

SITUATIONS REQUIRING SPECIAL PROTECTION

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TABLE 1

FIGURES 1-5

APPENDIX A

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors, and other interested parties with technical information for use in the design and construction of telephone systems of REA borrowers. It discusses situations infrequently encountered and unusual from a protection standpoint, and which may require the application of special protective measures in accordance with the following paragraphs. Because of the unusual nature and broad scope of the protection problems involved, this section does not contemplate the presentation of detailed recommendations covering all possible situations, but rather intends to set forth basic principles with illustrations of their application. Where special situations exist for which specific engineering procedure is not clear, the problem should be referred to REA for recommended action.

1.2 This section is being revised to expand the scope of the special protection situations covered to reflect the use of new devices such as gas tubes and to provide working principles adequate for the application of remedial measures.

2. SPECIAL PROTECTION EQUIPMENT

2.1 In order to make the optimum use of special protection equipment, this section will first review some of these devices and their functions.

2.2 Neutralizing Transformer

2.21 The principle of the neutralizing transformer is to produce induced potentials in the telephone conductors equal in magnitude and opposite in polarity to the potential caused by induction or a ground potential rise at a power station. The two ends of the primary winding are connected to the ground at different locations so that the voltage to be neutralized appears across this winding. Secondary windings, having a 1:1 ratio to the primary are then connected in series with the communications circuit in such a way that the potentials induced from the primary are opposed and approximately equal to the foreign potential. Figure 1A is a simplified illustration in the use of a neutralizing transformer for protection of a voice communications circuit serving a power substation.

2.22 While neutralizing transformers have appreciable dielectric strength, lightning arresters connected between all windings and grounded case are necessary to prevent damage by lightning. Appropriate arresters are commonly supplied as part of the neutralizing transformer assembly. Neutralizing transformers having a number of secondary windings associated with a single primary winding are available for use where several telephone lines are to be provided. The presence of neutralizing transformer windings in the telephone circuit usually results in transmission losses of less than 2dB. The effect on signaling, pulsing, and ringing should be evaluated from electrical characteristics obtainable from the supplier and the known limitations of the telephone system in individual cases.

2.3 Isolating Transformer

2.31 The isolating transformer is simply a 1:1 transformer with high dielectric capability which "isolates" the station terminal equipment from the remainder of the communications facility. Thus the station terminal is free to "float" with the local ground without feeding excess voltage back into the communications facility. Figure 1B illustrates use of the isolating transformer.

2.32 Isolating transformers are generally less expensive and more compact than neutralizing transformers. They are available with dielectric withstand capability from 1000V to approximately 25KV and insertion losses of approximately 1dB. One shortcoming of the isolating transformer is that it does not provide dc continuity.

2.4 Mutual Drainage Reactor

2.41 The mutual drainage reactor, or drainage coil, is designed to remove longitudinal currents induced in communications circuits with a minimum of disturbance to the transmitted signal, and to insure symmetrical protector operation.

2.42 When a mutual drainage reactor is used with protectors, as illustrated in Figure 1C, the result should be symmetrical arrester operation. When the lower voltage arrester sparks over, longitudinal current flowing to ground through winding #1 of the coil induces an equal potential in the other winding in a manner that supplements the voltage on that line conductor, essentially doubling the voltage across the second arrester and causing it to break down.

2.42 When dc is required on a line, two gaps must be used with the mutual drainage reactor as illustrated in Figure 1C. When no dc is required, a single gap will suffice, as shown in Figure 2A.

2.5 Short Circuiting Relay

2.51 The short circuiting relay (SCR) consists of white coded carbon air gap arresters, or equivalent gas tubes, for connection between the telephone line and ground. A relay, with its windings in series with the gaps is supplied, and the relay contacts are arranged to short circuit the gaps during most of the discharge period, as illustrated in Figure 1D. The relay contacts close in a few hundredths of a second, preventing permanent grounding of the arrester and at the same time bringing both conductors of a pair to a common potential thus, preventing transverse voltage after the first few milliseconds required for operation. SCR's are available in single and multipair units.

2.6 Gap Type Protectors

2.61 Gap type protectors include any devices which employ the breakdown of an isolation gap as a means of grounding a circuit. By the very nature of their operation, these devices become noise generators during the time they are conducting. As a result, they will render the circuit to which they are applied inoperative during the time they are broken down.

2.62 Carbon Blocks - Probably the most common gap type protector is the carbon block air gap device. These devices are available in a number of breakdown ranges, and the color coded as follows:

<u>Color Code</u>	<u>Nominal Breakdown Voltage</u>
White	600
Blue	1000
Yellow	1400

When low breakdown voltage carbon blocks are used, there is a tendency for them to become grounded and disable the circuit. For this reason, consideration should be given to using gas tubes on critical circuits where protection in the 600V range would be required.

2.63 Gas Tubes - The use of these devices is covered in REA TE & CM 823, so a further discussion will not be added at this point.

2.64 Surge or Lightning Arresters - The surge arrester is designed to discharge a surge of lightning current, yet prevent a continued flow of power current. These devices employ "expulsion" or "valve" elements in series with the gap for performing this function. The breakdown voltage rating of these devices is usually quite high, so caution must be taken to assure that this breakdown coordinates with the dielectric strength of the item being protected.

3. TELEPHONE PLANT SERVING POWER STATIONS

3.1 Power transmission and distribution systems are subject to occasional faults between phase wires and ground, usually during lightning storms, at which time the importance of maintaining communication facilities serving associated power generating stations and/or power substations is most urgent. In such situations excessive currents flow in the power station ground system and these in turn may result in interruptions to communication circuits serving the power station unless adequate precautions are taken.

3.2 Situations of this kind usually result from an accidental ground on a phase wire of a wye-connected power system, due perhaps to lightning flashover of an insulator, and resulting in appreciable current flow through the neutral wire and earth to the power station ground. Flow of this current through the station ground, to which the telephone protector ground is also connected, will raise the potential of the station ground structure and telephone protector ground terminal with respect to remote ground connections on the telephone line, such as at remote subscriber stations or at the central office termination.

3.21 When a power fault occurs, the potential of the earth surrounding the power station will be raised. This potential will decrease nonlinearly with distance from the station. The fraction of the station ground potential appearing at any given point will depend upon such factors as the area of the station ground grid and the presence of underground metallic systems such as pipe lines. For station ground structures covering up to about 35,000 square feet, the earth potential with respect to remote ground will usually drop to about 50 percent of its maximum value at a distance of about 200 feet from the structure.

3.22 Under these power fault conditions a telephone station protector grounded to the power station structure or to earth nearby may be raised in potential with respect to remote ground sufficiently to produce longitudinal currents in the telephone pairs with consequent arrester discharge and permanent grounding, and/or operation of fuses where fused protectors are required, with consequent interruption of service at a critical time.

3.3 Plans for communication arrangements serving power stations should include a careful survey to determine if provision of special protection is required. Where the product of ground return fault current and the station ground impedance is estimated to exceed 200 volts rms, it is probable that special protective measures will be necessary on all communications circuits important in power system operation.

3.4 The basic approach recommended by REA is to determine if the high voltage environment to which communications equipment may be subjected is excessive and if so, to use protection transformers as required to isolate or reduce these voltages to acceptable values. Gap type protectors should only be used as backup protection for lightning and other abnormal conditions. Drainage reactors should be used in conjunction with gaps to provide good circuit balance, longitudinal drainage, and low circuit noise.

3.5 Basic power service communications can be broken into four (4) categories:

3.51 Protective Relaying - In addition to the fundamental objective of protecting individual components from overload and damage, protective relaying must also protect the overall system from instability and failure when a segment of the system is suddenly removed from service. Due to the importance of these objectives communications equipment and facilities associated with protective relaying MUST be as reliable as possible.

3.52 Telemetry, Supervision, and Control - The ability to measure various parameters throughout the power system and to display these measurements in dispatching centers is important if a power system is to function smoothly. While not usually involved in the measurement or display, the telephone company may be expected to transmit this data from point to point.

3.53 Voice Communications - While some voice circuits to a power station are for routine low priority operation, voice circuits, either leased lines or a part of the dial network, serving a dispatching center may be critical for overall system operation. The main function of the dispatcher is coordinating between generator output and consumer demand. During an emergency the dispatcher must employ close coordination with interconnected power systems to supply the needed power and distribute it as required. The dispatcher's voice circuits are also used by police, etc., to report trouble conditions, such as the location of fallen lines, to the dispatcher. Needless to say, these critical voice circuits must not be put out of operation by a power fault.

3.54 Teleprinter - The teleprinter is used primarily when written copies of the transmittal are required, or for access to computers.

3.6 From a protection standpoint, communications services to a power station can be broken into two major categories as follows:

3.61 Circuits which must remain fully operational during a power fault. Examples include: protective relaying and critical telemetry, supervision and control circuits.

3.62 Circuits which can tolerate brief (fractional second) interruptions during power faults. Examples include: basic voice communication and most telemetry, supervision, and control circuits.

3.63 In order to assure that circuits are assigned to the proper category, power company engineers should be consulted fully. Only those who understand the performance required of each circuit should attempt to assign it to one of these categories.

3.7 In determining what mode of protection is to be used each of the two categories in Paragraph 3.6 can be subdivided into two additional subcategories, depending on whether dc continuity is required. Thus, we have four basic classes of communications circuits serving substations as follows:

- 3.71 Noninterruptable with no dc required.
- 3.72 Noninterruptable with dc required.
- 3.73 Briefly interruptable with no dc required.
- 3.74 Briefly interruptable with dc required.
- 3.8 Recommended protection for these circuits is as follows:
- 3.81 Noninterruptable with no dc Required - This type circuit would be utilized primarily for audio tone protective relaying, and some types of critical telemetry, supervisory, and control systems. Figure 2A illustrates the recommended protection procedures. Care should be taken to select an isolating transformer with dielectric capability matching or exceeding the anticipated worst case ground potential rise at the power station.
- 3.82 Noninterruptable with dc Required - This type circuit would be utilized primarily for pilot wire protective relaying and some forms of critical telemetry, supervision, and control systems. Figure 2B illustrates the recommended protection procedures. Power system faults usually have a large dc component which tends to saturate the neutralizing transformer. As a result, transformers with a high saturation current must be used if this method is to be effective. A sufficient number of non-loaded cable pairs should be used to energize the primary of the transformer to assure a sufficiently low impedance for the neutralization desired.
- 3.83 Briefly Interruptable with no dc Required - This type circuit would be utilized for most audio tone telemetry, supervision, and control circuits. Figure 2C illustrates the recommended protection procedures. With the exception of protection at the central office, this protection plan is similar to 2A, so similar precautions should be taken.
- 3.84 Briefly Interruptable with dc Required - This type circuit would be utilized for the dispatcher's voice circuits as well as some types of telemetry, supervision, and control circuits. Figure 2D illustrates the recommended protection procedures. The brief discussion of the neutralizing transformer in Paragraph 3.82 will also apply to this circuit.
- 3.85 Only plastic insulated cable, having good dielectric strength and good longitudinal balance should be employed in serving power stations. The use of pulp or paper cable is not recommended.

3.86 Gap type arresters, either air gap carbon blocks or gas tubes, become noise generators during the period when they are conducting current. Every effort should be made to reduce their firing to the limit consistent with preventing actual equipment damage. With this in mind, the heavy duty gas tubes at the power station terminal, as shown in Figures 2A-2D, should have breakdown voltages as high as possible while still coordinating with the terminal equipment. Note: The use of arresters with breakdown voltages above those of "white coded" carbons is not normally recommended for station, or terminal protection. Service to a power station is not, however, a normal situation.

3.87 The power station terminal protection, if required, should be placed as close to the equipment as possible. The neutralizing and isolating transformers, and their protection devices, should be placed in a single area reserved for these devices.

3.88 The lightning arrester used to protect the neutralizing and isolation transformers should coordinate with the dielectric strength of these devices, while being as high as possible to reduce circuit outages. Generally, a power system distribution class arrester will do the job.

4. PROTECTION OF TELEPHONE PLANT SUBJECT TO SEVERE LOW FREQUENCY INDUCTION

4.1 Telephone plant paralleling high voltage power lines may be subject to interfering potentials by induction. Occasions when such potentials are experienced will be (1) when the power system is faulted to ground or (2) under normal operating conditions when unbalanced currents to ground are excessive and/or when lines are in close proximity for long distances. In this category, the increasing use of extra high voltage (E.H.V.) transmission systems makes considerations of remedial measures essential. Recommendations for E.H.V. situations are contained in later paragraphs.

4.2 Protection for Power Fault Conditions

4.21 Power fault currents may produce voltages in paralleling telephone lines which are undesirable from standpoints of (a) personal hazard and (b) grounding of station protectors on the exposed telephone pairs.

4.211 Although the potentials induced in parallel telephone lines during power fault conditions may exceed values usually considered tolerable from a standpoint of personal hazard, the duration of the fault current is so short (approximately 15 cycles maximum) and the faults are so infrequent that the provision of protective measures for this purpose is not normally recommended.

4.212 In some cases long exposures of telephone lines to power fault current induction may experience sufficient induced potential to cause operation of station protectors within and adjacent to the exposure. The currents involved in these discharges may be such as to cause permanent grounding of the protectors, with serious loss of service. A "short circuiting relay (SCR) protector" is available for application where such conditions exist, or where new installations of telephone plant cannot be routed so as to avoid these severe exposures. Unless exposure conditions are extremely severe, the application of SCR protectors will not be justifiable on cable plant.

4.213 When required, short circuiting relay protectors are applied as supplementary elements within exposed lengths of telephone plant. Where an exposure is such as to require treatment, all of the open wire pairs should be equipped, preferably with the multiple type unit in which the relay's bridging contacts are operated simultaneously by means of a single ac pilot relay connected in the common protector ground lead. Details of the application of SCR protectors should be worked out in cooperation with REA engineers.

4.3 Evaluation of Exposure

4.31 Existing Lines - The need for added protection of existing lines against the effects of induced voltages from power system parallels will usually be indicated by excessive grounding of station protectors during power faults. Where telephone circuits exhibit serious circuit outages due to this cause, it is probable that increases have occurred in the power system influence rather than in the telephone system susceptibility. If experience with grounded protectors continues to be intolerable an analysis of the inductive relationship should be undertaken (See Appendix A) with the objective of determining the need for applying SCR protectors.

4.32 New Installations - Preparation for the installation of new telephone lines paralleling power distribution circuits for distances greater than three kilofeet should always include:

- (1) Measurements of earth resistivity.
- (2) Determination of the maximum expected power fault current.

- (3) Determination of the expected location of station protectors in and adjacent to the exposed section.

With this information analysis of the induced voltages and currents through station protectors should be made, with a determination of the likelihood of protector block grounding, in accordance with Appendix A.

4.4 Protection for Normal Power System Operating Conditions

4.41 Where ground return currents in paralleling power systems are excessive under normal operating conditions, objectionable potentials may be induced between telephone conductors and ground. Aside from noise considerations, induced potentials greater than 50V rms between telephone conductors and ground are considered unacceptable from a standpoint of personal hazard. Noncable plant will be more susceptible to excessive potentials than cable plant.

4.42 In order to determine whether a hazardous condition exists, information should be obtained regarding earth resistivity of the area and the estimated (unbalanced) 60 Hz current in the earth. With this information the induced potential may be calculated for different exposure lengths and separations. Table 1 gives the relationship between the necessary separation between the power and telephone lines and the product of ground current and exposure length, for a limiting potential of 50V rms from telephone conductors to ground.

4.43 In existing systems measurements of noise and/or line to ground potentials may be made.

4.5 Extra High Voltage Systems

4.51 The operation of EHV transmission systems may constitute a serious hazard to paralleling telephone systems, requiring additional protective measures. In planning construction, the separation between the telephone facility and the EHV system should be such that potentials between the cable shield and ground will not exceed 50 volts at any point. In existing telephone plant where EHV systems are constructed which result in anticipated potentials greater than 50 volts, application of neutralizing transformers should be undertaken. The spacing, selection, and details of connections of neutralizing transformers must be tailored to individual cases and should be determined by review with REA engineers. In general, neutralizing transformers would be connected at the approximate mid-point of a section such that the remnant voltage from conductors and

shield to ground does not exceed 50 volts. The preferred method of application is to connect the primary of a multipair neutralizing transformer in series with one or more spare pairs of the cable. Secondaries are connected in series with working pairs in such a way as to oppose the voltage induced into the primary.

5. RADIO AND MICROWAVE INSTALLATIONS

5.1 General - Mobile radio base station towers and microwave relay towers installations are generally susceptible to severe lightning strokes, and special protection measures are required. Where such stations are located in rural or suburban areas, conditions may be especially unfavorable due to lack of shielding by tall buildings. Requirements for protecting these facilities are explained in some detail in Appendix A to REA Form 397d, Design Specifications for Point-to-Point Microwave Systems, and Appendix A to REA Form 397e, Mobile and Fixed Dial Radiotelephone Specifications.

5.2 Protective Grounding

5.21 Buildings - Because of the large currents involved in nearby or direct lightning hits to towers and associated structures, the development of hazardous differences of potential between metal parts in associated buildings is a definite possibility. In order to avoid such potential differences it is essential that all metal elements of the building structure, such as steel reinforcing rods in concrete, metal sheathing, metal roof supports and trusses and metal piping and conduit systems be bonded to the station ground. Note: The bonding of steel reinforcing rods in concrete should be carried out and inspected by the engineer prior to pouring the concrete. If precast concrete slabs are used, the bonding of reinforcing rods between slabs is most difficult, yet without this bonding, damage may be expected from lightning strikes. This situation should be given careful consideration prior to employing precast concrete construction.

5.211 While it is desirable that the building grounds have low resistance, it is more important that all metal parts be bonded together and grounded in such a way as to obtain short paths to ground. Multiple paths to the common ground system are desirable.

5.22 Tower Installations - A typical tower grounding arrangement is illustrated in Figure 3. Self-supporting towers should have a ground rod driven at the base of each footing and bonded to the tower leg with a #6 or larger copper conductor. Interconnection of the tower and building grounding system should be made external to the building. Where wires connecting to ground cross they should be bonded together to avoid arcing. Also, care should be taken in placing grounding conductors to maintain appreciable (six feet or more) separation from

other grounded metal parts which may be hidden within the building structure -- such as structural members, steam, gas, or water pipes, etc. Where such members are accessible numerous bonds to the building grounding conductor are desirable to prevent arcing.

5.23 Where grounding or bonding conductors are likely to be subjected to mechanical injury they should be run in metal conduit. However, in order to avoid arcing, the grounding conductor should be bonded to the conduit at each end of the run.

5.24 Where extremely rocky soil exists or where ground rods cannot be driven for other reasons, a network of wires should be constructed in shallow trenches each of which will accommodate at least a 25-foot length of conductor. The trenches should radiate from corners of the tower structure in a symmetrical configuration. A length of conductor totaling 500 feet may be found necessary. Low resistance of such networks is not as important as distribution of the conductors over the nearby surrounding areas.

5.3 Pole-Mounted Installation - In some cases the radio antenna may be supported by a wood pole and connected by coaxial cable to power operated equipment located in a suitable outdoor cabinet. (See Figure 5). Common bonding of metal cabinets, conduit, telephone cable strand and shield, if present, to a grounding conductor connected to a driven ground system is essential. Where the power system MGN is accessible, the ground should be interconnected with it using a #6 or larger copper conductor.

5.4 Where antenna supports are attached to a metal building or located on a metal roof, the support, if made of metal, and all guy wires should be bonded together and connected to the metal frame of the building by a #6 or larger copper conductor. Grounded antenna supports or their grounding conductors should have either (1) at least six-foot separation from other grounded structures or (2) should be bonded to them by a #6 or larger copper conductor.

5.5 In order to minimize the possibility of damage to guy anchors embedded in concrete a ground rod (or rods) should be driven as close to each anchor as possible. All rods at each anchor should be bonded together and to the guy wire with a #6 copper conductor. Where earth resistivity is high, additional benefits will result from bonding the guy grounding system to the station grounding system if feasible.

5.6 Antennas and Connecting Coaxial Transmission Lines - Antennas should have built-in lightning protection between the radiating elements and the grounded tower or grounding conductor. Protection of the coaxial cable is usually supplied by means of a star gap between the inner conductor and the grounded outer sleeve. In order to minimize the possible build-up of excessive potentials between the inner conductor and connecting equipment and outer shell, the outer shell should be bonded to the tower or pole support grounding conductor at or near the top and bottom, thereby providing a parallel path for currents to ground. Coaxial line runs on poles should be protected by metal cable guards which should be bonded to the outer most conductor of the coaxial and to the grounding conductor.

5.7 Protection of Radio and Microwave Equipment

5.71 Radio Transmitting and Receiving Equipment - Mounting of radio receiving and transmitting equipment on grounded metal racks ordinarily provides a satisfactory means of common grounding. All such racks should be carefully bonded together and connected to the station ground by a conductor or bus not smaller than a #10 copper wire. Protectors applied to incoming exposed telephone circuits should be grounded to the station ground electrode by a separate #10 copper conductor.

5.72 Wave Guides and Coaxial Cables - Bonding of wave guides and the outer conductor of coaxial cables to the metal framework of the tower structure with #10 or larger copper conductors will provide adequate conductivity for the discharge of lightning currents. Details of the protection to be provided on connecting equipment are given in the following paragraphs.

5.8 Protection of Connecting Facilities

5.81 All cable pairs connecting a remote radio or microwave station to a central office should be terminated at the remote end in protected cable terminals equipped with arresters whose characteristics coordinate with the requirements of the equipment. The cable shield should be connected to the electronic equipment ground and to the central office ground where balanced conductors, such as video pairs, are used. If the connecting cable consists of coaxial tubes, the outer conductors of the tubes should be bonded to the cable shield at one end only to avoid ground loop currents.

5.82 Rural Areas - The protective arresters normally applied for protection of terminating equipment at the station and the CO will ordinarily be adequate for the protection of plastic insulated connecting cable pairs. Where cable pairs from the station are connected to a feeder cable, all of the pairs from the radio station should be protected using yellow coded carbon arresters or gas tube arresters having a rating of about 800 volts. Auxiliary protection of coaxial pairs is not required.

5.83 Power Service Protection - While lightning arresters applied to power distribution primary circuits provide adequate protection against lightning surges insofar as the distribution transformer and meter are concerned, voltages of sufficient magnitude to damage equipment connected to the secondary circuits may be readily developed. It is desirable therefore to apply arresters to the secondary power circuits. Such arresters are available having ratings ranging from 175 to 650 volts ^{1/}Most of the available types have a sparkover rating in excess of 2000 volts. Therefore, unless it is known that the power service equipment will withstand in excess of 2000 volt surges, it should be protected as indicated in Figure 4.

5.84 Both secondary and primary arrester ground conductors should be connected to the main station ground electrode unless the power company preference is to operate its system with separate primary and secondary grounds. In such cases the primary and secondary ground conductor should be interconnected through a suitable isolation gap, as determined by discussion with the power company.

5.85 It is important that all conduit, switch boxes, metal shielded cables, metal sheathed cables, and other noncurrent carrying metal parts be bonded together and connected to the main station ground.

^{1/} These ratings refer to the maximum potential at which the arrester with interrupt power follow-up currents rather than to sparkover voltages.

TABLE 1

Separation vs. Product of Exposure (kft)
and 60 Hz Ground I

for $E = 50V = ILZ$

$L \times I$	Mutual Impedance Z Ohms/kft	Separation - Ft. for		
		$\rho = 10$	100	1000 (Meter ohms)
250	.2	-		1.3
300	.166	-	2.2	6.5
400	.125	3.8	12.5	39
500	.10	11.4	36	120
750	.066	55	165	550
1000	.05	110	330	1100
2000	.025	330	950	3500
3000	.0166	500	1350	5100
5000	.01	650	1800	6700

E = Voltage - Telephone Conductor to Ground (rms)

L = Length of exposure kilofeet

I = Power fault* current - amperes

Z = Mutual impedance between power and telephone systems - ohms/kft

ρ = Earth resistivity of the area - meter ohms

*Or unbalanced power current in the earth.

PROTECTION OF TELEPHONE CIRCUITS SERVING
POWER STATIONS - NEUTRALIZING TRANSFORMER METHOD

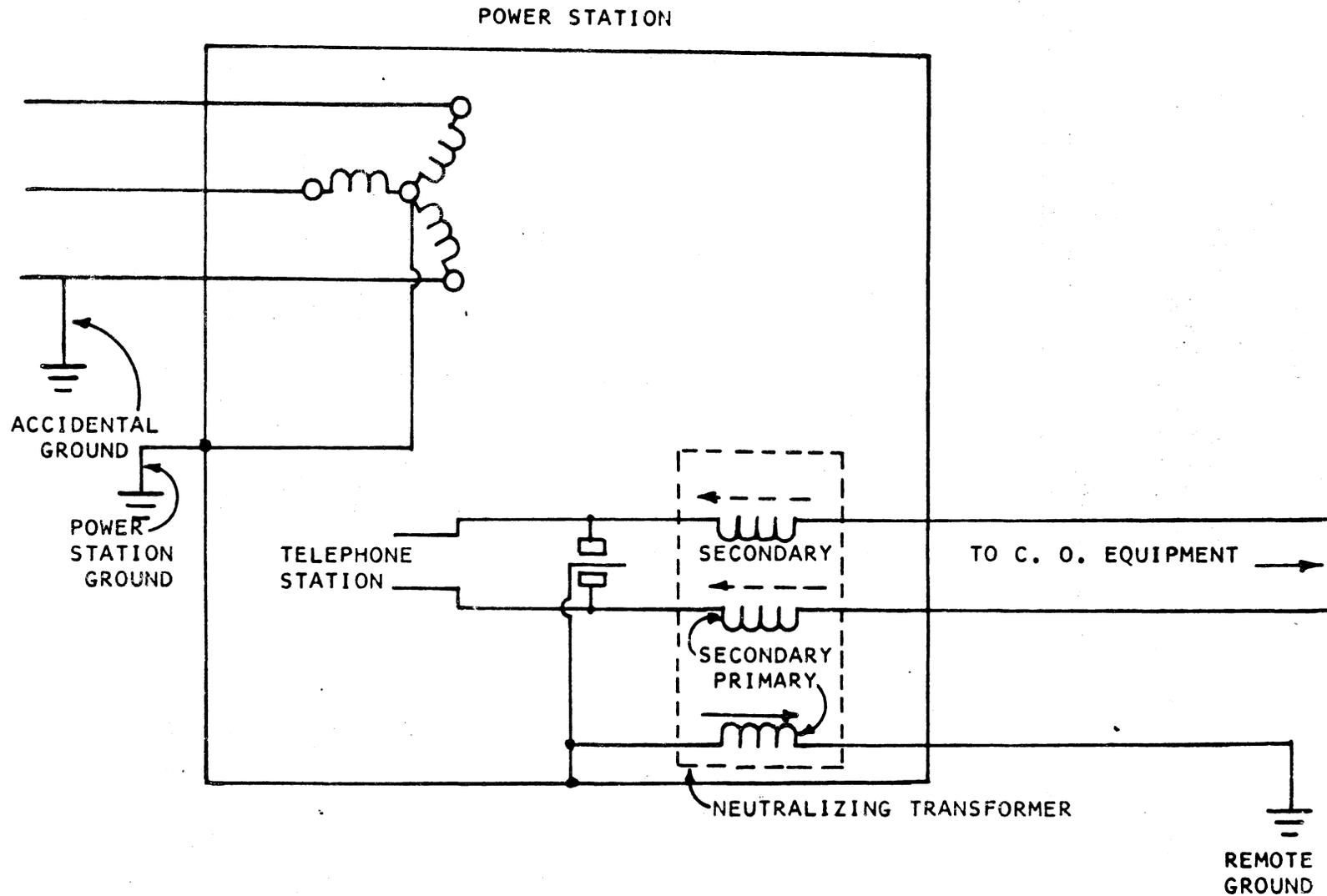


FIGURE 1A

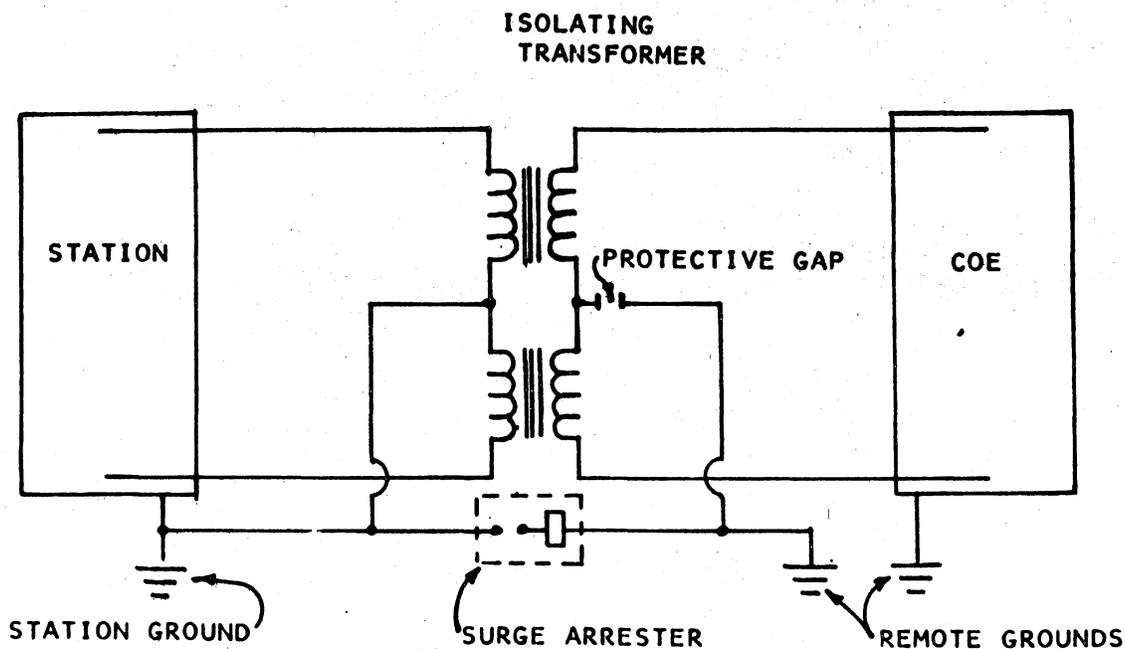


FIGURE 1B - APPLICATION OF AN ISOLATING TRANSFORMER

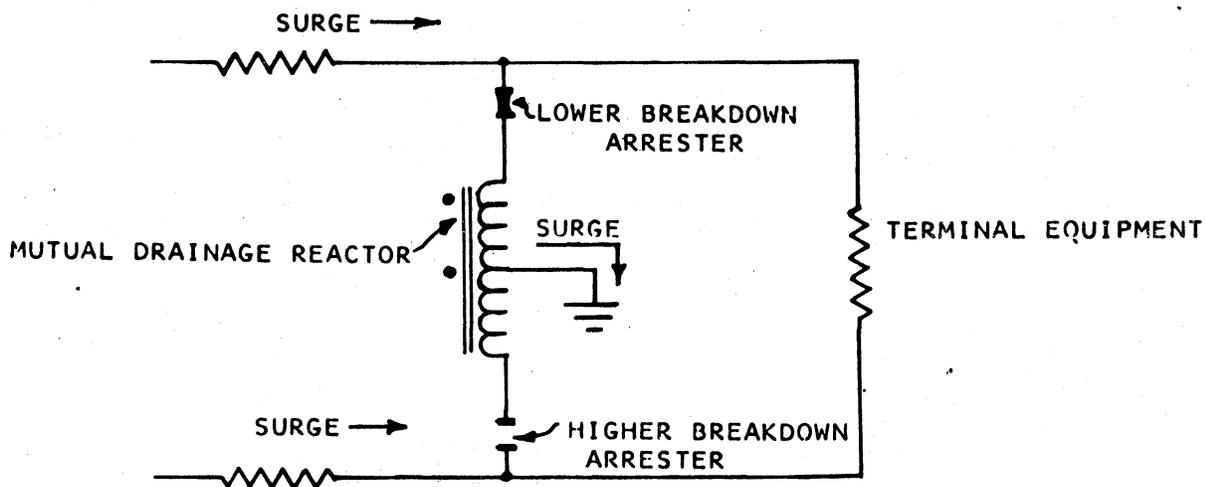


FIGURE 1C - APPLICATION OF MUTUAL DRAINAGE REACTOR

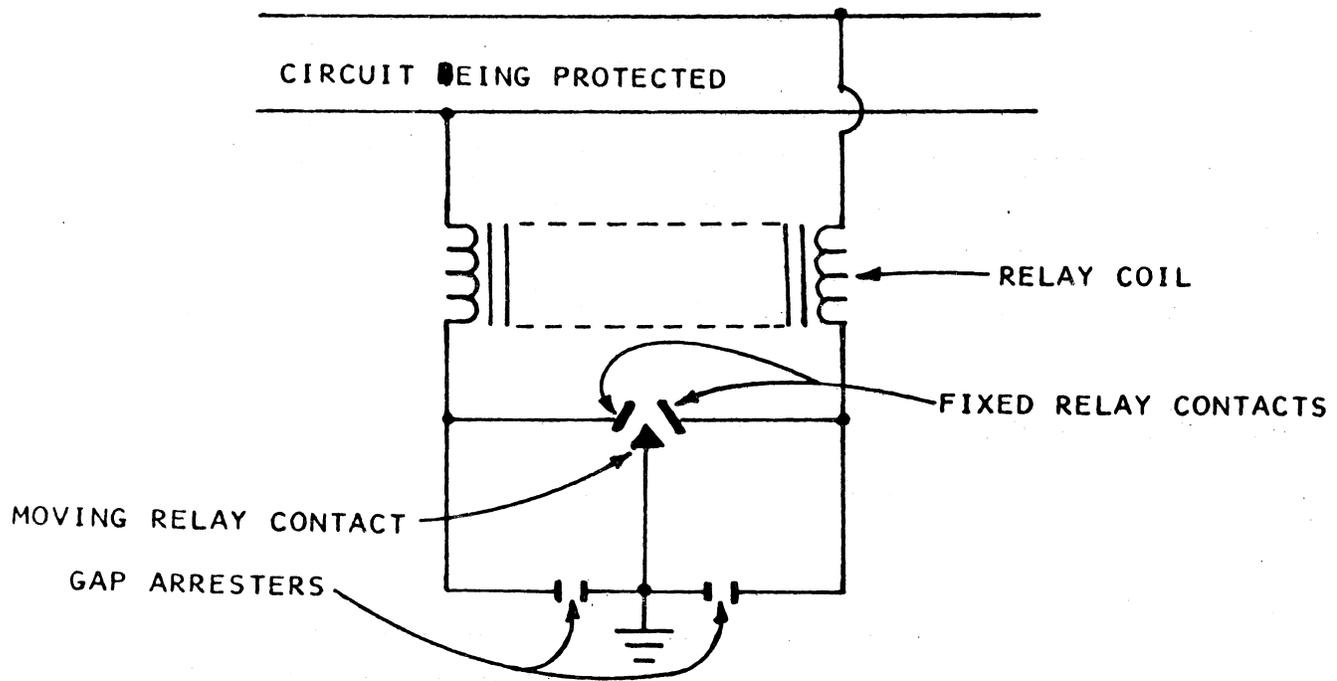
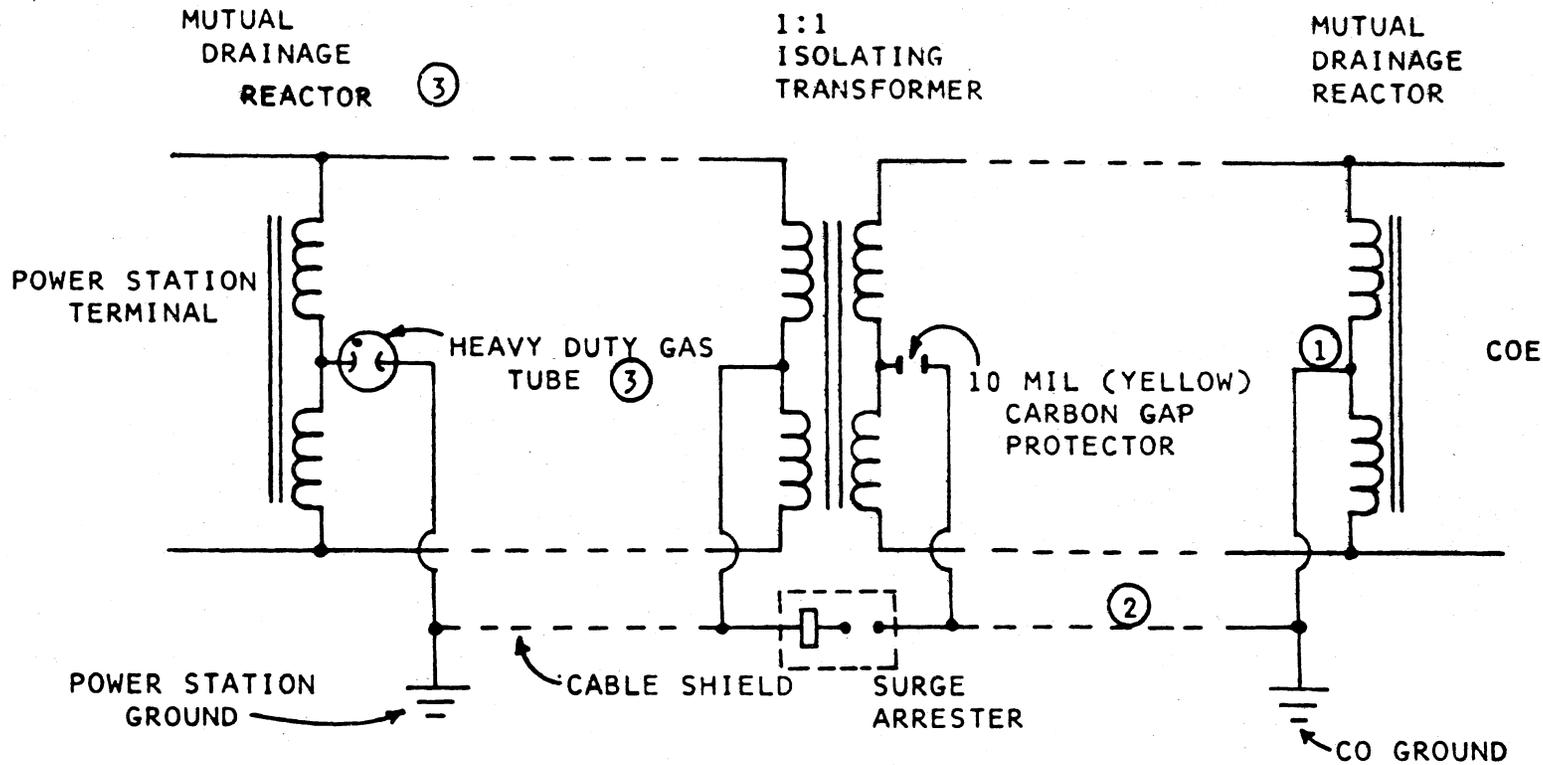


FIGURE 1D - APPLICATION OF A SHORT CIRCUITING RELAY

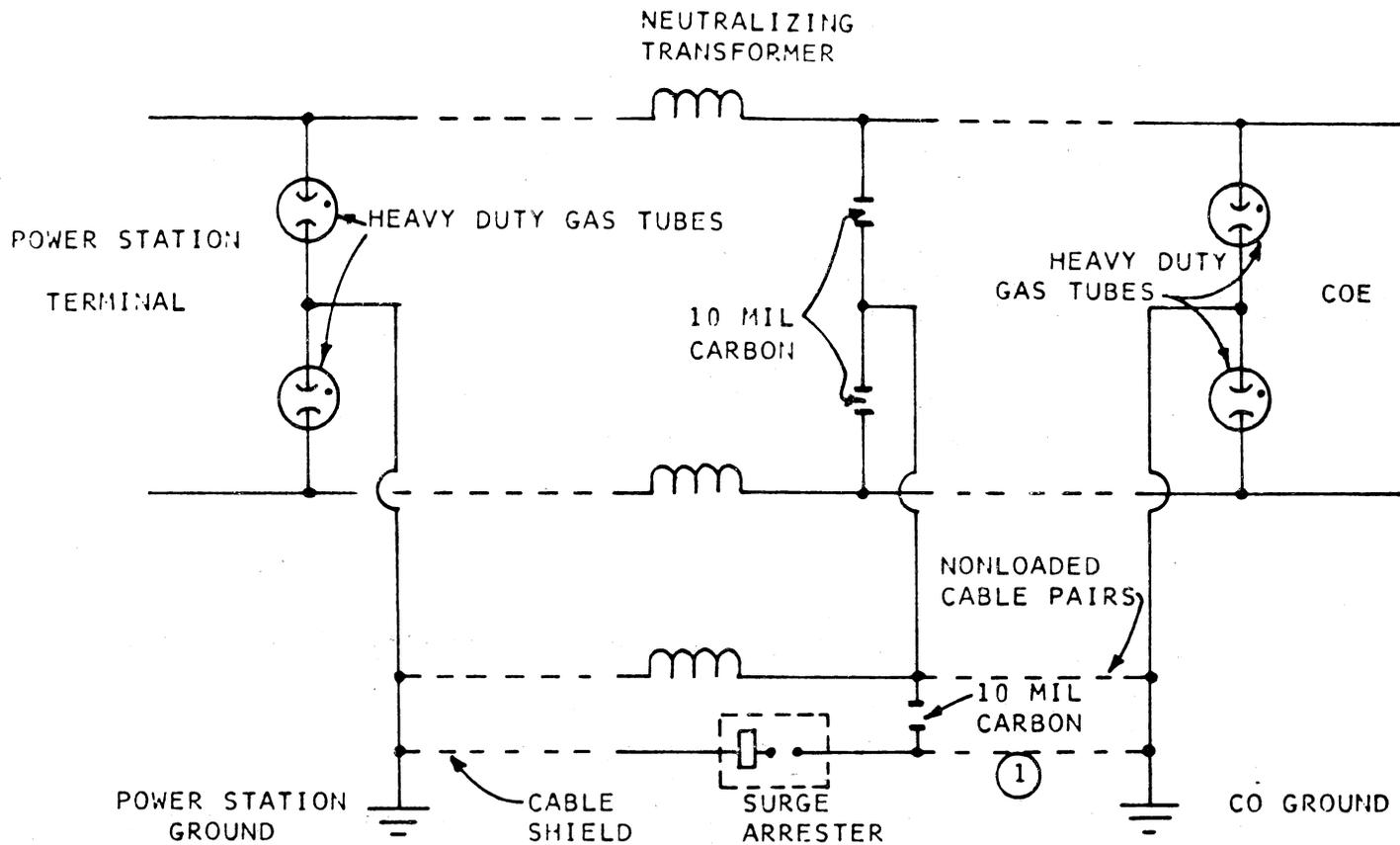


NOTES:

- ① NO MAINFRAME PROTECTORS TO BE USED.
- ② CABLE SHIELD MUST BE ISOLATED FROM GROUND FROM THE ISOLATING TRANSFORMER TO BEYOND THE AREA OF POWER STATION INFLUENCE.
- ③ IF THE CABLE FROM THE ISOLATING TRANSFORMER TO THE TERMINAL IS NOT EXPOSED TO POWER CONTACT, AND IS LESS THAN 75 FT. LONG, THIS UNIT IS NOT REQUIRED

PROTECTION FOR NONINTERRUPTABLE CIRCUIT WITH NO DC REQUIRED

FIGURE 2A

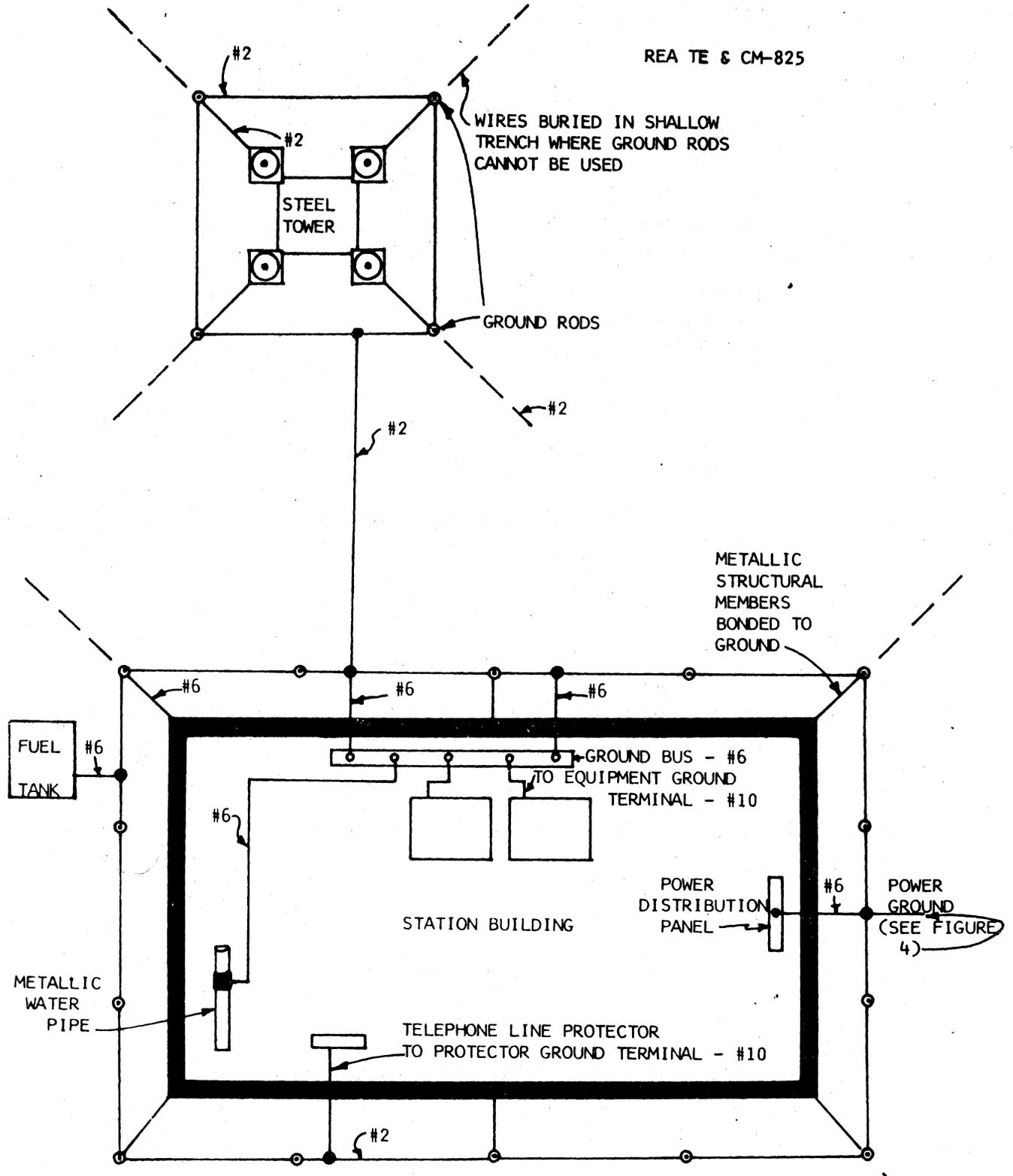


NOTES:

- ① CABLE SHIELD MUST BE ISOLATED FROM GROUND FROM THE NEUTRALIZING TRANSFORMER TO BEYOND THE AREA OF POWER STATION INFLUENCE.

PROTECTION FOR BRIEFLY INTERRUPTABLE CIRCUIT WITH DC RLQUIRED

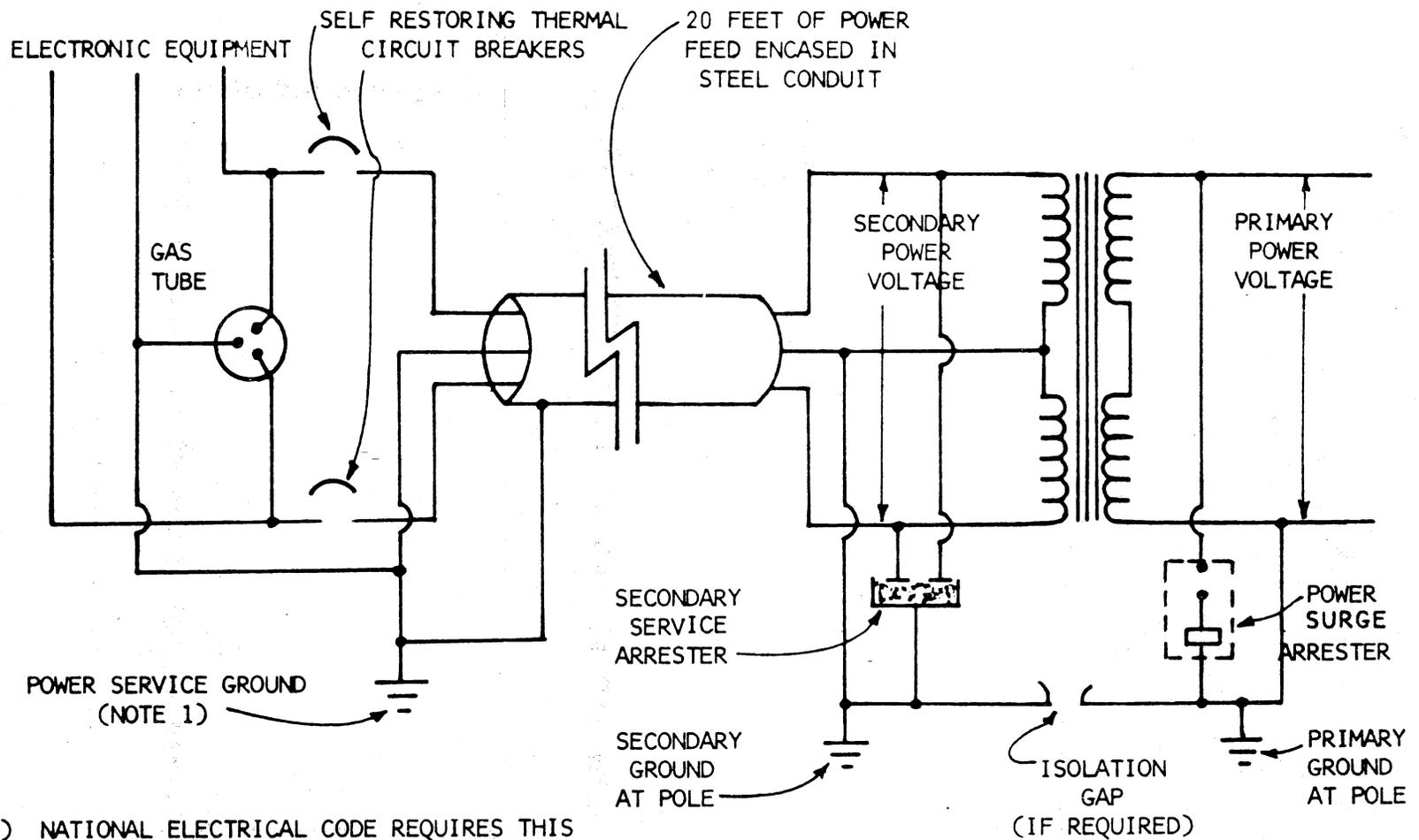
FIGURE 2D



NOTES:

- 1. CONNECTIONS TO GROUNDING SYSTEM TO BE #10 OR LARGER
- 2. ALL WIRE SIZES ARE FOR COPPER WIRE.

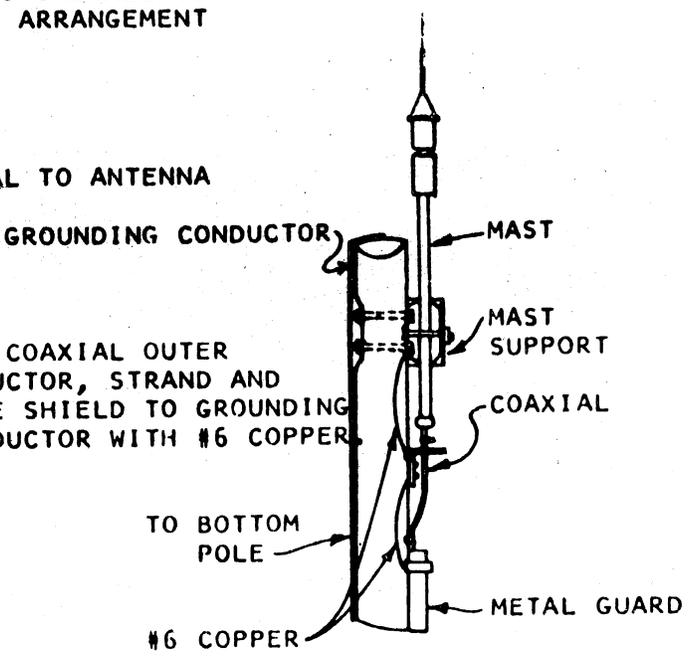
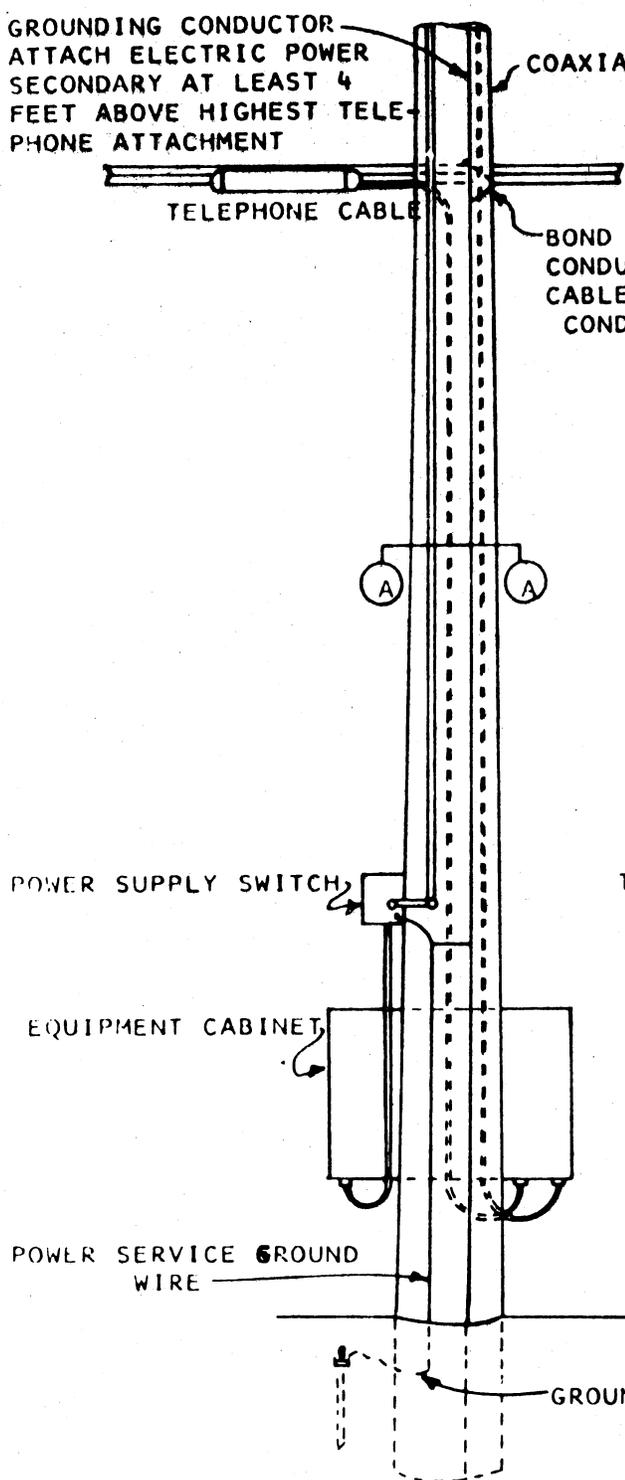
GROUNDING ARRANGEMENT - FIXED RADIO STATION FIGURE 3



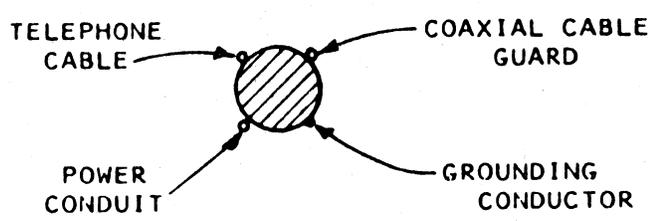
(NOTE 1) NATIONAL ELECTRICAL CODE REQUIRES THIS GROUND TO BE THE COMMON GROUND FOR BOTH POWER AND TELEPHONE, OR IF SEPARATE GROUNDS ARE USED THEY MUST BE BONDED TOGETHER WITH A #6 OR LARGER COPPER WIRE (OR THE EQUIVALENT).

FIGURE 4
POWER SERVICE PROTECTION

POLE MOUNTED INSTALLATION GROUNDING ARRANGEMENT



MAST SUPPORTING ARRANGEMENT



SECTION AA

TELEPHONE CABLE AND COAXIAL ON FIELD SIDE OF POLE. POWER CONDUIT AND GROUNDING CONDUCTOR ON STREET SIDE.

FIGURE 5

APPENDIX A

The determination of affects to be expected in telephone lines paralleling low frequency power lines involves calculation of voltage induced at the time of power fault and resultant currents delivered to station protectors within and adjacent to the paralleling exposure. From a knowledge of the magnitude and duration of these currents, the likelihood of protector permanent grounding may be estimated.

To accomplish these results, employ the following procedure:

1. Obtain an estimate of the maximum expected power fault current from the power company.
2. Measure earth resistivity in the area of the exposure in question. Take several measurements at a number of different locations in the area and average the results to obtain a figure for earth resistivity.
3. Calculate magnetically induced potential between conductors and ground, using Carson's formulae* for mutual impedance Z and known fault current I , as shown in the following example.
4. From these figures, determine if the induced voltage will be sufficient to break down protectors on the line, and if so, what the induced currents will be after this breakdown.
5. From the currents calculated in 4, estimate the number of protectors that will probably be grounded as a result of each fault. If the cost of replacing grounded arresters justifies, apply remedial protection.

The following is an illustrative example:

- Assume: (a) Power line fault current
 $I = 2 \text{ KA}$
- (b) Length of exposure
 $L = 5 \text{ KF}$
- (c) Earth resistivity
 $= 100 \text{ meter-ohms}$
- (d) Separation
 $S = 100 \text{ feet}$

*See Earth Conduction Effects in Transmission Systems by E. D. Sunde for data on the application of Carson's formulae.

Then, from Figure A the mutual impedance would be:

$$Z = .077 \text{ ohms/KF}$$

And, the longitudinal voltage induced in the telephone line will be:

$$\begin{aligned} E &= I \times Z \times L \\ &= 2000 \times .077 \times 5 \\ &= 770 \text{ volts} \end{aligned}$$

Assuming a 22 gauge telephone cable with stations at each end of the exposure, the protectors at these stations would be subjected to:

$$I = \frac{770}{5 \times 16.1} = 9.6 \text{ amperes}$$

From Figure B it can be seen that a current of 9.6 amperes would be likely to produce permanent grounding of carbon block arresters on the fourth 60 Hz discharge. If it is probable that the power line would have more than four 1/4 second faults (or different combination of fault occurrences and durations producing an equivalent amount of energy) during a period of 5 to 10 years the need for corrective action is indicated. If the line has not been built, the first approach should be to increase the separation between the two lines. If this is not practicable, heavy duty gas tube station protectors should be installed. If failures of the gas tubes occur, installation of short circuiting relays should be considered.

From a safety standpoint, not more than 50V rms ac should be permitted. The necessary separation to obtain this 50V level can be obtained by calculations as covered above. For quick reference, however, Table 1 of the main text or Figure C of this Appendix may be used. These give a comparison between the product of current and length of exposure versus separation, for several values of earth resistivity, for an induced voltage level of 50 volts from line to ground.

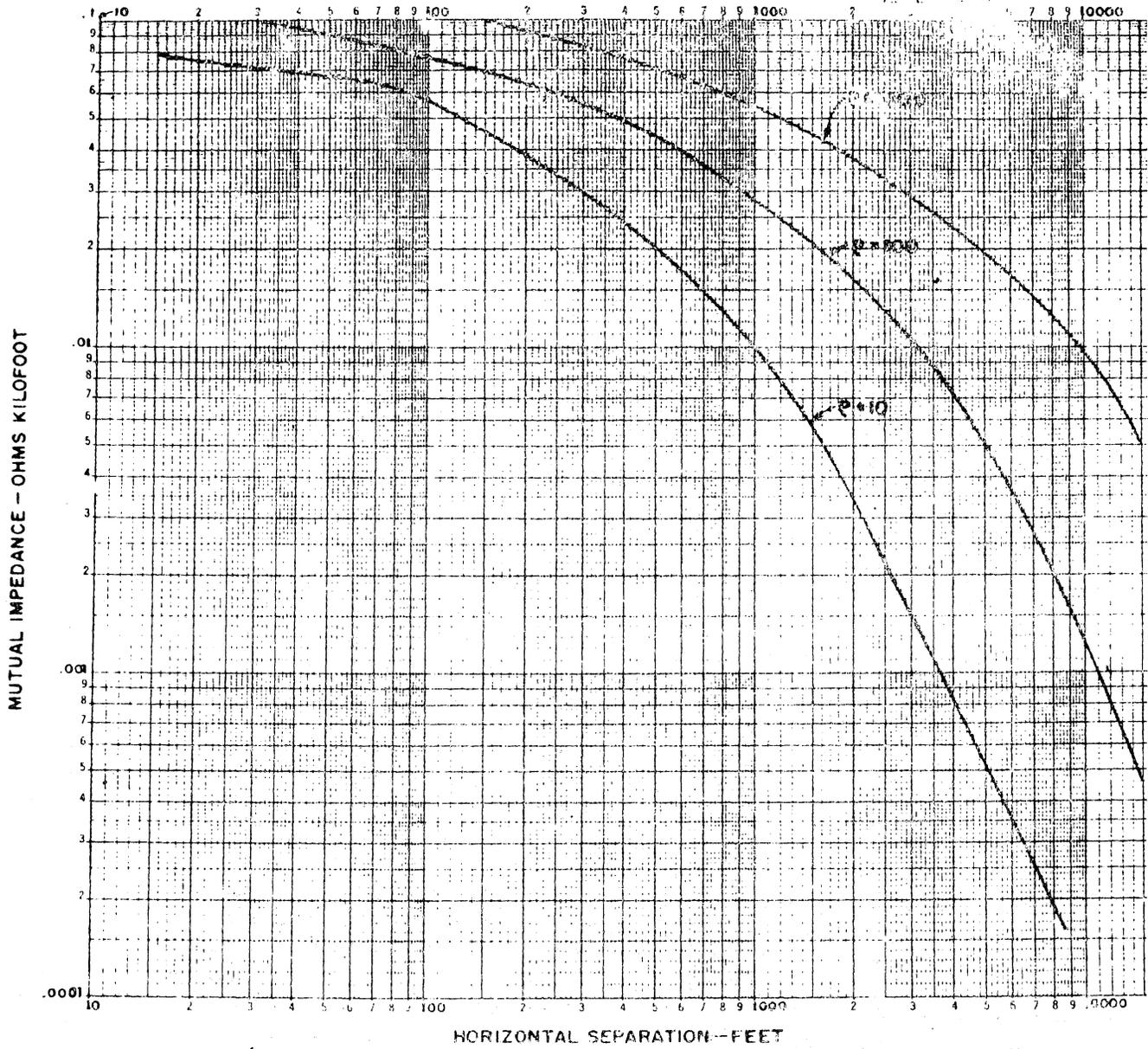


FIGURE A - MUTUAL IMPEDANCE VS SEPARATION
OF POWER LINE AND TELEPHONE CABLE

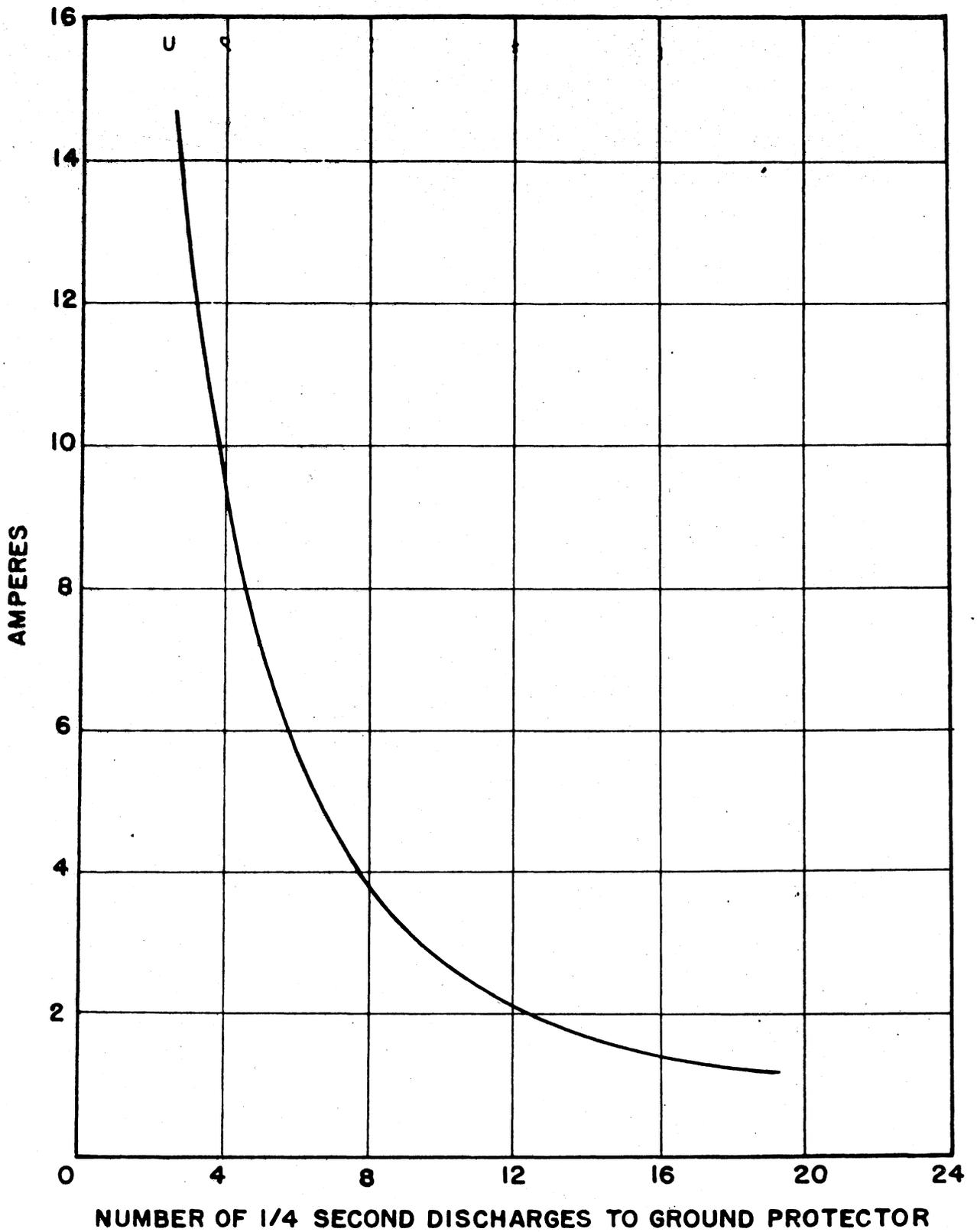


FIGURE B - CARBON BLOCK GROUNDING PROBABILITY

