Training Guide

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 (valves, 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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Recommended Student Training or Resources:

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<th>Recommended Student Training or Resources:</th>
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<td>▪ N/A</td>
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### Soil Resistivity

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<tr>
<th>Knowledge</th>
<th>Explain what is required prior to performing this task.</th>
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#### 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.

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<tr>
<th>Knowledge</th>
<th>Identify the equipment used to conduct a soil resistivity test.</th>
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A soil resistivity test will generally require a combination of the following components:

- Soil resistivity test instrument
- Metal pins
- Wiring
- Probe with two isolated electrodes
- AC or DC current source
- Ammeter and volt meter
- Soil box

**Note:**
The necessary equipment to perform a soil resistivity test will depend on the soil resistivity method, and may even vary within each method. For this reason, it is important to refer to the applicable standard operating procedures for a list of approved equipment.

**Soil Resistivity Test Instrument**

The soil resistivity test instrument, or meter, is an electronic device used to measure the resistance of soil. This instrument combines an alternator or vibrator current source, galvanometer, and resistance bridge measuring circuit all in one unit.
Generally, soil resistivity meters are battery operated and have the ability to produce AC current. They include a panel that, at a minimum, consists of four color coded terminals (C1, C2, P1, P2), a resistance range selector, and a dial or LCD display.

The majority of models can be used for different soil resistivity applications, such as the 4-Pin, 3-Pin, 2-Pin, and soil box methods. Ultimately, the features of each device will vary between manufacturers.

**Metal Pins**

In the 4-Pin Wenner soil resistivity method, metal pins are used to introduce current into the earth. Typically, pins are stainless steel rods that are 1/4-inch or 3/8-inch in diameter and two to three feet long. They have T-handles which facilitate their installation and uninstallation. Although soil resistivity pins tend to be the norm, other items, such as large screwdrivers, can be used to serve as electrodes in a soil resistivity test.

**Wiring**

Insulated lead wires are used to connect the soil resistivity meter to the metal pins or soil box terminals. Lead wires are often supplied as a set, consisting of four color coded wires of varying lengths ranging from 5’ to 65’ feet. They are labeled (C1, C2, P1, and P2) to facilitate connection to the soil resistivity meter terminals. Lead wires are typically harnessed and mounted on a hand-held reel for ease of use.

Special connectors, such as jumper leads, are usually supplied with each kit to facilitate connection to the metal pins.

Special leads and connectors are also available for use with the soil box method.

**Probe with Two Isolated Electrodes**

The probe with two isolated electrodes is a device that is used for the single probe resistivity application. There are various designs of such a device on the market, but the essential components include a probe rod with an insulated shaft and two electrically separated electrodes near its tip.

The electrodes are connected inside the shaft to the resistance measuring component. Depending on the model, the resistance measuring component can be mounted on the shaft of the probe or connected to the probe via test leads.

Older models utilize an audio receiver, an AC bridge, and headphones or similar devices for adjustment and balancing. Other models have additional features, such as the ability to measure a soil’s acidity level (pH).

**DC or AC current source**

An AC or DC current source is required to perform a soil resistivity test. Current sources may include, but are not limited to:

- storage batteries
- generators
- portable rectifiers, and
- soil resistivity meters

Soil resistivity meters like the type used for the 4-Pin application have the ability to produce AC current, which can eliminate the possibility of polarization of the soil pins – a common problem with DC tests.
**Ammeter and Voltmeter**

Although soil resistivity measurements that use the four-pin set up are often performed using a soil resistivity meter, such a measurement can also be obtained using an ammeter, voltmeter, and a DC power supply.

As seen in the illustration, the ammeter is connected in series between one of the outer pins (C1, C2) and the current source, and the voltmeter is connected in parallel to the circuit across the two inner pins (P1, P2). The ammeter will display the quantity of current flowing through the circuit, while the voltmeter will measure the voltage drop between the two inner pins.

This equipment combination can also be used with the soil box method.

**Soil Box**

Soil Boxes are used when soil samples are removed from the field and brought into a lab for testing. Soil boxes consist of a non-conducting plastic container, metal end plates for passing test current through the sample, and removable pins. Soil boxes are commercially available and are offered in a variety of sizes.

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**Knowledge**

| Identify and describe the different soil resistivity methods. |
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There are different methods of measuring soil resistivity. The most common include the following:

- Wenner
- Single Probe
- Soil Box

**4-Pin Wenner Method**

The 4-Pin Wenner Method is perhaps the most commonly used soil resistivity method. It is named after Dr. Frank Wenner, the developer of the theory and procedure.

The Wenner method is used to measure the resistivity of larger volumes of soil to various depths without the need to excavate and is often used in determining the final selection of test sites for CP installations.

The Wenner procedure consists of installing four metal pins into the ground in a straight line. The pins are labeled from one end to the other as C1, P1, P2, and C2. The spacing of the pins is equal to the depth to which the average soil resistivity is to be measured.

The resistivity is obtained by driving current through the soil via the two outer pins, or current pins (C1 and C2), and measuring the resistance between the two inner pins, or potential pins (P1 and P2). The resistance value that is obtained is then calculated to obtain the soil resistivity in ohm-cm.

**Single Probe Method**

The single probe method is a two-point resistivity measurement. This method consists of pushing the probe rod into the ground and measuring the resistance between the two electrodes (exposed metal surfaces) located at the tip of the probe. The resistance between the two points is proportional to the resistivity of the soil immediately surrounding the electrodes.

An advantage of the single probe rod method is the speed in which resistivity measurements can be obtained and the minimal calculations involved. This makes this method practical when testing prospective sites for CP installations without having to use in-depth or extensive soil resistivity techniques.

The limitation of the single probe method is that the resistivity value only represents a small localized volume of soil (also true with the soil box method). The resistivity obtained is only representative of the soil...
immediately surrounding the tip of the rod.

**Soil Box Method**

The soil box method is used to measure the resistivity of soil samples that are removed from the field, typically during excavations or boring.

This method consists of placing the soil sample inside the soil box, driving current through the sample via the two end plates, and measuring the voltage drop across the two inner pins; this voltage drop is proportional to the soil resistivity. A multiplier is then used to obtain the resistivity of the soil sample.

The soil box method allows the option of obtaining the resistivity measurement on-site or in a laboratory. Another advantage is that it can provide soil resistivity at various depths during an excavation. As the excavation progresses, numerous soil samples that correspond to specific layers of soil can be collected.

A shortcoming of this method is recreating the original conditions of the soil. Compaction of the soil, loss of moisture, and contamination of the soil are all factors that could affect the resistivity measurement.

### Skill

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<th>Perform a soil resistivity test.</th>
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The procedures for performing a soil resistivity test will vary due to a number of factors, such as soil resistivity method, equipment, and pipeline operator requirements. Therefore, it’s important to refer to the applicable standard operating procedures when conducting the test.

The following section will provide a basic overview of a soil resistivity test using the Wenner, single probe, and soil box methods.

**4-Pin Wenner Method**

Prior to conducting the test, determine the location of the test and the depth to which the soil resistivity is to be averaged.

This information can be obtained by consulting with the pipeline operator.

Next, align the pins C1, P1, P2, and C2 in a straight line from one end to the other, and select the appropriate pin spacing.

The desired depth to measure will determine the appropriate pin spacing. Pin spacing is usually 2.5, 5, 10, 15, or 20 feet.

If other metallic structures lie within the sphere of the soil being measured, align the pins perpendicular to the pipe as illustrated in the image.

Drive each pin into the ground. Pin depth should not exceed one-fifth of the pin spacing selected. If necessary, water the pin/soil interface for better results.

Make the necessary connections in accordance with manufacturer instructions and operator requirements.

Ensure the equipment is properly calibrated and/or charged (if applicable). Next, energize the equipment and...
complete the Wenner Soil Resistivity Test in accordance with manufacturer instructions and operator requirements.

Record the pin spacing, resistance or amperes and volts, and any other pertinent information, and calculate the soil resistivity in ohm-cm utilizing the following formula:

\[ \rho = 191.5 \times a \times R \]

Where:
- \( \rho \) = soil resistivity in ohm-cm
- \( a \) = pin spacing in feet
- \( R \) = measured resistance between P1 and P2 in ohms

**Note:**
If the voltmeter-ammeter-DC power supply procedure is used, consideration should be given to the possible polarization of the pins. To mitigate this problem, the test current should be interrupted and should not be left on continuously. The current pins (C1 and C2) should also be reversed during the course of the testing.

**Single Probe Method**

Prior to performing a soil resistivity test using the single probe method, ensure the two electrodes near the tip of the probe are clean and not rusted.

Next, connect the probe rod to the resistance measuring component. This can be accomplished either by mounting the measuring component onto the shaft of the probe or through the use of test leads (depending on the model).

Drive the probe rod into the ground to the depth of the desired measurement (Note that the electrodes are located at the tip of the probe). Longer probes are available on the market if greater depths need to be measured.

**Warning:** Care must be taken when inserting the probe rod into the ground to avoid potential damage to the pipe and/or its coating.

Ensure the equipment is properly calibrated and/or charged (if applicable). Next, energize the equipment and measure the resistance between the two electrodes in accordance with manufacturer instructions.

Record the soil resistivity and any other pertinent information.

**Soil Box Method**

To measure the soil resistivity of a soil sample using the soil box method:

Remove the potential pins (P1 and P2) from the soil box and pack the soil to be tested into the box until full. During packing, ensure proper compaction is achieved. The level of compaction should resemble, as much as possible, the compaction of the area where the soil was taken.
Next, insert the potential pins and re-compact the soil to ensure adequate contact between the pins and the soil. The soil should be even and level with the top of the box to obtain accurate measurements.

Once this is done, the soil sample is ready to be measured.

To measure the resistivity, perform the following in accordance with manufacturer instructions:

- Connect the four test leads from the four pins to the proper equipment
- Read the meter (in ohm centimeters) for resistivity
- Record the measurement

### 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 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: 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, and vapor from casing vents.

#### React/Respond:

Proper reactions/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

#### AOC: 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 could include, but are not limited to, damaged coating during soil probing.

#### React/Respond:

Proper reactions/responses to take in the event 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:
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|   | • 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 |