CABLE

ELECTRICAL PROTECTION

ENGINEERING CONSIDERATIONS

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1. GENERAL

1.01 This Bell Service Practice (BSP) discusses power and lightning damage to aerial, buried, and underground telephone cable and presents protective measures. Protection of terminal equipment is covered in other practices.

1.02 When it is necessary to revise this BSP, the reasons for the revisions will be listed in this paragraph.

1.03 Telephone cable is classified as exposed and protective measures are required when the cable is subject to any of the following:

(a) Disturbances from lightning (see paragraph 8.03)

(b) Contact with power conductors operating at more than 300 volts rms to ground

(c) Ground potential rise exceeding 300 volts rms to ground

(d) 60-Hz induction exceeding 300 volts rms to ground.

The exposure analysis and protection requirements given in this BSP are based on the classifications, definitions, and basic requirements presented in BSP 876-100-100.

1.04 Protection considerations for a specific cable installation should include all the exposures encountered, whatever the source, and the protective measures should be coordinated to mitigate these exposures. While this may seem self-evident, experience has shown that plant has occasionally been carefully protected against one source of exposure while another source was neglected. Lightning protection, for example, is primarily a voltage limiting task requiring protector gaps, while power protection additionally includes a current limiting task which requires fuse links. Fuse links required for current limiting purposes are not effective for lightning protection. However, low impedance cable shields and grounds are effective primary measures for both lightning and power fault protection.

1.05 Protection considerations and evaluations of cable plant should not be allowed to become confused with or by administrative distinctions and terminology (e.g., exchange area, toll, loop, trunk, etc.). Protection philosophy, requirements, and the resulting protection level are determined by safety considerations, history of trouble, environmental conditions, and traffic volume not by administrative distinctions.

1.06 Buried and aerial cable are subject to lightning exposure. Unfortunately, the belief persists that buried plant is safe from lightning strokes simply because it is below the ground surface. Part 8 shows that although buried cable receives fewer low-magnitude strokes, the average crest-current magnitudes of lightning strokes to buried cable are greater than to aerial cable. However, underground cable in metropolitan areas is not generally exposed to lightning or power. The underground construction method by design eliminates the possibility of power contacts. Lightning exposure is minimized by the shielding effects of surrounding buildings, metallic pipe systems, and by other cable shields in the conduit. However, underground cable may become exposed indirectly via aerial or buried cable extensions into an exposed environment. Underground cable in open areas is exposed to lightning and may also be exposed to power induction or ground potential rise.

1.07 When considering plant construction classifications for protection purposes, submarine cable is classified as buried cable. Bridge-crossing cable in conduit is classified as underground cable. Strand supported cable, attached to the side of a bridge, is classified as aerial cable. These construction arrangements are protected in accordance with their classifications.

1.08 Although the construction of fiber optic cable differs from that of conventional twisted pair telephone cables, the bonding and grounding principles that apply to paired cables are applicable with some modification to fiber optic cables. Since most fiber optic cables contain no metallic transmission conductors, in the electrical sense, protectors are not used. Fiber optic cable often employs steel reinforcing wires to provide mechanical strength or may incorporate a metallic shield component for mechanical or lightning protection. The steel reinforcing wires and metallic shield component are susceptible to power contact, induction, ground potential rise and lightning currents. Bonding and grounding, although not necessary for noise mitigation, are important for power fault de-energization, removal of lightning currents and personnel safety.

1.09 The procedures and requirements for insulating joints and capacitor installation in paired cable are applicable to fiber optic cable. In particular, care must be taken to assure that the fiber optic strength members or metallic shield components do not short circuit existing insulating joints.

1.10 Table A is an important basic aid for determining the dielectric strength adequacy of a particular cable type for its intended use. These values may be expected in field application, unless otherwise stated, and may be used in conjunction with the evaluations for exposure and determinations of trouble rate discussed in this BSP.

2. CONSTRUCTION AND THE CODES

2.01 Good construction, including adequate mechanical strength and spacing between power and communication facilities, is the primary defense against power contacts. The second measure is a coordinated protection plan to provide paths to ground on the communication facilities sufficient to prevent excessive voltage rise in the communication plant and to conduct enough power line fault current to ground to rapidly operate de-energizing devices (fuses, breakers, etc.) on the faulted power line or to cause the power line conductors to fuse open at the fault point. Coordinated protection is achieved by the cooperative effort of telephone and power company personnel.

2.02 Insulation on communication conductors may in many instances withstand power voltages but dependence upon insulation alone usually introduces considerable hazard. Generally, outside plant construction insulation, such as for self-supporting cable and other types of jacketed cable (strand supported and buried) are not considered sufficient to prevent energizing the plant when a power contact occurs. Jackets are primarily intended to provide mechanical and corrosion protection.

2.03 Clearance rules for communication facilities with respect to power facilities, roads, railroads, etc., are covered in the 918-and 620-Divisions of the BSPs. These practices are kept in accordance with provisions of nationally recognized codes covering these considerations, such as the National Electrical Safety Code (NESC) and the National Electrical Code (NEC) as discussed in BSP 876-100-100. Where applicable local regulations may apply or are more stringent and must be followed for example, in California General Orders 95 and 128 apply.

2.04 Before joint-use agreements are approved, however, refer to factors to be considered and general limitations applicable in BSP 876-102-100.

3. AERIAL PLANT POWER EXPOSURE

3.01 Controlling factors and limitations on joint-use arrangements are categorized into four voltage ranges within which the conditions vary. Requirements for treating the telephone cable in each of the four voltage categories are minimum requirements. Additional measures or uniform treatment of two or more voltage categories may be desirable in some areas because of local conditions, to reduce noise and simplify administration.. Safety and service reliability are primary considerations in joint-use agreements with power company facilities up to 150 kV rms phase-to-phase. Joint use at voltages exceeding 150 kV rms phase-to-phase is not allowed due to safety limitations. The following requirements apply to joint-use arrangements with multigrounded neutral power systems, unigrounded wye power systems and delta systems.

A. Joint Use With Multigrounded Neutral Systems

3.02 **Caution:** The secondary neutral of an electrical service to dairy farms in rural areas may be deliberately isolated from the primary neutral by the electric utility company. Dairy cows can be sensitive to stray voltages as low as 1/2 volt ac. Separation of primary and secondary neutrals mitigates stray neutral voltages which may adversely affect milk production. Bonding of cable shields and service wire shields to the secondary neutral in such cases could circumvent the intended mitigation. The isolation of these neutrals may be difficult to detect in the field. It is recommended that procedures be established with the electric utility company to identify locations with isolated neutrals and that procedures be established to protect them.

3.03 Where multigrounded neutral (MGN) power systems are involved, the telephone cable shield and strand must be bonded to the neutral. The neutral of an MGN system must be continuous throughout the primary and secondary sides, must be run with the phase conductors, and must be grounded at least four times per mile. In some older MGN systems, the primary and secondary neutrals are not connected. Where telephone cable is in joint use with such a system, it must be recognized that, in the event of a power fault on the secondary, the aerial plant may carry a substantial part of the fault current since the cable plant is bonded to both the primary and secondary neutrals. Bonding intervals between the MGN and the cable strand will be in accordance with the applicable voltage range (paragraphs 3.06 to 3.23 and Table C).

B. Joint Use With Unigrounded Systems

3.04 Avoid joint use with unigrounded wye power systems operating at more than 2.9 kV to ground unless there is a suitable grounding medium available. This can be the MGN or grounded secondary neutral of a lower voltage system on the same pole line, the MGN or grounded secondary neutral of an adjacent system or telephone company provided ground rods. There is no minimum requirement for the secondary neutral to be acceptable for bonding. Bonding and grounding intervals will be in accordance with the applicable voltage range (Paragraphs 3.06 to 3.23 and Table D).

C. Joint Use With Delta Systems

3.05 Where possible, avoid joint use with delta systems operating at more than 2.9 kV to ground because of the difficulty in clearing faults on these systems. Single phase to ground faults may persist for substantial lengths of time and may not be detected. Multiphase faults to ground are difficult to clear and can cause extensive plant damage. Bonding and grounding intervals will be in accordance with the applicable voltage range (Paragraphs 3.06 to 3.23 and Tables C & D). **WARNING:** Secondary neutrals which may be grounded separately from lightning arresters on poles carrying a delta power system can be difficult to identify. Under no circumstances should the telephone cable shield or strand be bonded to the arrester ground. If a bond to a secondary neutral is necessary, arrangements should be made to have the electric utility identify and make the connection to the secondary neutral. Where joint use with delta systems cannot be avoided, bonds can be placed to an adjacent MGN system or to the vertical down lead of a distribution transformer.

D. Current Carrying Capability of Strand

3.06 When telephone cable plant is constructed in joint use with power that exceeds 2.9 kV to ground, it is necessary to assure that the strand has adequate current carrying capability to clear fault currents without suffering extensive damage. Where the strand's current carrying capability is adequate, damage to the telephone plant usually will be limited to the span where the power contact occurs. Current carrying capability is expressed as I^2t. "I" is the maximum estimated power fault current which will flow as a result of a power contact to the strand and "t" is the total time in seconds that the fault current flows. This time includes the initial clearing time (power relay operation time plus circuit breaker clearing time) and any additional time the fault current flows during breaker reclosures.

3.07 I^2t capability for various strands is shown in Table B. Values for each strand size are given for the case where the contact occurs between two bonds or grounds and the fault current is assumed to split equally in each direction. Also shown is the case where there is only a single bond or ground and the entire current flows in one direction.

3.08 The estimated value of maximum fault current and circuit breaker operation time should be obtained from the power company relay engineer or by calculation as described in BSP 876-103-100. The I^2t values of Table B are based on adiabatic conditions with a maximum time of current flow not greater than 5 seconds. At the I^2t values given, the resistance of the strand increases by a factor of 2.3 times. Changes in resistance of the support strand should be considered when determining fault current and I^2t requirements. Strand strength remains adequate, but cable damage and melting of the supporting web of self-supporting cable occurs for I^2t values exceeding 50% of the values shown.

3.09 Where the power is provided with overcurrent protection having characteristics of a 200T or smaller size fuse, all sizes of cable strand covered in the table are considered to have adequate current carrying capability and the I^2t need not be determined. In cases where the I^2t value cannot be determined, it is necessary to place a bond or ground at each terminal to prevent the terminal from being energized as a result of the strand burning open.

Table B
Strand I^2t Capability

Type Of Strand	Strand Resistance	Maximum Fault I^2t Entering Strand (Kiloamperes^2 X Seconds)	
	Ohms Per Kft (Cold)	Equal Current Split in Strand (1/2 Each Direction)	All Current One Direction in Strand
6M	1.42	32	8
10M	1.16	48	12
16M	.804	100	25
25M	.630	172	43
6.6M (Self Support)	2.77	8	2

Note: Strand I^2t capability of 8 Kiloamperes^2 X Seconds or greater is considered adequate for deenergizing power systems protected by 200T fuses or smaller if the resultant fault current is 1500 amperes or greater. At the values given, strand resistance increases by a factor of 2.3 times. Strand strength remains adequate but cable damage and melting of the support web of self-supporting cable occurs for I^2t values exceeding 50% of Table B values. I^2t is based on adiabatic conditions with time of current flow not greater than 5 seconds.

3.10 Additional discussion of the rules for applying I^2t is contained in the following paragraphs, which cover specific voltage ranges and in Tables C and D.

E. 5.0 kV RMS and Less Phase-to-Phase (2.9 kV to Ground)

3.11 Cable plant exposed to this range of voltage normally does not require added protection beyond that provided by insulation and by bonding and grounding practices described in BSP Divisions 624-, 631-, 633, etc.. Low impedance grounds are assured by bonding the aerial cable shield to underground cables, to central office grounds, and particularly to multigrounded neutrals (MGN). If a MGN is not available, bond to the secondary neutral ground or telephone company provided ground rod as recommended in paragraph 3.04. Bonds or grounds must be placed at the beginning and end of the exposed section and at 1/4 mile intervals. Use No. 6 AWG copper conductors for bonding and grounding. The bonding or grounding interval may be less than 1/4 mile if there is a history of lightning trouble or the lightning exposure environment appears especially severe (Paragraph 8.03).

F. 5.0 kV RMS to 26.0 kV RMS Phase-to-Phase (2.9 kV to 15 kV to Ground)

3.12 The rules applicable to the less than 5.0 kV range also apply here, except that protectors are also required at drop and wire branches from pulp-insulated cable. PIC cable plant does not require protectors at these points unless located in a severe lightning exposure situation (severe lightning exposure situations for PIC cable exist where the cable is associated with towers, airports, mountain top services, and long rural lines). When placing lashed cable, the strand need not meet I^2t values if there is either an umbrella of secondary power between the primary facilities and the telephone plant, or if there is an umbrella of existing telephone cable of adequate I^2t value (Table B). Present bonding and grounding requirements apply. Where I^2t values cannot be met, bonds or grounds must be placed at every terminal, not to exceed 450 feet for 6.6M strand.

G. 26.0 kV RMS to 60.0 kV RMS Phase-to-Phase (15 kV to 34.6 kV to Ground)

3.13 The rules applicable to the less than 5.0 kV range and to the 5 to 26.0 kV range also apply here except for the bond or ground at each terminal and the bonding or grounding interval. Bond the cable strand and shield to the power MGN or secondary neutral ground or telephone company provided ground rod at each terminal location. If there is a bond or ground on an adjacent pole and strand I^2t values have been met, the bond or ground at the terminal may be omitted. In this voltage range, bonds or grounds must be placed at the beginning and end of the joint-use section and at 1/8 mile intervals.

3.14 The bonds between station protector grounds and power service grounds should be verified and, if missing or improper, replaced or corrected to minimize voltage differences due to power contact or lightning disturbances. These voltage differences must be equalized or limited by common grounding to reduce shock hazard and to prevent arcing and damage to equipment and property. (See BSP 876-300-100MP.)

3.15 When the exposed cable extends beyond the 26 to 60 kV joint-use section, protection will be required for stations and cable plant beyond the exposure. This protection is necessary because, in the event of a fault in the joint-use section, fault current will seek paths to ground via the cable extension and station protectors. This current must be interrupted at the station drops or diverted to an MGN, secondary neutral or other ground. When the extension is on a lower voltage MGN power system (less than 26 kV), the MGN, secondary neutral ground of the lower voltage system or telephone company provided ground should be used for grounding the telephone plant. When the extension is on nonjoint-use poles, telephone company provided grounds must be provided.

3.16 Protective measures for self-supporting cable are the same as for cable supported on bare strand as described in paragraphs 3.13 through 3.15, except that the bond specified at the terminal as optional in paragraph 3.13 is mandatory at each terminal for self-supporting cable if I^2t values are not met.

3.17 When placing self-supporting or lashed cable, the strand need not meet I^2t values if there is either an umbrella of secondary power between the primary facilities and the plant or if there is an umbrella of existing telephone cable of adequate I^2t value (Table B). Present bonding requirements apply. Changes in resistance of support strand should be considered in determining fault current and I^2t capability.

3.18 For power coordination purposes, the I^2t value for 6.6M self-supporting cable strand is approximately 25 percent of that for 6M bare strand (see Table B). The 6.6M self-supporting cable strand is slightly smaller (1/4 inch diameter) and of a higher tensile strength steel than bare strand (5/16 inch diameter) which accounts for the lower I^2t value (inductive reactance values are essentially the same).

H. 60.0 kV RMS to 150.0 kV RMS Phase-to-Phase (34.6 kV to 86.6 kV to Ground)

3.19 Wire facilities connected to or branching from the cable within a joint-use section operating at 60.0 to 150.0 kV are not acceptable because of lack of adequate conductivity for fault current ground paths.

3.20 Joint-use with 60.0 to 150.0 kV is to be avoided unless an umbrella of lower voltage power distribution circuits is positioned between the power transmission and telephone facilities. The lower voltage circuits will provide a mechanical barrier and help prevent direct contacts between the transmission conductors and telephone cable. Generally, these low voltage distribution circuits will also assure the presence of an MGN or secondary neutral ground and readily available vertical ground wires. Where there is a discontinuity in the lower voltage umbrella, the MGN or a secondary neutral ground conductor of the lower voltage distribution system must be extended throughout the discontinuity and placed above the telephone cable to maintain a partial barrier between the cable and the higher voltage system. (Power systems in the 60.0 to 150.0 kV range are usually 3 wire delta or unigrounded systems that have no neutral conductor to use as a common bonding and grounding electrode.) When bonding to the power utility's neutral, a vertical ground wire must be provided on each pole in the area of discontinuity throughout which the neutral conductor is extended.

3.21 The telephone cable shield and supporting strand must be bonded to an MGN, or secondary neutral ground vertical wire or telephone company provided ground rod at each pole throughout the entire length of the joint construction including areas of lower voltage system discontinuity. The MGN or secondary neutral ground, used for grounding the cable, should also be available and used for common grounding at the station protectors. These provisions will afford multiple paths to ground for fault currents and tend to limit voltages appearing at the station protectors.

3.22 Telephone stations served from facilities exposed to this joint construction must be inspected to determine that fuseless protectors are in place and that protector and power service grounds are interconnected as specified in BSP Division 460.

3.23 Stations served from laterals and extensions of the exposed cable should also be given special consideration. If the neutral of the higher voltage system is common with a lower voltage system serving the station, both neutrals will be subjected to a large rise in potential in the event of a fault. Therefore, the cable shield and strand should be bonded to an effective ground (such as an MGN, secondary neutral ground or telephone company provided ground rod) at points approximately 1,000 and 2,000 feet from the end of the higher voltage exposure. If the neutral of the lower voltage system is isolated from the higher voltage neutral, the cable shield and strand should be bonded to an effective ground where the cable becomes joint with the neutral of the lower voltage system. The MGN or secondary neutral ground of the isolated lower voltage system is a satisfactory effective ground. A second ground should be placed approximately 1,000 feet beyond the first bond.

3.24 A nonjoint-use cable crossing on a joint-use common pole, or a nonjoint extension, should be handled the same for 60 to 150 kV as described for 26 to 60 kV in paragraph 3.15.

3.25 A summary of the preceding protection recommendations for the four power system voltage ranges is presented in Tables C and D.

I. Fiber Optic Cable Protection

3.26 Steel reinforcing wires and any metallic shield component of fiber optic cable must be bonded and grounded. In addition, continuity of these components should be maintained throughout the cable run. Bonding of the steel reinforcing wires and metallic shield to the support strand should be done at closures with the distance between bonds not to exceed 1.5 miles. Where the distance between closures exceeds 1.5 miles, additional bonds must be installed.

3.27 Closures for these cables are designed so that when properly assembled to the cable, continuity of the reinforcing wires across the splice is maintained. A No. 6 AWG ground wire is provided in the closure which must be bonded to the support strand. Closures should also be grounded at each Building Entrance Facility, Cable Entrance Facility and repeater hut.

3.28 When exposed, the support messenger must be grounded at the appropriate interval for the joint-use voltage, Tables C & D. Also, bond the support strand to other strands at 1/4 mile intervals, at each crossover and at each branch.

J. Grounded or Insulated Guys

3.29 Numerous situations are described and categorized in BSP 621-405-011 where pole guys may be exposed to power contact. Exposed guys must always be grounded or insulated to avoid personnel hazard and plant damage. BSP 621-405-011 should be consulted when planning guy placement to determine whether they are to be grounded or insulated. In California, consult BSP 621-405-011PT.

K. Common Pole Crossing

3.30 A common pole crossing does not constitute a power exposure. This arrangement is not likely to result in a contact between power conductor and a telephone cable in the event of a break in the power conductor. If a break should occur, the power conductor will most likely pull away from the pole and clear of the telephone cable as it falls to the ground. Except for the normal clearance rules, no protection measures, such as bonding to the MGN or grounding, are necessary. A common pole crossing should not be confused with a common crossing on a joint-use pole line, which does require careful bonding and grounding.

L. Electrostatic Charge

3.31 Whenever electrostatic discharge is suspected or reported involving personnel on aerial plant due to the influence of nearby extra high voltage (EHV) power lines, refer to BSP 876-100-102 for protective measures.

M. Bonding and Grounding of Cable Armor

3.32 The electrical continuity of armor or the steel barrier of unsoldered mechanical (UM) protected cable must be maintained throughout the entire length of the cable. Bonds or grounds should be made at the same locations that are specified for the cable shield. Connections to the UM armor for continuity or bonding should be external to and independent of pressurized and filled closures.

3.33 The armor must be grounded where the cable enters a Building Entrance Facility, Cable Entrance Facility or repeater hut. At each end of an armored cable run, bond the armor and cable shield. The cable shield should not be grounded through the UM armor or a UM ground. (The UM armor may be grounded through the cable shield ground if an independent ground connection is not convenient.). Bond the UM armor to the cable shield within non-pressurized or non-filled terminals and closures to provide a UM armor connection to the support strand at all sheath openings.

4. BURIED PLANT POWER EXPOSURE

A. Joint Trench - Random and 1-Foot Separation

4.01 Joint buried plant in the same trench with power cables is not considered exposed to power contact when a 1 foot minimum separation is maintained between the telephone cable and power cable. The 1 foot separation is a minimum spacing compromise regardless of voltage range. This rule, however, does not preclude lightning exposure, low frequency induction or ground potential rise. BSP Sections 917-356-001 and 917-356-100 cover the requirements for buried urban distribution systems.

4.02 Joint buried plant in the same trench with power cables with no deliberate effort to maintain separation is called random separation. This plant arrangement is limited to subscriber end distribution cable between the serving area interface and the subscriber. The cable plant is considered exposed only if the power exceeds 300 volts rms to ground. The arrangement is permissible with nominal voltages no higher than 20 kV phase-to-neutral on wye systems and 5.3 kV phase-to-phase on delta systems. For protection and control of inductive interference, see BSP Sections 917-356-001, 917-356-101 and 873-503-101. In California, random separation is limited to subscriber end buried service wires and buried secondary power conductors (drops) when specific electrical protection conditions are met. The buried service wire is classified as exposed. The arrangement is permissible with nominal voltages no higher than 300 volts rms to ground.

4.03 In addition to the voltage limitations placed upon joint random construction, the National Electrical Safety Code specifies that the power conductors must also include a bare or semiconducting jacketed grounding conductor in continuous contact with the earth. The grounding conductor may be a sheath, shield or both, a separate conductor in close proximity to the power conductors, or concentric neutral conductors. The concentric neutral conductors when used as the grounding conductor may be bare or covered with a semiconducting outer jacket which affords protection against corrosion and physical damage while maintaining electrical contact between the neutral conductor and earth. The presence of semiconducting jacketed power cables which have a carbon-black impregnated outer jacket may contribute to the corrosion of buried telephone plant. (See RL 83-07-018.)

4.04 In both types of joint trench plant construction, the telephone cable shield and power neutral ground wire or power apparatus should be bonded together at all the locations prescribed below:

(a) Not more than 1000 feet apart; i.e., no point on the telephone cable should be more than 500 feet from a bond.

(b) At least at every other terminal (pedestal or buried type cable closures supplying service wires or service cables). The bond must not be omitted on any two adjacent terminals.

(c) At the telephone terminal (pedestal or buried type cable closures supplying service wires or service cables) nearest to each transformer. The bond must be made to the transformer itself, to the multi-grounded neutral, a secondary neutral or secondary pedestal served from that transformer.

(d) At all above ground telephone terminals, apparatus cases and cable closures which are within 10 feet of any above ground power apparatus. Such bonds must be made directly to the above ground apparatus.

These joint trench bonding requirements are reflected in BSP 629-020-100.

Table C

Protection Requirements For Aerial Cable In Joint Use With MultiGrounded Wye Power

Minimum Requirements	**Power System Voltage In kV To Ground (Power System Voltage In kV Phase-to-Phase)**			
	0.3 - 2.9 (.5 - 5.0)	**2.9 - 15 (5.0 - 26.0)**	**15 - 34.6 (26.0 - 60.0)**	**34.6 - 86.6 (60.0 - 150.0)**
Bonding Interval - Strand To **Neutral**	Both Ends of Section and 1/4 Mile Intervals	Both Ends of Section and 1/4 Mile Intervals	Both Ends of Section and 1/8 Mile Intervals	Every Pole
Umbrella of Lower Voltage Power Conductors Required Between Cable and Power	No	No	No	Yes
Ampacity (I^2t) of Strand Must Be Verified (Table B)	No	Yes	Yes	Yes
Bond Every Terminal to MGN	No	No	Yes	Yes
Metallic Shield Construction Required For Branches (No Wire)	No	No	No	Yes
118 Type Protectors or 10-Mil Blocks Required On Wire Branches to Pulp Cable	No	Yes	Yes	Wire Branches Not Permitted
Bonds Between Protector and Power Service Ground At Stations Must Be Verified	No	No	Verification Of Bonds Recommended At Customer Locations Served By Terminals In The HVJU Section	Yes

Table D

Protection Requirements For Aerial Cable In Joint Use With Uni-Grounded Wye and Delta Power In Areas Where Bonding to Neutrals is Not Allowed

Minimum Requirements	**Power System Voltage In kV To Ground (Power System Voltage In kV Phase-to-Phase)**			
	0.3 - 2.9 (.5 - 5.0)	**2.9 - 15 (5.0 - 26.0)**	**15 - 34.6 (26.0 - 60.0)**	**34.6 - 86.6 (60.0 - 150.0)**
Grounding Interval - Strand To Telephone **Ground Rod**	Both Ends of Section and 1/4 Mile Intervals	Both Ends of Section and 1/4 Mile Intervals	Both Ends of Section and 1/8 Mile Intervals	Every Pole
Umbrella of Lower Voltage Power Conductors Required Between Cable and Power	No	No	No	Yes
Ampacity (I^2t) of Strand Must Be Verified (Table B)	No	Yes	Yes	Yes
Ground Every Terminal to Pacific Bell Ground Rod	No	No	Yes	Yes
Metallic Shield Construction Required For Branches (No Wire)	No	No	No	Yes
118 Type Protectors or 10-Mil Blocks Required On Wire Branches to Pulp Cable	No	Yes	Yes	Wire Branches Not Permitted
Bonds Between Protector and Power Service Ground At Stations Must Be Verified	No	No	Verification Of Bonds Recommended At Customer Locations Served By Terminals In The HVJU Section	Yes

B. Community Antenna Television (CATV) Cables

4.05 In buried installations where the telephone and CATV cables share a trench that does not also contain primary power cables, bonding to the outer conductor of the CATV cable is not required. Also, bonding to the CATV distribution pedestals near telephone apparatus is not required.

4.06 Bonding is not required for the following reasons:

(a) Safety: The low voltages and currents on CATV lines do not pose a significant hazard. The common bonding in buildings (required by the NEC) provides voltage equalization along the route.

(b) Electrical Protection: Although bonding to CATV cables would divide any lightning and power fault currents, CATV cables could also be the source of these currents.

(c) Inductive and RF Interference: CATV's high frequency and low power signal has not created any problem in these areas.

C. Separate Trenches 3 Feet or Less Apart

4.07 Where power and telephone cables are in separate trenches 3 feet or less apart, bonding requirements must be the same as for joint trench (see Part 4A).

D. Separate Trenches More Than 3 Feet Apart

4.08 Where power and telephone cables are in separate trenches more than 3 feet apart, a bond must be made at all above ground telephone terminals, apparatus cases and cable closures which are located within 10 feet of any above ground power apparatus. These bonds must be made directly to the above ground power apparatus. These bonding requirements are also reflected in BSP 629-020-100.

4.09 Additional bonding is recommended but may result in economic penalties. The decision to bond or not should be made locally in consideration of the following factors:

(a) From a safety standpoint, when the separation between completely buried power and telephone cables is more than 3 feet, there is little chance of a person making accidental contact between the two. Bonding is important, however, between telephone cables and power systems serving the same customer to limit the interchange of current at the customer location during power fault conditions or during lightning disturbances. In the absence of bonds, fault current flowing from the power neutral to the telephone ground at the customer location may result in excessive current over the telephone service wire. In addition, large lightning currents flowing between the telephone and power ground at the customer location have been one of the factors contributing to damage of electronic station apparatus such as PBXs and key equipment. Bonds between power neutrals and cable shields as described for joint trench can reduce these currents.

(b) Bonding also lowers the impedance to ground and may help reduce noise. When bonds are specified for noise mitigation, they should be place at convenient points at or near both ends of the parallel trenches and at least once every mile.

E. Common Right of Way and Aerial Power

4.10 Where buried telephone cable is located in the same right of way or easement with an aerial power line, bond all above ground telephone terminals, apparatus cases and cable closures which are located within 10 feet of an MGN or secondary neutral vertical down lead, conduit or power apparatus where the power system is less than 34.6 kV to ground. In addition, for inductive interference reasons, bonds should be made at or near both ends of the exposure and at least once every mile. Additional information can be found in BSP 629-020-100. At voltages higher than 34.6 kV to ground, there may be a coordination problem, if power faults occur, where isolation or special treatment may be preferable.

F. Armor Continuity

4.11 The continuity of the armor of buried cable should be maintained. The bonding and grounding considerations addressed in paragraphs 3.32 and 3.33 for aerial cable are also applicable to buried cable. In addition, the armor should be bonded across sheath openings external to the splice closure with a #6 AWG copper conductor. At pedestal locations, the bonding or grounding should be done within the closure. As with aerial plant, the armor should be bonded to the power neutral at the same location as required for the cable shield.

G. Bonding Methods

4.12 Bonds or grounds must be provided by a #6 AWG copper wire (bare or insulated) and approved connectors. Convenient bonding or grounding locations should be chosen to minimize the length of the bonding wire and to facilitate the connection to the power neutral. These locations will generally be at transformer or at power pedestals where the power company employees have access to the power neutral ground wire. Where local procedures have been established, bonds may be made directly to primary or secondary multi-grounded neutrals other than at transformers or pedestals. These bonds may be required where transformer and/or power pedestal locations are more than 1,000 feet apart.

5. UNDERGROUND PLANT POWER EXPOSURE

5.01 Underground cable is normally isolated from power conductors, with telephone and power facilities installed in separate structures. This arrangement is classified as unexposed and can only become exposed indirectly by aerial or joint random buried extension to the underground telephone cable in a joint use arrangement. In this case, junction protection (fuse cable) is required. Telephone cable installed in conduit across a bridge with power in a separate conduit is unexposed and classified as underground construction.

5.02 Underground cable should not be bonded in handholes and manholes where the cable is just pulled through. When a splice occurs in the manhole, the metallic sheath component shall be bonded to the manhole ground. When more than one splice occurs in a handhole, the splice cases shall be bonded together.

5.03 It is our policy to avoid installing telephone cable with power conductors in separate ducts of the same conduit structure or in joint manholes or handholes. The National Electrical Safety Code (NESC) and California Public Utilities Commission General Order 128 (GO 128) requires separate conduit systems or structures with minimum spacing limits depending on the type of material separating the two conduit systems. The National Electrical Code (NEC) (800-11) has requirements similar to the NESC and GO 128 that require separation of power conductors and communications conductors entering a building. The NESC and GO 128 contain provisions that allow joint use manholes. However, these arrangements should be avoided when possible. The primary reason for discouraging common underground construction is worker safety. Secondly, in the event of a problem on the telephone cable, it is difficult to make cable repairs without danger of contact with power conductors. If both power and telephone facilities are damaged, service restoration may be delayed due to the time required to coordinate repair efforts of power company and telephone company personnel.

Note: GO 128 applies in California only.

5.04 The following restrictions apply to non-SBC LEC cables using SBC LEC owned cable ducts:

(a) Circuits using the cable facilities cannot use ground as a conductor.

(b) Cables or conduits carrying commercial ac power are not permitted.

(c) If the normal voltages carried by the cable exceed 50 volts ac rms to ground or 135 volts dc to ground, except for momentary signaling and control voltages, the cable must have a grounded sheath or shield.

(d) The cable may carry voltages and currents permitted by the NEC Class 3 Signal Circuit requirements.

(e) Coaxial cable that exceeds the limits of the NESC or GO 128 in California cannot use the same duct as SBC LEC cable.

(f) Cables that exceed the limits of paragraphs (c) and (d) but do not exceed the limits of the NESC or GO 128 are permissible. These cables cannot occupy the same ducts as the cables that meet the limits of paragraph (c), (d) and (e).

(g) Multi-tube coaxial cable may carry continuous dc voltages up to 1800 volts to ground where the conductor current will not exceed one-half ampere and where the cable has two separate grounded metal sheaths or shields and a suitable insulating jacket over the outer sheath or shield. Such cable must occupy a separate duct. The power supply shall be so designed and maintained that the total current carried over the route sheath shall not exceed 200 microamperes under normal conditions. Conditions which would increase the current over this level shall be cleared promptly**. Note: This requirement applies to multi-tube coaxial cables not CATV type coaxial cables.**

Fiber Optic Cable

5.05 Underground fiber optic cable should not be bonded in handholes and manholes where the cable is just pulled through. When a splice occurs in the manhole, the steel reinforcing wires and metallic sheath component (if present) shall be bonded to the manhole ground. In this manner, the reinforcing wires and metallic sheath component will be bonded to the reinforcing wires and sheath of all other fiber optic cables as well as the sheaths of any paired cables in the same manhole. Joint use of manholes and handholes with power, as well as the placing of fiber optic with power conductors in separate ducts of the same conduit structure is not recommended. When more than one splice occurs in a handhole, the splice cases shall be bonded together.

Armor

5.06 Cable armor or a UM steel barrier that starts or ends in a manhole should be bonded to the manhole ground with a #6 AWG copper conductor. The armor should be bonded across sheath openings external to closures using a #6 AWG copper conductor and the bond also connected to the manhole ground.

6. UNUSUAL POWER EXPOSURE

6.01 Exposure problems have been encountered by at least one operating company in a large metropolitan area which probably indicates a trend in the power industry with serious consequences for the telephone industry. In order for a power company to meet increasing demands for power, more transmission or subtransmission lines and substations could be built, the voltage on existing lines could be increased or the substation transformer capacity (kVA or MVA) ratings could be increased. Large increases in transformer capacity have resulted in operating current magnitudes over 1000 amperes that during power fault conditions may constitute a 60 Hertz induction hazard to paralleling telephone cable. The need for corrective measures has arisen along joint right-of-ways when joint trench construction has been used, in utility corridors where power is aerial on metal towers with telephone cable buried nearby, or when power and telephone cable are in joint use construction. Refer to BSP 873-503-101 for information concerning planning and mitigation measures to be used in these situations.

6.02 Where high magnitude operating currents or fault currents are expected to present an induction hazard (50 volts rms or greater to ground) to buried cable in joint trench construction with standard separation, request that the power company provide a concentric neutral power conductor as the preferred shielding method. If a shield wire is used instead of a concentric neutral, it should be placed between the power conductors and the telephone cable close to the telephone cable. (Refer to BSP Division 873 for additional information on shield factor, calculation of shield currents and use of shield conductors.)

6.03 Where aerial transmission or subtransmission lines on steel towers share a common right-of-way with buried telephone cable, it is recommended that the power company be requested to provide skywires (if not already provided) interconnecting the metal structures of adjoining towers. In the event of an insulator flashover, fault current will be dissipated to earth at several towers, thus reducing the magnitude of current in the earth at the flashover point. However, most of the fault current will return to the substation via the earth rather than the skywire. Studies and experience have shown that the first few feet of separation between the tower footing and the buried cable are the most critical. For example, the voltage to ground at a point 20 feet from the tower is only approximately 20 percent of the voltage to ground of the footing itself. (The footing voltage to ground under fault conditions will be less than the phase to ground voltage.)

7. CABLE PROTECTION IN THE POWER STATION ENVIRONMENT

7.01 Cables serving electric power stations or passing through the power station zone of influence may require special measures to protect them against the effects of ground potential rise (GPR) and induction caused by faults in the electric power system. Not only are the protection requirements for telecommunication cables serving electric power stations a function of the GPR and/or induction impacting the serving cable but also of the utilities service performance objectives for the telecommunication services being provided. Under some circumstances, a high dielectric dedicated cable may be required to serve the power station exclusively. In contrast to the normal bonding and grounding procedures employed for general use cable, the metallic shield of a high dielectric dedicated cable is deliberately isolated from ground. These protection requirements are described in BSP 876-310-100MP.

7.02 Supplemental protection measures for general use cables which are routed through the power station GPR are contained in BSP 876-310-100MP.

8. DETERMINING THE LEVEL OF PROTECTION REQUIRED AGAINST LIGHTNING

8.01 Lightning protection levels and measures recommended in this section are primarily intended for protection of the plant from damage. Personnel protection is a separate consideration covered by supplementary measures applied at repeaters, stations and central offices (see BSP Sections 876-200-100, 876-300-100MP and 876-500-100). Supplementary protection measures provide the required level of personnel protection at the most effective locations.

8.02 To determine the extent of lightning exposure of plant for protection purposes, the plant environment, traffic concentration and evaluation should proceed as follows for optimum cost effectiveness.

A. Environment and History

8.03 In areas where thunderstorm activity is less that five thunderstorm days a year and earth resistivity is 100 meter-ohms or less, plant is not considered exposed to lightning. Experience has shown that insulation, normal grounding and bonding provides adequate protection in such areas. However, regardless of soil resistivity and thunderstorm incidence, all plant of any construction type that is elevated above the average altitude of the surrounding terrain or is associated with high structures is considered exposed to lightning. For example, plant constructed on mountains or associated with fire towers, commercial radio sites or microwave radio stations are considered exposed to lightning. Where the above values of thunderstorm activity and earth resistivity are generally exceeded, all aerial plant is classified as exposed to lightning. The one exception to this rule is plant located in metropolitan areas where buildings are close together and sufficiently high (relative to the telephone plant) to provide "cone of protection" shielding. Two cones overlapping the telephone cable, one from each side, are preferable. (The cone of protection principle is explained in BSP 876-210-100.)

8.04 The most reliable indication of the need for lightning protection on a particular route is a history of lightning trouble. This history many times reveals the effects of hidden geophysical features such as large expanses of bed-rock near the surface. The result may be localized high earth resistivity which, if combined with even moderate thunderstorm activity, can result in lightning trouble.

8.05 In some cases, there will be no established history of lightning trouble on a given or proposed route. Here it is recommended that the need for protection be determined on the basis of environmental and traffic considerations or by local operating rules. A typical example of such rules applies to the T1 repeatered line as described in BSP 876-500-100. The T1 rules are based more on multiple cable shielding effects, traffic and administrative considerations than on environmental considerations.

8.06 Buried cable is subject to lightning strokes of higher magnitude than is aerial cable as shown in Figures 1 and 2. This fact is contrary to a prevalent belief that buried plant is beyond reach of lightning strokes. Whether or not actual exposure is mild or severe depends on the frequency of strokes to the cable in the associated environment.

8.07 Metropolitan environments offer maximum protection against lightning strokes to plant. This is true because high buildings present intercept strokes, offer cone of protection shielding and direct intercepted strokes to the extensive metallic piping systems below ground. These systems provide many low impedance paths for dispersing stroke current to earth. Under these conditions, an insignificant amount of current will appear on the shield of aerial or underground cable. Accordingly, neither type of plant is usually considered exposed to lightning (buried cable protection is not usually used in metropolitan environments).

8.08 Suburban environments usually lack the high structures found in a metropolitan area, but generally do have similar extensive metallic piping systems. Therefore, the exposure of aerial and buried cable to direct strokes of lightning is moderate. Metallic piping systems provide rapid drain of the stroke current to earth and discourage direct strokes to earth from arching to nearby buried cable. However, stations and offices served by aerial or buried cable in a suburban environment require protection devices if the lightning activity and earth resistivity exceed the minimums given in paragraph 8.03.

8.09 Rural environments offer practically no shielding to the telephone cable and have insignificant amounts of metallic pipe structure in the earth. These conditions combine to make the aerial or buried telephone cable a major target for lightning strokes if the minimums of paragraph 8.03 are significantly exceeded. All stations and repeaters require protection devices, and if thunderstorm activity is heavy and the exposure severe, supplemental shielding and grounding for the cable may be necessary. Branches and junctions may require full-count protection even for PIC cable, especially if the PIC is of small diameter and is associated with towers, airports, mountain-top services and long rural lines.

B. Traffic Concentration and Nature

8.10 After lightning exposure of the cable has been evaluated (paragraphs 8.01 to 8.09), the nature and level of applied protection (if required) depends partially on the concentration of traffic. The level of protection also depends on the mechanical design of the cable. Consider three types of cable all approximately the same physical size that are generally exposed to lightning.

(a) A 900 pair cable carrying voice frequency (VF) loop circuits

(b) A 900 pair combination VF and wire facility carrier trunk cable

(c) A 22 tube coaxial trunk facility for long haul carrier communications.

An appreciation of the relative need for and level of protection required on these three cables may be gained from the following facts. The two paired facility cables by nature are very sturdy in construction and highly resistant to lightning damage while the tubes in the coaxial cable are subject to crushing due to the explosive effects of lightning.

8.11 Loss of service in the coaxial cable due to the crushing effects of lightning on the coaxial individual tubes would be catastrophic for the wide area served by this trunk facility cable that may be carrying over 108,000 message channels. Therefore, coaxial cable is protected with bare shield wires buried above the cable. The basis for this method of protecting a trunk cable is explained in paragraph 10.08 but is applied specifically to coaxial cable in BSP 876-404-100.

8.12 At the other extreme is the 900 pair loop circuit cable. Protection level requirements in this case are usually minimal because of low traffic concentration and the usual suburban-metropolitan location where shielding and ground structures divert lightning strokes. The dielectric strength of the particular type of cable will also dictate protection level. Interruption of service, while serious, affects only subscribers in a predictable area where the costs and benefits of protection measures can be compared against the low probability of outage time and cost of associated repairs. The 900 pair VF and carrier trunk facility protection problem stands somewhere between the extremes of the 900 pair exchange loop cable and the coaxial cable. The level of protection for the combination cable should be relatively high because of traffic concentration. Partial service can usually be maintained and the magnitude of damage limited by applying supplemental protection measures.

8.13 The 900 pair loop circuit cable, a distribution type plant, has many taps and branches with frequent connections to individual stations. The possible combinations of grounds are so great that an analysis to predict trouble rate and trouble location is impractical. Grounds associated with such cable may act either as sinks or sources of lightning. Accordingly, special emphasis is placed on protection of the stations and central office. Where exposure levels appear to be high, both through pairs and tap pairs should be protected at branch points and drops to minimize pair-to-pair faults that predominate in this type plant. (See these measures in paragraph 10.05.)

8.14 Trunk pairs normally proceed from one end of a cable to the other without side taps. Pair-to-pair voltages are relatively small as long as common coupling is maintained between all core conductors and the cable shield. Lightning trouble in this type cable is therefore of the core-to-shield type since the core conductors act essentially as a unit with respect to the shield.

8.15 Buried trunk cables include an external insulating jacket to protect the shield against corrosion. High levels of lightning current between jacket and earth will greatly exceed the dielectric strength of the jacket, producing punctures at numerous points. Shield current propagation will then be practically the same as with a shield in direct soil contact. Current flowing in the shield produces a shield-to-earth potential, which is a function of shield current magnitude and the impedance of the shield to earth. The core conductor potential rises with the shield potential but a net potential difference will develop, designated the core-to-shield voltage ($V_{C\text{-}S}$). Since $V_{C\text{-}S}$ is imposed across the insulation between the shield and the core, an approximation of $V_{C\text{-}S}$ would help determine the adequacy of the dielectric strength of the insulation in protecting the core from shield to core breakdown.

8.16 The manner in which surge current departs from the cable shield to surrounding soil is fundamental in determining the magnitude of $V_{C\text{-}S}$. Generally, shield current attenuation as the current pulse travels along the shield is primarily a function of soil resistivity and current waveform. The cable diameter and depth of burial are of secondary importance. Therefore, the criterion for adequate cable protection is to provide core insulation around the conductor complement of sufficient dielectric strength to withstand by itself, or with the aid of supplemental measures, the probable core-to-shield voltage level set by environmental conditions. Rigorous studies of these conditions and system design considerations have resulted in cable manufactured to withstand most lightning exposure and to minimize water penetration through shield punctures (see Table A).

9. ESTIMATED LIGHTNING TROUBLE RATES ON BURIED TRUNK CABLE

9.01 It is necessary to determine the adequacy of a buried trunk cable in a given environment from a protection standpoint. It is also necessary to evaluate the need for supplemental protective measures. If the possibility of trouble is indicated, the trouble rate should be estimated by the following analysis. High concentration of traffic makes this type of analysis worthwhile. Remedial methods are found in paragraph 10.01.

9.02 Figures 1 and 2 show the highest magnitude stroke crest current to be expected. Figure 2 shows that only about 5 percent of all strokes to buried cable will exceed 100 kA. (The equivalent value for aerial cable, Figure 1, is 75 kA.) Typically, cable is designed to conduct these high magnitude strokes for the period of time required for the current to depart into the earth along the cable. The effect on the cable core during this time interval depends on:

1. Earth resistivity

2. Arching distance and

3. Core-to-shield voltage.

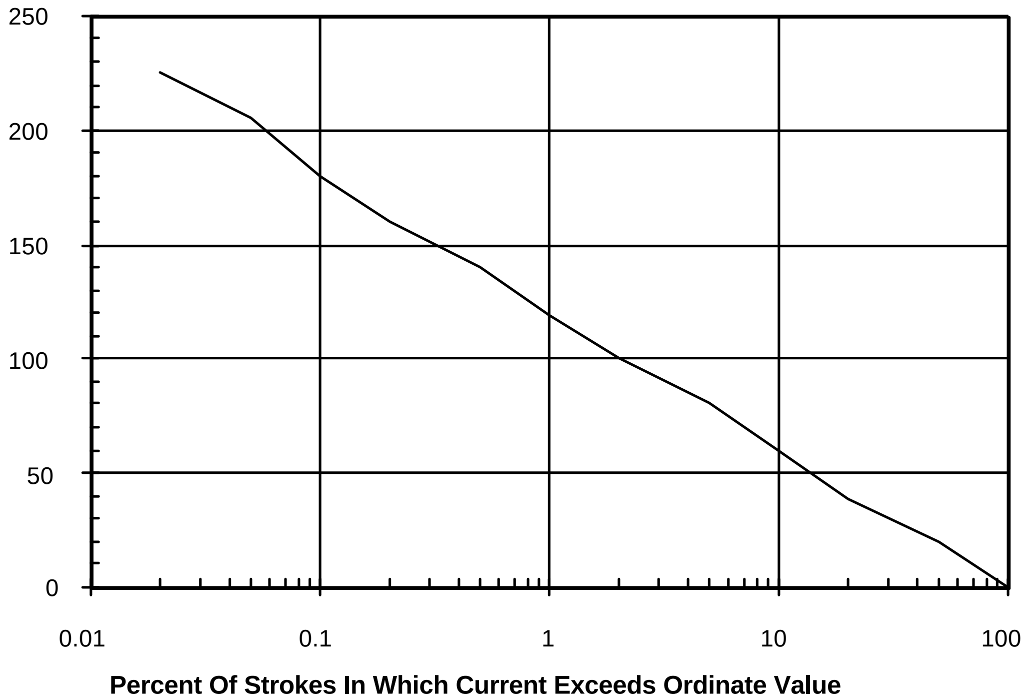

Figure 1 - Distribution of Lightning Stroke Crest Currents to Aerial Structures

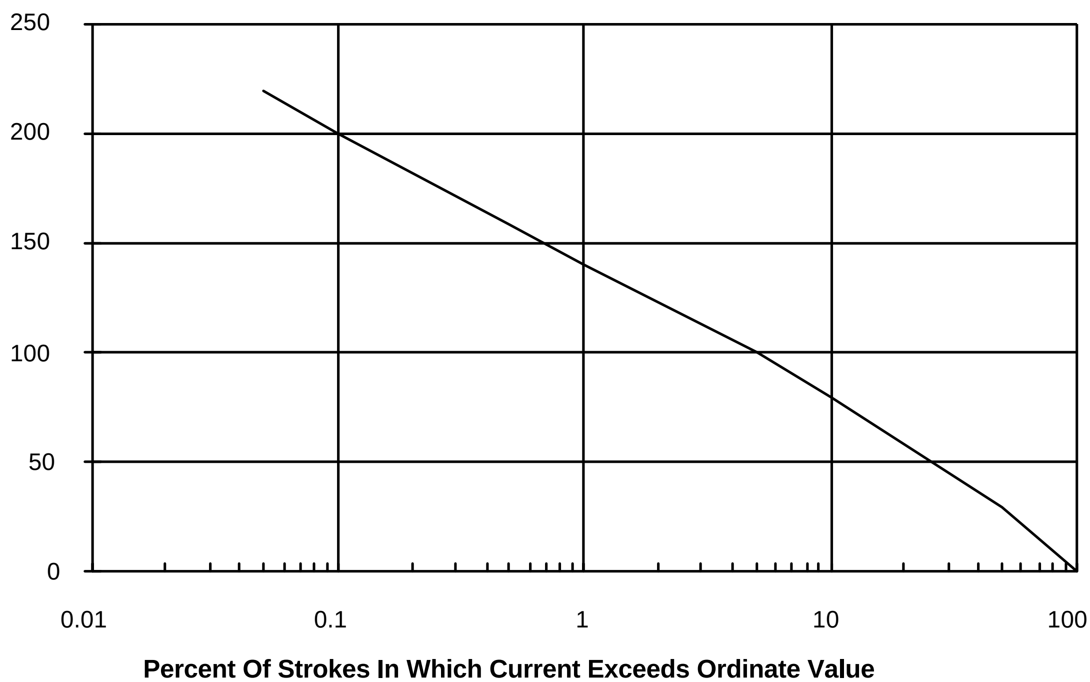

Figure 2 - Distribution of Lightning Stroke Crest Currents to Buried Structures

When these three factors have been determined, it is then possible to estimate the strokes to the cable or the trouble rate and the additional protective measures if indicated. This involves calculation of the probable stroke collecting area along the cable route and selection of the appropriate stroke factor.

9.03 Earth resistivity is determined by the usual methods, the most reliable of which is actual measurement to determine representative mutual resistance (R_m) of the earth along the route. This is done with a ground resistance measuring set using the four point method (see BSP 876-700-100). When R_m is obtained from the meter and the spacing of the probes in feet are applied to the following expression, ground resistivity, ρ is obtained in meter-ohms.

$$\rho = 1.92 * S * R_m$$

Where:

ρ = Resistivity in meter-ohms

R_m = Mutual resistance (from test set)

S = Spacing of probes in feet. (Select spacing to measure ρ to depth of cable.)

9.04 Arcing distance is the distance between a point on the surface of the earth directly above the cable and the point at which lightning strikes the earth. Arcing distance increases as ρ increases. An increase in ρ increases the probability that a stroke will reach a buried cable rather than dissipating into the earth. Observation confirms that it is easier for a stroke to ionize a path across the surface of the earth rather than entering it, especially if ρ is high. Arcing distance may be approximated from the following expression:

$$d = 0.8\sqrt{\rho}$$

Where:

d = Arcing distance in feet measured on surface

ρ = Resistivity in meter ohms

Then if ρ = 100 meter-ohms, the arcing distance (d) is 8 feet

or if ρ = 1000 meter-ohms, the arcing distance (d) is 25.3 feet

or if ρ = 10,000 meter-ohms, the arcing distance (d) is 80 feet.

Arcing distance can be further increased by the presence of other conductors such as metal fences and tree roots in moist soil. This dependence on terrain will be accommodated by a terrain factor (K_2) in paragraphs 9.07 and 9.12.

9.05 The stroke collecting area per selected number of miles of cable is the number of square miles along the cable and within the stroke arcing distance on either side of the cable that lightning is likely to strike.

$$A = [2 (d) M]/5280$$

Where:

M = Miles of cable

A = Square miles

d = Stroke arcing distance in feet (from paragraph 9.04).

Therefore, if:

ρ = 1000 meter-ohms

d = 25.3 feet

A = [2 (25.3) 100] / 5280 = .96 square miles per 100 miles of cable.

9.06 The Stroke factor (K_3) of 0.37 or 0.28, for the geographical area under consideration must be selected for application to the remaining calculations. Stroke factor is the number of lightning strokes per square mile per thunderstorm day as defined in BSP 876-100-100. For areas subject to large numbers of frontal type storms, K_3 is .037 strokes/square mile/thunderstorm day. For areas where convection type storms predominate, K_3 is 0.28 strokes/square mile/thunderstorm day. This information is shown in Figure 4. Use 0.28 stroke factor for areas north of the northern boundary line for high incidence of frontal type storms and 0.37 for area south of this same line.

9.07 The strokes to the cable, determined from the next expression, show the annual number of strokes that may contact the cable, but do not indicate the trouble rate.

$C = N * K_2 * K_3 * A$ or

$C = [N * K_2 * K_3 * (2d) * M] / 5280$

Where:

C = Annual number of strokes contacting the cable (strokes/year)

N = Annual number of thunderstorm days (Figure 4) (TD/YR)

K_2 = Terrain factor

= 1 for flat country

= 2 for wooded country (trees within 100 feet of cable)

K_3 = Stroke factor (see paragraph 9.06) strokes/square mile/thunderstorm day

A = Area susceptible to strokes in square miles (see paragraph 9.05).

Therefore, if:

N = 60 thunderstorm days in one year (see paragraph 9.06)

A = 0.96 square miles (example in paragraph 9.05)

K_2 = 1

K_3 = 0.37 (see paragraph 9.06).

Then C = 60 * (0.37) * 0.96 = 21.3 strokes contacting the cable in one year.

9.08 Thunderstorm Activity: The rate of occurrence of lightning damage during thunderstorm days (TD) is directly dependent on the annual number of lightning flashes to ground per square mile. For buried cable, soil resistivity is also an important factor in determining lightning damage. The average area over which a buried cable will attract lighting strokes to earth is proportional to the square root of soil resistivity ($\sqrt{\rho}$). Thus, the annual number of lightning strokes during thunderstorm days to a buried cable (exposure factor) is directly proportional to the product of $\sqrt{\rho}$ and TD/year or Exposure Factor = $\sqrt{\rho}$ * Annual TD. The higher the exposure factor, the more severe the exposure, implying the increasing possibility of cable damage. The contour map of the United States shown in Figure 5 is divided geographically to show the relative exposure factor for buried cable in the divided areas. The data shown for the different locations of Figure 5 was derived by combining the average $\sqrt{\rho}$ for soil and the corresponding number of thunderstorms for the same area.

9.09 Core-to-shield voltage can be determined from the information already calculated and the additional elements associated with the following expression:

$$V_{C\text{-}S} = K_1 * J * R * \sqrt{\rho}$$

Where:

K_1 = Waveshape factor (rise and decay time to 1/2 value) 1.9 for typical waveshape of 1 X 50 µsec

J = Lightning stroke current in kiloamperes from Figure 2

R = Resistance of cable shield, ohms/mile obtainable from BSP 626-020-013 (2.3 ohms, the resistance for 1 1/2 inch diameter PASP sheath cable, is used as a representative value)

ρ = Soil resistivity in meter-ohms.

9.10 The following examples have been worked out using the formula in paragraph 9.09:

(a) For 95 percent of all strokes and ρ = 100 meter-ohms,

$$V_{C\text{-}S} = 1.9\ (100)\ (2.3)\ \sqrt{100} = 4370 \text{ Volts.}$$

(b) For 95 percent of all strokes and ρ = 1000 meter-ohms,

$$V_{C\text{-}S} = 1.9\ (100)\ (2.3)\ \sqrt{1000} = 13{,}819 \text{ Volts.}$$

(c) For 50 percent of all strokes and ρ = 1000 meter-ohms,

$$V_{C\text{-}S} = 1.9\ (30)\ (2.3)\ \sqrt{1000} = 4146 \text{ Volts.}$$

The induced $V_{C\text{-}S}$ level should be calculated for the percentage of strokes against which the cable is to be protected (see Figure 2). This voltage level should then be compared with the dielectric strength of the cable (Table A). If the dielectric strength is not exceeded, then no further calculations are necessary and the cable will not likely be damaged.

If, however, the dielectric strength is exceeded, proceed to paragraph 9.11 to determine if the calculated trouble rate is acceptable or unacceptable. The overall acceptability of the risk is based on an engineering cost effectiveness study of traffic concentration and service reliability considerations versus estimated outage time and repair costs.

9.11 The trouble report rate per year can be approximated for a specific type of cable in the actual environmental terrain by a three step process as described in the following paragraphs.

9.12 The first step is to evaluate the selected cable for maximum shield current permissible using the expression given in paragraph 9.09. However, instead of solving for V_{C-S}, solve for the stroke crest current J. The crest current obtained will divide and flow in opposite directions from the point of contact along the cable shield. This current will induce the core-shield voltage that will equal the dielectric factory test voltage limit shown in Table A.

$$J = V_{C-S} / (K_1 R \sqrt{\rho})$$

Where:

J = Critical value of lightning stroke crest current in kiloamperes

K_1 = Waveshape factor (rise and decay time to 1/2 value) 1.9 for typical waveshape of 1 X 50 µsec

V_{C-S} = Core-shield dielectric voltage limit for selected cable in volts (obtain from Table A)

R = Resistance of selected cable shield in ohms/mile (see R values in BSP 626-020-013)

ρ = Earth resistivity in meter-ohms (see paragraph 9.03).

9.13 Using the formula in paragraph 9.12, the following examples have been worked out:

(a) V_{C-S} = 20,000 volts, K_1 = 1.9

R = 2.3 ohms/mile

if ρ = 1000 meter-ohms

J = 20,000 / [(1.9) (2.3) (31.6)] = 145 kA.

(b) V_{C-S} = 20,000 volts, K_1 = 1.9

R = 2.3 ohms/mile

if ρ = 100 meter-ohms

J = 20,000 / [(1.9) (2.3) (10)] = 458 kA.

9.14 The second step in the process is to determine the number of lightning strokes per year to the collecting area of the selected cable in the affected terrain environment.

$$C = [(2d)\ NM\ K_2\ K_3] / 5280$$

Where:

C = Lightning incidence in strokes per year

2d = 1.6 $\sqrt{\rho}$ (see paragraph 9.04)

ρ = Earth resistivity in meter-ohms

N = Annual number of thunderstorm days

M = Miles of cable

K_2 = Terrain factor

= 1 for flat terrain

= 2 for wooded country (trees within 100 feet of cable)

K_3 = Stroke factor of 0.28 or 0.37 (see paragraph 9.06)

9.15 Using the formula in paragraph 9.14, the following examples have been worked out:

(a) Given: high ρ, wooded terrain and high thunderstorm day activity (70 thunderstorm days is high or 95 percentile for USA)

Then:

2d = 1.6 $\sqrt{1000}$ K_2 = 2

N = 70 K_3 = 0.37

M = 100

C = [(1.6) (31.6) (70) (100) (2) (0.37)] / 5280

= 50 strokes/year (for 100 miles of cable).

(b) Given: average ρ, flat country and moderate thunderstorm day activity (42 thunderstorm days is median for USA)

Then:

2d = 1.6 $\sqrt{100}$ K_2 = 1

N = 40 K_3 = 0.28

M = 100

C = [(1.6) (10) (40) (100) (1) (0.28)] / 5280

= 3.4 strokes/year (for 100 miles of cable).

9.16 The third step in the process is to determine from Figure 2 what percentage of strokes to the cable will exceed the critical values of J determined in paragraph 9.12. Figure 2 shows that in example (a) in paragraph 9.15, about 1 percent of the strokes to the cable will exceed the critical J; in example (b) in paragraph 9.15, none will exceed the critical J. In the first case, .01X50 = 0.5 troubles/year. If the trouble rate appears to be an unacceptable risk, the alternatives are to either use a larger pair count cable to obtain a lower resistance shield or to provide additional shielding (see paragraph 10.06).

10. LIGHTNING PROTECTION MEASURES

A. Shield Continuity

10.01 Shield continuity is of primary importance where the cable is exposed to lightning. A poor splice closure or terminal may not be adequate for conducting lightning currents. High magnitude lightning currents passing through the splice may arc and fuse open the joint. This arcing is likely to damage core conductors.

10.02 Grounds must be placed on aerial cable shields periodically where lightning exposure exists. If exposure is severe, grounds should be established at no greater than 1/4 mile intervals except for cable used for critical services to power stations (see BSP 876-310-100MP). If a MGN ground or secondary neutral ground is available on the pole, the shield and strand should be bonded to this ground to take advantage of its low impedance characteristic. If a MGN or secondary neutral ground is not available, use a telephone company provided ground rod.

10.03 The infrequent availability of good ground electrodes along buried cable routes and the presence of the polyethylene outer cable jacket combine to isolate the cable from ground for considerable distances. This condition is largely offset in buried loop plant by the shielding effects of other metallic pipe systems in the earth. Where these pipe systems are few or of plastic construction, a heavy dependence is placed on continuity of the cable shield through the shield of the buried service wire to the station ground electrode. In buried trunk plant, the shields are grounded at repeater local grounds, to MGN or secondary neutral grounds (if available at the repeaters) and to other cable shields at crossings or branches in manholes from which the buried plant often originates.

B. Bonds

10.04 Bond all cable shields together in handholes and manholes and bond the cable shields of all cables to the metal reinforcing structure of manholes. At repeater stations, the shields of cables serving all systems located there should be bonded to the repeater station's ground electrode system. In aerial construction, all cables and equipment owned by other utilities or operators and located in communications space must be common bonded to limit potential differences for personnel protection. These bonds will also help avoid extensive damage caused by arcing in the event of a lightning stroke to either facility. All systems (including CATV) located in communications space must be grounded and bonded together. The bonds between power neutral, telephone cable and other communication facilities must be made within the communications space. If a local ground is provided, a single ground connection must be made from the common bond within the communications space down the pole to earth. It is imperative that the separate ground connections between the different facilities and the ground electrode be avoided. If separate connections without common bonds are allowed, the high impedance of either ground path to a steep wave front stroke will result in arcing between the facilities and the ground connections. The bonding conductors should be #6 AWG copper conductor.

C. Junction Protection

10.05 Junction or branch protection of the main cable may be necessary where exposure of a branch or smaller junctioning cable appears to be severe or where there is a history of lightning trouble. In addition to maintaining shield continuity at the splice, the branch or junctioning pairs and through pairs will require full count protection, even if the main cable is PIC. Economic considerations for the application of full count protection, and the application of cable protectors in general, are described in BSP 876-405-100. The cable shield should be grounded at the location of the full count protection. Gas tube protectors that will coordinate with the dielectric strength of the pair insulation should be used.

D. Additional Shielding

10.06 Additional shielding, especially for buried trunk cable, may be necessary when lightning exposure is especially severe or traffic concentration is high. This type of shielding takes the form of either a buried counterpoise wire bonded to the cable shield at one end or two buried shield wires placed well above and to the side of the cable. (Refer to BSP 876-210-100 for examples of the use of parallel counterpoise wire.)

E. Buried Counterpoise

10.07 Buried counterpoise wire is often used with smaller cables (aerial and buried) which lack the shield conductivity of larger cables necessary to withstand lightning currents. The radio station environment often requires the use of smaller cables for distant connection to other types of telephone facilities in a severe lightning environment. The buried counterpoise is applied by bonding one end of a #6 AWG bare copper wire to the cable shield at the point where lightning is likely to enter the cable (for example, at the entrance to a radio station or at an aerial-to-buried cable lateral. The remainder of the counterpoise wire is then buried along the cable right of way for a minimum distance of 1,000 feet. The purpose of a buried counterpoise wire is to reduce conductive lightning current on the cable shield.

F. Bare Shield Wires

10.08 Bare shield wires may be plowed in along with the cable or may be placed afterward. When used with paired cables, shield wires reduce the current carried by the cable shield and thus reduce the core-to-shield voltage.

10.09 The Current Sharing Factor resulting from the use of buried shield wires depends principally upon the number of wires, separation from one another and from the cable. It depends also upon the number and size (diameter) of the cables and to some extent upon the resistance of the shield wires. While the Current Sharing Factor can be computed for any given configuration, the accuracy obtained is doubtful because of the many variables involved in the overall problem. For this reason, the approximate figures given below are satisfactory estimates of the effectiveness of shield wires. These assume that wires at least as large as .102 inches diameter (10 AWG) copper are used and that the wires are separated from each other and from the cable by at least 1 foot.

Current Sharing Factor*

Number of Shield Wires	1 Cable	2 Cables
1	.70	.75
2	.50	.55
3	.35	.40

***** The Current Sharing Factor should not be confused with shield factor used in inductive coordination.

Wire diameter size may have to be increased from .102 inches (10 AWG) to .128 inches (8 AWG) or to .162 inches (6 AWG) if installation problems make it difficult to properly place the finer gauge wire.

10.10 The Current Sharing Factor mentioned in paragraph 10.09 represents that percentage of the total stroke current that flows on the cable shield(s). The current value represented by this factor must be divided by the number of cables being shielded to determine the current flowing on individual cables. For example, assume a 1,000 Ampere stroke current to a buried cable protected by two shield wires, then 1000 A * 0.50 = 500 A will flow on the cable shield. If two similar sized cables are protected by two shield wires, then (1000 A * 0.55) / 2 = 550 A /2 = 275 A will flow on each cable shield. This relationship is valid up to a cable size difference of 2:1. If the two cables are of more than 2:1 difference in size, a calculation for the current conducted through each shield will be necessary to determine what proportion of the 550 A total input will flow on each shield.

10.11 A reduction in $V_{C\text{-}S}$ (see paragraph 9.09) effected by addition of shield wires, may be determined by multiplying J by the applicable current sharing factor to determine a reduced value of $V_{C\text{-}S}$. For example, in paragraph 9.10 , by using two shield wires, J is reduced from 100 kA to 50 Ka. Therefore, $V_{C\text{-}S}$ is reduced from the initial 4,370 V as follows:

$$V_{C\text{-}S} = 1.9\ (50)\ (2.3)\ \sqrt{100} = 2185 \text{ Volts.}$$

For engineering purposes, however, the reduction in $V_{C\text{-}S}$ effected by addition of shield wires may be approximated by simply multiplying the initial $V_{C\text{-}S}$ by the applicable sharing factor.

10.12 The shield wire procedure covered in paragraph 10.08 through paragraph 10.11 is intended for paired facility cable. Coaxial facility cable is more susceptible to lightning damage than is paired cable due to the "crushing" effect on coaxial tubes. Therefore, additional system considerations are involved in the configuration and placement of shield wires for coaxial cable protection, as described in BSP 876-404-100.

10.13 While shield wires are an effective means of mitigation, they are not without disadvantages. Experience has shown that they reduce conductor failures and tend to localize them when they do occur but at the same time tend to increase troubles due to sheath holes. This comes about because of arcing between the shield wires and the cable shield. This can be minimized by placing the wires so that they cannot come too close to the sheath. Theoretically, the effectiveness of shield wires in reducing the current on the cable shield increases as the spacing between them and the cable is increased. From a practical standpoint, however, the maximum spacing of the wires, when they are placed at the same time as the cable, is dependent upon the capabilities of the equipment. When shield wires are placed at a later date, there are more choices as to position, but it is limited by the number of cables and their position relative to the right-of-way. The best general recommendation appears to be to place the shield wires in the most practical and economical manner, mutually separated and separated from the cables by at least 1 foot. Copper has a higher galvanic potential than lead (about .5 volts higher) and when the two are bonded and placed in the ground the lead tends to corrode. For this reason, shield wires should not be bonded directly to lead sheathed cable. Occasional discontinuities in the shield wires, as might occur at road crossings, will not appreciably affect their performance.

11. PROTECTION RECOMMENDATIONS

A. Filled Core (Waterproof) PIC Cable

11.01 Waterproof cable, available in alpeth or ASP sheath, is recommended as first choice for buried cable installation. The waterproofing compound, which floods all core space and between sheath layers, effectively excludes water from the core and prevents its spread beneath sheath layers in the event of a sheath puncture. The steel in the ASP sheath is much stronger than aluminum for bond clamp installation; thus providing a better grounding and bonding facility than other sheaths such as alpeth. Alpeth sheath can be used in protected areas which are well matted with underground metallic structures and where shield continuity with PAP sheath, air core cable has presented no problem. (Refer to BSP Divisions 632 and 633 for splicing and splice closure information respectively.)

B. Air Core PIC Cable

11.02 PIC cables can be obtained with alpeth, PAP, PASP, ARPAP or ARPASP sheaths with additional tape armor to meet the various mechanical or electrical protection requirements encountered in aerial, underground and buried construction.

11.03 The PAP sheath PIC cable affords the highest available core-to-shield and pair-to-pair dielectric strength and therefore offers excellent protection against lightning. The PASP, ARPAP and ARPASP sheaths also afford equivalent lightning protection with additional advantages. The PASP sheath is widely used for protection against mechanical damage as well as lightning damage in buried plant. The ARPAP sheath provides additional buried plant protection against moisture. It is the preferred sheath when cables are to be pressurized. ARPASP provides for more mechanical protection.

C. PIC Cable

11.04 Because of the high dielectric strength of polyethylene and polypropylene insulation, fewer electrical troubles will be experienced with PIC cable. Should trouble experience indicate the need for additional protection on PIC cable to meet severe conditions, protection can applied in the same manner as for pulp insulated cable. Additional information on protection for PIC cable can be found in BSP 876-405-100.

D. Pulp Cable

11.05 Pulp cables can be obtained with PASP, lepeth or polyjacketed lepeth sheath for aerial and underground plant. Additional outer protection is provided when necessary to meet the various mechanical and electrical protection requirements.

11.06 Lepeth and PASP sheath afford the highest available core to shield dielectric strength. Lepeth with tape armor, polyjacketed lepeth and PASP sheath afford good buried plant protection against severe lightning conditions. Stalpeth and lead sheaths used in underground and aerial plant affords minimum lightning protection; however, lightning protection is improved by the addition of tape armor. Lead sheath aerial cable is usually considered to have satisfactory lightning and power contact protection because the lead sheath is in continuous contact with grounded strand.

E. Connections to Pulp Cable

11.07 Pulp insulated cables are susceptible to conductor insulation failure from lightning currents brought in over drop wire or open wire from nearby strokes to ground. When buried, these cables are also subject to lightning damage from voltage between the metallic shield and ground. Lightning may puncture the polyethylene jacket and may or may not fuse holes in the shield near the stroke point. With PASP, ARPAP or ARPASP sheath, the inner polyethylene jacket provides an effective barrier against moisture and reduces the possibility of conductor troubles. This feature and the extra core to sheath dielectric strength makes the use of these sheaths highly desirable for buried pulp cable where exposure to lightning is severe.

11.08 Where aerial cable that is exposed to lightning is connected to 1000 feet or more of a single cable in a conduit run between an aerial branch and an underground conduit run having additional cables, the strand and cable shield should be grounded at the last pole to a MGN power system or secondary neutral ground if one exists. Otherwise, a driven ground rod may be used.

11.09 In developed areas where there are paralleling metallic pipe systems in the street or on rear property lines connections to pulp insulated cable should be treated as follows:

(a) If there are no aerial branches, no special precautions are needed.

(b) If aerial branches are added to a buried pulp cable, adequate protection will usually be obtained if a single auxiliary #6 AWG copper shield wire is plowed in with the buried cable and bonded to the shield at all splices. The shield wire should be run for a distance of about 500 feet on each side of the aerial branch junction as shown in Figure 3. This auxiliary shield wire will reduce conductive current on the cable shield and maintain the residual shield current at a minimum level throughout it length. If the branch occurs at the end of the buried cable, the shield wire should extend back from the end for a distance of about 1000 feet. In each case, the shield wire should be bonded to the cable shield at all splices within the length of the shield wire run.

11.10 Undeveloped Areas Without Paralleling Metallic Pipe Lines: Where the earth resistivity from the surface down to depths of 100 feet and more is less than 100 meter ohms and thunderstorm activity totals less than 10 thunderstorm days per year, follow the procedures outlined in paragraph 11.11 for pulp insulated cable. The shield wire should provide adequate protection in the event of a lightning or power contact with aerial branches. Where high earth resistivity (over 100 meter-ohms) and more than 10 thunderstorm days per year are the rule, the use of waterproof, ASP sheath PIC is recommended as first choice; air core PASP sheath PIC as second choice.

11.11 Auxiliary Protection - Wire Connections to Pulp Insulated Cable: Where open, rural or urban wire is connected to a pulp insulated cable, the 6-mil blocks or gas tubes across the junction between the wire and cable shield may have to be supplemented by auxiliary (backup) protection. Auxiliary protection consists of 10-mil protector blocks placed approximately 1/4 mile out from the cable junction on the wire pairs and grounded locally to reduce duty and current delivered to protection at the junction. The ground may be (in order of preference) the MGN, secondary neutral ground or made ground consisting of ground rods or buried wire.

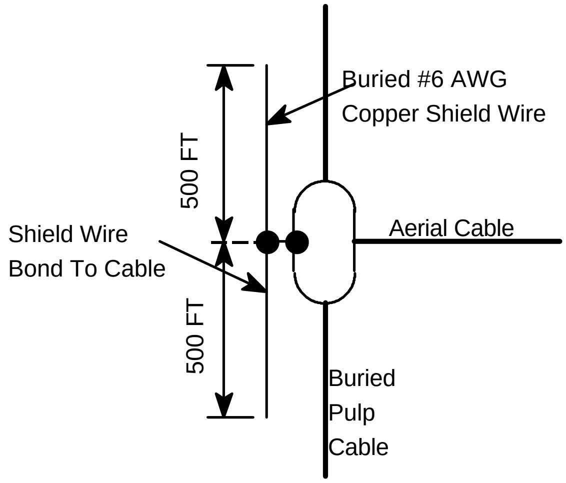

Figure 3 - Auxiliary Shield Wire At Aerial Branches From Buried Pulp Cable

12. REFERENCES

12.01 Additional information may be found in the following references:

1. Bodle, D. W. and Gresh, P. A., "Lightning Surges in Paired Telephone Cable Facilities," Bell System Technical Journal. Vol. XL (March 1961), pp 547 - 576.

2. E.L. 24 Protection Considerations for Joint Use Construction of Telephone Facilities and Power Lines in 20 to 60 kV Class.

3. P.E.L. 7436 Protection Considerations for Joint Use Construction of Telephone Facilities and Power Transmission Lines in the 60 to 150 kV Range.

4. E.L. 2982/P.L. 2769 Buried Plant - Joint Use With Power - Construction and Maintenance Precautions.

5. Sunde, E. D., Earth Conduction Effects In Transmission Systems, New York, N.Y. Dover Publications Inc., 1968, Chapter IX, Page 301.

Table A

Dielectric Test Value Of Telephone Cables (Note 1)

Air Filled Core (Note 2)									
Conductor	Pair Gauge		Type of Cable	Core	Outer Jacket	Factory Test Values In KV (AC rms or DC)			
Insulation	CU	AL	Sheath Note 3	Insulation		Cond - Cond	Core - Shield		Cond. - Shield
(AD)							1 Core Wrap	2 Core Wraps	
Pulp	26 (T)		Lead (L)	Paper		.35 ac	0.85 ac	2.0 ac	
Pulp	24 (M)		Lead (L)	Paper		.35 ac	1.0 ac	2.0 ac	
Pulp	22 (A)		Lead (L)	Paper		.35 ac	1.0 ac	2.0 ac	
Pulp	19 (B)		Lead (L)	Paper		.35 ac	1.0 ac	2.0 ac	
(AD)									
Pulp	26 (T)		Lepeth (D)	Paper & Poly		.35 ac	20.0 dc		
Pulp	24 (M)		Lepeth (D)	Paper & Poly		.35 ac	20.0 dc		
Pulp	22 (A)		Lepeth (D)	Paper & Poly		.35 ac	20.0 dc		
Pulp	19 (B)		Lepeth (D)	Paper & Poly		.35 ac	20.0 dc		
(AD)							1 Core Wrap	2 Core Wraps	
Pulp	26 (T)		Stalpeth (C)	Paper	Polyethylene*	.35 ac	0.85 ac	2.0 ac	
Pulp	24 (M)		Stalpeth (C)	Paper	Polyethylene*	.35 ac	1.0 ac	2.0 ac	
Pulp	22 (A)		Stalpeth (C)	Paper	Polyethylene*	.35 ac	1.0 ac	2.0 ac	
Pulp	19 (B)		Stalpeth (C)	Paper	Polyethylene*	.35 ac	1.0 ac	2.0 ac	
(AD)									
Pulp	26 (T)		PASP (H)	Paper & Poly	Polyethylene*	.35 ac	20.0 dc		
Pulp	24 (M)		PASP (H)	Paper & Poly	Polyethylene*	.35 ac	20.0 dc		
Pulp	22 (A)		PASP (H)	Paper & Poly	Polyethylene*	.35 ac	20.0 dc		
Pulp	19 (B)		PASP (H)	Paper & Poly	Polyethylene*	.35 ac	20.0 dc		
(KD)									
Pulp	22 (A)		Lead (L)	Paper		.35 ac	1 Core Wrap	2 Core Wraps	
							1.0 ac	2.0 ac	.35 ac
(KD)									
Pulp	22 (A)		Lepeth (D)	Paper & Poly		.35 ac	20.0 dc		.35 ac

Table A

Dielectric Test Value Of Telephone Cables (Note 1)

Air Filled Core (Note 2)									
Conductor Insulation	Pair CU	Gauge AL	Type of Cable Sheath Note 3	Core Insulation	Outer Jacket	Factory Test Values In KV (AC rms or DC) Cond - Cond	Core - Shield		Cond. - Shield
(KD							1 Core Wrap	2 Core Wraps	
Pulp	22 (A)		Stalpeth (C)	Paper	Polyethylene	.35 ac	1.0 ac	2.0 ac	.35 ac
(KD)									
Pulp	22 (A)		PASP (H)	Paper & Poly	Polyethylene	.35 ac	20.0 dc		.35 ac
(BK)									
Solid Poly	26 (T)		Alpeth-PIC (A)†	Rubber-Mylar‡	Polyethylene*	2.4 dc	5.0 dc		
Solid Poly	24 (M)		Alpeth-PIC (A)†	Rubber-Mylar‡	Polyethylene*	3.0 dc	5.0 dc		
Solid Poly	22 (A)		Alpeth-PIC (A)†	Rubber-Mylar‡	Polyethylene*	4.0 dc	10 dc		
(BH)									
Solid Poly	19 (B)		Alpeth-PIC (A)†	Rubber-Mylar‡	Polyethylene*	5.0 dc	10 dc		
(BK)									
Solid Poly	26 (T)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene*	2.4 dc	20.0 dc		
Solid Poly	24 (M)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene*	3.0 dc	20.0 dc		
Solid Poly	22 (A)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene*	4.0 dc	20.0 dc		
(BH)									
Solid Poly	19 (B)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene*	5.0 dc	20.0 dc		
(BK)									
Solid Poly	26 (T)		ARPAP (T) ARPASP (U)§	Mylar‡	Polyethylene*	2.4 dc	20.0 dc		
Solid Poly	24 (M)		ARPAP (T) ARPASP (U)§	Mylar‡	Polyethylene*	3.0 dc	20.0 dc		
Solid Poly	22 (A)	20 (D)	ARPAP (T) ARPASP (U)§	Mylar‡	Polyethylene*	4.0 dc	20.0 dc		
(BH) (AH)									
Solid Poly	19 (B)	17 (C)	ARPAP (T) ARPASP (U)§	Mylar‡	Polyethylene*	5.0 dc	20.0 dc		

Table A

Dielectric Test Value Of Telephone Cables (Note 1)

Air Filled Core (Note 2)								
Conductor	Pair	Gauge	Type of Cable	Core	Outer Jacket	Factory Test Values In KV (AC rms or DC)		
Insulation	CU	AL	Sheath Note 3	Insulation		Cond - Cond	Core - Shield	Cond. - Shield
(AB)								
Poly-PVC	24 (M)		ALVYN (M)	Mylar‡	PVC	3.0 dc	10.0 dc	
Poly-PVC	22 (A)		ALVYN (M)	Mylar‡	PVC	4.0 dc	20.0 dc	
(MC)								
DEPIC	25 (R)		Stalpeth (C)	Mylar	Polyethylene	2.0 dc	5.0 dc	2.0 dc
(MC)								
DEPIC	25 (R)		PASP (H)	Mylar	Polyethylene	2.0 dc	20.0 dc	2.0 dc
DEPIC	24 (M)		PASP (H)	Mylar	Polyethylene	3.0 dc	20.0 dc	8.0 dc
(MC)								
DEPIC	24 (M)		Bonded Stalpeth (Z)	Mylar	Polyethylene	3.0 dc	10.0 dc	8.0 dc
(LC)								
DEPIC	22 (A)		ARPAP (T)	Mylar	Polyethylene	1.5 dc	20.0 dc	
(DC)								
DEPIC	26 (T)		Bonded Stalpeth (Z)	Mylar	Polyethylene	1.0 dc	5.0 dc	
(KH)								
Solid Poly	22 (A)		Alpeth-PIC (A)	Rubber-Mylar	Polyethylene	4.0 dc	10.0 dc	4.0 dc
Solid Poly	19 (B)		Alpeth-PIC (A)	Rubber-Mylar	Polyethylene	5.0 dc	10.0 dc	5.0 dc
(KH)								
Solid Poly	22 (A)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene	4.0 dc	20.0 dc	4.0 dc
Solid Poly	19 (B)		PASP (H) PAP (G)	Rubber-Mylar Polyethylene	Polyethylene	5.0 dc	20.0 dc	5.0 dc

Table A

Dielectric Test Value Of Telephone Cables (Note 1)

Water Proof (Filled Core) Cables (Note 4)								
Conductor	Pair	Gauge	Type of Cable	Core	Outer Jacket	Factory Test Values In KV (AC rms or DC)		
Insulation	CU	AL	Sheath Note 3	Insulation		Cond - Cond	Core - Shield	Cond. - Shield
(AJ) (AG)								
Polypropylene	26 (T)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	2.4 dc	5.0 dc	
Polypropylene	24 (M)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	3.0 dc	5.0 dc	
Polypropylene	22 (A)	20 (D)	ASP (W) Alpeth (A)	Mylar	Polyethylene*	4.0 dc	10.0 dc	
Polypropylene	19 (B)	17 (C)	ASP (W) Alpeth (A)	Mylar	Polyethylene*	5.0 dc	10.0 dc	
(AL) (AF)								
DEPIC	26 (T)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	1.7 dc	5.0 dc	
DEPIC	24 (M)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	2.0 dc	5.0 dc	
DEPIC	22 (A)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	2.5 dc	10.0 dc	
DEPIC	19 (B)		ASP (W) Alpeth (A)	Mylar	Polyethylene*	3.5 dc	10.0 dc	
DEPIC		20 (D)	ASP (W) Alpeth (A)	Mylar	Polyethylene*	3.0 dc	10.0 dc	
DEPIC		17 (C)	ASP (W) Alpeth (A)	Mylar	Polyethylene*	4.0 dc	10.0 dc	
(CJ)								
Polypropylene	22 (A)		ASP (W)	Mylar 2 Layers	Polyethylene	5.0 dc	20.0 dc	
(ML)								
DEPIC	24 (M)		Bonded ASP (Y)	Mylar	Polyethylene	3.0 dc	10.0 dc	8.0 dc
(LL)								
DEPIC	22 (A)		ASP (W)	Mylar	Polyethylene	4.0 dc	10.0 dc	
(KJ) (KG)								
Polypropylene	22 (A)		ASP (W)	Mylar	Polyethylene	4.0 dc	10.0 dc	8.0 dc
(KL) (KF)								
DEPIC	22 (A)		ASP (W)	Mylar	Polyethylene	2.5 dc	10.0 dc	8.0 dc
DEPIC	19 (B)		ASP (W)	Mylar	Polyethylene	3.5 dc	10.0 dc	8.0 dc

Table A

Dielectric Test Value Of Telephone Cables (Note 1)

Video Pair Cables								
Conductor	Pair Gauge		Type of Cable	Core	Outer Jacket	Factory Test Values In KV (AC rms or DC)		
Insulation	CU	AL	Sheath Note 3	Insulation		Cond - Cond	Core - Shield	Cond. - Shield
(16-PEV-L)								
Videos - Exp. Poly. Pairs - Pulp	16 (H)		Stalpeth Lead Poly-jacketed Lead		Paper	Videos 3.0 dc Pairs .5 dc	Videos & Pairs 1 or 2 Core Wraps 1.5 dc	
Videos - Exp. Poly. Pairs - Pulp	26 (T)		Stalpeth Lead Poly-jacketed Lead		Paper	Videos 3.0 dc Pairs .5 dc	Videos & Pairs 1 or 2 Core Wraps 1.5 dc	
Videos - Exp. Poly. Pairs - Pulp	24 (M)		Stalpeth Lead Poly-jacketed Lead		Paper	Videos 3.0 dc Pairs .5 dc	Videos & Pairs 1 or 2 Core Wraps 1.5 dc	
Videos - Exp. Poly. Pairs - Pulp	22 (A)		Stalpeth Lead Poly-jacketed Lead		Paper	Videos 3.0 dc Pairs .5 dc	Videos & Pairs 1 or 2 Core Wraps 1.5 dc	
Videos - Exp. Poly. Pairs - Pulp	19 (B)		Stalpeth Lead Poly-jacketed Lead		Paper	Videos 3.0 dc Pairs .5 dc	Videos & Pairs 1 or 2 Core Wraps 1.5 dc	

Notes:

Note 1: The dielectric test value represents the guaranteed minimum of the actual dielectric strength of the cable.

Note 2: Values for air filled cables for new cable prior to installation. Values may be somewhat less after installation depending on the handling care and whether core remains dry or wet.

Note 3: Refer to BSP 626-020-011 for meanings of abbreviations and exchange cable letter code for cable sheaths, conductor insulations and protective coverings.

Note 4: Values for waterproof (filled core) cables are considered representative for installed values.

* Surge withstand dielectric strength of outer polyethylene jacket at the factory is approximately 60 kV peak. Installation and rodents may degrade this value.

† Alpeth sheath is no longer standard for cables having pulp or paper insulated conductors.

‡ Various other non-hygroscopic materials are approved.

§ Core-to-shield voltages applied to outer aluminum shield.

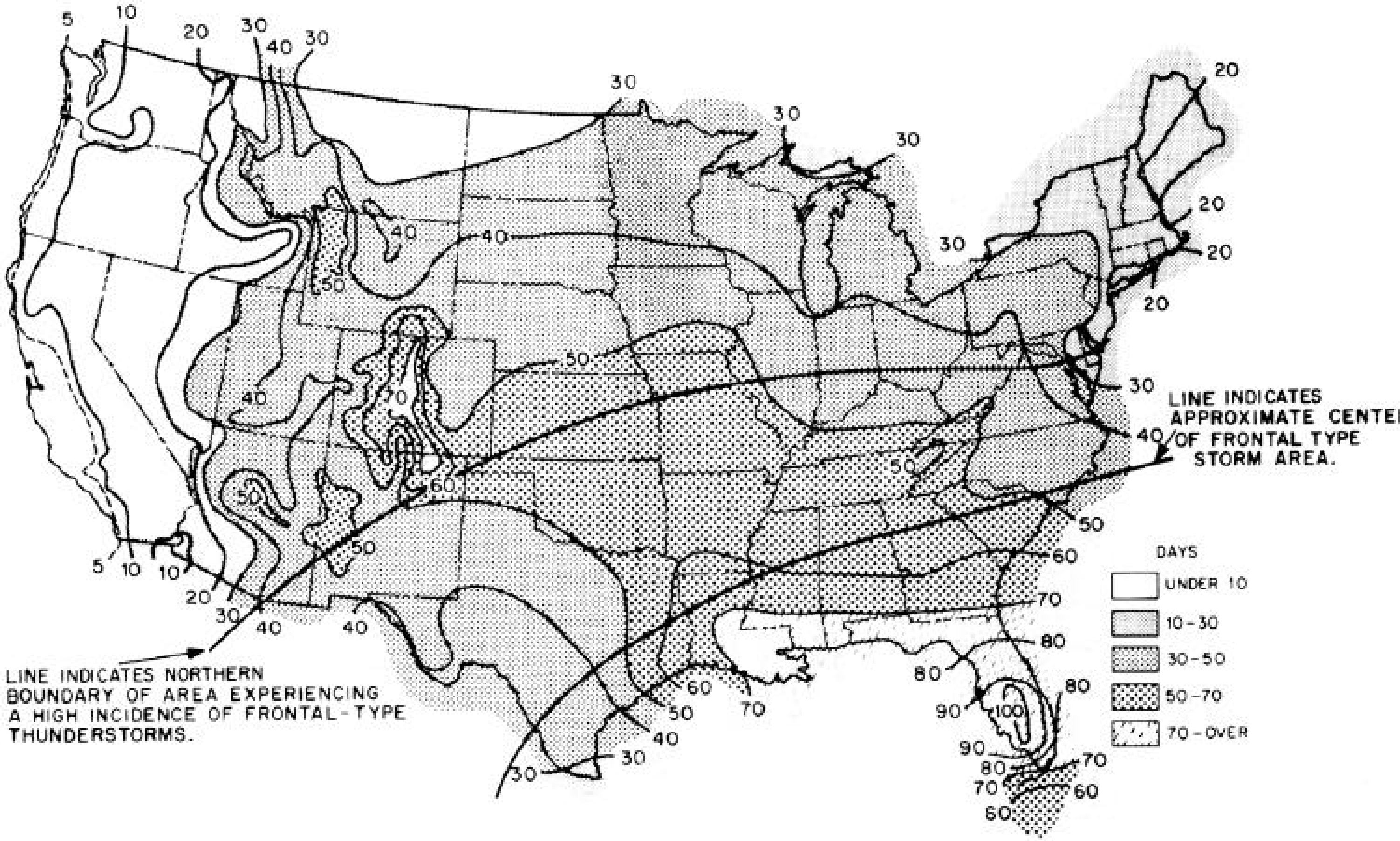

Figure 4 - Average Annual Number of Days With Thunderstorms (United States)

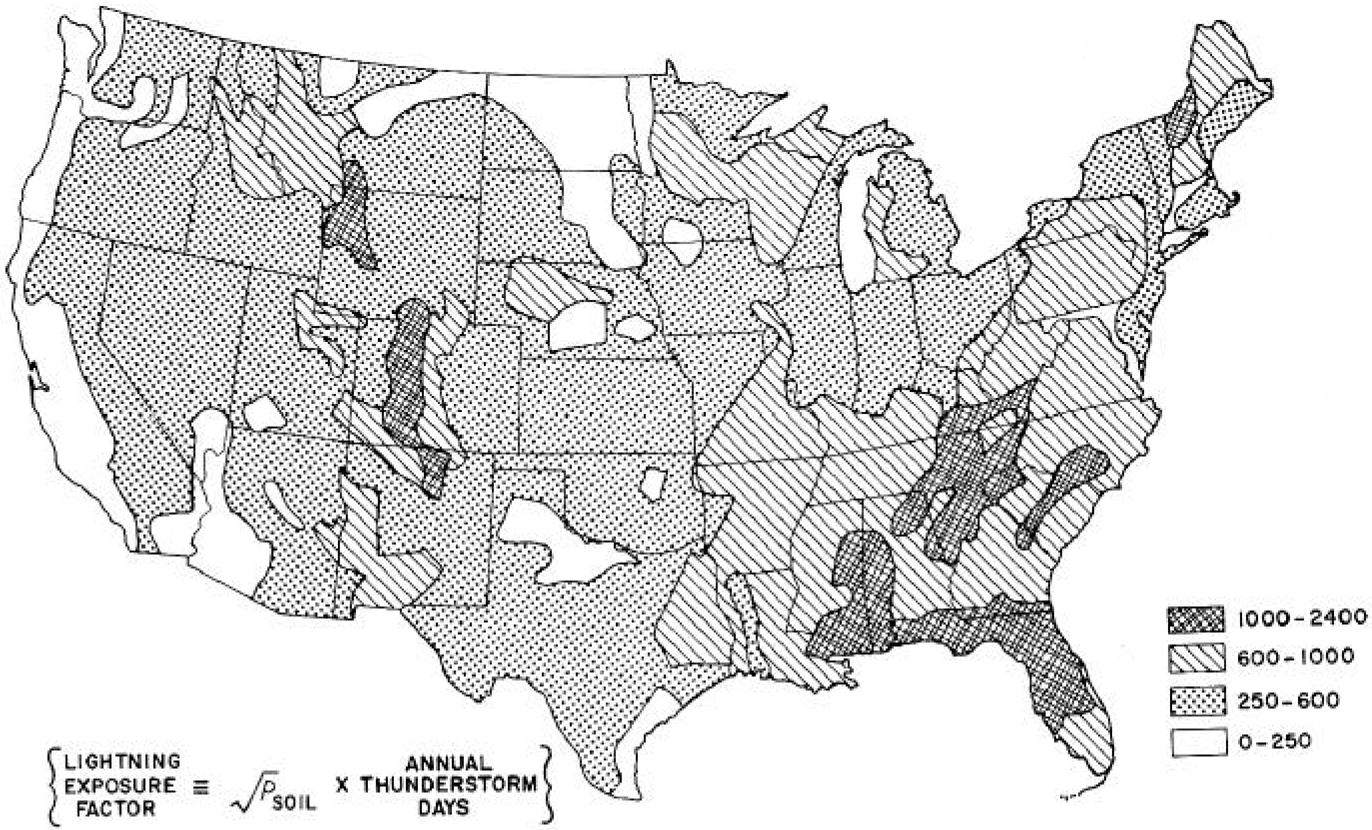

Figure 5 - Estimated Lightning Exposure for Buried Cable in the United States