Digital Ground Resistance Testers Models 3640 and 4610

USER MANUAL

AEMC®
INSTRUMENTS

Owner's Record

The serial number for the Model 3640 or Model 4610 is located on the bottom of the instrument. Please record this number and purchase date for your records.

DIGITAL GROUND RESISTANCE TESTER MODEL 4610

CATALOG #2114.94

SERIAL #: ____________________

PURCHASE DATE: ____________________

DISTRIBUTOR: ____________________

DIGITAL GROUND RESISTANCE TESTER MODEL 3640

CATALOG #2114.92

SERIAL #: ____________________

PURCHASE DATE: ____________________

DISTRIBUTOR: ____________________

99-MAN-100143
1st Revision
Printed 02/98

AEMC® Instruments
by Chauvin Arnoux, Inc.

Table of Contents

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

International Electrical Symbols

☐ This symbols signifies that the current probe is protected by double or reinforced insulation. Use only factory replacement parts when servicing the instrument.

⚠ This symbol signifies CAUTION! and requests that the user refer to the user manual before using the instrument.

Receiving Your Shipment

Upon receiving your shipment, be 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.

Packaging

The Digital Ground Resistance Testers Models 3640 (Cat. #2114.92) and 4610 (Cat. #2114.94) are shipped with a soft carrying case, batteries and a user manual.

The Digital Ground Resistance Tester Model 3640 Kit (Cat. #2114.93) is shipped with a hard carrying case, set of two reels with 150-ft. leads, one 16-ft lead, two T-shaped handles, batteries and a user manual.

The Digital Ground Resistance Tester Model 4610 Kit (Cat. #2114.95) is shipped with a hard carrying case, set of two reels with 300-ft leads, one reel with 90-ft lead, one 16-ft lead and four electrodes (rods) with T-shaped handles, batteries and a user manual.

Description

The Digital Ground Resistance Testers Models 3640 and 4610 perform accurate ground resistance measurements (2- and 3-pole) on single rods or computer grids. In addition the Model 4610 performs soil resistivity measurements (4-pole) and it may also be used for touch potential measurements.

These autoranging testers automatically seek out the optimum measurement range. To use, connect the leads, press to measure, and read. Three LED lights on the front panel continuously warn the user of measurement problems (open leads, high stray voltage, etc.) to ensure accurate and reliable tests. The ground testers are built into a water and dust-resistant case, and performs well in noisy environments.

Optional Accessories

Test kit for ground resistance testing includes hard carrying case, set of two reels with 300-ft leads, one 90-foot lead, one 16-foot lead, and four electrodes (rods) with T-shaped handles providing easy soil penetration and improved rod-soil contact, Cat. #2118.31

Ground Test Kit with three leads (16, 98, 98-ft) two T-shaped ground rods, and soft carrying case, Cat. #100.132A

Ground Test Kit with one 16-ft lead, two 150-ft leads on spools with wind-up handles, two T-shaped ground rods, and carrying case with slot for Model 3620/3640, CAT. #2114.96

Set of 5 replacement fuses (0.1 A 250 V, 0.25 x 1.25"), Cat. #2970.12

25Ω Calibration Checker, Cat. #2118.58

Control and Connector Identification

4610

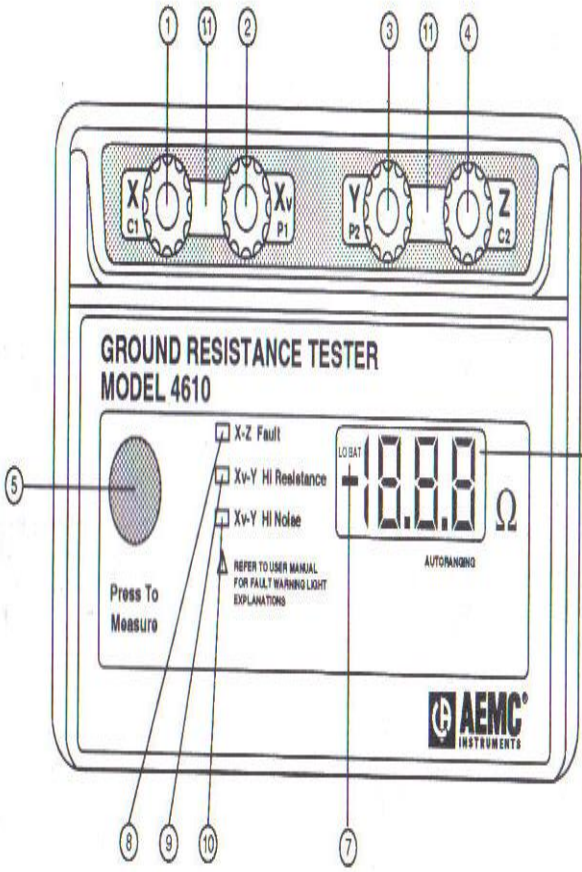


Figure 1

1. Input terminal X (C1)
2. Input terminal Xv (P1)
3. Input terminal Y (P2)
4. Input terminal Z (C2)
5. Push-to-measure button
6. Display
7. Low battery indicator
8. X-Z fault indicator
9. Xv-Y high resistance indicator
10. Xv-Y high noise indicator
11. Ground resistance shorting links

Control and Connector Identification

3640

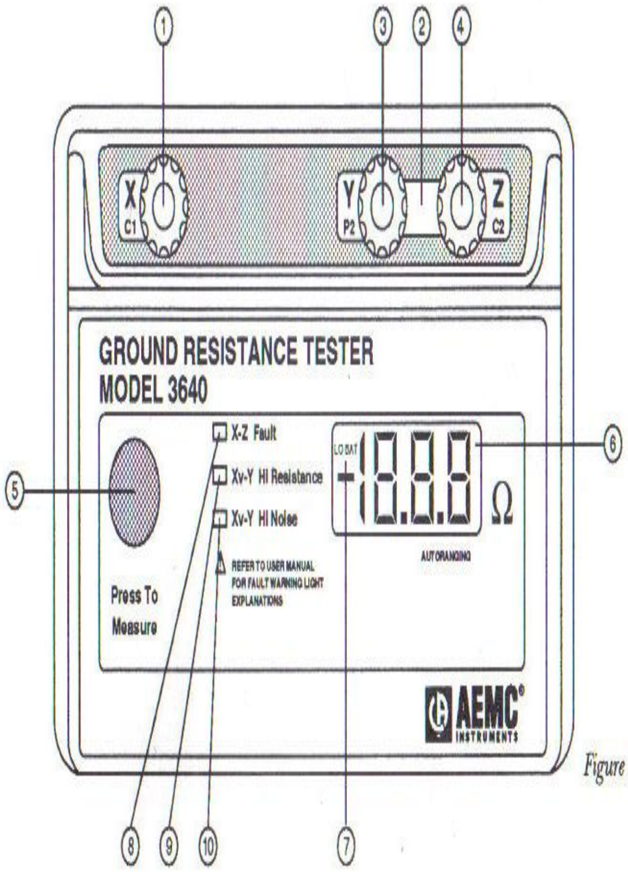


Figure 2

1. Input terminal X (C1)
2. Ground resistance shorting link
3. Input terminal Y (P2)
4. Input terminal Z (C2)
5. Push-to-measure button
6. Display
7. Low battery indicator
8. X-Z fault indicator
9. Xv-Y high resistance indicator
10. Xv-Y high noise indicator

Specifications

Note: Accuracies and specifications are given for an ambient temperature of 23°C ± 3 K, RH of 45 to 55%, battery power at 8 volts, auxiliary resistance at the measurement terminals < 200 Ω, no stray voltage and a magnetic field from 0 to 40 A/m.

ELECTRICAL SPECIFICATIONS

Measurement Ranges: Autoranging: 0 to 2000Ω

Ranges	20Ω	200Ω	2000Ω
Measurement	0.00 to 19.99Ω	20.00 to 199.9Ω	200.00 to 1999Ω
Resolution	10 mΩ	100 mΩ	1Ω
Test Current	10 mA	1 mA	0.1 mA
Accuracy	2% reading ± 1 ct	2% reading ± 1 ct	3% reading ± 3 cts
Open Voltage	< 42 V peak		

Operating Frequency: 128 Hz square wave

Max. Auxiliary Rod Resistance:

Range	*Current Circuit*	*Voltage Circuit*
20 Ω	3 kΩ	50 kΩ
200 Ω	30 kΩ	50 kΩ
2000 Ω	50 kΩ	50 kΩ

Response Time: Approximately 6 seconds for a stabilized measurement

Interference: Models 3640 & 4610 are designed to reject high levels of interference voltage (DC, 50/60 Hz, harmonics):

DC voltage in series with X: 20 V

AC voltage in series with Y: 13 V peak

AC voltage in series with Z: 32 V peak

Specifications (cont.)

Voltage Withstand: Both models are fuse protected. In the event of a system fault, the units can withstand 250 Vrms with spikes of 3000 V AC or 1000 V DC.

Power Supply: Eight 1.5 V "AA" batteries; Alkaline recommended. "LO BAT" indication on LCD

Typical Operating Time: 1800 15-second measurements

Fuse Protection: High breaking capacity 0.1 A, 250 V, 0.25" x 1.25"

MECHANICAL SPECIFICATIONS

Connection: Color-coded terminals accept spade lugs with minimum gap of 6 mm or standard 4 mm banana jacks

Display: 7 segment LCD, .71" (18 mm) high (3-1/2 digit); 2000 counts LCD also indicates overrange, test lead shorts and lead reversals.

Operating Temperature: 14° to 131°F (-10° to 55°C), 0 to 90% R.H.

Storage Temperature:
-40° to 158°F (-40° to 70°C), 0 to 90% R.H. with batteries removed

Dimensions: 8.7 x 5.4 x 5.9" (220 x 136 x 150 mm)

Weight: 2.9 lbs (1.3 kg)

Case: Heavy-duty, ABS

Colors: *case* - safety yellow; *front panel* - gray

Specifications (cont.)

SAFETY SPECIFICATIONS

CE Mark

Electrical:
IEC 1010-1 Cat III, Pollution degree 2, 42 volts

Electromagnetic Compatibility:
Emission: EN 50081-1
Immunity: EN 50082-1

Mechanical Shock: IEC 68-2-27

Vibration: IEC 68-2-6

Drop Test: IEC 68-2-32

Case Material: UL94

Environmental: O-ring sealed against dust and water to IP50

LED Indicators

The three indicators described below confirm the correct measurement being taken if none of them are lit.

Note: Refer to page 29, "Incorrect Measurement Indication – Tips and Solutions", to help alleviate these problems.

X-Z Fault

LED signals that the voltage between terminals X and Z exceeds 30 V peak. There are four possible causes:

- the resistance of the current circuit between X and Z is too high
- interference voltage in the current circuit is too high
- the fuse is blown
- the circuit is open (lead not connected)

X-Y High Resistance (3640)

Xv-Y High Resistance (4610)

LED signals that the resistance in the voltage circuit (between Xv and Y or X and Y) is too high (approximately 50 kΩ) or that the circuit may be open.

Flashing will continue throughout the measurement, even if the resistance drops below the threshold; for example, after reconnecting or lowering auxiliary rod resistance.

In this case, you must release the push-button and press again after the fault has been corrected.

Occasionally, a stray voltage above 6 V DC may also set off this light.

Check the leads for a possible solution.

X-Y High Noise (3640)

Xv-Y High Noise (4610)

LED signals the presence of excessive noise (approximately 13 V peak) in the voltage circuit (between Xv and Y or X and Y).

Power Supply

Battery Test

- Short-circuit the X and Z terminals.
- Press the "Measure" button.

If the low battery indicator ("7" in Figure 1 or Figure 2) lights up, change the batteries. If the indicator does not light, the batteries are sufficiently charged.

Average Battery Operating Time:

- 7 hours for 10 mA test current (approximately 1800 15-second measurements).

If the "LO BAT " indicator ("7" in Figure 1 or Figure 2) lights up, the batteries have lost power. Thereafter, the available operating time remaining is approximately 100 15-second measurements. Change the batteries promptly when the "LO BAT" indicator is lit.

Replacing Batteries

- Loosen the two fastening screws on the battery compartment cover, which is located on the bottom of the case.
- Remove the battery compartment cover to gain access to the eight 1.5 V "AA" batteries (See Figure 3).
- Replace the worn batteries and reassemble the instrument.

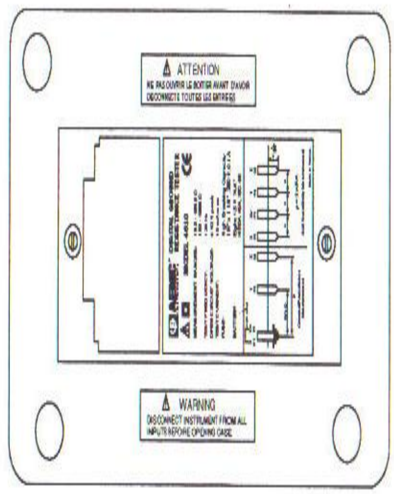


Figure 3

Replacing the Safety Fuse

An internal fuse which provides protection for up to 250 V AC is used to protect the instrument against voltages into the test leads. To replace the fuse:

- Do not replace the fuses when the instrument is connected.
- Loosen the two fastening screws on the battery compartment cover, which is located on the bottom of the case.
- Remove the battery compartment cover to gain access to the fuse holder (See Figure 4).
- Replace the fuse with the appropriate replacement (Figure 4) and reassemble the instrument.

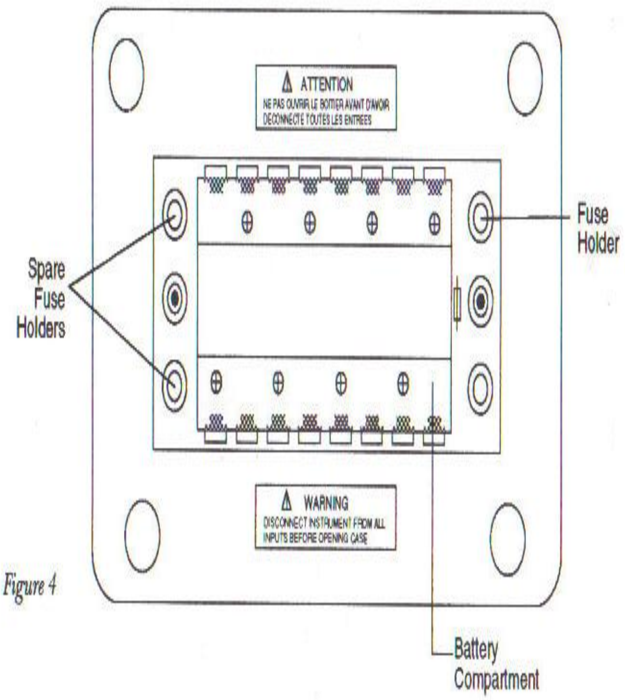


Figure 4

Grounding Electrode Resistance

Figure 5 illustrates a grounding rod. The resistance of the electrode has the following components:

(A) the resistance of the metal and that of the connection to it

(B) the contact resistance of the surrounding earth to the electrode

(C) 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 the overall resistance is negligible.

(B) The National Institute of Standards and Technology 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.

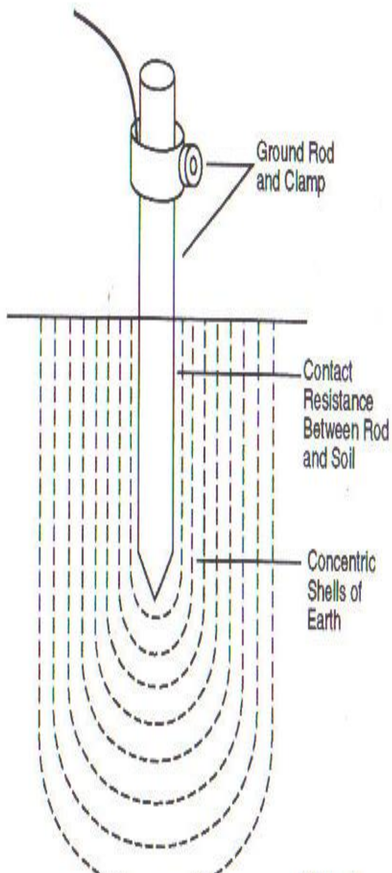


Figure 5

(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:

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

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

L = grounding electrode length

ρ = grounding electrode radius

ρ = average resistivity in ohms-cm.

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 6).

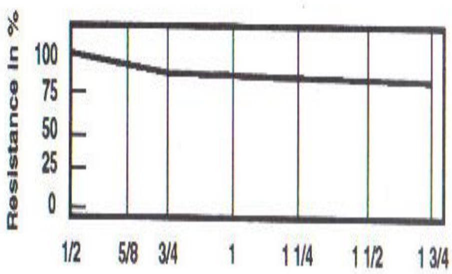
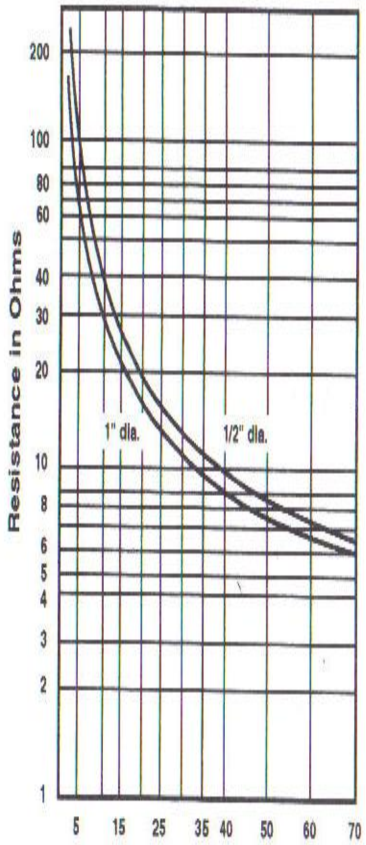


Figure 6

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 7).



Ground Resistance Versus Ground Rod Depth *Figure 7*

The NEC® (1987, 250-83-3) requires a minimum of 8 ft (2.4 m) to be in contact with the soil. The most common is a 10 ft (3 m) cylindrical rod which meets the NEC® code. A minimum diameter of 5/8 inch (1.59 cm) is required for steel rods and 1/2 inch (1.27 cm) for copper or copper clad steel rods (NEC® 1987, 250-83-2). Minimum practical diameter for driving limitations for 10 ft (3 m) rods are:

- 1/2 inch (1.27 cm) in average soil
- 5/8 inch (1.59 cm) in moist soil
- 3/4 inch (1.91 cm) in hard soil or more than 10 ft driving depths

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.

	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

Figure 8

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 (Figure 9).

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

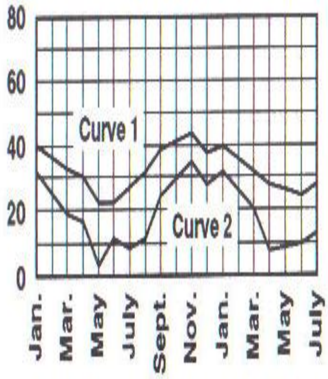
Figure 9

The resistivity of the soil is also influenced by temperature. Figure 10 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,
C	**F**	**Ohm-cm**
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

Figure 10

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 11. 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.



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

Figure 11

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. Figure 12 shows the substantial reduction in resistivity of sandy loam brought about by an increase in chemical salt content.

Chemically treated soil is also subject to considerable variation of resistivity with changes in temperature, as shown in Figure 13. If salt treatment is employed, it is, of course, necessary to use ground rods which will resist chemical corrosion.

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

Figure 12

The Effect of Temperature on the Resistivity of Soil Containing Salt*

(Sandy loam, 20% moisture, salt 5% of weight of moisture)

Temperature (Degrees C)	Resistivity (Ohm-centimeters)
20	110
10	142
0	190
-5	312
-13	1440

Figure 13

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

Effect of Ground Rod 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 9). The Nomograph value is an approximation.

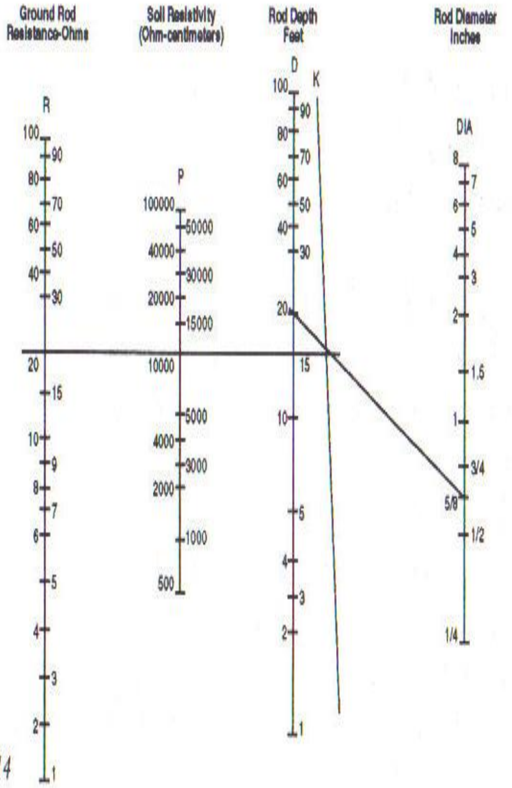


Figure 14

Grounding Nomograph

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.

Ground Resistance Values

NEC® 250-84 (1987): resistance of man-made electrodes:

> "A single electrode consisting of a rod, pipe, or plate which does not have a resistance to ground of 25 ohms or less shall be augmented by one additional of any of the types specified in section 250-81 or 250-83. Where multiple rod, pipe or plate electrodes are installed to meet the requirements of this section, they shall be not less than 6 ft (1.83 m) 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, and 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 15 ohms is recommended; and in distribution lines, where maximum resistance of 25 ohms is preferred. All electrical systems constructed in accordance with the National Electrical Code®, should not exceed 25 ohms.

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.

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 = 20 V 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.

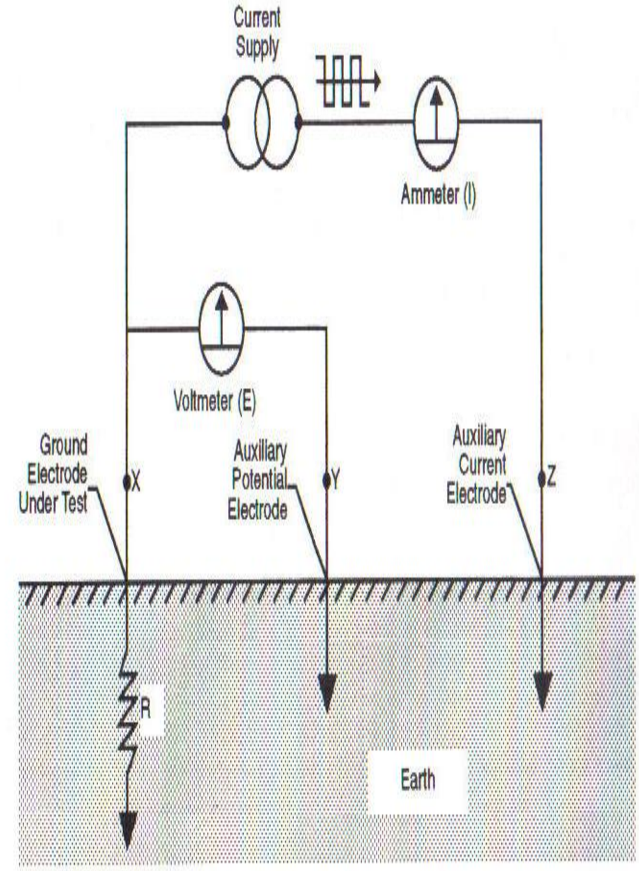


Figure 15

(Note: Terminals X and Xv are shorted together in three-point measurement.)

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) (Figure 16), 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.

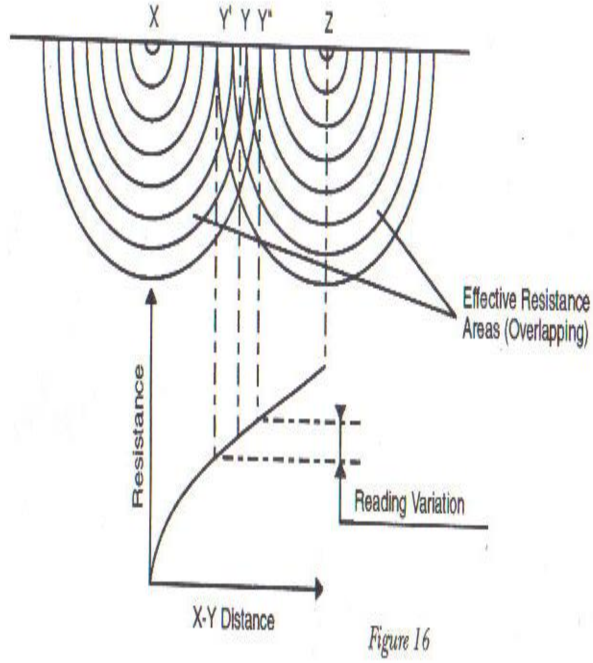


Figure 16

On the other hand, if the auxiliary potential rod Y is located outside of the effective resistance areas (Figure 17), 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 17.

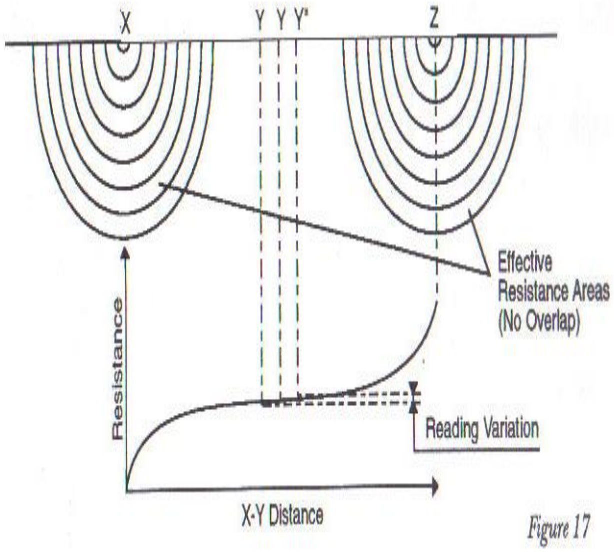


Figure 17

Measuring Resistance of Ground Electrodes (62% Method)

The 62% method has been adopted after graphical consideration and on 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 18 and Figure 19.

4610

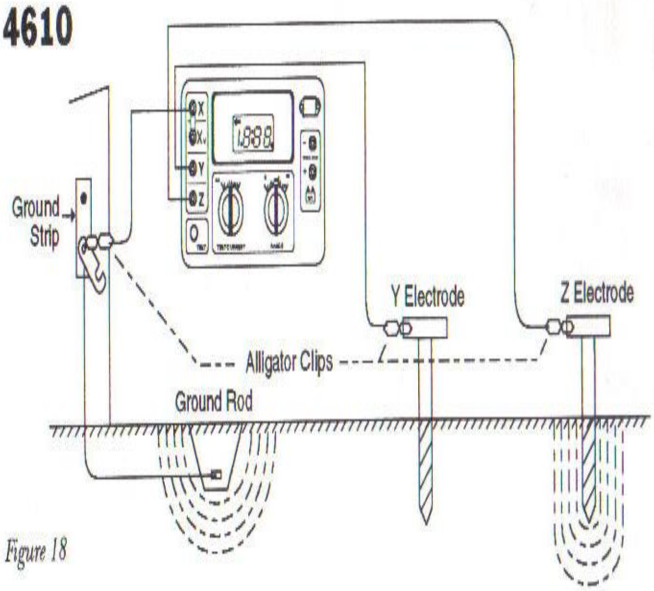


Figure 18

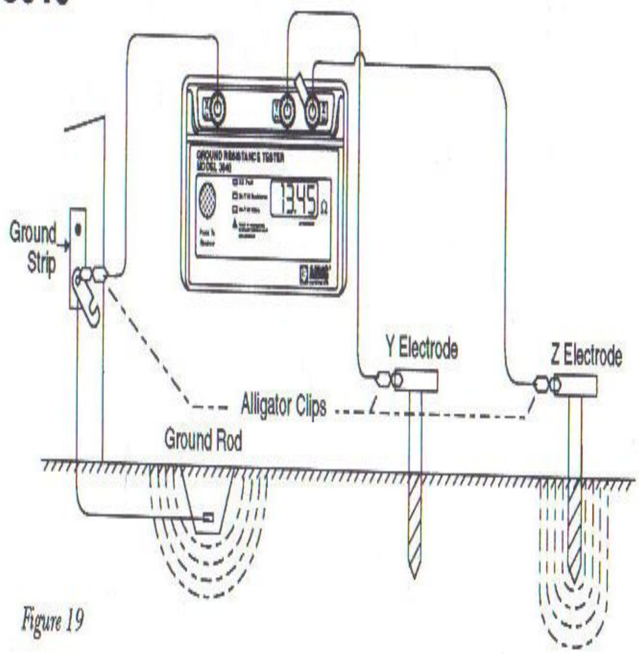


Figure 19

Consider Figure 20, 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.

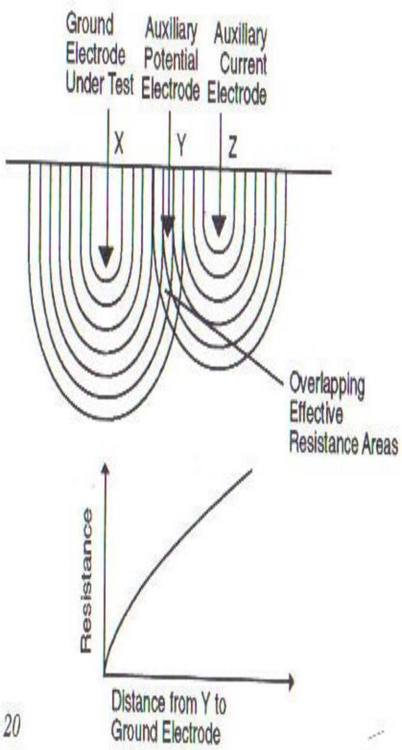


Figure 20

Now consider Figure 21, 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.

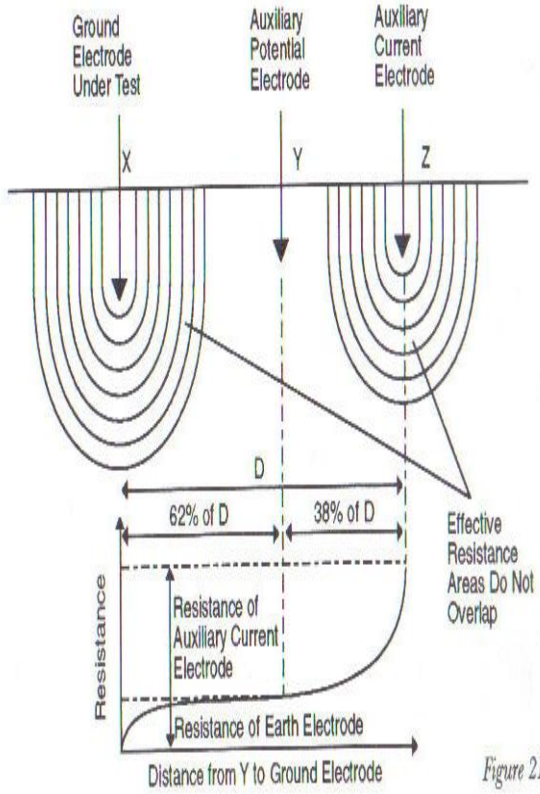


Figure 21

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.

Ground Resistance Measurement Procedure (3-Point)

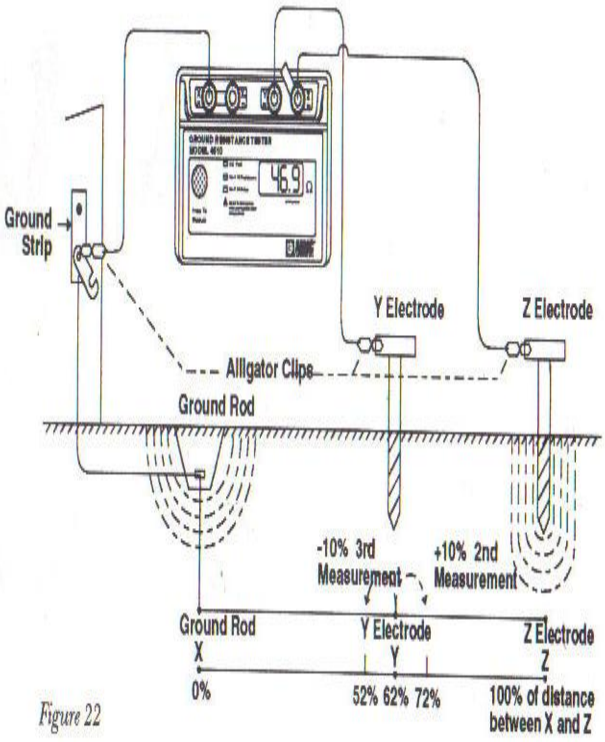


Figure 22

WARNING: Use extreme caution when disconnecting the ground connection from the rest of the circuit. Current may be flowing and a dangerous potential could exist between the disconnected wires.

- X and Xv (C1, P1) are shorted
- Disconnect shorting link between Y and Z (C2, P2)
- Connect X to the ground rod to be tested
- Connect Y (P2) to the central electrode
- Connect Z (C2) to the outer electrode
- Depress the "Measure" button to measure ground resistance

Over-range Indication

Over-range is indicated when the display reads 1, or when the display is blinking and the indicator ("9" in Figure 1 or Figure 2) is lit.

Incorrect Measurement Indication – Tips and Solutions

The LED indicators ("8", "9" or "10" in Figure 1 or Figure 2) show excessive electrode resistance and/or excessive transient noise and/or stray current.

In the event of an incorrect measurement indication:

- Improve the quality of the connection to earth of auxiliary ground electrodes Y and Z. Z is the most likely source of problems caused by excessive electrode resistance.
- Check connections for continuity between leads and electrodes.
- Be sure that electrodes are properly inserted; they should be buried as much as possible.
- If high electrode resistance still exists after properly inserting auxiliary electrodes into the earth, try pouring water on and around the auxiliary electrodes. This will improve their electrical connection to earth.
- If stray currents are suspected, one solution to reduce their influence is to move both Y and Z electrodes in an arc relative to the X electrode (try, e.g., a 90° shift), and test again.

- Display of 0.00: Xv and Y are short-circuited.
- Display of <0: X and Z or Xv and Y rods are reversed.

Accuracy

Accuracy may be affected by auxiliary ground rod (Ry, Rz) resistance levels and by stray signal levels (earth currents).

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 23).

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 (i.e., 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).

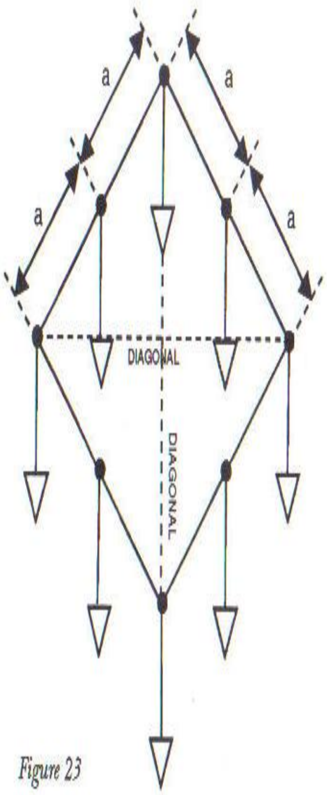


Figure 23

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

Figure 24

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 test lead resistances will also be included in the measurement 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 25.

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

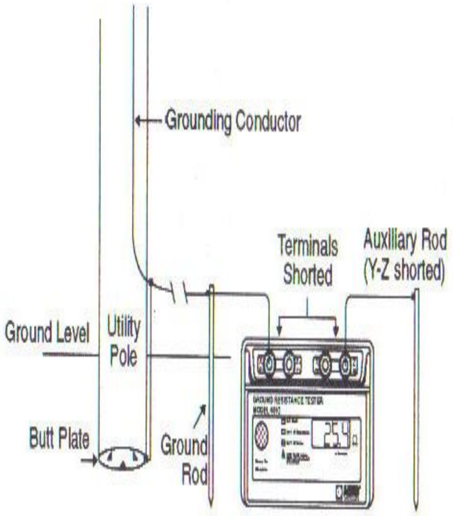


Figure 25

Continuity Measurement

Connect the shorting strips between X and Xv (C1, P1), and Y (P2) and Z (C2).

Continuity measurement is made with two leads, one from X–Xv, the other from Y–Z (P2, C2); push the "Measure" button to measure.

4610

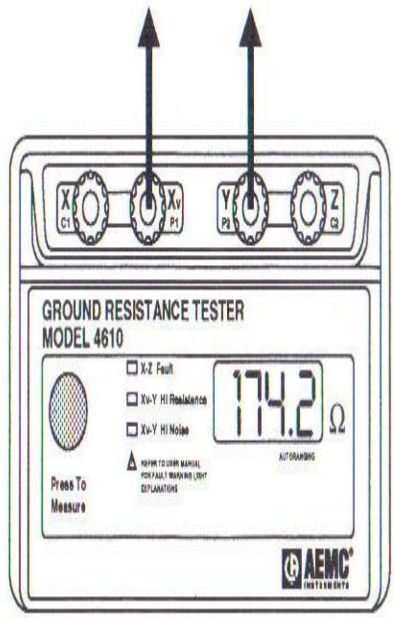


Figure 26

3640

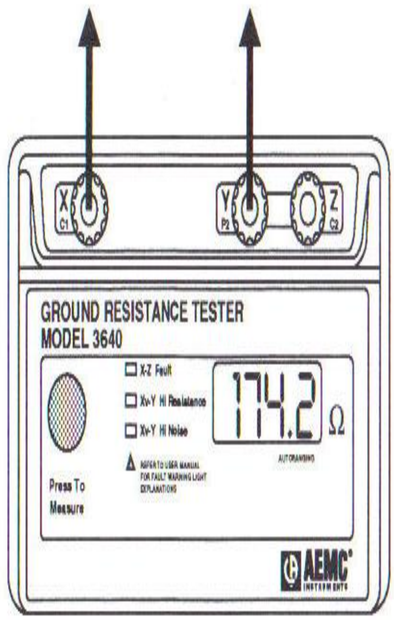


Figure 27

Soil Resistivity Measurements for Model 4610 Only

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 bedrock and other geological phenomena. Second, resistivity has a direct impact on the degree of corrosion in underground pipelines. A decrease in resistivity relates to an increase in corrosive 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 two point and the four point method. The two point method is simply the resistance measured between two points. For most applications, the most accurate method is the four point method, which is used by the AEMC® Instruments Model 4610 Ground Tester. The four 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. The Model 4610 is calibrated to read directly in ohms.

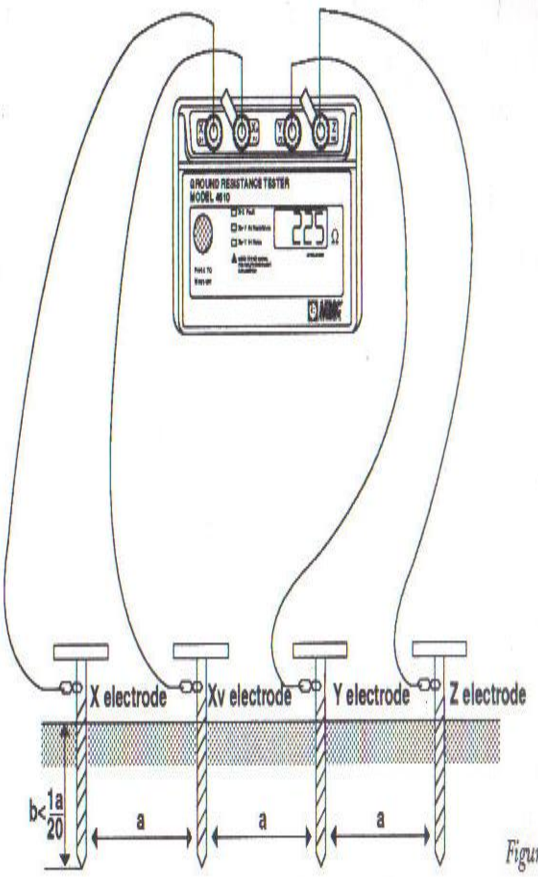


Figure 28

Soil Resistivity Measurement Procedure (4-Point)

Given a sizable 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. (Consult Figure 28.)
- 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 inches (0.15 meters), 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.
- Press the "Measure" 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 (r):

  $r = 2\pi \times R \times A$

  A = distance between electrodes in meters

  ρ = resistivity in Ω meters

  R = ohms reading obtained on Model 4610

Example 1: For measurement performed in soil with a high limestone content, the reading is R = 225 Ω, with A = 3 meters.

$\rho = 2\pi \times 225\ \Omega \times 3\ m$

$\rho = 4350\ \Omega m$

Example 2: After inspection, the area to be investigated has been narrowed down to a plot of ground approximately 75 square feet (22.5 m2). Assume that you need to determine the resistivity at a depth of 15 feet (450 cm). The distance "A" between the electrodes must then be equivalent to the depth at which average resistivity is to be determined (15 ft., or 450 cm). Using the more simplified Wenner formula ($r = 2\pi$ AR), the electrode depth must then be 1/20th of the electrode spacing or 8-7/8" (22.5 cm). If the electrode spacing is greater than 1/20th of the electrode spacing, the following formula must be used:

$$\rho = \frac{4\pi AR}{1 + \frac{2A}{\sqrt{(A^2 + 4B^2)}} - \frac{2A}{\sqrt{(4A^2 + 4B^2)}}}$$

Lay out the electrodes in a grid pattern (Figure 30 below) and connect to the Model 4610 as shown in Figure 29. 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) = $2\pi \times R \times A$

A (distance between electrodes) = 450 cm

$\rho = 6.28 \times 15 \times 450 = 42{,}390\ \Omega$-cm

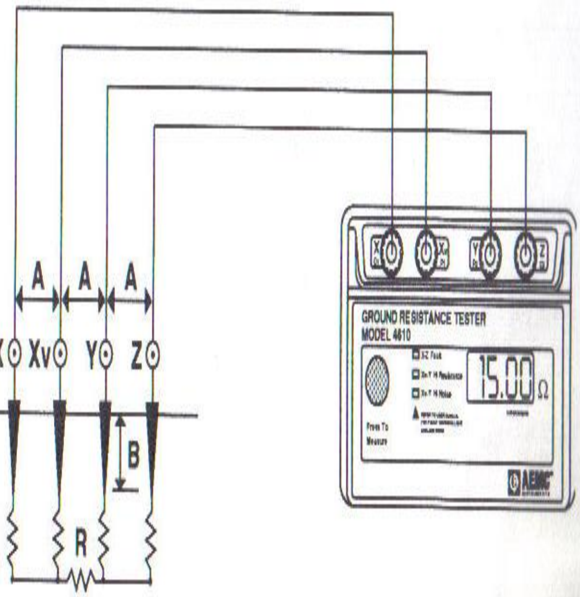


Figure 29

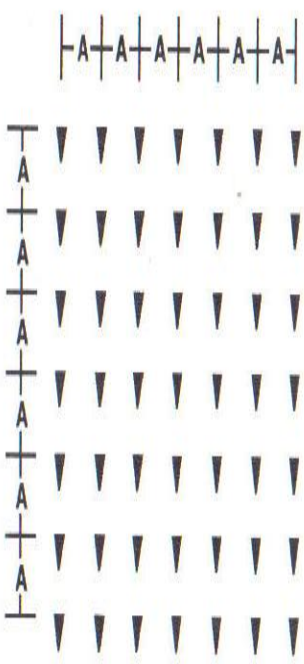


Figure 30

How to Use 25Ω Calibration Checker

The calibration checker is good for both the 3640 and 4610. The calibration checker has a resistance of 25Ω. The procedure to use the calibration checker is as follows:

- Loosen the X, XV (4610 only), Y and Z terminals.
- Insert the resistor as shown in Figure 30 or 31.
- Tighten down the terminals X, XV (4610 only, Y and Z.
- Push down the Press to Measure button.
- Compare the reading on the display to the measurement range provided on the label.

Note: For alignment purposes of the test resistor it is best if the shorting links are connected between X and XV for the Model 4610 and Y and Z for the Models 3640 and 4610.

For example if a measurement was performed on the Model 4610 the instrument should read from 24.15Ω to 25.85Ω and from Figures 30 and 31 below the display reads 25.0Ω and the measurement is in good working condition.

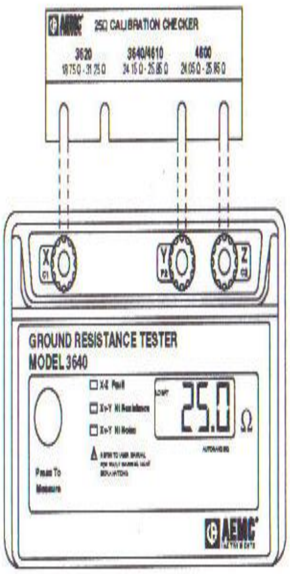


Figure 30

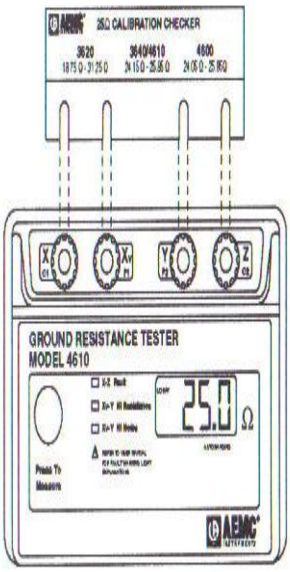


Figure 31

Repair and Calibration

To guarantee that your instrument complies with the factory specifications, we recommend that the Models 3640 & 4610 be submitted to our factory service center at one-year intervals for recalibration, or as required by other standards.

For instrument repair and/or calibration, please call our factory, toll-free, at **(800) 945-AEMC** (800-945-2362):

CHAUVIN ARNOUX, Inc.
d.b.a. AEMC® Instruments
15 Faraday Drive
Dover, NH 03820 USA
Tel: (800) 954-2362
(603) 749-6434
Fax: (603) 742-2346

(Or contact your authorized distributor.)

Estimates for repairs, normal recalibration, and calibration traceable to N.I.S.T. are available upon request. Overseas customers must receive written authorization before returning any instrument.

Technical and Sales Assistance

If you are experiencing any technical problems, or require any assistance with the proper use or application of this instrument, please call our technical hotline:

CHAUVIN ARNOUX, Inc.
d.b.a. AEMC® Instruments
99 Chauncy St.
Boston, MA 02111 USA
Tel: (800) 343-1391
(617) 451-0227
Fax: (617) 423-2952
www.aemc.com

Acknowledgments

We acknowledge and thank the ITT Blackburn Company for their permission to reprint numerous charts and graphs found in their Data folder 7303. This highly recommended and valuable Data folder is available upon request from ITT Blackburn Company.

Limited Warranty

These Ground Resistance Testers Models 3640 & 4610 are warrantied to the owner for a period of 1 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 Ground Resistance Testers Models 3640 & 4610 have been tampered with, abused or if the defect is related to service not performed by AEMC® Instruments.

What AEMC® Instruments Will Do: If a malfunction occurs within the 1 year period, you may return the Ground Resistance Testers Models 3640 & 4610 to us for repair or replacement free of charge, provided we have your REGISTRATION CARD on file. AEMC® Instruments will, at its option, repair or replace the faulty material.

Note: If a card is not on file, we will require a dated proof of purchase as well as your REGISTRATION CARD accompanied by the defective material.

What You Must Do: First obtain a return authorization by phone or by fax from AEMC® Instruments, then return the Ground Resistance Testers Models 3640 & 4610, indicating place and date of purchase, with a written explanation of the reason for return. Return material, postage pre-paid to:

Chauvin Arnoux, Inc.
d.b.a. AEMC® Instruments
Service Department
15 Faraday Drive
Dover, NH 03820 USA
Tel: (800) 945-2362
(603) 749-6434
Fax: (603) 742-2346

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

For full warranty coverage, please read the Warranty Card which is affixed to the Warranty Registration Card. Please keep the Warranty Card with your records.