Common Covered Task 419OP
Cathodic Protection Potential Measurement

Directions

This training guide is to be used by a Veriforce Authorized Evaluator/Trainer and Trainee during on-the-job training (OJT) or prior to an evaluation as a resource. (S) Indicates a demonstration or skill task; (K) indicates a knowledge task.

OJT Reminder

OJT is an active hands-on process. Practice should be as similar to the actual job task as possible. However, if the training is being provided on an actual job site while a covered task is actually being performed, the Evaluator either needs to be qualified on that covered task or be assisted by someone who is qualified on the covered task. The Evaluator should closely monitor the Trainee's practices to ensure safe and correct task performance. At no time should a non-qualified individual perform, or train for, a covered task unless directed and observed by a qualified individual. However, if the “span of control” for that particular covered task is “1:0” (requiring only qualified individuals to perform the covered task), the training must be simulated. Training is simulated by “walking through” the task and simulating all actual manipulations (values, switches, tools, etc.) an individual would use during the performance of a covered task. Simulating includes the use of safety and administrative requirements as if the task were being performed live. Refer to the Veriforce Evaluator Training Program for more on how to conduct formal OJT.

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CCT 419OP
Training Guide

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Recommended Student Training or Resources:

- DOT 49 CFR 192.465(a)
- DOT 49 CFR 192.620(d)(8)
- DOT 49 CFR 195.573(a)

Introduction

Whenever we take a measurement, whether it’s length through a ruler, temperature through a thermometer, or pressure through a pressure gauge, we are obtaining some sort of value. The same can be said about Cathodic Protection (CP) potential measurements.

But what exactly does the value of a potential measurement mean? What exactly are we measuring?

To answer these questions, it may be helpful to take a quick look at external corrosion, cathodic protection, and the role that potential measurements play.

External corrosion can affect almost any metallic component in a pipeline system. With time, it can consume the metal of these components, weakening the strength of a pipeline system and increasing the risk of leaks and failures. While we know that corrosion can be dangerous, we often don’t quite understand the what, why, and how of external corrosion.

What is External Corrosion?

External corrosion is an electrochemical reaction. In other words, it’s a chemical reaction that involves electric charges. It occurs when a metallic structure, such as a pipeline, comes into contact with an electrolyte. An electrolyte is a substance that allows the flow of electrical current. In the case of a buried pipe, the electrolyte is the soil in which it is buried. For a submerged pipe, the electrolyte is the water that surrounds it.

Why does Corrosion Occur?

Because the metal makeup of a pipeline is not the same throughout, a voltage difference, or potential, is created between different areas on the surface of the pipe. When a pipeline is buried, this voltage difference causes electrical current to flow through the soil from one area on the pipe surface to another. The area where current leaves the pipe is referred to as “anodic” and the area where current enters the pipe is referred to as cathodic.

Now, because the anodic area is more negative than the cathodic area and because current flows from negative to positive, the two areas have a need to balance out. A chemical reaction causes charged particles, called ions, to leave the anodic area and enter the soil causing the metal to break down. This results in corrosion at the anodic area.

Meanwhile, ions are collected at the cathodic area, which causes a hydrogen film to form. This process, often referred to as polarization, protects the metal from corrosion. What happens here, at the cathodic area, is the basic principle of cathodic protection.

Cathodic Protection

The goal of cathodic protection (CP) is to reduce the voltage difference, or potential, between the anodic and cathodic area of a corrosion cell. CP achieves this by supplying electrical current (through the use of an external element) to the surface of a pipeline, turning anodic areas into cathodic areas.

When electrical current flows to the surface of a pipeline, it changes the potential of the pipeline in the negative direction.
This is where the structure-to-electrolyte potential measurement (a type of potential measurement) comes into play. When you take a structure-to-electrolyte potential measurement you are measuring the potential difference between the structure and the electrolyte. The potential that is measured is recorded and then analyzed to determine whether the structure is being protected from corrosion.

**Importance of Covered Task**

Because pipeline operators use potential measurements to determine the need for corrosion control and to evaluate the effectiveness of their CP systems, it is extremely important that you perform this covered task correctly. Not doing so can cause pipeline operators to make incorrect interpretations and decisions regarding corrosion control, putting the integrity of their pipelines at risk.

**Knowledge:** Explain what is required prior to performing this task.

**Pipeline Operator-Approved Procedures and Appropriate Equipment/Material**

Prior to performing this task, you will need to have the pipeline operator-approved procedures as well as the appropriate equipment and materials. The procedures will outline requirements for performing this task that are specific to the pipeline operator. Operators may also have specific requirements regarding the type of equipment that can be used to perform this task. Therefore, it’s important to follow the specific requirements of the procedures and only use operator-approved equipment. Doing so can ensure the task is performed correctly and according to the pipeline operator’s standards.

**Knowledge:** Identify and describe the test equipment required to complete a potential measurement.

In order to take a CP potential measurement, you will need a high impedance voltmeter and a reference cell.

**Voltmeter**

A voltmeter is an instrument used for measuring the potential difference, or voltage, between two points in an electrical or electronic circuit. There are two types of voltmeters: analog and digital.

**Analog Voltmeter**

Analog voltmeters use a needle and a calibrated scale to indicate values. These instruments have an internal magnet with a moving electric coil. As current passes through the coil, a needle that is attached to the coil moves across the scale of the voltmeter and produces a reading.

**Digital Voltmeter**

Digital voltmeters are electronic instruments that collect data and display an average value. The digital data is normally displayed on a liquid crystal display (or LCD).

Some digital voltmeters are equipped with a variety of features, such as the auto-range feature which allows for the measurement of different voltage values.

**Other Devices**

Another type of device that can be used to perform this task is the multimeter. Multimeters have the capability of measuring voltage in addition to other electrical values. Most multimeters combine three distinct types of
meters (voltmeter, ammeter, and ohmmeter) into a single device. Because of this, multimeters are widely used by field personnel when performing CP measurements.

**Note:** For training purposes, the terms multimeter and voltmeter will be used interchangeably in this training.

The data logger is another device that can be used in place of the voltmeter or multimeter. Regardless of what type of device is used, it is important to make sure the selected equipment is approved by the pipeline operator.

**High Input Impedance (Resistance)**

Digital meters used for CP potential measurements must be equipped with high input impedance (or high input resistance for analog type meters). But why is this so?

When a meter is connected to a circuit, the meter becomes part of the circuit it is measuring. The meter itself changes the resistance of the circuit it is measuring, so therefore it also changes the reading.

Input impedance is the ability of a meter to measure a circuit parameter without affecting the reading. The higher the impedance, the more accurate the readings will be. And since accurate information is needed to properly evaluate the condition of a pipeline, a high impedance voltmeter is therefore required.

The good news is that most conventional meters on the market today have an internal impedance of 10 megohms, which is suitable for most applications.

**Reference Cell**

Because the structure-to-electrolyte interface cannot be directly measured in the case of a buried or submerged pipe, a reference cell is used to take a potential measurement.

Reference cells (also known as reference electrodes or half-cells) are electrodes which have a stable and well-known electrode potential.

The most common types of reference cells that are used to perform CP potential measurements include the:

- Copper-copper/sulfate (CuCuSO₄)
- Silver-silver/chloride (AgAgCl)

**Note:** It’s important to use the correct reference cell as outlined in the pipeline operator procedures. Some pipeline operators will only allow the use of a specific type of reference cell.

**Copper-Copper/Sulfate (CuCuSO₄)**

The CuCuSO₄ reference cell consists of a copper rod and a saturated copper sulfate solution housed inside of a plastic tube with a porous plug at one end. The plastic tube is partially clear in order to see the level of solution. The CuCuSO₄ reference cell is typically used for structures in soil or fresh water.

**Silver-silver/chloride (AgAgCl)**

For high chloride environments such as seawater and marsh lands, a AgAgCl reference cell is required. The AgAgCl reference cell consists of a silver rod housed in manufactured seawater solution.

Depending on the model, some kits will contain a different body type, one for land and the other for offshore use. The offshore type will usually come with a brass weight and a waterproof adapter.

It is important to note that the type of reference cell to use will be determined by the environment in which the cell is placed. For example, if a CuCuSO₄ is used in high chloride environments, such as sea water, it can suffer from chloride contamination, which may produce inaccurate readings.

**Electrode Extension (Optional)**

A common accessory of the reference cell is the electrode extension.
The electrode extension is a rod that connects to the reference cell. This piece of equipment allows CP personnel to take potential measurements in hard to reach areas. It also allows personnel to take a reading without having to crouch or bend over, making it easier to take potential measurements during CP surveys.

### Knowledge

**Identify and describe the structure-to-electrolyte potential measurement.**

A structure-to-electrolyte potential measures the potential difference between the surface of a structure and the electrolyte. This potential difference is measured with reference to an electrode (or reference cell) in contact with the electrolyte.

The structure can be a metallic pipe, pipe component, a buried or submerged tank, tank bottom, or any other steel structure. The electrolyte refers to the surrounding soil or liquid that is in contact with the structure.

Structure-to-electrolyte potentials are taken for many different purposes. Not only do they help determine the adequacy of CP, they can also be used to test for electrical isolation and shorted pipeline casings, among other things.

In the case of pipelines, the most common types of structure-to-electrolyte potential measurements are the pipe-to-soil and pipe-to-water potentials.

#### Pipe-to-Soil Potential

A pipe-to-soil potential measures the potential of the pipe in soil with respect to a standard reference electrode in contact with the earth. In this type of measurement, the pipe and the reference cell are connected to the appropriate terminals of the multimeter. The connection to the pipeline can be done via a **test point**. A test point is an individual, specific monitoring point that is connected to the structure to which a multimeter can connect in order to obtain the measurement. Test points are typically found within **test stations**, although other pipeline components, such as risers and valves, can also serve as test points.

#### Pipe-to-Water Potential

Pipe-to-water potentials are similar in nature to pipe-to-soil potentials. The difference is that the reference cell is placed in water. As mentioned previously, fresh water applications will require a conventional CuCuSO₄ reference, while high chloride environments, such as seawater, will require a AgAgCl.

### Skill

**Describe the proper calibration, setup, and use of the equipment to perform a measurement.**

#### Inspection and Calibration

CP potential measurements are useless if the equipment is damaged or not properly calibrated. All equipment should be inspected for damage as specified by the pipeline operator and properly calibrated in accordance with the manufacturer.

#### Multimeters

Multimeters should be inspected before operation to make sure they are in good working condition. To test their accuracy, a measurement on a known potential can be performed. This can help to confirm the accuracy of the meter.

Multimeters should be calibrated and certified annually or as specified by the pipeline operator. All meters should have a calibration sticker attached to them or documentation available stating the details of the calibration.
Reference Cells

Reference cells should be inspected for damage and kept away from direct sunlight. They should be kept at least three-quarters full, with a well-saturated copper sulfate solution. There should always be a few extra sulfate crystals in the reference cell to ensure the solution is saturated. If the solution has a milky appearance, the solution should be replaced and the copper rod cleaned. Distilled water should be used to refill the reference cell. Reference the manufacturer’s instructions for specific information.

Precautions should also be taken when the reference cell is stored or used in environments where the ambient temperature is below freezing. Freezing temperatures can freeze the copper sulfate solution and damage the porous plug, making it difficult to obtain a reading. Anti-freezing products are available from most reference cell manufacturers and can be used when using or storing the reference cell in low temperature conditions.

Extra attention should be given to the porous plug of the reference cell. The porous plug should be in good condition and free of debris in order to achieve good contact with the electrolyte. Because the plug is porous, contaminants in the soil can gradually move into the reference cell, generating inaccurate potentials. Because of this, reference cells should be inspected and calibrated before each use.

A reference cell can be calibrated by measuring the potential difference against a master or standard reference cell. To calibrate, place the electrodes in water in a non-conductive container and measure the potential difference. Another way to calibrate is to place the porous plugs of each electrode end to end in water.

Please note that the standard reference cell should never be used in the field. Its sole purpose is for calibration only. To ensure that you calibrate your reference cell properly, refer to the manufacturer’s instructions as well as your pipeline operator procedures.

Setup & Use of Equipment

The following will describe a basic overview of how to take a CP potential measurement, more specifically a pipe-to-soil potential using a digital multimeter at a test station. For instructions that apply to your specific situation, make sure you refer to your pipeline operator procedures.

Before you begin, ensure you are wearing and/or using the standard safety equipment as stated by your company. As a safety measure, it is also recommended to measure the AC voltage between the pipeline and the ground, especially when high voltage power lines or other AC power sources are nearby.

1. Once all safety measures are in place, begin the procedure by setting the multimeter to the DC Volt scale.
   - If the meter does not have an auto-range feature, it will have to be set to the appropriate scale for the measurement. This can be done by starting with the highest DC volt scale and working your way down to the lowest scale that can capture the value being measured.

2. Next, connect the multimeter negative (“common” or black) lead to the reference cell.

3. Place the reference cell in direct contact with the soil and directly over the pipeline.
   - When doing this, ensure: the cap is removed from the porous plug of the reference cell, the reference cell is placed in a vertical position (with the tip down), the plug makes good contact with the ground, and the soil where the reference cell is placed is moist. Add water if necessary.
   - **Note:** Inaccurate readings may be obtained if the reference cell is placed on concrete or similar surfaces.
   - For pipe-to-water potential measurements, make sure the reference cell is not completely submerged unless the top end of the reference cell has been sealed.

4. Next, connect the multimeter positive lead (red) to the pipeline via the test point.
• It’s important to note that if you connect the negative lead to the reference cell and the positive lead to the pipeline, this will normally result in a negative potential reading. However, if the leads are reversed, you will obtain a positive reading and must record the opposite polarity from the one being displayed.

5. Lastly, obtain and record the pipe-to-soil potential.

• Check your pipeline operator procedures, but most operators will require you to record the polarity, value, units, and type of reference cell used. For example: -0.85V CSE. The (-) is the polarity, 0.85 is the value, V is for the unit, and CSE is an abbreviation for the CuCuSO₄ reference cell. It’s important to note that a CP potential measurement is only representative of the CP condition on the pipeline at the specific contact point and for a short length on either side.

Once the reading is obtained, it is analyzed to determine whether adequate CP is present. To do this, pipeline operators use the established criteria outlined in the Department of Transportation (DOT) external corrosion control regulations.

The most common criterion used in determining adequate CP is a (cathodic) voltage of -0.850mV (or -0.85V) with reference to a saturated CuCuSO₄ reference cell.

In the case of a buried pipeline, if the potential difference between the pipe and the CuCuSO₄ reference cell (contacting the soil directly above and as close as possible to the pipe) is equal to or more negative than -0.850mV, the -0.850mV criterion is satisfied and it can be determined that adequate CP has been provided at that specific point.

However, there are other considerations that must be taken into account when interpreting potential measurements. Voltage drops in the pipe-to-soil potential circuit must be considered as well as whether the CP system is ON or OFF at the moment the measurement is taken. Also, not all pipeline operators will use the -0.850 mV criterion. Therefore, you should always follow your pipeline operator procedures in order to properly interpret the data.

Should you obtain a reading that is not within the desired range, you should troubleshoot, if qualified to do so, or notify the proper personnel.

Abnormal Operating Conditions (AOCs)

Candidates are required to possess the ability to RECOGNIZE and REACT to the listed AOCs for each task. Be prepared to answer questions concerning additional AOCs that may be relevant. Evaluators may ask questions about AOCs throughout the evaluation.

An AOC is defined in 49 CFR §§ 192.803 and 195.503 as:

A condition identified by the pipeline operator that may indicate a malfunction of a component or deviation from normal operations that may:

• Indicate a condition exceeding design limits; or
• Result in a hazard(s) to persons, property, or the environment.

Recognize: Unintentional releases, vapors, or hazardous atmosphere could be signs that an abnormal operating condition has occurred. Examples could include, but are not limited to:

• Blowing gas
• Puddles
• Dead vegetation
• Vapors from casing vents
React/Respond: Proper reactions and/or responses to take in the event of an unintentional release, vapors, or hazardous atmosphere include the following:

- Eliminate potential ignition sources.
- Move to a safe location.
- Notify emergency response personnel, as appropriate.
- Limit access to location, as necessary.
- Follow appropriate procedures for notification, documentation, and remedial action.

Recognize: Material defects, anomalies, or physical damage of pipe or a component that has impaired or is likely to impair the serviceability of the pipeline are abnormal operating conditions. Examples include, but are not limited to:

- Damaged risers
- Exposed pipe
- Missing line marker
- Frayed or missing test leads
- Atmospheric corrosion

React/Respond: Proper reactions/responses to take in the event of material defects, anomalies, or physical damage of pipe or a component that has impaired or is likely to impair the serviceability of the pipeline include the following:

- Determine extent, cause, and potential hazard(s) of defect, anomaly, and/or damage.
- Mark the location so it may be easily located, as appropriate.
- Follow appropriate procedures for notification, documentation, and remedial action.

Recognize: Failure or malfunction of pipeline component(s) is an abnormal operating condition. Examples could include, but are not limited to:

- Damaged test station
- Inoperative rectifier

React/Respond: Proper reactions/responses to take in the event of a failure or malfunction of pipeline component(s) include the following:

- Determine extent, cause and potential hazard(s) of failure and/or malfunction.
- Follow appropriate procedures for notification, documentation, and remedial action.

Glossary

**abnormal operating condition**

A condition identified by the operator that may indicate a malfunction of a component or deviation from normal operations that may indicate: a condition exceeding design limits; or result in a hazard(s) to persons, property, or the environment.

**AOC**

abnormal operating condition

**CCT**

common covered task

**CFR**
**electrolyte**
a chemical substance containing ions that migrate in an electric field. For the purpose of this standard, electrolyte refers to the soil or liquid adjacent to and in contact with a buried or submerged metallic piping system, including the moisture and other chemicals contained therein.

**resistance**
a material's opposition to the flow of electric current; measured in ohms.

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

**test point**
an individual, specific monitoring point typically found within a test station to facilitate cathodic protection measurements; aka a test.

**test station**
a location or an aboveground appurtenance, in which test leads are found to measure cathodic protection.

**voltage**
an electromotive force or a difference in electrode potentials expressed in volts.