TC 6-02.6 (TC 11-6)

Grounding Techniques for Tactical Equipment and Systems

NOVEMBER 2017

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Headquarters, Department of the Army

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Grounding Techniques for Tactical Equipment and Systems

Contents

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Figures

Tables

Preface

Training Circular (TC) 6-02.6 provides various grounding techniques for tactical communications equipment and systems including the Surface Wire Grounding Kit. This TC is intended to supplement detailed grounding and safety information found in doctrine publications and equipment technical manuals. Grounding is a basic communications procedure, each Soldier should know how and why to perform grounding procedures regardless of the equipment they are operating.

The principle audience for TC 6-02.6 is all Army professionals and contractors who plan, operate, maintain, and use grounding devices for tactical equipment and systems. This publication provides grounding techniques information and guidance to commanders, staffs, operators, and maintainers that execute oversite grounding procedures for the Army. TC 6-02.6 provides a significant resource to Army trainers and educators.

Commanders, staffs, and subordinates ensure their decisions and actions comply with applicable Unites States, international, and in certain cases, host nation laws and regulations. Commanders at every level ensure their Soldiers operate according to the laws of war and the rules of engagement. (See FM 27-10.)

Additionally, Commanders and subordinate leaders ensure that all members of the Army Profession are expected to live by, adhere to, and uphold the moral principles of the Army Ethic. The training objective is for trusted Army professionals to accomplish their missions in the right way; ethically, effectively, and efficiently. Commanders and subordinate leaders, as moral exemplars and stewards of the Army profession, understand that their leadership facilitates the command climate, shared understanding, and mutual trust necessary to develop cohesive teams of trusted Army professionals (ADRP 1).

TC 6-02.6 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and in the text; the term is italicized and the number of the proponent publication follows the definition. This publication is not the proponent for any Army terms. For other definitions shown in the text, the term is italicized and the number of the proponent publication follows the definition.

TC 6-02.6 applies to the Active Army, Army National Guard, Army National Guard of the United States, and United States Army Reserves unless otherwise stated.

The proponent of TC 6-02.6 is the United States Army Cyber Center of Excellence. The preparing agency is the Cyber Center of Excellence Doctrine Branch and United States Army Cyber Center of Excellence. Send comments and recommendations on a Department of Army Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, United States Cyber Center of Excellence, ATTN: ATZH-DT (TC 6-02.6), 506 Chamberlin Avenue, fort Gordon, GA 30905-5735; by e-mail to usarmy.gordon.cyber-coe.mbx.gord-fg-doctrine@mail.mil.

Introduction

This training circular is a guide to proper earth grounding methods and procedures for use with tactical systems. It describes different earth grounding systems and provides guidance on the proper methods for their installation. Earth grounding helps to protect personnel and equipment from electrical faults and power surges. Earth grounding also helps reduce circuit noise and other transmission interference that can degrade communications-electronics system performance (CECOM TR 98-6). The instructions contained in this circular are designed to supplement information not often found in technical manuals. It will help in setting up effective and safe earth grounding systems for tactical equipment, systems, and shelters. The procedures outlined in this training circular can assist in solving grounding problems which may be encountered. For detailed grounding procedures, consult the specific manual on the tactical equipment or systems being operated or installed. Failure to ground equipment or improper grounding can lead to serious injury or death. The equipment is also subject to catastrophic failure from electricity surges. Improper grounding can lead to burned-out circuit cards or complete destruction of a piece of equipment or the entire system may become non-mission capable.

TC 6-02.6 contains five chapters:

Chapter 1 covers the three basic types of grounding systems. Earth ground, equipment ground, and chassis ground.

Chapter 2 describes the many techniques used for grounding. Such as rods, plates, and wires contacting the earth. This chapter explains each system, recommends materials and kits to use, and how to install the system you select.

Chapter 3 explains the different types of soil conditions that a Soldier may find in a tactical operation for the employment of equipment and systems that need to be grounded. The kinds of soil, its moisture content and temperature all affect how well the equipment of system will operate.

Chapter 4 discusses the different types of terrain and how it can affect grounding procedures selected.

Chapter 5 provides helpful hints and additional information that will help the user if grounding procedures become a problem.

Appendix A provides a general grounding checklist that can be utilized by commanders, staffs, leaders, and Soldiers for their equipment and systems that require an earth ground.

Chapter 1

Types of Grounds

This chapter covers the three basic grounding systems: earth ground, equipment ground, and chassis ground.

BASIC GROUNDING SYSTEMS

1-1. All Soldiers need to keep basic grounding techniques and procedures in mind prior to employment of their communication and electronic equipment. Failure to perform basic grounding techniques could lead to equipment failure, network outages, and ultimately personnel injury or death.

EARTH GROUND

1-2. In order to protect communications and electronic equipment from built up or induced electrical charges or lightning strikes, provide a metal path to earth ground. Charges that can build up or be induced onto equipment or are exposed to external high voltages are sent harmlessly into the earth if all the fundamental pieces of an effective grounding system are used.

1-3. An earth grounding system helps to keep the electrical potential on noncurrent-carrying metal surfaces at a similar level as that of the surrounding earth. Earth grounding is only part of the overall ground system. The other is to ensure that all equipment and power supplies in the equipment, shelter or system are bonded with a common equipment grounding conductor.

1-4. Earth ground consists of three key components that work together (see figure 1-1 on page 1-2). These components are the equipment grounding conductor (green wire), the connection point (ground lug or terminal), and the earth grounding electrode (ground rod). (CECOM TR 98-6).

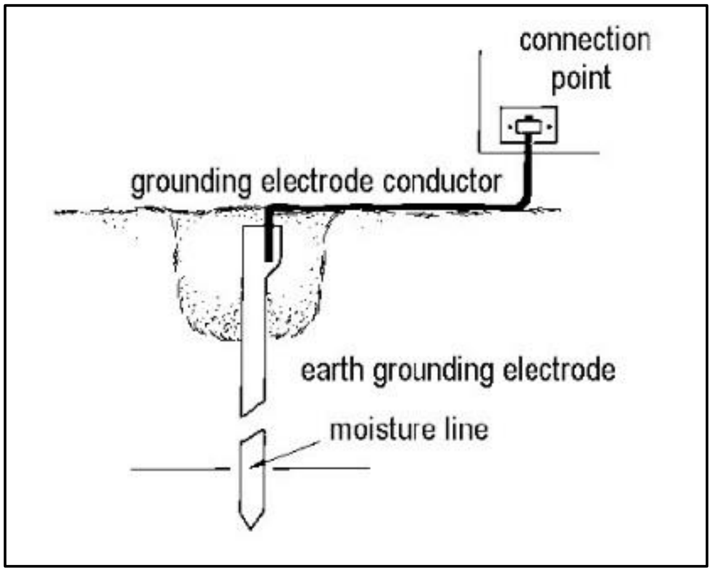

Figure 1-1. Earth ground

Note. That the top of the installed rod is below, the earth's surface plane. This reduces dangerous voltages near the rod during a storm and helps to avoid tripping hazards.

EQUIPMENT GROUND

1-5. A good equipment ground is needed to connect all the components of the system or equipment shelter to a common earth ground. This kind of ground connects the metal mounting frames, cases, dust covers and cable shields of the equipment to a common ground bus.

1-6. Equipment ground protects the user from being shocked when touching the equipment, and it protects the equipment from being damaged.

1-7. Equipment ground creates a low-impedance path to permit overcurrent protection devices to open as well as limits voltages between exposed conductive surfaces or ground. In most cases the wire used that connects the equipment to the ground bus is green (see figure 1-2 on page 1-3).

Figure 1-2. Equipment ground

CHASSIS GROUND

1-8. A chassis ground is used in all electrical (electronic) equipment, vehicles, and generators. For example inside the equipment enclosure of a satellite transportable terminal, there are some visible parts connected to the metal chassis (ground) (see figure 1-3 on page 1-4).

1-9. The purpose of chassis ground is to connect (bond) individual items to the equipment grounding conductor in alternating current systems or negative in DC current systems. This bonding holds all conductive parts at the same voltage to prevent shock hazards. Also it provides short-circuit path to clear circuit breakers in the event of a ground fault.

Figure 1-3. Chassis ground

1-10. A good example of a chassis ground is in the electrical system of your satellite transportable trailer and its generator. One terminal of the battery, usually the negative, is connected directly to the chassis. Likewise all equipment in the rear equipment enclosure is individually connected to a common ground bus which is tied to the chassis of the trailer. This is then tied to the roadside ground lug for which the surface wire grounding kit is attached thus completing the grounding of all components of the satellite transportable terminal.

Chapter 2
Grounding Systems

This chapter discusses the purpose of grounding systems and the various key components used with earth grounding.

PURPOSE OF GROUNDING SYSTEMS

2-1. An earth grounding system helps keep the electrical potential on noncurrent carrying metal surfaces at a similar level as that of the surrounding earth. Earth grounding also provides a preferred discharge path for externally generated electrical surges due to power switching, faults, or lightning. This earth ground reference is established by firmly connecting a number 6 American wire gauge wire between the equipment (generator, communications electronics system, shelter) and running it to a buried metal electrode (ground rod, water pipe, plates) which is in contact with moist subsoil or reaches into the underground water table. See the American wire gauge table 2-1 on page 2-13 for more information.

2-2. It is important to note that earth grounding is only a part of the total ground system. Equally important to the earth grounding system is the need to inter bond all equipment and power supply enclosures through the equipment grounding conductor (green wire), as well as the need to bond the power supply neutral circuit conductor to earth (known as system grounding). However, since the primary area of Soldier involvement is in the area of earth grounding shelters, generators, and equipment using rods and straps, this will be the area of focus. For more information on the additional requirements associated with equipment grounding conductors and system grounding, see CECOM TR-98-6.

DANGER

Ensure equipment being grounded does not have power applied. If the equipment has power and a fault current occurs while working with the grounding system, a hazardous condition may exist.

EARTH GROUNDING SYSTEM KEY COMPONENTS

2-3. The earth grounding system consists of three key elements which when are properly incorporated together make an effective grounding system. These elements are the earth grounding conductor, the connection point, and the earth grounding electrode.

A lack of attention to any of the three elements can create a weak link which could lead to a failure.

EARTH GROUNDING CONDUCTORS

2-4. The purpose of the earth grounding conductor is to provide a low impedance path between the equipment noncurrent-carrying metal parts (enclosure) and the earth. The term "low impedance" is used, which covers both resistance (which is independent of signal frequency) and reactance (resistance that changes with frequency). The importance of this can be best illustrated as follows: given a properly sized earth grounding wire is provided which has a number of loops and sharp bends. This grounding path may show a low resistance reading using an ohmmeter, and may indeed be suitable for DC or 60 Hertz (low frequency) related events. However, the loops and sharp bends will substantially increase the path's impedance during higher frequency events such as lightning related transients (over 100,000 Hertz) and signal noise. This example points out the reason why in some cases equipment grounding-related problems occur although a grounding wire is provided. Along with loops and sharp bends, other factors that affect path impedance include wire size, length, shape and surface area.

CONNECTION POINT

2-5. Connections in a grounding system are very important and often overlooked. Though grounding connections can look fine, they may fail if loose or corroded. Usually the equipment (generator, shelter) has a built-in terminal for connecting the ground strap. To connect the ground strap to the surface end of the ground rod, there may be a terminal (thumb) screw (see figure 2-1) or a ground clamp. If neither is present, install the ground rod using the wrap method.

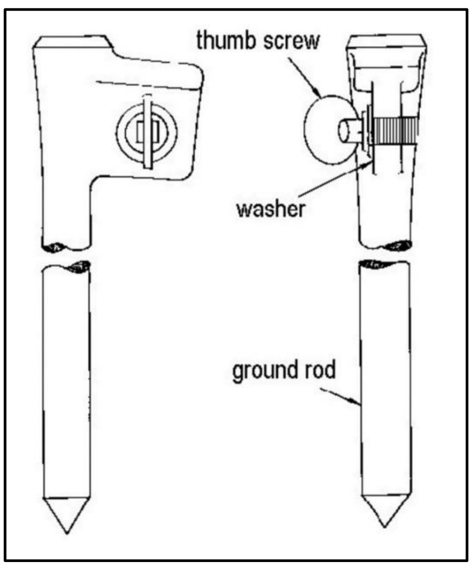

Figure 2-1. Ground rod with terminal screw

Clamp or Screw Method

2-6. Clamp or screw connections tightly to prevent loosening over time. Use a lock washer where nuts or bolts are used. Do not over tighten the connection to the point where the conductor strands are damaged. When using a clamp, always have the clamp body compress the grounding electrode conductor against the rod (see figure 2-2). Using clamp screw to compress the electrode conductor against the ground rod results in a bad connection. CECOM TR 98-6.

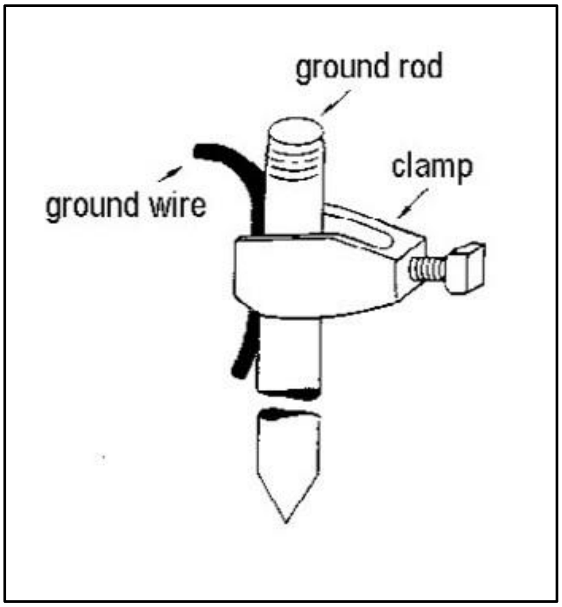

Figure 2-2. Ground rod clamp

2-7. Ground clamps come in many different shapes and sizes, but they all have one purpose, to hold the ground strap tightly against the ground rod. When attaching, ensure that the bonding surfaces are free of paint, corrosion, grease, or dirt. Performing weekly inspections of the ground clamp will ensure the connection points are not building up with corrosion and also serve to identify any potential tripping hazards.

2-8. Connecting dissimilar metals, especially copper and aluminum or copper and galvanized parts can cause corrosion at the bonding point. If you cannot avoid mixing different metal connections, then more frequent inspection or cleaning of the connection points may be necessary.

Wrap Method

2-9. Use the wrap method for a temporary installation if a terminal screw or ground clamp is not available. Bind the ground strap to the rod by using strong, flexible bare copper wire. First scrape the rod and the strap with a knife so the metal shines. Place the strap in parallel with the rod (figure 2-3 on page 2-4) and be sure the strap is connected to the rod in an upward direction as shown. The strap should never be wrapped around the rod. Wrap about 24 turns of the copper wire around the strap and rod. Only a copper or bronze strap should be connected to the rod.

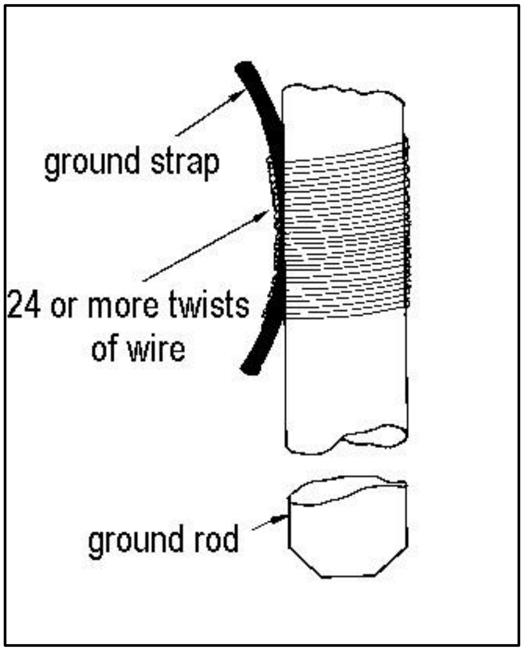

Figure 2-3. Wrap method

2-10. Dissimilar metals react chemically with each other to produce corrosion at the points of contact. This destroys the connection. If the strap is not copper or bronze, you must use a bimetallic connector. For copper or bronze, if you cannot solder the connection, twist the ends of the wire as tight as you can without breaking them.

Note. Remember grounds are clean, tight, and inspected regularly.

EARTH GROUND ELECTRODE

2-11. Various types of earth ground electrodes are used to establish an interface with the earth ground. The most commonly used electrode is the ground rod, which is available in various lengths and configurations.

2-12. Under certain conditions, a good earth ground can be achieved by connecting to existing objects such as a buried metal pipe or the steel frame of a building. Where poor soil conditions exist, other methods and combinations of methods are required, which are discussed later. The following is a description of some of the typical earth grounding electrodes that are used.

Ground Rod

2-13. A ground rod is the most often used grounding system and it is also the most often misused (see figure 2-4). Army communications equipment and systems are issued with ground rods and are made of metal that does not corrode or rust easily. Some rods may be longer and thicker than others, but the ground rod alone will not do the job. You need a complete ground rod system to include a ground strap and a device (terminal screw or clamp) to connect the strap to the surface end of the ground rod. Installation instruction are also provided with the communication equipment and in the technical manual associated with it.

2-14. The Army inventory has two common ground rods: the 9-foot ground rod, or the 6-foot ground rod. The 6-foot rod is being phased out and replaced by the 9-foot rod. You may continue using a 6-foot rod as long as it is serviceable. The 6-foot rod comes in a single section, whereas the 9-foot rod is a three-section rod. Ground rods can be installed using a sledge hammer or in the case of the sectional rod, a slide hammer and strike plate.

***Note*.** It is very important to know that aluminum is not to be used in the material for any type of grounding electrode.

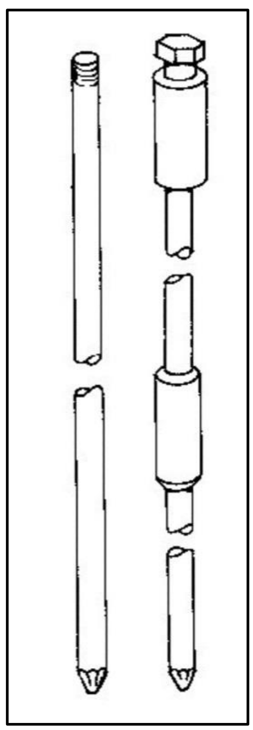

Figure 2-4. Driven head sectional ground rod

Ground Rod System

2-15. How well a ground rod system works also depends on the terrain and the installation process. The following information will help to determine the best method to use.

Ground Rod Installation

2-16. First, clean all the components. Second, get the ground rod into the subsoil to make a good ground. Topsoil, generally speaking, is not a good conductor of electricity. Dig a hole about six to eight inches deep that is about 18 inches wide. This should get you into the subsoil and at the same time give you room to work.

2-17. Next, strike the end of the rod just hard enough to drive it into the ground, driving the rod straight down into the ground. The manner the ground rod is driven into the ground has a direct bearing on how well it should work (see figure 2-5). When the subsoil finds driving the rod straight down is not permissible, drive the rod at an angle of 30 but no more than 45 degrees. This can make it easy to remove if you have to relocate the ground rod or your communications equipment.

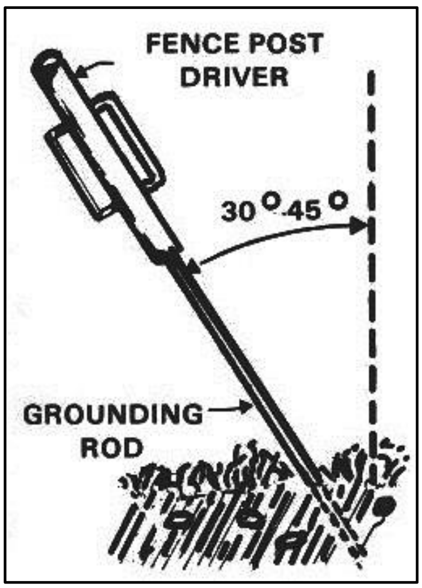

Figure 2-5. Ground rod and driver

2-18. Drive the rod into the ground with enough force to emplace the rod without disturbing the soil. Doing so allows more surface area of the soil to remain in contact with the rod enhancing its grounding properties. The best way to drive the rod is with a fence post driver. A sledge hammer can be used only if a fence post driver is not available. Some ground rod systems come with a slide hammer which performs the same driving techniques as the fence post driver.

2-19. Finally, when the end of the rod is about 3 inches above the bottom of the hole, connect the ground strap to it. Fill the hole with water and let it soak in. Keeping the soil around the rod moist will help increase the possibility of good grounding system (see figure 2-6).

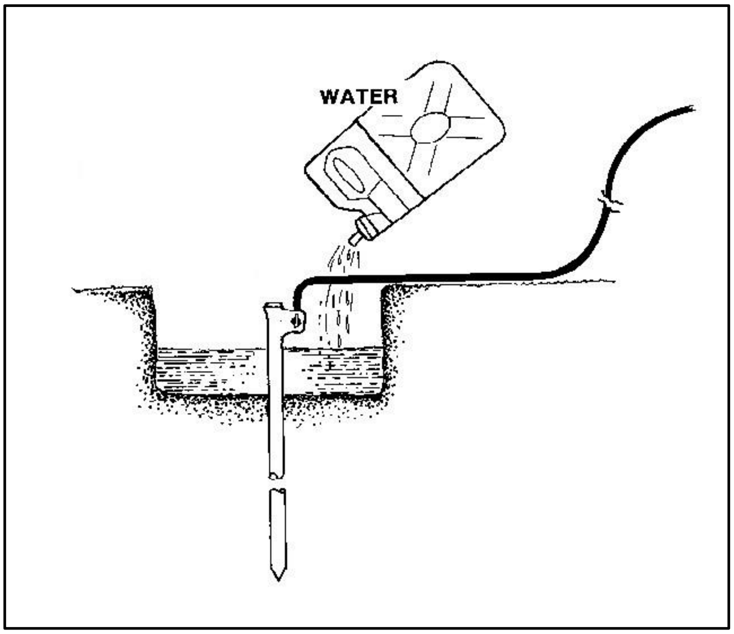

Figure 2-6. Soaking ground rod installation with water

Ground Rod Removal

2-20. When it is time to move the equipment, be prepared to find that the ground rod is difficult to remove. Ground rods can be removed by the use of a vehicle jack (see figure 2-7 on page 2-8). Soldiers should ensure that all power has been removed prior to the de-installation of the ground. Use of all safety equipment is required. If a ground rod cannot be removed by various methods it may have to be recovered by digging it out if time permits.

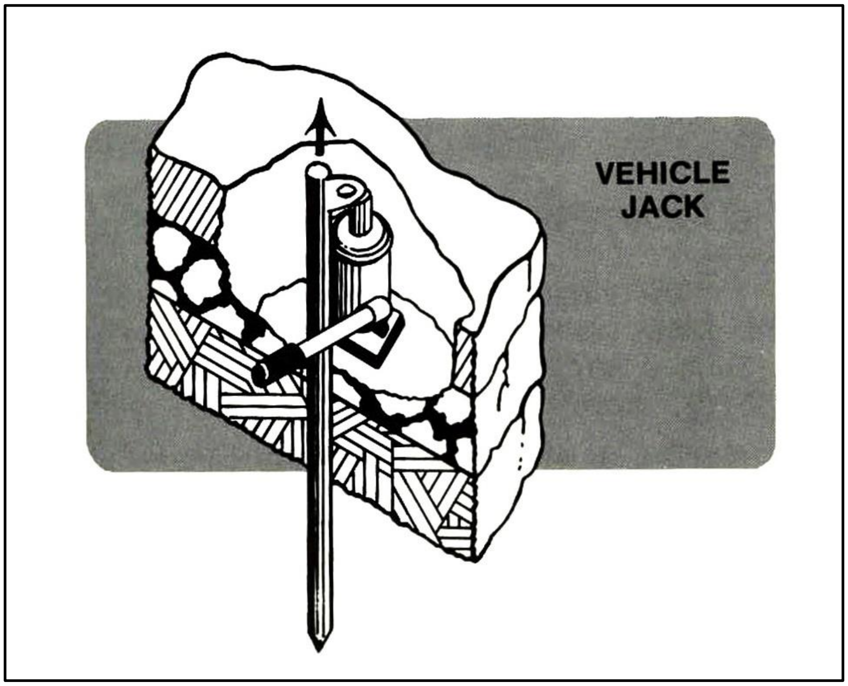

Figure 2-7. Ground rod removal with vehicle jack

Grounding Plates

2-21. Though more difficult to install, plates can achieve very low earth resistance values. The plates must have at least three square feet of surface contact with ground (front and back of plate is 18 inches by 18 inches). Some soil conditions require a larger surface area for which it is recommended to use a plate that is nine square feet. Such a plate would have a 50 percent larger surface area than that of the 9-foot ground rod listed above. Plates should be a minimum of 1/4 inch thick if iron or steel, or 1/16 inch thick if nonferrous.

2-22. Select a metal bolt, nut and lock washer and drill a hole in the center of the plate just large enough for the bolt. Fasten an appropriate grounding strap to the plate ensuring the connection is clean and tight.

2-23. Dig a hole so that the ground plate can be buried vertically at five feet below the surface (see figure 2-8 on page 2-9). Though in some circumstances soil conditions may only allow for the plate to be placed horizontally. Pour a mixture of water and salt into the soil around the plate to further increase soil conductivity if necessary.

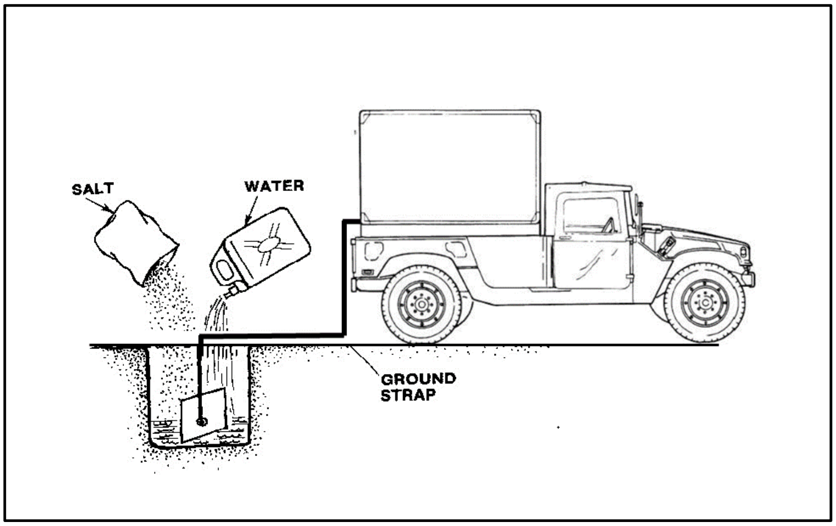

Figure 2-8. Grounding plate installation

2-24. Connect the other end of the grounding strap to the equipment. Keep the path as straight as possible. Ensure any part of the ground system is void of tripping hazards.

Surface Wire Grounding Kit

2-25. This grounding system was designed primarily for use with systems requiring high mobility and quick installation and removal. It is easily emplaced and removed, offering a reasonable option in situations where driving/retracting conventional ground rods would be difficult and time consuming to install. It consists of 15 ten-inch cast steel stakes installed in a circular pattern and interconnected with a 3/16-inch steel cable. The Surface Wire Grounding Kit (SWGK) is available in the Army inventory under the official nomenclature of Grounding Kit, MK-2551 A/U (see figure 2-9 on page 2-10).

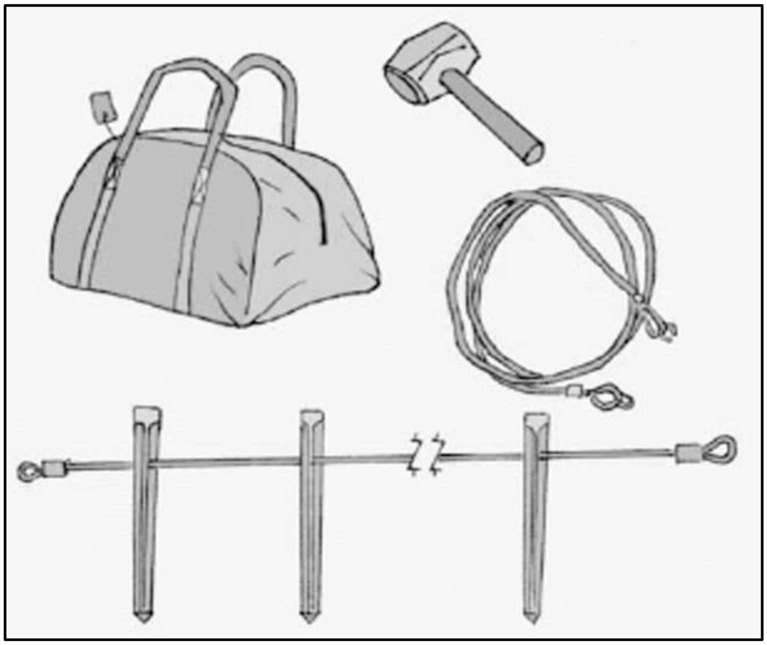

Figure 2-9. Surface wire grounding kit

Surface Wire Ground System Installation

2-26. Remove components from the system bag. Inspect the components and make sure they are clean and serviceable. Lay the cable in a U shaped pattern around the equipment avoiding any sharp bends or twists in the cable. Space the stakes evenly apart from each other. Attach the connector end of the cable to the equipment grounding lug.

2-27. Begin with the stake closest to the grounding lug. Pull the cable taut. Twist the stake 30 to 45 degrees. Using the supplied 3 pound sledge hammer drive the stake until the top is flush with the ground (see figure 2-10 on page 2-11). Continue until all stakes are driven in the ground. Driving the stakes fully into the ground and slightly twisting them helps to ensure a tight connection between the stakes and cable.

2-28. Using the two provided jumper cables connect them to the mid and end of the cable to the equipment. The purpose of these jumpers is to meet high-current survivability guidelines, such as lightning strikes. It is not necessary to scrape away paint to improve the clips connections however the grounding lug ends must still be attached to a stud or lug that is free of paint, grease, or dirt.

Note. When handling the components of the surface wire ground kit ensure you use safety glasses and gloves. Loose strands in the 3/16 inch cable can cause cuts.

Figure 2-10. Surface wire grounding kit installation

Surface Wire Ground Kit Removal

2-29. For safety concerns disconnect equipment power and ensure all working on removing the SWGK has gloves and safety glasses on. This will allow supply capacitors a chance to discharge (see equipment specific technical manuals for details). Next remove the jumper cables and coil them back up. Then remove the terminal lug from the grounding stud.

2-30. To assist with the removal of the stakes use the hammer and tap each peg from side to side. Also you may find that in some soil conditions you may be able to lift up on the main cable on either side of the stake will be sufficient enough to remove it. Continue until all stakes are removed.

2-31. Take the time to clean off any excess soil at this time. Coil all items and along with the hammer and place the equipment back into the provided tool bag.

WARNING
For systems that operate on the move and transition to at the halt, ensure that the earth grounding system is installed first before interconnecting to any external communications systems or power sources.

Water Plumbing

2-32. Traditionally, this was the preferred grounding electrode at fixed sites since the resistance to earth of the extensive water piping system was quite low. However, much plumbing is being changed over to or being coated with nonconductive materials, and therefore is no longer as reliable.

2-33. If using this technique, the Soldier should verify that the water pipe has a minimum of 10 feet of non-coated pipe in the connection area. If this is true, then connect the ground strap to the underground pipe or object just like you would with a ground rod. You might have to use a clamp or wrap method unless there is a usable bolt or screw. Ensure the area the strap is placed on is clean and that the connection is tight. Connect the other end of the strap to your equipment and the ground is complete.

WARNING
If you use an underground pipe, tank or object you must make sure it does not contain gasoline, oil, and other flammable liquids.

Buried Tanks

2-34. Just as with water plumbing, buried tanks can provide an effective earth grounding terminal. However, tanks are often coated with or made of nonconductive materials which can reduce grounding effectiveness. Never use tanks with flammable contents.

Horizontal Rods or Conductors

2-35. Buried horizontal rods and conductors are an acceptable alternative where soil is shallow. Ideally, buried horizontal conductors made with copper material or copper-clad steel should meet the American Wire Gauge of 2 (see American wire gauge chart table 2-1 on page 2-13). Never use aluminum conductors as the earth grounding electrode because it quickly oxidizes and greatly increases resistance to earth.

Table 2-1. American Wire Gauge Conductor Size Chart

AWG	*Diameter*	*Diameter*	*Resistance*	*Resistance*
0000 (4/0)	0.46	11.684	0.049	0.16072
000 (3/0)	0.4096	10.40384	0.0618	0.202704
00 (2/0)	0.3648	9.26592	0.0779	0.255512
0 (1/0)	0.3249	8.25246	0.0983	0.322424
1	0.2893	7.34822	0.1239	0.406392
2	0.2576	6.54304	0.1563	0.512664
3	0.2294	5.82676	0.197	0.64616
4	0.2043	5.18922	0.2485	0.81508
5	0.1819	4.62026	0.3133	1.027624
6	0.162	4.1148	0.3951	1.295928

Metal Framework of a Structure

2-36. Often, a nearby steel frame building can serve as a suitable earth round. Depending on the size of the metal building and the type of footings, a very low resistance to earth may exist. To ensure a suitable ground, all elements of the framework must be bonded well, especially between the steel frame and the footing steel reinforcement bars.

Grids

2-37. These consist of buried copper cables that form a network of squares over an entire area. This grounding system, though effective, is the least practical from a tactical standpoint, therefore it is not addressed in detail this circular.

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Chapter 3

Soil Conditions

This chapter introduces various soil types and qualities. Different types of soil have different electrical characteristics.

SOIL TYPES

3-1. Soil is usually divided into two distinct layers. The first layer (one to six inches) is topsoil, normally dry and loosely packed. The second layer is the subsoil, it is generally tightly packed and retains moisture, and provides the best electrical ground. Table 3-1 provides a brief summary of soil types, ground qualities, and suggested types of earth grounding electrodes.

Table 3-1. Soil type and quality

Type of Soil	*Quality of Ground*	*Suggested Earth Ground Electrode*
Organic soil, high water content	Very good	Ground rod, surface wire grounding kit
Clay, loam, shale	Good	Ground rod, surface wire grounding kit, or plate
Mixed (Clay, loam, or shale mixed with sand or gravel)	Poor	Buried pipes, building frame, or other metal object or a ground plate or several ground rods electrically connected together
Gravel, sand, stone	Very poor	Additional steps may be required; treating soil to increase conductivity or installation of additional ground electrodes

3-2. The soils are derived of several characteristics. These include moisture content, temperature, and soil treatment.

MOISTURE CONTENT

3-3. Wet soil passes electric current better than dry soil and makes your grounding system work more efficient. Use chemicals (conductive additives) whenever you can and keep the soil moist (see figure 3-1 on page 3-2).

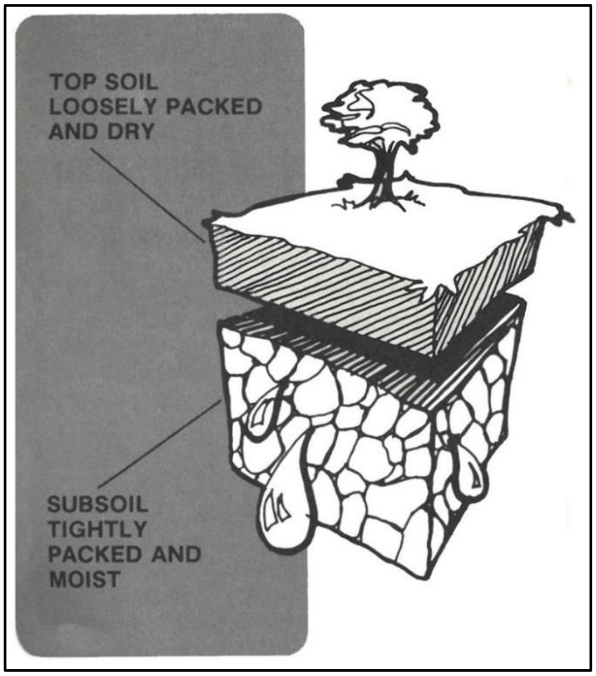

Figure 3-1. Moisture content

TEMPERATURE

3-4. Ice is a poor conductor of electric current. When the temperature of the soil drops below freezing, 32 degrees Fahrenheit, the moisture in the soil freezes and the effectiveness of the grounding system decreases. There are several remedies to strengthen the connection. Finding a buried metal object such as an underground pipe or building frame could be used. If none are available you can use several ground rods driven as deep as possible, keeping the spacing at least two rod lengths apart. Alternatively, a horizontal trench can be used. The trench should be treated with a salt water mixture to improve conductivity. In rare cases where the frost line is too deep and installed grounding system is not working it is very important to ensure that all equipment is bonded together with grounding straps. This can help prevent potentials from developing between two pieces of equipment (see figure 3-2 on page 3-3).

Figure 3-2. Temperature

SOIL TREATMENT

3-5. If your ground resistance, as measured by a null-balance earth tester or equivalent device, is 25 ohms or more, you may add chemicals to lower the resistance. The ideal resistance measured should be 10 ohms. The following chemicals, listed in order of preferred use, are recommended for good results—

- Magnesium sulfate (Epsom salts).
- Copper sulfate (blue vitriol).
- Calcium chloride.
- Sodium Chloride (common table salt).
- Potassium nitrate (saltpeter).

3-6. In the above list, sodium chloride or common table salt, is usually most accessible in the field. Use as follows—

- Dig a hole about one foot deep and three feet across.
- Mix five pounds of chemical to five gallons of water and pour it into the hole.
- Let it seep in.
- Install the ground rod and connect the ground strap.
- Continue to keep soil around the rod moist.

3-7. Since this blend will seep into the ground, repeat adding the saltwater mixture once a week for the first four weeks then repeat only on monthly intervals afterwards.

3-8. For environmental reasons always check to ensure that chemicals can be used at your grounding location. If chemicals cannot be obtained or used using water alone can still help improve soil conductivity (see figure 3-3).

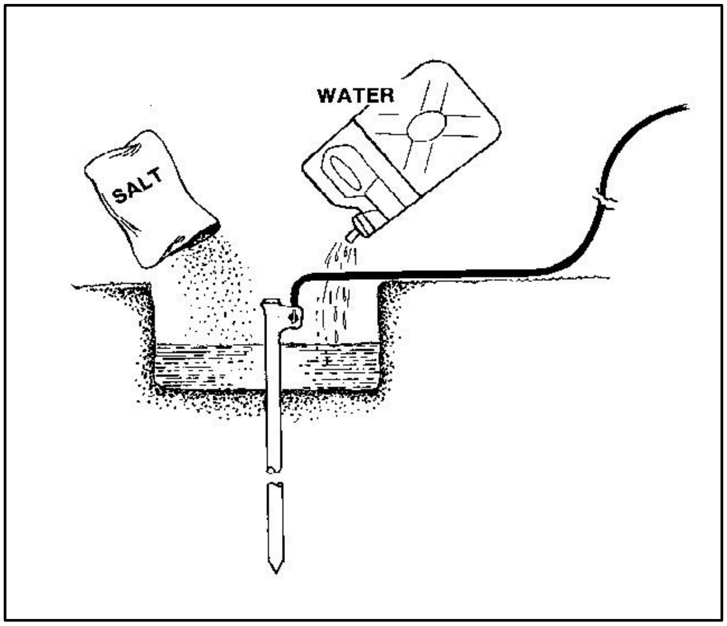

Figure 3-3. Chemical treatment

Chapter 4
Terrain and Climate Conditions

This chapter discusses the impact of terrain and climate on deployable force Army tactical communication systems. These conditions present a variety of problems in establishing a solid ground.

TERRAIN TYPES

4-1. The soil for each climate type determines what basic grounding procedure the Soldier should use to produce an effective ground for equipment protection. There are four basic terrain types, desert, mountain, tropic, and arctic.

DESERT TERRAIN

4-2. The extreme dry and loosely packed sandy soil of the desert area (figure 4-1) makes very poor electrical grounds. The use of large ground plates or sectional ground rods are advantageous because of the large metallic area that is in contact with the soil. The surface wire ground system can also provide a good ground in this soil type. The use of chemicals is strongly recommended in desert areas. If possible, locate your equipment near an oasis or subterranean water source. If you have equipment in a shelter or location that has an air conditioner you can route the condensation water to the grounding area.

Figure 4-1. Sandy or dry soil

MOUNTAIN TERRAIN

4-3. Site selection is key to solving the grounding problem. In soil that has lots of rocks, the contact area of the driven ground rod and actual soil is much less. Thereby reducing the effectiveness of the ground or increasing the resistance. In this soil type (figure 4-2) the ground rod can be buried horizontally or you may be able to obtain a good ground by locating near a stream bed or some type of water source. To increase the effectiveness of a ground in this terrain the use of a salt water mixture can be used. Salt placed along the horizontal trench above the ground rod will leach into the soil whenever it rains.

Figure 4-2. Rocky or hard compact soil

TROPIC TERRAIN

4-4. If the soil is moist and heavily covered with vegetation, the ground rod may be the most effective approach (see figure 4-3 on page 4-3). Surface growth should be removed if a surface wire ground system is to be installed to allow good contact of the wire and pegs to the earth. Soil in this terrain usually has enough moisture making it easy to install rods. The main concern in a tropical environment is the fast build-up of corrosion. The connection of the ground strap to the ground system must be kept clean and dry (waterproof tape) to ensure a good electrical path.

Figure 4-3. Wet or moist soil

ARCTIC TERRAIN

4-5. When the soil is frozen (below 32 degrees), it is hard to get a good electrical ground. Cold soil substantially increases soil resistance and also earth grounding resistance. The SWGK should be used wherever the ground stakes can be driven through the surface. Ground rods can be used if they can be driven completely. If you have something that is already grounded, such as a metal buildings or underground pipes, you may connect to them for your ground. You can also drive several ground stakes into the soil at various locations to the greatest depth possible. If you get a poor ground because the soil conductivity is low, use chemicals to condition the soil (see figure 4-4 on page 4-4).

Figure 4-4. Frozen soil

SOIL RESISTIVITY

4-6. As discussed above the type of soil directly effects the grounding equipment or system. Each soil type has a certain electrical resistance measured in Ohms. Table 4-1 assists the equipment operator or planner in determining the general resistance of the soil and how it impacts the ability to achieve a less or equal to 25 ohm ground.

Table 4-1. Soil type and resistance

Soil Type	***Soil Resistance in Ohms-meter***
Bentonite	2 to 10
Clay	2 to 100
Wet Organic Soil	10 to 100
Moist Organic Soil	100 to 1,000
Dry Organic Soil	1000
Sand and Gravel	150 to 1,000
Surface limestone	100 to 10,000
Limestone	5 to 4,000
Shale stone	5 to 100
Sandstone	20 to 2,000
Granites, basalts	1,000
Decomposed genesis	5 to 500
Slates	10 to 100

Chapter 5
Helpful Hints

This chapter contains additional information that assists the operator of tactical communications equipment and systems when trouble shooting grounding procedures.

GROUNDING TIPS

5-1. In situations where equipment, systems, or shelters must be located six to eight feet within each other they need to be bonded. Bonding of equipment means to share a common grounding point (ground rod) or to have a grounding conductor (minimum 6 AWG) between the two ground lugs of each shelter.

5-2. Do not forget to check any remotely located equipment that extends from its primary shelter or location. Performing these steps can prevent injury where by a person could touch both metal surfaces of different voltage potentials could develop between them should a fault occur.

GROUNDING NETWORKS

5-3. In areas of very poor soil conductivity, you can improve grounding by installing multiple grounds or interconnecting several grounding systems (see figure 5-1). A second SWGK extended in the opposite direction from the first, or at least in a different direction, could provide equipment with a better overall ground resistance.

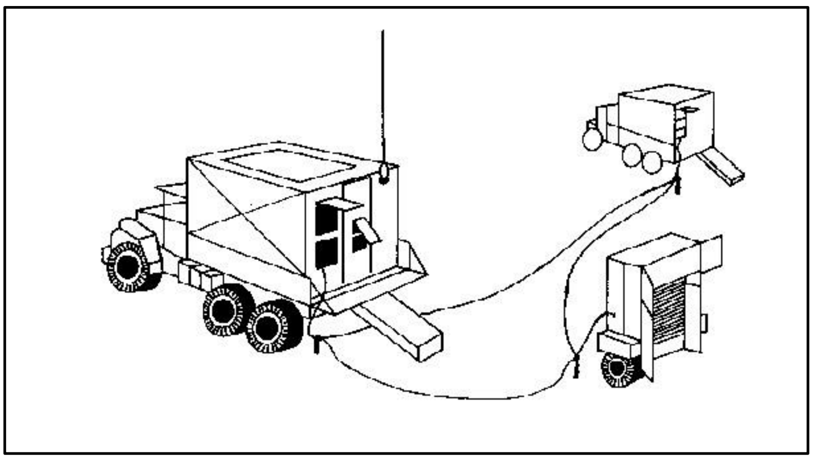

Figure 5-1. Multiple equipment grounding

Improvised Ground Rods

5-4. A ground rod kit may get lost due to the tactical situation, or lack of time to recover it. A Solider can improvise a good ground rod by using a substitute material. Make sure that the material chosen is strong enough to drive into the ground without bending. The ideal substitute would be a copper rod about 180 centimeters or six feet long and a dimeter of 1.9 centimeters, about ¾ inch thick.

Other Improvised Ground Rods

5-5. A length of steel reinforcing rod is a very good substitute for the standard ground rod. Steel is rigid and can be cut to the same length as the rod it replaces. For easy soil penetration, cut one end of the steel rod into a chisel shape with a hacksaw.

5-6. A steel fence post, the kind used for wire fencing, barbed wire makes an excellent ground rod. However, most posts of this type have a protective coat of paint that must be removed to get an effective ground.

5-7. A metal water or gas pipe cut to the right length (eight to ten feet) can be used as a substitute rod. Flattening one end of the pipe to a chisel shape increases the ease of driving it into the soil (see figure 5-2).

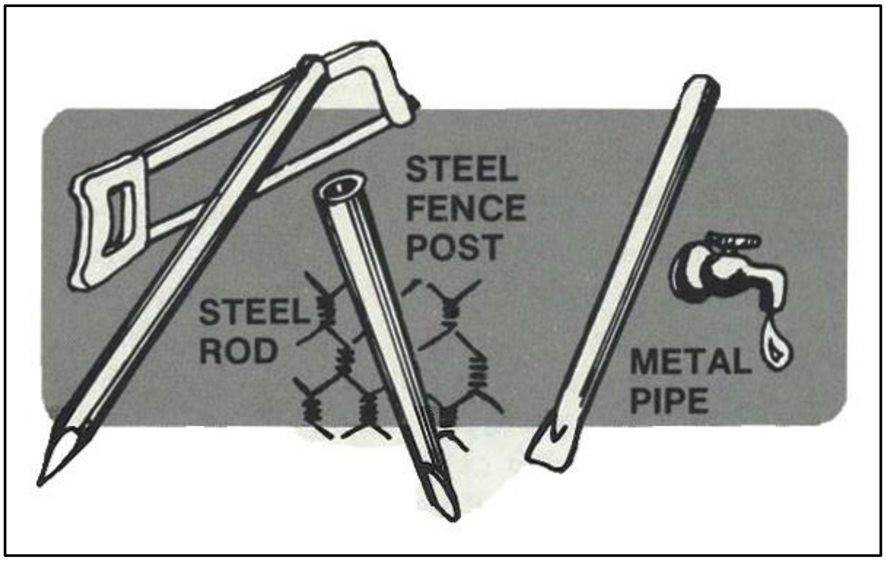

Figure 5-2. Improvised ground rod items

Note. Never use an underground gas or propane line as a source to attach a ground strap.

EARTH GROUND ELECTRODE RESISTANCE MEASURING

5-8. To reduce the chance of electrical shock and provide optimal equipment operations it is good practice to measure the resistance of the ground system prior to its installation. There are several fall of potential methods. Common practice in a tactical situation would be to use the 62 percent fall of potential method. This will provide a reading that will indicate if the installed ground system is good or may need to be chemically treated based on the soil conditions for which the ground system is installed.

62 Percent Fall of Potential Method

5-9. If available, use a null-balance earth tester or other approved resistance testing device to check your grounding system using the fall of potential method (see figure 5-3 on page 5-4). Do not use a standard multimeter. To perform a test of the ground with this type of equipment check the following—

- Disconnect your equipment or system from the ground electrode (rod).
- Connect terminals P1 and C1 together and run a heavy, short flexible cable from them to your ground rod. On some earth testers a single terminal labelled X is provided.
- Connect terminal C2 or C to a 30 meter long cable which should be stretched out as far away from the ground system as possible and clamped to a 20 to 30 inch ground rod provided with the tester. Make sure you place the rod firmly in the ground. This is the current spike.
- Connect terminal P2 or P to a 50 to 60 foot long cable which should be stretched along the first cable and clamped to a 30 inch ground rod at its end. Make sure you place the rod firmly into the ground. This is the potential spike.
- In some cases you may be limited on distance from the ground rod under test to the current spike. In this instance the potential spike needs to be 62 percent in distance from the measured distance of the current spike.
- Turn on your earth tester. If it is not battery operated, you need to turn the hand crank to make it work.
- On some battery operated earth testers you can read the resistance of the ground directly. However, on many of them you might have to adjust the dials so that the meter does not deflect from its center position when you push the test button. The dial reading then tells you the resistance.
- If you get a reading of 25 ohms or less, you can consider the ground resistance adequate. Ideally you want to achieve a resistance of 10 ohms. If you get a higher reading, you should try an alternate grounding method (preferably the SWGS); or you should attempt to reduce the ground resistance by treatment with chemicals, or the installation of multiple ground rods.
- You should not use an ohmmeter or a multi-meter to test your ground. Such devices do not give valid resistance measurements.

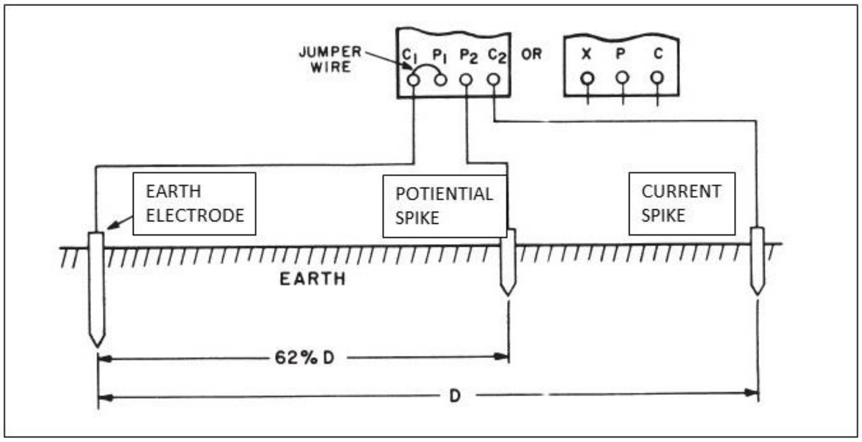

Figure 5-3. Fall of potential resistance method

ENGINEER SUPPORT

5-10. Engineer support is reasonably available at most locations. The engineers may assist you by performing soil tests, excavating where necessary, and making recommendations for grounding.

REMINDERS FOR GROUNDING

5-11. In certain cases we tend to rush the installation of our tactical equipment and systems. In doing this we can insert problems with equipment operation before we begin. Here are some reminders to assist you in establishing a good ground.

GROUND RODS OR KITS TIPS

5-12. Ensure that all ground rods and or kits are—

- Clean- remove paint, oil, and grease.
- Complete- verify for the proper ground strap, clamps, and connections.
- Sharp- rod points are ready for soil penetration.

EQUIPMENT TIPS

5-13. The condition and location of equipment influences the ground connection. If the ground connection is not good, try the following—

- Insure that the ground connection is clean and complete.
- Connect equipment to an existing permanent ground, when possible.
- Relocate equipment, if possible, when adequate grounding cannot be obtained.

INSTALLATION TIPS

5-14. Always install stakes in a straight line, if possible. Moisten surrounding area. Add conductive chemicals (salt) to soil, if needed. When installing ground rods, ground straps and ground plates there are some specific tips to assist with strengthening the ground connection. Ground rods should be—

- Installed to full length so that top of ground rod is 3-5 inches below terrain.
- Surrounded by moisture area. Add conductive chemicals (salt) to soil, if needed.

5-15. Ground Straps should—

- Be made from braided copper material or heavy gauge wire.
- Not contain any loops or kinks.

5-16. Ground Plates should be—

- Used in dry and or sandy soil.
- Placed horizontally or vertically depending on the terrain.

CONNECTIONS TIPS

5-17. The proper bond of grounding equipment is necessary for a good ground connection to occur. Below are some tips to assist with the terminal screw/clamp and wrap method connections.

5-18. Terminal Screws or Clamps should be—

- Clean, no paint, oil or grease.
- Tight so that ground strap is held securely and firmly against the grounding surface.

5-19. Wrap Method should—

- Be such that the ground strap is held firmly and securely in place against the ground rod by stripped flexible wire.
- Only be used if no other connection is available.

GROUND ROD DRIVING EQUIPMENT TIPS

5-20. There are two most commonly used ground rod driving tools used for driving rods. The fence post driver is the preferred driving tool and can be made locally. A light weight hammer should be used to sink rods without disturbing the soil.

5-21. Fence post drivers should be—

- The preferred driving tool.
- Either as part of your basic issue items or additional authorized list equipment. Or one could be made locally.

5-22. Hammers should be—

- Light weight, enough to sink the rod without disturbing the soil.
- Ensure all safety concerns are addressed prior to using the hammer.

Appendix A
Grounding Checklist

This checklist (see table A-1) details the principal factors required for a durable and effective grounding and lightning protective system. Not all of the items require compliance, depending on the circumstances. Rather, the grounding and lightning protection systems should be reviewed in light of this checklist to ensure that no particular area has been left unaddressed. For more details see CECOM TR 93-1.

GROUNDING CHECKLIST

A-1. All tactical systems and equipment come with technical manuals that may cover how to ground the equipment. Most units have established standard operating procedures that outline how to conduct grounding operations in a training or deployed environment. The grounding checklist shown in table A-1 provides the main areas to consider when grounding any Army tactical piece of equipment or system.

Table A-1. Grounding checklist

Preparation (check prior to installation of a Grounding System):	
	Has consideration been given to the placement of equipment, shelters from an earth grounding perspective (soil quality)?
	Has consideration been given to how extensive the earth grounding electrode system should be?
	Has the soil condition been considered in selecting the type and quantity of earth grounding electrodes?
Earth Grounding Conductor Considerations:	
	Is the grounding wire suitably sized and of a corrosion-resistant material?
	Are loops, kinks, and sharp bends avoided?
	Are grounding conductors routed horizontally or down toward the ground rod? (Avoid going up and over objects).
	Are splices in the conductor avoided?
	Are the grounding wires free of heavy corrosion and damage, especially at the ends?
Observations to make at each Bonding Point:	
	Are ground wires twisted around ground rods, masts?
	Are wires rigidly clamped (not twisted or solely taped)?
	Are clamps or bonding points adequately secured to avoid loosening with time?
	Are grounding or bonding connections free of paint or any signs of corrosion?
	Are dissimilar materials avoided at the bonding point?

Table A-1. Grounding checklist (continued)

Items to check at each Ground Rod (Earth Grounding Electrode):	
	Are ground rods or other electrodes suitably installed?
	Are ground rods or other electrodes free of paint?
	Is the use of aluminum for electrodes avoided?
	Where possible, are electrodes installed away from areas where rocks are evident (signifying poor soil conditions)?
	Where soil is shallow, are ground rods/wires buried horizontally?
	If used, are grounding plates suitably sized?
	Where the Surface Wire Grounding Kit is employed, are the two jumper cables installed?
	Are electrodes installed where the ground receives rain water or other moisture?
	Are grounding electrodes installed away from locations with normal pedestrian traffic or personnel tents?
	Are power and signal cables laid across or near earth grounding conductors or cables?
	When earth ground resistance is questioned (poor soil, buried plumbing (coated metal) has a test been conducted?
	Where soil quality is poor, are multiple grounding electrodes installed and interconnected?
	Where soil quality is poor, is conductivity enhanced through the use of salt?
Check the following areas for a Lightning Protective Masts:	
	Is equipment requiring protection located within the Lightning Protection Mast cone of protection?
	Is the air terminal at top of the Lightning Protection Mast durable?
	Is a suitable grounding conductor provided from the air terminal to ground?
	Is the Lightning Protection Mast suitably grounded via a dedicated ground rod?
	If any separate grounding electrodes are located near the Lightning Protection Mast grounding electrode, are they interconnected to the Lightning Protection Mast grounding electrode?
	Are all bonding connections secure? (Clamped, not taped or twisted)
Other considerations for checks on a Grounding System:	
	Are personnel informed to remain within appropriate shelters when possible during electrical storms?
	Are all grounding locations inspected following electrical storms to ensure that damage was not sustained?
	If tents are used to house personnel, are they located away from ground rods and antenna masts (tents provide poor protection; especially where personnel lie across the ground)?

Glossary

SECTION I – ACRONYMS AND ABBREVIATION

CECOM	Communications-Electronics Command
SWGK	surface wire grounding kit
TC	training circular

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Index

Entries are by paragraph number.

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