **READ** the voltage as quickly as possible between L1 and L2. **IDENTIFY** this current as C1 and voltage as V2.
7	**DISCONNECT** the battery before polarization occurs.
8	**CALCULATE** a corrected voltage drop by one of the following: • If V1 flows in same direction as V2, **SUBTRACT** V1 from V2. • If V1 flows in opposite direction of V2, **ADD** V1 to V2 and designate the result as V3.
9	**CALCULATE** the casing resistance per foot between L1 and L2 by using the following formula: R1 = V3 / (C1 x D)
10	**RE-ENERGIZE** the DC current between the casing and the carrier pipe using connections “#2” in Figure 4. **DESIGNATE** this current as C2.
11	As battery circuit is energized, **READ** the voltage drop between L1 and L2 as quickly as possible. **IDENTIFY** this voltage as V4.
12	**DISCONNECT** the battery before polarization occurs.
13	**CALCUALTE** a corrected voltage drop using same procedure described above. **IDENTIFY** this voltage drop as V5.
14	**CALCULATE** the distance from L2 to the contact. **USE** the following formula: (V5 / C2) / R1
15	**IMPRESS** a current (C3) between the casing and the pipeline using connection “3” as shown in Figure 4.
16	**MEASURE** and record the voltage drop and polarity between L1 and L2. **IDENTIFY** this as V6.
17	**CALCULATE** a corrected voltage drop V7. If current flow in same direction add the voltages, if current flow in opposite **SUBTRACT** the results.
18	**CALCULATE** the distance from L1 to the casing contact using the following formula: L1 = (V7 / C3) / R1
19	**DOCUMENT** results on the applicable form(s).

NOTE: The following is an example.
Given:

- D = 76'
- V3 = 0.0017 Volt
- Cl = 10 Ampere

Approximate 4% error, which is not unreasonable.

A. 0.0017 / (10 x 76) = .00000224 ohm for R1

B. V5 = .00044 Volt C2 = 10 ampere
(.00044 / 10) / .00000224 = 19.6' from L2 to contact

C. V7 = .0012 Volt C3 = 10 Ampere
(.0012 / 10) / .00000224 = 53.6' from L1 to contact

D. 19.6' + 53.6' = 73.2 ft. vs. 76' between L1 and L2.

- The sum of the distances L2 to contact and L1 to contact should compare favorably to D if only one contact is involved.
- If the sum of L1 plus L2 is not comparable to “D”, more than one short is indicated.

If the methods described in this SOP are inconclusive, use other methods to determine shorted casings, consulting with the Corrosion Specialist.

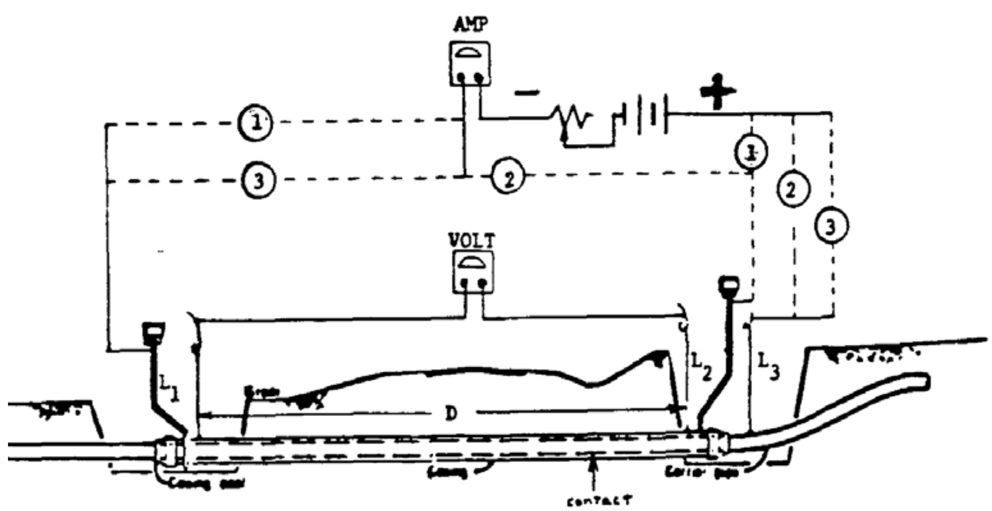

Figure 4: Short Location Test Circuit

7.5 Remedial Action

Follow the procedures below when testing confirms a casing is shorted.

Step	Activity
1	**MONITOR** shorted casing in accordance with *SOP I.22 Gas Leakage Survey*
2	**REVIEW** ILI inspection data, if available, with Integrity personnel to determine if external corrosion has or is occurring within the casing**.**
3	**DETERMINE** a course of action intended clear the shorted casing. A remediation plan should be in place within six months after discovery. Attempt to clear shorted casings by implementing the following actions: • **INSPECT** the test wires for possible direct shorts, and repair as necessary. • **EXCAVATE** the ends of the casing and inspect the clearance between the casing, vent, and carrier pipe. If contact exists trim back casing ends if applicable, reposition the carrier using guidance from *SOPHL I.08 Lowering or raising In-Service Pipelines* and replace damaged insulators and end seals with approved insulators and end seals. • When a shorted casing cannot be cleared by implementing the above actions with the pipeline in-service, **CONSIDER** installing new carrier pipe insulators when the pipeline segment is out of service for other scheduled repair, replacement, or modification; or **CONSIDER** filling the casing/pipe interstice with high dielectric casing filler. • If ILI data indicates actionable corrosion or corrosion growth on carrier pipe within casing, **SCHEDULE** replacement of carrier pipe or complete casing removal. Schedule removal of shorted casings at locations where crossings have been abandoned.
4	If the short cannot be removed and available ILI data indicates no corrosion or if attempts to clear the short are deemed impractical, continue to **MONITOR** in accordance with SOP I.22 *Gas Leakage Survey*.
5	**DOCUMENT** findings of the attempt to clear the shorted casing or include analysis and justification of impracticality on the applicable form(s).

NOTE: Requests to deviate from step 3 of the above procedures must be approved by Governance Authority of section 5.0.

8.0 Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

- D.12.A Panhandle Eastern Test Maintenance Record
- D.12.B Polarization Test Record
- D.12.E Road Casing Maintenance Record
- Corrosion Database

9.0 References

HLD.03 Pipe to Soil Survey

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Function	**OQ Task**
Measure Structure-to-Electrolyte Potentials	PLOQ406
Commission and maintain cathodic protection Electrical Isolation Devices between casing and carrier	PLOQ410

Code Reference:	**Procedure No.: HLD.13**	
49 CFR: 195.575	***Effective Date:*** ***04/01/18***	

1.0 Purpose

This Standard Operating Procedure (SOP) describes how to install components and equipment to isolate them from a Cathodic Protection System as well as perform isolation testing.

2.0 Scope

Electrical isolation must be maintained between structures, equipment, or components:

- When they are being independently cathodically protected
- When one requires cathodic protection and the other does not

Equipment that does not require cathodic protection must be electrically isolated to prevent stray currents from interfering with calibration and operation.

3.0 Applicability

This SOP applies to company facilities where cathodic protection is utilized.

Cathodic protection shorts can compromise structure potentials and/or cause cathodic protection of company facilities to drop below required levels.

4.0 Frequency

As required

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

Terms	Definitions
Electrical isolation device	Various dielectric components installed between pipeline components to provide electrical isolation (e.g., isolating flanges, unions, casing spacers, etc.)

7.0 Electrical Isolation Devices

Several methods exist to determine whether an isolated device is electrically shorted.

Operations Personnel uses the methods described in the following procedures to determine and remediate any electrically shorted devices:

- Pipe-to-soil test
- High frequency impedance test
- Applied current test
- Analysis and follow-up
- Guidelines for installation of electrical isolation devices
- Remedial action

7.1 Pipe-to-Soil Test

Follow the procedure below for pipe-to-soil testing.

Step	Activity
1	If pipe-to-soil potentials on both sides of the isolating joint are identical or nearly identical, **SUSPECT** the cause is short circuits.
2	For suspected short circuits, **INSPECT** and **TEST** insulation flange kits by using an isolation tester.

NOTE: Potential differences less than 100 mV are indications of a possible short.

7.2 High Frequency Impedance Test

Use specialized equipment for testing above grade and underground isolation devices.

Step	Activity
1	**USE** a high frequency impedance measuring instrument in accordance with the manufacturer's recommendations.
2	If the high frequency test produced inaccurate results for below-ground insulators, **PERFORM** additional tests, such as line current flow, as required.

NOTE:

- At high frequencies, current flow travels only along the skin of metallic conductors.
- This method is suited for locating shorted bolts on isolating flanges because large differences in the high frequency impedance occur between un-shorted bolts and shorted bolts.

7.3 Applied Current Test

The following procedure describes the applied current test.

Step	Activity
1	**CYCLE** the rectifier.
2	If the isolating joint is in an isolated area, **USE** a battery and a temporary anode bed. **REFER** to Figure 1.

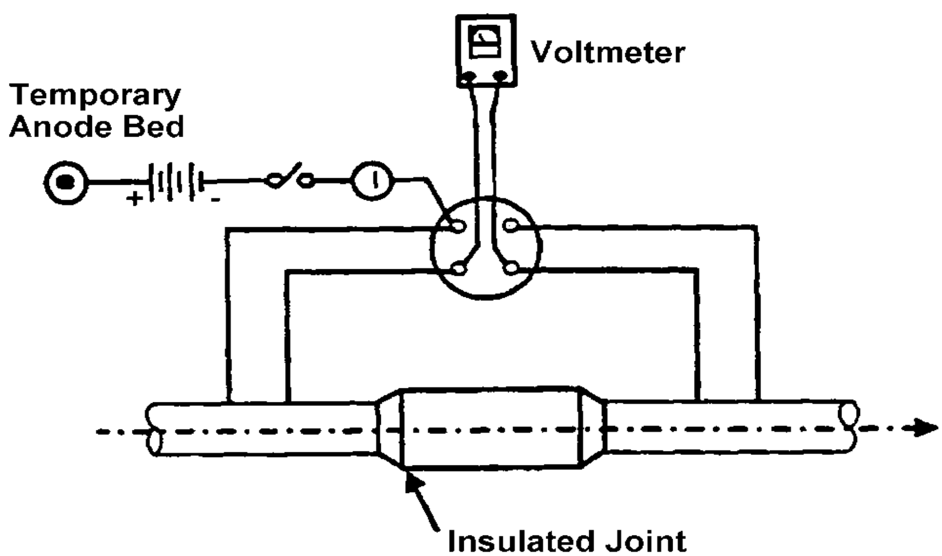

Figure 1

Step	Activity
3	**CONNECT** a DC voltmeter across the isolating joint.
4	**SWITCH** the current ON and **CONFIRM** there is current flow.
5	If a voltage change across the isolating joint is observed, **CONCLUDE** the isolating joint is electrically isolated.

NOTE: The short circuits may be in bypass piping loops or equipment on both sides of the isolating joint tied to one of the following:

- A common grounding system
- One or more of the flange bolts
- The isolating gasket

Step	Activity
6	If no voltage change is measured, **CONCLUDE** a short circuit exists.
7	**RECORD** all test conditions, measurements, and results of tests in the Corrosion database.

7.4 Analysis and Follow-up

If a short circuit is indicated, take the following actions.

CAUTION: Proper safety precautions are required when working on high pressure piping.

Step	Activity
1	Where practical, **REPAIR** or **REPLACE** the insulator.

Step	Activity
2	**CHECK** piping layout drawings for bypass loops.
3	If the isolating joint is in a station yard or congested area, **REVIEW** the situation to **DETERMINE** if recent work activity in the area may be the cause of the problem.

NOTE:

- A bypass line may have been permanently or temporarily installed.
- Remedial measures may include repair of an isolating flange kit while in service by replacing the insulation of each bolt.

Step	Activity
4	If there are bypass loops with above grade isolating flanges, **CONDUCT** the high frequency impedance test to **CHECK** for shorted bolt connections.
5	**TAKE** remedial measures to **RESTORE** effective cathodic protection when short circuits exist that interfere with effective cathodic protection.

7.5 Guidelines for Installation of Electrical Isolation Devices

Install equipment or devices to electrically isolate company structures at the following locations when new facilities are installed or existing facilities are modified. Refer to Engineering Standards for guidelines and details of various situations..

- At the point of delivery of town border or meter stations or established insulator locations. Grounding cells or other suitable surge arrestors are to be installed across the insulator in hazardous areas or where required by the customer.
- On the downstream side of the meter on farm tap lines. If the farm tap line is in close proximity to a rectifier and ground bed and current interference is detected, a bond or magnesium anode may be necessary to control return current flow on the farm tap line.
- Between a bridge structure and the pipeline where current requirements indicate excessive loss of pipeline cathodic protection.
- At the producer connection on wellheads, at purchase locations, or at established aboveground company facilities. Consider possible internal conductive liquid or

other internal conductive materials when determining where to place the isolating device.

- Between a casing and the carrier pipe.
- At all company metallic structures not requiring cathodic protection, such as metal valve boxes, conduit, fences, etc., regardless of size or description unless the cathodic protection is designed to be effective with connections to these metallic structures.
- Metals of different anodic potential where corrosion can occur as a result of this difference.
- Where fault currents or lightning can affect the pipeline such as close to electrical transmission tower footings or ground cables. Refer to HLD.23 Induced AC Measurement and Mitigation
- Exchanges or interconnect points with other pipeline companies.
- Control, ESD, and telemetering piping and electrical conduit or wiring at producers, customers or exchange points with company facilities.

7.5.1 Electrical Installation of an Electrical Isolation Device

Follow this procedure to verify that electrical isolation is in accordance with requirements for new and existing facilities.

Step	Activity
1	When using flange insulation kits, **SELECT** the kit that has the size, material, pressure rating, and style to accommodate the application.

NOTE: It is important to understand the system to be protected so that the appropriate kit can be applied.

Kits basically consist of:

- An isolating gasket (Type E, Type F, or ring type joint styles)
- Isolating sleeves for the individual bolts (sleeves or integral sleeves/washers)
- Isolating washers (single washer, double washers, or integral sleeves/washers)

Options include:

- Single washer set
- Double washer set
- Integral sleeve/washer sets

Step	Activity
2	**USE** a double washer set so that a backup washer is available if one washer fails. **EXCEPTION: DO NOT USE** double washer sets for below-ground applications. The bolts would be isolated from either side of the piping and therefore unprotected by the cathodic protection system.
3	For locations where piping is threaded or welded in place rather than flanged, **USE** isolating unions.

NOTE: Typically, unions are used on smaller diameter piping.

CAUTION: Over-tightening can destroy the nonmetallic part of the union and short out the system.

Step	Activity
4	When installing isolating unions, **DO NOT OVERTIGHTEN**.

Code Reference :	**Procedure No.: HLD.13**	
49 CFR: 195.575	***Effective Date:*** ***04/01/18***	**Page 9 of 10**

7.6 Remedial Action

Perform the following procedure for remedial action when inadequate electrical isolation is found.

Step	Activity
1	**TAKE** prompt remedial action where tests indicate a loss of electrical isolation and this condition results in a potential problem, failure to meet one of the cathodic protection criteria at standard test stations on protected structures, or detrimental effects to pipelines.
2	**RESTORE** isolation except in cases where other measures can be taken that will adequately protect company and/or foreign structures if the loss of isolation does not require prompt action.
3	**REPAIR** or **SUBMIT** a work order requesting the repair.

8.0 Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

Corrosion Database

D.40.A Corrosion Control Remedial Action

Activity	PEPL/TGC/SR Reporting
Acknowledge the requirements as outlined in the SOP have been completed. Record exceptions in the description tab.	EAM

9.0 References

Engineering Standards

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Function	OQ Task
Commission and maintain cathodic protection Electrical Isolation Devices between casing and carrier	PLOQ410
Commission and maintain cathodic protection Electrical Isolation Devices between flanges, prefabricated assemblies, and fittings.	PLOQ411

ENERGY TRANSFER

Interference Testing and Mitigation

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 1 of 10**

1.0 Purpose

This Standard Operating Procedure (SOP) describes the detection, measurement, mitigation, and documentation of stray current interference from foreign sources, such as nearby pipeline cathodic protection systems, direct current powered transit systems, and mining operations.

2.0 Scope

Certain Direct Current (DC) systems introduce current into the ground during their operation (intentionally or unintentionally). If a pipeline or other buried metallic structure is located near such a DC system, some of the current may use the pipeline or buried metallic structure as a path to return the DC to its source. Such actions will result in corrosion unless steps are taken to mitigate the problem. Refer to Figures 1 and 2 in Appendix B: for examples of interference or stray current corrosion.

3.0 Applicability

This SOP applies to company facilities and for sites identified as possible candidates for cathodic protection.

4.0 Frequency

As required: perform interference testing and mitigation.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

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6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms.*

Terms	**Definitions**
Anodic interference area	The area where stray current enters the pipeline or buried metallic structure.

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 2 of 10**

Terms	**Definitions**
Cathodic interference area	The area where stray current i leaves the pipeline or buried metallic structure.
Dynamic stray current	A stray current that is always changing such as: DC Welding operations, DC Transit systems, DC Mining Activities even Telluric currents (Sun Spot activity).
Stray current	Direct current which by its magnitude and direction of flow adversely affects underground metallic structures.
Static stray current	Static is a stray current that is steady state such as: Other Impressed Cathodic Protection systems of foreign operators.

7.0 Interference Testing and Mitigation

Operations Personnel follow the procedures in this section to detect and mitigate cathodic interference areas.

7.1 Detection

Follow the steps below to detect interference problems.

Step	**Activity**
1	**LOOK** for interference during any of the following activities: • Annual corrosion control surveys • Close Interval Survey • Installation of new impressed current cathodic protection units (company or foreign) or adjustments to existing units • Testing in areas of known stray DC caused by DC transit and mining operations • Information exchanged with other pipeline, transit, and mining companies

NOTE:	The first indication of a stray current is a change in the pipe-to-soil potentials causing higher or lower values compared to the previous survey data with no readily apparent cause.

Step	**Activity**
2	**INVESTIGATE** potential interference problems using one or more of the following procedures.

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 3 of 10**

Step	Activity
	• A P/S potential measurement with the suspected current source (rectifier) switched ON and OFF. Per *SOP HLD.03 Structure-to-Electrolyte Potential Measurement* • A Close Interval Survey over the suspected area, per *SOP HLD.15 Close Interval Survey*. • Line current flow measurements per *BP D.04 Line Current Flow Measurements*.
3	**RECORD** all information on the applicable form(s) for *Interference Test Data*.

NOTE: Cooperate with foreign line operators, as required, to investigate and mitigate potential interference problems. Remain firm on the company's needs to investigate potential threats to the integrity of our pipelines.

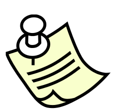
7.2 Mitigation Techniques

Operations Personnel use the potential restoration method, or another method approved by Corrosion Specialist to solve cathodic interference problems.

7.2.1 Potential Restoration

Follow the procedure below to restore potentials to a value which mitigates stray current interference.

Step	Activity
1	**ACCOMPLISH** potential restoration by establishing a bond between the interfered and the interfering pipeline. **REFER** to Figure 5 in Appendix B:



NOTE:

- Bonds between company and foreign pipelines are usually installed at or near the pipeline crossing.
- Bonds provide a low resistance (metallic) return path for interference current to return to its source.
- Bonds can mitigate anodic interference areas, allowing restoration of potentials to provide adequate levels of cathodic protection.

Step	Activity
2	To **DETERMINE** the potential value to be restored, **CONNECT** a current interrupter to the interfering rectifier(s) or arrange for manual interruption of rectifier current.
3	**READ** pipe-to-soil potentials, on the interfered pipe with the interfering rectifier(s) ON and OFF and record readings.
4	**RESTORE** pipe-to-soil potentials on the interfered pipeline to the value measured with the interfering rectifier OFF or to a polarized potential value more negative than 850 mV, after the interfering rectifier has been turned back ON.

NOTE: Resistance bonds are commonly used to restore potentials to acceptable levels while limiting the amount of current required for mitigation. A Corrosion Specialist must approve the installation of all direct bonds.

Step	Activity
5	**DETERMINE** whether bond is critical in accordance with *SOP HLD.19 Critical Bond Inspection.*
6	**NOTIFY** Corrosion Specialist and Operations Manager that a bond has been installed along with the appropriate inspection interval.
7	**UPDATE** the corrosion database to include new bond.
8	**COMPLETE** the applicable form(s) for *Interference Test Data.*

7.2.2 Alternative Restoration Techniques

One or more of the following alternative procedures may be used to mitigate interference currents

Step	Activity
1	**PROVIDE** supplemental cathodic protection to interfered pipeline to **RESTORE** the pipe-to-soil potential reading to its pre-interfered value; and/or

NOTE: This may restore the pipe-to-soil potential to its pre-interfered value, or a value that is sufficiently mitigates the effects of the interference.

2	**COAT** or **RECOAT** the interfered and/or the interfering pipeline at the point(s) of greatest exposure.

CAUTION: Carefully inspect all coatings used to mitigate interference with a holiday detector. After coating is installed, repeat investigation to determine whether the point of current discharge has shifted.

Step	Activity
3	**INSTALL** galvanic anodes at the crossing.
4	**ATTACH** anodes to the pipeline discharging current and lay the anodes next to the pipeline receiving current. The anode acts as the discharge point.
5	If possible, **INSTALL** a shunt aboveground to monitor the remaining life of the anode and the amount of current being discharged.
6	**MAKE** a note in the annual survey database. **REFER** to Figure 6 in Appendix B:

NOTE:

- Galvanic anodes provide low resistance current pick-up and discharge point for the interference current.
- Galvanic anodes should be connected to company facilities through a shunt at a test station. Do not direct connect anodes to company structures.
- Install shunts between the anodes and pipeline(s) to monitor the remaining life of the anodes and levels of interference current.

Step	Activity
7	**COMPLETE** the applicable form(s) for *Interference Test Data*.
8	**UPDATE** the Corrosion Database as applicable.

8.0 Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

- D.14.A Interference Test Data
- Corrosion Database

9.0 References

HLD.03 Structure-to-Electrolyte Potential Measurement
BP D.04 Line Current Flow Measurements
HLD.15 Close Interval Survey
HLD.19 Critical Bond Inspection

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 6 of 10**

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	OQ Task
Commission and Maintain Cathodic Protection Bonds	PLOQ409
Inspect Rectifier and Obtain Readings	PLOQ408
Measure Structure-to-Electrolyte Potential – AC / DC	PLOQ406
Conduct Close Interval Survey	PLOQ407A

Appendix B: Figures

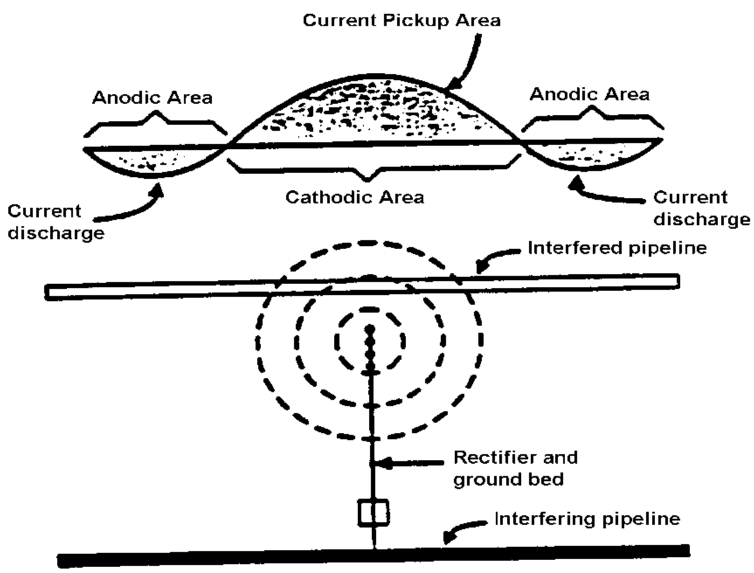


Figure 1: Anodic Interference

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 7 of 10**

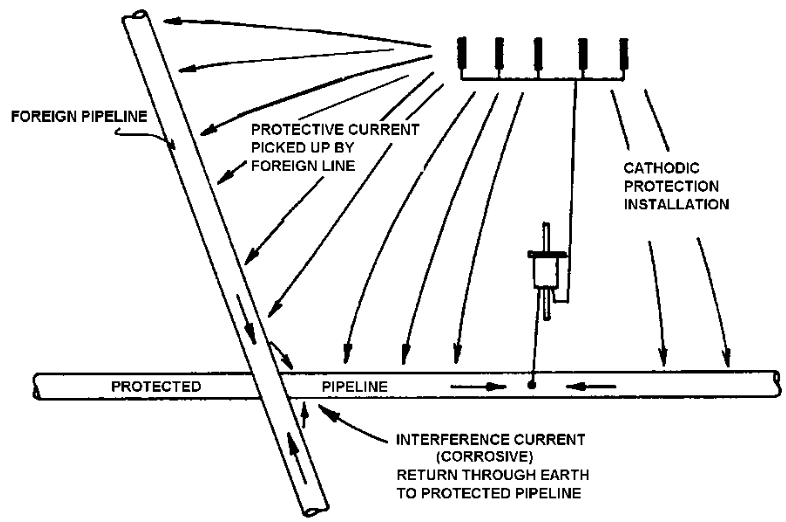


Figure 2: Cathodic Protection Interference

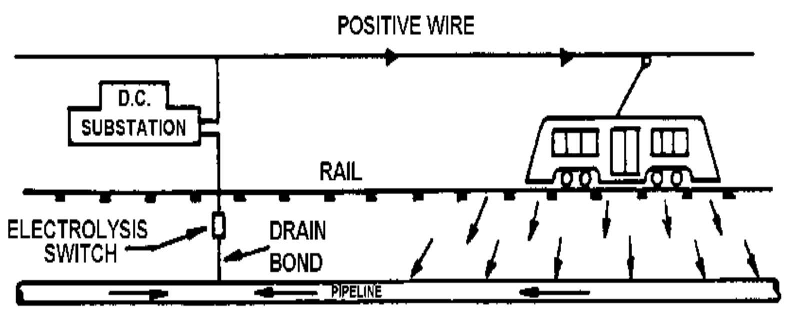


Figure 3: Drainage Bond with Diode Assembly Switch

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 8 of 10**

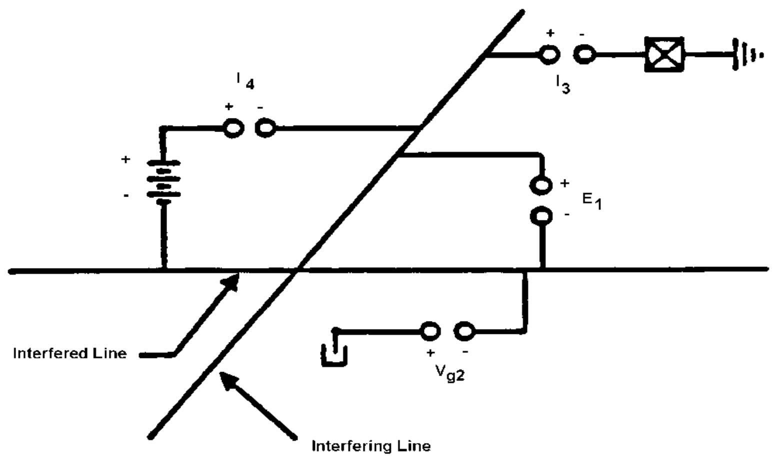


Figure 4: Pearson Network

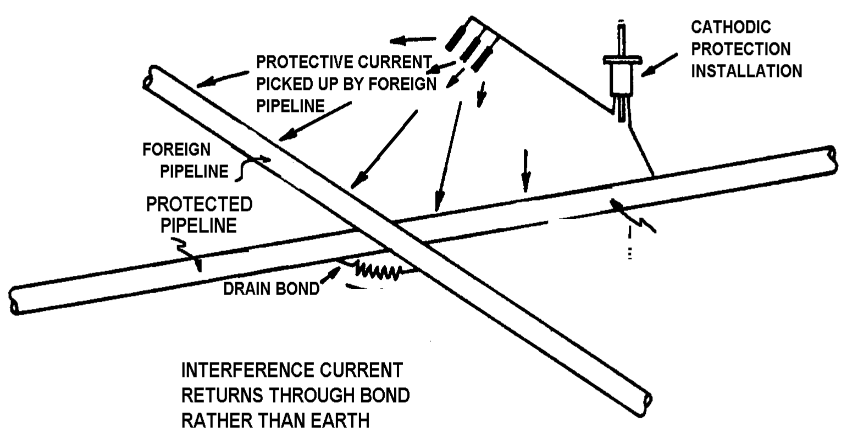


Figure 5: Interference Drainage Bond

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 9 of 10**

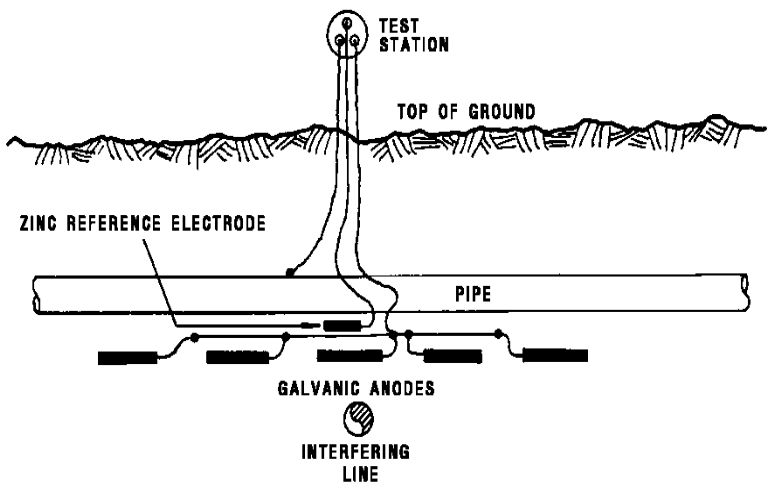


Figure 6: Anodes to Overcome Interference Effect of Foreign Line

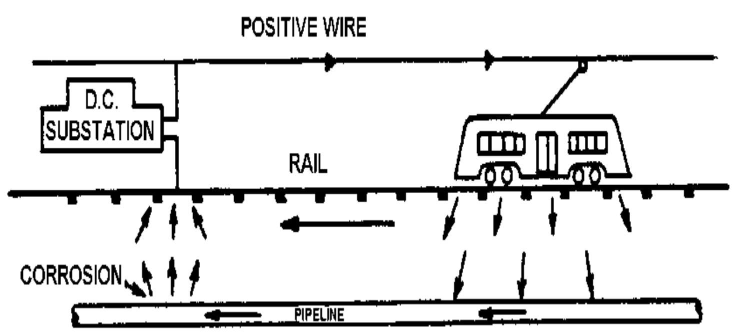


Figure 7: Stray Current from Electrified Railway

Code Reference :	**Procedure No.: HLD.14**	
49 CFR 195.577	***Effective Date: 04/01/18***	**Page 10 of 10**

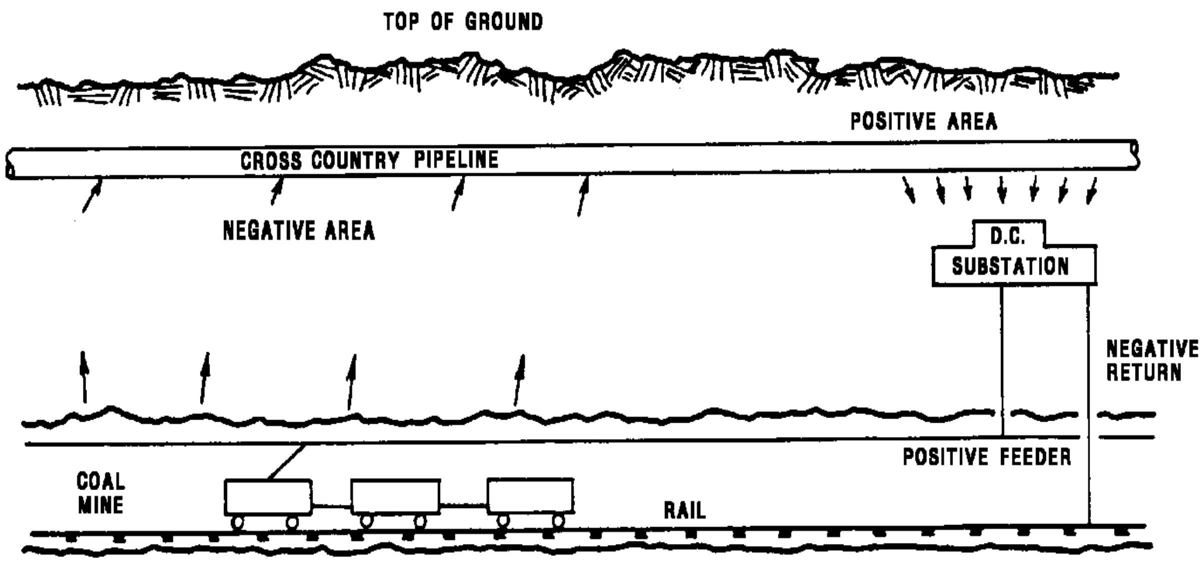


Figure 8: Stray Current from Coal Mine

ENERGY TRANSFER

Close Interval Surveys

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.15**	
49CFR 195.573	***Effective Date: 04/01/18***	**Page 1 of 15**

1.0 Procedure Description

This Standard Operating Procedure (SOP) describes Close Interval Surveys (CIS) conducted by company personnel or contractors. Specific guidance can be found in the Company CIS Specifications.

2.0 Scope

CIS involves measuring pipe-to-soil potentials at varying distance intervals directly over a pipeline. Data obtained during a CIS can facilitate a more thorough evaluation of the level of Cathodic Protection (CP) on the pipeline section.

3.0 Applicability

This SOP applies to all company owned buried or submerged piping.

4.0 Frequency

Within (2) years after a hazardous pipeline is place in service and cathodic protection is applied.
Conduct Close Interval Surveys to:

- Determine the level of CP between test stations.
- Facilitate use of an alternative CP criterion.
- Identify the extent of low potential areas.
- Locate areas of probable coating defects.
- Identify areas influenced by stray currents.
- Quantify voltage (IR) drops in “ON”, “INSTANT OFF”, and “OFF/STATIC” potential measurements.
- Identify possible shorted casings.

NOTE: Pipeline segments are selected for CIS based on an analysis of historical performance of the CP systems; ILI results, physical inspection results, or risk management ranking. CIS is typically performed at a frequency of 5 to 7 years for piggable pipeline segments and 3 to 5 years for unpiggable pipeline segments unless site conditions warrant more frequent survey intervals. Consideration should be given to scheduling CIS in conjunction with ILI runs (within 3 months prior or post ILI run) for data integration and analysis purposes.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Code Reference :	**Procedure No.: HLD.15**	
49 CFR 195.573	***Effective Date: 04/01/18***	

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Area Director/Division Vice President

6.0
Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms*.

Terms	Definitions
Far Ground Potential	Structure-to-electrolyte potential(s) obtained adjacent to a test station with the reference electrode directly over the pipeline and the pipeline connection via a trailing wire to a remote (far) test station. Far Ground potentials are taken in conjunction with Metallic IR and Near Ground potentials during a CIS.
Lateral Potentials	Structure-to-electrolyte potentials obtained perpendicular to the pipeline, usually 10 feet from the centerline of the pipeline. Lateral potentials are taken in conjunction with Near Ground, Far Ground, and Metallic IR potentials during a CIS to establish magnitude and direction of current flow through the soil.
Metallic IR	Component of error (IR drop) in potentials voltage unique to trailing wire CIS due to a portion of the measuring circuit (i.e. the pipeline) carrying CP current. Metallic IR potentials are taken in conjunction with Near and Far Ground potentials during a CIS to establish magnitude and direction of current flow through the pipeline.
Near Ground Potential	Structure-to-electrolyte potential(s) obtained with the reference electrode directly over the pipeline and the pipeline connection via an adjacent test station. Near ground potentials are taken in conjunction with Metallic IR and Far Ground potentials during a CIS.

7.0
Close Interval Surveys

Operations Personnel utilizes one or more of the following CIS methods to obtain detailed information about the effectiveness of the CP system:

- Current applied CIS
- Current interrupted CIS
- Current off (Native, Static, or Depolarized) CIS
- Contractor performed CIS (Special conditions are provided for CIS when conducted by an outside contractor)
- Right-of-Way Policy

NOTE: Contract CIS crews may only be directed to attempt simple repairs (i.e., reset AC breakers or replace fuses) to restore historic levels of CP. Any additional repairs must be conducted by company personnel.

NOTE:
- Utilize appropriate reference electrodes for all CIS
- Calibrate electrodes prior to each day's data collection

7.1 Current Applied CIS

Utilize current applied CIS to obtain structure-to-electrolyte potentials with all sources and drains of CP current operating at normal levels.

Step	Activity
1	**VERIFY** that all known sources of CP current (rectifiers, bonds, anodes) are operating at expected/historical levels prior to beginning the survey. If unexplained variances exist, do further testing per *SOP HLD.09 Current Source System Installation and Inspection, SOP HLD.10 Anode Bed Inspection and Installation.* Perform remedial measure prior to CIS if practicable.
2	**VERIFY** that all known electrical isolation devices are operating at expected/historical levels (shorted/not shorted) prior to beginning the survey. If unexplained variances exist do further testing per *SOP HLD.13 Electrical Isolation Devices.* Perform remedial measure prior to CIS if practicable.
3	**VERIFY** that all known drains of CP current (interference bonds, grounding systems, etc.) are connected to the pipeline and operating at expected/historical levels. If unexplained variances exist do further testing per *SOP HLD.14 Interference Testing and Mitigation.* Perform remedial measure prior to CIS if practicable.
4	**LOCATE** and **MARK** the pipeline over the portion to be surveyed. **USE** a chain, wire counter, or surveyor's wheel for distance measurement. Use GPS equipment, as applicable.
5	**MEASURE** structure-to-electrolyte potentials at the first test stations upstream and downstream of the area to be surveyed. This requirement may be performed during the CIS, if the survey interval spans test stations.
6	**SELECT** a survey interval. Intervals can range from three (3) to fifty (50) feet, based on the survey purpose. **USE** three foot intervals if the survey will be used to determine the adequacy of CP.
7	**OBTAIN** an electrical connection to the pipeline at the nearest test station or by using a probe bar. **VERIFY** that length of electrical leads/wire spool is adequate to span the survey area.
8	**MEASURE** structure-to-electrolyte potentials in accordance with *SOP HLD.03 Structure-to-Electrolyte Potential Measurement*. Pipe-to-soil potentials will be taken per the prescribed interval in the walking cane fashion. Potential readings to include far ground (FG), near ground (NG), and metallic IR (IR), must be collected at all casings, taps, dielectric insulators, foreign line crossings, bonds, valves, and test stations and entered into the data stream. Potentials at cased road crossings must include casing and carrier potentials. Potentials at foreign line crossings must include FG, NG IR, and bond current measurement with polarity for both company and foreign.
9	**RECORD** potentials using a Field Data Terminal (FDT) or the applicable form(s) for *Close Interval P/S Survey Data.* **DOWNLOAD** electronic CIS data into the Corrosion Database.
10	**IDENTIFY** data obtained between each connection to the pipeline (i.e., test point) with consecutive run numbers.

Step	Activity
11	**REVIEW** potentials as collected and **STOP** survey if a significant, unexplained variation in potentials is observed. **VERIFY** operation of all current sources/drains/isolators. **REPEAT** survey if CP current sources/drains are not found to be operating as expected. If unable to correct variances, schedule further testing per SOPs HLD.09, HLD.10, HLD.13, and HLD.14.
12	**OBTAIN** and **RECORD** near ground, far ground, metallic IR, and lateral potential readings at each pipeline connection beyond the start point.
13	**CONSIDER** the significance of metallic IR on all current applied CIS potentials.
14	**ADJUST** current applied CIS potentials, as required, to account for significant metallic IR.
15	**REVIEW** data and **DETERMINE** the adequacy of CP in accordance with *SOP HLD.22 Application of Cathodic Protection Criteria*.
16	**COMPLETE** the applicable form(s) for *Corrosion Control Remedial Action*, as required, when CIS was performed to verify that low potentials have been remediated.
17	**RECORD** the following data in the manual or electronic data stream for all Current Applied CIS: • Date of survey • Line name and number • Starting station number • Ending station number • Direction of survey • All above grade appurtenances including exposed pipe • Physical features (fences, roads, creeks, power lines, water bar, washes, etc.) • Ambient temperature and weather conditions • Pipeline connection information (i.e., test point, above grade appurtenance, or probe rod) • Casing potentials • Potentials at both sides of insulating devices location and output of current sources (station #) • Location and status of bonds (station #) • Field comments

NOTE: Significant metallic IR is most common when potentials are obtained using a trailing wire in close proximity to impressed current systems. Metallic IR can be measured by taking far ground and near ground potentials; however, this method will require use of a probe rod if the length of the survey does not span test stations.

7.2 Current Interrupted CIS

Utilize Current Interrupted CIS to obtain current applied and instant off structure-to-electrolyte potentials. All sources and drains of CP current should be operating at normal levels with synchronized current interrupters installed at each.

NOTE: Standard current interruption cycles are as follows.		
"ON" Cycle	**"OFF" Cycle**	**Comments**
800 mS	200 mS	Fast cycle survey must be approved by Sr. Manager of Corrosion Services as it requires specialized equipment. Allows for on/off at each point.
4 sec	1 sec	
7 sec	3 sec	
8 sec	2 sec	

Step	Activity
1	**VERIFY** that all known sources of CP current (rectifiers, bonds, anodes) are operating at expected/historical levels prior to beginning the survey. If unexplained variances exist do further testing per *SOP HLD.09 Current Source System Installation and Inspection, SOP HLD.10 Anode Bed Inspection and Installation.* Perform remedial measure prior to CIS if practicable.
2	**VERIFY** that all known electrical isolation devices are operating as expected (shorted/not shorted) prior to beginning the survey. If unexplained variances exist do further testing per *SOP HLD.13 Electrical Isolation Devices.* Perform remedial measure prior to CIS if practicable.
3	**VERIFY** that all known drains of CP current (interference bonds, grounding systems, etc.) are connected to the pipeline and operating as expected. If unexplained variances exist do further testing per *SOP HLD.14 Interference Testing and Mitigation.* Perform remedial measure prior to CIS if practicable.
4	**SELECT** an interruption cycle to be used during the survey.
5	**SYNCHRONIZE** current interrupters and install at each current source/drain.
6	**LOCATE** and **MARK** the pipeline over the portion to be surveyed. **USE** a chain, wire counter, or surveyor's wheel for distance measurement. Use of sub-meter GPS equipment is required if using an FDT
7	**SELECT** a survey interval. Intervals can range from three (3) to fifty (50) feet, based on the survey purpose. **USE** three foot intervals if the survey will be used to determine the adequacy of CP.
8	**MEASURE** structure-to-electrolyte potentials at the first test stations upstream and downstream of the area to be surveyed. This requirement may be performed during the CIS, if the survey interval spans test stations.
9	**OBTAIN** an electrical connection to the pipeline at the nearest test station or by using a probe bar. **VERIFY** that length of electrical leads/wire spool is adequate to span the survey area.
10	**MEASURE** structure-to-electrolyte potentials in accordance with *SOP HLD.03 Structure-to-Electrolyte Potential Measurements*. Pipe-to-soil potentials will be taken per the prescribed interval in the walking cane fashion. Potential readings to include On/Off far ground (FG), near ground (NG), metallic IR (IR), must be collected at all casings, taps, dielectric insulators, foreign line crossings, bonds, valves, and test stations and entered into the data stream. Potentials at cased road crossings must include casing and carrier potentials during on and off cycles (interrupted survey only).

Step	Activity
	Potentials at foreign line crossings must include On/Off FG, NG IR, and bond current measurement with polarity for both company and foreign. **OBTAIN** both "ON" and "OFF" readings at each electrode placement when total survey distance is less than 1,000 feet.
11	**IDENTIFY** data obtained between each connection to the pipeline (i.e., test point) with consecutive run numbers.
12	**RECORD** "ON" and "OFF" potentials using a Field Data Terminal (FDT) or using the applicable form(s) *for Close Interval P/S Survey Data.* **DOWNLOAD** electronic CIS data into the Corrosion Database.
13	**REVIEW** potentials as collected and **STOP** survey if a significant, unexplained variation in potentials is observed. **VERIFY** operation of all current sources/drains/isolators/interrupters. **REPEAT** survey if current sources/drains/isolators/interrupters are not found to be operating as expected. If unable to correct variances, schedule further testing per appropriate SOPs.
14	**OBTAIN** and **RECORD** near ground, far ground, metallic IR, and lateral potential readings (On and Off cycles) at each pipeline connection beyond the start point.
15	**REVIEW** near ground, far ground, metallic IR and lateral potential readings (On and Off cycles) and **DETERMINE** whether current interruption is sufficient. **INSTALL** additional current interrupters and **REPEAT** survey, as required. **CONTACT** Corrosion Specialist if assistance is required to determine adequacy of current interruption.
16	**REVIEW** survey data at each pipeline connection to **VERIFY** synchronization of current interrupters.
17	**STOP** survey and **INSPECT** each current interrupter if review of data indicates that current interruption is not within 5% of the On cycle. **REPEAT** survey if current interruption equipment is found to not be synchronized. **CONTACT** Corrosion Specialist if additional troubleshooting is required.
18	**INSPECT** each current interrupter daily to ensure operation.
19	**REVIEW** data and **DETERMINE** the adequacy of CP in accordance with *SOP HLD.22 Application of Cathodic Protection Criteria*.. Complete the applicable Cathodic Protection Survey Analysis D.15.A. Enter low potential areas in the LPA editor that do not meet the <-.850 off criteria and applicable D.40.A Corrosion Control Remedial Action Report. Reference SOP HLD.40. Send electronic CIS data to Houston Corrosion Services to be entered into GIS Data Base
20	**COMPLETE** the applicable D.15.B Close Interval P-S Survey Data form(s) for all Manual, non-electronic data collector type Close Interval Surveys performed. Enter any LPAs into the LPA Editor. Send survey to Houston Corrosion Services to enter into GIS Data Base.
21	**COMPLETE** the applicable D.15 A Cathodic Protection Survey Analysis and D.40.A Corrosion Control Remedial Action Report(s) as required, when CIS was performed to verify that low potentials have been remediated.

Step	Activity
22	**RECORD** the following data in the manual or electronic data stream for all current interrupted CIS. All electronic data to have embedded Sub-Meter GPS: • Date of survey • Line name and number • Starting station number • Ending station number • Direction of survey • All above grade appurtenances • Physical features (fences, roads, creeks, power lines, water bar, washes, etc.) • Ambient temperature and weather conditions • Pipeline connection information (i.e., test point, above grade appurtenance, or probe rod) • Casing potentials • Potentials at both sides of insulating devices • Location and output of current sources (station #) • Location and status of bonds (station #) • Field comments

NOTE:

- Potentials recorded when all influencing CP current sources are interrupted (OFF Potentials) closely approximate the polarized potential of a pipeline.
- It is rarely possible to interrupt all current on a pipeline due to long line currents, tellurics, direct connect galvanic anodes, varying degrees of polarization on electrically continuous pipelines, etc.
- Sufficient current interruption is achieved when metallic IR potentials (On and Off) indicate that at least 90% of the influencing current is interrupted. Personnel should be aware that current interrupted or “Off” potentials more negative than 1250 mV may indicate insufficient current interruption regardless of whether 90% current interruption is achieved.
- If 90% current interruption cannot be achieved, a “Rule of Thumb” target for adequate current interruption is a maximum of 10 mV potential difference between the far and near test station leads (metallic IR potential) during the Off Cycle. This is not always possible on parallel pipeline systems.
- In the event that the source of the metallic voltage (IR) drop cannot be identified / eliminated, and if “Off” potentials exceed 1250 mV on pipelines outside of ground bed gradients consult the Corrosion Specialist to determine whether the survey should continue.
- GPS synchronized current interruption equipment is preferred for all company performed current interrupted survey and required for all contractor performed current interrupted survey.

- Two-channel telluric surveys may be used to determine the effects of transient currents occurring while the survey is being performed. Telluric currents are most common on pipelines running north/south in the northern US and Canada.

7.3 Current Off CIS (Native, Static, or Depolarized CIS)

Utilize current Off CIS to obtain native potentials on new pipelines prior to the application of CP current or depolarized potentials on a pipeline that was previously under CP. All sources and drains of CP current must be identified and disconnected from the line at a sufficient time interval prior to beginning the survey.

Step	Activity
1	**RECORD** structure-to-electrolyte potentials at a representative number of test stations in the area to be surveyed.
2	**DE-ENERGIZE** or **DISCONNECT** all known sources and drains of CP current (rectifiers, bonds, anodes).
3	**VERIFY** that all known electrical isolation devices are operating as expected (shorted/not shorted) prior to beginning the survey. . If unexplained variances exist do further testing per *SOP HLD.13 Electrical Isolation Devices.* Perform remedial measure prior to CIS if practicable.

NOTE: If CP current is found to be flowing through an electrical isolation device, the device must either be repaired or the foreign CP system must be de-energized prior to beginning a static survey.

Step	Activity
4	**RECORD** potentials at representative test stations to monitor depolarization of the line. Monitoring intervals, should be based on site conditions, but should rarely exceed 14 to 21 days.
5	**BEGIN** current Off CIS when potentials at all monitored test stations having gone through the depolarization curve, have bottomed out and stabilized within 20 mV in a 24 hours period, and are at least 100 mV greater than polarized (instant off) potentials recorded at the same locations.

NOTE: The time required to sufficiently depolarize a pipeline is based on multiple factors and can require hours, days, or weeks. Monitoring intervals should be based on site conditions and should indicate a steady decay of potentials. Consult the Corrosion Specialist for additional guidance in determining when to begin the current Off CIS.

Step	Activity
6	**LOCATE** and **MARK** the pipeline over the portion to be surveyed. **USE** a chain, wire counter, or surveyor's wheel for distance measurement. Use Sub-Meter GPS equipment if using an FDT

Step	Activity
7	**SELECT** a survey interval. Intervals can range from three (3) to fifty (50) feet, based on the survey purpose. **USE** three foot intervals if the survey will be used to determine the adequacy of CP.
8	**OBTAIN** an electrical connection to the pipeline at the nearest test station or by using a probe bar. **VERIFY** that length of electrical leads/wire spool is adequate to span the survey area.
9	**MEASURE** structure-to-electrolyte potentials in accordance with *SOP HLD.03 Structure-to-Electrolyte Potential Measurements*. Pipe-to-soil potentials will be taken per the prescribed interval in the walking cane fashion. Potential readings to include far ground (FG), near ground (NG), and metallic IR (IR), must be collected at all casings, taps, dielectric insulators, foreign line crossings, bonds, valves, and test stations and entered into the data stream. Potentials at cased road crossings must include casing and carrier potentials. Potentials at foreign line crossings must include FG, NG IR, and bond current measurement with polarity for both company and foreign.
10	**IDENTIFY** data obtained between each connection to the pipeline (i.e., test point) with consecutive run numbers.
11	**RECORD** potentials using a Field Data Terminal (FDT) or using the applicable form(s) for *Close Interval P/S Survey Data*. **DOWNLOAD** electronic CIS data into the Corrosion Database.
12	**REVIEW** potentials as collected and **STOP** survey if a significant, unexplained variation in potentials is observed. **VERIFY** that all current sources/drains are de-energized or disconnected. **VERIFY** that all isolators are operational. **REPEAT** survey if current sources/drains/isolators are not found to be operating as expected. If unable to correct variances, schedule further testing per appropriate SOPs
13	**OBTAIN** and **RECORD** near ground, far ground, metallic IR, and lateral potential readings (On and Off cycles) at each pipeline connection beyond the start point.
14	**REVIEW** over-the-line, near ground, far ground, metallic IR and lateral potential readings. **STOP** survey if significant, unexplained variations in potentials are observed or if potentials indicate that significant levels of CP current are flowing on or to the pipeline. **VERIFY** that all current sources/drains are de-energized or disconnected. **VERIFY** that all isolators are operational. **REPEAT** survey if current sources/drains/isolators are not found to operate as expected. **CONTACT** Corrosion Specialist if assistance is required to determine whether significant adequacy of current interruption.
15	**REVIEW** data and **DETERMINE** the adequacy of CP in accordance with SOP D.22. *Application of Cathodic Protection Criteria*. Complete the applicable Cathodic Protection Survey Analysis D.15.A Enter low potential areas in the LPA editor that do not meet the 100 mV polarization criteria and applicable D.40.A Corrosion Control Remedial Action Report. Reference SOP D.40. Send electronic CIS data to Houston Corrosion Services to be entered into GIS Data Base.
16	**COMPLETE** the applicable D.15.B form(s) for all manual non-electronic data collector type close interval surveys performed. Enter any LPAs into the

Step	Activity
	LPA Editor that do not meet 100 mV polarization criteria. Send survey to Houston Corrosion Services to enter into GIS Data Base.
17	**COMPLETE** the applicable D.15.A Cathodic P-S Survey Analysis and D.40.A Corrosion Control Remedial Action Report(s) as required, when CIS was performed to verify that low potentials have been remediated.
18	**RECORD** the following data in the manual or electronic data stream for all current Off CIS. All electronic data to have embedded Sub-Meter GPS: • Date of survey • Line name and number • Starting station number • Ending station number • Direction of survey • All above grade appurtenances • Physical features (fences, roads, creeks, power lines, water bar, washes, etc.) • Ambient temperature and weather conditions • Pipeline connection information (i.e., test point, above grade appurtenance, or probe rod) • Casing potentials • Potentials at both sides of insulating devices • Location and output of current sources • Location and status of bonds • Field comments

7.4 Contractor Performed CIS

- When a contractor performs CIS, the company shall furnish the following:
  - Right-Of-Way (ROW) that can be traversed by a walking crew.
  - A company representative that is available at all times when the CIS crew is on the ROW.
  - The location of all company owned and foreign CP current sources and electrical isolation devices. Most recent inspection data must be provided for each.
  - Company must either provide keys for any device required to be access by the contractor (i.e., rectifiers) or be available at any time access is required.
  - The location of all rectifiers, test points, casings, and bonds and most recent inspection data for each (i.e., test point survey results, rectifier inspection results, etc.).
  - Applicable maps and/or drawings.
  - Identification of known foreign jurisdictional facilities line crossings, parallel current sources, foreign facilities, bond locations.
  - Special conditions for ROW access and landowners.
  - Company procedures to be followed if an abnormal operating condition is observed.

Normal work hours are 8 hours per day, 5 days per week on weekdays, excluding holidays.

NOTE:

- The company allows charges for re-surveyed pipelines due to causes beyond the contractor's control, such as frozen ground, dry earth, bad test stations, or stray/interference currents, unidentified current sources, down ICCP units, etc.
- Contractor errors resulting in pipe location error of more than five (5) feet, chaining error of more than 2%, or pipe-to-soil potential error of more than 5% when re-surveyed are at the contractor's expense.

7.4.1
Initial Survey Requirements

Notify company representative if rectifier/bond/test station as-found conditions do not match records from the most recent inspection period.

NOTE: Contract CIS crews may only be directed to attempt simple repairs (i.e., reset AC breakers or replace fuses) to restore historic levels of CP. Any additional repairs must be conducted by company personnel.

7.4.2
Side Drain Surveys

The contractor collects continuous side drain lateral measurements, as directed, as follows.

Step	Activity
1	**OBTAIN** computerized data collection of three-channel close interval surveys with the P/S over the pipe, left lateral P/S, and right lateral P/S reading at three foot nominal intervals.
2	**VERIFY** right and left laterals are ten (10) feet perpendicular from the center line of the pipe.

7.4.3
Field Data Terminals

Contractors follow these additional steps when using field data terminals and voltmeters.

Step	Activity
1	**VERIFY** that all Field Data Terminals (FDT), Sub-Meter GPS units, and/or Digital Voltmeters (DVM) are approved by the company prior to beginning the survey.
2	**COLLECT** and **STORE** all data electronically at the time of the data collection.
3	**CALIBRATE** FDT/DVM daily by measuring and comparing a known voltage source.
4	At the beginning of the first and last run of the day: • **RECORD** wave from at the test station • **COMPARE** the FDT to a DVM at the test station, using the same electrical connection and reference electrodes.

NOTE: The results of these comparisons are recorded as comments in the electronic CIS data stream.

7.4.4
P/S Potentials

Contractors follow these additional steps when collecting pipe-to-soil potentials.

Step	Activity
1	**OBTAIN** pipe-to-soil measurements at a nominal spacing of three (3) feet using the "walking cane" method.
2	**MARK** the low potential areas, as directed by the company representative, with comments in the electronic data; placement of pin flags or stakes and/or using GPS equipment.

7.4.5
Contact Resistance

Notify company representative if contact resistance results in data "scatter." If scatter is suspected, measure ON and OFF potentials:

- Standing still versus measurements at survey pace
- Standing still versus six inches under the topsoil
- Under six inches topsoil versus watering the right-of-way

NOTE: The company representative determines whether data scatter is acceptable.

7.4.6
Voltage (IR) Drop Consideration (Metallic)

Notify company representative if metallic IR indicates that ninety percent (90%) total current interruption requirement was not met.

NOTE:

- Ninety percent current interruption requirement may be waived if total metallic IR is less than 10 mV.
- If the metallic voltage (IR) drop indicates that total current interruption is not achieved, and the non-interrupted current source results from a contractor equipment malfunction, the contractor corrects the problem and re-surveys the affected runs at the contractor's expense.
- In the event the company did not correctly identify the current source causing inadequate current interruption, then the contractor stands by (paid time) during additional current interrupter setup.
- In the event that the source of the metallic voltage (IR) drop cannot be identified / eliminated, and if "Off" potentials exceed 1250 mV on pipelines

outside of ground bed gradients, consult the Corrosion Specialist to determine whether the survey should continue.

7.4.7 Distance Measuring: Chaining

Obtain pipeline measurements using the “taut chain” method or approved wire counter. Any errors exceeding 2% are re-surveyed at contractor’s expense.

7.4.8 Accuracy

The contractor operator follows these requirements to ensure collection of accurate measurements.

Step	Activity
1	**VERIFY** that distance measuring accuracy is within ± 5% of the company stationing in any individual run.

NOTE: Total survey footage shall be accurate within ± 2% of the company stationing.

Step	Activity
2	**VERIFY** all appropriate maps and drawings are used so that physical feature data entries correspond to actual pipeline station numbers.
3	**VERIFY** that pipe-to-soil potential measurements are accurate within ± 5% of a calibrated standard for the company voltmeter and reference electrode.

7.5 Right-of-Way Policy

Prior to a right-of-way operation, the company reserves the right to verify the accuracy and ability of pipeline locating personnel during the survey. Contract personnel must be qualified, and demonstrate competence in the use of pipeline locators.

7.5.1 Pipe Location

The contractor operator follows these requirements prior to and after conducting a close interval survey in a right-of-way.

Step	Activity
1	**LOCATE** the pipeline with suitable equipment prior to collecting the data to verify the reference electrode is placed over the pipeline.
2	**FLAG** the pipeline at 100-foot intervals, starting at a known location.
3	Within 48 hours of completing the survey: • **RETRIEVE** the flagging materials. • **REMOVE** the light-gauge survey wire from the right-of-way.

NOTE: Flagging requirements may be waived by company representative when pipe locating is performed in conjunction with the CIS and the locator remains within line of sight of the CIS operator.

7.5.2 Reporting Requirements

The contractor operator follows the steps below to provide the company with the following information:

- Daily field reports
- Run summary
- Final report

Step	Activity
1	**PROVIDE** field plots of potentials versus distance to the company representative within 24 hours of data collection. Pencil corrections of stationing errors, comments, and edits are acceptable on the field plots. All required data sets required by this SOP must be included in the daily field plots.
2	**PROVIDE** a listing of run numbers with daily field plot to include: • Run number • Begin station/end station • Total footage per run (from hard chain or wire counter) • Total flagged footage (i.e., low potentials) • Company feet begin to end • Calculated miles

NOTE:

- Unique run numbers must be assigned for each segment of CIS that designate a permanent aboveground pipeline appurtenance.
- Run numbers shall not be duplicated.
- Survey runs should not span distances greater than 1 mile unless the spacing of aboveground company facilities also exceeds 1 mile.

Step	Activity
3	**PROVIDE** the final reports, plots, and/or electronic data within 60 days of completion of field work.

NOTE: Company representative is responsible for reviewing daily plots of CIS data to verify compliance with company requirements.

8.0 Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

- Corrosion Database
- D.15.A Cathodic P/S Survey Analysis
- D.15.B Close Interval P/S Survey Data Form
- D.40.A Corrosion Control Remedial Action Report
- LPA Tracker

9.0 References

HLD.03 Structure-to-Electrolyte Potential Measurement
HLD.09 Current Source System Installation and Inspection
HLD.10 Anode Bed Inspection and Installation
HLD.13 Electrical Isolation Devices
HLD.14 Interference Testing and Mitigation
HLD.22 Application of Cathodic Protection Criteria
HLD.40 Corrosion Control Remedial Action
Potential Gradient Surveys on Buried or Submerged Metallic Pipelines
ETC CIS Specifications 2016

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Task Description	**OQ Task**
Conduct Close Interval Survey	PLOQ407A
Measure Structure-to-electrolyte Potential	PLOQ406
Inspect Rectifier and Obtain Readings	PLOQ408
Commission and maintain cathodic protection bonds	PLOQ409
Underground Pipeline - Locate and Temporarily Mark	PLOQ605

ENERGY TRANSFER

Critical Bond Inspection

Standard Operating Procedures

Applicable to Hazardous Liquids Pipelines and Related Facilities

Code Reference:	**Procedure No.: HLD.19**	
49 CFR 195.573	***Effective Date:*** ***04/01/18***	**Page 1 of 4**

1.0 Procedure Description

This Standard Operating Procedure (SOP) describes how to monitor critical bonds.

2.0 Scope

Critical bonds are electrical bonds required to maintain safe and effective levels of cathodic protection of company facilities. Because the bonds are critical, monitoring requirements are more stringent and the understanding of the current flow more crucial.

3.0 Applicability

This SOP applies to all company facilities that contact foreign structures.

4.0 Frequency

Six (6) times each calendar year, at intervals not to exceed two and one-half (2-1/2) months: Inspect and document inspection results.

5.0 Governance

The following table describes the responsibility, accountability, and authority for this SOP.

Function	Responsibility	Accountability	Authority
All Tasks	Corrosion Technician	Operations Manager	Director of Operations / Division Vice President

Code Reference :	Procedure No.: HLD.19	
49 CFR 195.573	*Effective Date:* *04/01/18*	Page 2 of 4

6.0 Terms and Definitions

Terms associated with this SOP and their definitions follow in the table below. For general terms, refer to *SOP HLA.01 Glossary and Acronyms.*

Terms	Definitions
Critical Interference Bond	An electrical bond between the company and foreign structures is considered critical if its failure would jeopardize the cathodic protection level of the company's pipeline due to interference. Critical bonds generally have the following characteristics: • Designed by agreement between different owners/operators • Utilizes a hard wire/shunt connection • Uses proper labeling of wire terminals for ease of understanding • Housed in a junction box-type enclosure This type of bond may be considered critical to one owner/operator or another based on the above criteria.

7.0 Critical Bond Inspection

Operations Personnel follow these procedures to take pipe-to-soil measurements on the company structure and on the foreign structures in order to inspect critical bonds, take action if needed, and document inspection results.

Step	Activity
1	**MEASURE** the current flow and direction through a shunt.
2	**CONNECT** the voltmeter using the following convention for attaching leads: • For bonded structures, **CONNECT** the positive lead to the company side shunt terminal.

	• If both sides belong to the company, **CONNECT** the negative lead to the upstream side of the shunt terminal.

NOTE:

1. A positive (+) reading indicates that the company structure is returning interference current from a foreign current source and returning the current to the foreign current source negative through the bond.
2. A negative (-) reading indicates that the foreign structure is returning interference current from a Company current source and returning the current to the Company current source negative through the bond.

Step	Activity
3	**MEASURE** the pipe-to-soil potentials of the company pipeline and the foreign structure at the foreign pipeline crossing test site in accordance with *SOP HLD.03 Structure-to-Electrolyte Potential Measurement*
4	**MEASURE** the critical bond current drain in accordance with *BP HLD.05 Shunt Current Flow Measurement.*

NOTE: If verification is necessary, disconnect the bond and take pipe-to-soil measurements on the company and foreign structure. After inspecting, reconnect the bond if necessary.

Step	Activity
5	If the critical bond is found broken or not draining sufficient current to provide mitigation of interference on the company pipeline, **TAKE** remedial measures to restore interference mitigation, including any of the following: • **RERUN** the current Company procedure for interference testing and mitigation in accordance with *SOP HLD.14 Interference Testing and Mitigation* • **PROVIDE** supplementary cathodic protection • **REPAIR** existing cathodic protection facilities on company or foreign line • **REPAIR** the bond itself

Step	Activity
6	If tests determine the bond is no longer needed or is no longer critical, **REMOVE** the bond or classify it as non-critical.
7	**RECORD** the data in the Corrosion Database.

8.0 Documentation Requirements

Record data in electronic database or utilize the following form(s) as applicable:

- Corrosion database

9.0 References

HLD.03 Structure-to-Electrolyte Potential Measurement

HLD.14 Interference Testing and Mitigation

HLD.05 Shunt or Resistor Current Flow Measurement

Appendix A: OQ Task Requirements

The table below identifies the Operator Qualification (OQ) task requirements for this SOP.

Function	OQ Task
Commission and maintain cathodic protection bonds	PLOQ409