

KEY TELEPHONE SYSTEM GROUNDING AND SPECIAL PROTECTION REQUIREMENTS

1. GENERAL

1.01 This section contains information on grounding and protection applicable to Key Telephone System (KTS) installations. It is intended to provide general background knowledge needed by the installer. More detailed coverage of related equipment and procedures can be found in Section 460-100-400, Protection and Grounds.

1.02 This section is a complete revision of Issue 1 and provides information that is more usable and easier to understand.

1.03 The terms listed below are defined here with respect to their specific usage in this section:

- (a) **Ground**—The arbitrary zero reference point for an electrical potential. A large conducting body, such as the earth, used as a common return for an electrical circuit. Ideally, earth ground provides a zero-voltage level.
- (b) **Building Ground**—An acceptable ground connection provided by building construction steel in contact with earth ground or a bare copper wire encased in concrete building footing.
- (c) **Cold Water Pipe Ground**—An acceptable ground connection provided by a continuous buried metal pipe with at least 10 feet of length in moist earth and carrying cold water into the building where the KTS is installed.
- (d) **Multigrounded Neutral (MGN) System**—A grounded commercial power distribution system in which the neutral wire is grounded at frequent intervals along the distribution system. MGN service is now in common use and usually provides a good ground point for a KTS.
- (e) **Transient Voltage**—A high-level voltage pulse of short duration and irregular waveshape such as might be induced into a telephone or power line by lightning activity or in power lines by load switching.
- (f) **Surge Current**—Sudden high current caused by a transient voltage.
- (g) **Potential**—Voltage difference between two circuit points.
- (h) **Circuit Ground**—In KTS power supplies, the positive side of the dc output; the reference point for the negative output voltages and the return path for grounded signaling. Physically, it is the terminal labeled "LOC GRD", "GRD", or "G".
- (i) **Frame Ground**—The path through which the frame, case, or chassis of the KTS power supply is connected to the commercial power service ground; "green wire" ground conductor in the power cord. Holds frame at near zero potential if ac power is accidentally shorted to power supply frame. *Not* the same as circuit ground.
- (j) **Entrance Conduit**—The conduit which carries the power service cable from the point of building attachment to the service entrance box where it is fused and distributed.
- (k) **Branch Conduit**—The conduit which carries branch power circuit wiring from the service entrance box to outlet points or secondary service boxes within the building.
- (l) **Potential Equalization**—A means for maintaining two or more circuit points at approximately same potential; usually achieved by bonding points or by providing a single connection point for all circuits involved.
- (m) **High-Rise Building**—A multistory building utilizing structural steel and/or reinforced concrete construction. Separate KTS installations may be located on any or all floors.

2. BASIC PROTECTION REQUIREMENTS

2.01 Station protection is always required where telephone or power lines are exposed to

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lightning-induced transients. Protection is also required when outside plant telephone facilities (cable, open wire, drops, etc) are exposed to possible contact with 300-volt (or higher) power line circuits. **Therefore, all KTS installations shall be grounded and protected in accordance with this practice unless otherwise specified by local instructions.**

2.02 Unprotected telephone equipment can also be damaged in lightning areas even though both the telephone and power lines are entirely buried. In this case, damage can occur when a lightning stroke causes the earth ground associated with an installation to rise with respect to the central office (CO) ground.

2.03 *KTS installations usually require station protection in lightning areas regardless of power exposure of the telephone plant.* This condition is discussed in more detail in Part 4 of this practice. Briefly, however, the key station must be protected from the voltages that can be developed between any two ground points. These ground points include the KTS power supply ground, the commercial power ground, the station protection ground, and the CO or PBX ground. **It is strongly recommended that protection of KTS lines always be considered in areas where thunderstorm activity can occur.** The lack of such protection can result in damage to and failure of circuit pack and power supply components. Fig. 1 illustrates a typical installation protected and grounded according to the requirements presented here.

2.04 For detailed information on protector selection, ground rod installation methods, hardware, etc, refer to Section 460-100-400.

2.05 This practice outlines grounding and protection arrangements that will satisfy the requirements for most installation situations. Illustrations of both good and poor grounding methods are shown, but involved theoretical explanations have been avoided. Situations not adequately covered by this information should be referred to the responsible local supervisor or designated company representative.

2.06 *High-Rise Buildings:* The material in this practice applies equally as well to KTS installations in high-rise buildings as it does to smaller structures. It is recognized, however, that special problems may be encountered in the location of satisfactory grounding points in high-rise buildings.

Ideally, a specific telephone ground is provided on each floor during construction; this ground should be located and used. Otherwise, proper grounding must be accomplished through the methods presented in this practice.

2.07 In exposed areas do not install KTS equipment where the necessary station protection grounding cannot be provided (ie, if access to the water system or power ground is not possible and a ground rod cannot be driven). Advise the local supervisor or designated company representative of the situation as soon as possible.

3. BASIC PROTECTION THEORY

Carbon Block Operation

3.01 An electrical current will arc across a gap (an air space) in a circuit when a specific level of voltage is impressed across the circuit points that form the gap. Station-type carbon block protectors utilize this arcing action to limit foreign potentials on telephone lines.



Station protectors must be equipped with 3-mil carbon blocks (white blocks). Do not use blue or yellow blocks.

The 3-mil blocks will arc over at a peak voltage of about 600 volts.

3.02 The effect of a protector with 3-mil carbon blocks on a typically high-voltage waveform is illustrated in Fig. 2. The blocks operate on either positive or negative voltage peaks that exceed the firing point of the gap (approximately 600 volts in this example).

3.03 The waveform in Fig. 2 can represent any high-voltage condition that can develop on telephone lines, for example, lightning surges, switching transients, power crosses, etc. In any case, the carbon blocks arc over as the voltage level reaches point A. The current flow associated with the foreign voltage will be shunted to ground via the arc path; the voltage on the station telephone line, with respect to the protector ground terminals, will be equal to the voltage drop across the carbon blocks (usually less than 50 volts). These conditions will be maintained, as illustrated by dark shading, until the voltage is reduced to the level indicated by point B. In other words, the arc is sustained

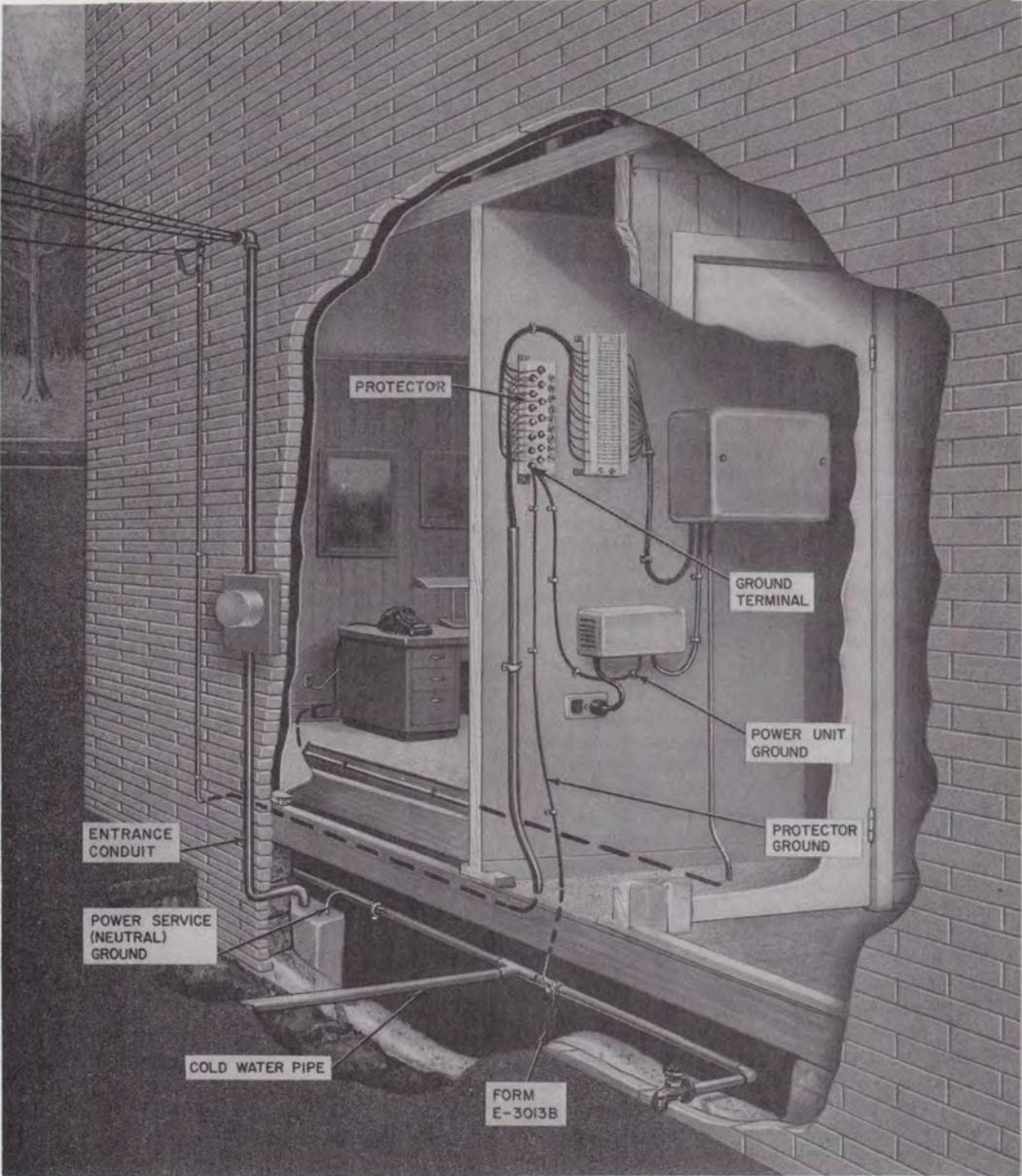


Fig. 1—Properly Grounded 1A2 Key Telephone System

and the line is held near ground potential until the voltage declines to a level that will cause the arc to extinguish. Point B was selected as typical of most low energy transients for illustration purposes only; this point can vary considerably depending on the amount of current involved.

3.04 That part of the waveform between points A and B, indicated by the dashed line, represents the voltage levels that would have been impressed across station apparatus (line circuits, power supply, telephone sets) had station protection not been provided or had the protector blocks failed to operate properly.

3.05 Power Crossed with Telephone Line:

Protectors are also required to protect telephone equipment and customer premises from primary power voltages that can become connected to the telephone line as a result of physical crosses between lines. This electrical protection is provided in a manner similar to the operation described above, except the telephone line will be permanently grounded if the power cross continues for a sufficient period of time. Thus, protectors will safely bypass large currents to ground until the current path is opened.

3.06 Gas Tube Type Protectors: Gas tube protectors function in a manner similar to carbon block operation, except that the tubes do not always fail in the shorted mode as carbon blocks do. (Failure of a protector means that it does not recover to its normal condition after carrying a surge current to ground.) Gas tubes generally have a lower firing voltage than carbon blocks and a considerably longer life expectancy. However, they are expensive and do not provide a greater degree of line protection. Therefore, gas tubes are to be used only when locally authorized; they are usually installed in areas where excessive carbon maintenance is required due to frequent thunderstorm activity. However, the present generation of gas tubes may fail in the open mode (ie, not be able to bypass another surge to ground) and should not be used in place of carbon blocks, but rather, in addition to them, strictly to reduce maintenance visits. This arrangement will insure that the line will continue to be protected in the event of a tube failure. (The 123B1A protector provides carbon blocks and gas tubes in a parallel arrangement.)

3.07 Fuseless and Fused Protectors: Telephone plant is usually arranged in a way that permits the use of fuseless protectors. These protectors provide only carbon block-type protection, but they are capable of handling large currents. It is necessary, however, that fusible links be located between the protectors and possible power contact points to justify use of fuseless protectors. This is usually accomplished by providing a length of fine gauge (finer than the cable or drop facilities) cable pairs or jumper wires between CO lines and the station drop. For example, a fusible link can be provided by connecting a terminal to a 22-gauge cable with a length of 24- or 26-gauge cable. The length of finer cable acts as a fuse and will burn open before power levels exceed the rated capacity of the protectors.

3.08 Fused protectors are necessary under certain conditions, usually where a fusible link is not installed and the station protection is located inside a building. The following conditions require the application of fused protectors.

- (1) The station is served by open or rural wire, the power system is not MGN, and the power neutral is not grounded to a water pipe.
- (2) The station is served by open or rural wire and no bridle wire fusible link is provided.
- (3) Underground service wire is connected by encapsulated splices to 19- or 22-gauge buried cable that is jointly buried with power lines. Where this condition exists, a fused protector should be specified on the service order.

4. DESCRIPTION OF REQUIRED KTS PROTECTION

4.01 Improper protection of KTSs can result in station equipment damage that may require frequent visits to station locations for the purpose of replacing defective line equipment, power supplies, lamps, and fuses. Damage of this type is usually caused by lightning or power-induced voltage transients. A good protection system can substantially reduce these problems.

4.02 A telephone station protection system consists of protection equipment and wiring that permits only relatively small voltage differences to develop between telephone equipment and other electrical equipment or grounded building fixtures when either lightning or power surge current is

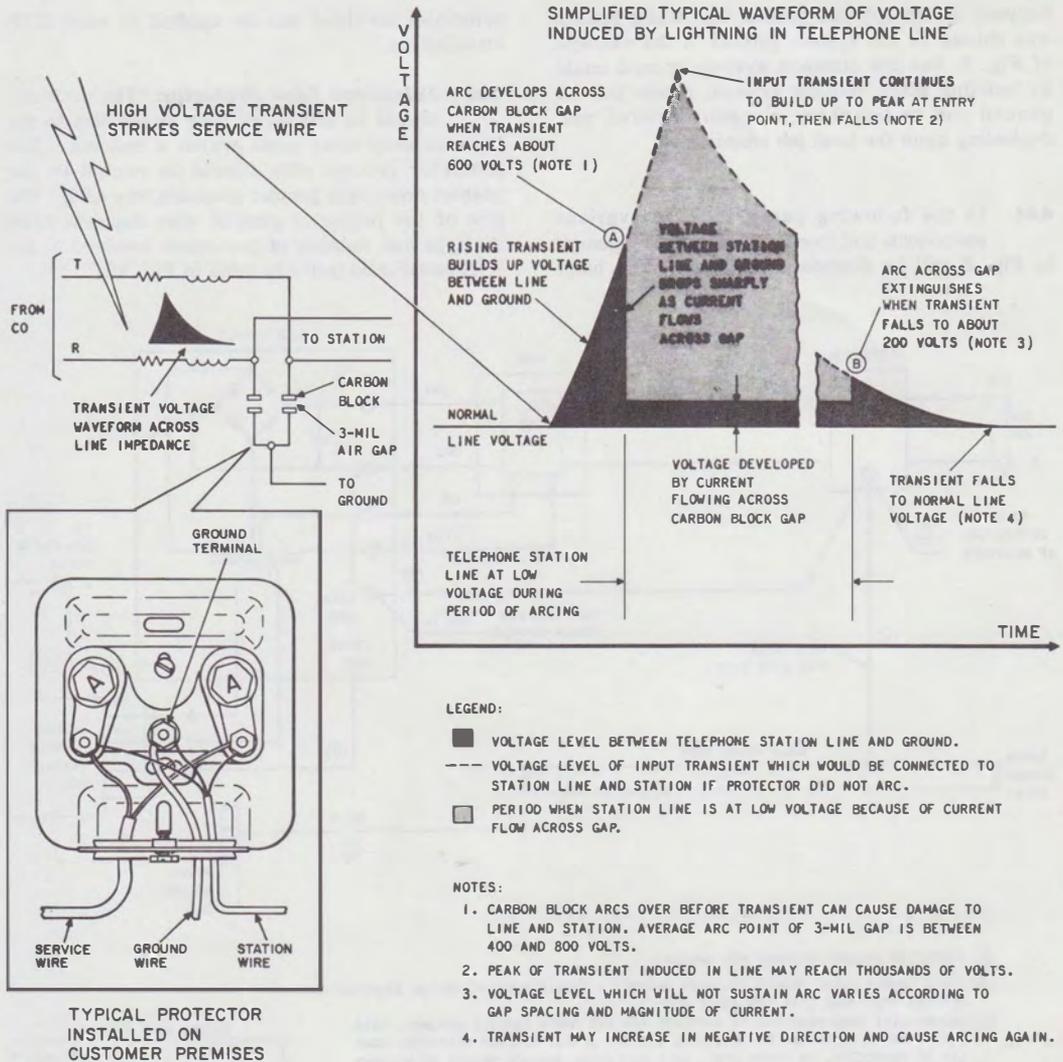


Fig. 2—Carbon Block Action on Telephone Line Hit by High-Voltage Transient

flowing. The primary danger of allowing high-voltage levels to develop between ground points is that current can arc across from one circuit to another if the potential difference becomes sufficiently high. This flow of current can damage equipment.

4.03 KTS protection usually consists of basic telephone line protection (standard fused or

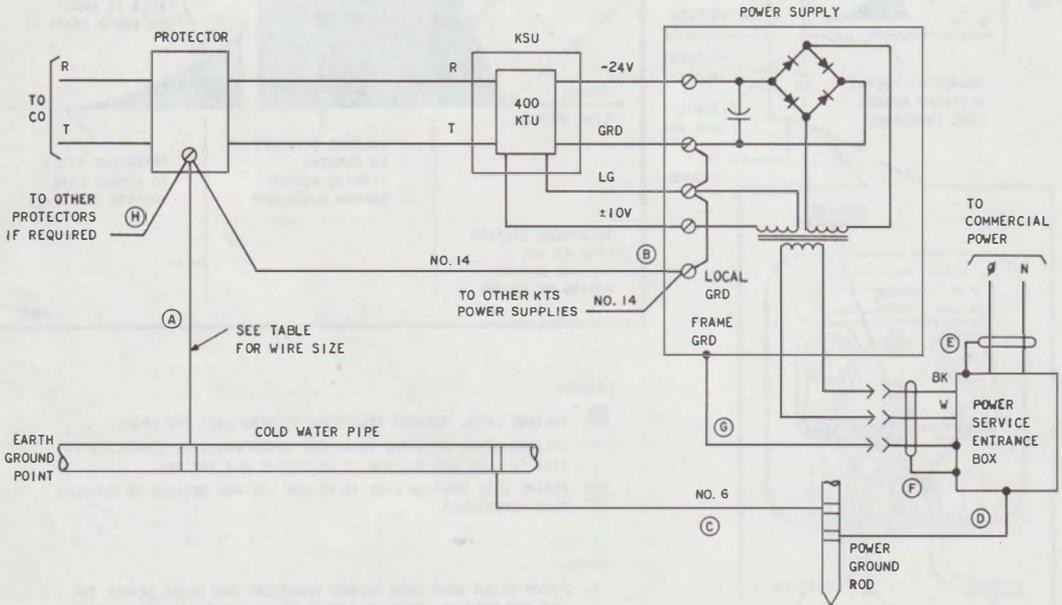
fuseless protectors) connected to an acceptable ground point. Fig. 3 illustrates a typical KTS grounding arrangement that meets protection requirements if installed properly. Note that all grounded points are connected to the cold water pipe either directly or by way of a bond wire. Utilization of the same ground point limits the level of potential differences that can develop

between system ground points. The water system was chosen as the system ground in the example of Fig. 3, but the common system ground could be building steel, footing ground, power service ground rod or telephone company ground rod, depending upon the local job situation.

4.04 In the following paragraphs, the various components and connections of the arrangement in Fig. 3 will be discussed in detail. The basic

principles involved can be applied to most KTS installations.

4.05 **Telephone Line Protector:** The protector should be located as near as possible to the cable or drop entry point within a building. The protector ground wire should be routed to the nearest acceptable ground available (see 4.06). The size of the protector ground wire depends upon the type and number of protectors involved in the KTS installation (refer to table in Fig. 3).



LEGEND:

- (A) PROTECTOR GROUND (PRIMARY KTS GROUND).
- (B) POWER SUPPLY LOCAL GROUND (CIRCUIT GROUND) - PROVIDES FOR POTENTIAL EQUALIZATION BETWEEN TELEPHONE LINE AND POWER SUPPLY.
- (C) GROUND WIRE BOND REQUIRED TO EQUALIZE KTS AND POWER SERVICE GROUNDS. THIS BOND MUST BE INSTALLED BY TELEPHONE COMPANY IF NOT ALREADY PROVIDED. BOND CAN BE CONNECTED, ON POWER SIDE, TO A DIFFERENT SERVICE GROUND POINT THAN SHOWN (FOR EXAMPLE, ANYWHERE ALONG GROUND WIRE (D) OR TO SERVICE ENTRANCE CONDUIT (E)).
- (D) POWER SERVICE GROUND WIRE.
- (E) POWER SERVICE ENTRANCE CONDUIT.
- (F) POWER SERVICE BRANCH CONDUIT - NOT ACCEPTABLE GROUND POINT FOR TELEPHONE EQUIPMENT.
- (G) GREEN WIRE GROUND - CONNECTS FRAME GROUND OF POWER SUPPLY TO POWER SERVICE GROUND BY WAY OF GROUND PRONG IN THREE-PRONG PLUG. NEVER CUT OFF GROUND PRONG TO FIT TWO-PRONG OUTLET; USE ADAPTER DESCRIBED IN PARAGRAPH 4.08.
- (H) BOND BETWEEN PROTECTORS. GROUND WIRE BETWEEN PROTECTORS SHOULD BE SAME SIZE AS GROUND WIRE (A).

GROUND WIRE CAPACITY

SIZE	NO. OF PROTECTED CKTS	
	FUSELESS	FUSED
NO. 14	1	3
NO. 12	2	6
NO. 10	6	7
NO. 6	7 OR MORE	8 OR MORE

NOTE:

WIRE BETWEEN PROTECTORS SHALL BE SAME SIZE AS WIRE BETWEEN PROTECTOR AND GROUND.

Fig. 3—Typical KTS Grounding Arrangement

Ground Selection

4.06 Selection of an acceptable point for connecting the protector ground wire is of the utmost importance in achieving a well-protected installation. The protector ground serves as the primary KTS ground reference point. The flow chart in Fig. 4 is designed to help the installer identify the best choices of ground available in most job situations. The decision blocks contain questions regarding the installation conditions, the responses to which will lead to selection of an acceptable ground. The flow chart should be followed until the last block in the path is reached. The referenced notes and figures provide additional information and illustrations of actual installation procedures.

4.07 It may sometimes be difficult to decide whether a ground point is acceptable or not, and the installer will have to rely on his experience and judgment. In general, a ground point is **unacceptable** if it does not make good contact with earth ground. The definitions in 1.03 are a practical guide to selecting the right ground, in conjunction with the use of the flow chart. The following points must also be considered:

- No one type of grounding system—power service, cold water pipe, or building—should be regarded as basically superior to another. However, an **MGN power system** can usually be counted on for good grounding while the others may be difficult to verify.
- A metallic cold water pipe is acceptable **only** if it is known to meet the requirements of 1.03(c).
- Plastic pipe is **always unacceptable**. Furthermore, even if the interior cold water pipe is metallic, it is possible that the buried service pipe is plastic.
- Insulating joints or sections are often installed in private water systems to reduce noise and vibration from pumps. They make metallic pipe **useless** for grounding unless they are bonded across to buried metallic pipe, or unless the pipe is bonded to another acceptable ground.
- In cases where more than one acceptable ground is available, route the protector

ground wire as directly as possible to the nearest one.

- Always verify that when the ground sources used for the commercial power service ground and the telephone protector ground are different, they are bonded together.

KTS Power Supply Local Ground (Circuit Ground)

4.08 After the protector ground wire (A in Fig. 3) has been connected to the best available ground (a cold water pipe in the typical situation shown in Fig. 3), the power supply output circuit (or local) ground must always be connected to the protector ground terminal. This connection (B) provides a necessary ground for the power supply and also insures that the power supply and protector ground reference points will be at the same potential under all surge conditions. The connection should be made with wire no smaller than 14-gauge. Route ground wire (B) as physically close as possible to the telephone lines between the protector and the key service unit (KSU). This will increase electrical coupling between the telephone lines and the ground wire which, in turn, reduces the potential difference between them and helps prevent arcing. In the case where several power supplies are used, strap the ground terminal of each supply (with a 14-gauge wire) to the ground terminal of the one that is connected to the protector ground.



Never use branch electrical conduit (F) as the ground point for the power supply local ground (B). Branch conduit is totally unacceptable as a KTS ground because good electrical continuity usually cannot be guaranteed, the actual connection between the conduit and earth ground can be difficult to identify, and branch conduit runs usually involve unknown distances to ground.

4.09 KTS Power Supply Frame Ground: The case or framework of the power supply is normally grounded through the ac green wire circuit (G in Fig. 3). The green wire connects to the power service ground by way of the power supply cord, the ground prong of the power cord plug, and the mating connector of a 3-conductor power outlet. If only a 2-conductor power outlet is available and the outlet box is known to be grounded, a Hubbell BL12433 adapter (or equivalent) may be

HOW TO SELECT A GOOD GROUND FOR KTS PROTECTOR

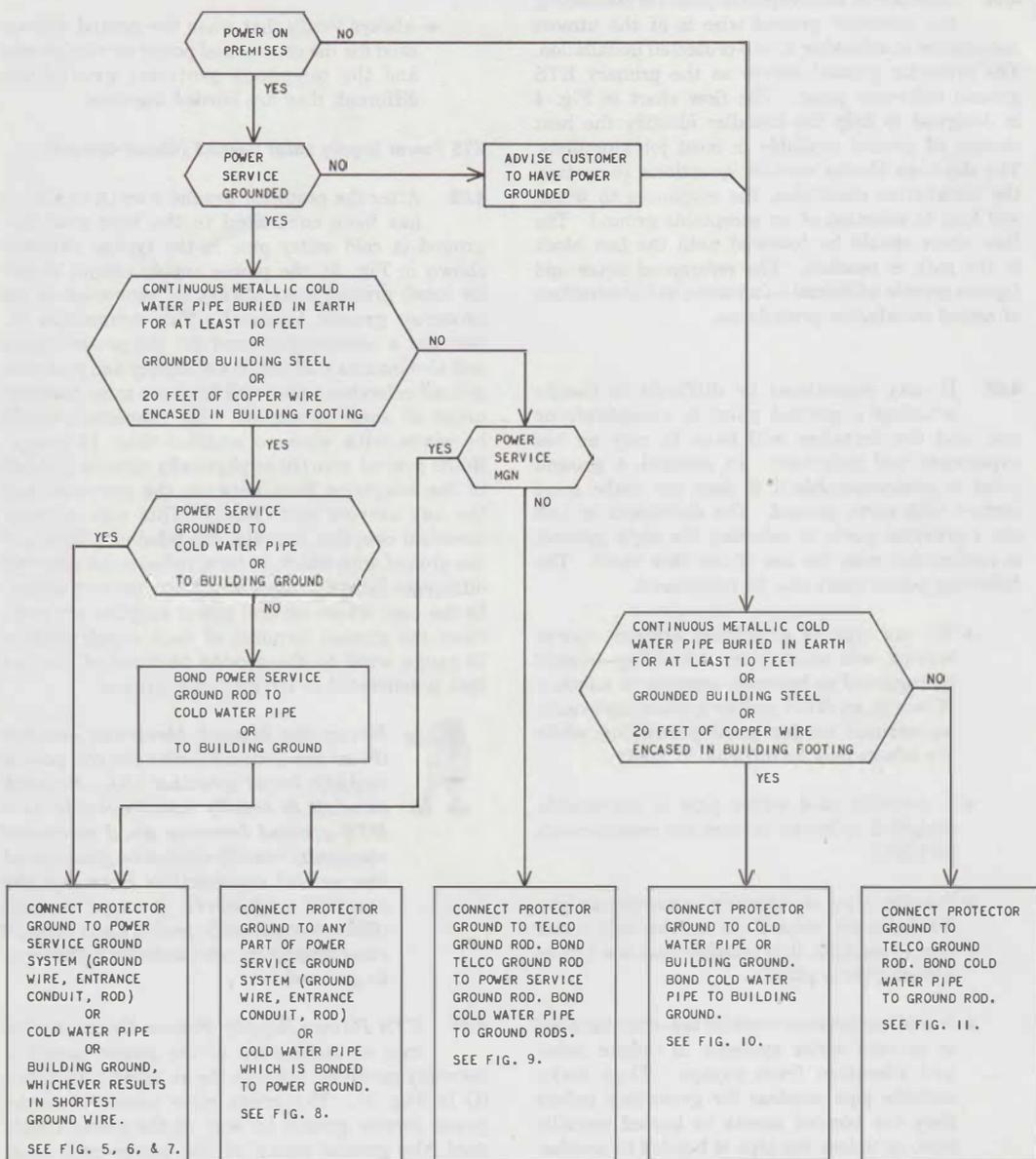


Fig. 4—Protector Ground Selection

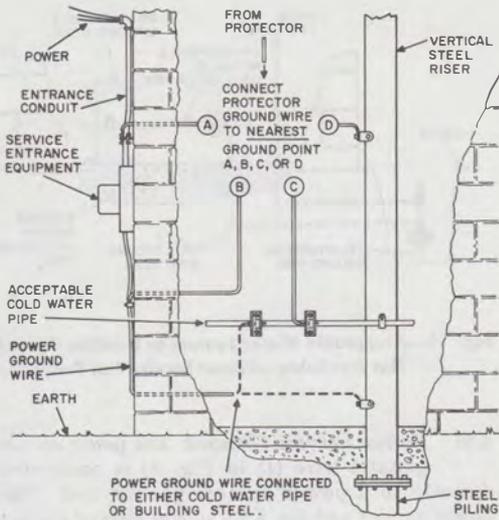


Fig. 5—Acceptable Water System or Building Ground—Power Service Grounded to Cold Water Pipe or Building Steel

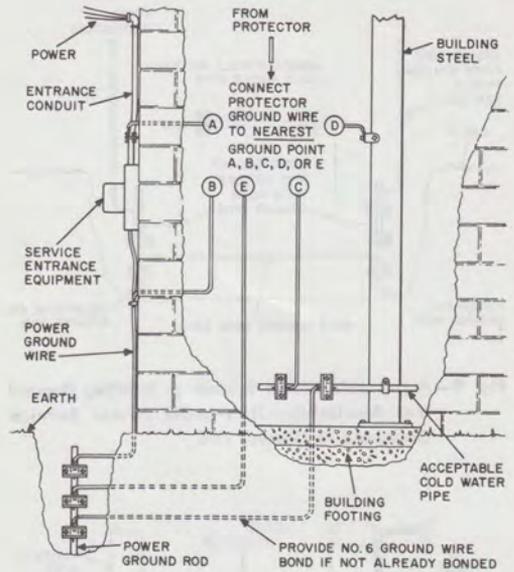


Fig. 7—Acceptable Water System—MGN Power Service Grounded to Ground Rod

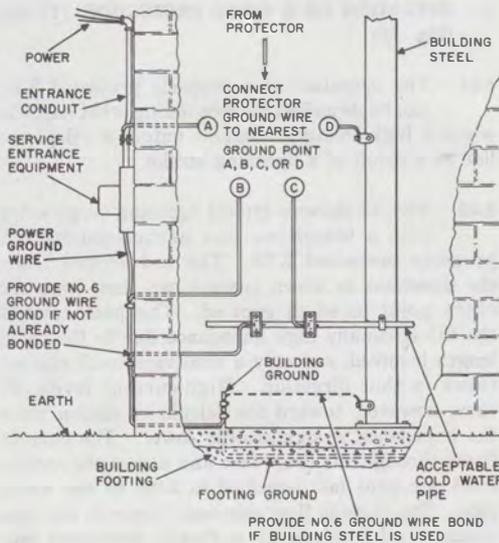


Fig. 6—Acceptable Water System or Building Ground—Power Service Grounded to Building Ground

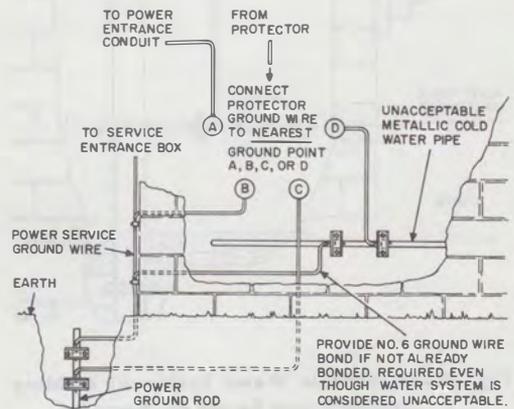


Fig. 8—Acceptable Water System or Building Ground Not Available—MGN Power Service Grounded to Ground Rod

used to match the 3-prong plug to the outlet. When the available power outlet box is not grounded, the framework ground of the power supply must

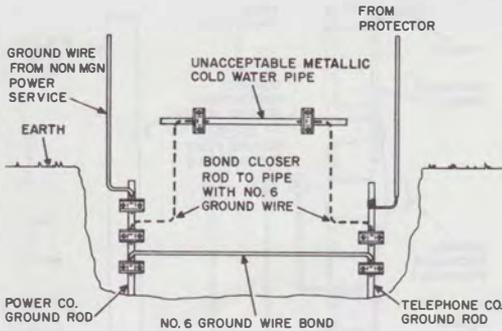


Fig. 9—Acceptable Water System or Building Ground Not Available—Non-MGN Power Service Grounded to Ground Rod

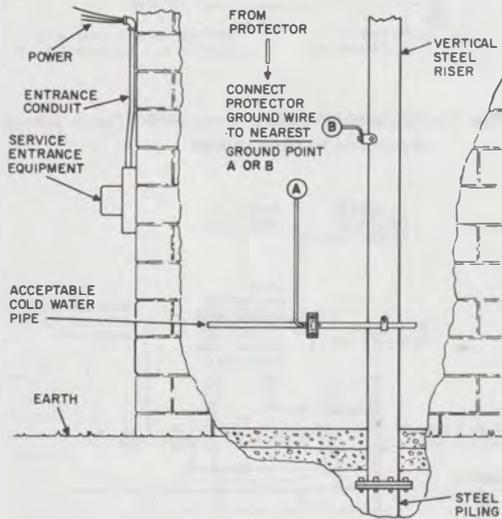


Fig. 10—Acceptable Water System or Building Ground—Power Service Not Grounded

be directly connected to the nearest acceptable system ground point through a 14-gauge, or larger, wire.

Caution: *Never modify the power supply plug by cutting off the ground prong to adapt it for use with a 2-conductor outlet.*

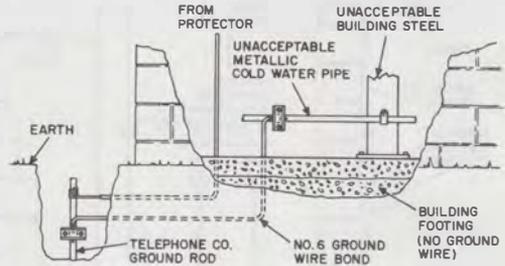


Fig. 11—Acceptable Water System or Building Ground Not Available—Power Service Not Grounded

4.10 Power Service Ground: The power service ground wire (D in Fig. 3) is connected directly to a power system ground rod. The power service and the KTS should always share a common ground source; this can be accomplished by bonding the two grounds together with No. 6 wire (C). If the power company has not already bonded their power ground rod to the ground selected for the KTS, the telephone company must do so as part of the KTS installation.

5. OPERATION OF A GOOD PROTECTION SYSTEM (Fig. 12)

5.01 The operation of a properly protected KTS can be described by considering what happens when a high-voltage transient enters a telephone line as a result of a lightning stroke.

5.02 Fig. 12 shows a typical lightning surge entry into a telephone line associated with a properly protected KTS. The red arrows show the directions in which current can flow from the entry point to earth ground. The path toward the CO is usually high impedance due to the cable length involved, and only a relatively small current flows in that direction. High-current levels do flow, however, toward the telephone station since the impedance is significantly lower. The current flows through the drop wire and across the carbon block air gaps (as described in 3.02) to the water pipe. The current flow continues through the pipe system until the energy is finally dissipated into the earth.

5.03 Meter M1 (a symbolic way of showing the magnitude of the voltage difference between

points) indicates that the voltage difference between the KTS protector ground and the power service ground is minimal; they are connected to the same water pipe. Therefore, since the KTS power supply ground is connected to the protector ground, the voltage between the power supply and the commercial power service is small, and the possibility of internal arcing between circuits is eliminated.

5.04 Meters M2 and M3 indicate that a small voltage difference, equal to the firing voltage of the carbon blocks, does develop between the telephone line and both the KTS power supply and the commercial power service. However, its maximum peak is not high enough to cause arcing from one circuit to another.

6. KTS INSTALLATIONS EXPOSED TO SURGE DAMAGE DUE TO IMPROPER GROUND CONNECTIONS

Protector Grounded to Ground Rod (Fig. 13)

6.01 Fig. 13 illustrates an installation similar to the one shown in Fig. 12, except a ground

rod rather than a water pipe was provided as the protector ground. The difference between these two installations might seem trivial at a glance, but a more detailed evaluation of the possible effects will demonstrate that a vast difference in protection capability can actually exist.

6.02 As was the case in Fig. 12, the protector blocks will operate and surge currents will flow toward earth ground by way of the protector ground. However, because the current must flow through the ground wire and ground rod, a high-voltage difference (possibly several kilovolts) can develop between the protector ground terminal and the water pipe system (meter M1). Since the line side of the protector is at approximately the same potential as the ground side while the carbon blocks are conducting, the telephone line potential (M2) above the power supply local ground (which is connected to the water pipe ground) will be almost the same as that indicated by M1. Meter M3 shows that the same potential difference also exists between the telephone line and the commercial power leads.

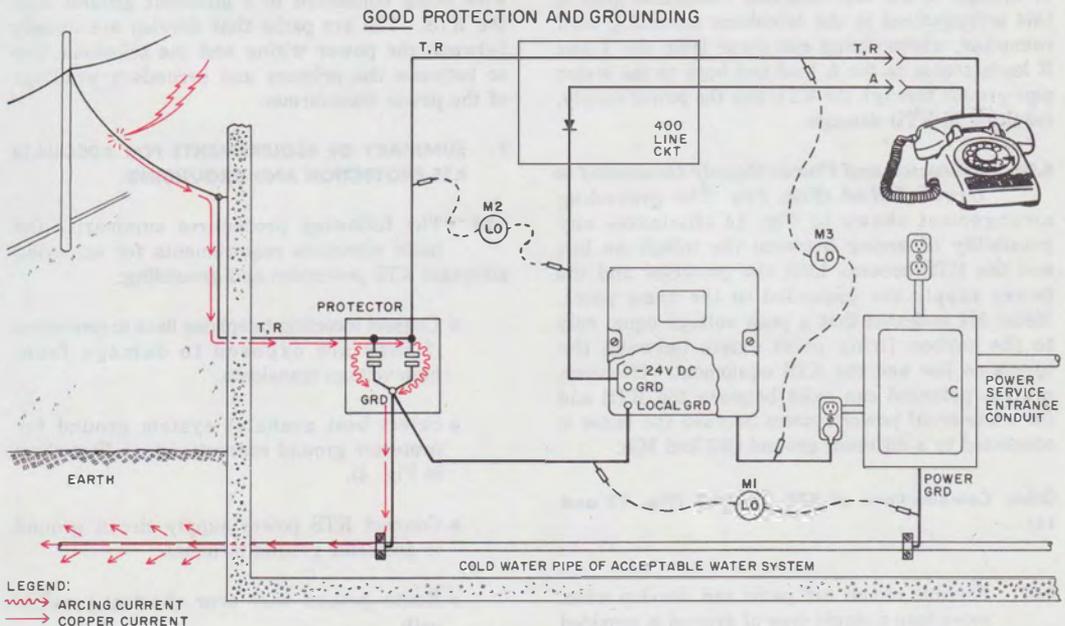


Fig. 12—All Grounds Bonded to Cold Water Pipe

6.03 The red arrows show how current can flow toward the water pipe ground if sufficient potential is present to arc from the telephone line to another circuit path. For example, an arc can develop between the telephone leads and the power supply leads on a 400D KTU printed wiring board at about 2 kilovolts. Therefore, in the case illustrated by Fig. 13, KTU component damage is most likely to occur as a result of surge current flow from the telephone line to the power supply ground (cold water pipe) through KTU components.

6.04 A surge current that enters a poorly grounded circuit will seek a better ground path associated with adjacent circuitry if circuit paths are close enough together to permit an arc to develop. Therefore, it is extremely important that all system grounds be provided from the same ground source to minimize interaction between system grounds and reduce damaging potential differences.

6.05 Fig. 13 also illustrates that an arc path can develop between the telephone set and nearby electrical outlets or other grounded systems, resulting in damage to the set. Another vulnerable area in this arrangement is the telephone mounting cord connector, where arcing can occur from the T and R leads across to the A lead and back to the water pipe ground through the KTU and the power supply, resulting in KTU damage.

6.06 *Protector and Power Supply Grounded to Ground Rod (Fig. 14):* The grounding arrangement shown in Fig. 14 eliminates any possibility of arcing between the telephone line and the KTS because both the protector and the power supply are grounded to the same point. Meter M1 indicates that a peak voltage equal only to the carbon firing point exists between the telephone line and the KTS equipment. However, a large potential can exist between the KTS and the commercial power system because the latter is connected to a different ground (M2 and M3).

Other Combinations of KTS Grounds (Fig. 15 and 16)

6.07 Possible circuit arc paths can develop when more than a single type of ground is provided for the KTS. For example, Fig. 15 illustrates another grounding arrangement that exposes the KTS equipment to possible damage from line surges.

The water pipe ground that is shown connected to the power supply is a better ground (lower resistance) than the ground rod; therefore, some of the surge current in the telephone line will attempt to arc across local circuitry in order to discharge energy into the better ground.

6.08 A ground rod is used to ground all system points in the installation shown in Fig. 16. This diagram illustrates how a ground, which is not the best available, can offer system protection as long as all grounds are connected to this point. Note, however, that high-voltage levels can develop between this system and the local water system (meter M1) or with respect to local building steel. Arcing could occur from some part of this installation to a nearby water pipe.

6.09 *Commercial Power Line Surges:* Commercial power line surges can also cause KTU, lamp, and power supply damage. Some system damage can result when these high-level transient voltages are coupled through the KTS power supply by transformer action. However, equipment damage occurs more frequently as a result of the neutral wire being connected to a different ground than the KTS. The arc paths that develop are usually between the power wiring and the telephone line or between the primary and secondary windings of the power transformer.

7. SUMMARY OF REQUIREMENTS FOR ADEQUATE KTS PROTECTION AND GROUNDING

7.01 The following procedures summarize the basic minimum requirements for achieving adequate KTS protection and grounding:

- Connect incoming telephone lines to protectors if they are exposed to damage from high-voltage transients.
- Select best available system ground for protector ground connection (use flow chart in Fig. 4).
- Connect KTS power supply circuit ground to protector ground terminal.
- Route ground wire over shortest possible path.
- Bond power service ground to KTS ground source if they are not the same.

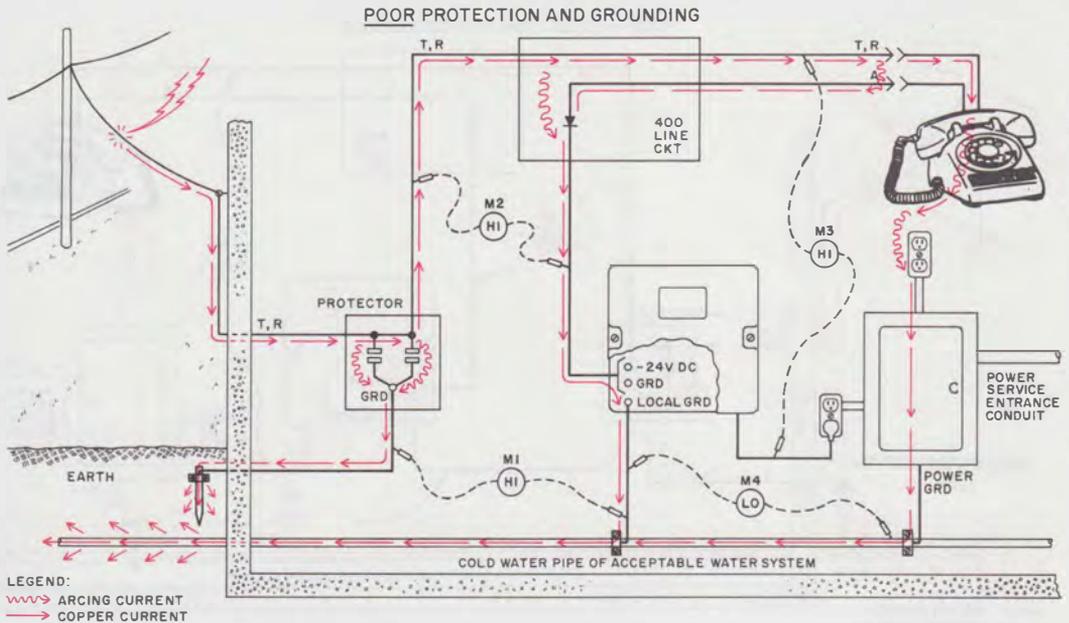


Fig. 13—Protector Ground Bonded to Ground Rod and KTS Power Supply and AC Power Grounds Bonded to Cold Water Pipe

- Be sure that KTS power supply frame ground is connected to commercial power service ground.

7.02 Certain procedures must be avoided when protecting a KTS installation:

- Do not use branch circuit conduit for ground.
- Do not use sprinkler system, gas, or hot water pipes for ground.
- Do not splice ground wire more than once.
- Do not connect power supply circuit ground and frame ground together.
- Do not cut off the ground prong on the power supply plug.

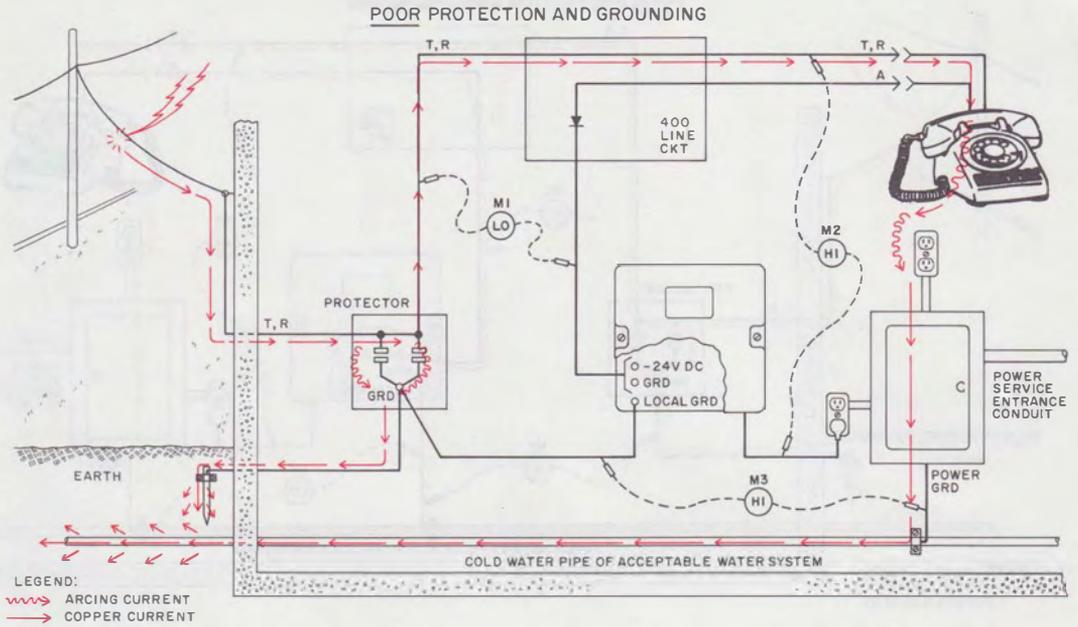


Fig. 14—Protector and KTS Power Supply Grounds Bonded to Ground Rod and AC Power Ground Bonded to Cold Water Pipe

MARGINAL PROTECTION AND GROUNDING

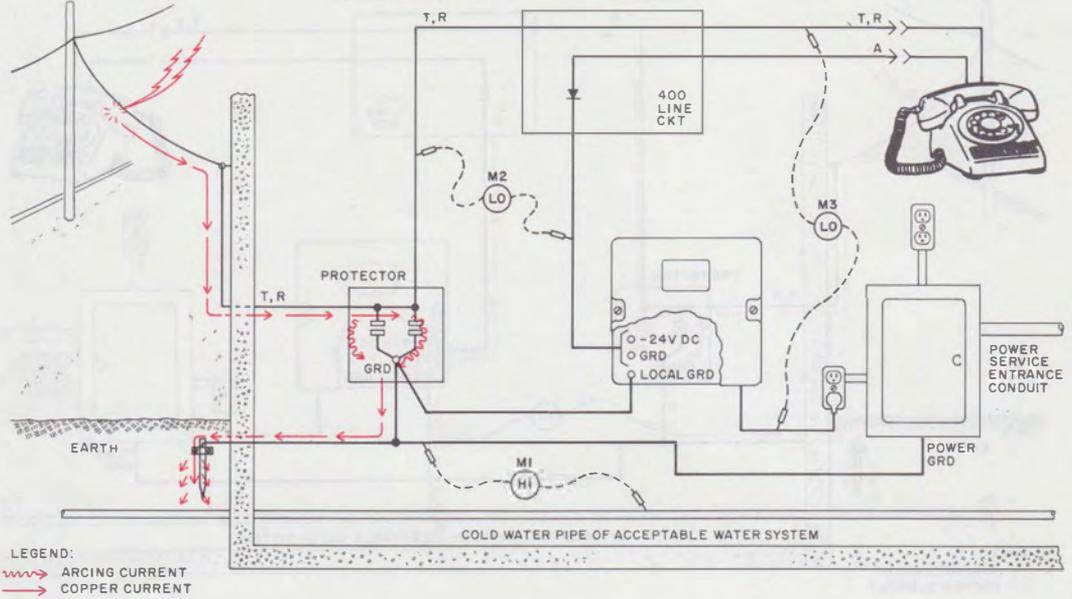


Fig. 16—All Grounds Bonded to Ground Rod