

ELECTRICAL PROTECTION OF CENTRAL OFFICE EQUIPMENT

Purpose: The purpose of this addendum is to issue Appendix B, Protection Systems for Central Office Located Antenna Installations, and Appendix C, Analysis of Central Office Grounding System to TE&CM 810.

Attachment

Appendix B

Protection Systems for Central Office Located Antenna Installations

1. General

1.1 Antennas and supporting structures for microwave, mobile radio and paging systems are generally susceptible to lightning strokes because of their height and high conductivity. Rural conditions contribute even more to this susceptibility because of generally poorer grounding conditions and the lack of shielding by tall buildings. Digital central office equipment is especially vulnerable since even low voltages can severely damage components of a digital switch.

1.2 This appendix provides guidelines for designing and constructing protection systems for antenna installations. It is not meant to suggest development of systems that are unreasonably expensive or otherwise impractical. Wire and ground rod sizes are presented as minimums and do not preclude the use of larger sizes.

2. Protection Grounding and Bonding

2.1 Large currents caused by near or direct lightning hits to towers and associated structures can cause hazardous voltage differences between metal parts. These voltage differences result from current flowing through the resistance and inductance of these metal parts and grounding conductors. Bonding is essential to prevent voltage differences. All metal elements of the building structure, such as steel reinforcing rods in concrete, metal sheathing, metal roof supports and trusses, and metal piping and conduit systems should be bonded to the station ground. Although it is desirable that the station ground have low resistance, it is more important that all metal parts be bonded together to keep them at the same voltage. Thus, sensitive equipment such as digital switches can remain at the same potential relative to the rest of the office, even though there may be a rise in the overall ground potential.

2.2 Placing ground conductors in metal conduit should be avoided if possible. However, where grounding or bonding conductors are run in metal conduit to avoid mechanical damage, the conductor should be bonded to the conduit at both ends to decrease inductance and prevent arcing.

2.3 Connection methods for ground wires and conductors are discussed in "Installation Procedures" found in TE&CM Section 802. In general buried connections should be welded to assure a permanent low resistance.

2.4 Ground rods should always be driven straight into the ground to achieve maximum depth and lowest resistance to ground.

3. Tower Installations

3.1 Design Objective

The design objective of the tower ground is to produce a network that matches or comes close to matching the ground resistance of the central office. This match should prevent a large current from flowing into the central office by giving it a low impedance path to ground at the tower. Refer to TE&CM Section 802 and to the manufacturer's instructions for additional information. Every effort should be made to obtain the design objective.

3.2 Self-Supporting Tower Installations

A typical self-supporting tower installation is shown in Figure B-1. As a minimum, these structures should have a ground rod 5/8" x 8' (1.6 centimeters x 2.4 meters) driven at the base of each footing and bonded to the tower leg with a #6 copper conductor. This conductor should gently slope downward with no sharp bends (as shown in Figure B-2). However, ground rods should be placed close to the tower base and the conductor dressed in a manner that will avoid accidental damage to the grounding system or injury to workmen. All of these ground rods should be bonded together with a #6 bare copper conductor buried at least two feet underground. Reinforcing bars in the concrete base should be bonded to the ground rods as well as to the tower structure. Where these bars touch each other, they should be fused together to prevent arcing. Waveguide and coaxial cable should be bonded in accordance with Paragraphs 6.3 and 6.4. It is also necessary to bond the antenna supporting structure to the C.O. ground (See Paragraph 3.4).

3.3 Guyed Tower Installations

A guyed tower installation is shown in Figure B-3. Guyed towers should be protected by a ground ring at least 10 feet (3 meters) across. This ring should be made of #6 bare copper conductor buried at least two feet underground and bonded to at least four - 5/8" x 8' (1.6 centimeter x 2.4 meters) ground rods. The structure itself should be bonded to the ground ring by two separate connections of #6 copper conductor. If the base is concrete, the reinforcing bars should be bonded to the structure and to the ground ring. Waveguide and coaxial cable should be bonded in accordance with Paragraphs 6.3 and 6.4. The ground ring should also be bonded to the C.O. ground. A ground rod should be driven at each guy anchor and bonded to the guy wire with a #6 or larger copper conductor. Multiple guy wires on the same anchor should all be bonded together and to the ground rod with a #6 conductor.

3.4 Bonding the Tower Ground to the C.O. Ground

Although the tower ground should absorb most of the lightning energy, it should be bonded to the C.O. ground to prevent a voltage difference from developing between the two. This connection should be made outside the C.O. building in a ground well as shown in Figure 28 of TE&CM Section 802. Refer to Figure 6 and Table A of TE&CM Section 810 for proper conductor size.

4. Pole Mounted Antennas

4.1 A pole mounted installation is shown in Figure B-4. Grounding systems for protection of pole mounted antennas need to protect both the pole and the equipment connected to the antenna. Poles that have antennas extending above the top of the pole are in a cone of protection formed by the antenna. The antenna acts as a lightning rod and needs to be appropriately grounded (See Paragraph 6.2). Microwave, and other installations which leave the top of the pole exposed, need a lightning rod mounted on top of the pole extending at least 1 foot (30 cm) above the top of the pole. A down lead of #6 copper conductor should be used to connect the lightning rod or antenna to the ground ring at the base of the pole. The ground ring should consist of at least 3 ground rods separated from each other by at least 10 feet (3 meters), and bonded together with #6 bare copper conductor buried at least two feet underground. The ground ring should be bonded to the C.O. ground field external to the C.O. building. This connection should be made to a ground rod inside a ground well as shown in Figure 28 in TE&CM Section 802. Refer to Figure 6 and Table A of TE&CM Section 810 for proper conductor size.

5. Antenna Towers Mounted on Top of Buildings

5.1 Antenna towers on top of buildings should have a ground ring of #6 copper conductor bonding the legs at their bases. #2 copper conductor down leads should be bonded to each tower leg and brought down the outside of the building to ground rods except on structural steel buildings (See Figure B-5). These ground rods should also be bonded together with #6 bare copper conductor buried between them. This ground ring should be bonded to the central office ground in a ground well as shown in Figure 28 in TE&CM Section 802. A reinforced concrete building should have its antenna structure bonded to the reinforcing bars in the concrete. These bars should in turn be bonded to the ground ring. Reinforcing bars should be fused together wherever they touch to prevent arcing.

5.1.1 Structural steel buildings should have each leg of the tower bonded to the structural steel with #2 copper conductor. The structural steel should be bonded to the ground ring with #2 copper conductor at each corner of the building. If these bonds are made, the structural steel usually provides an adequate ground itself without use of the #2 copper conductor ground leads, down the side of the building.

5.1.2 Structural steel or reinforcing bars should be integrated into the building ground and bonded to the water system and power system neutral.

6. Antennas and Connecting Coaxial Transmission Lines and Waveguides

6.1 Antennas and connecting transmission lines need to be suitably protected from lightning without introducing significant attenuation to the radio signal. Ideally, lightning current should flow through other conductors such as metal towers and grounded down leads. However, since this is not always the case, bonding procedures must be employed to protect equipment connected to the transmission line.

6.2 Antennas

Antennas should have a good ground path to adequately dissipate lightning currents. Ground plane antennas, such as folded monopole antennas, can be directly bonded to the tower or ground down lead. Microwave horns, dishes, and reflectors should also have a direct path to ground via a grounding kit connected to the waveguide at a point close to the antenna (See Paragraph 6.3). Coaxial antennas should be protected by a star gap arrestor. A star gap arrestor is a serrated washer connected directly to the center conductor of the antenna. Lightning surges effectively see a short circuit across the gap to ground through the outer conductor while the transmission path is left relatively unaffected. Other types of air gap arrestors may also be used. One additional method employs a shorted quarter wavelength stub connected to the coaxial cable at the base of the tower or pole. The shorted end of the stub is connected to ground giving lightning a good ground path. Since the shorted stub is a quarter wavelength, it should not affect the radio signal.

6.3 Waveguides

Using a grounding kit, waveguides should be bonded to the tower or ground down lead at least at the top and bottom of the antenna structure. Grounding kits are usually available from the manufacturer. The braided conductor of the grounding kit should be connected in a downward direction from the waveguide to the tower since lightning will generally not flow in an upward direction from the waveguide to the tower. A properly installed ground kit is shown in Figure B-6. Waveguides should be bonded to the tower at points of support to prevent arcing. Ice shields or other supporting structures running between the tower and central office should be bonded to both the tower and central office ground field. A grounding kit should be used to bond waveguides to the central office and tower ground field just prior to the waveguide's entrance to the building (as shown in Figure B-7).

6.4 Coaxial Cable

The outer conductor of the coaxial cable should be bonded to the tower or ground down lead at least at the top and bottom of the antenna structure. Non-insulated coaxial cable should also be bonded at intermediate points of support to prevent arcing. Added protection can be provided by means of a ground entry plate connected to the building (See Figure B-7). All transmission lines should be bonded to the plate with grounding kits. The braided end of the grounding kit should run in a downward direction. The plate itself should be bonded to the central office and ground field by a #6 copper conductor. If convenient, this connection should also be to a ground rod in a ground well as shown in Figure 28 in TE&CM 802.

7. Protection of Radio Equipment

7.1 Radio equipment should be integrated into the central office grounding scheme to divert lightning currents from it and the C. O. switch. Transmitters, receivers, and multiplexers should be mounted on grounded metal racks bonded to the master ground bar by a conductor or bus with a resistance no greater than 0.01 ohms (refer to Figure 6 of TE&CM 810).

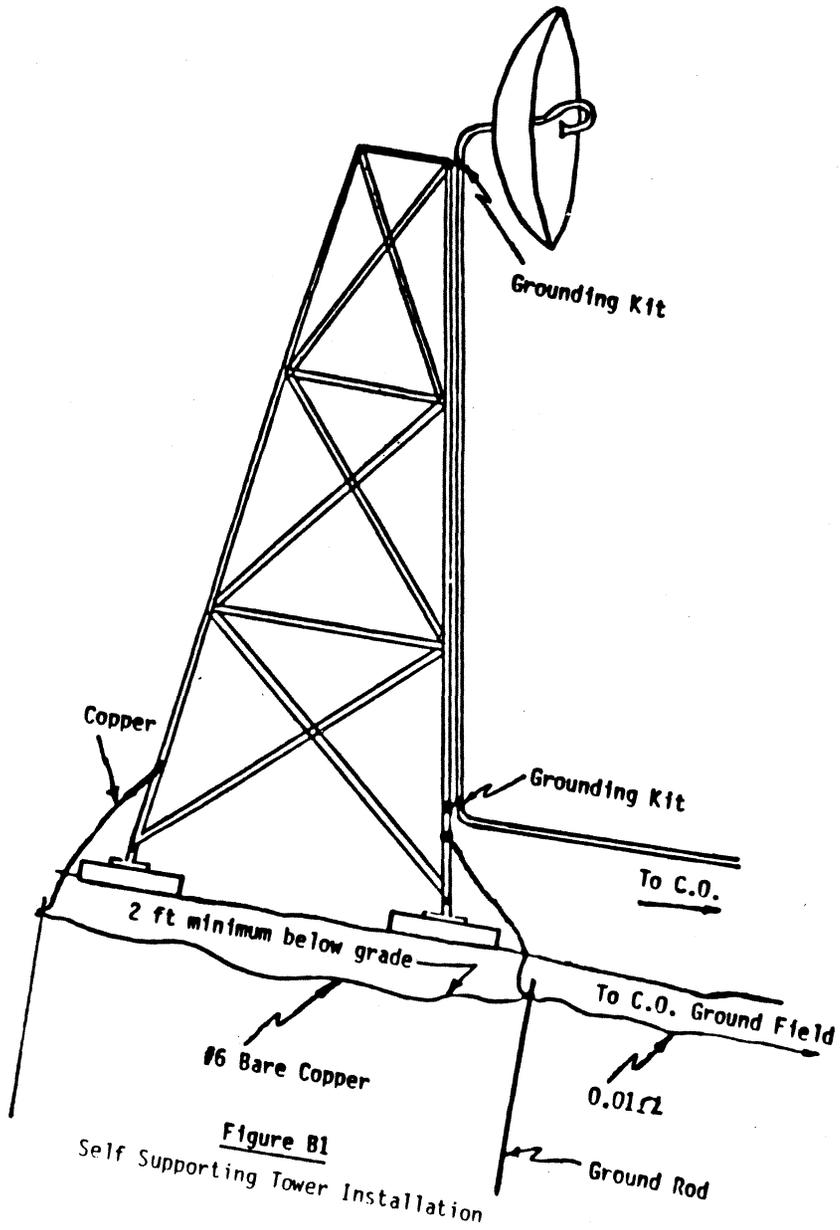


Figure B1
Self Supporting Tower Installation

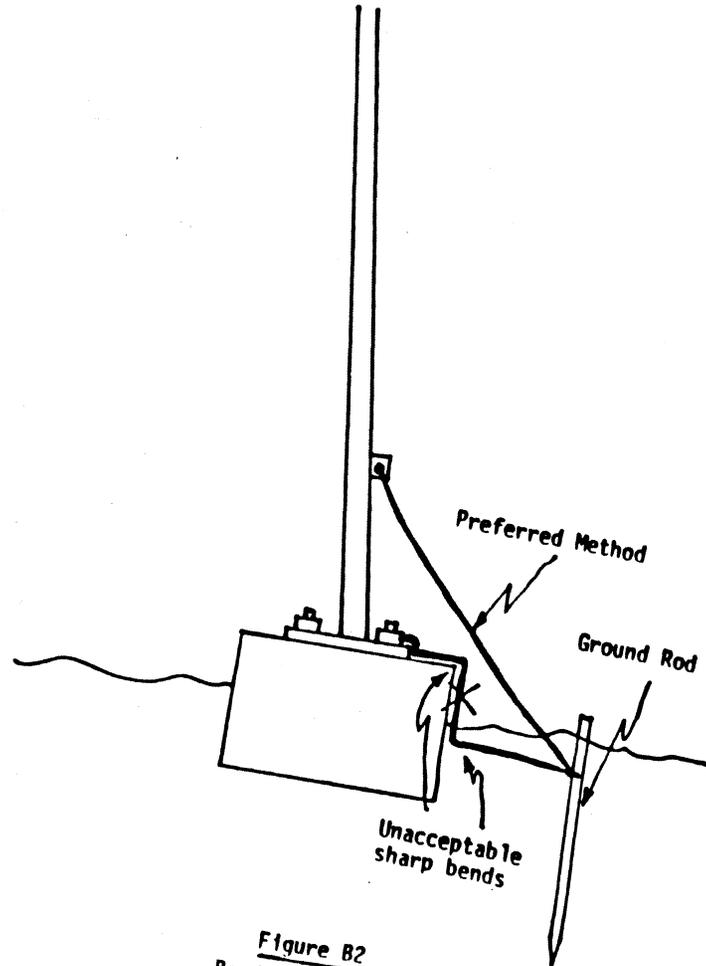
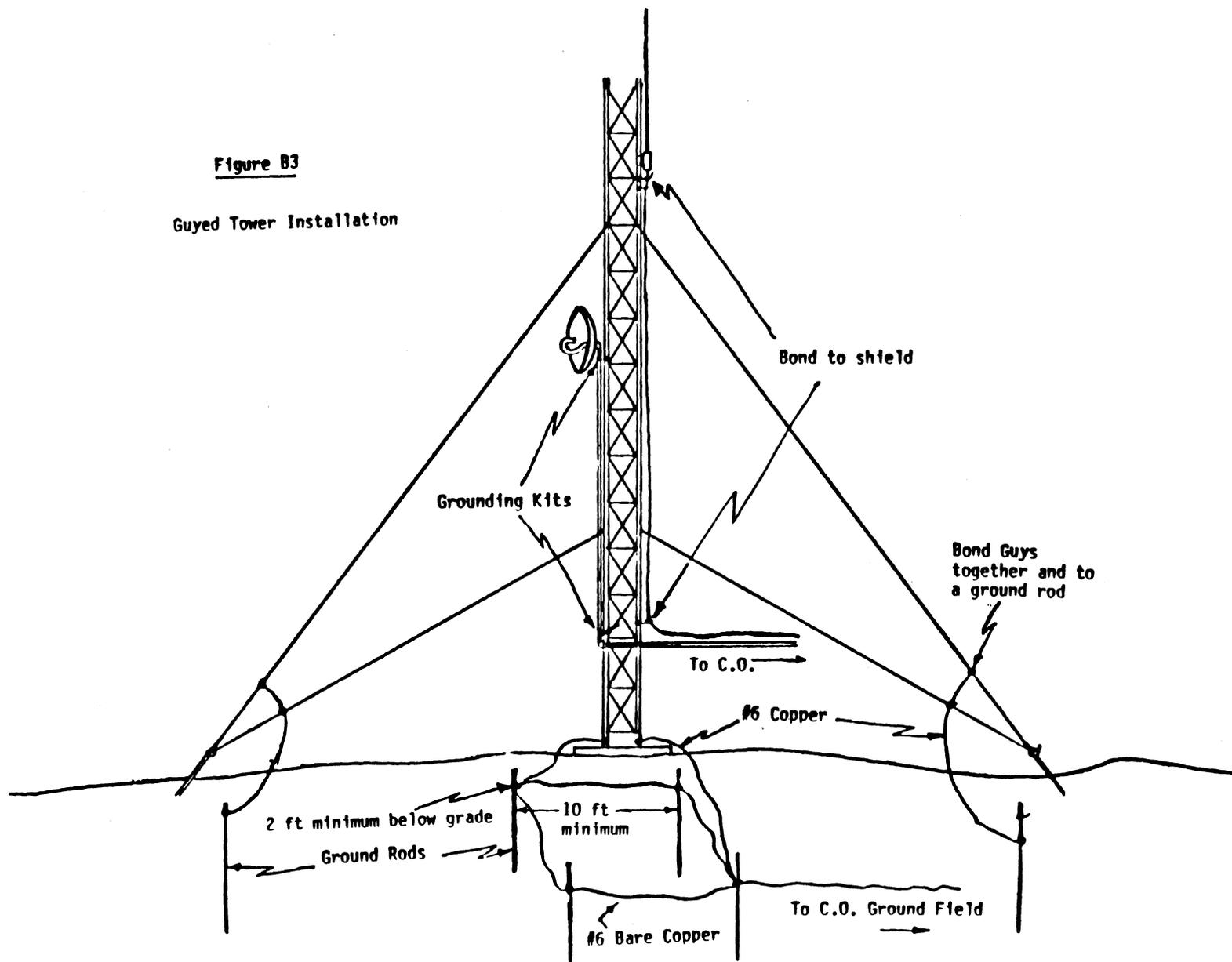


Figure B2
Bonding Details

Figure B3
Guyed Tower Installation



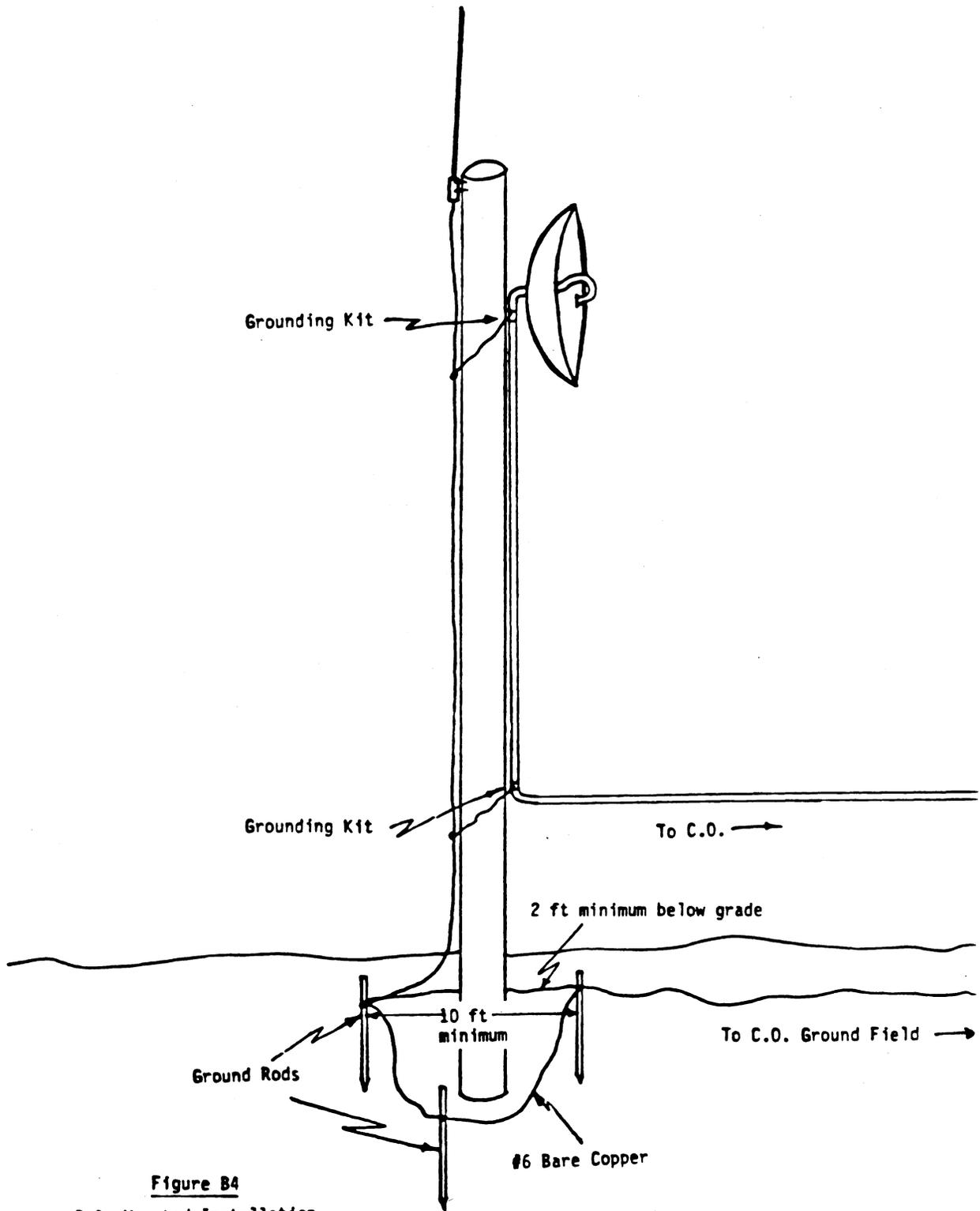


Figure B4
Pole Mounted Installation

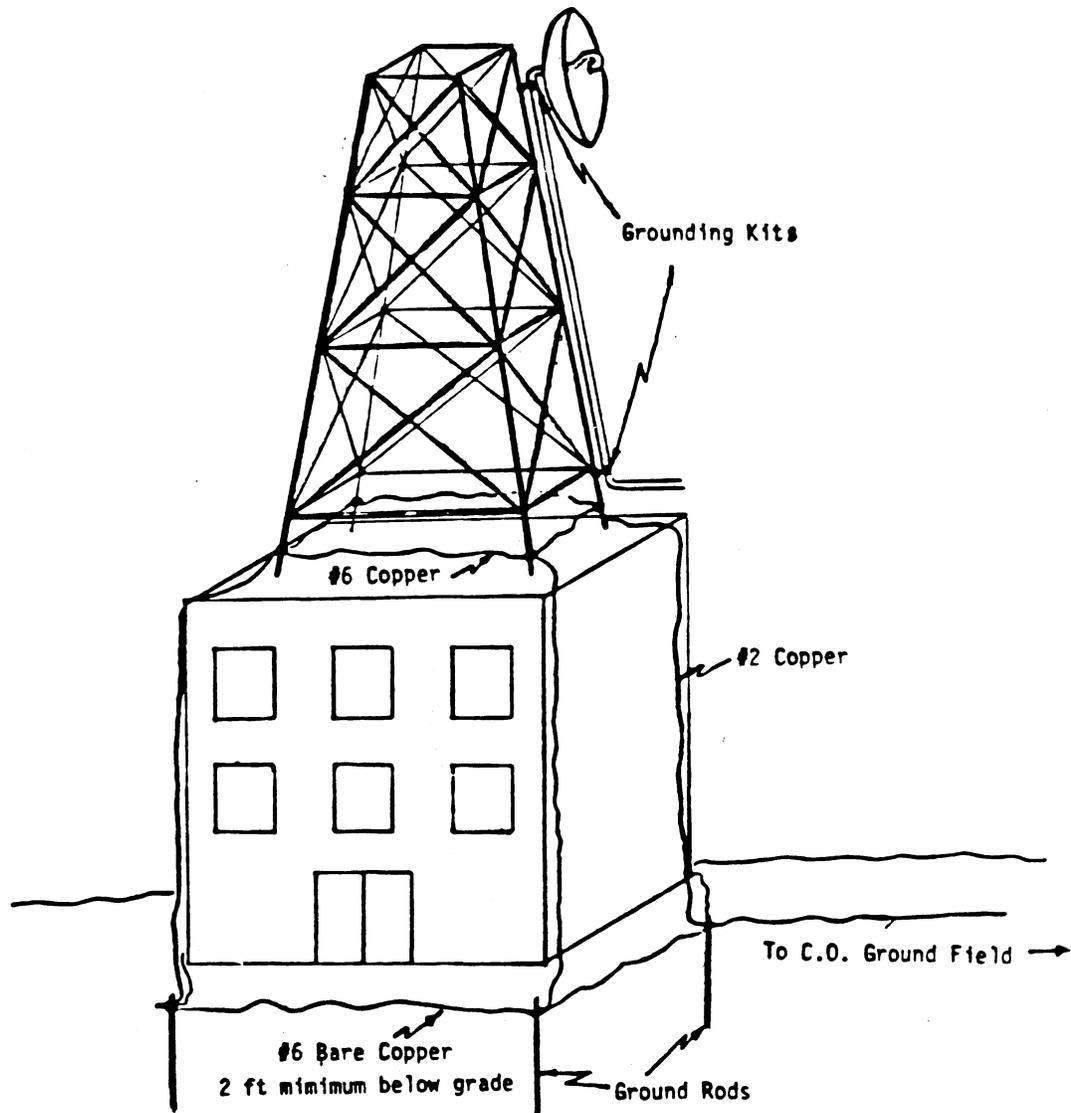


Figure B5
Building Mounted Installation

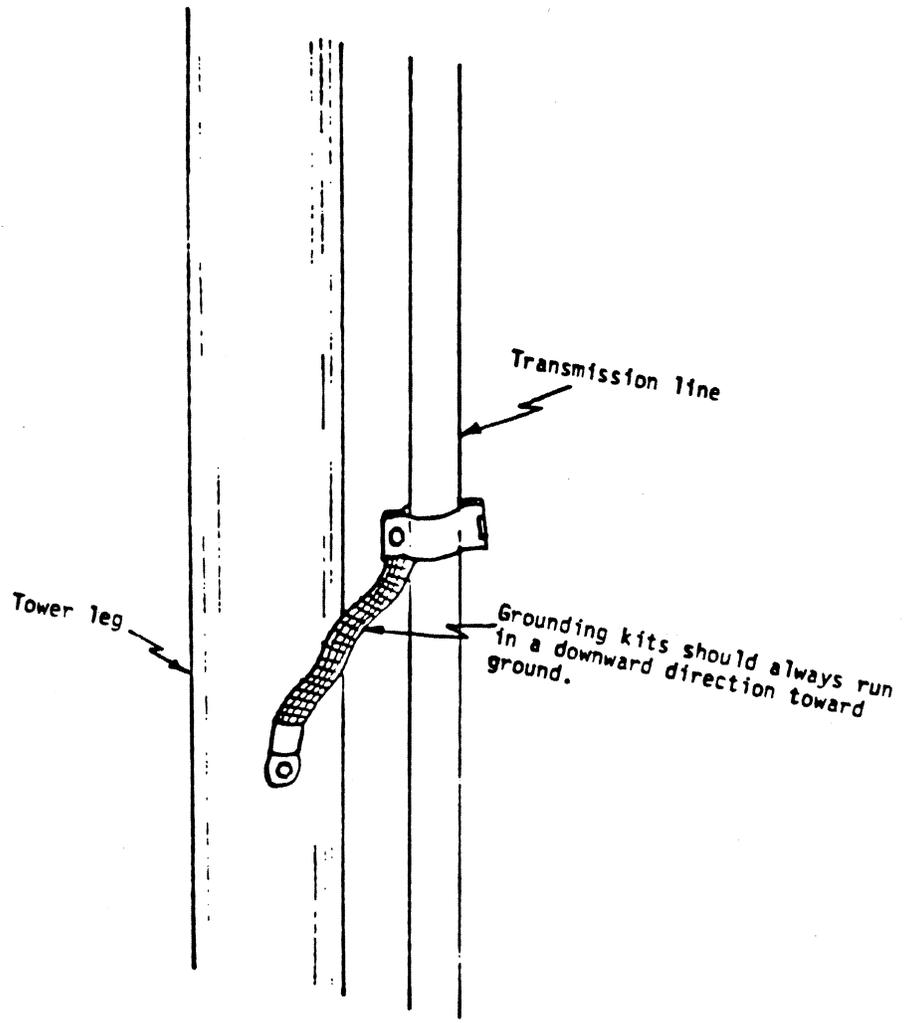


Figure B6
Tower Grounding Kit Installation

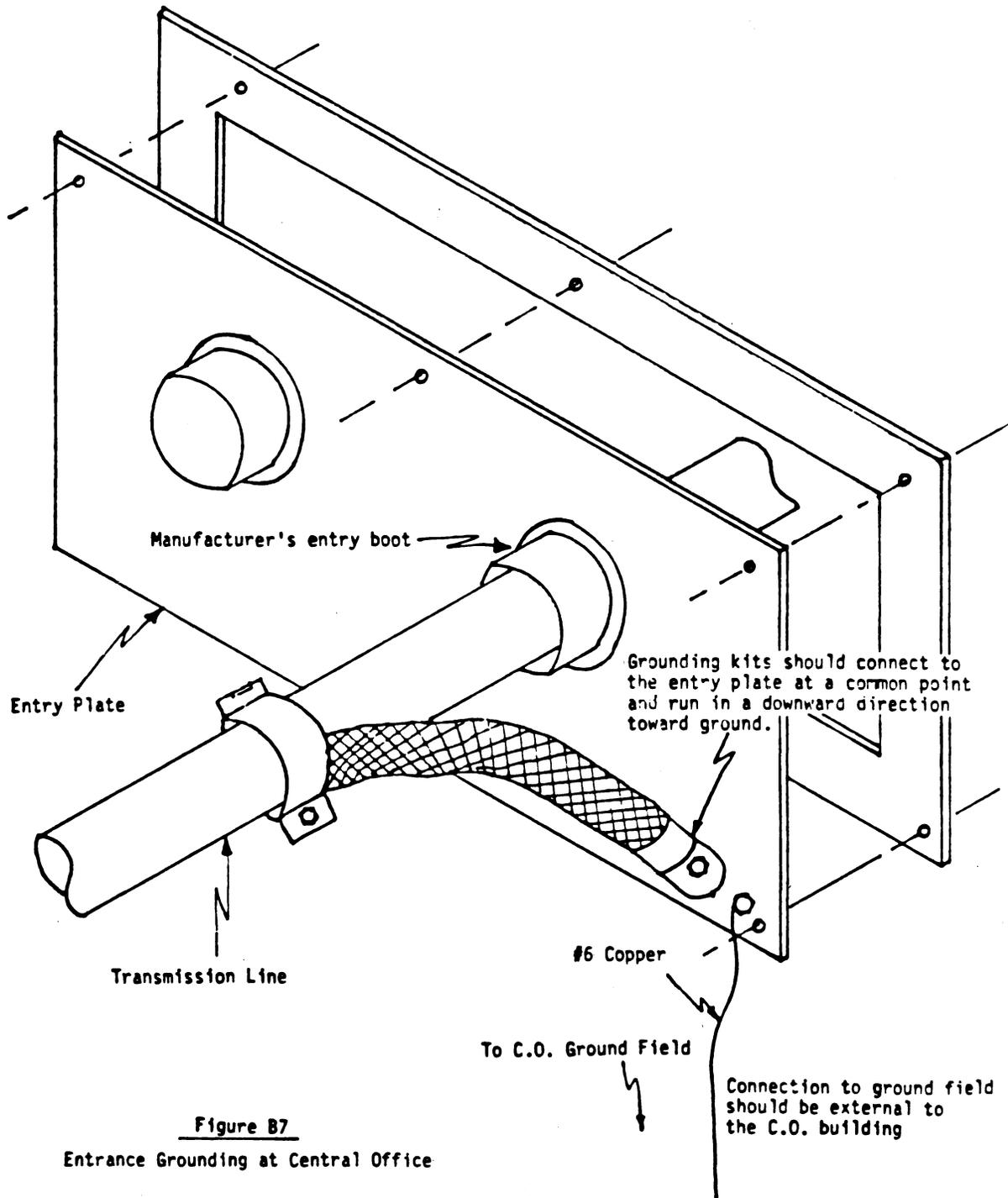


Figure B7
Entrance Grounding at Central Office

APPENDIX C

ANALYSIS OF CENTRAL OFFICE GROUNDING SYSTEM

1. GENERAL

1.1 This Appendix discusses a technique for analyzing a central office grounding system. The method presented will provide information as to where there may be missing elements in a grounding system. Use of this technique is recommended for analyzing newly installed grounding systems. Further, annual analysis of all grounding systems is recommended so that any problems which may have arisen during the year may be detected and corrected.

1.2 The procedure uses a small clamp-on probe together with a portable ammeter. The ammeter should have a useful range from milliamperes to at least twenty amperes. There are several types available which are capable of completing these tests.

2. PROCEDURE

2.1 Start the analysis at the Master Ground Bar (MGB). This is the hub of a central office grounding system (the single point ground).

2.1.1 First, prepare a sketch of the MGB with all of the conductors, labeling each with the name of the ground bar to which it is connected at its other end.

2.1.2 Second, place the clamp or probe around each conductor and read the ac current. Then, record the current at the appropriate conductor on the sketch. Repeat until the current associated with each conductor has been recorded on the sketch. The completed sketch at this location will be similar to the one shown in Figure 1C.

2.2 Proceed next to the Cable Entrance Ground Bar (CEGB) and prepare a sketch similar to the one prepared for the MGB. Then complete the measuring and recording of the conductor currents in the same manner as with the MGB. A sample CEGB sketch is shown in Figure 2C.

2.3 Complete the same operations for all of the remaining ground bars in the office: MDF Ground Bar (MDFB), Ground Window Bar (GWB), and any Intermediate Ground Bars (IGB).

2.4 During preparation of the sketches at each location, check to determine if all of the conductors are connected to the ground bar in accordance with the concepts of TE&CM 810. The most critical conductors are those to the Surge Producers (interior radio equipment, cable shields, and cable pairs), and the Surge Absorbers (power neutral, CO ground field, and water system.)

3. ANALYSIS OF THE CONDUCTOR CURRENTS

3.1 Prediction of the precise current level that will be flowing along each grounding conductor is not possible. These levels are determined by the amount of voltage induced in the outside telecommunications facilities from paralleling power systems. Therefore, only a comparative analysis of the recorded current values can be made. Table I lists the typical range of currents for various grounding conductors.

3.2 The most important factor in the analysis is the comparison of current levels on conductors connected to the Surge Absorbers (power neutral, water system, and C.O. ground field). The maximum current should be flowing on the ac bypass conductor (the conductor between the MGB and the neutral ground bar in the power system entrance panel.) Where there is a metallic water system, the next highest current should be flowing in the conductor between the MGB and the water system. There should be less current flowing on the conductor to the central office ground field than on the other two conductors.

3.2.1 Systems installed in areas where there are no metallic water systems that can be integrated into the system should have the maximum current flowing to the power system neutral via the ac bypass conductor. The current flowing to the central office ground field should be smaller than that flowing to the power system neutral as it would be in systems where all three Surge Absorbers are present.

3.2.2 Some systems will be installed in areas where not only are there no metallic water systems but, sometimes the power systems are operating with either ungrounded neutrals or in a delta configuration. In these areas, the only ground available for the central office will be the central office ground field. The level of induced power influence in these areas will normally be quite low and the measured current to the ground field will usually be in the same range as that found at all offices.

3.3 The range of current that will be typically found flowing to the power system neutral will be in the range of one to twenty amperes. The actual level will fluctuate within this range depending on the level of power influence.

3.3.1 Current flowing toward the water system will be lower than that flowing in the ac bypass conductor. There are several factors that control the level of current in the conductor to the water system. The major factor is how extensive the metallic water system is. When the metallic portion of the system is only ten to fifteen feet (3 to 4.6 meters) in length, the current will typically be in the range of 100 to 1000 milliamperes in offices that are served by power systems that do not have a grounded neutral. Currents in this range found in offices served by grounded-neutral power systems usually indicate that one of two grounding conductors is missing

or open circuited. Either the ac bypass conductor or the conductor between the water system and the neutral ground bar in the power entrance panel (required by the National Electrical Code) is missing or open circuited. This should be corrected before proceeding further. When the office is served by a grounded neutral power system or when the metallic water system covers an extensive area, the current in the conductor to the water system will be in the range of one to five amperes (possibly higher.)

3.3 2 The current measured on the conductor to the central office ground field will be significantly lower than that flowing to the other Surge Absorbers in all cases. This current will typically be in the range of 100 to 500 milliamperes.

3.4 The ac current from power system induction in the outside plant flowing into the office on the cable shields will be in the range of one to twenty amperes. This is controlled by the level of power influence and will fluctuate over a wide range during the day as power system load demand changes. This current will be measured on the conductor between the CEGB and the MGB. Where the conductor from the central office ground field enters the office in the cable vault and is connected to the CEGB, the total current to the MGB will be less than current that flows directly to the ground field from the cable shields. Due to the normal current fluctuations, the currents assumed to be flowing toward and away from each ground bar will not always add precisely. Differences as high as fifteen percent are normal. When the difference is higher than this, remeasure the currents.

3.4.1 The induced current flowing into the office on the cable pairs will normally flow to ground via the battery feeds on the line cards. This current returns to the MGB via the conductor to the positive battery terminal. Its magnitude is typically in the range of 100 to 500 milliamperes. Should a significantly higher current be measured, the ac bypass conductor is usually missing or open-circuited. Some offices have line circuits with a high impedance to ground (10,000 ohms and over). The current between the positive battery terminal and the MGB in these offices will be negligible.

3.4.2 Some central offices are collocated with CATV systems. A significant current will flow into the offices on the outer shields of the coaxial cable associated with these systems. These cable shields should be integrated into the central office grounding system via the CEGB. The current from CATV systems can exceed that which is associated with the outside plant of the telecommunications system. This current will typically range from one to twenty, or more, amperes.

3.5 The range of current measured on all other grounding conductors associated with the grounding system will vary from a trace to several hundred milliamperes. These currents are normal and relate to how closely the equipment in the bays is associated with the the outside plant.

3.6 There will always be some current measured on the conductor to the Ground Window Bar (GWB). This current will usually be in the range of 50 to 200 milliamperes. When a higher current is found, the search should proceed beyond the GWB to determine why the higher current is present and whether such current is detrimental to in the specific equipment installed in the office.

4. VISUAL INSPECTION

4.1 A visual inspection should be completed during measuring. Each grounding conductor should be traced from the ground bar to its far end. There are several items which should be closely checked during this stage of the operation. These are outlined in the following paragraphs.

4.2 The conductor should be continuous, end to end, with no splices, or intermediate terminations. Also, the conductor should be sized for the distance between the two ends, as shown in TABLE A of TE&CM 810.

4.3 There should be no sharp bends along the entire length of the conductor. Sharp bends increase the surge impedance of the conductor reducing the grounding system efficiency.

4.4. Grounding conductors should not pass through any metallic conduit or pipe as this will also increase the surge impedance of the grounding conductor. Should an existing grounding conductor be found passing through a metallic pipe, solidly strap it to the pipe at each end. This will eliminate the adverse condition and provide a low impedance path for surge currents.

4.5 Copper ground bars in the grounding system should be mounted on insulators except for the MDFB. The MDFB may be mounted directly on the metal frame. The protector strips on the MDF should be connected together with #6 solid copper wire, rather than relying on the steel frame to conduct surge currents to ground.

4.6 The area outside the building should also be inspected to determine that the entire grounding system has been properly integrated. The following paragraphs list those items which should be studied during the outside inspection:

4.6.1 Look at metallic fences around the building and surrounding area. If any of the fences pass within six feet of the building, storage facility, ground field, or any other grounded structure, bond them to the grounding system outside of the central office building. This includes straps at all gates to insure continuity to the grounding system when the gates are open.

4.6.2 Radio towers located adjacent to the central office building should have a dedicated ground field as if they were located in an isolated

area (Refer to Appendix B, TE&CM 810.) This ground field should be bonded to the central office ground field outside of the building.

4.6.3 Air conditioning or heating systems that are mounted on platforms, outside and adjacent to the building should also be provided with a separate dedicated ground field. This ground field should be bonded to the central office ground field outside of the building. Further, air ducts from the system that enter the building should have fiber insulating sections in them just before they enter the building. The internal duct system should be bonded into the building steel.

4.6.4 Connections to the central office ground field, outside of the building, should be mounted in hand holes or ground wells (Refer to TE&CM 802.)

5. COMMON PROBLEMS

5.1 Several common problems are listed below that have been found during visual inspections of central office grounding systems. They are included in this Appendix to alert the person reviewing the grounding system to some specific items to watch for.

5.2 The routing of surge-carrying grounding conductors (Surge Producers and Surge Absorbers) in cable racks and troughs parallel to signal carrying conductors that enter the isolated zone this is a rather frequent condition and can result in line circuit damage during periods of surge activity. Since the signaling conductors in this area are not shielded, the coupling is from the E, or voltage field, rather than the H, or magnetic field. Their location is on the central office side of the main frame protectors and thus they are extremely vulnerable to surge damage.

5.3 Conductor size should not change at the end of a grounding conductor routing. This will reduce the efficiency of the grounding conductor's ability to carry surge currents to ground. This condition is most frequently found in the ac bypass conductor near the point where the conductor enters the power system entrance panel, as illustrated in Figure 3C. The ac bypass conductor should be continuous from end to end with no change in conductor size.

5.4 At some locations not only has the conductor size been reduced but an unacceptable butt splice is used, as shown in Figure 4C. Surge currents will not follow a sharp turn, which presents a very high impedance to fast rising surge currents. Instead, the surge currents will seek and find another path to ground. This is likely to result in damage to the sensitive electronic equipment. Therefore, butt splices should never be used in grounding connections.

5.5 Sometimes, the ac bypass conductor is found routed to a branch power panel rather than back to the power entrance panel. This condition can also lead to some unexpected problems. First, the size of the conductor between the branch and entrance panels is apt to be smaller than the recommended size. Second, the conductor between the two panels will be located in metallic conduit and the conductor and conduit will not be solidly bonded at each end. This will cause a high voltage differential to be present during periods of surge current. Last, the conductor between the two panels will be carrying load current from electrical service beyond the branch panel. Part of this current is likely to flow back through the MGB.

Transients which can be transmitted into the switching equipment, can result in damage to electronic components. These transients are due to switching in the power loads. The ac bypass conductor should be routed in the prescribed manner for maximum protection of the switching equipment.

5.6 The protector strips at the MDF should be bonded together with a #6 solid copper conductor but inspection may find that the string of strips has not been bonded to the MDFB. This arrangement produces a high impedance to surge currents and will force the surge into the line circuit.

5.7 Many offices are found lacking secondary power protection. Secondary power protection is a very important aspect of CO protection. There is justification for using such protection regardless of the lightning activity of the area since even in areas of moderate to light activity there will be an occasional thunderstorm and power system transients (switching, etc.) take place in all areas. The cost of the secondary protection is small compared to the cost of repairing damage.

5.8 Sometimes, the conductor from the central office ground field is brought into the cable vault and connected to the CEGB. This configuration can be used where the conductor installed between the CEGB and the MGB is large enough to make one bar an extension of the other. This is accomplished when the conductor is at least 750MCM. Smaller conductors may cause problems and should not be used.

5.9 Some offices have an arrangement where the MGB is divided into two bars. The Surge Absorbers and Surge Producers are all connected to one bar and all other grounding conductors are connected to the other. The conductor between these two ground bars is sometimes under sized. This arrangement is acceptable if the conductor is large enough to make one bar an extension of the other. Installation of a 4/0, or larger, conductor is recommended.

5.10 Locations are frequently found where the grounding conductors have been dressed for appearance at the point of connection to the ground bars. The bends placed in the conductors to improve the appearance increase the impedance to flow of surge currents and reduce the efficiency of the overall

grounding system. The conductors should be connected to the ground bars and routed in the most direct manner possible with, ideally, no bends in the conductors. Where bends are necessary, they should be gentle so as to add minimum impedance to the flow of surge currents.

TABLE I

TYPICAL GROUNDING CONDUCTOR CURRENT RANGES

- A. Office with CO ground field, MGN and metallic water system.
- B. Office with CO ground field and MGN.
- C. Office with CO ground field and metallic water system (delta or uni-grounded wye connected power)
- D. Office with CO ground field (delta or uni-grounded wye power system)

OfficeType: Conductor	A	B	C	D
Between MGB and Power Entrance Panel Board	1-20A	1-20A	10-500mA	10-500mA
Between MGB and Water System	1-5A	1-5A	.1-1A	
Between MGB and CO Ground Field	100-500mA	100-500mA	100-500mA	100-500mA
Between MGB and CEGB	1-20A	1-20A	.2-1A	100-800mA
Between MGB and Positive Battery	100-500mA	100-500mA	10-200mA	10-200mA
Between MGB and GWB	0-100mA	0-100mA	0-100mA	0-100mA
Between MGB and MDFB	100-300mA	100-300mA	50-100mA	50-100mA
Between MGB and CXR, or other Equipment Bays	100-300mA	100-300mA	50-100mA	50-100mA

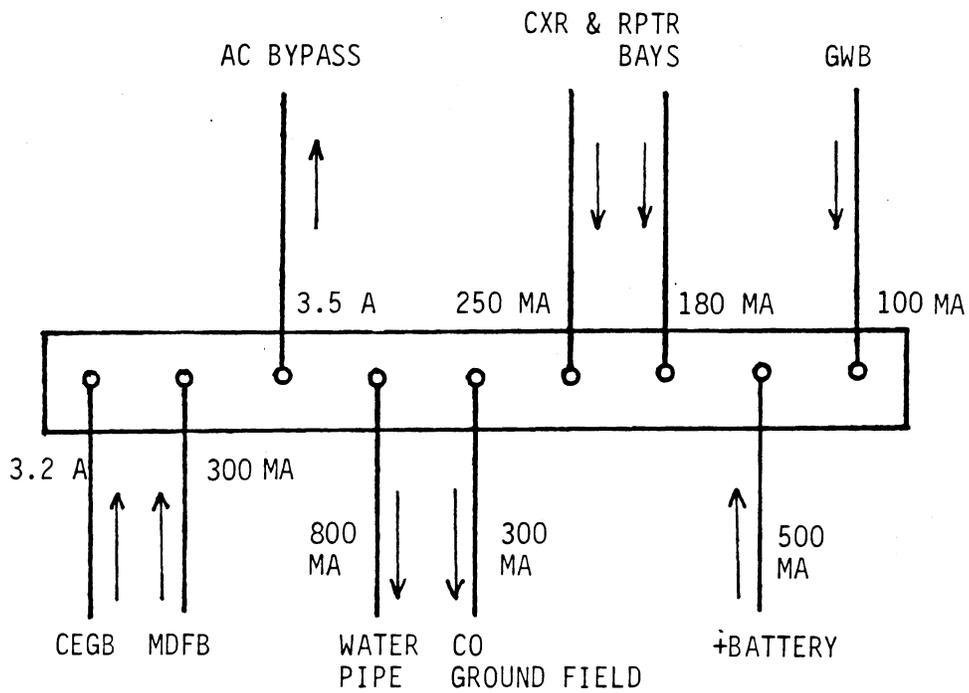


FIGURE 1C

TYPICAL MASTER GROUND BAR CURRENTS

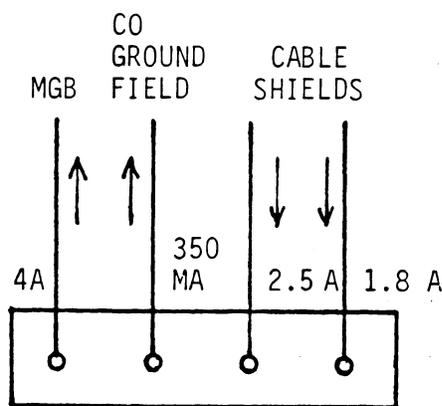


FIGURE 2C

CABLE ENTRANCE GROUND BAR CURRENTS

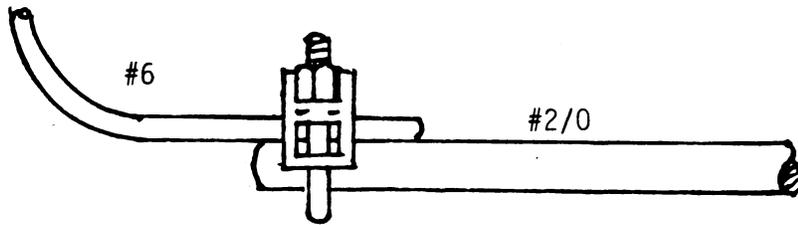


FIGURE 3C

UNDESIRABLE REDUCTION IN SIZE
OF GROUNDING CONDUCTOR

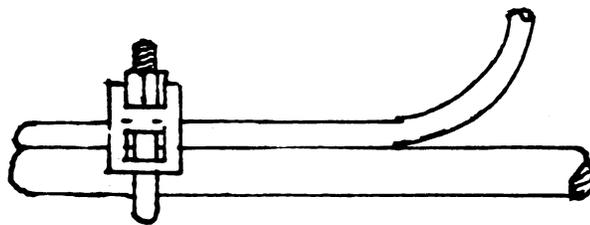


FIGURE 4C

UNDESIRABLE BUTT-SPLICE IN
GROUNDING CONDUCTOR