GROUND RESISTANCE TESTING PRINCIPLE

(Fall of Potential — 3-Point Measurement)

The potential diference between rods X and Y is measured by a voltmeter, and the current flow between rods X and Z is measured by an ammeter. (Note: X, Y and Z may be referred to as X, P and C in a 3-point tester or C1, P2 and C2 in a 4-point tester.) (See Figure 13.)

By Ohm's Law E = RI or R = E/I, we may obtain the ground electrode resistance R. If E = 20 V and I = 1A, then

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

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.

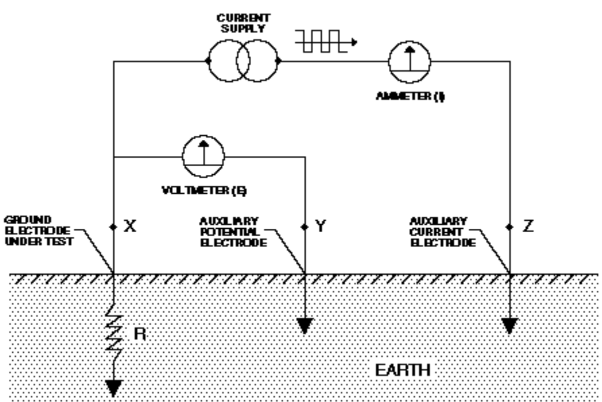

FIGURE 13

Position of the Auxiliary Electrodes on 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, as in Figure 14), 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.

NOTES

NOTES

On the other hand, if the auxiliary potential rod Y is located outside of the effective resistance areas (Figure 15), 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 15. The region is often referred to as the "62% area."
(See page 13 for explanation).

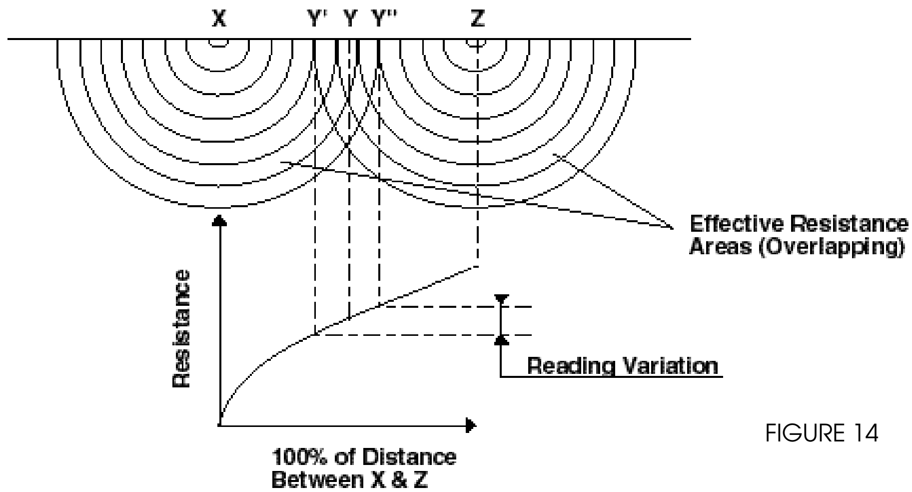

FIGURE 14

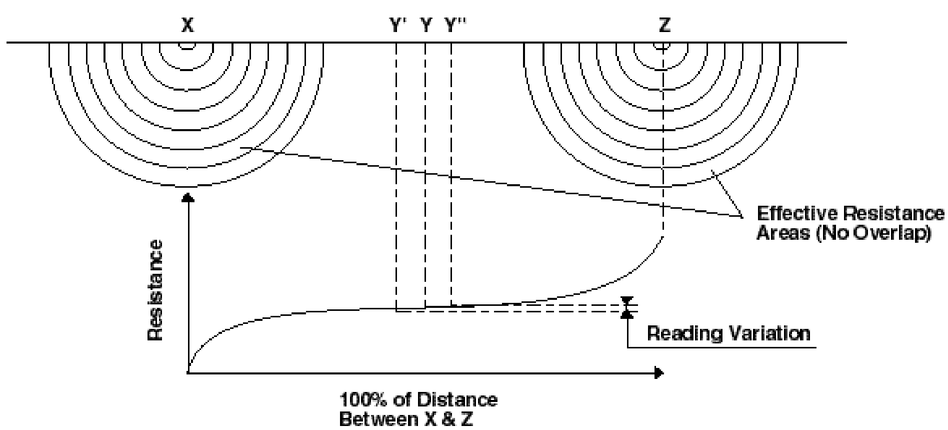

FIGURE 15

Measuring Resistance of Ground Electrodes (62% Method)

NOTES

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 16.**

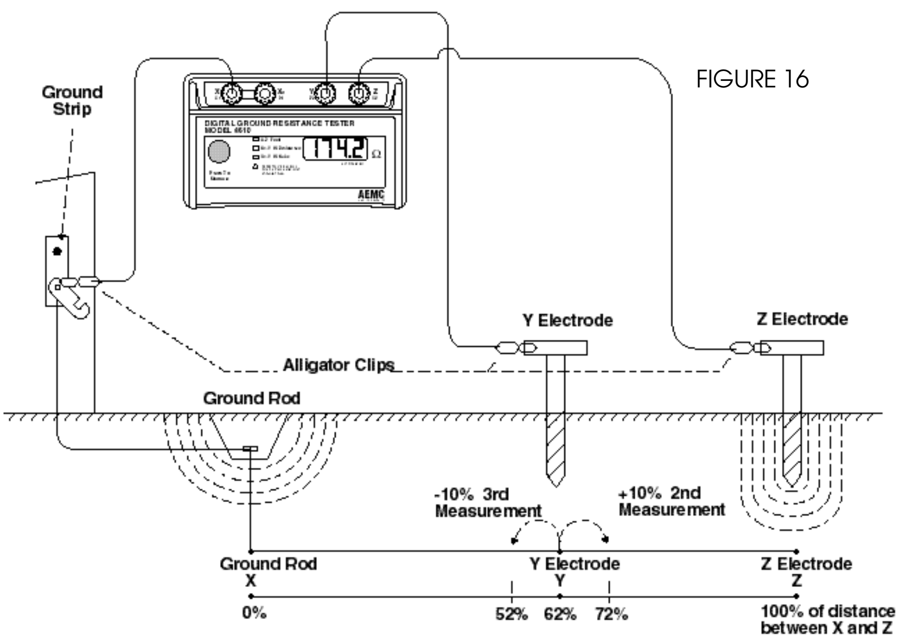

FIGURE 16

Consider Figure 17, which shows the efective 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.

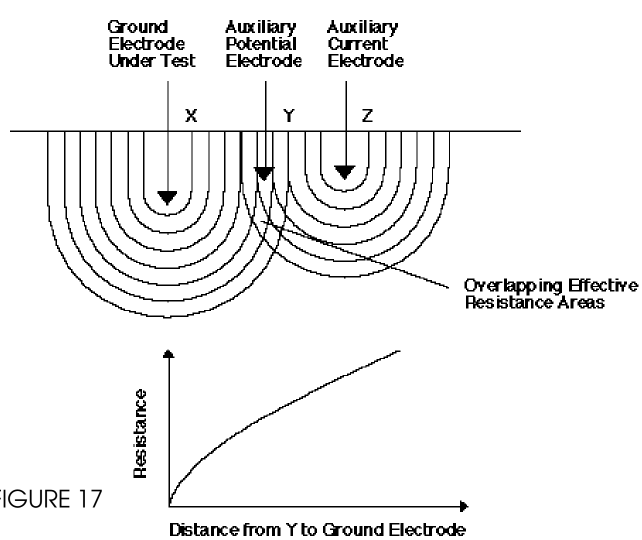

FIGURE 17

NOTES

Now consider Figure 18, 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.

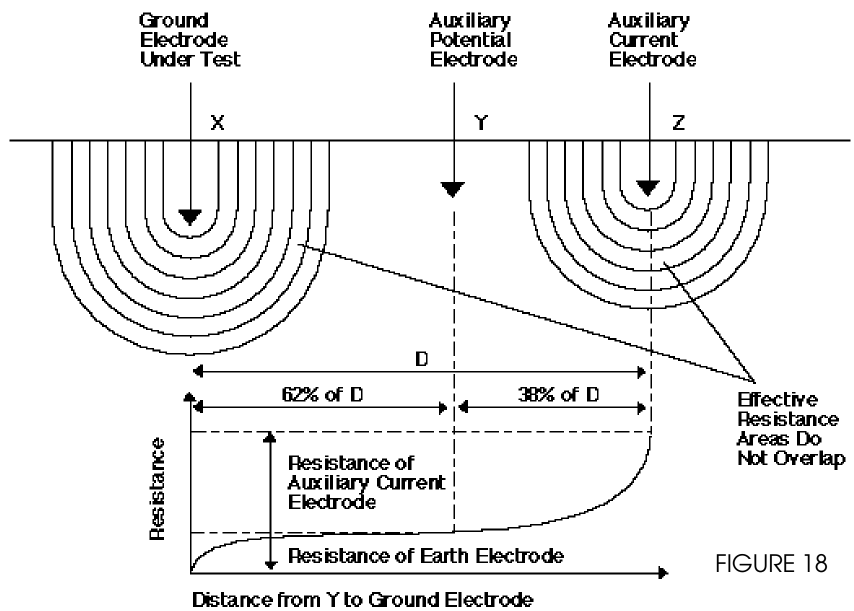

FIGURE 18

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

MULTIPLE ELECTRODE SYSTEM

NOTES

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 being used, they are driven in a straight line; when four or more are being used, a hollow square configuration is used and the ground electrodes are still connected in parallel and are equally spaced (Figure 19).

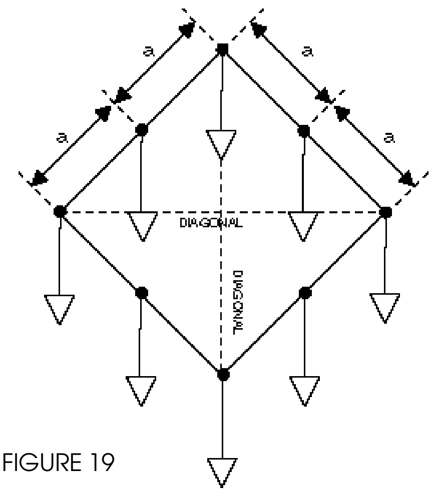

FIGURE 19

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).

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

NOTES

TWO-POINT MEASUREMENT
(SIMPLIFIED METHOD)

This is an alternative method *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 back-up in tight areas. See Figure 20.

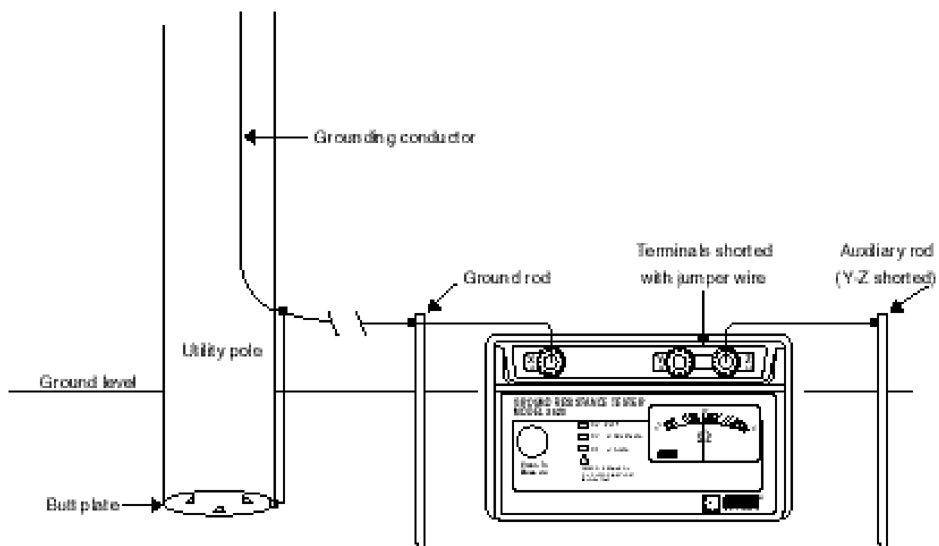

FIGURE 20

CONTINUITY MEASUREMENT

Continuity measurements of a ground conductor are possible by using two terminals (Figure 21).

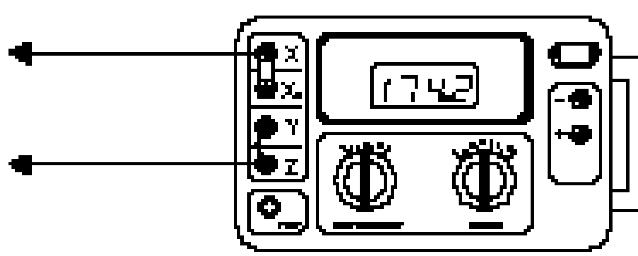

FIGURE 21

TECH TIPS

NOTES

Excessive Noise

Excessive noise may interfere with testing because of the long leads used to perform a fall-of-potential test. A voltmeter can be utilized to identify this problem. Connect the “X”, “Y” and “Z” cables to the auxiliary electrodes as for a standard ground resistance test. Use the voltmeter to test the voltage across terminals “X” and “Z” (Figure 22).

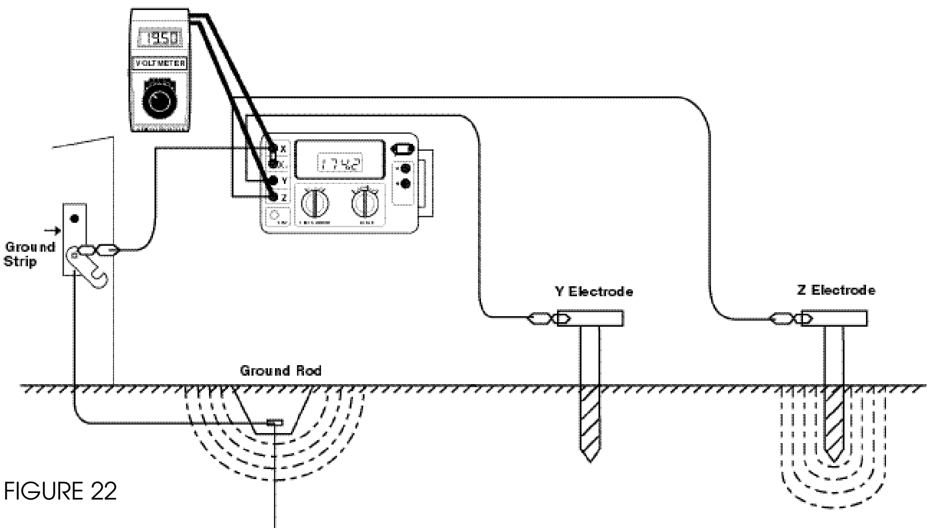

FIGURE 22

The voltage reading should be within stray voltage tolerances acceptable to your ground tester. If the voltage exceeds this value, try the following techniques:

A) Braid the auxiliary cables together. This often has the effect of canceling out the common mode voltages between these two conductors (Figure 23).

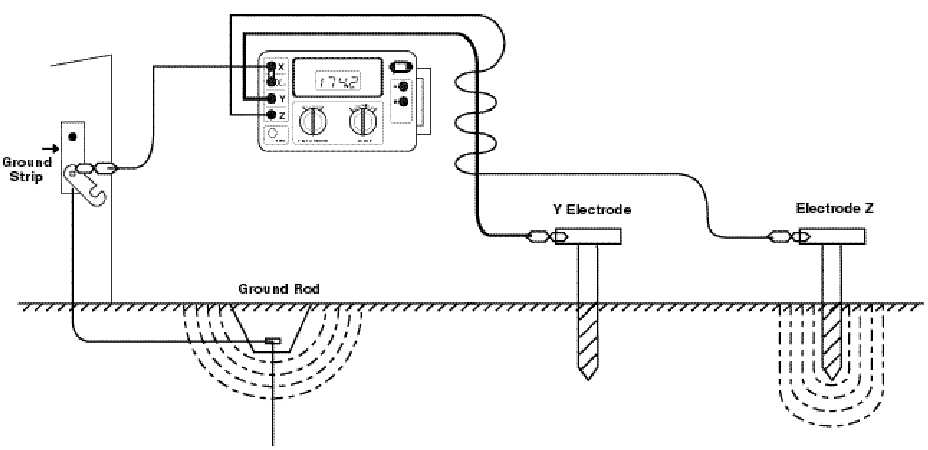

FIGURE 23

NOTES

B) If the previous method fails, try changing the alignment of the auxiliary cables so that they are not parallel to power lines above or below the ground (Figure 24).

C) If a satisfactory low voltage value is still not obtained, the use of shielded cables may be required. The shield acts to protect the inner conductor by capturing the voltage and draining it to ground (Figure 25).

1. Float the shields at the auxiliary electrodes.

2. Connect all three shields together at (but not to) the instrument.

3. Solidly ground the remaining shield to the ground under test.

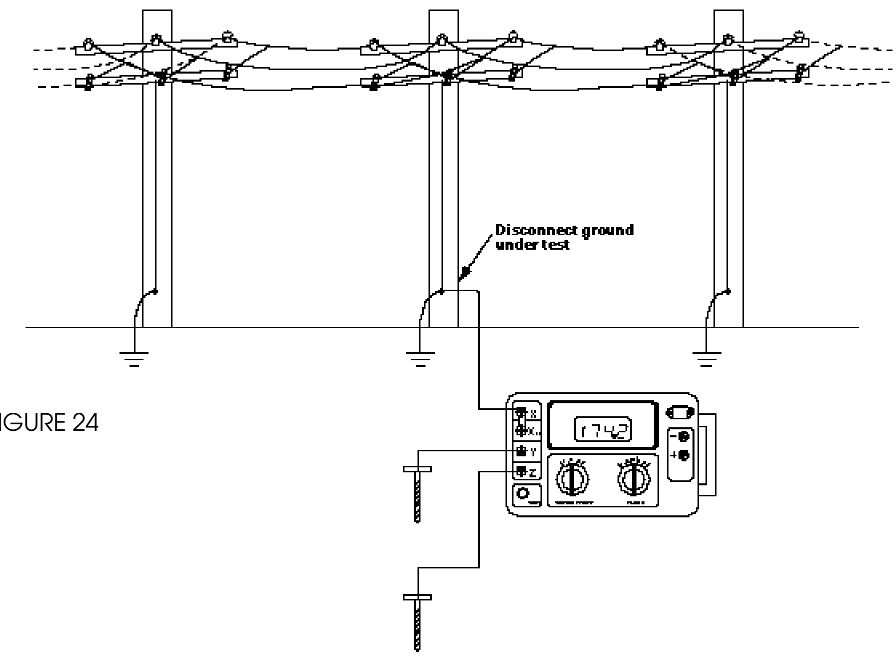

FIGURE 24

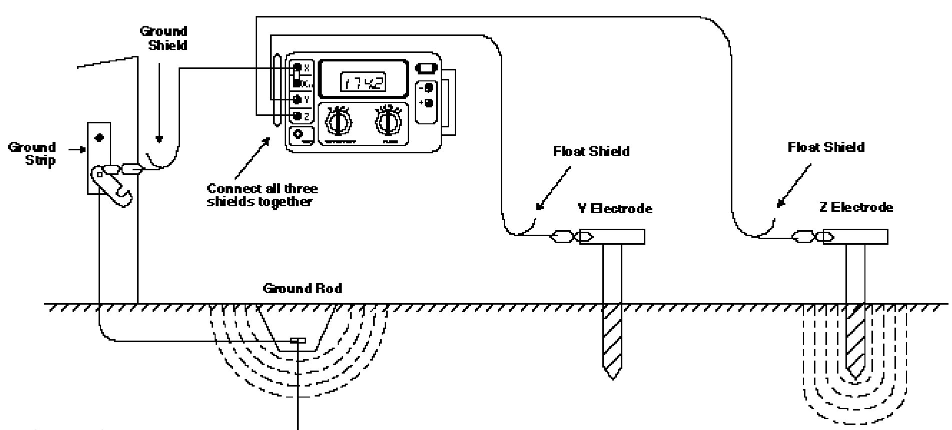

FIGURE 25

Excessive Auxiliary Rod Resistance

The inherent function of a fall-of-potential ground tester is to input a constant current into the earth and measure the voltage drop by means of auxiliary electrodes. Excessive resistance of one or both auxiliary electrodes can inhibit this function. This is caused by high soil resistivity or poor contact between the auxiliary electrode and the surrounding dirt (Figure 26).

To ensure good contact with the earth, stamp down the soil directly around the auxiliary electrode to remove air gaps formed when inserting the rod. If soil resistivity is the problem, pour water around the auxiliary electrodes. This reduces the auxiliary electrode's contact resistance without affecting the measurement.

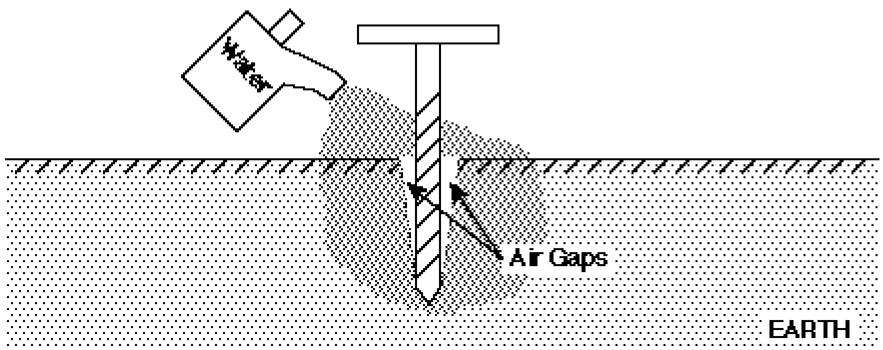

FIGURE 26

Tar or Concrete Mat

Sometimes a test must be performed on a ground rod that is surrounded by a tar or concrete mat, where auxiliary electrodes cannot be driven easily. In such cases, metal screens and water can be used to replace auxiliary electrodes, as shown in Figure 27.

Place the screens on the floor the same distance from the ground rod under test as you would auxiliary electrodes in a standard fall-of-potential test. Pour water on the screens and allow it to soak in. These screens will now perform the same function as would driven auxiliary electrodes.

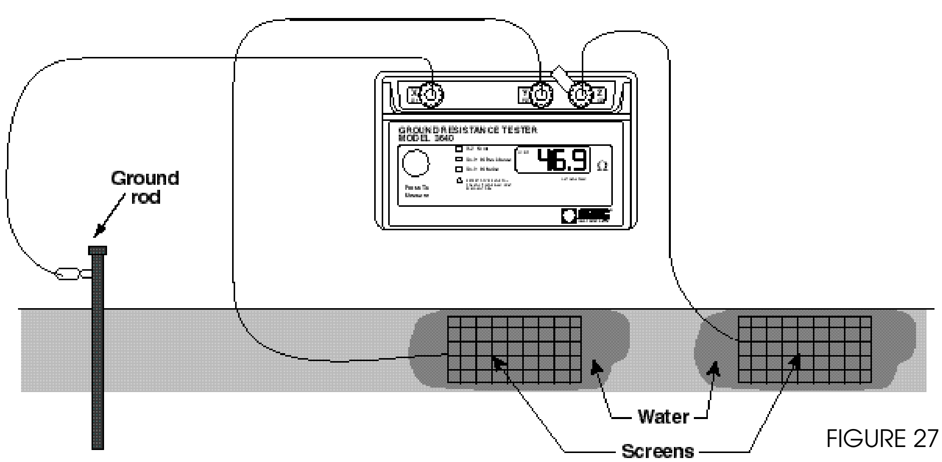

FIGURE 27

NOTES

NOTES

TOUCH POTENTIAL MEASUREMENTS

The primary reason for performing fall-of-potential measurements is to observe electrical safety of personnel and equipment. However, in certain circumstances the degree of electrical safety can be evaluated from a different perspective.

Periodic ground electrode or grid resistance measurements are recommended when:

1) The electrode/grid is relatively small and is able to be conveniently disconnected.
2) Corrosion induced by low soil resistivity or galvanic action is suspected.
3) Ground faults are very unlikely to occur near the ground under test.

Touch potential measurements are an alternative method for determining electrical safety. Touch potential measurements are recommended when:

1) It is physically or economically impossible to disconnect the ground to be tested.
2) Ground faults could reasonably be expected to occur near the ground to be tested, or near equipment grounded by the ground to be tested.
3) The “footprint” of grounded equipment is comparable to the size of the ground to be tested. (The “footprint” is the outline of the part of equipment in contact with the earth.)

Neither fall-of-potential resistance measurements nor touch potential measurements tests the ability of grounding conductors to carry high phase-to-ground fault currents. Additional high current tests should be performed to verify that the grounding system can carry these currents.

When performing touch potential measurements, a four-pole ground resistance tester is used. During the test, the instrument induces a low level fault into the earth at some proximity to the subject ground. The instrument displays touch-potential in volts per ampere of fault current. The displayed value is then multiplied by the largest anticipated ground fault current to obtain the worst case touch potential for a given installation.

For example, if the instrument displayed a value of .100Ω when connected to a system where the maximum fault current was expected to be 5000A, the maximum touch potential would be: 5000 x .1 = 500 volts.

Touch potential measurements are similar to fall-of-potential measurements in that both measurements require placement of auxiliary electrodes into or on top of the earth. Spacing the auxiliary electrodes during touch potential measurements differs from fall-of-potential electrode spacing, as shown in Figure 28 on the following page.

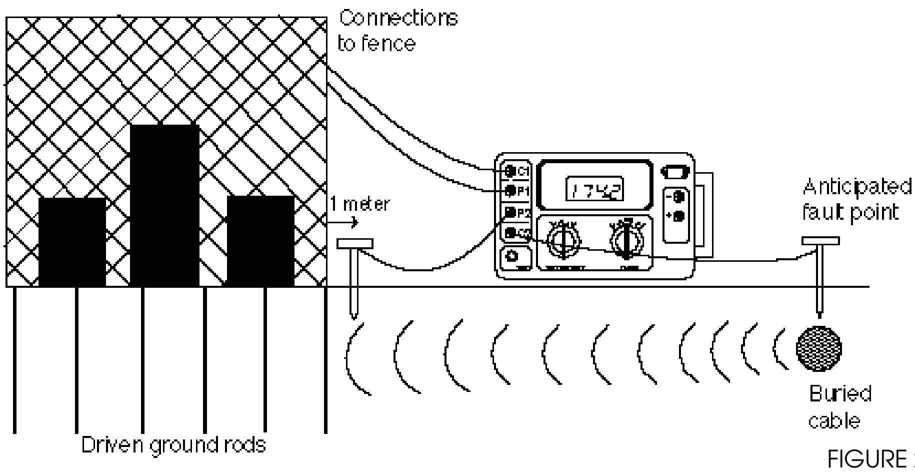

FIGURE 28

NOTES

Consider the following scenario: If the buried cable depicted in Figure 28 experienced an insulation breakdown near the substation shown, fault currents would travel through the earth towards the substation ground, creating a voltage gradient. This voltage gradient may be hazardous or potentially lethal to personnel who come in contact with the affected ground.

To test for approximate touch potential values in this situation, proceed as follows: Connect cables between the fence of the substation and C1 and P1 of the four-pole earth resistance tester Position an electrode in the earth at the point at which the ground fault is anticipated to occur, and connect it to C2. In a straight line between the substation fence and the anticipated fault point, position an auxiliary electrode into the earth one meter (or one arm's length) away from the substation fence, and connect it to P2. Turn the instrument on, select the 10 mA current range, and observe the measurement. Multiply the displayed reading by the maximum fault current of the anticipated fault.

By positioning the P2 electrode at various positions around the fence adjacent to the anticipated fault line, a voltage gradient map may be obtained.