CHAPTER 16 TROUBLESHOOTING PROCEDURES

16.1 General

16.1.1 This chapter contains general troubleshooting procedures for isolating a fault in all types of airport series lighting circuits.

16.2 Safety

(a) Troubleshooting tests contained in this chapter may involve voltages that are dangerous. Safety precautions must be exercised for the protection of personnel and property.
(b) Personnel performing the testing and troubleshooting procedures must be experienced in high-voltage techniques and must be adequately supervised. All maintenance personnel should be thoroughly trained in emergency procedures for treatment of electrical shock.

Note: Trouble shooting procedures that are intended to be carried out should be checked for accordance with local rules of safety.

16.3 Initial Fault Investigation

16.3.1 Series circuits are subject to two primary types of malfunctions, shorts to ground or opens. Keep in mind that an airfield lighting series circuit powered by a constant current regulator is an ungrounded circuit. Therefore, the circuit and CCR will function normally with one ground on the circuit. It is only when two or more grounds appear and a “short circuit” path is created that the current begins to flow through the earth, around the lighting load, and a section of lights appears out. In the case of an open in the primary field circuit, no current can flow and the entire circuit goes out.

16.3.2 In addition to faults in the circuit, there may be a shorting failures across the windings of the AGL transformer. Remember that even though these transformers are often referred to as isolation transformers, they were not designed for personnel protection. They are merely designed to isolate the secondary from the primary circuit to allow the circuit to continue to operate with a lamp burned out. A shorted transformer may not cause a circuit malfunction and could therefore remain unnoticed in normal operation with a live primary. In the case of systems not having grounding of the secondary winding, this exposes you to the full voltage present on the primary circuit and can be especially dangerous if a ground fault is present on the primary circuit. Refer Figure 16-1 below.

This condition is especially dangerous when working with inset lights and removing them from the light base can while the circuit is energized. As soon as the fixture is unbolted and lifted from the can, you become the path to ground. Some have tried to alleviate this hazard by attaching a ground wire from the bottom of the light fixture to a grounding lug on the inside of the can. However, you cannot know if the wire is truly connected until you remove the fixture, at which time it is too late.

Grounding one end of the secondary winding substantially reduces the hazard, but again is dependent upon whether the grounding is truly connected. It is best to remain on the side of caution and de-energize the circuit before re-lamping or removing the fixture. Similarly, one should not pick up knocked-over elevated fixtures when the circuit is energized.
16.3.3 Constant current regulators larger than 10kW are required to have open circuit protection that will shut the CCR down within two seconds after current flow has been interrupted. Most manufacturers, however, provide this protection on all their CCRs. When in doubt, check your CCR’s operating manual. Open circuits can exist in conjunction with grounds and if the CCR can develop enough voltage to overcome whatever resistance exists in the circuit, it will establish current flow and continue operating.

16.3.4 In most instances, we learn of a malfunctioning lighting circuit from a report made by the control tower or through an operations report. Sometimes it is noticed by an electrician making a routine daily runway inspection or light check. Either way, the complaint may consist of a section of lights out or an entire circuit not functioning. The first step in an initial fault investigation is to make a quick visual inspection of the affected lighting on the airfield. 16.3.5 This will provide information as to whether an entire circuit is out or just a portion of the lighting on a specific circuit is affected. This gives an electrician a good idea as to the possible cause of the malfunction. If an entire circuit is out, the problem could be an open circuit in the field wiring or a malfunctioning CCR. If only a portion of the lights on a circuit is out, the problem is most likely due to a short to ground at each end of the affected section. Keep in mind that if the malfunction is due to a short to ground in the field circuit, the longer the circuit remains energized, the more damage will result at the location of the ground faults due to arcing.

16.3.5 In the vault, once the exact malfunctioning circuit has been determined, the regulator supplying the circuit can be located. Turn the regulator local control to the “OFF” position and shut down and lock out the power supply to the regulator. If a standard Style S1 cutout is present, disconnect the S1 and separate the blades of the cutout switch on the field side of the switch. This will allow you to check both the continuity and insulation resistance in the field circuit. After separating the ends of the field circuit by either separating the blades of the S1 or disconnecting at least one end of the field circuit from the regulator, prepare to take a measurement for continuity in the circuit.

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16.3.7 The regulator may be provided with a Load Disconnect and Test (LDT) Isolator. Replacing the "Circuit in Service" plate with the "Circuit in Test" plate will cause the output terminals of the regulator to be short circuited and disconnected from the field circuit.

16.3.8 If using a volt-ohm-meter (VOM), the first step is to set the meter to the R x 1 scale and “zero” the meter (if using a Digital MultiMeter [DMM], these steps are not necessary). This is accomplished by setting the meter to the desired scale (R x 1 in this case) and touching the two meter leads together. Make sure the leads are plugged into the correct sockets in the meter (on most VOMs, this is the + and common sockets) and adjust the “zero ohms” knob until the meter needle is at the zero point (usually on the right side of the meter scale). After this adjustment has been made, take a reading of the resistance in the field circuit by checking between the two separated conductors of the field circuit. If no continuity can be read in the circuit, check for a short to ground in each side of the circuit and then proceed to Section 16.5, “Locating Open Circuit Faults.” If the circuit shows continuity (a measurable amount of resistance) normally between 20 to 70 ohms, the circuit is not open. If a much higher resistance is measured (1000 ohms +), then a high resistance open circuit fault has occurred. Many times this is indicative of a transformer with a faulty primary winding that has not completely burned open yet. It could also be due to a cut cable which has both ends in contact with the earth.

16.3.9 If the resistance in the circuit checks normal, proceed to check the resistance to ground from each end of the circuit to ground. If any resistance can be read to ground with the meter set at R x 1, then one or more low resistance shorts to ground exist and troubleshooting procedures are moved to the field. If the meter reads no continuity (no meter movement) when the circuit is checked to ground, set the meter for the R x 100 and R x 10,000 scales respectively and, after zeroing the meter, check for a short to ground on these two scales. Remember that the positive (red) lead should always be connected to the circuit or conductor under test and the negative (black) lead should be connected to ground. Also be aware that on the R x 10,000 scale, merely touching the meter leads with your fingers will produce a reading. Most ground faults serious enough to cause the lights to go out will be reading less than 1000 ohms to ground, usually less than 100 ohms to ground and will be easily indicated on the R x 1 scale. If no ground fault is detected on the circuit with the VOM or DMM, use an insulation resistance tester to test the circuit. Insulation resistance testers operate at much higher voltages, 500 to 5000 volts, and are more useful in locating a high resistance ground fault.

16.3.10 If no problems are detected in the field circuit, the next step is to try to energize the CCR using the manual control on the front of the CCR. After reconnecting the field circuit to the CCR, or reinstalling the S1 and turning the primary power back on to the regulator, begin by putting the switch in the step 1 position and note if the CCR comes on. If it does not, the problem may be as simple as a tripped breaker or blown fuse and you should proceed to check for proper input voltage to the CCR. If the CCR energizes for about 2 seconds and then shuts off, the fault is likely a malfunction of the open circuit or over current protection circuitry in the CCR. If the field circuit appears normal, disconnect and lock out the primary power source to
the CCR and perform a short circuit test by shorting the output of the regulator with a #10 or larger wire, and test the operation of the regulator again. If the regulator still shuts off after a few seconds, there is an internal problem with the regulator or its controls. Consult the operation and maintenance manual for the CCR for specific troubleshooting instructions.

16.3.11 If the CCR remains on and appears to be operating normally on the lowest brightness setting, continue switching the CCR up through the brightness steps while noting the increase in current output on the meter until the maximum brightness is reached, either step 3 or step 5 depending on the style of the regulator. If the regulator has a normal output on the lower steps, but the output is low on the highest step, the regulator may be overloaded or there may be too much inductance in the field circuit. Perform a short circuit test of the regulator by turning the regulator off and disconnecting and locking out the primary power to the regulator. Then connect a 6mm$^2$ (#10 AWG) wire across the output and re-energize the regulator. If the regulator operates normally with the output shorted, this would indicate an overload is present in the field circuit. If there have been no additional loads added to the field circuit, check for burnt out lamps or otherwise open secondary connections on the field transformers. Newer regulators are required to withstand up to 30% open-circuited AGL transformers. Older regulators may only tolerate 10%. When a large number of open-circuited transformers exist on the output of a regulator, it increases the inductive loading on the regulator and will cause the regulator to act strangely and many times appear overloaded. One cause of this condition may be a lightning strike that has blown out a large number of lamps in the circuit.

16.4 Locating ground faults in the field

16.4.1 Once it has been established that the circuit is shorted to ground, the troubleshooting procedures can be moved to the field. Keep in mind that if there is a section of lights out on the circuit, there will ALWAYS be at least two shorts or ground faults in the circuit. At this time the circuit may be energized and a visual inspection can be made to try to locate the faults. If the circuit is a simple loop configuration, a visual inspection can sometimes be an effective means to find the problem. It is best to have someone at the vault with a radio so that as soon as the good to bad transition areas in the circuit are located, word can be sent to the vault to shut off the regulator and lock it out so that repairs can be made. Drive the circuit looking for any section of lights that are out or appear to be extremely dim and mark this area by putting a surveyor’s flag or a paint mark at the locations of the last light burning and the first light out as shown in Figure 16-2. After the circuit has been de-energized and locked-out, check the lights at each end of these “transition areas” for burned transformers, connectors, etc. Always remember that there will be at least two shorts in the circuit and both must be repaired. In some instances, especially in the case of direct buried cables or when the circuit has been energized for a long period of time while ground faults are present, more than two shorts to ground may have occurred.
16.4.2 The best method for finding ground faults after the initial visual inspection has been made is to locate them using the VOM. Leave the ends of the circuit separated at the vault and suspend the ends of the cables in free air if disconnected from the S1 cutout or other connection. Refer to as-built plans if available to locate the center of the circuit and break the circuit at that point by disconnecting the cable at one side of the transformer. (See Figure 16-3). Take a reading to ground in both directions from this point and determine which way the fault is located. It is entirely possible that the meter may indicate a fault in both directions from this point or only in one direction as there may be two or more faults in the same section of cable. Leaving this connection open (if possible), proceed to a point in the circuit approximately halfway between the midpoint and the vault in the direction of the fault and break the circuit again. As before, take a reading on the circuit in each direction to determine the location of the fault. Continue until each fault is located and corrected.
16.4.3 During the course of troubleshooting, you may find that when you remove a transformer from the can or the ground that the fault seems to disappear. When this happens the fault is located at that transformer; normally you can visually see the burned transformer. However, in the case of an internal primary to secondary short in the transformer, there may not be anything readily apparent. Look at the fixture attached to the transformer and check to see if the socket or secondary plug is burned. This is usually a good sign of a primary to secondary short. A short of this nature can be confirmed by touching one lead of the VOM to one of the primary leads of the transformer and touching the other to one of the sockets on the secondary connector. If the transformer is shorted, continuity will be indicated on the meter. Sometimes checking between one of the primary connectors and the outside body of the transformer will indicate a transformer with a significant leak to ground. This can be performed with an insulation resistance tester for better results. If checking the insulation integrity of transformers, you can also submerge the transformer in a bucket of water and connect the positive lead of the Megger to one of the primary leads and the negative lead to a bare wire dropped into the bucket. If any leakage is shown, the transformer is suspect or bad depending on the reading. Reasonably new transformers should read over 1000 megohms, with readings decreasing with age.
16.5 Locating Open Circuit Faults

16.5.1 Open circuits can be successfully located using similar tactics as those used for locating short circuits or ground faults. If the circuit appears to be grounded in conjunction with an open, the troubleshooting procedure used for finding ground faults may be used since the open and ground will likely be located at the same place. Many times a cable will burn in two if left operating after a short to ground has developed. If the initial fault investigation has revealed an open in the field circuit and the circuit does not appear to be grounded, de-energize the regulator and lock out the regulator power supply and proceed to the field and locate the approximate center of the circuit.

*TIP: Any time an open circuit is indicated, the first question to ask is: “Has anyone been doing any excavating in the vicinity of the airfield?” If so, go out and look for a pile of fresh dirt and you will likely find your problem.*

16.5.2 For this type of troubleshooting where you are looking for continuity, it is helpful to
have the ends of the circuit connected together at the vault via the S1 cutout or some other means --- see Figure 16-5. That way, when the problem is corrected, it can be verified by being able to read a loop from any point in the circuit. Proceed to the approximate midpoint of the circuit and disconnect the circuit at the transformer and ground the circuit in both directions. Check for continuity to ground at another point in the circuit by disconnecting the transformer. If the circuit is connected together at the vault and you have only one open in the circuit, you should read continuity in one direction but not the other back to the grounded midpoint of the circuit. When the grounded conductor is identified, have someone at the midpoint connection make and break the connection to ground in one direction and then the other until you have established which section of the circuit is open. Then proceed to a point halfway between your present location and the grounded midpoint in the section of the cable that is open and take another reading. If this time you can read to ground in the direction of the midpoint of the circuit, then you know that the open is behind you or between you and the last point you tested. By moving the intentional ground point and looking for continuity in each section of the circuit, the open(s) can be quickly located. See Figure 16-5 for details.

![Figure 16-5. Locating Open Circuit Faults](image)

**16.6 Interconnected circuit faults**

16.6.1 It is common for airfields with multiple circuits to experience interconnecting faults. There are two main types of interconnecting faults. The first occurs when two or more circuits contain grounds and/or opens in a manner that electrically connects the circuits together. The second type occurs when two or more circuits do not contain any faults, but they become capacitively coupled together.

16.6.2 When multiple circuits contain faults that connect them together, a section of primary cable is common to all circuits involved. (See Figures 16-6 & 16-7.) Multiple ground faults are the most common cause of this problem. A continuity check between the suspected circuits will confirm if they are electrically connected. To troubleshoot this condition, disconnect and isolate the output leads of regulator “B,” then locate the circuit fault on regulator “A” circuit. This will usually locate the common fault area of both circuits.
16.6.3 This figure illustrates what may happen when there are two load to load shorts on the circuits. Notice that the lights in this condition are affected, causing the area between the two shorts to dim on both circuits. If the illuminated lights on the B load were to go unnoticed, the presence of this condition could easily be confused with symptoms of two grounds on a single circuit. The give-away is the portion of the B load lights that are on. Driving the circuit would locate the bright/dim transitions and the location of the shorts. Had the load between the shorts of load A been much larger (more lights) than the load in between the shorts of load B, the smaller load would have been brighter. In the illustration, the loads between the shorts are equal.
and the current is divided equally between the two loads.

16.6.4 A capacitive coupling fault occurs when two or more series circuits run parallel and in close proximity to each other. This situation becomes a problem if the circuits have monitors on them because the induced currents can simulate field faults. A continuity check between the suspect circuits confirms they are not electrically connected together. To correct a capacitive coupling fault, simply swap the output leads of one of the regulators involved. This will cancel the capacitive coupling effect.

!!WARNING!!

The troubleshooting methods and procedures outlined in the following paragraphs involve dangerous voltages and should only be attempted by qualified personnel using appropriate safety procedures. Also, while sometimes helpful or necessary, be aware that these methods are by their nature “destructive testing” and if performed indiscriminately can result in more damage occurring in the field circuit.

The following troubleshooting methods are best described as “destructive testing.” These methods can be used when either time constraints or difficulty testing using an ohm meter or insulation resistance tester makes traditional troubleshooting impractical. One such instance might be in the case of direct buried circuits where traditional troubleshooting is difficult and time consuming due to having to dig up each connection to perform testing. Another case when this type of troubleshooting might be considered is when a runway circuit is out of service, and time is of the essence due to disrupting air traffic operations at your facility. These methods do require that the circuit have a significantly low resistance to ground at the point of the fault, preferably less than 1000 ohms to ground, the less the better. It should also be noted that small regulators (10kW or less) may not develop sufficient voltage to be effective.

16.7 Intentional ground test

16.7.1 The Intentional Ground Test is another method used to find a single ground fault. (See Figures 16-8a & 16-8b.) If an insulation resistance test indicates a ground in the circuit, but a visual inspection is inconclusive, this test method will help locate the problem.

16.7.2 First, shut off and lock out the regulator. Next, label the two regulator output leads “1” and “2.” Connect a 45-watt AGL transformer and light fixture between regulator output “1” and ground as shown in Figure 16-8. The ground resistance of the test connection must be very small. Next, energize the regulator. Keep away from the test setup. If the test lamp illuminates, there is at least one ground fault on the circuit. The brighter the test lamp glows, the lower the resistance of the ground fault(s). With the regulator energized, conduct a visual inspection of the circuit.
16.7.3 If there is a section of dim or out light fixtures, a ground fault exists between the last light operating properly and the first dim or out light. Mark this area.

16.7.4 If all the lights are dim or out, the ground fault is between output “2” and the first light fixture on that side of the circuit.

16.7.5 If all the lights appear to be OK, the ground fault is between output “1” and the first light fixture on that side of the circuit.

16.7.6 De-energize and lock out the regulator. Switch the test transformer/light assembly from output “1” to output “2” (See Figure 16-8). Energize the regulator. The test lamp should illuminate. Conduct a visual inspection of the circuit.

16.7.7 If there is a section of dim or out light fixtures, and the location of the “good to bad” lights is in the same spot as marked in Paragraph 16.7.3, the circuit has a single ground fault at that location. (The transition area is the same, but the lights that were on in Paragraph 16.7.3 should now be off, and the lights that were off in Paragraph 16.7.3 should now be on.) De-energize and lock out the regulator. Check the connector kits, cable splices, etc., between the two adjacent light fixtures of the marked area and repair or replace suspected faults as necessary. At this point a VOM or insulation resistance tester may be used to verify faulty transformers, etc. Once the single ground fault is cleared, the test lamp will not illuminate when the regulator is energized. Remember, stay away from the primary cable while the regulator is on.

16.7.8 If there is a section of dim or out light fixtures and the location of the “good to bad” lights is not in the same spot as marked in Paragraph 16.7.3, there are at least two ground faults on the circuit. Mark this new transition area. De-energize and lock out the regulator. Check the connector kits, cable, transformer, etc., between the two adjacent light fixtures of the newly marked area and repair or replace suspected faults as necessary. As each fault is cleared, energize the regulator and perform a visual inspection of the circuit. Keep away from the energized primary cable and always lock out the regulator when handling the cable. The “good
to bad” transition area should move toward the spot marked in Paragraph 16.7.3. Continue troubleshooting the faults in this manner until the last ground is repaired and the test lamp does not illuminate when the regulator is energized.

16.7.9 If all the lights appear to be operating correctly, the ground is between output “2” and the first light on that side of the circuit. (The same as found in Paragraph 16.7.4.) De-energize and lock out the regulator. Work from the light fixture towards output “2.” Check the cable, connector kits, splices, etc., and repair or replace suspected faults as necessary. The ground fault has been fixed when the test lamp does not illuminate when the regulator is energized.

16.7.10 If all the lights are dim or out, the ground fault is between output “1” and the first light fixture on that side of the circuit (the same as found in Paragraph 16.7.5). De-energize and lock out the regulator. Work from the light fixture towards output “1.” Check the cable, connector kits, splices, etc., and repair or replace suspected faults as necessary. The ground fault has been fixed when the light fixtures operate properly and the test lamp does not illuminate when the regulator is energized. Remove the fault marker(s) from the field.

16.7.11 If a Megger is not available, the intentional ground test can be modified to become a valuable preventive maintenance tool. (See Figure 16-9.) Connect the transformer/light assembly to the regulator output through an S-1 cutout, as shown in Figure 16-9. When the S-1 handle is removed, the intentional ground is connected to the circuit. Once a month, shut off the regulator and pull the S-1 handle out. Energize the regulator to the high step and observe the test lamp. If the circuit has developed a ground fault, the lamp will illuminate. The lower the resistance of the fault, the brighter the lamp will glow. The main advantage of performing this check regularly is that a single ground fault can be detected and located easily, before multiple faults affect the visual appearance of the circuit. The general rule of thumb is, if the test lamp glows, the ground needs to be located and repaired. Add this procedure to your preventive maintenance routine and you will always stay one step ahead of grounding troubles.
16.8 Grounded Output Test for Locating Open Circuits

16.8.1 The grounded output test is similar to the intentional ground test used to locate ground faults (Paragraph 16.7). In order for this test to work, the open fault needs to be grounded. (See Figure 16-10.) If the open is not grounded or the ground resistance of the fault is too great, this method may only work with large kW rated regulators. Make sure the regulator is off. Refer to Figure 16-10. Mark the regulator leads “1” and “2.” Remove lead “1” from the regulator. Cap or tape the bare end of lead “1.” Make sure it does not touch anything, and stay away from it when the regulator is energized. Next, connect the regulator output terminal, from which “1” was removed, to earth ground. Once again, the ground resistance of this connection must be as low as possible. Energize the regulator to the highest step. Stay away from the test connection to ground.
16.8.2 If the regulator trips off on open circuit protection, do not attempt to energize the regulator a second time. Either the regulator is too small or the ground resistance of the fault is too large. In most cases, 4 and 7.5 kW regulators do not have enough power to drive a grounded output test that has any ground resistance at the fault location. Ideally, the best regulator to use would be a 30kW for 6.6 amp circuits, and a 70 kW for 20 amp circuits. If possible, connect the circuit to the largest regulator in the vault and try again. If the circuit cannot be turned on, troubleshoot the open fault with the ohm meter/megohm test. (See Paragraph 16.5.)

16.8.3 If the regulator stays on and is registering output current, the open circuit fault can be found using the grounded output test. It is common for the regulator output current to fluctuate with this test set up. This condition will not damage the regulator, but continue to operate the regulator only long enough to locate the fault. Once the fault is cleared, the regulator should return to normal operation. With the regulator energized, conduct a visual inspection of the field circuit. There should be a section of lighted fixtures and a section of out fixtures. Mark the “good to bad” transition area. The open fault will be between the last light fixture operating and the first non-illuminated fixture. If all the lights are on, the open is between output “1” and the first fixture on that side of the circuit. If all the lights are out, the open is between output “2” and the first fixture on that side of the circuit. De-energize and lock out the regulator.

16.8.4 Remove the ground connection from the regulator output terminal. Reconnect lead “1” to the regulator output terminal. Next, remove lead “2” from the regulator. Cap or tape the bare end of lead “2,” making sure it does not touch anything and stay away from it when the regulator is energized. Next, connect the regulator output terminal from which “2” was removed, to earth ground. Energize the regulator to the highest step. Stay away from the test connection to
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16.8.3 Conduct a visual inspection of the field circuit. This time the fixtures that were on in the last test should be out and the fixtures that were out in the last test should be on. The visual appearance of the circuit now should be the exact opposite of Paragraph 16.8.3 with the “good to bad” transition area in the same location. If this is true, the open is between the two light fixtures adjacent to the fault marker. De-energize and lock out the regulator. Start at one light fixture and work toward the other checking AGL transformer windings, connections, splices, and the primary cable for opens. Repair or replace any defects as necessary. To verify the open fault has been corrected, measure the resistance across output “1” and “2” with an ohmmeter. If the resistance is less than 700 ohms, the circuit is free of all opens. Anything over 700 ohms indicates the presence of an open or high resistance fault somewhere on the circuit. Remember, every circuit will have a different resistance value depending on the number and wattage of the light fixtures, but 700 ohms is the maximum for any airfield circuit. Remove the ground connection from the regulator and reconnect output “2” to the regulator. Energize the regulator to the high step for approximately thirty minutes. This will double check that the repair work was done correctly. Perform a visual inspection of the circuit and remove the fault marker(s) from the field.

16.9 Using heat sensing equipment to locate ground faults

16.9.1 Any time there are two shorts to ground in a series circuit, the current flowing to ground through the breach in the cable or transformer insulation produces heat. This is caused by the arcing that occurs when a good solid connection is not present in an electrical circuit. In the case of series circuits operated by constant current regulators, the regulator can produce very high voltages and damage and heat from arcing can be great. Some airports have learned to use this unfortunate circumstance to their advantage. By utilizing economical infrared thermometers, the electrician is able to measure the difference between the temperatures of a “normal” light can or fixture and one that is running an abnormally high temperature. Infrared thermometers are available that use laser sighting and are effective at distances long enough to allow their use from a moving vehicle. Using this equipment, an electrician can drive down the runway or taxiway checking the temperature of each light/can until one is found that exhibits a higher temperature than the rest and then investigate that light. This method has proven to be a great time saver at several airports. See Chapter 15, Test Equipment, for more information on this equipment.

16.10 Using Cable Fault Locating Equipment to Locate Ground Faults

16.10.1 Cable locating and fault finding technology has improved vastly over the years with many manufacturers offering equipment capable of locating underground cable and ground or shield faults. These units consist of a transmitter and receiver and if equipped for fault finding, usually have an optional A-frame pickup unit for use with the receiver. They are able to detect the location of ground faults in direct buried cables and can be highly accurate. See Chapter 15, Test Equipment, for more information on this equipment.