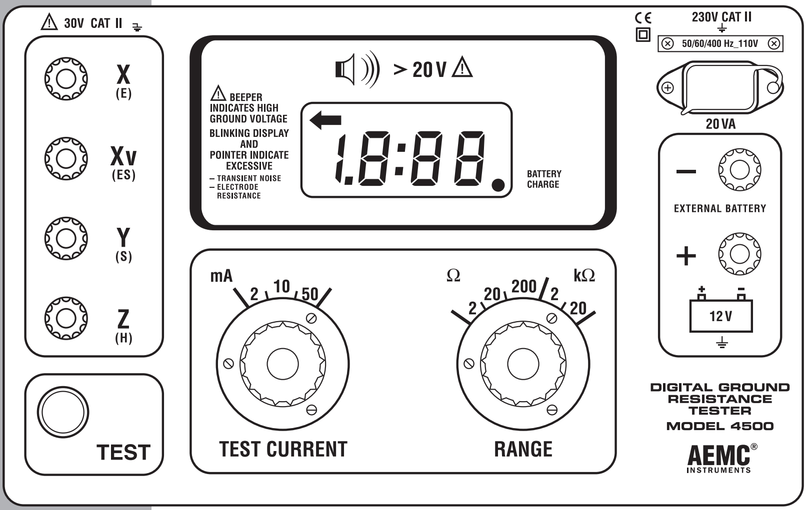
■ DIGITAL GROUND RESISTANCE TESTER

4500



ENGLISH

User Manual

AEMC® INSTRUMENTS

Owner's Record

The serial number for the Model 4500 is located on the front of the instrument. Please record this number and purchase date for your records.

GROUND RESISTANCE TESTER MODEL 4500

CATALOG #: 450.100

SERIAL #: ______________________________

PURCHASE DATE: ______________________________

DISTRIBUTOR: ______________________________

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INTRODUCTION

⚠ Warning ⚠

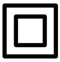
"It should be impressed on all personnel that a lethal potential can exist between the station ground and a remote ground if a system fault involving the station ground occurs while tests are being made. Since one of the objects of tests on a station ground is the establishment of the location of an effectively remote point for both current and potential electrodes, the leads to the electrodes must be treated as though a possible potential could exist between these test leads and any point on the station ground grid."

- excerpted from IEEE Std. 81-1962

These safety warnings are provided to ensure the safety of personnel and proper operation of the instrument.

- The instrument must not be operated beyond its specified operating range.
- Safety is the responsibility of the operator.
- All metal objects or wires connected to the electrical system should be assumed to be lethal until tested. Grounding systems are no exception.
- Use extreme caution when using the instrument around energized electrical equipment.
- Never attempt to use the instrument to twist or pry the ground electrode or ground wire away from the equipment being grounded.
- AEMC® Instruments considers the use of rubber gloves to be an excellent safety practice even if the equipment is properly operated and correctly grounded.
- Always inspect the instrument and leads prior to use. Replace any defective parts immediately.

1.1 International Electrical Symbols



This symbol signifies that the instrument is protected by double or reinforced insulation. Use only specified replacement parts when servicing the instrument.

This symbol on the instrument indicates a WARNING and that the operator must refer to the user manual for instructions before operating the instrument. In this manual, the symbol preceding instructions indicates that if the instructions are not followed, bodily injury, installation/sample and product damage may result.

Risk of electric shock. The voltage at the parts marked with this symbol may be dangerous.

1.2 Receiving Your Shipment

Upon receiving your shipment, make sure that the contents are consistent with the packing list. Notify your distributor of any missing items. If the equipment appears to be damaged, file a claim immediately with the carrier and notify your distributor at once, giving a detailed description of any damage. Save the damaged packing container to substantiate your claim.

1.3 Ordering Information

Ground Resistance Tester Model 4500 .... Cat. #450.100

Includes AC power supply cord, 12V nickel-cadmium battery (installed), adhesive label (C1-P1-P2-C2), hex key, spare fuse, and user manual.

1.3.1 Accessories and Replacement Parts

Test Kit for Model 4500.. **Cat. #100.525**

Includes Canvas Bag, [2] 500 ft Color-coded Leads on Reels, [1] 30 ft Color-coded Lead, [2] T-shaped Auxiliary Ground Electrodes.

Test Kit for 3-Point Testing (Supplemental for 4-Point testing) .... **Cat. #2130.61**

Includes Carrying Bag, [2] 100 ft Color-coded Leads, [1] 16 ft Lead and [2] 16" T-shaped Auxiliary Ground Electrodes.

Battery – Replacement 12V NiCD .... **Cat. #2960.10**

Fuse - Set of 3, 3.15A, 250V, 6 x 32mm (charger board)........ **Cat. #100.357**

Fuse – Set of 5, 0.1A, 380V, 6 x 32mm (measure board)......... **Cat. #2970.12**

Set of 2, T-shaped Auxiliary Ground Electrodes .... **Cat. #100.335**

Ground Tester Video/Workbook Set .... **Cat. #2130.64**

25Ω Calibration Checker .... **Cat. #2130.59**

Tape Measure – AEMC 100 ft... **Cat. #2130.60**

NEW: Order Accessories and Replacement Parts Directly Online
Check our Storefront at ***www.aemc.com*** *for availability*

PRODUCT FEATURES

2.1 Description

The Digital Ground Resistance Tester Model 4500 is a rugged, easy-to-use tester which is specifically designed for measuring very low resistance on large grounding systems (ground grids, ground mats), even under difficult conditions such as high stray currents or excessive auxiliary electrode resistance.

This high performance instrument is capable of measuring up to 20kΩ, and direct reading with a resolution of 1 milliohm is possible. The extra large 3½ digit LCD display minimizes the possibility of operator reading error, and dual indicators (blinking display and arrow) warn the operator when excess stray current or auxiliary electrode resistance is present, or when there is a lack of continuity between leads and electrodes. A beeper notifies the user if a voltage greater than 20V peak is present between the terminals X and Y or X and Z when the ground leads are connected.

The Model 4500 can be used to perform soil resistivity measurements with the four-point method by using the high 20kΩ range and is designed in a sturdy, dust and water-resistant carrying case with a detachable cover.

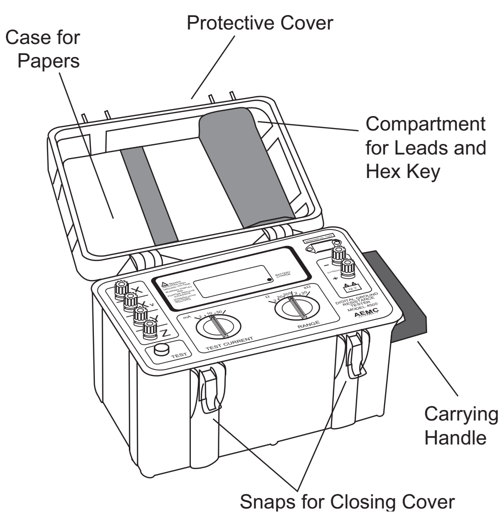


Figure 1

2.2 Detaching the Cover

To detach the cover from the case, apply downward pressure to the rear portion of the cover while gripping it firmly.

To re-attach the cover, fit the hinges into the respective housings and apply strong rear-to-front pressure to the cover until it snaps into place.

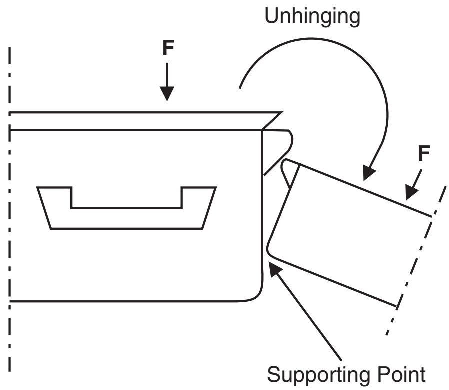


Figure 2

2.3 Control Features

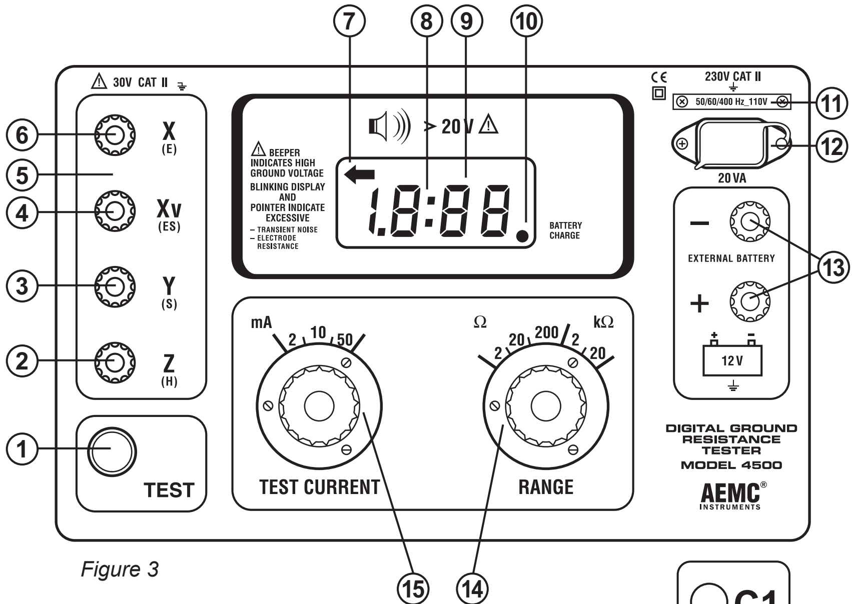
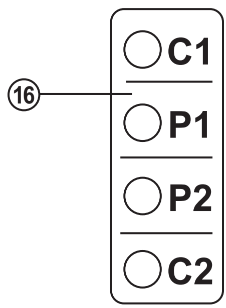


Figure 3



1. Test button
2. Input Terminal (Z)-(C2)
3. Input Terminal (Y)-(P2)
4. Input Terminal (Xv)-(P1)
5. Shorting strip
6. Input Terminal (X)-(C1)
7. Incorrect measurement indicator
8. Low battery indicator
9. Display
10. Battery charge indicator
11. Supply voltage indicator
12. Jack for power supply cord
13. Connecting terminals for power supply from external battery (12VDC)
14. Range selector switch
15. Test Current selector switch
16. Adhesive label (C-1, P-1, P-2, C-2) supplied with each instrument

SPECIFICATIONS

3.1 Electrical Specifications

Reference Conditions: 23°C ±3K, 30 to 50% RH; power supply -12V ± 0.2V; no electrical or magnetic field, no auxiliary rod resistance, no noise voltage.

NOTE: Specifications given for 60Hz distribution systems; if 50Hz, consult factory.

Ranges	2Ω	20Ω	200Ω	2000Ω	20kΩ
Resolution	1mΩ	10mΩ	0.1mΩ	1Ω	10Ω
Recommended Current Ranges	10mA or 50mA	2mA, 10mA, or 50mA		2mA or 10mA	2mA or 10mA

Maximum Output Voltage: 38Vrms

Accuracy (see chart on following page):
±2% of Reading ± 1ct from 10% to 100% of range

Test Current Ranges: 2mA, 10mA, 50mA

Maximum Auxiliary Electrode Resistance:

Ry: 50kΩ on 20Ω, 200Ω, 2000Ω, and
20kΩ ranges; 5kΩ on 2Ω range

Rz: 2mA range: 15kΩ
10mA range: 3000Ω
50mA range: 400Ω

Noise Influence on Accuracy:
0.5% of range (max) to 20V peak-to-peak (20 x peak)

Operating Frequency: 128Hz square wave

Dielectric Test: 2000Vrms, 50/60Hz between four interconnected measuring terminals and any external metal ground between line input and measuring terminals on front panel.

Power Supply: One built-in rechargeable 12V battery, or external 12VDC

Battery Life:
4 hrs on 50mA test current (800 15-second measurements)
7 hrs on 2mA and 10mA test currents (1500 15-second measurements)

Charging Time: 14 hours typical

Charging Supply Voltage: Internally selectable 110/220V, 45 to 450Hz

Low Battery Indication: Battery can be recharged with built-in dual voltage charging unit: 94 to 127V or 187 to 253V (47 to 450Hz).

⚠ **WARNING:** Do not fully discharge batteries.

Fuse Protection: 250Vrms (measurement circuit) via 3.15A 250V fuse

3.2 Accuracy

<table>
<tr><th colspan="2" rowspan="2">Range</th><th rowspan="2">Resolution</th><th rowspan="2">Test Current</th><th rowspan="2">Accuracy in % of Reading</th><th colspan="2">* Maximum Value of Y and Z Electrodes Having Influence < 1%</th></tr>
<tr><th>Ry</th><th>Rz</th></tr>
<tr><td rowspan="6">2Ω</td><td rowspan="3">0 to 0.2Ω</td><td rowspan="3">1mΩ</td><td>2 mA</td><td></td><td rowspan="2">5kΩ</td><td rowspan="18">600Ω to 20kΩ to be selected in relation to the test current</td></tr>
<tr><td>10mA</td><td rowspan="2">± 5mΩ ± 1ct</td></tr>
<tr><td>50mA</td><td>5kΩ</td></tr>
<tr><td rowspan="3">0.2Ω to 2Ω</td><td rowspan="3">1mΩ</td><td>2mA</td><td>± 2% ± 30mΩ ± 1ct</td><td rowspan="2">5kΩ</td></tr>
<tr><td>10mA</td><td>± 2% ± 3mΩ ± 1ct</td></tr>
<tr><td>50mA</td><td>± 2% ± 1ct</td><td rowspan="13">10kΩ</td></tr>
<tr><td colspan="2" rowspan="3">20Ω</td><td rowspan="3">10mΩ</td><td>2mA</td><td rowspan="11">± 2% ± 1ct of 10% to 100% of full scale</td></tr>
<tr><td>10mA</td></tr>
<tr><td>50mA</td></tr>
<tr><td colspan="2" rowspan="3">200Ω</td><td rowspan="3">0.1Ω</td><td>2mA</td></tr>
<tr><td>10mA</td></tr>
<tr><td>50mA</td></tr>
<tr><td colspan="2" rowspan="3">2kΩ</td><td rowspan="3">1Ω</td><td>2mA</td></tr>
<tr><td>10mA</td></tr>
<tr><td>50mA*</td></tr>
<tr><td colspan="2" rowspan="3">20kΩ</td><td rowspan="3">10Ω</td><td>2mA*</td></tr>
<tr><td>10mA*</td></tr>
<tr><td>50mA*</td><td></td></tr>
</table>

No accuracy specification - do not use

* See Table III for maximum auxiliary resistance

3.3 Table of Influencing Parameters

Parameters	Reference Conditions	Operating Conditions	% of Measurement	
			Typical	Maximum
Supply Voltage	12V ±0.2V	11 to 14V DC	0.2%/volt	0.3%/volt
Temperature	73˚F ±37˚F 23˚C ±3˚C	23˚F to 122˚F -5˚C to 50˚C	±0.5%/50˚F[3] ±0.5%/10˚C	±1%/50˚F[3] ±1%/10˚C
Auxiliary Electrode Resistance (Ry)	Ry = 0	0 to 50kΩ[1]	0.5%/10kΩ[1]	1%/10kΩ[1]
Influence of Auxiliary Electrode Resistance (Rz) in Relation to Test Current	Rz = 0	See Table 3	2mA: 0.1%/10kΩ 10mA: 0.1%/3kΩ 50mA: 0.1%/1kΩ	2mA: 0.3%/10kΩ 10mA: 0.3%/3kΩ 50mA: 0.3%/1kΩ or 5 cts
DC Voltage in Series with Rx	N/A	0 to 20V DC[2]	N/A	
AC 60 Hz Stray Voltage Influence in Series with Rx, Ry or Rz	N/A	See Table 3		

Table 1

1. For the 2Ω range (2mA and 10mA test currents), maximum Ry is 5kΩ. Influence will typically be 0.5%/5kΩ, with a maximum of 1% max/5kΩ or 3cts.
2. Presence of DC voltage may tend to limit the maximum (Rx + Rz) level indicated within Table 3.
3. From 10% to 100% of measuring scale interval. It is necessary to add the following quantities to those indicated with Table 1:

   ± 10mΩ for 2Ω/2mA range
   ± 3mΩ for 2Ω/10mA range
   ± 1 count for other ranges

3.4 Influence of Stray Voltage

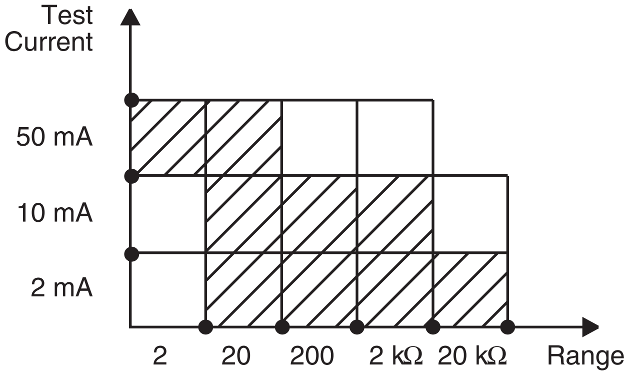


Table 2

Shaded areas indicate the ranges in which measurements can be performed, where 40V, 50/60Hz peak-to-peak stray voltage is present, without obtaining error levels representing more than 0.5% of the measurement range.

3.5 Influence of Auxiliary Resistances

In the absence of stray signals, the maximum values for (Rx+Rz) which will allow measurements to be performed, are those indicated within Table 3.

Range / Current	2Ω	20Ω	200Ω	2 kΩ	20 kΩ
50 mA	Rx + Rz = 600Ω max			(*)	(Do not use)
10 mA	Rx + Rz = 4000Ω max				(*)
2 mA	Rx + Rz = 20 kΩ max				(*)

Do not use

Table 3

* Even if auxiliary resistance of Rz = 0, the maximum reading is < 2000-counts on these three ranges (voltage limiting circuit at output terminals).

Table 4 shows the maximum resistance of the current circuit (Rx + Rz) for stray voltage of 10V peak-to-peak.

Range / Current	2Ω	20Ω	200Ω	2 kΩ	20 kΩ
50 mA	Rx + Rz = 400Ω max				(Do not use)
10 mA	Rx + Rz = 3000Ω max				
2 mA	Rx + Rz = 15 kΩ max				

Shaded: Do not use

Table 4

3.6 Mechanical Specifications

Display:
2000-count, 7 segment LCD, .71" (3-1/2 digit)

Connection:
Via terminals (wires; forked lugs with min gap of 6mm) banana jacks with Ø 4mm

Operating Temperature:
14° to 122°F (-10° to 50°C)

Case:
Heavy-duty plastic, with detachable cover and carrying handle

Colors:
Case - Safety yellow; Front Panel - Brown

Dimensions:
15.75 x 10.2 x 9.8" (400 x 260 x 250mm)

Weight:
14 lbs (6.5 kg) approximate

3.7 Safety Specifications

CE

Impact Resistance:
Shock and vibration according to MIL-T-28800D class 3

Environmental:
O-ring sealed faceplate against water and dust, sealed cover when closed; IEC529, DIN 0470-T1

EN 61010-1 +A2 (ed. 95)

Double Insulation ⧈

30V, Cat. II for measurement
230V, Cat. II for battery charger
12V, Cat. II for auxiliary supply

EN 61557

Electromagnetic Compatibility:
Emmission and Immunity: IEC 61326-1 (ed. 98)

OPERATION

4.1 Grounding Electrode Resistance

Figure 4 illustrates a grounding rod. The resistance of the electrode has the following components:

- the resistance of the metal and that of the connection to it
- the contact resistance of the surrounding earth to the electrode
- the resistance in the surrounding earth

More specifically:

A) Grounding electrodes are usually made of a very conductive metal (copper) with adequate cross sections so that overall resistance is negligible.

B) The National Institute of Standard and Technology (N.I.S.T.) has demonstrated that the resistance between the electrode and the surrounding earth is negligible if the electrode is free of paint, grease or other coating, and if the earth is firmly packed.

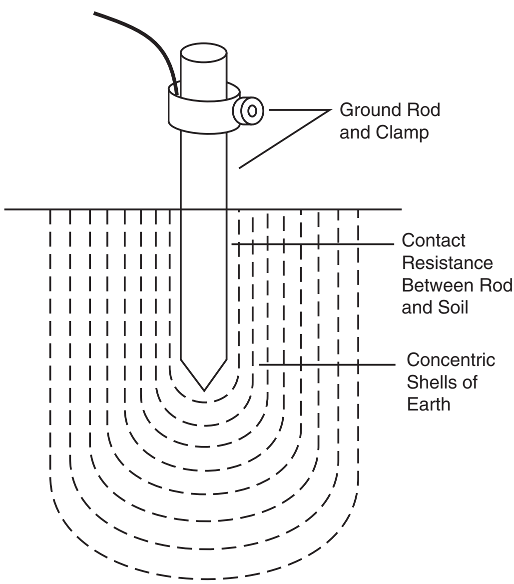


Figure 4

C) The only component remaining is the resistance of the surrounding earth. The electrode can be thought of as being surrounded by concentric shells of earth or soil, all of the same thickness. The closer the shell to the electrode, the smaller its surface; hence, the greater its resistance. The farther away the shells are from the electrode, the greater the surface of the shell; hence, the lower the resistance. Eventually, adding shells at a distance from the grounding electrode will no longer noticeably affect the overall earth resistance surrounding the electrode. The distance at which this effect occurs is referred to as the effective resistance area and is directly dependent on the depth of the grounding electrode.

In theory, the ground resistance may be derived from the general formula:

$$R = \rho \frac{L}{A} \qquad \text{Resistance} = \text{Resistivity} \times \frac{\text{Length}}{\text{Area}}$$

This formula clearly illustrates why the shells of concentric earth decrease in resistance the farther they are from the ground rod:

$$R = \text{Resistivity of Soil} \times \frac{\text{Thickness of Shell}}{\text{Area}}$$

In the case of ground resistance, uniform earth (or soil) resistivity throughout the volume is assumed, although this is seldom the case in nature. The equations for systems of electrodes are very complex and often expressed only as approximations. The most commonly used formula for single ground electrode systems, developed by Professor H. R. Dwight of the Massachusetts Institute of Technology, follows:

$$R = \frac{\rho}{2\pi L} \qquad \frac{\{(\ln 4L) -1\}}{r}$$

R = resistance in ohms of the ground rod to the earth (or soil)

L = grounding electrode length

r = grounding electrode radius

ρ = average resistivity in ohms-cm

4.1.1 Effect of Ground Electrode Size and Depth on Resistance

Size: Increasing the diameter of the rod does not materially reduce its resistance. Doubling the diameter reduces resistance by less than 10%.

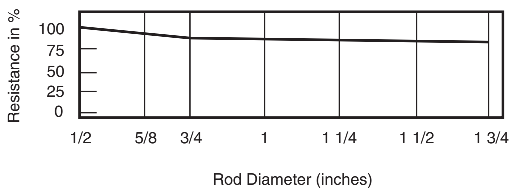


Figure 5

Depth: As a ground rod is driven deeper into the earth, its resistance is substantially reduced. In general, doubling the rod length reduces the resistance by an additional 40%.

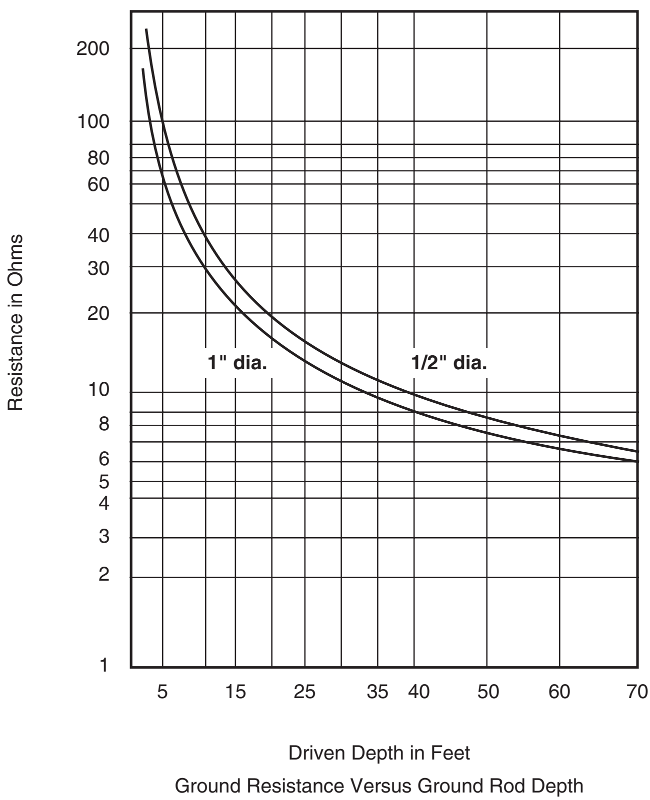


Figure 6

NEC® 2014 250.52 (A)(5) requires a minimum of 8 ft (2.4m) of the electrode to be in contact with the soil. The most common of electrode is a 10 ft (3m) cylindrical rod which meets the NEC® code, which requires a minimum diameter of 5/8" (1.59cm).

4.1.2 Effects of Soil Resistivity on Ground Electrode Resistance

Dwight's formula, cited previously, shows that the resistance to earth of grounding electrodes depends not only on the depth and surface area of grounding electrodes but on soil resistivity as well. Soil resistivity is the key factor that determines what the resistance of a grounding electrode will be, and to what depth it must be driven to obtain low ground resistance. The resistivity of the soil varies widely throughout the world and changes seasonally. Soil resistivity is determined largely by its content of electrolytes, consisting of moisture, minerals and dissolved salts. A dry soil has high resistivity if it contains no soluble salts.

	Resistivity, Ω-cm		
Soil	**Minimum**	**Average**	**Maximum**
Ashes, cinders, brine, waste	590	2,370	7,000
Clay, shale, gumbo, loam	340	4,060	16,300
Same, with varying proportions of sand and gravel	1,020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Table 5

4.1.3 Factors Affecting Soil Resistivity

Two samples of soil, when thoroughly dried, may become in fact very good insulators, having a resistivity in excess of 109 ohm-centimeters. The resistivity of the soil sample is seen to change quite rapidly until approximately twenty percent or greater moisture content is reached.

Moisture content, % by weight	Resistivity, Ω-cm	
	Top Soil	Sandy Loam
0	> 109	> 109
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	19,000	10,500
20	12,000	6,300
30	6,400	4,200

Table 6

The resistivity of the soil is also influenced by temperature. Table 7 shows the variation of the resistivity of sandy loam, containing 15.2% moisture, with temperature changes from 20° to -15°C. In this temperature range the resistivity is seen to vary from 7200 to 330,000 ohm-centimeters.

Temperature		Resistivity Ω-cm
˚C	˚F	
20	68	7,200
10	50	9,900
0	32 (water)	13,800
0	32 (ice)	30,000
-5	23	79,000
-15	14	330,000

Table 7

Because soil resistivity directly relates to moisture content and temperature, it is reasonable to assume that the resistance of any grounding system will vary throughout the different seasons of the year. Such variations are shown in Figure 7 below. Since both temperature and moisture content become more stable at greater distances below the surface of the earth, it follows that a grounding system, to be most effective at all times, should be constructed with the ground rod driven down a considerable distance below the surface of the earth. Best results are obtained if the ground rod reaches the water table.

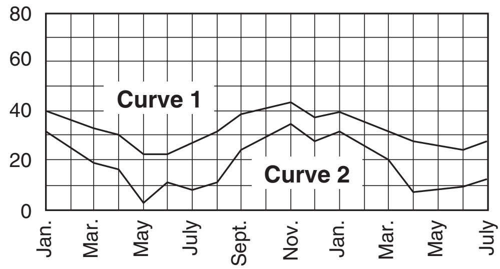


Figure 7

Seasonal variation of earth resistance with an electrode of 3/4" pipe in rather stony clay soil. Depth of electrode in earth is 3 ft for Curve 1, and 10 ft for Curve 2.

In some locations, the resistivity of the earth is so high that low-resistance grounding can be obtained only at considerable expense and with an elaborate grounding system. In such situations, it may be economical to use a ground rod system of limited size and to reduce the ground resistivity by periodically increasing the soluble chemical content of the soil. Table 8 shows the substantial reduction in resistivity of sandy loam brought about by an increase in chemical salt content.

The Effect of Salt* Content on the Resistivity of Soil **(sandy loam, moisture content, 15% by weight, temperature 17˚C)**	
Added Salt % by weight of moisture	**Resistivity (Ohm-centimeters)**
0	10,700
0.1	1,800
1.0	460
5	190
10	130
20	100

Table 8

Chemically treated soil is also subject to considerable variation of resistivity with changes in temperature, as shown in Table 9 on the next page. If salt treatment is employed, it is, of course, necessary to use ground rods which will resist chemical corrosion.

The Effect of Temperature on the Resistivity of Soil Contining Salt* (sandy loam, 20% moisture; salt 5% of weight of moisture)	
Temperature ˚C	**Resistivity** (Ohm-centimeters)
20	110
10	142
0	190
-5	312
-13	1440

Table 9

*Such as copper sulfate, sodium carbonate and others. Salts must be EPA or local ordinance approved prior to use.

4.1.4 Effect of Ground Electrode Depth on Resistance

To assist the engineer in determining the approximate ground rod depth required to obtain a desired resistance, a device called the Grounding Nomograph may be used. The Nomograph, shown on the following page, indicates that to obtain a grounding resistance of 20 ohms in a soil with a resistivity of 10,000 ohm-centimeters, a 5/8" OD rod must be driven 20 feet. NOTE that the values indicated on the Nomograph are based on the assumption that the soil is homogeneous and, therefore, has uniform resistivity (Figure 8). The Nomograph value is an approximation.

Grounding Nomograph

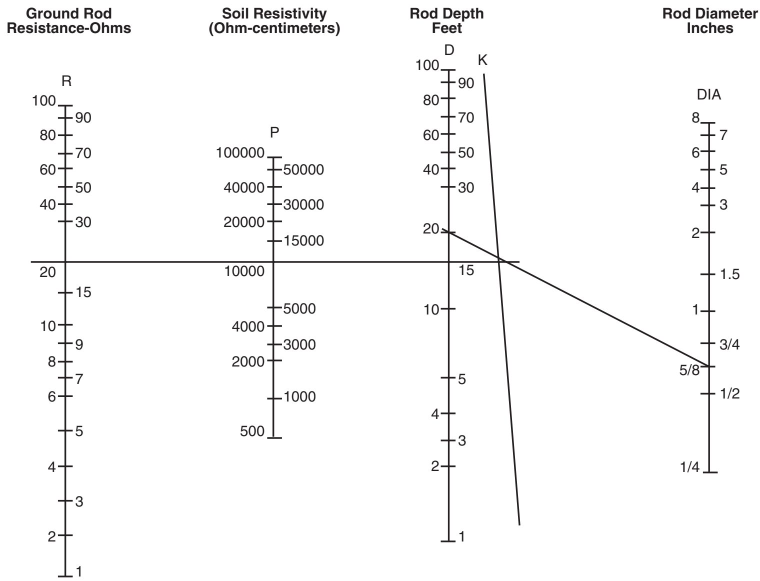


Figure 8

1. Select required resistance on R scale.
2. Select apparent resistivity on P scale.
3. Lay straightedge on R and P scale, and allow to intersect with K scale.
4. Mark K scale point.
5. Lay straightedge on K scale point and DIA scale, and allow to intersect with D scale.
6. Point on D scale will be rod depth required for resistance on R scale.

4.2 Ground Resistance Values

NEC® 2008 article 250.56 regarding the resistance of rod, pipe and plate electrodes states that if the rod, pipe, or plate does not have a resistance of 25Ω or less to ground shall be augmented by one additional electrode of any of the types specified by 250.52 (A)(4) through (A)(8). Where multiple rod, pipe or plate electrodes are installed to meet the requirements of the section, they shall not be less than 6 feet apart.

FPN: The paralleling efficiency of rods longer than 8 feet is improved by spacing greater than 6 feet apart.

The National Electrical Code® (NEC®) states that the resistance to ground shall not exceed 25Ω. This is an upper limit and guideline, since much lower resistance is required in many instances.

"How low in resistance should a ground be?"

An arbitrary answer to this in ohms is difficult. The lower the ground resistance, the safer, and for positive protection of personnel and equipment, it is worth the effort to aim for less than one ohm. It is generally impractical to reach such a low resistance along a distribution system or a transmission line or in small substations. In some regions, resistances of 5Ω or less may be obtained without much trouble. In others, it may be difficult to bring resistance of driven grounds below 100Ω.

Accepted industry standards stipulate that transmission substations should be designed not to exceed one ohm resistance. In distribution substations, the maximum recommended resistance is 5Ω. In most cases, the buried grid system of any substation will provide the desired resistance.

In light industrial or in telecommunications central offices, 5Ω is often the accepted value. For lightning protection, the arresters should be coupled with a maximum ground resistance of 1Ω.

These parameters can usually be met with the proper application of basic grounding theory. There will always exist circumstances which will make it difficult to obtain the ground resistance required by the NEC®. When these situations develop, several methods of lowering the ground resistance can be employed. These include parallel rod systems, deep driven rod systems utilizing sectional rods and chemical treatment of the soil. Additional methods, discussed in other published data, are buried plates, buried conductors (counterpoise), electrically connected building steel, and electrically connected concrete reinforced steel.

Electrically connecting to existing water and gas distribution systems was often considered to yield low ground resistance; however, recent design changes utilizing non-metallic pipes and insulating joints have made this method of obtaining a low resistance ground questionable and in many instances unreliable.

Ground rods, of course, will be required in high voltage transmission lines, where maximum resistance of 15Ω is recommended; and in distribution lines, where maximum resistance of 25Ω is preferred. All electrical systems constructed in accordance with the National Electrical Code®, should not exceed 25Ω.

The measurement of ground resistances may only be accomplished with specially designed test equipment. Most instruments use the Fall of Potential principle of alternating current (AC) circulating between an auxiliary electrode and the ground electrode under test; the reading will be given in ohms and represents the resistance of the ground electrode to the surrounding earth. AEMC® Instruments has also recently introduced a clamp-on ground resistance tester.

NOTE: *The National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association.*

4.3 Ground Resistance Testing Principle
(Fall-of-Potential — 3-Point Measurement)

Three-point measurement is used to measure resistance to ground of ground rods and grids. The potential difference between rods X and Y is measured by a voltmeter, and the current flow between rods X and Z is measured by an ammeter.

By Ohm's Law E = RI or R = E/I, we may obtain the ground electrode resistance R.

If E = 20V and I = 1 A, then:

$$R = \frac{E}{I} = \frac{20}{1} = 20\Omega$$

It is not necessary to carry out all the measurements when using a ground tester. The ground tester will measure directly by generating its own current and displaying the resistance of the ground electrode.

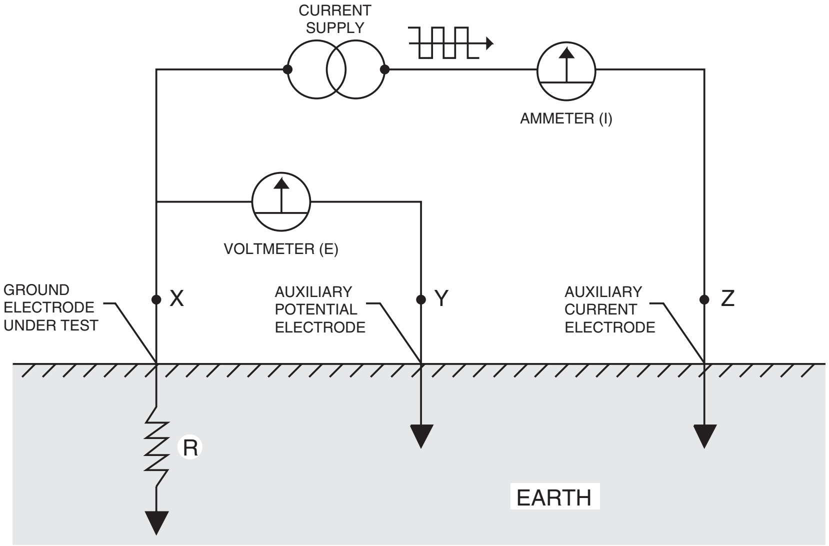


Figure 9

NOTE: Terminals X and Xv are shorted together in three-point measurement.

4.3.1 Position of the Auxiliary Electrodes in Measurements

The goal in precisely measuring the resistance to ground is to place the auxiliary current electrode Z far enough from the ground electrode under test so that the auxiliary potential electrode Y will be outside of the effective resistance areas of both the ground electrode and the auxiliary current electrode. The best way to find out if the auxiliary potential rod Y is outside the effective resistance areas is to move it between X and Z and to take a reading at each location. If the auxiliary potential rod Y is in an effective resistance area (or in both if they overlap), by displacing it, the readings taken will vary noticeably in value. Under these conditions, no exact value for the resistance to ground may be determined.

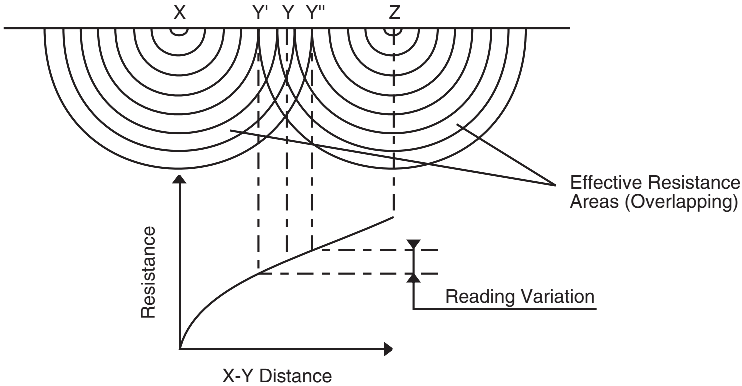


Figure 10

On the other hand, if the auxiliary potential rod Y is located outside of the effective resistance areas, as Y is moved back and forth the reading variation is minimal. The readings taken should be relatively close to each other, and are the best values for the resistance to ground of the ground X. The readings should be plotted to ensure that they lie in a “plateau” region as shown in Figure 11.

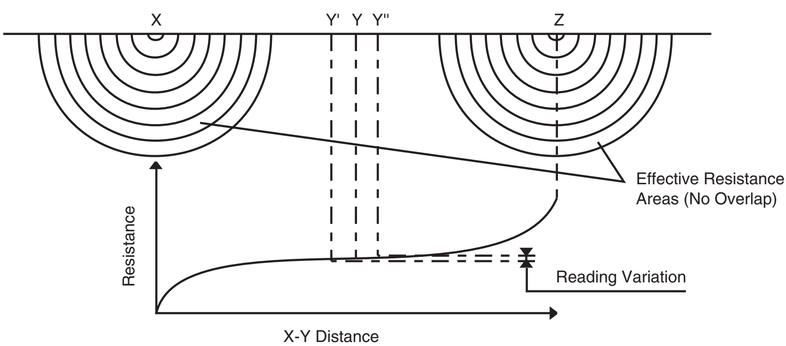


Figure 11

4.4 Measuring Resistance of Ground Electrodes (62% Method)

The 62% method has been adopted after graphical consideration and after actual test. It is the most accurate method but is limited by the fact that the ground tested is a single unit. This method applies only when all three electrodes are in a straight line and the ground is a single electrode, pipe, or plate, etc., as in Figure 12.

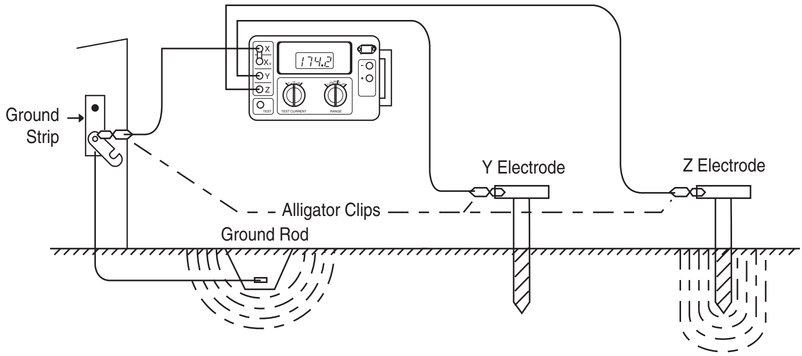


Figure 12

Consider Figure 13, which shows the effective resistance areas (concentric shells) of the ground electrode X and of the auxiliary current electrode Z. The resistance areas overlap. If readings were taken by moving the auxiliary potential electrode Y towards either X or Z, the reading differentials would be great and one could not obtain a reading within a reasonable band of tolerance. The sensitive areas overlap and act constantly to increase resistance as Y is moved away from X.

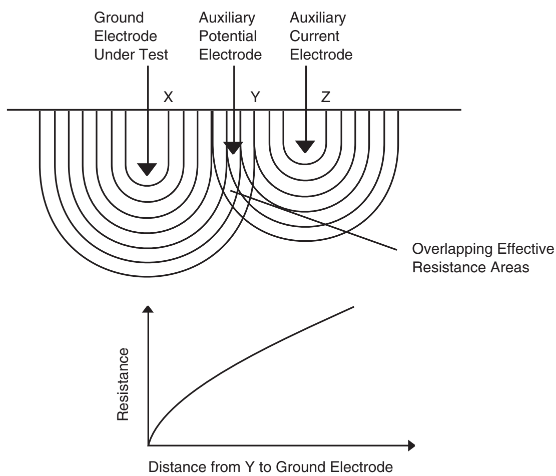


Figure 13

Now consider Figure 14, where the X and Z electrodes are sufficiently spaced so that the areas of effective resistance do not overlap. If we plot the resistance, measured we find that the measurements level off when Y is placed at 62% of the distance from X to Z, and that the readings on either side of the initial Y setting are most likely to be within the established tolerance band. This tolerance band is defined by the user and expressed as a percent of the initial reading: ± 2%, ± 5%, ± 10%, etc.

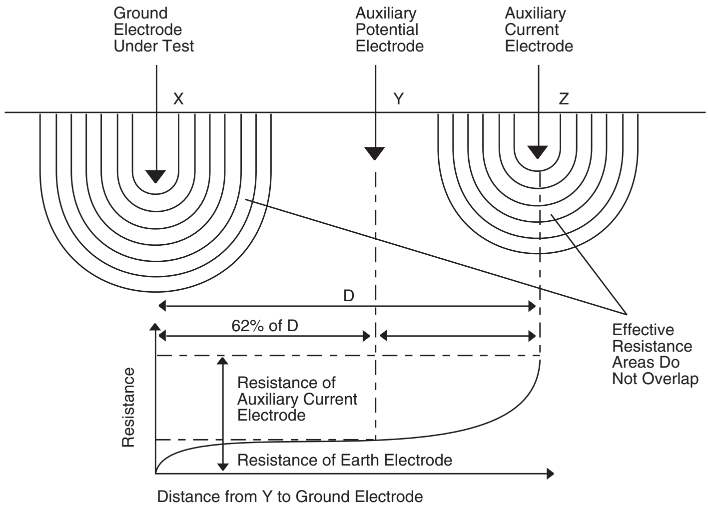


Figure 14

4.4.1 Auxiliary Electrode Spacing

No definite distance between X and Z can be given, since this distance is relative to the diameter of the electrode tested, its length, the homogeneity of the soil tested, and particularly, the effective resistance areas. However, an approximate distance may be determined from the following chart which is given for a homogeneous soil and an electrode of 1" in diameter. (For a diameter of 1/2", reduce the distance by 10%; for a diameter of 2" increase the distance by 10%.)

Approximate distance to auxiliary electrodes using the 62% method:

Depth Driven	Distance to Y	Distance to Z
6 ft.	45 ft.	72 ft.
8 ft.	50 ft.	80 ft.
10 ft.	55 ft.	88 ft.
12 ft.	60 ft.	96 ft.
18 ft.	71 ft.	115 ft.
20 ft.	74 ft.	120 ft.
30 ft.	86 ft.	140 ft.

4.5 Ground Resistance Measurement Procedures (3-Point)

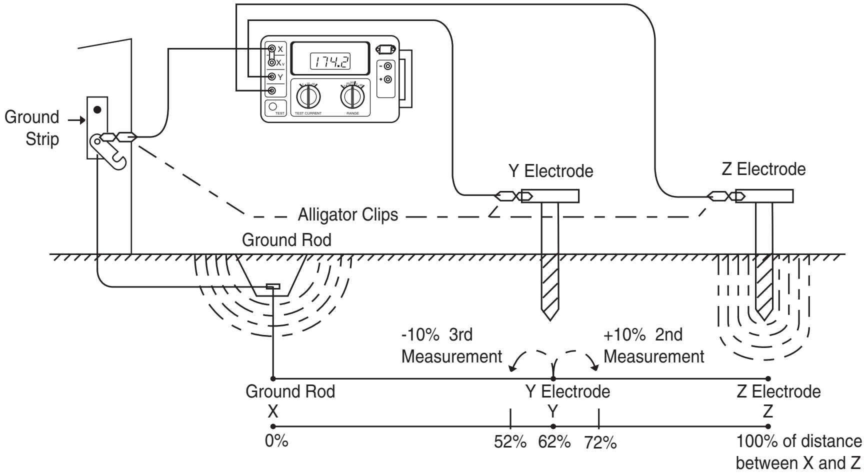


Figure 15

⚠ **Warning:** Do not disconnect the ground of a live circuit.

- X and Xv (C1, P1) are shorted.
- Connect X to the ground rod to be tested.
- Connect Y (P2) to the central electrode.
- Connect Z (C2) to the farther electrode.
- Use the range selector switch, and select a range with a measurement capability between 2 and 2000Ω.
- Using the test current selector switch, select the highest current for which you observe a stable reading, and for which the display is not blinking, or use the following guidelines:

Ranges	2Ω	20Ω	200Ω	2000Ω	20kΩ
Resolution	1mΩ	10mΩ	0.1mΩ	1Ω	10Ω
Recommended Current Ranges	10mA or 50mA	2mA, 10mA, or 50mA		2mA or 10mA	2mA or 10mA

4.5.1 Over-range Indication

Over-range is indicated when the display reads 1, or when the display is blinking and the indicator is lit.

4.5.2 Incorrect Measurements

The incorrect measurement indicator shows excessive electrode resistance and excessive transient noise and stray current; it also indicates when the selected test current is too high.

In the event of an incorrect measurement indication:

- Select the next lowest test current.
- Improve the quality of the auxiliary ground electrodes Y and Z; Z is the most likely source of problems with excessive resistance.
- Check connections for continuity between leads and electrodes.
- Be sure that electrodes are properly inserted; they should be completely buried, if possible.
- If stray currents are suspected, one solution to reduce their influence is to move both Y and Z electrodes in and arc relative to the X electrode (e.g. try a 90° shift), and test again.

4.6 2-Point Measurement (Simplified Measurement)

This is an alternative method to three-point measurement when an excellent ground is already available.

In congested areas where finding room to drive the two auxiliary rods may be a problem, the two-point measurement method may be applied. The reading obtained will be that of the two grounds in series. Therefore, the water pipe or other ground must be very low in resistance so that it will be negligible in the final measurement. The lead resistances will also be measured and should be deducted from the final measurement.

This method is not as accurate as three-point methods (62% method), as it is particularly affected by the distance between the tested electrode and the dead ground or water pipe. This method should not be used as a standard procedure, but rather as a backup in tight areas. See Figure 16.

Procedure

- Short X and Xv (C1, P1)
- Short Y and Z (P2, C2)
- Connect X to ground rod to be measured
- Connect Z to an electrode
- Measure as in the three-point method

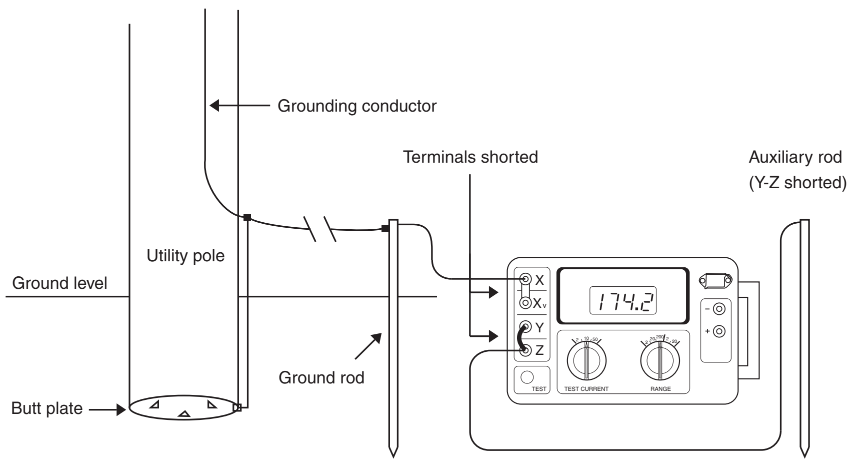


Figure 16

4.7 Continuity Measurement

After the shorting strip has been properly positioned between X and Xv (C1, P1), connect the Y (P2) and Z (C2) terminals together as well.

Continuity measurement is made with two leads, one from X-Xv, the other from Y-Z (P2, C2); push the “TEST” button to measure.

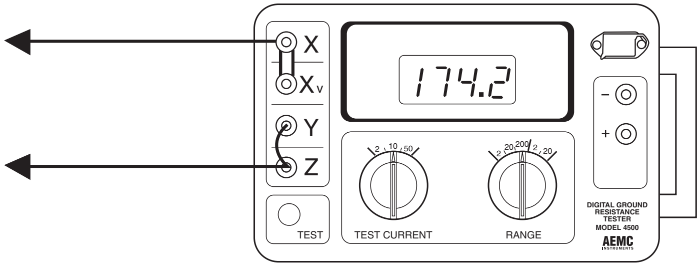


Figure 17

4.8 Soil Resistivity Measurements

Why make soil resistivity measurements?

Soil resistivity measurements have a threefold purpose. First, such data are used to make sub-surface geophysical surveys as an aid in identifying ore locations, depth to bed rock and other geological phenomena. Second, resistivity has a direct impact on the degree of corrosion in underground pipelines. A decrease in resistivity relates to in increase in corrosion activity and therefore dictates the protective treatment to be used. Third, soil resistivity directly affects the design of a grounding system, and it is to that task that this discussion is directed. When designing an extensive grounding system, it is advisable to locate the area of lowest soil resistivity in order to achieve the most economical grounding installation.

Resistivity measurements are of two types, the 2-point and the 4-point method. The 2-point method is simply the resistance measured between two points. For most applications, the most accurate method is the 4-point method, which is used in the Model 4500 Ground Tester. The 4-point method, as the name implies, requires the insertion of four equally spaced, and in-line, electrodes into the test area. A known current from a constant current generator is passed between the outermost electrodes. The potential drop (a function of the resistance) is then measured across the two innermost electrodes. Model 4500 is calibrated to read directly in ohms.

1000A x 1

Where: A = distance between the electrodes in centimeters

B = electrode depth in centimeters

If A > 20 B, the formula becomes:

$\rho = 2\pi AR$ (with A in cm)

$\rho = 191.5 AR$ (with A in feet)

ρ = Soil resistivity (ohm-cm)

This value is the average resistivity of the ground at a depth equivalent to the distance "A" between two electrodes.

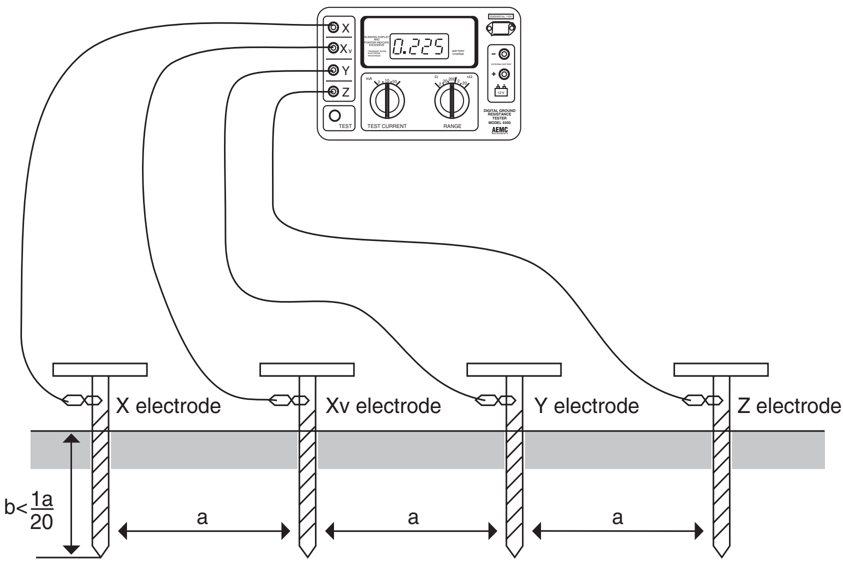


Figure 18

4.9 Soil Resistivity Measurement Procedure (4-Point)

Given a sizeable tract of land in which to determine the optimum soil resistivity, some intuition is in order. Assuming that the objective is low resistivity, preference should be given to an area containing moist loam as opposed to a dry sandy area. Consideration must also be given to the depth at which resistivity is required.

- Disconnect the shorting strip from the X and Xv terminals.
- Arrange the electrodes in a straight line. Be sure that distances between electrodes are identical: e.g. 3 meters between each electrode (See Figure 18).
- The distance between poles is proportional to the average depth of the soil sample you wish to make.
- The electrodes should be placed at a depth of approximately 6" (0.15m), so that the depth is approximately 1/20th of the distance between electrodes.
- Use leads to connect the X, Xv, Y, and Z electrodes to the respective terminals on the Digital Ground Resistance Tester.
- It is preferable to place the selector in a range position which varies inversely in relation to the distance identified as “A”; in other words, the farther apart the four electrodes, the lower the test current should be.
- Press the “TEST” button.
- Read the resistance level (R) indicated on the display.
- In the event of difficulties in performing measurements, consult the previous instructions concerning ground resistance measurements.
- Apply the following formula in order to determine resistivity (ρ):

  $\rho = 2\pi \times 225\Omega \times 3\text{m}$

  $\rho = 4350\ \Omega\text{m}$

Example: After inspection, the area to be investigated has been narrowed down to a plot of ground approximately 75 square feet (22.5m^2). Assume that you need to determine the resistivity at a depth of 15ft. (450cm). The distance “A” between the electrodes must then be equivalent to the depth at which average resistivity is to be determined (15 ft, or 450cm). Using the more simplified Wenner formula ($\rho = 2\pi$ AR), the electrode depth must then be 1/20th of the electrode spacing or 8-7/8" (22.5cm).

Lay out the electrodes in a grid pattern (Figure 20) and connect to the Model 4500 as shown in Figure 19. Proceed as follows:

- Remove the shorting strip between X and Xv
- Connect all four auxiliary rods

For example, if the reading is R = 15,

ρ (resistivity) = 2π x R x A

A (distance between electrodes) = 450cm

ρ = 6.28 x 15 x 450 = 42,390 Ω-cm

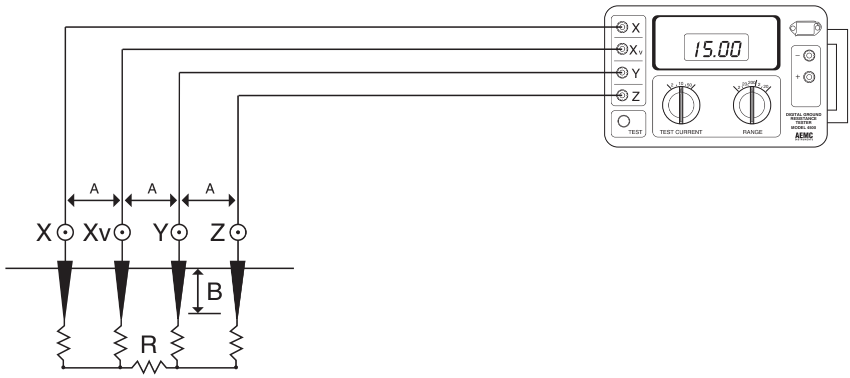


Figure 19

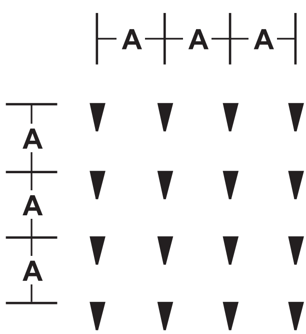


Figure 20

4.10 Multiple Electrode System

A single driven ground electrode is an economical and simple means of making a good ground system. But sometimes a single rod will not provide sufficient low resistance, and several ground electrodes will be driven and connected in parallel by a cable. Very often when two, three or four ground electrodes are used, they are driven in a straight line; when four or more are used, a hollow square configuration is used and the ground electrodes are still connected in parallel and equally spaced (Figure 21).

In multiple electrode systems, the 62% method electrode spacing may no longer be applied directly. The distance of the auxiliary electrodes is now based on the maximum grid distance (e.g. in a square, the diagonal; in a line, the total length. For example, a square having a side of 20 ft will have a diagonal of approximately 28 ft).

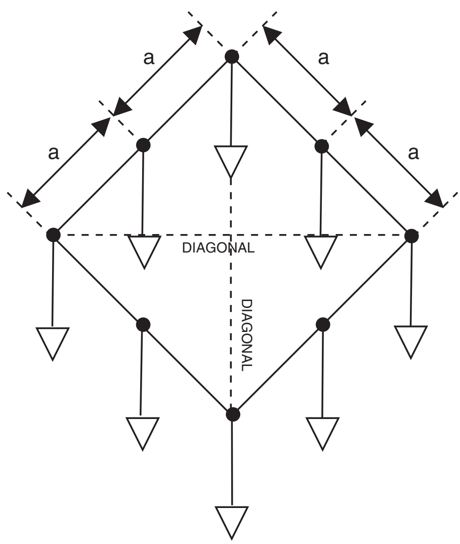


Figure 21

Multiple Electrode System		
Max Grid Distance	**Distance to Y**	**Distance to Z**
6 ft	78 ft	125 ft
8 ft	87 ft	140 ft
10 ft	100 ft	160 ft
12 ft	105 ft	170 ft
14 ft	118 ft	190 ft
16 ft	124 ft	200 ft
18 ft	130 ft	210 ft
20 ft	136 ft	220 ft
30 ft	161 ft	260 ft
40 ft	186 ft	300 ft
50 ft	211 ft	340 ft
60 ft	230 ft	370 ft
80 ft	273 ft	440 ft
100 ft	310 ft	500 ft
120 ft	341 ft	550 ft
140 ft	372 ft	600 ft
160 ft	390 ft	630 ft
180 ft	434 ft	700 ft
200 ft	453 ft	730 ft

MAINTENANCE

5.1 Warning

Please make sure that you have already read and fully understand the WARNING section on page 3.

- To avoid electrical shock, do not attempt to perform any servicing unless you are qualified to do so.
- To avoid electrical shock and/or damage to the instrument, do not get water or other foreign agents into the case. Turn the Instrument OFF and disconnect the unit from all circuits before opening the case.

5.2 Power Supply

5.2.1 Testing Battery Voltage

- Short-circuit the X and Z terminals.
- Turn the current selector (see Figure 3) to 50 mA.
- Turn the range selector to 20Ω.
- Press the “Test” button.

If the colon (“8” in Figure 3) lights up, recharge the batteries. If the colon does not light, the batteries are charged.

5.2.2 Average Operating Time

- 4 hrs on 50mA test current (800 15-second measurements)
- 7 hrs on 2mA and 10mA test currents (1500 15-second measurements)

If the colon lights up, the battery has lost power. Thereafter, the available operating time remaining is approximately 100 15-second measurements.

When this situation arises, recharge the battery at once or obtain power from an external battery (see the following paragraphs).

5.2.3 Recharging Built-In Battery

- Use the power cord stored inside the compartment within the cover.
- Plug the power cord into the female input jack.
- Connect the other end of the cord to a power outlet (voltage must be the same as voltage indicated on the plate identified as “11”).
- The red light will turn on and remain lit while the battery is recharging. Charging time is 14hrs. minimum for a discharged battery.

NOTE 1: The battery may be charged for more than 14 hours without damaging the instrument (internal protection).

NOTE 2: Do not allow the battery to remain discharged for more than several days.

NOTE 3: If an instrument is not used frequently, the battery should be recharged regularly, three-month intervals are recommended.

5.2.4 Power Supply from External Battery

The external battery should be directly connected to the appropriate terminals. Be sure to observe the proper polarities. The external battery does not charge the internal battery.

NOTE: It is not necessary to remove the battery supplied with the instrument when using an external battery or supply.

5.2.5 Replacing Battery

- Use the hex key to unscrew the six fastening screws from the chassis, which are located on the bottom of the case.
- Pull out the chassis (Figure 22). Remember to unplug the ribbon cable which connects the power supply board in the bottom of the case to the boards mounted in the chassis.
- Remove the wing nuts, the spacers, and the protective cover to gain access to the two 12V DC battery (See Figure 23).

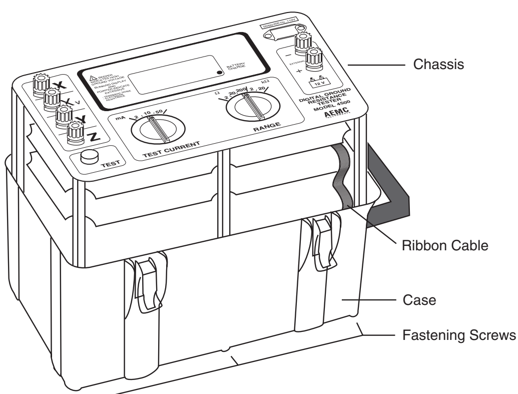


Figure 22

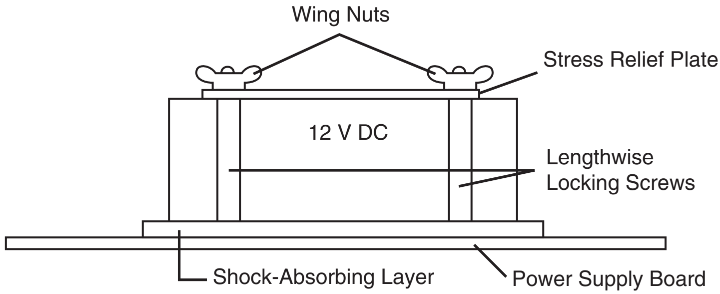


Figure 23

- Disconnect the two wires which connect the battery to the power supply board.
- Replace the worn battery.
- Connect the new 12V DC battery to the power supply board. Pay close attention to the polarities printed on the power supply board.

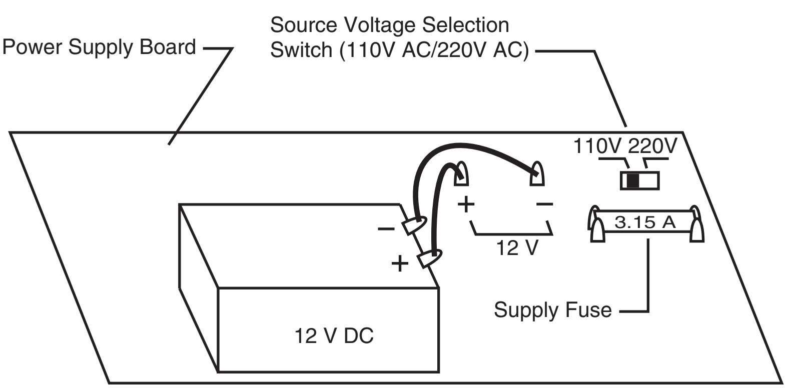


Figure 24

5.2.6 Changing the Supply Voltage (110/220VAC)

- Open up the Model 4500. Position the selector switch on the power supply board (See Figure 24).
- Set the plate (“11” in Figure 3) which indicates “220V AC” on one side and “110V AC” on the other, to the selected voltage.
- Reassemble the Model 4500.

WARNING

- If the supply switch is set to 110V AC and the instrument is connected to 220V AC, the battery charge indicator (see Figure 3) will turn on for several seconds, but will then turn off. The fuse will blow. Do not continue to run the instrument.
- If the supply switch is set to 220V AC position and the instrument is connected to 110V AC, the indicator will not turn on. The instrument will not recharge or operate.

  NOTE: For either situation, errors in completing connections will not endanger the instrument.

5.2.7 Replacing the Supply Fuse

An internal fuse is used to protect the instrument against an improperly selected supply voltage.

To replace this fuse:

- Remove the six hex screws from the bottom of the case (see Figure 22), and lift the chassis from the case housing.
- Replace the fuse (Figure 24) and reassemble the instrument.

5.2.8 Replacing the Safety Fuse

An internal fuse which provides protection for up to 500V AC is used to protect the instrument against voltages into the test leads.

To replace this fuse:

- Remove the six hex screws from the bottom of the case (see Figure 22), and lift the chassis from the case housing.
- Turn the chassis over.
- Replace the fuse (Figure 25) and reassemble the instrument.

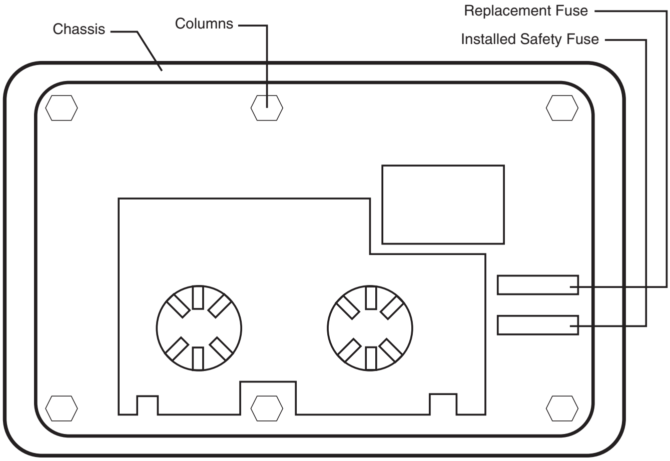


Figure 25

5.3 Cleaning

⚠ **Disconnect the instrument from any source of electricity.**

- Use a soft cloth lightly dampened with soapy water.
- Rinse with a damp cloth and then dry with a dry cloth.
- Do not use alcohol, solvents or hydrocarbons.

5.4 Storage

If the instrument is not used for an extended time period, the battery should be recharged regularly. Three-month intervals are recommended.

Repair and Calibration

To ensure that your instrument meets factory specifications, we recommend that it be scheduled back to our factory Service Center at one-year intervals for recalibration, or as required by other standards or internal procedures.

For instrument repair and calibration:

You must contact our Service Center for a Customer Service Authorization Number (CSA#). This will ensure that when your instrument arrives, it will be tracked and processed promptly. Please write the CSA# on the outside of the shipping container. If the instrument is returned for calibration, we need to know if you want a standard calibration, or a calibration traceable to N.I.S.T. (Includes calibration certificate plus recorded calibration data).

Ship To: Chauvin Arnoux®, Inc. d.b.a. AEMC® Instruments
15 Faraday Drive
Dover, NH 03820 USA

Phone: (800) 945-2362 (Ext. 360)
(603) 749-6434 (Ext. 360)
Fax: (603) 742-2346 or (603) 749-6309
E-mail: repair@aemc.com

(Or contact your authorized distributor)

Costs for repair, standard calibration, and calibration traceable to N.I.S.T. are available.

NOTE: You must obtain a CSA# before returning any instrument.

Technical and Sales Assistance

If you are experiencing any technical problems, or require any assistance with the proper operation or application of your instrument, please call, mail, fax or e-mail our technical support team:

Chauvin Arnoux®, Inc. d.b.a. AEMC® Instruments
200 Foxborough Boulevard
Foxborough, MA 02035 USA

Phone: (800) 343-1391
(508) 698-2115
Fax: (508) 698-2118
E-mail: techsupport@aemc.com
www.aemc.com

NOTE: Do not ship Instruments to our Foxborough, MA address.

Limited Warranty

The Model 4500 is warranted to the owner for a period of one year from the date of original purchase against defects in manufacture. This limited warranty is given by AEMC® Instruments, not by the distributor from whom it was purchased. This warranty is void if the unit has been tampered with, abused or if the defect is related to service not performed by AEMC® Instruments.

For full and detailed warranty coverage, please read the Warranty Coverage Information, which is attached to the Warranty Registration Card (if enclosed) or is available at www.aemc.com. Please keep the Warranty Coverage Information with your records.

What AEMC® Instruments will do:

If a malfunction occurs within the one-year period, you may return the instrument to us for repair, provided we have your warranty registration information on file or a proof of purchase. AEMC® Instruments will, at its option, repair or replace the faulty material.

REGISTER ONLINE AT:
www.aemc.com

Warranty Repairs

What you must do to return an Instrument for Warranty Repair:

First, request a Customer Service Authorization Number (CSA#) by phone or by fax from our Service Department (see address below), then return the instrument along with the signed CSA Form. Please write the CSA# on the outside of the shipping container. Return the instrument, postage or shipment pre-paid to:

Ship To: Chauvin Arnoux®, Inc. d.b.a. AEMC® Instruments
15 Faraday Drive • Dover, NH 03820 USA

Phone: (800) 945-2362 (Ext. 360)
(603) 749-6434 (Ext. 360)
Fax: (603) 742-2346 or (603) 749-6309
E-mail: repair@aemc.com

Caution: To protect yourself against in-transit loss, we recommend you insure your returned material.

NOTE: You must obtain a CSA# before returning any instrument.

11/15

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Chauvin Arnoux®, Inc. d.b.a. AEMC® Instruments
15 Faraday Drive • Dover, NH 03820 USA • Phone: (603) 749-6434 • Fax: (603) 742-2346
www.aemc.com