

ELECTRICAL PROTECTION OF CARRIER EQUIPMENT

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FIGURES

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and equipment manufacturers with information and recommendations on the electrical protection of carrier equipment. The primary purpose of this section is to discuss equipment protection considerations. However, the safety of the general public and telco personnel always take priority over equipment protection. Safety considerations are briefly covered in a generalized manner; but it should be noted that this section is not a safety manual. National and local electrical safety codes outline specific requirements related to safety. The generalized recommendations in this section are intended to be in agreement with national and local codes. In the case of conflict, the national and local codes must be followed.

1.2 There are national and industry standards and guidelines on electrical protection, safety, smoke, fire and related subjects. Some of these publications provide very narrow coverage of their subject; but others are broad national standards enforced by local regulations. Two major national standards are the National Electrical Code sponsored by the National Fire Protection Association; and the National Electrical Safety Code sponsored by the IEEE.

1.3 Certain REA publications discuss electrical protection of carrier equipment and its component parts in a limited manner. For instance, REA Specification PE-60d outlines certain tests that are required before carrier equipment is REA listed. The required tests are not exhaustive in scope; but they provide minimum guidelines to ensure that the manufacturer has reviewed the equipment for adequate electrical protection and safety.

1.4 REA TE&CM Section 801 provides a rather detailed discussion on the sources of electrical surges and how these surges enter telephone cable facilities. The two sources of electrical surges are lightning and electrical system power fault currents. Power fault currents may be caused by mechanical faults, or may be triggered by lightning. Power switching transients are similar to power fault currents.

1.4.1 Lightning and power surges can enter the telephone cable pairs by conduction and by induction. Conduction of surges into cable pairs caused by direct power contact or dielectric breakdown will likely result in permanent facility damage. On the other hand, conduction of surges into cable pairs caused by ground potential rise and breakdown of local protector gaps (i, e., station protectors, etc.) could be damaging, but is more likely to result in only momentary facility disturbance. The effects of surge induction on cable pairs are similar to conduction. Surges may be induced into cable pairs from paralleling ground currents or cable shield currents. Surge induction may cause breakdown and be followed by surge conduction. Electrical surges that are harmless to facilities can still be damaging to sensitive electronic equipment applied to those facilities.

1.5 Equipment electrical protection techniques are usually implemented by (a) limiting the voltage across the equipment; and (b) limiting the current through the equipment. This is basically accomplished by impeding the currents, or by providing alternate paths of much lower impedance than the devices being protected. Potentially damaging voltages and currents are reduced or diverted into these alternate paths bypassing more sensitive areas of the equipment.

2. CARRIER EQUIPMENT PROTECTION TECHNIQUES

2.1 Carrier equipment protection should be an extension of a philosophy and practice of telephone system protection. To the maximum practical extent, electrical surges should be diverted away from sensitive electronic equipment. A companion technique is to equalize the electrical potential in the area of the equipment to the maximum practical extent. Techniques for accomplishing this protection range from total isolation from the electrical environment to the use of super rugged protective devices; both extremes are impractical. More practical techniques are cable shield continuity, common bonding, grounding, partial isolation, dielectric strength, high voltage arresters, current limiting devices, and low voltage protection. The carrier equipment protection is designed independently from the telephone system protection, but must be designed to be effective when merged into the system.

2.2 The multilevel protection incorporated into a PCM carrier repeater serves as an example of electronic equipment protection (Figure 1). High voltage gap devices (A) are used to limit the voltage across the line terminals. These are usually 350 volt 2 element or 3 element gas tubes. Series resistors (B) provide current limiting for lightning and electric system fault currents flowing through the repeater (about 5.6 ohms each). Low voltage limiting devices (C) are placed across the input and output of the sensitive electronic circuits (zener diodes, varistors, etc.). The high voltage gaps and series resistors are coordinated; as the surge current through the repeater increases, the series resistors provide enough voltage drop across the repeater to acti-

vate the high voltage protector gaps and bypass large surge currents. Voltage differences at repeater inputs and outputs (due to current differences in tip and ring conductors) are limited or clamped to minimize damage to sensitive electronic circuits within the repeater.

2.2.1 There is generally a relatively low impedance through a repeater (input to output) due to the internal power supply. A lightning induced surge into the repeater may or may not fire the gas tube arresters, depending on the magnitude (current/voltage) of the surge. For example, a high level surge from the east direction would likely fire the gas tube between terminals 1, 2 and ground. If the arresters are well grounded at the repeater location, most of the surge will be dissipated to ground through the arrester at 1-2. Part of the surge may fire other arresters at that location or be passed through the repeater components to other cable pairs (i.e., 3-4) seeking other (distant) grounds. If the repeater is arranged in a non-grounded "bypass" mode (as described in paragraph 2.5) or if the local repeater ground is poor, a high level surge at 1-2 may fire the arresters at 1-2, 3-4, and perhaps several other terminals connected to the "floating" ground plane (chassis) at the repeater to seek other (distant) grounds. Repeater damage is minimized by the coordinated series and shunt protection.

2.2.2 Most induced surges are low level current surges, and are unlikely to fire the arresters. A low level surge at 1-2 will pass through the series resistors at 1-2, through the repeater (transformers and power supply), through the series resistors at 3-4 and into the cable pair in the west direction seeking ground. (Note: The surge is being dissipated in the repeater, cable pair, and eventually through one or more paths into ground.) These low level surges may be more destructive to the electronics. The arrester does not fire; thus, there is no alternative low impedance path and all of the surge must pass through the repeater. Again, the current through the repeater and voltage across input and output electronics are limited to minimize damage.

2.2.3 Lightning surges are generally high energy short duration surges. Except for very large nearby lightning strokes the above protection technique is usually very effective. Of more concern are the long duration power fault currents. REA Specification PE-60d requires that the repeater withstand a power fault current of up to 10 amps for 11 cycles (0.183 seconds) of 60 hertz power. This requires that each series resistor (5.6 ohms) dissipate 5 amps, or 140 watts for 0.183 second; with 8 resistors in each repeater, this is 1120 watts that must be dissipated in each small size repeater. This has provided a high degree of protection from induced power fault currents. Protection from more severe surges must come from action by telco management and implemented elsewhere in the system.

2.3 Protectors: The most popular high voltage gap protection devices used with carrier systems are 350 volt 2 element or 3 element gas tubes. Other high voltage protective devices range from carbon blocks to 5 element gas tubes, metal oxide varistors (MOV), transzorb, and crowbar circuits. Two and three element gas tubes are popular because they strike a good balance between service reliability and cost. Carbon blocks are low in cost, but generally have a shorter service life than gas tubes. Five element gas tubes are in limited or experimental use in carrier systems. Their advantage is that when the gas tube fires across any gap, all gaps activate and short both

input and output terminals. Other high voltage protection devices are not currently in wide use in carrier systems because of higher cost or technical deficiencies.

2.3.1 Arresters are generally classified by the "nominal" voltage breakdown from a slowly rising dc voltage. A 350 volt gas tube is designed to break down at 350 volts, but may have a dc breakdown value of 300 to 500 volts; and this value may change over the useful service life of the device. Other characteristics such as impulse breakdown, holdover and service life are also defined by the gas tube manufacturer, by the carrier manufacturer, or by a formal specification such as REA Specification PE-80, as the circumstances warrant. These characteristics must be coordinated with the carrier system design. For instance, the gas tube breakdown and holdover voltage across tip and ring of a pair could be very low for a PCM repeater. However, it must be relatively high for a station carrier repeater because the systems are powered with about 270 volts across the pair (+135 and -135 volts). The carrier manufacturer may utilize a standard type of gas tube, but may impose certain requirements (limits, testing, etc.) beyond that normally guaranteed by the gas tube manufacturer. When adding or replacing gas tube arresters in carrier systems, be sure that the replacements equal or exceed the minimum characteristics of the carrier manufacturer provided arresters. (Note: This is sometimes difficult to determine because the carrier manufacturer may use a part number and internal specifications to identify the arrester rather than published specifications.)

2.4 Figure 2 shows the most common repeater gap protection arrangements in current use. Figure 2A shows the use of two element gas tubes between line and ground, and Figure 2B shows the use of three element gas tubes between line and ground. While the protection arrangements in Figure 2 are rather standard, there are other arrangements in use. These other arrangements may be standard for a specific product line, or may be alternative arrangements for specific purposes. Figure 3 shows some of these arrangements. Figure 3A shows a combination of longitudinal and grounded protection. The longitudinal gas tubes have low breakdown characteristics (i.e., 90 volts) and protect the repeater input as well as input to output.

2.4.1 The use of a five element gas tube is illustrated in Figure 3B. The advantage of using a five element gas tube for protection is that when a surge causes any gas tube element to fire, all elements become conductive. A surge entering by one cable pair conductor would cause the gas tube to fire and effectively short the input cable pair and the output cable pair to ground. (Note: There will be a short ionization delay before other gas tube elements become conductive resulting in longitudinal and metallic voltages across the unit for a brief period of time.) The use of five element gas tubes for electronic equipment is considered experimental at this time. The technique shows promise; but there is limited experience to verify improvement over the standard methods shown in Figure 2 using two and three element gas tubes. To a degree, the line-to-line and line-to-ground breakdown characteristics can be established independently. The line-to-line breakdown can be higher or lower than line-to-ground breakdown by the element spacing design. The first two illustrations shown in Figure 3C would have a lower breakdown between line and ground elements; the last illustration

would have a lower breakdown between line elements. The line-to-line breakdown can never exceed twice the line-to-ground breakdown. However, it is possible to have a low line-to-line breakdown with a line-to-ground breakdown several times higher by spacing the ground electrode at a much greater distance.

2.4.2 Carrier subscriber terminals are generally protected in the same manner as repeaters. The methods shown in Figure 2 are the most common, but those shown in Figures 3A and 3B could also be used. The method shown in Figure 3D is sometimes used also. An additional 2 element gas tube provides for a lower breakdown across the cable pair on the voice frequency drop side; the same arrangement may not work on the carrier frequency line side if the system is powered with +135 and -135 volts on the cable pair (i.e., station carrier). This would provide 270 volts dc across the cable pair on the line side and less than 50 volts dc on the drop side. The gas tube characteristics such as breakdown and holdover voltage must be matched to the equipment and application.

2.5 Bypass protection for carrier repeaters is a variation of standard protection where the arresters break down to a common point (i.e., inner chassis) that is isolated from ground. Specific recommendations for the use of bypass protection are not included in the section. However, bypass protection is used by some telephone companies and a discussion of this technique is included for completeness.

2.5.1 Bypass protection was developed for cable routes used exclusively for trunk carrier. The philosophy was to ground the system at each end; but to float the arresters connected to cable pairs along the trunk route. The end-to-end cable pair resistance provided a large series impedance to lightning and power fault currents induced into these pairs.

2.5.2 To avoid surge voltage differences and possible dielectric breakdown between pairs, all pairs within the cable should be treated in the same manner (floated or grounded). Where subscribers are served from the cable (by voice frequency or by carrier circuits) cable shield grounds and cable pair grounds will be introduced along the cable route. (Cable pairs become temporarily grounded when station protectors or carrier channel arresters break down to ground). Thus, bypass protection on a system basis may be practical for cable routes used exclusively for trunk carrier, but is not practical for cables in subscriber or mixed service.

2.5.3 The floating bypass repeater housing is defined in REA Specification PE-60d. The bypass housing must have a dielectric breakdown of at least 11 KV ac or 15 KV dc between the inner chassis and outer housing; or may have less dielectric capability with a long life breakdown gap (i.e., 1500 to 3000 volts) between the chassis and housing if the outer housing is conductive. A bypass housing can be arranged for either bypass or grounded protection by removing or adding a heavy strap between the chassis and housing (It is actually an "optional" bypass housing.) Bypass protection is illustrated in Figure 4A and grounded protection with the strap in place is illustrated in Figure 4B.

2.5.4 For the safety of telephone personnel, rubber gloves should be worn or the inner chassis must be grounded while working inside bypass housings. Some housings are grounded automatically when opened. (Adequate bonding between the chassis and housing should be verified). When grounding is not automatic, telephone personnel must connect a heavy gauge ground while the housing is open. A temporary ground clip is first connected to a good grounding point at the housing (ground side), and the other end is then connected to the repeater chassis to equalize the voltage at the housing. The chassis should be treated as if energized until it has been safely grounded.

2.6 Summary: Protection engineers sometimes debate the merits of grounded or bypass carrier repeater protection, and the merits of periodic cable shield grounds and connections to the power system multigrounded neutral (MGN). REA lacks good telco statistical data; but the successful reduction of equipment failures at some telcos has been attributed to increased cable and equipment grounding, and to the bonding of cable shields to the power system MGN. Avoiding the power system MGN is not possible in subscriber cables because of the common bonding at subscriber locations. Since this cannot be avoided, the use of grounds and MGN connections on a planned basis has merit. Thus, the recommendations in this section are written on the basis that cable shield grounds and carrier equipment protection grounds are generally advantageous. Bypass repeater protection should be limited to those special circumstances where grounding and MGN connections are judged to be a disadvantage (i.e., perhaps in the immediate vicinity of a substation or high voltage transmission line).

3. OFFICE EQUIPMENT CONSIDERATIONS

3.1 Carrier equipment mounted in central office buildings should meet the applicable electrical codes and the recommendations outlined in TE&CM Section 810. With the increased use of electronic equipment within central office buildings, the importance of establishing and following good electrical protection and grounding practices becomes greater. Each electronic equipment manufacturer may prefer minor variations of accepted standard practices. However, there is a variety of electronic equipment in service; and all must be adapted to certain defined standard practices, especially grounding techniques. Within the framework of standard grounding guidelines, various types of electronic equipment can coexist with minor variations in protection and grounding. Refer to TE&CM Section 810 for specific protection and grounding recommendations within central office building.

3.2 Because of the sensitivity of certain types of electronic equipment (i.e., processors, electronic switches, etc.) to electrical impulses, it becomes important to confine these impulses to areas outside the "equipment" room. Specifically, all high voltage gap protection connected to outside plant should be excluded from the equipment area.

3.2.1 Because of the wide variety of gap protection devices used on the main distribution frame (MDF) and the lack of control over the use of these devices, manufacturers of electronic equipment have used alternate means of assuring adequate equipment protection. Three methods are intermediate distribution frames (IDF), protection panels at the top of equipment racks, and protectors on equipment shelf backplanes or circuit cards. These protectors are located within the equipment area. When the protectors break down, electrical

surges are brought deep into the equipment area. By inductive coupling into other wires or by instantaneous ground potential rise, electrical impulses can be fed into sensitive equipment. This may or may not cause permanent damage to the equipment, but could cause other problems in switching and processing.

3.2.2 Establishing adequate protection and grounding requires cooperation between manufacturers, installers and telco personnel. While it is highly recommended that gap protection devices be removed from the equipment area, it is also highly recommended that the proper protective devices be utilized.

3.3 Office Recommendations: It is recommended that all high voltage gap protection be located at the cable entry point. That locations would normally be at or near the MDF protection bays. The protection devices could be a part of the MDF, or could be separate IDF or protection panels. The important point is to ensure that it is at the cable entry location and that it is properly applied (refer to TE&CM Section 810). When large quantities of new electronic equipment are installed (i.e., digital COE, carrier, etc.), protection and grounding practices should be reviewed. Because of existing equipment in service, some degree of protection rearrangement may be necessary. Contact the electronic equipment manufacturers and discuss how this can best be accomplished.

4. OUTSIDE EQUIPMENT CONSIDERATIONS

4.1 Outside equipment in need of protection includes carrier repeaters, subscriber terminals, and accessory devices. Outside plant practices are an integral part of equipment protection. There is much similarity between voice frequency noise and carrier system protection. Certain techniques used to minimize the source of voice frequency noise should also reduce the severity of electrical surges entering the electronic equipment. Specifically, this refers to good shield continuity, bonding, grounding, and connections to the power system multigrounded neutral (MGN). When the power influence (60 hertz) is reduced to correct a steady state voice frequency noise problem, it is likely that carrier protection has also been improved in that the effects of 60 hertz fault currents have also been reduced.

4.1.1 There may be occasions when it is desirable to avoid connections to the power system MGN, but these are the exception. There must be common bonding between the electric and telephone ground at each subscriber's residence (station). There are occasional other bonds between the electric MGN and cable shields for safety reasons. Since there are numerous random cable shield to ground and cable shield to MGN connections, it is desirable to make (additional) connections on a planned basis.

4.1.2 For safety reasons, it is strongly recommended that housings with exposed metallic surfaces inside or outside in a close area be bonded together and grounded with a local ground rod. This is called the "step-and-touch" rule. Any metallic surfaces, ground surfaces or other conductive surfaces that are within reach by step-and-touch must be bonded

together to avoid potential differences and minimize electrical shock hazards to telephone personnel and to the general public. Where the carrier equipment is installed in a manner that minimizes this hazard (i.e., small integrated nonmetallic housings), local grounding may be omitted.

4.2 Good cable shield continuity is essential for minimizing voice frequency noise and cable protection as well as carrier system protection. Telephone system maintenance practices should include checking for good shield continuity and shield bonding on some planned (long term) basis. Voice frequency noise problems on some routes may be a signal that a shield continuity and bonding review is past due.

4.2.1 Cable shield bonding hardware and the installation of that hardware are perhaps the weakest link in long term reliability of outside plant. Bonding problems may be the result of at least three factors. They are basic hardware deficiencies, inadequate instructions on their use, and instructions not completely followed by the installer. If shield bonding inspections indicate any of these deficiencies, they should be dealt with by purchasing hardware that meets or exceeds REA requirements, by adequate training on the installation of the hardware, and by follow up inspections to verify improvement.

4.2.2 Cable shields should be grounded at frequent spacing intervals. Continuous cable shield grounding would be ideal for equalizing the potential between cable shields and ground. REA has experimented with a semiconducting jacket cable for this purpose. To date, this experiment has essentially failed because the cable jacket has not retained its conducting characteristics. A semiconducting jacket cable may eventually prove successful, but may not be practical for some northern states where the frost line reaches the cable burial depth. An alternative to continuous grounding is frequent grounding. TE&CM Section 817 provides an in-depth discussion on effective grounding of cable shields. While this thorough and complete approach might be limited to the areas of high lightning damage, a simplified approach to grounding should be considered for all cables. The recommended minimum is to provide at least one ground per kilometer or per mile (8 foot rods) and to make connections to the power system MGN at each power tap location as outlined in TE&CM Section 451.7. While this is not a very scientific approach, evenly spaced placement of grounds (even unmeasured) is better than sporadic unplanned grounds. Even pedestal stakes connected to cable shields help equalize potential differences, although these stakes generally provide poor individual grounds.

4.3 Cable Shield Recommendations: The following recommendations apply to cable routes utilizing carrier. Inspect cables and verify shield continuity. As a minimum, it is recommended that cable shields be grounded at evenly spaced intervals not to exceed one kilometer or one mile and connected to the power system MGN as outlined in paragraph 4.2.2. In areas of high lightning damage, more attention should be given to the grounding of cable shields as outlined in TE&CM Section 817. Judgement should prevail where existing carrier systems are providing satisfactory service without the recommended shield grounds. Verify that the bonding and grounding are adequate for safety, and use judgement based on local circumstances for additional grounding.

4.4 Repeater Locations: Carrier in service in rural areas is typically

analog station carrier for subscriber service and T1 type digital carrier for trunk service. Digital carrier use is increasing for subscriber service also. N type carrier is declining in use. Repeater spacing for digital carrier is at about one mile intervals and station carrier repeater spacing is at about 3 to 4 mile intervals with subscriber channels at more frequent intervals. As a general rule, each repeater housing should be bonded to the cable shield and bonded to a local ground for safety. This is especially necessary for the larger metal housings, but might be omitted for the smaller nonmetallic housings that minimize the opportunity for shock hazard (see paragraph 4.1.2). Some carrier manufacturers recommend that a local ground of 25 ohms or less be provided for equipment protection. While local grounds of 25 ohms or less are desirable, a system of evenly distributed grounds is more effective under power fault conditions even with much higher individual ground values. The object is to distribute power fault currents over a wide area rather than concentrate those currents into single point grounds.

4.4.1 Circumstances may exist that warrant special protection considerations. Some of these special considerations are outlined in paragraph 7.

Where repeaters and subscriber terminals are at a common location, protection practices used for subscriber terminals should also be applied to repeaters at that location.

4.5 Subscriber Terminals: The carrier system subscriber channel is, in effect, a central office line circuit that has been moved to a field location. It is not an exact duplicate of the COE line circuit, but does extend some of the basic line circuit functions to a remote location. Therefore, the carrier subscriber terminals should be treated somewhat like the COE.

4.5.1 Some form of ground is necessary at the subscriber terminal for the following reasons. Experience dictates that subscriber line circuits should have a static drain path to ground. Any reasonable ground connection is adequate for this purpose, including the cable shield or local high resistance ground. Exposed conducting surfaces of the housing (inside and outside) must be bonded to the cable shield, to all other exposed conducting surfaces within reach by step-and-touch, and to a local ground for safety. Some judgement is required in establishing a criterion for the local ground. It is recommended that an objective of 25 ohms or less be established for each subscriber terminal local ground. The minimum acceptable value should reflect (a) the quantity of circuits (channels) to be protected, and (b) the difficulty in achieving 25 ohms or less at some locations. The minimum local ground at a subscriber terminal is one 8 foot ground rod for one channel. For a subscriber terminal of 24 or more channels, an effort should be made to achieve 25 ohms or less. Local grounding for the smaller nonmetallic housings can be omitted if the cable shields are grounded as recommended in paragraph 4.3.

4.5.2 Additional bonding requirements apply where local ac power is utilized at subscriber terminals. This is covered in paragraph 5.

4.6 Bonding Conductor Sizes: The minimum copper conductor sizes required for bonding and grounding are briefly outlined. Specific circumstances

may warrant larger conductor sizes. Where MGN connections and ac power are not required, the minimum conductor size for grounding and bonding is 14 AWG. These conductors are usually insulated, but may be bare if adequately covered where exposed to the public near ground level. Bonds between carrier housings and local power grounds must be 6 AWG. (Note: This assumes that the definition of "bonding two electrodes" applies). For bonding metallic surfaces within housings (short runs, protected area), 18 AWG can be used. For nonmetallic housings that present no safety hazard, conductors for bonding and grounding are determined by the manufacturer for equipment protection.

5. AC POWER AT FIELD LOCATIONS

5.1 AC power and standby batteries are sometimes required at carrier subscriber terminals, or at intermediate carrier power insertion locations. When ac power is used at field locations, additional bonding and/or grounding requirements are imposed for safety. Certain other installation practices may be desirable at these locations, but are not "requirements".

5.2 Figure 5 shows an ac power arrangement with a multistage protection system. The protection hardware includes a secondary power arrester, steel conduit, fuses or breakers, power service protector, local bonding and grounding, and miscellaneous fuses and/or breakers within the carrier housing. Variations of this arrangement are used as a coordinated system to protect personnel and equipment.

5.2.1 The first stage of protection consists of the secondary power arrester at the weatherhead followed by at least 6 meters or 20 feet of steel conduit. (Note: The use of a secondary power arrester may be limited to more severe lightning and power surge problems). The steel conduit provides a series impedance (inductive reactance) to fast rising electrical surges such as lightning and power transients. This series impedance tends to isolate the power load (carrier power supplies, etc.) and aids in causing the secondary power arrester to break down (if equipped). The secondary power arrester is a very rugged gap type arrester with a voltage breakdown in the range of 1200 to 2000 volts.

5.2.2 The next stage of protection is generally located inside the power switch box. The series protection may be a fuse or a thermal circuit breaker. It is desirable that the breaker be of the automatic resetting type to avoid the necessity of dispatching telco personnel to manually restore the power. The shunt protector is called a power service protector. It may be a gap device such as a gas tube, or may be a solid state device such as a metal oxide varistor.

5.3 The carrier may be pad mounted, pole mounted and separated from the ac power pole, or pole mounted on the same pole making the ac power connection. If the carrier housing is on the power pole, the power cable (and conduit) is routed down the pole and enters the housing near the bottom. If the carrier housing is separated from the power pole, the power cable (and conduit) is routed down the power pole, into the ground, and

up into the carrier housing at or near the bottom. Most field locations of carrier that require ac power are arranged for emergency backup. The housing and power panel contain the necessary ac plug and commercial power disconnect (for safety) to use a small portable ac generator during an extended loss of commercial ac power.

5.4 Adequate bonding and grounding are required at ac power locations for safety. The local ground for the cable and carrier terminal should be 25 ohms or less at ac power locations. The local ground may be common for the power and telephone if both are on the same pole. The power ground must use a 6 AWG (or larger) conductor. Separate grounds and other exposed metal surfaces must be bonded with a 6 AWG conductor if within reach by step-and-touch at a commercial ac power location. (See paragraph 4.6 also).

6. EQUIPMENT AT SUBSCRIBER LOCATIONS

6.1 Carrier equipment or accessories may be installed at subscriber locations. The equipment may range from a single channel of subscriber carrier or accessory hardware to digital carrier systems for voice and/or high speed data for business applications. The equipment may be mounted at the protector (subscriber side), or inside the subscriber's premises. The focus at subscriber locations is on the protection of the subscriber against electric shock and fire. National and local electrical safety codes must be followed. In addition, equipment using commercial ac power should be listed by Underwriters' Laboratories (UL). The UL listing provides reasonable assurance that equipment installed in the subscriber's premises will not cause injury to personnel or property when the equipment is handled in a reasonable manner. It is especially important to follow the applicable bonding and grounding requirements of the electrical and safety codes, and the recommendations outlined in TE&CM Section 805, Electrical Protection at Subscriber Stations.

6.2 Outside Mounted Equipment: As a general guideline, it is recommended that all carrier equipment and accessories be mounted along the cable route rather than at subscriber's buildings. However, subscriber channels are sometimes mounted on the outside surface of subscriber's buildings (on the subscriber side of the protector). The primary source of equipment protection in this application comes from the station protector. The equipment may contain secondary protection within the equipment housing, but such protection should be coordinated with the station protector. These units are generally insulated and present no special hazards. Review the manufacturer's instructions for any special considerations such as bonding and grounding. (It is assumed that commercial ac power is not required in these applications).

6.3 Inside Equipment - No AC Power: As with the outside mounted equipment, these units generally present no special hazards. Since these units are located inside the subscriber's building and are more available for tampering, there is a slightly increased possibility of shock and fire.

6.4 Inside Equipment - AC Power: Subscriber channels and accessory devices mounted inside subscriber's buildings that require commercial ac power can be categorized broadly as low power and high power devices. The low power devices are generally small and very power efficient. Power is generally provided through the combinations of a small transformer, rectifier, and rechargeable battery. The transformer is usually UL listed as a Class II energy limiting unit (similar to a "doorbell" transformer). The transformer is designed with adequate dielectric and limited power capability to minimize the possibility of electrical surge damage and fire. Larger applications of carrier inside subscribers' buildings are usually installed along with other equipment such as PBX's and key systems. In these applications, the electrical protection and safety procedures for the subscriber carrier should be treated as a protection system, and handled the same as for the other equipment installed in subscribers' buildings.

7. SPECIAL CONSIDERATIONS

7.1 Power Transmission Lines: Buried and aerial telephone facilities should be separated from high voltage power transmission lines to the extent practical. The telephone facilities should not be placed directly under power transmission facilities and crossings should be minimized.

7.2 Aerial Cable: Refer to TE&CM Section 815 for aerial cable protection practices. In general, the protection of carrier systems applied to aerial cable is the same as for buried cable applications. Because aerial cable is more exposed to surges from lightning and power facilities, more attention should be given to bonding and grounding of cable shields and strands.

7.3 Joint Use: Aerial telephone cables in joint use on poles with the electric power distribution facilities (i.e., generally 14 to 35 kV) is simply an extension of the aerial cable category. Aerial telephone cables will almost always be in some joint use with the electric facilities, even if it is the occasional crossings at junctions and service at buildings. It becomes a matter of degree of exposure. It is recommended that carrier applications be limited to 16 kilometers or 10 miles of joint use construction. Again, refer to TE&CM Section 815 for aerial cable protection practices. Because of the increased hazard to personnel and property, adequate bonding, grounding, and MGN connections are important to minimize potential differences between conducting surfaces. Cable shields, cable support strands and the electric system MGN should be bonded together and grounded frequently. Vertical ground wires and other exposed conducting surfaces should also be bonded together where they appear on a common pole, or are within reach by step-and-touch.

7.4 Power Crossings: Where carrier is applied to aerial and buried telephone cables that cross high voltage electric transmission lines (i.e., generally above 50 kV), the following is suggested. Refer to TE&CM Section 815 for aerial cable protection practices and Section 816 for buried cable protection practices. Generally, there is no special concern for buried cable crossing under electric transmission lines.

Cable grounds are generally avoided in the crossing area except for exposed conducting surfaces such as pedestal housings. Where possible, carrier equipment should not be placed in the immediate area of the power crossing. For aerial cable, the cable in the crossing area might be considered "sacrificial" to some extent. That is, in the rare event that a damaging power contact does occur, the extent of damage should be minimized. One way of minimizing the damage area is to provide low resistance grounds for the cable shields and strands at a distance of 300 feet or more from the transmission line on both sides of the crossing. This practice tends to concentrate the damage within the immediate vicinity of the power crossing with carrier equipment located outside the "sacrificial" area.

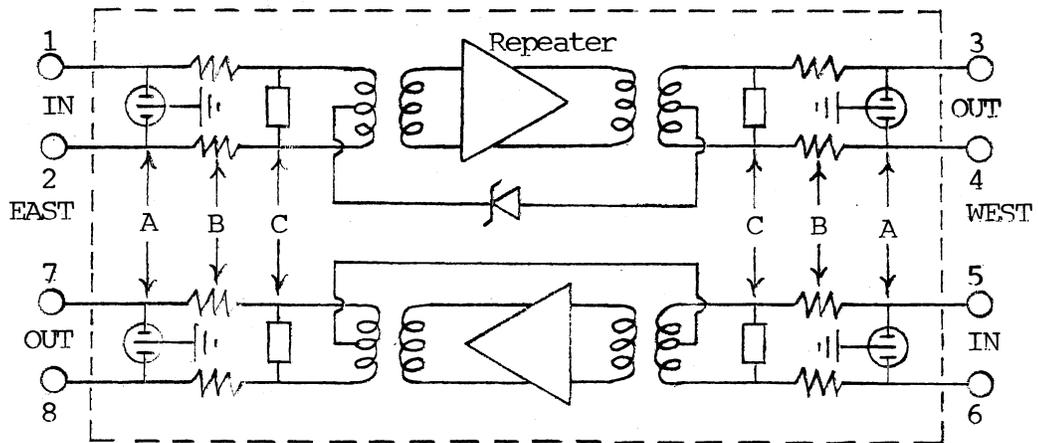
7.5 Power Substations: If no telephone service is provided for the power substation, the recommendation is to route the telephone cable away from the substation to the extent practical. There are tools to minimize the effects of power fault currents into telephone cables, even when the substation is served by carrier. Some of these techniques are discussed in TE&CM Section 825. Where possible, the carrier equipment should be located outside the immediate area of the substation. As with cable voice frequency circuits, the voice drops from the subscriber carrier into the substation might be equipped with neutralizing transformers or other devices. Service to larger substations where voice and data communications are more critical can be accomplished by more elaborate means. There are small optical fiber carrier systems designed especially for this purpose. The communications between the substation and the outside world is transmitted over a nonmetallic optical fiber for a short distance (i.e., one-half mile). It is then converted into a conventional carrier system and transmitted by telephone cables.

7.6 Bypass Protection: There may be special circumstances where the isolation of carrier equipment is beneficial. One method for accomplishing this isolation has been the "REA bypass protection" of cable carrier repeaters. The use of nongrounded bypass protection should be limited to the occasional repeater locations where damage probability is greater when the protectors are grounded than when they "float". There are several variations of bypass protection; refer to paragraph 2.5 for more details. For the safety of telephone personnel, the inner chassis must be grounded while working inside the bypass housing.

7.6.1 The "bypass housing" is more correctly an "optional bypass housing". This type housing can be arranged for grounded or bypass protection by the addition or removal of a strap between the inner chassis and the outer housing. REA has no specific recommendations for the use of bypass protection. Where the telephone company is uncertain, or has reason to believe that bypass protection may be advantageous in an application, the bypass housing should be used. The bypass housing offers the flexibility of providing either protection mode. It might be difficult or impractical to modify a "grounded" housing to provide bypass protection.

FIGURE 1

PCM CARRIER REPEATER - MULTILEVEL PROTECTION

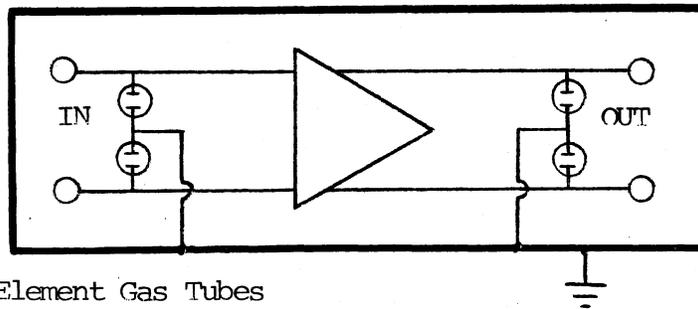


Notes: A = High Voltage Gaps (2 or 3 Element Gas Tubes)
 B = Current Limiting Resistors (5.6 Ohms)
 C = Low Voltage Limiting (Zeners or Varistors)

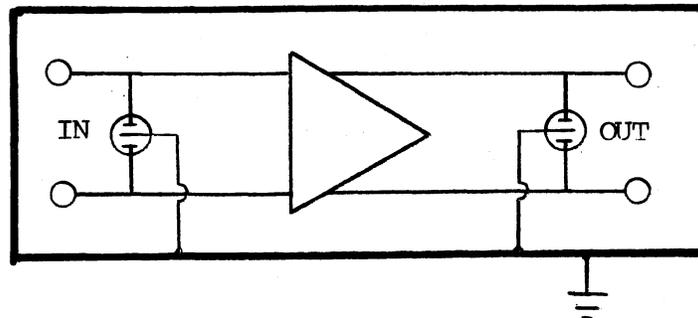
FIGURE 2

COMMON REPEATER GAP PROTECTION

A. Two Element Gas Tubes



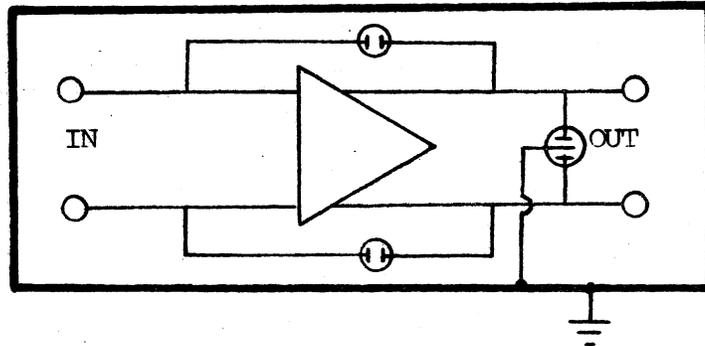
B. Three Element Gas Tubes



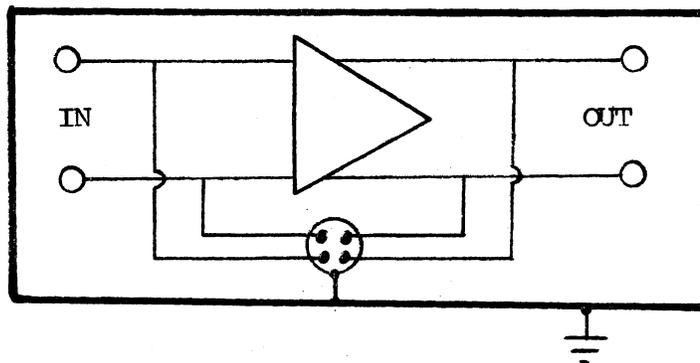
7
FIGURE 3

OTHER REPEATER GAP PROTECTION

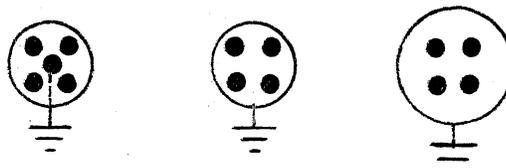
A. Combination Protection - Longitudinal and Grounded



B. Five Element Gas Tube Protection

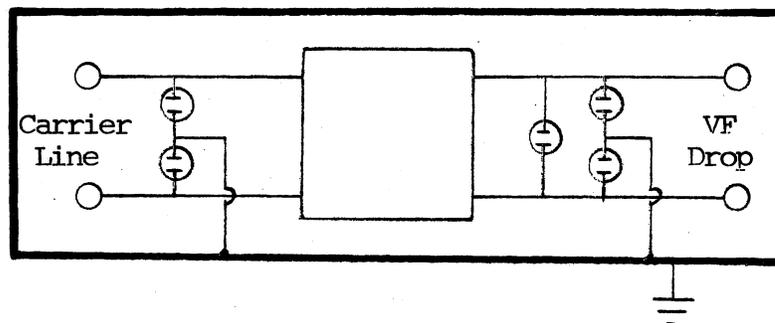


C. Five Element Gas Tubes



Voltage breakdown from line to ground could be low or high, depending on gas tube design.

D. Subscriber Terminal Protection

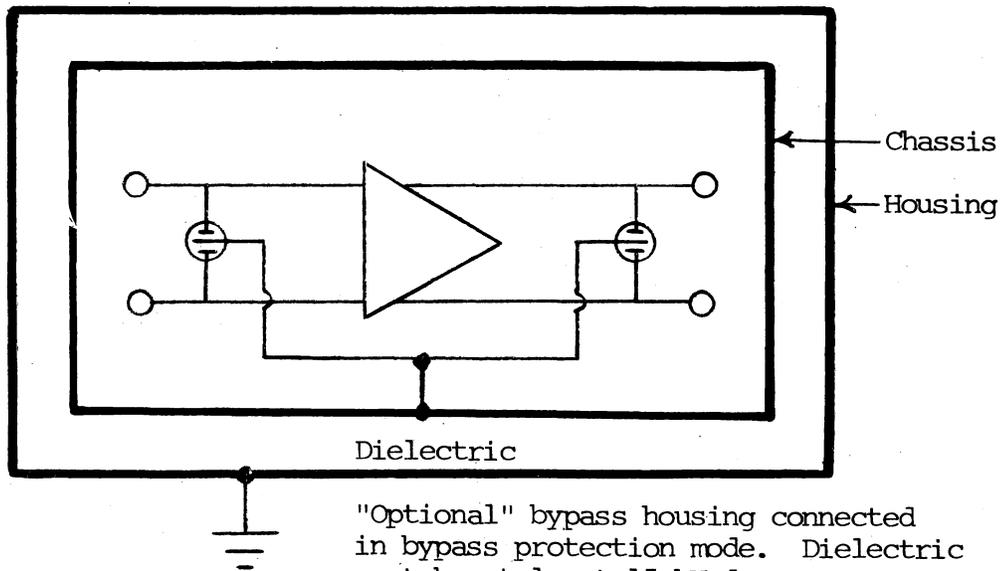


Subscriber terminals may be protected like this or any of the arrangements shown for repeater protection.

FIGURE 4

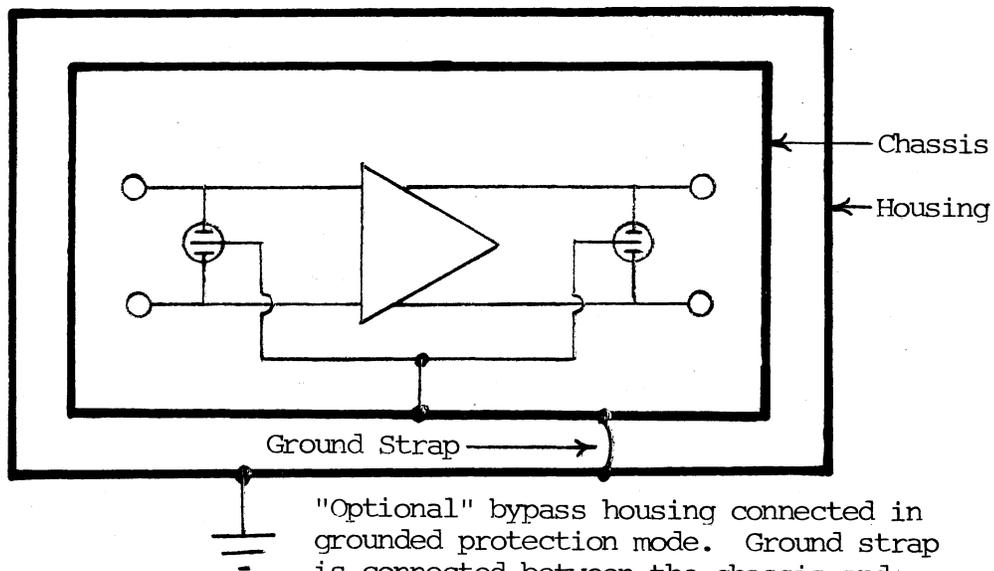
BYPASS REPEATER PROTECTION

A. Bypass Protection Using Dielectric



"Optional" bypass housing connected in bypass protection mode. Dielectric must be at least 15 kV dc. Protectors connected to common chassis, but not grounded.

B. Bypass Housing With Grounded Protection



"Optional" bypass housing connected in grounded protection mode. Ground strap is connected between the chassis and housing.

FIGURE 5

AC POWER AT FIELD LOCATIONS

