UNITED STATES OF DEPARTMENT OF AGRICULTURE
Rural Utilities Service

BULLETIN 1751F-815

SUBJECT: **Electrical Protection of Outside Plant**

TO: All Telecommunications Borrowers
RUS Telecommunications Staff

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OFFICE OF PRIMARY INTEREST: Engineering Standards Branch, Telecommunications Standards Division

PREVIOUS INSTRUCTIONS: This bulletin replaces Telecommunications Engineering and Construction Manual (TE&CM) Section 815, Number 4, issued April 1969; Section 816, Number 3, issued July 1969; Addendum No. 1 for Section 816, issued January 1971; Addendum No. 2 for Section 816, issued December 1972; Section 817, Number 1, issued March 1980.

FILING INSTRUCTIONS: Discard TE&CM Sections 815, 816, Addenda 1 and 2 for Section 816, and 817 and replace them with this Bulletin. File this bulletin with 7 CFR 1751 and RUSNET.

PURPOSE: To provide information concerning the electrical protection principles for aerial and buried cable along with information on effective grounding of cable shields. It describes the normal methods for protecting aerial circuits from lightning and power contacts by means of arresters, shield grounding, and shield bonding.

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Administrator Date

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INDEX:

Protection
Protection, Electrical
Protection, Outside Plant

ABBREVIATIONS

ANSI American National Standards Institute
AWG American Wire Gauge
CEGB Cable Entrance Ground Bar
GPR Ground Potential Rise
MGB Master Ground Bar
MGN Multigrounded Neutral
NEC National Electrical Code
NESC National Electrical Safety Code
NEXT Near-end Crosstalk
NFPA National Fire Protection Association
PCM Pulse Code Modulation
PIC Plastic-Insulated Conductor
PM2A Ground Wire Assembly Unit
TE&CM Telecommunications Engineering and Construction Manual

DEFINITIONS

Cable A group of insulated conductors formed into a compact core and covered with a protective sheath.

Non-current carrying conductors Non-telecommunications conductive materials such as metallic cable shields and strength members, metallic cable lashing wires, guy wires, and cable support wires, etc.

Plastic-insulated conductor (PIC) cable Cable consisting of conductors covered with an extruded coating of plastic.

Sheath The nonmetallic outer covering over the shield of certain types of cables.

Shield The metallic components of a cable sheath that help to minimize outside electrical interference in cable conductors and that help to direct lightning and power cross discharge currents to ground.

1. DISTURBING POTENTIALS

1.1 Lightning: Lightning is a transient discharge between a charged cloud and the earth or another cloud, involving high peak currents (several tens of thousands to more than a 100,000 amperes) usually lasting a few hundred microseconds. Lightning surges in cable plant may occasionally arise because of direct strokes to pole tops or to the cable itself. Successful protective measures against damage are usually not practicable for direct lightning strokes to elements of telephone cable plant. Fortunately, however, lightning disturbances more commonly appear in cable plant in lower energy levels by conduction from connecting distribution wire, by induction from nearby strokes-to-earth, by conduction from the earth at or near the stroke point to the cable through guys or pole grounding wires, or because of a rise in ground potential at nearby grounded points such as station protectors. If adequate protective measures are not taken, lightning discharges may result in the breakdown of the insulating materials between cable conductors and the grounded metallic cable shields or between the conductors themselves. The effect of dielectric failure on service outage will depend on the magnitude and duration of the surge and the susceptibility of the materials involved to permanent damage, such as melting of the conductor and conductor insulation or carbonization of the conductor insulation.

1.1.1 Excessive lightning surge currents can cause telecommunications conductors to fuse open. The use of improved plastic insulation, however, has increased the dielectric strength of cable conductors to the point at which dielectric failure seldom occurs. The dielectric strength of cable causes the current surges to flow through the conductors rather than being bypassed through conductor insulation. As a result, lightning damage to plastic cable plant is more likely to be caused by conductor fusing rather than from dielectric failure.

1.2 Power Contacts: Mutual association of telephone cable (or wire) facilities with power distribution circuits, as a result of joint use or joint occupancy of poles or at crossings, involves the possibility of incidental electrical contacts between these systems. Such electrical contacts usually are caused by severe mechanical stresses produced by high wind, heavy ice and snow loads, or combinations of these factors. Although peak currents in cable plant as a result of such contacts are likely to be in the order of hundreds rather than thousands of amperes, their duration is in the order of seconds rather than microseconds. Consequently, power contacts are likely to subject telephone plant to heating and burning, as well as dielectric stress.

Power contacts with metal shielded cable and strand may occasionally burn down cable because of resulting arcing and current flow, or more likely may only generate sufficient enough current flow in telecommunications conductors to result in fusing of conductors. Fortunately, however, the frequency of power contacts is much lower than that of lightning interference.

2. PROTECTION PRINCIPLES

2.1 Lightning Protection:

2.1.1 Direct lightning strokes to cable plant are likely to cause extensive damage because of the magnitude of the currents involved. However, because the cost for total protection, if even possible, would be immense and because such strokes occur so infrequently, protection against direct strokes is impracticable.

2.1.2 Lightning surges may also reach the conductors and/or shields of aerial cable by currents conducted from non-cable plant, by induction from nearby strokes-to-ground, and by currents developed because of rise in ground potential at stroke points near station protector installations. (The term "non-cable plant" as used here refers to wire circuit facilities not enclosed in a metal shield, such as overhead drop wires.) Cables having plastic-insulated conductors do not require protective measures except in unusual circumstances as outlined in subsequent paragraphs.

2.1.3 To prevent dielectric failure of the cable conductor insulation (by cable design), all conducting elements of a cable installation have to be at the same potential. The shields of all aerial cable sections should be bonded together and to connecting underground or buried cable shields and to the central office ground. Cable support strands (messengers) should be electrically continuous and cable shields should be bonded to the support strands (messengers) at appropriate intervals.

2.2 Power Contact Protection: Important protective construction practices also consist of providing low impedance paths to ground which will aid in rapid de-energization of a power line in the event of a power contact. Such grounding is also required by the National Electrical Safety Code[1] (NESC[1]).

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[1] All references to the National Electrical Safety Code in this document pertain to the 1993 edition. Readers are urged to refer to the edition of the NESC and any, more stringent, local codes.

3. LIGHTNING PROTECTION FOR PLASTIC-INSULATED CABLE

3.1 Surge Dielectric Strength: The surge dielectric strength of cable utilizing plastic-insulated conductors is conservatively considered for engineering design purposes to be as follows:

	SURGE DIELECTRIC STRENGTH	
INSULATOR TYPE	**CONDUCTOR-TO-CONDUCTOR**	**CORE-TO-SHIELD**
SOLID GEL FILLED	**20 kV**	**35 kV**
GEL FILLED, EXPANDED	**15 kV**	**25 kV**

Cables having dielectric strengths of these magnitudes will in most cases be free from damage by lightning. The relative immunity of PIC cable without arresters (except in special circumstances) to lightning damage has been well established by experience in the Bell Systems and RUS borrower systems over a period of many years.

3.2 Protection of PIC Cable: The protection of PIC cable in all areas normally should consist of: (1) bonding and grounding cable shields at the central office,
(2) maintaining electrical continuity of the shield,
(3) bonding cable shields to support strands (messengers),
(4) grounding of cable shields (in aerial circuits via grounding messengers, etc.,) (5) providing gas tubes or the equivalent at junctions with facilities serving severely exposed stations, (6) protecting against fusing of cable conductors, (7) complying with the NEC[2] at service drops, and (8) providing supplementary protection measures at known severe exposure locations.

3.2.1 Bonding and Grounding Cable Shields at Central Offices: The shields and other metallic members of plant entering a central office should be bonded to each other and to the central office ground. This bonding helps to minimize harmful differences of potential between the various cables entering the central office. RUS requires that special provisions be undertaken for bonding and grounding of outside plant cable shields, metallic armor, etc., with terminating cables in a central office. Basically, non-current carrying metallic outside plant items (shields, armor, strength members, etc.,) are all bonded

[2] All references to the National Electrical Code in this document pertain to the 1993 edition. Readers are urged to refer to the edition of the NEC and any, more stringent, local codes.

together in a entering cable vault and they are in turn bonded to a Cable Entrance Ground Bar (CEGB) installed within the vault. The CEGB is, in turn, bonded to the office's Master Ground Bar and the elaborate grounding provisioning established at the office. The shields of the office's terminating cables are (deliberately) electrically isolated in the cable vault and connected to the office ground only at their other end, at the office mainframe ground bar. The purpose of this grounding and bonding arrangement is to divert any incoming surges that may be on the outside plant cable shields, armor, etc., directly to ground and not provide a path for these surges to make it directly to other parts of the mainframe. For more detail on these special central office procedures, readers should refer to TE&CM Section 810 (proposed conversion to RUS Bulletin 1751F-810).

3.2.2 Maintaining Electrical Continuity of Shields: It is important that electrical continuity of aerial cable shields be maintained and that such shields be bonded to any connecting buried or underground cable shields in order to provide a path to ground for lightning and power currents, and to provide an effective noise shield. The installation of ready-access enclosures and the application of cable splicing procedures as covered in RUS Standard PC-2, Bulletin 345-6 (proposed conversion to 7 CFR 1755.200), will usually ensure adequate bonding of shields from a protection standpoint.

3.2.3 Bonding Cable Shields to Support Strands (Messengers): Cable shields should be bonded to support strands (messengers) at frequent intervals to prevent arcing and to provide a low impedance path to ground for power contact or lightning related surge currents. Plastic-jacketed cable should be bonded between the shield and strand at all splices, terminals, and loading points. The methods of bonding the shield to the strand depend on the types of enclosures used and are described in detail in PC-2.

3.2.3.1 Four or more bonds per mile (Two and one-half or more bonds per kilometer [km]) should be provided if possible without opening the plastic jacket solely for this purpose. Where long runs without splices, terminals, or load points are involved, at least one bond per mile (1.6 km) should be provided even if the cable sheath has to be opened solely for this purpose. If more than one cable is attached to the same pole, the shields of the various cables should be bonded together: (1) at crossing poles; (2) at the beginning and ending of multi cable runs; and (3) at approximately 1500 foot (460 meter) intervals in long multi-cable runs.

3.2.4 Grounding of Cable Shields/Support Strands (Messengers): Normal construction practices and NESC provisions require that cable shields, messengers, and other non-current carrying metallic hardware be effectively grounded. It is especially important to effectively ground cable shields, messengers and non-current-carrying metallic hardware at dead ends and other junction points for noise mitigation, personnel protection, and/or power contact protection. Such grounds are also beneficial in reducing lightning potentials between the core and the shield if voltage limiting gaps (such as terminal studs or arrester gaps) are applied to the conductors. Grounds are also beneficial in reducing the probability of fusing of cable conductors from lightning surges by diverting a portion of the surge to ground before it reaches the cable conductors. (See Section 4 of this bulletin for additional detail on grounding provisions.)

3.2.5 Gas Tubes or the Equivalent at Junctions with Facilities Serving Severely Exposed Stations: At junctions with facilities of any type or length serving stations that are severely exposed to lightning surges (such as fire towers and radio towers), it is recommended that 800 volt or greater breakdown gas tube arresters be installed on the exposed pairs between the conductors and the shield. An accepted alternative to gas tubes would be to install yellow-coded, 10 mil (0.3 mm) gap carbon arresters.

3.2.6 Protection Against Fusing of Cable Conductors: The probability of fusing cable conductors can be minimized by providing conducting paths for surge currents, which divert the incoming surges to the shield and ground before they reach the cable conductors. The measures described in Paragraphs 3.2 through 3.2.5 usually accomplish this.

3.2.7 Service Drops: Arresters for lightning protection are not normally required at points where service drops are connected along aerial cable runs. Connections of drop wires to aerial cable conductors normally should be made so as to meet National Electrical Code (NEC), formally identified as ANSI/NFPA 70, fuse coordinating requirements for station protection. Connection details are shown on the Construction Drawings in the "Telephone System Construction Contract," RUS Form 515.

3.2.8 Supplementary Measures: In addition to the above items, under severe exposure conditions, supplementary protection measures may be needed, e.g., plant protection near electric power generating stations and substations. Details of such supplementary protection should be determined by a borrower after a careful study.

4. BONDING AND GROUNDING FOR POWER CONTACT PROTECTION

4.1 Bonding at Power Crossings: Where practicable, crossings between aerial telephone cables and electric distribution lines of any type should be made on jointly used or jointly occupied poles. At joint pole crossings with Multi Grounded Neutral (MGN) type power lines, the cable support strand (messenger) should be interconnected to the MGN via a vertical pole ground wire. Where it is not practicable to obtain joint pole crossings with electric distribution lines and for all aerial crossings with electric transmission lines, in span crossings may be used. For all in span crossings, protection of the telephone plant depends primarily on adequate structural strength and clearances, which in some cases may require putting the telephone plant in underground conduit or using buried cable.

4.2 Bonding in Joint Use or Joint Occupancy:

4.2.1 Where a telephone cable is supported by the same poles used for electric supply circuits of the MGN type, the cable shield and suspension strand (messenger) should be grounded by bonding the strand to the MGN as described in Paragraph 4.2.4. These bonding connections should be made at the following locations:

4.2.1.1 Where the joint use or joint occupancy arrangement begins and ends;

4.2.1.2 On every electric supply pole that carries a vertical pole ground wire to which are connected transformers, capacitors or other types of power equipment that draw load current under normal conditions; and

4.2.1.3 If the joint use or joint occupancy section is longer than 1/2 mile (0.8 km), bonds should be made to the MGN every 1/4 mile (0.4 km). The NESC requires additional grounding considerations for certain messenger sizes where the messengers are exposed to possible power contacts, power induction, or lightning. If the ampacity of the messengers are not adequate for system grounding conductors, grounding of messengers has to be increased to intervals of eight per mile (1.6 km).

4.2.2 Where telephone cables are supported by the same poles used for electric supply circuits of the non-MGN type, cable shields should be grounded by means of their connections to the central office ground and by such other additional grounds as necessary to satisfy the frequency of occurrence described in Paragraph 4.2.1.3. Cable suspension strand should be bonded to the vertical pole ground wire on poles carrying vertical pole ground wires to which are connected transformer, capacitors, or other types of equipment that draw load currents.

4.2.3 Vertical pole ground wires on electric supply poles interconnected to transformers or capacitor banks should be connected directly to the power system neutral. The transformers or capacitor banks should also have direct connections to the power system neutral. At such locations visual inspection from the ground should be made, before climbing, to ascertain that the vertical pole ground wire is actually connected to the neutral. <u>If the vertical pole ground wire is not connected, this fact should be reported to the power company; and the wire should be regarded as energized. The pole should not be touched or climbed by the telephone line workers until the condition has been corrected by the power company.</u>

4.2.4 Where interconnection of the support strand (messenger) to the MGN is recommended in 4.1 and 4.2.1, the interconnection should be accomplished by the appropriate method for the conditions prevailing at the pole in question as listed below:

4.2.4.1 If the pole is already equipped with vertical pole ground wire connected to the MGN, then a ground wire assembly unit (PM2A) should be installed. A bonding conductor should be attached to vertical ground wire by telephone construction personnel if it is satisfactory to the power company.

4.2.4.2 If the pole is not equipped with vertical ground wire, a ground wire assembly unit (PM2A) should be installed and sufficient slack left to permit the bonding wire to be extended to and connected to the MGN if the pole in question is at the beginning or at the end of the joint use section. Connection of the bonding wire to the MGN should be made only by the power company. For intermediate bonds recommended by 4.2.1, a pole already equipped with a pole ground wire should be selected and a ground wire assembly unit (PM2A) should be installed.

4.2.5 In most instances, interconnection of the cable shield to the MGN will result in a decrease in noise levels on the telephone system because of the additional shielding effect provided by the neutral conductor. In a few instances noise levels could increase if excessive residual power currents flow in the shield as a result of bonding. This situation is most likely to occur if the resistance of the neutral to ground is relatively high. In such instances removal of a number of bonds to the MGN to reduce the shield current usually will be beneficial.

5. MISCELLANEOUS SITUATIONS

5.1 Underground/Buried Cable Dips in Aerial Cable Runs: No special protection is required at the junctions of aerial cable and short underground or buried plastic-sheathed cable dips in aerial cable runs.

5.2 Protection at Loading Points: Loading coils meeting RUS specification PE-26 are designed such that no supplementary protection is required in addition to the measures recommended herein for protection of the associated cable.

5.3 Buffer Protection: Where a good shield ground such as a MGN of approximately 25 ohms or less cannot be obtained at or within 200 feet (60 meters) of a cable-noncable junction, the beneficial effect of such a ground may be achieved by placing buffer protection in the form of yellow coded arresters between the non-cable pairs and ground at a point about 1500 feet ± 1000 feet (460 meters ± 300 meters) from the junction, provided a ground of approximately 25 ohms or less can be obtained at that point.

5.4 Pole Lightning Protection Wires: Lightning protection wires may be necessary to prevent the splitting of wood poles used for cable supports in certain areas of high lightning incidence and severe exposures. RUS borrowers should make a study of local conditions to determine to what extent this protection is required. Normally, extensive use of lightning protection wires is necessary in the shaded areas of the map on Figure 1, Lightning Damage Probability Map, and in unshaded areas which have more than 60 thunderstorm days per year. In systems within areas affected by high levels of lightning damage and where local experience clearly indicates the need, lightning protection wires should be installed on poles which are severely exposed because of being on or near the top of a hill with little or no shielding such as buildings, trees, or a higher foreign pole line. In hilly areas, installation of protection wires on a number of consecutive poles is desirable. With flat terrain where the exposure is more uniform and less severe, protection wires should be installed on every third or fourth pole. In the unshaded areas of the map in Figure 1, which have less than 30 thunderstorm days per year, pole lightning wires are not necessary. (Note: RUS Borrower areas not shown on Figure 1, such as Alaska, Hawaii, and the Federated States of Micronesia, Guam, Puerto Rico, Republic of Marshall Islands, Republic of Palau, and the Virgin Islands are considered low probability lightning damage areas.)

6. ELECTRICAL PROTECTION FOR BURIED/UNDERGROUND CABLE

6.1 Plastic-Insulated Conductor (PIC) Cable and Wire: Polyethylene insulated conductor and jacketed cable and wire require a minimal of electrical protection because of their inherent high dielectric strength and quality. Difficulties caused by dielectric failure have been reduced to a minimal amount through the extensive application of PIC cable and wire. Power cross, lightning surge, and other sources of unwanted high currents on the telephone plant can, at times, cause cable or wire conductors to fuse. While finer gauge conductors are more susceptible to this type of damage, the economic advantage in their use will usually outweigh the higher rate of fusing incidence as compared with coarser gauge facilities.

6.2 Lightning Protection: Buried cable and wire are not normally as susceptible to damage from lightning surges as other categories of outside plant. However, buried plant may be subjected to lightning damage in one of the following ways: (1) by direct strokes to the shield or strokes-to-ground which are eventually directed to the shield; (2) by surges conducted to the buried plant from connecting facilities which are struck; (3) by induction from nearby strokes-to-ground; and (4) by currents developed because of a rise in ground potential at stroke points near grounded station protectors or other grounded facilities. While the dielectric strength of PIC cable will withstand most of the surges occurring from items 2, 3, and 4 above; direct lightning strokes will normally cause damage to the cable. The damage is caused by the magnitude of currents involved. However, direct strokes to buried cable occur infrequently.

6.2.1 Current surges which reach buried and underground cables from conductors of connecting plant such as buried line wires, buried services, or aerial non-cable type plant, are usually confined to the conductors by the high dielectric strength of the plastic insulation on the conductors and the inner jacket. Frequently the exposed connecting conductors have a coarser gauge than the buried cable conductors to which they connect. Both the coarser gauge of connecting conductors and the high dielectric strength of the plastic insulations tend to increase the probability of fusing the cable conductors.

6.2.2 The use of buried fine gauge cable conductors in telephone systems has resulted in conductor fusing becoming more prevalent than dielectric failure.

6.2.3 As noted previously, loading coils meeting RUS specification PE-26, are designed to withstand substantial lightning surges without damage. Present designs will withstand current surges which approach the fusing current of 28 AWG wire. While this fusing current is less than that of 24 AWG cable, it is large enough that only a small percentage of surges reaching cables will cause loading coil damage. Therefore, gap protection of loading coils in buried plant is not normally required. In areas susceptible to very severe lightning damage, protection for loading coils can be added at a later date if needed. Where protection of loading coils is necessary, standard or heavy duty gas tubes with a slowly rising dc breakdown voltage of approximately 350 Volts should be used. It is recommended that these gas tubes be connected in a longitudinal non-grounded bypass tube configuration, as discussed in TE&CM Section 822, "Electrical Protection of Carrier Equipment", (proposed conversion to Bulletin 1751F-822).

6.3 Power Contact Protection: Cable and wire facilities which are actually buried in the earth are not considered as being exposed to power line contacts except those buried in the same trench with power distribution cables. Protective measures are, therefore, not required for buried plant except for those which may be required for the protection of connecting facilities, subscriber stations, and exposed aerial inserts as prescribed in practices covering such plant and as supplemented herein. Aerial inserts in buried plant are considered as being exposed when the possibility exists that they could be contacted by power line conductors operating in excess of 300 volts to ground. Where joint buried construction is involved, protection measures should be applied as described in TE&CM Section 640, "Design of Buried Plant-Physical Considerations", (proposed conversion to Bulletin 1751F-640).

7. LIGHTNING PROTECTION FOR BURIED/UNDERGROUND PLANT

7.1 Dielectric Protection of Buried/Underground Plant is limited to the following measures: (1) gas tube or equivalent arresters at junctions with facilities serving severely exposed stations and (2) bonding and grounding of buried wire and cable shields.

7.2 Facilities Serving Severely Exposed Stations: Terminal blocks equipped with standard or heavy duty gas tube arresters having dc breakdown voltages of 800 volts or greater and installed in suitable mountings and enclosures are recommended at junctions between buried wire or cable and facilities serving stations that are severely exposed to lightning (such as fire towers and radio towers) regardless of the length or type of connecting facilities. Yellow coded (10 mil) (0.3 mm) carbon blocks may be used as an alternative to gas tubes.

7.3 Bonding/Grounding of Buried Wire and Cable Shields:

7.3.1 Complete bonding of shields of buried cable and wire to maintain electrical continuity of shields throughout the buried plant and the connections from buried plant to aerial plant, central offices, and subscriber station protectors is recommended. Grounding of buried cable and wire shields is advantageous from lightning protection considerations and is a requirement of the NESC (to effectively ground non-current carrying metallic plant).

7.3.2 The shields of all buried wires and cables entering a central office should be bonded to each other and interconnected with the central office ground bus or grounding conductor. This bonding eliminates harmful differences of potential between the various cables entering the central office. RUS requires special bonding and grounding at central offices. See Paragraph 3.2.1 of this bulletin for some of the basic considerations of the special grounding and bonding that RUS requires at central offices. For more specific details, see TE&CM Section 810 (proposed conversion to RUS Bulletin 1751F-810).

7.3.3 At junction points the shields and support wires of interconnecting facilities should be bonded to the metallic shield of the main buried cable or wire. The grounding bracket in terminal housings should be used to facilitate making these connections. The grounding bracket should be connected to a ground rod with at least a #6 AWG grounding conductor. The shield of buried service wires should likewise be bonded to the metallic shield of the main cable and connected at the subscriber end to the station protector grounding terminal.

7.3.4 The use of pulse code modulation (PCM) carrier systems and the concern for near end crosstalk (NEXT) has led to the development of a cable in which the pairs are divided into two bundles which are isolated from each other by a "screen" designed to reduce the crosstalk from one bundle to the other primarily by reducing the capacitance unbalance between pairs. Because this screen does not have the same insulation as the cable shield, the screen should not be treated as a shield where electrical protection is concerned. The screen should not be connected to ground at any point and it should deliberately be made electrically discontinuous at pedestals.

7.4 Protection of connecting facilities having appreciably lower dielectric strength than plastic-insulated conductor (PIC) cable and wire is required as follows: (1) arresters at the central office, and (2) arresters at carrier repeaters and terminals.

7.4.1 Arresters at the central office provide main frame arrester protection on all cable pairs entering the central office.

7.4.2 Carrier repeaters and terminals and most other electronic equipment used on cable pairs have low dielectric strength compared with the dielectric strength of cable pairs. Such equipment should, therefore, be protected in accordance with RUS TE&CM Section 822 (proposed conversion to RUS Bulletin 1751F-822).

8. POWER CONTACT PROTECTION FOR BURIED/UNDERGROUND PLANT

8.1 **<u>Aerial Inserts</u>:** Aerial inserts may consist of strand supported buried cable, underground cable, aerial cable, or wire supported buried wire. When an aerial insert of any type is exposed to power contacts by being joint with, crossing under, or otherwise subject to possible contact with power conductors operating at voltages in excess of 300 volts, the aerial insert should be considered as exposed. Support strands (messengers) or wires of exposed aerial inserts should be effectively grounded by connecting to an MGN. If an MGN is not available, effective grounding by driven electrodes or other means is necessary. The support strand (messenger) of aerial inserts should be grounded in accordance with the NESC at four or eight times a mile (1.6 km), depending on the conductivity of the support strand (messenger). (See Rule 215C3 of the NESC and Paragraph 4.2.1.3 for details). Because RUS has standardized on use of #6 AWG copper grounding conductors, seven wire steel strand messengers of 1/4" (6.4 mm) and 5/16" (7.9 mm) should be grounded 8 times each mile (1.6 km) while 3/8" (9.5 mm) and 7/16" (11 mm) should be grounded four times each mile (1.6 km).

8.1.1 The conductors of exposed aerial inserts in buried wire or cable should be isolated from the buried portions on both sides of the insert in order to maintain the unexposed status of the buried plant. Isolation of the conductors of exposed aerial inserts is necessary so that fuseless-type station protectors may be used and isolation may be accomplished by any of the following procedures:

8.1.1.1 <u>If the conductors of the buried plant on both sides of the aerial insert are 24 AWG copper or smaller, no fuse</u>

links are required. Buried type wire or cable may be used for the aerial insert following construction practices for aerial cable.

8.1.1.2 If the conductors of the buried plant are coarser than 24 AWG copper, the preferred construction is to install 24 AWG cable as the aerial insert. The 24 AWG insert then provides the necessary fusing coordination with the connected stations on both sides of this insert. Where the aerial insert extends for more than a few spans, the effect of the use of 24 AWG on transmission should be checked.

8.1.1.3 If the conductors of both the buried plant and the aerial insert are coarser than 24 AWG, isolation of the exposed aerial insert should be accomplished by providing 24 AWG copper fuse links between the aerial insert and the buried portions of the cable. These fuse links should be applied at both ends of the exposed insert, as shown in Drawings 951 and 952 of RUS Bulletin 345-150, RUS Form 515a. In order to minimize the cost of isolating aerial inserts, the 24 AWG links should usually be installed in terminal housings that are required for other purposes at points nearest to each end of the aerial insert. Color-coded 24 AWG leads at least 8 inches (20.32 centimeters) long should be spliced in series with each conductor of the cable between the end of the buried portion of the cable and the adjoining end of the aerial insert. The color code should be preserved. If subscriber's services or buried wire branch tap leads are distributed from the buried plant terminal housings involved, the leads should be connected to the unexposed side of the fuse link. Exposed aerial taps should be connected to the exposed side of the fuse links. The shields of all cables or wires in the buried plant terminal housings should be bonded together and grounded to the same ground electrode to which the support strand (messenger) is grounded. A typical exposed aerial insert is shown in Drawing 951 of RUS Bulletin 345-150.

8.2 Aerial Line Extensions: All aerial noncable-type line extensions from buried plant should be connected to the buried wire or cable through a wire link capable of safely fusing at currents less than the ampacity (current carrying capacity in amperes) of the subscriber's service. The 24 AWG copper leads connected to terminal blocks or 20 AWG bridle wires are adequate for this purpose. The term "noncable-type circuits" as used here refers to wire circuit facilities not enclosed in a metallic shield. Buried wire is considered to be a "cable type" facility.

8.2.1 Where buried plant facilities are extended by exposed aerial wire facilities, power contact protection should be applied to the aerial facilities in accordance with applicable RUS practices. Where the applicable practices require protection devices at the junction with buried plant, the low impedance ground required for the power protection device should be utilized to provide additional lightning protection to the buried plant. A low impedance path to ground can be accomplished by bonding the buried cable or wire shield to the grounding conductor or ground electrode of the power contact protector.

8.3 Aerial Drop Wires Connected to Buried Plant: Where economically feasible, the connection of aerial drop wires to buried wire or cable should be avoided in favor of buried services.

8.3.1 Aerial drop wires exposed to the possibility of contact with electric distribution facilities operating in excess of 300 volts to ground should be connected to the buried facilities through a 24 AWG copper fuse link or a 20 AWG. This fuse link is recommended as a protective measure to prevent large fault currents from reaching other stations served by the buried wire or cable. It will also prevent damage to coarser gauge buried facilities. The station being served should be protected in accordance with applicable station protection practices.

9. GROUNDING OF BURIED WIRE AND CABLE SHIELDS

9.1 Grounding at Junctions: As previously indicated, grounding of buried wire or cable shields at junctions with other types of facilities is recommended by RUS and it helps in compliance with the NESC requirements to effectively ground non-current carrying metal facilities.

10. METALLIC HOUSINGS ON VERTICAL POWER POLES

10.1 Bonding: When a metallic buried plant housing is mounted on a power pole, the grounding conductor of the housing should be bonded with at least a #6 AWG bare copper wire to the vertical pole ground wire, if present, on the pole. The purpose of this bond is to maintain the ground wire and the buried plant housing at the same potential, thereby preventing a shock hazard that otherwise might exist during a fault condition on the power line.

10.2 When Carrier Equipment is not Grounded: With certain types of cable carriers, the carrier equipment manufacturers have recommended that the carrier equipment not be connected to an electric system ground. In such instances carrier equipment housings and/or metallic buried plant housings enclosing carrier equipment should be bonded to vertical pole ground wires as recommended in Paragraph 10.1, but the carrier circuitry and chassis should be isolated from the metallic housing by insulation having at least 20 kV dc dielectric strength. The provision of this dielectric between the carrier circuitry and the housing makes it possible to use floating by-pass protection or protection grounded to a remote separate ground, and still maintain the buried housing at the same potential as the vertical pole ground wire. It is the responsibility of the carrier equipment suppliers to provide the 20 kV dielectric strength between the carrier circuitry and chassis, and the metallic housing. See TE&CM Section 822 (proposed conversion to RUS Bulletin 1751F-822) for additional details on carrier protection.

11. EFFECTIVE GROUNDING OF CABLE SHIELDS

11.1 General: Application of an effective grounding system is recommended for all locations. Both the National Electrical Code (NEC) and the National Electrical Safety Code (NESC) cite a 25 ohm resistance-to-ground for grounding systems. See Section 250-84 of the NEC and Rule 96B of the NESC. Note by attempting to obtain at least four grounds per mile (1.6 km), attention to obtaining 25 ohms at individual grounds is not necessary (except at special equipment sites) as the multiplicity of grounds helps to achieve an overall low impedance to ground.

11.2 The Purpose of Grounding Cable Shields is to protect telephone plant from the effects of ground potential rise (GPR) caused by power system faults. Grounding telephone cable shields helps to direct excessive voltages and currents induced on the shields to earth. This can often be achieved before these currents and voltages reach the location of plant or equipment requiring protection.

11.3 The Application of an Effective Grounding System can increase the flow of current in the shielding circuit and help to reduce noise. The shield should be continuous with no opens or bonding problems, so that the maximum benefits of effective grounding can be realized.

11.4 Isolating Damage Caused by a Lightning Stroke: An effective grounding system can isolate damage by dissipating the current through multiple paths to ground along the cable shield. Because of the high magnitude of current in a lightning strike and the associated GPR, it is not feasible to protect the entire telephone plant from damage. As a result it is desirable to isolate damage from a near or direct lightning strike to the least plant length as possible.

11.5 **Obtaining a 25 Ohm Ground** Provision of a ground at every location with a resistance-to-ground of 25 ohms or less cannot always be accomplished with a 5 foot (1.5 meter) ground rod. Use of a longer rod or multiple rods connected together may be necessary. This is especially true in areas of the country where there is an extremely high earth resistivity. In many areas of the country the winter frost line exceeds 18 inches (45.7 cm) or more. In such areas of the country use of eight foot (2.4 meter) rods should be made standard practice.

12. EFFECTIVE GROUNDING THEORY

12.1 **Effective Grounding** is based on the theory that multiple grounds along a cable shield will provide a low resistance-to-ground. This low resistance-to-ground provides for the dissipation of high voltages and currents induced or conducted on the cable shield.

12.2 **Spacing of Electrodes**: For protection purposes, it is desirable to have the earth electrodes spaced every quarter mile (0.4 km) but this is not practical in most buried cable plant. In aerial plant, especially in situations of joint use or joint occupancy, grounding of messengers at four or eight times a mile (1.6 km) is required by the NESC and is most beneficial because the lower the value of effective resistance-to-ground, the better the overall system will perform during power cross situations.

12.3 **Selection of Electrode**: Once the earth resistivity at a location has been determined, selection of the proper electrode can be made. A 5 foot (1.5 meter) rod is normally used. If the earth resistivity at the location is extremely high, an 8 foot (2.4 meter) rod should be used. An 8 foot (2.4 meter) rod should also be used in areas where the average frost line is 18 inches (45.7 cm) or deeper.