

IEEE Guide for the Application of Gas Tube and Air Gap Arrester Low-Voltage (Equal to or Less than 1000 V_{rms} or 1200 Vdc) Surge- Protective Devices

Sponsor

**Surge-Protective Devices Committee
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Abstract: Assistance in selecting the most appropriate type of low-voltage surge-protective device (either gas tube or air gap) for a particular application is provided. Evaluation of the characteristics of each device to meet specific service requirements is also given.

Keywords: air gap surge arrester, breakdown voltage, communication circuits, current, gas tube surge arrester, power circuits

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Introduction

[This introduction is not a part of IEEE Std C62.42-1992, IEEE Guide for the Application of Gas Tube and Air Gap Arrester Low-Voltage (Equal to or Less than 1000 V_{rms} or 1200 Vdc) Surge-Protective Devices.]

This guide is a revision of IEEE Std C62.42-1987 and has been rewritten to include air gap devices in addition to gas tube arresters, which were the subject of the original document. Subsequent revisions will include other types of low-voltage surge-protective devices.

This guide supplements IEEE Std C62.31-1987 and IEEE Std C62.32-1981. The purpose of this guide is to assist in selecting the most appropriate type of device for a particular application and in evaluating the characteristics of devices to meet specific service requirements.

IEEE Std C62.42-1992 presents an explanation of the electrical environment in which gas tube and air gap surge-protective devices shall operate, a comparison of the major difference between the two types of devices considered, a description and the theory of operation of gas tube and air gap devices, and guidance in applying and interpreting the respective test specifications for the arrester characteristics.

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Figure 9 was taken from Cobine, J. D., *Gaseous Conductors*. New York: Dover Publications Inc., 1958.

Contents

CLAUSE	PAGE
1. Overview.....	1
1.1 Scope.....	1
2. References.....	2
3. Electrical environment.....	3
3.1 Lightning.....	3
3.2 Low-energy static source	8
3.3 Power interference	9
3.4 Switching transients	10
3.5 Electrostatic discharge	10
3.6 Electromagnetic pulse (EMP).....	12
4. Comparison and selection of air gaps vs. gas tubes.....	12
5. Gas tubes.....	13
5.1 Description.....	13
5.2 Theory of operation.....	13
5.3 Arrester test characteristics.....	15
5.4 Application of gas tube surge arresters.....	20
6. Air gaps.....	25
6.1 Description.....	25
6.2 Theory of operation.....	26
6.3 Arrester test characteristics.....	26
6.4 Application of air gap surge arresters	28
6.5 Backup air gap surge arresters.....	31
Annex A Circuit behavior of gas tube arresters	33
Annex B Circuit behavior of carbon air gap surge arresters	38
Annex C Bibliography	41

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1. Overview

This guide provides assistance in selecting the most appropriate type of device for a particular application and in evaluating the characteristics of devices to meet specific service requirements.

This guide is divided into six clauses. Clause 1 provides the scope of this guide. Clause 2 lists references to other standards. Clause 3 explains the electrical environment in which gas tube and air gap surge-protective devices shall operate. Clause 4 compares the major difference between the air gap surge arrester and the gas tube surge arrester. Clauses 5 and 6 give a description and the theory of operation of gas tube and air gap devices, and guidance in applying and interpreting the respective test specifications for the arrester characteristics.

This guide also contains three annexes. These provide additional information for understanding and using this guide, but they are not part of the guide. Annex A illustrates the circuit behavior of gas tube arresters. Annex B illustrates the circuit behavior of carbon air gap surge arresters. Annex C contains a bibliography of the references used in developing this guide.

1.1 Scope

This guide applies to surge-protective devices used in systems with voltages equal to or less than 1000 V_{rms} or 1200 Vdc. These protective devices are designed to limit voltage surges on balanced or unbalanced communication circuits and on dc to 420 Hz power circuits. Although telephone circuits are a major application of air gap and gas tube surge arresters, this guide will also provide useful information for many other surge-protection applications.

For protection under the specialized conditions found at power stations, consult IEEE Std 487-1992¹ and IEEE Std C37.90.1-1989. For a recommended practice on surge voltages in low-voltage ac power circuits consult IEEE Std C62.41-1991. For technical performance guidelines for gas tube surge arresters on wire line telephone circuits consult ANSI C62.61-1985.

This guide is intended to complement IEEE Std C62.31-1987 and IEEE Std C62.32-1981 for air gap surge-protective devices. The definitions used in these three standards are the same. For other definitions refer to IEEE Std 100-1992. With this guide the user will be able to evaluate the various types of gas tube and air gap surge arresters in terms of his or her own particular applications. The guide will consider the sources and nature of transients, the characteristics of gas tube and air gap surge arresters, and the concepts necessary to choose the appropriate product.

When used in conjunction with IEEE Std C62.31-1987 and IEEE Std 62.32-1981, this guide will give the user guidance in selecting the right product and interpreting its specifications.

¹Information on references can be found in clause 2.

2. References

This guide shall be used in conjunction with the following publications:

Accredited Standards Committee C2-1993, National Electrical Safety Code.²

ANSI C62.61-1985, Gas Tube Surge Arresters on Wire Line Telephone Circuits.³

ANSI/NFPA 70-1993, National Electrical Code.⁴

IEC 801-4 (1988), Electromagnetic compatibility for industrial process measurement and control equipment, Part 4: Electrical fast transient/burst requirements.⁵

IEEE Std C37.90.1-1989, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI).⁶

IEEE Std C62.1-1989, IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits (ANSI).

IEEE Std C62.31-1987, IEEE Standard Test Specifications for Gas-Tube Surge-Protective Devices (ANSI).

IEEE Std C62.32-1981 (Reaff 1987), IEEE Standard Test Specifications for Low-Voltage Air Gap Surge-Protective Devices (ANSI).

IEEE Std C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits (ANSI).

IEEE Std 80-1986 (Reaff 1991), IEEE Guide for Safety in AC Substation Grounding (ANSI).

IEEE Std 81-1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms.

IEEE Std 367-1987, IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault (ANSI).

IEEE Std 487-1992, IEEE Recommended Practice for the Protection of Wire Line Communications Facilities Serving Electric Power Stations (ANSI).

²The National Electrical Safety Code is available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA.

⁵IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembe, CH 1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶IEEE publications are available from the IEEE Service Center.

3. Electrical environment

Electrical and electronic systems and networks (facilities) are subject to disturbances from external sources of electrical energy. These sources include electric power circuits and natural phenomena, such as lightning and low-energy static influences. The effects of such disturbances may be confined to interference with normal use or operation, as in the case of noise or interference with signaling; or may be capable of creating hazards to users, maintenance personnel, and equipment.

3.1 Lightning

Lightning is a transient high-current electrical discharge. It occurs when some region of the atmosphere attains an electrical charge of sufficient potential to cause dielectric breakdown of the air.

The most common source of lightning is the thundercloud. Charged regions of the thundercloud emerge as shown in figure 1. This concentration of charge induces a similar, but opposite, concentration of charge in the earth beneath the cloud, in another portion of the same cloud, or in another cloud. When the electric field gradient exceeds the dielectric strength of the air, lightning discharges (cloud-to-cloud, within a cloud, or cloud-to-ground) take place as shown in figure 1.

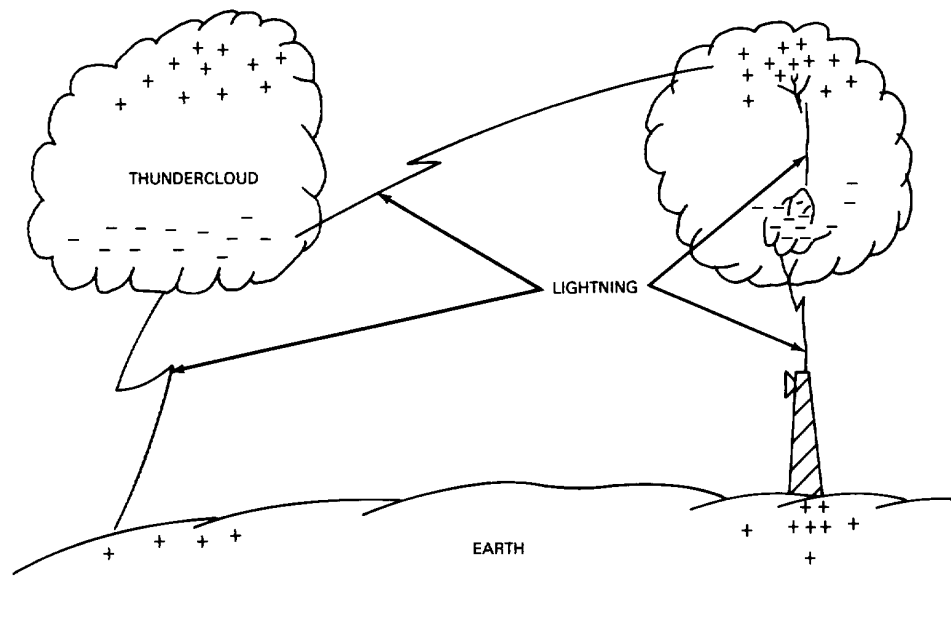


Figure 1—Source of lightning

A complete lightning flash may last as long as 0.25 s, and may consist of several strokes of high-current discharge separated by periods of up to 0.1 s when current flow is significantly reduced. Figure 2 illustrates a typical time history of a lightning flash (see also [B2]⁷ and [B9]).

⁷The numbers in brackets correspond to those of the bibliographical references in annex C.

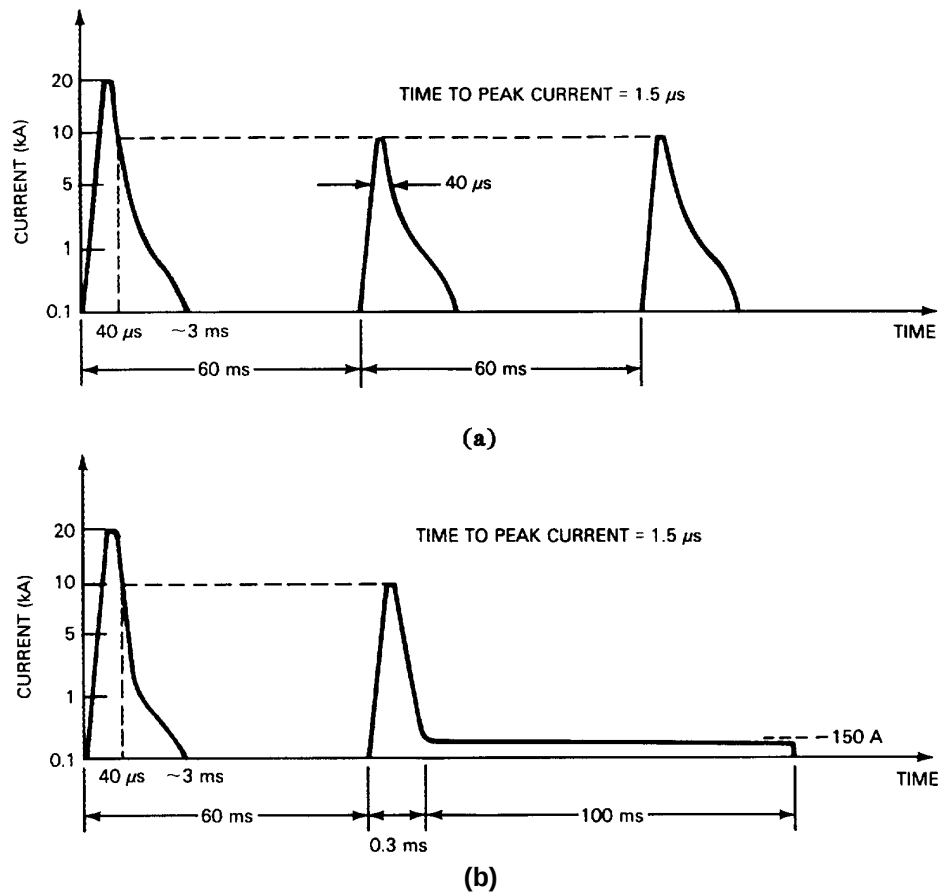


Figure 2—Time history of typical (basic) lightning models
a) Flash without any continuing current surges
b) Flash with final stage continuing current

3.1.1 Direct lightning stroke

The crest current magnitude of an actual lightning stroke varies widely. Figure 3 illustrates the distribution of a lightning stroke's crest currents to aerial structures (see [B2], [B24], and [B9]). Typical surges conducted or induced into wire line facilities would be considerably smaller because of the availability of alternate paths. As a result, protectors at the terminations of these facilities are normally not designed to withstand the full crest current of direct strokes.

3.1.2 Indirect lightning stroke

In addition to direct strokes, facilities may be subjected to lightning-caused potentials in the following manners:

- Induction from nearby strokes to earth
- Arcing to facilities from the earth, a tree, or a structure incurring a direct stroke
- Lightning currents also may be conducted to wire line facilities when strokes take place near grounded points. For example, a stroke to ground near a protected terminal will raise the earth potential at the protector so that surge currents will flow from the protector ground, through the protector, to other ground points outside the direct influence of the stroke.

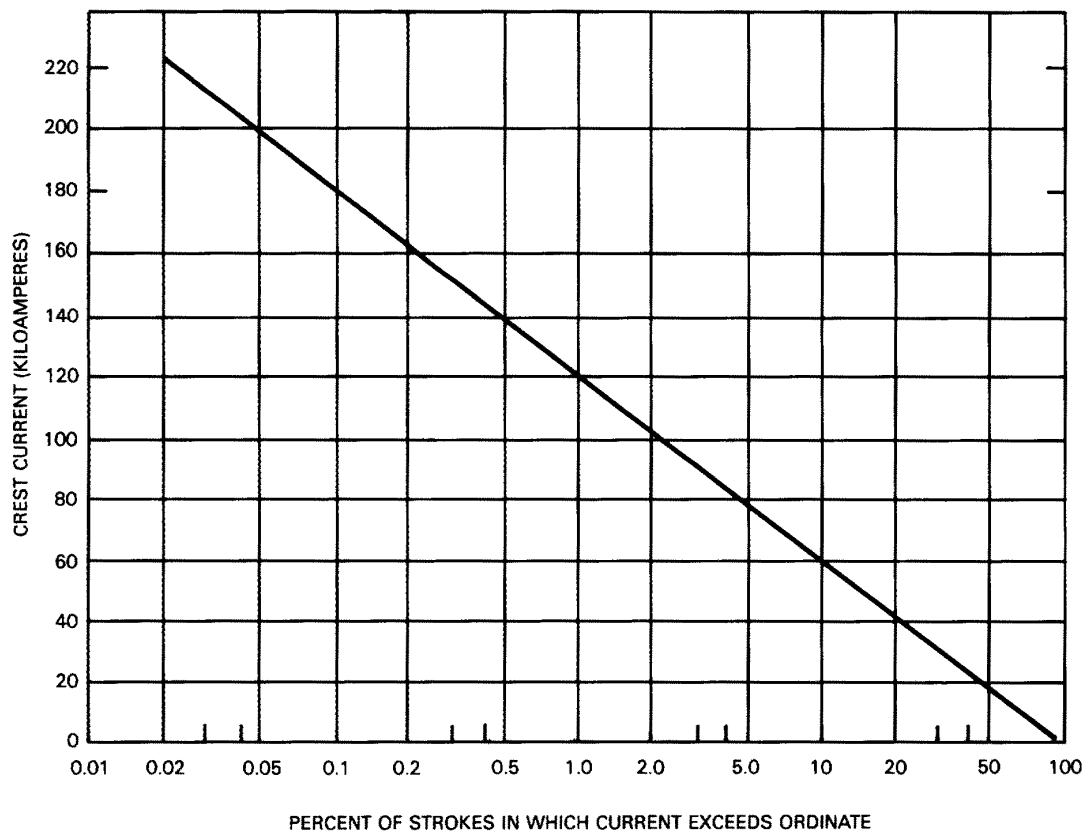
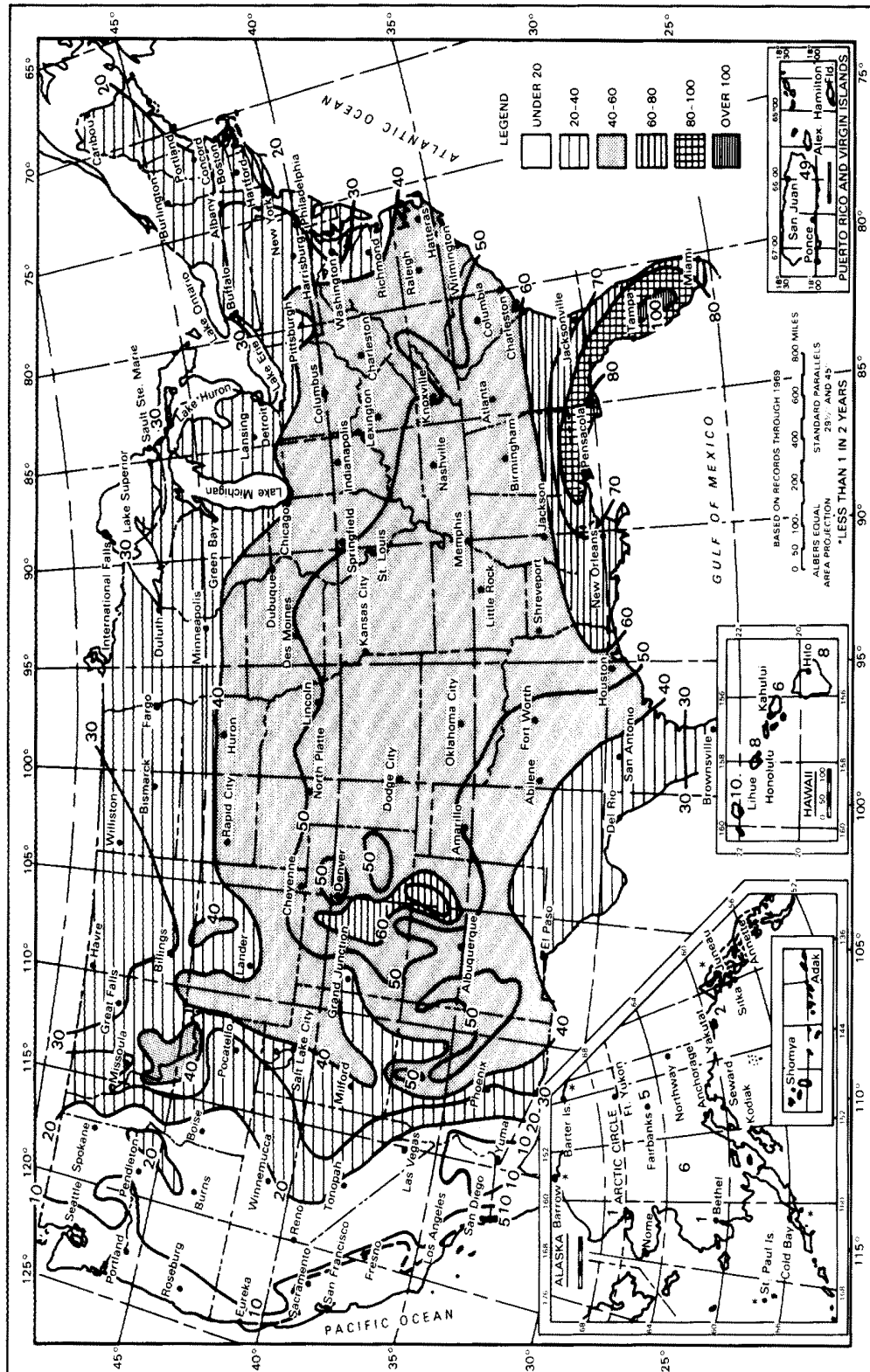


Figure 3—Distribution of lightning stroke crest currents to aerial structures

3.1.3 Factors affecting the exposure to lightning damage

When estimating the exposure to lightning damage, several variables shall be considered. Briefly, they include:

- a) Storm frequency or incidence
 - 1) The traditional measure of storm frequency is the number of *thunderstorm days* experienced at a given location during the year. A *thunderstorm day* is defined as any day during which thunder can be heard at a specific observation point. An isokeraunic map in figure 4 shows the mean annual number of days the United States has thunderstorms (see [B3]). Similar information for Canada is shown in figure 5 and for the world in figure 6 (see [B5]).
 - 2) The *thunderstorm day* statistics allocate equal weighting to a day with one storm or to a day with numerous storms occurring for hours. The hazard of damage is obviously greater for long duration or multiple-occurrence storms. An improved description of the lightning hazard could be provided by an estimate of the number of thunderstorms expected at a location. A report is available (see [B10]), which provides a representative analysis of the monthly and annual frequency of thunderstorms for the contiguous United States. This publication includes the mean annual number of thunderstorms for the United States, as shown in figure 7, as well as monthly maps.



Source: National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC.

Figure 4—Mean number of days with thunderstorms (USA) [B3]

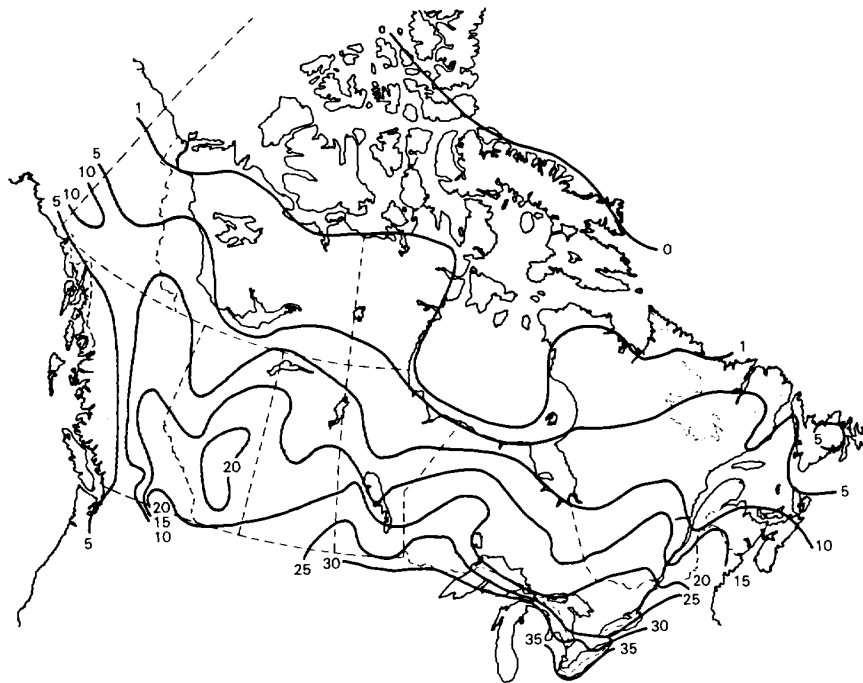


**Figure 5—Mean annual number of days with thunderstorms
(Based on the period 1941–1960) (Canada) [B5]**

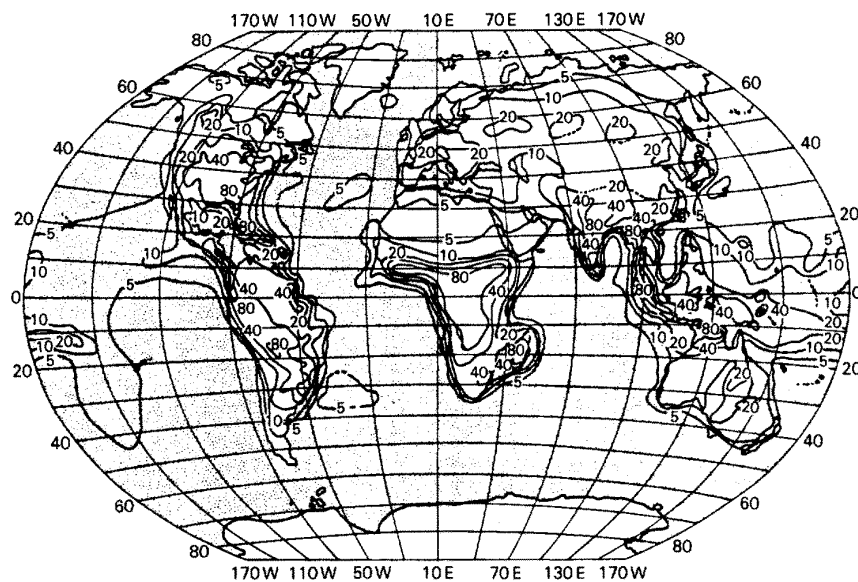
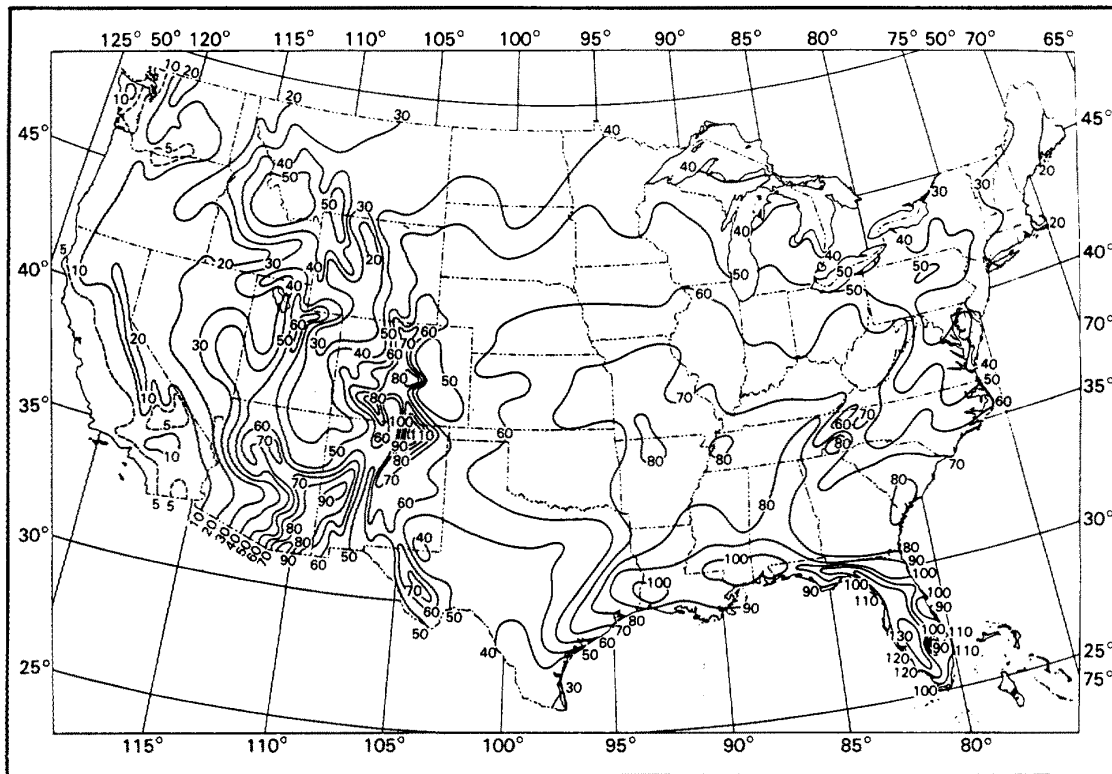


Figure 6—Average annual number of days with thunderstorms (World) [B5]



Source: National Climatic Data Center, National Thunderstorm Frequencies for the Contiguous United States, Nov. 1981.

Figure 7—Mean number of thunderstorms (USA, annual) [B10]

- b) *Earth resistivity.* Earth resistivity is also important in determining the exposure to lightning damage. The unit of earth resistivity, the ohm-meter, is defined as the resistance, in ohms, between opposite faces of a cube of earth one cubic meter in volume (see [B14] and IEEE Std 81-1983). If earth resistivity is high, the distance through the earth over which a given stroke would arc to a buried conductor or structure, and the distance that lightning currents would have to travel along a conductor before attenuating to harmless values are greater than if the earth resistivity is low. The result is that the exposure to lightning damage may be greater in some areas of the country with high earth resistivity and only moderate incidence of storms, than it is in other locations with low resistivity and greater incidence. Earth resistivity varies from a few ohm-meters to more than 10 000 ohm-meters.
- c) *Other considerations.* Engineering judgment, based on the best available experience and information, needs to be exercised to obtain optimum protection for the system under consideration. For example, a microwave tower in a low-lightning incidence area, but on a hilltop, may require special protection while facilities in a city of tall buildings located in an area of high-lightning incidence, but served by cable in duct runs, may require only minimal protection.

3.2 Low-energy static source

In some areas, open wire lines are subjected to excessive static potentials through wind-blown sand or snow. Such potentials are low in energy, the latter being proportional to the capacitance between line and earth and therefore, proportional to the length of the lines involved. The resulting interference effects are in the category of circuit noise, mainly due to intermittent breakdown of protective devices.

3.3 Power interference

The power network is an important environmental factor that can adversely affect low-voltage wire line facilities in a number of ways. Capacitive or inductive coupling, ground faults, or direct contacts can produce hazardous voltages. They can also cause damage to facilities as a result of overstressed or overheated elements. Permissible induced ac interference voltages should be considered when determining the minimum dc breakdown voltage of a gas tube surge arrester. See IEEE Std 367-1987 and IEEE Std 487-1992.

3.3.1 Characteristics of ac power systems and their effects on wire line facilities

Refer to [B19] and IEEE Std 487-1992. An electrical power network consists of many kinds of systems that generally fall into two types of circuit configurations (see also [B5]).

3.3.1.1 Types of circuits

- a) *Ungrounded circuits.* In an ungrounded circuit, single line-to-ground faults produce low-ground return currents, since the only return path to the source is the distributed capacitance-to-ground of the ungrounded line. These low currents are unlikely to induce disturbing currents and voltages into nearby wire line facilities. However, the low currents are unlikely to de-energize the power circuit and a second line-to-ground fault on another phase conductor of the same line may produce disturbing currents or voltages.
- b) *Grounded circuits.* Grounded circuits permit high currents during single line-to-ground faults because of the low-impedance return path. These currents may be high enough to induce disturbing voltages into nearby wire line facilities. However, rapid de-energization of faults is easier to achieve on these systems and the disturbance is likely to be of short duration.

3.3.1.2 Forms of coupling

There is usually more than one form of coupling between power systems and low-voltage wire line facilities. A combination of capacitive, resistive, and inductive coupling is usually present.

- a) *Capacitive coupling.* A steady state voltage can appear on a low-voltage wire line facility located in the electric field of a power system. The voltage level of an insulated wire line is determined by the relative position of the two facilities and by the voltage of the power line facility. The current that can flow to ground from a wire line is dependent upon the capacitance between the two facilities, and is therefore a function of the length of exposure. Electric influence through capacitive coupling is rarely a problem on properly terminated low-voltage wire lines.
- b) *Resistive coupling.* Resistive coupling can be divided into two categories:
 - 1) *Power contact.* Damage to wire line facilities due to accidental contacts between electric power supply lines and low-voltage wire line facilities (aerial or underground) is a possible hazard requiring protection measures. In extreme cases, the potential on the low-voltage wire line facility may approach that of the power conductor and currents may cause fusing of the low-voltage plant. Fault current duration may range from a fraction of a second to 5 s if the fault is interrupted automatically, or otherwise to indefinitely large time intervals [B19].
 - 2) *Ground potential rise.* When a fault to ground occurs on a transmission or distribution line terminating in a grounded-neutral transformer bank at a power station or substation, fault current will flow from ground to the system neutral by way of the station grounding system. Since the grounding system has a finite impedance to ground, it will experience a rise in potential with respect to remote earth, because of this ground-return fault current. Grounded facilities near the power station or substation can experience a portion of this voltage with respect to wire line facilities that are remotely terminated. These same effects can be experienced in the vicinity of the power fault.