Ground Testing FAQs

Can I use an insulation tester to do the same test?
No. This is a common error. Field operators are often issued a MEGGER ® instrument from stores, without its being checked to determine whether it's an insulation or ground tester. Insulation testers are designed to measure at the opposite end of the resistance spectrum from a ground tester. No one wants grounds that measure in megohms Insulation testers use high test voltages in the kilovolt range. Ground testers are limited, for operator safety, to low voltages. Insulation testers do commonly have low-voltage, low-resistance continuity functions and these are frequently misused to make jiffy ground tests. However, a continuity test can only make an arbitrary measurement between an installed electrode and a reference ground, which is assumed to have negligible resistance. This does not afford a reliable measurement of the resistance the earth offers to a ground fault current. Even this arbitrary measurement may not be reliable, since a dc continuity test can be influenced by soil transients, the electrical noise that is generated by utility ground currents trying to get back to the transformer, as well as other sources.

The required measurement is of resistance; why can't I use a multimeter?
For the same reasons that a continuity range on an insulation tester should not be used. Measurements made with a dc multimeter are subject to distortion by electrical noise in the soil. A multimeter offers no means of verifying that the resistance displayed represents anything other than an arbitrary measurement between two convenient points. With a multimeter, one can measure the resistance of the soil between a ground electrode and some reference point, such as the water pipe system, but a fault current may encounter a higher resistance. Genuine ground testers are amenable to field-developed standard procedures that have built-in cross-checks that expose insufficient test conditions.

What is the difference between a two-point, three-point, and four-point test?
Literally, the number of points of contact with the soil. More specifically, these commonly used terms refer to dead earth, fall of potential, and Wenner method tests, respectively. In the dead earth method, contact is made at just two points: the ground electrode under test and a convenient reference ground, such as the water pipe system or a metal fence post. In the fall of potential method, a genuine ground tester makes contact via the test electrode, plus the current and potential probes. With the Wenner method, no ground electrode is involved, but rather the independent electrical properties of the soil itself can be measured using a four-probe setup and a recognized standard procedure.

Can't I simply make a measurement to a reference ground?
This common method often uses an instrument other than a dedicated ground tester. It is referred to as the dead earth method because the reference ground is only being used for the test and is not normally part of an electrical system. It can be the water pipes, a metal fence post, or even a rod driven just for the test. The method is popular because of its ease and generality, but is not recommended. Since the reference ground happens to be located by a combination of convenience and chance, it is only a matter of luck if the soil resistance to it actually represents the true electrical ground resistance. Furthermore, the measurement has to be accepted on faith, because there is no way to validate it, as there is with accepted standard methods. The method has no independent recognition from standards authorities, and so is of no use in establishing the reliability of results or in liability protection.

How do I know if my ground is good?
The most widely used specification is that of the NEC, which mandates for residential grounds a resistance of 25 or less. This is not a particularly difficult specification to meet. Others are more demanding, and may be specified by the engineer designing an electrical system, or by a client, or may come as part of the warranty requirements for advanced equipment. The most commonly encountered specification for industrial grounds in general is 5 or less. Computers and process control equipment may demand as little as 1 or 2 .

How often should I test my grounds?
Odd intervals of 5, 7, or 9 months are recommended so that the various seasons will all be encountered in succession. This is because the quality and effectiveness of a ground are profoundly affected by weather and seasons. If quarterly or semiannual testing schedules were used, certain months would consistently be missed, and these could be the ones in which the grounding is most stressed by the weather. Adopting irregular intervals, on the other hand, ensures that worst case seasons will be revealed. Since a ground fault, potential fire or accident, can happen at any time, your protection is only as good as the ground condition in the worst time of year.

How do I go about designing a good ground?
Traditionally, the trial-and-error method was used and could be enhanced by an individual's experience. This consists of designing the ground during the process of installation, and repeatedly testing it in progress, until the desired spec has been met. For example, a rod can be driven then tested. A second rod can be coupled to the first, driven deeper, and tested again. This procedure is repeated until spec is met. Similarly, a second rod can be added in parallel (driven into the soil separately and connected by a conductor rather than coupled end-to-end) and tested. Additional rods can then be added to form a ground bed until a sufficiently low resistance is obtained. The trial-and error method is still frequently used and often works well. But its limitation is that it is subject to the Law of Diminishing Returns: more and more work for less and less reward. In optimal soil conditions, a satisfactory ground can be achieved with only a few retests. But in more difficult environments, one can end up wasting the day without realizing the goal.

A more ordered approach is available and begins with the manufacturers of grounding materials. They will commonly provide, at little or no cost, engineering programs to calculate the best theoretical design in advance. These are usually available on computer disc and require the input of some data, which include resistivity measurements of the available area, and the ground resistance specification that must be met. From this data, the program calculates a design which can be installed as a unit rather than the piecemeal approach of trial-and-error. A single resistance test should then verify that the spec has been met and, if not, only a simple addition or adjustment should be sufficient.

How do I hook up my leads?
With a three-terminal model, the common is connected to the ground being tested. The shortest available lead is used for this connection because the test ground should be close at hand and the lead resistance will be part of the measurement. If the tester is a four-terminal model, the operator has some discretion. The C1 and P1 terminals can be jumpered or not. If jumpered electronically by means of the appropriate test button (newer models have separate test buttons for three- or four-terminal operation), the lead should be taken from the C1, not the P1. The internal connection made by means of the test button is

resistive, not a dead short. If the test lead is run from the P1, this internal resistance will show up in the measurement. If both terminals are to be used, two leads are run to the test ground. In this genuine four-wire bridge configuration, no lead resistance enters the measurement. So the choice is resolved between time and accuracy. Three-wire is quicker because it requires less hookup. If the test spec isn't unusually low, the little bit of lead resistance doesn't hurt. Four-wire requires a bit more work, but if you must meet one or two W , it may be helpful to make the accuracy as sharp as possible.

The longest lead is connected to the C2 terminal, and normally, or in the absence of any other specifics, stretched out to its full length. The P2 receives the lead of intermediate length and this will probably be moved several times between the tested ground and the current probe, according to the dictates of the specific procedure being used.

How do I know how far to extend the leads?
Unfortunately, there's no failsafe method of determining this in advance without the possibility of some trial-and-error. That's because soil conditions are infinitely variable. In highly conductive soils, the resistive volume surrounding the test ground is comparatively small and acceptable measurements may be made from as little as 25 ft away. As soil type and conditions worsen, and/or the resistance spec goes down, the resistive field enlarges and can become quite extensive. Then, extremely long test leads may be required in order to get out of the resistive field of the electrode being tested. How can this very important consideration be approached?

First, industry rules-of-thumb exist and are often seen reproduced in tables in the literature. These vary somewhat depending on the disposition and experience of the issuing agent, but in general it can be said that the current lead is extended four to five times the length of the maximum dimension of the ground being tested (some more rigorous authorities recommend ten times). For example, with a driven rod, the current probe would be placed five times (or whatever multiplier is being used) the depth; with a ground bed, five times the diagonal; for counterpoise, five times the diameter, and so on. Just remember, these are only rules of thumb. They are not strict requirements. The underlying concept is that the practice will provide a reasonably good likelihood of getting an acceptable test on the first try. But this is neither guaranteed nor mandated. If the calculated distance is impractical or impossible, there is nothing wrong with testing at whatever distances are available. The only thing being risked is the increased possibility that the result won't qualify, and the test will have to be repeated; i.e., more trial-and-error.

Secondly, you may just use whatever is available. If it is not inconvenient to run the leads out to the maximum (100 ft or more), there is a good chance that most tests will be adequate. As long as an acceptable test procedure is followed, bad results caused by insufficient probe spacing will be recognized and thrown out. The more you can live with trial-and-error, the less concern there need be about getting it right the first time. And, operator experience is invaluable. Familiarity with local conditions and previous tests are often all that is needed for the experienced operator to make a practical decision on the first try.

And thirdly, the test procedure being used has something to do with the amount of lead length that will be needed. Some methods (e.g., Slope Method) tend to require less distance than others (e.g., fully developed Fall of Potential) for a given test ground. Just remember, as far as lead length is concerned the ends justify the means. If an acceptable test result (that is, coherent and repeatable) is obtained, the leads were long enough.

What is the significance of the provided lead lengths?
As a generalization, they are long enough to yield an acceptable test on the first try in most common environments. The one false conclusion that must not be inferred is that they are the exact lengths needed in all situations. That is to say, do not merely stretch the leads out to their full lengths, conduct a test, and leave. You may, and most likely will, have a good test but there is no certainty. There are many atypical environments in which the provided lead lengths are not enough. Any attempt at a universal lead set would be highly impractical, inordinately long, and a nuisance to work with in most routine test situations. The provided leads will be adequate in most instances,\ but a margin must be allowed for situations in which longer lengths will have to be used. No lead set design can serve as a preordained substitute for good fundamental practice.

Do I just go out 62 feet and take my measurement?
This practice does have limited applicability, but should not be relied upon. It frequently appears in the literature as the "62% Rule" (more specifically, 61.8). It is based on calculations that have shown that, under ideal conditions, a Fall of Potential graph will encounter the value that represents the theoretical true ground resistance at a position that is 61.8% of the distance to the current probe. The theoretical true resistance is the value for that ground electrode in that location if the resistance of the entire planet could be measured. Of course, it cannot but fortunately for practical considerations all but a miniscule amount of that resistance is determined by the conditions in the immediate area which can be measured. Because resistance rises well above theoretical true in the vicinity of the current probe, the total graph therefore will include the value equivalent to theoretical true.

The limitation of the "62% Rule" is that it assumes ideal conditions. These include adequate probe spacing and homogeneous soil. Soil is rarely entirely homogeneous (of a thoroughly consistent nature) and around graded construction sites, it will be particularly disturbed. Therefore, by pure misfortune, the potential probe at 62% of the total distance may be driven into a localized hot spot where the soil in a small area is not representative of the prevailing condition. This could cause a reading to be too high, resulting in unnecessary improvement of the ground. Conversely, it could make the reading low, resulting in the facility being left without the intended protection. And unlike other standard test methods, the result of the 62% test has to be taken on faith; i.e., there is no built-in safety check to toss out readings taken with inadequate spacing. Again, unless the probes happen to be separated by sufficient spacing, a reading could be taken on the rise of the resistance vs. spacing curve, and falsely indicate that the ground has met spec.

So, where can this method be successfully used? It may be that in some non-critical applications, the speed and ease of this test may make it attractive to risk the occasional bad test slipping by. Unless thoroughly justified, however, that is not a recommended idea. Utilities may sometimes scour an area with these abbreviated tests for a line of pole grounds, for instance. But there is always a back-up team that performs a second test by a more rigorous means on any locations that aren't in agreement with expectations from previous records. The most advantageous use of this method, then, is where the assumptions have been met; that is to say, where previous thorough testing has established the distances, points of probe placement, and so on, and they are recorded in a maintenance history. In such cases, subsequent maintenance testing can be performed without as great an expenditure of time and effort by using the "62% Rule".

Does it matter how deep I drive the probes?
No, not once a threshold value for maximum contact resistance has been met (we are referring to test probe resistance here, not the installed ground that is being tested). It is a common fallacy that driving the test probes deeper will lower the readings. Imagine your readings changing as you drive the probes; what would be the correct value? It's true that the resistance of the ground under test does change as the test probes are moved, but the standardized procedures deal with this and provide a means of determining when the correct reading has been achieved. With respect to the probes, this is not necessary. They need only make a minimum amount of contact with the soil, the attainment of which can be recognized by merely observing the display indicators. Once contact is achieved, the test may proceed. And with instruments from AVO, the resistance tolerance in the test circuits is particularly high, so that threshold contact is readily attained. So much so that it may not be necessary to even penetrate the surface. Just laying the probes flat and watering them down often lowers contact resistance enough to meet the threshold tolerance.

My testing is all on concrete and macadam; how can I drive probes?
The good news is that you probably don't have to. Our models have uncommonly high resistance tolerances in the test circuits (typically 4, 40, & 400 k for the current circuit, 75 k for the potential). Any surface contact of a resistance less than these high thresholds is enough. Therefore, you may only need to lay the test probes flat on the surface and establish contact by wetting the area. Concrete conducts current fairly well and chances are good that you'll have an acceptable test. Macadam is not as good because of the non-conductive tar, but you may still be able to achieve enough contact. You'll know because indicator lights on the tester warn you if the contact threshold has not been met. If that becomes a problem, you can improve your chances by using a contact mat instead of the provided probes. Mats are flexible metallized conductive pads that mate with the surface contours. They are readily available from ground materials suppliers.

I have no room to stretch out the leads; what do I do?
Try another method. This is not as cavalier an answer as it may sound. Good samaritans have anticipated this problem long ago, and developed specialized test procedures to meet it. Test procedures are described in IEEE Standard No. 81 and are readily available from the general ground-testing literature. Most procedures are generalized variations of the comprehensive Fall of Potential Method but some have been devised as answers to specific situations like testing in congested areas. The most-used procedure for this particular problem is the Star-Delta Method. This is an adaptation of the two-point method, with arithmetic built in to compensate for the uncertainties that make more generalized two-point testing unreliable. Specifically, rather than going straight out with potential and current leads, the test probes are arranged in a fairly close triangle around the ground under test. A series of two-point measurements are made between the various pairs of elements in the array (probe to ground and probe to probe), plugged into a series of equations, and then you have your answer. If there are problems in the test setup, the arithmetic doesn't compute to a coherent answer and you know to try again with a different configuration.

What safety precautions should I observe when performing a ground test?

Industry-standard safety practices are always a good idea, if for no other reason than to condition personnel against becoming lax and wandering unprotected from one electrical environment to another. But with current model Megger® ground testers specifically, there are few requirements. The instruments themselves present no potential hazard. While testers of years ago sometimes used high currents and voltages, and some lines still do, all Megger models have taken advantage of microprocessor sensitivities in order to limit both voltage and current within levels safe for human operation. No more than 50 V and 10 mA are produced, except when using the DET2/2 in its high-current mode, in which case a maximum of 50 mA are produced at low voltage. The only possible hazard in a ground test then is from the electrical system if the test is being performed on a ground electrode while it remains on line. Incidentally, because of the low voltage and current, plus uncommon frequency, the ground tester does not introduce any intrusive signal onto the electrical system that might trip protective devices or interfere with operation. The reverse can occur, however. The electrical system can intrude on the tester. That is to say, if a fault condition occurs while the ground test is being performed, the ground electrode will be brought on line by the fault current going to earth and voltages can develop across the tester. These can damage the instrument and threaten the operator. For personnel safety, however, all that needs to be done is to follow standard safety practices, such as wearing insulated electrical gloves and working on a protective mat. To protect the instrument, fused leads can be used.

I've tested a ground and gotten a reading of 520 Ohms. Is there something that I've done wrong?
Probably not. As long as the tester is in calibration and a standard test procedure has been followed adequately, you can rely on the measurement. The problem is with the ground, not with the operator. It is not at all uncommon to discover grounds that are anything but! Because of neglect, deterioration, drastic changes in environment, poor installation, lack of forethought in design, or any of a number of common causes, ground electrodes may be providing little or no protection. To seek out and correct these bad grounds is why the test is being made in the first place. Do not be surprised to find ground electrodes that measure in the hundreds, even thousands, of Ohms. It is a good idea to first perform a few repeat tests so as to confirm the bad news, and then start digging.

I have a large grid to test; how do I know what model to choose?
The size of the grid hardly matters to the tester. It does matter, however, to the operator. The two principle effects of grid size are on lead lengths and method chosen, rather than model of instrument. Any model can, at least nominally, test any grid. Just because you might have an economical model, don't become dismayed by a large grid, and assume a special instrument is required. As long as an accepted test method is followed rigorously and yields coherent results, the measurement is reliable. Large grids do, however, often require long lead lengths and/or special test methods. It is more important that the operator give thought to these considerations than to the instrument itself. In some difficult situations, the high current available from the DET2/2 can be of help in establishing adequate test current, but this can be accomplished in other ways also, such as by driving deeper probes or watering the probe area. A good operator relies on his own experience as well as on the instrumentation. No model is meant to serve as a substitute for human abilities. The combination of an experienced, thoughtful operator and a high quality instrument is always the best tool.

How do I test a counterpoise system?
Although it is notably different in design from a standard ground rod or bed, a counterpoise system is nothing special to the ground tester. Fall of Potential, and its derivative methods, still provide the means

of testing. Theoretically, the system should test essentially the same from any point, although local realities can sometimes superimpose their effects. For that reason, it is a good idea to repeat the test in various directions, in order to average out possible localized variations. Contact can be made with the counterpoise system at any convenient, accessible point. Remember, as long as the system was designed and installed correctly, all of its elements should be in parallel with respect to the ground.

Other requirements may prevail as well with respect to the conductors coming off the tower and their connections to the system. Therefore, it is recommended to thoroughly examine specifications. The test may not actually entail a single measurement, but rather it may include both the electrical relationship of the buried system to the soil and of the conductors to the system and the tower. The actual ground resistance measurement remains the same but it may have to be supplemented by verification of complete continuity from the tower to the buried electrode. Of course, this is true of any ground but is often more elaborately and rigorously specified for counterpoise systems because of their demanding requirements for symmetry in order to smoothly conduct high-current faults from lightning strokes. To be thorough, a high-current, low-resistance ohmmeter, such as a Biddle® DLRO®, should be used to check for continuity across bonds, welds, clamps, and similar conductive elements. But as a mere backup or spot check, multimeters, or even a ground tester placed in two-terminal configuration, may suffice. If the system has already been buried, there is a problem, but it is not hopeless. An instrument such as the Multi-Amp® Safety Ground Test Set is a highly specialized unit that can inject a high current into a buried system in order to test that the individual elements comprising it have sufficient continuity through bonds and welds. Do not confuse this with a ground test, however. The electrical relationship with the surrounding soil is separate and must be verified by a recognized ground test.

Can I test my ground conductors with your model?

Yes and no. First, it is essential to identify terms and what all is actually required of a test procedure. It is not uncommon that what someone means by a ground test is actually comprised of two separate measurements, one involving the surrounding soil; the other the continuity of conductors. Read your test specifications and requirements carefully so that nothing is overlooked. Once installed, the ground electrode will be connected to the electrical system by one or more conductors. This connection may vary anywhere from the usual copper conductor extending from the ground buss at the service entrance to a rod driven at the base of the building, to the elaborate and symmetrical connections designed to conduct lightning with a minimum of impedance from a tower to a counterpoise ground. These connections must offer little resistance, otherwise the whole purpose of establishing a ground is defeated. To thoroughly test them, an appropriate instrument is an ohmmeter with a high test current capable of exploiting weaknesses, loose connections, corrosion, poor welds, and such, and revealing them in the measurement. A common multimeter does not do this, because it makes its measurement with only a few milliamps of current. A Biddle® DLRO®, which can output 10, or up to 100, Amps will perform a rigorous test that will satisfy the most demanding inspector. As a handy backup check, a multimeter can be used and even a ground tester, with its pairs of current and potential terminals jumpered together to produce two terminals, can serve this purpose. Mainly, just be aware that your test requirements may include both a separate ground test and a continuity test across the connectors. Incidentally, the ground test should be conducted before connection is made to the electrical system. If made after, the entire power grid becomes part of the measurement, all the way back to the substation ground. This is still useful in determining the overall ground but the actual quality of the local ground cannot be assessed.

I need greater lead lengths than your kit provides; what do I do?

This is simpler than it may look. There is nothing exotic about the leads and probes used to adequately conduct a ground test. The wire is 14-gauge braided copper, covered by rubber insulation. Any suitable wire can be used to extend the length of the test setup, down to 18 gauge. Connection is made to the tester by universal terminals that will accept spade lugs, banana plugs, and even bare conductor. The probe end is a copper alligator clip covered with a protective rubber boot. All of these materials are readily available and can be used to increase the expanse of a test setup. Contact resistance from stringing lengths together will most likely not present as much of a problem as might be expected, because of the high resistance tolerance in the test circuits. If too much contact resistance does occur, warning lights on the tester will give the operator ample indication that some additional steps must be taken. The probes too are not highly specialized and general ground rods, even railroad spikes, can be used to penetrate the soil. Again, the warning indicators will let the operator know if there is any problem with the choice of accessory materials. It is for this reason that AVO offers leads and probes as optional accessories, to allow planners the option of making use of their own materials.

It has just rained heavily; will this influence my test?
Yes. There's little you can do about the weather, except be aware of its effects and work accordingly. Soil conductivity is based on electrical conductance by dissolved ions in moisture, not unlike the action of a car battery. When it rains, the increased moisture dissolves salts in the soil and promotes added conductivity. Resistance goes down. If the only goal was to "make spec", you could try watering the area before the arrival of the inspector. But that only defeats the purpose of installing a ground. Remember, the electrode is only as good as its worst day, because a fault situation can occur at any time. If it has rained all night, and the electrode barely meets spec, chances are that it will not when tested during dry weather. The ground design should be improved. Take all of this into consideration, and plan accordingly.

I have a ground installed in sandy (or rocky) soil; what can I do to test this?
The test is the same, but chances are the results won't be pleasant. It is much more difficult to ground in sandy or rocky soil. Sand does not hold water well and so the moisture that is needed to promote electrical conductivity readily drains away. Rocky soils have poor overall consistency, lots of space between individual elements, and reduced surface contact with the buried electrode. All of these conditions mean that the original design and installation must be more rigorous and thorough than in more agreeable types of soil. If this wasn't done in the first place, chances are that the results of a later ground test will prove unpleasant.

The test itself isn't categorically different, but it may be advisable to take some special steps to make it more successful. In rocky terrain, it may be necessary to use longer, more robust test probes in order to attain sufficient contact with the soil. The tester's indicators will apprise the operator of this. And since ground systems in poor soils generally have to be larger and more elaborate, their electrical field zones are much larger and more diffuse than those of simpler grounds. Therefore, it may require excessive lead lengths to get outside the ground's sphere of influence for a good test. Be prepared to switch to an alternate method that does not require as much distance (e.g., Slope Method). In general, it is a good practical idea to become familiar with several recognized test procedures, some standard and some specialized, so as to be always ready to adapt to an atypical situation if your usual method fails to provide a coherent result.

If I water the test probes to improve contact, won't this influence my result?

No. Remember, it is the resistance of the ground electrode that is being measured, not that of the test probe. The probe is merely a tool. Once a minimum amount of contact is made with the soil (below a resistance threshold, which is indicated by an LED on the tester), the setup is ready to go on with the test. In order to achieve sufficient contact, it is perfectly legitimate to water the area around the probes. This is like sanding an alligator clip with emery paper before connecting to a circuit; just a specialized means of improving contact. Watering the area around the ground electrode lower its resistance too, and this, of course, does influence the test result. If the test setup has adequate spacing, however, the probes will be far enough away outside of the electrical field of the test ground so that watering them has no influence on the test result.
