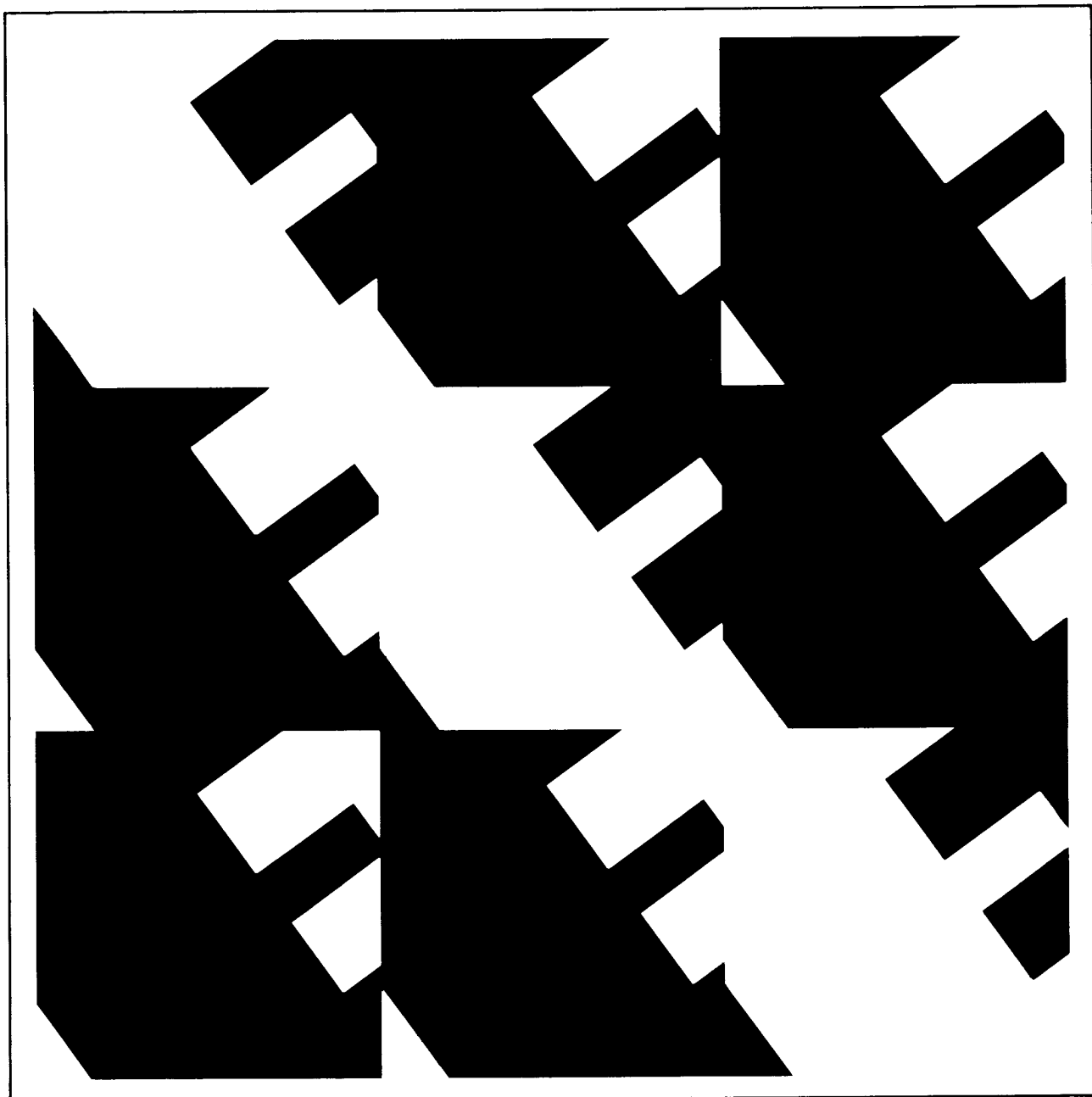


IEEE Guide for the Application of Gas Tube Arrester Low-Voltage Surge-Protective Devices



ANSI/IEEE C62.42-1987



Published by The Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street, New York, NY 10017, USA
November 9, 1987

SH11692

An American National Standard
**IEEE Guide for the Application of
Gas Tube Arrester
Low-Voltage Surge-Protective Devices**

Sponsor
**Surge-Protective Devices Committee of the
IEEE Power Engineering Society**

Approved September 19, 1985
IEEE Standards Board

Approved October 29, 1986
American National Standards Institute

© Copyright 1987 by

**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017, USA**

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Foreword

(This Foreword is not a part of ANSI/IEEE C62.42-1987, IEEE Guide for the Application of Gas Tube Arrester Low-Voltage Surge-Protective Devices.)

This application guide was written to complement ANSI/IEEE C62.31-1984. This application guide is intended to be helpful to the reader in evaluating the various types of gas tube arresters in terms of his own particular applications. It is a guide in relating various tests of gas tubes to applications.

Suggestions for improvements of this guide will be welcomed. They should be sent to

Secretary

IEEE Standards Board

Institute of Electrical and Electronics Engineers, Inc

345 East 47th Street

New York, NY 10017

At the time this standard was balloted, the accredited American National Standards Committee C62, Surge Arresters, had the following members:

J.L. Koepfinger, Chairman

<i>Organization Represented</i>	<i>Name of Representative</i>
Association of American Railroads	R.W. Mcknight
Bonneville Power Administration	E.J. Yasuda
Rural Electrification Administration	Geo J. Bagnall
Electric Light and Power	R.A. Jones
	W.J. Lannes
	W.R. Ossman
	D. Soffrin
	J.W. Wilson
Institute of Electrical and Electronics Engineers	G.L. Gaibrois
	Dales E. Hedman
	S.S. Kershaw
	J.L. Koepfinger
	E.J. Adolphson (Alt)
	J.J. Keane (Alt)
National Electrical Manufacturers Association	R.D. Ball
	M.G. Comber
	John A. Gauthier
	D.W. Lenk
	A. Sweetana
	M. Craddock (Alt)
Exchange Carriers Standards Association	L.H. Sessler
	M. Parente (Alt)
Underwriters Laboratories	P. Notarian
	R.W. Seelbach (Alt)
Canadian Standards Association	D.M. Smith
Members-at-Large	Ed Marrow
	F.D. Martzloff
	J. Osterhout

At the time this guide was approved, the membership of the Low-Voltage Surge-Protective Devices Application Guide Working Group of the IEEE Power Engineering Society consisted of:

S. Potocny, Chairman

L. Baker
J. Boy
J. Cawley
G. Clarke

E. Grabowski
W. Kapp
J. Koepfinger
E.H. Marrow, Jr
F. Martzloff

D. Turner, Secretary

J.J. Napiorkowski
R. Odenberg
M. Parente
R. Prieto

Other individuals who contributed were:

L. Bishop
E.J. Cohen
S. Furuto
C. Hansell

W. W. Hines
H. Johnson
D. Nelson
C.A. Rychetsky
P. Speranza

D. Sweeney
P. Winch
D. Worden
G. Zappe

At the time this guide was approved, the membership of the Surge-Protective Devices Committee of the IEEE Power Engineering Society was:

E.J. Yasuda, Chairman

J.A Hetrick, Secretary

R.D. Ball, Vice-Chairman

L.S. Baker
C.L. Ballentine
F.G. Berg
R.G. Black
E.W. Boehne
G.D. Breuer
J.J. Burke
E.J. Cohen
D.C. Dawson
R.W. Flugum
H.E. Foelker
G.L. Gaibrois
E.A. Goodman
C.D. Hanell

G.S. Haralampu
D.E. Hedman
A.R.E. Hileman
W.W. Hines
D.W. Jackson
I.B. Johnson
S.S. Kershaw
J.L. Koepfinger
J.A. Mambuca
E.H. Marrow, Jr
F.D. Martzloff
D.J. Melvold
J.J. Napiorkowski

R. Odenberg
R. Ossman
J.C. Osterhout
M. Parente
J.D.M. Phelps
S.A. Potocny
P. Richman
E.C. Sashaug
P. Speranza
K.B. Stump
A. Sweetana
E.R. Taylor, Jr
A.C. Westrom
S.G. Whisenant

The following persons were on the balloting committee that approved this document for submission to the IEEE Standards Board:

L.S. Baker
R.D. Ball
C.L. Ballentine
G.A. Baril
F.G. Berg
R.G. Black
E.W. Boehne
G.D. Breuer
J.J. Burke
E.J. Cohen
P.G. Cummings
D.C. Dawson
F.A. Denbrock
R.W. Flugum
H.E. Foelker
G.L. Gaibrois

E.A. Goodman
C.D. Hansell
G.S. Haralampu
D.E. Hedman
J.A. Hetrick
A.R. Hileman
W.W. Hines
D.W. Jackson
S.S. Kershaw
J.L. Koepfinger
M.J. Leib
J.A. Mambuca
E.H. Marrow
F.D. Martzloff

D.J. Melvold
J.J. Napiorkowski
R. Odenberg
W.R. Ossman
J.C. Osterhout
M. Parente
S.A. Potocny
P. Richman
E.C. Sakshaug
P.D. Speranza
K.B. Stump
A. Sweetana
E.R. Taylor
A.C. Westrom
S.G. Whisenant
E.J. Yasuda

When the IEEE Standards Board approved this standard on September 19, 1985, it had the following membership:

John E. May, Chairman

John P. Riganati, Vice Chairman

Sava I. Sherr, Secretary

James H. Beall
Fletcher J. Buckley
Rene Castenschild
Edward Chelotti
Edward J. Cohen
Paul G. Cummings
Donald C. Fleckenstein

Jay Forster
Daniel L. Goldberg
Kenneth D. Hendrix
Irvin N. Howell
Jack Kinn
Joseph L. Koepfinger*
Irving Kolodny
R. F. Lawrence

Lawrence V. McCall
Donald T. Michael*
Frank L. Rose
Clifford O. Swanson
J. Richard Weger
W. B. Wilkens
Charles J. Wylie

*Member emeritus

Contents

SECTION	PAGE
1. Scope and Introduction.....	7
2. References	7
3. Environment	9
3.1 Introduction.....	9
3.2 Lightning.....	9
3.3 Low-Energy Static Source.....	15
3.4 Power Interference.....	15
3.5 Switching Transients	16
3.6 Electromagnetic Pulse (EMP).....	16
4. Description and Theory of Operation	16
4.1 Description	16
4.2 Operation.....	17
5. Arrester Characteristics	19
5.1 DC Breakdown Voltage Test.....	19
5.2 Capacitance Test	20
5.3 Insulation Resistance Test	20
5.4 Impulse Breakdown Voltage Test	20
5.5 Maximum Single Impulse Discharge Current Test	20
5.6 Impulse Life Test.....	20
5.7 AC Discharge Current Test	21
5.8 Alternating Follow Current Test.....	21
5.9 DC Holdover Test	21
5.10 Transition Time Test	21
5.11 Impulse Transverse Voltage Test	21
5.12 AC Transverse Voltage Test	21
5.13 Volt-Ampere Characteristic Test	21
5.14 Crosstalk Test.....	21
6. Application of Gas Tube Surge Arresters.....	23
6.1 General	23
6.2 Operational Compatibility.....	24
6.3 Voltage Limiting	24
6.4 Failure Mode.....	25
6.5 Operations to Failure.....	25
6.6 Grounding and Bonding	26
6.7 Location of Arresters	26
6.8 Codes and Standards.....	28

FIGURES

Fig 1	Source of Lightning.....	9
Fig 2	Time History of Typical (Basic) Lightning Models (a) Flash without any Continuing Current Stages (b) Flash with Final Stage Continuing Current	10
Fig 3	Distribution of Lightning Stroke Crest Current to Aerial Structures.....	11
Fig 4	Mean Annual Number of Days with Thunderstorms (USA).....	12
Fig 5	Average Annual Number of Days with Thunderstorms (Based on the Period 1941-1960) (Canada).....	13
Fig 6	Average Annual Number of Days with Thunderstorms (World).....	13

FIGURES	PAGE
Fig 7 Mean Number of Thunderstorms (USA, Annual).....	14
Fig 8 Functional Components of a Two Electrode Gas Tube Arrester (Simplified).....	17
Fig 9 Paschen Curves for Air and Argon.....	18
Fig 10 Typical Volt-Ampere Characteristics.....	19
Fig 11 Simplified Illustration of Line-to-Line Voltage Unbalance (a) Line-to-Ground Voltage A-G, B-G (b) Line-to-Line Voltage (Metallic Voltage) A-B (c) Schematic of Arresters Connected A-G, B-G.....	22
Fig 12 Typical Arrangements of Gas Tube Surge Arresters.....	23
Fig 13 Protection of Circuit Composed of Two Signaling Leads and a Ground Terminal.....	24
Fig 14 Possible Overheating of Interior Wiring (a) When Protector is Located Remotely from Building Entrance (b) When Secondary Arrester is Used	27
APPENDIXES	
Appendix A Circuit Behavior of Gas Tube Arresters.....	29
Appendix B Bibliography	34
APPENDIX FIGURES	
Fig A1 Idealized Surge Protection Circuit.....	30
Fig A2 Simulated Transient Voltage Source.....	30
Fig A3 Rectilinear Volt-Ampere Characteristic of Gas Tube Surge Arresters.....	31
Fig A4 Surge Arrester Voltage and Current for Fig A3 (a).....	32
Fig A5 Surge Arrester Voltage and Current for Fig A3 (b).....	33

An American National Standard

IEEE Guide for the Application of Gas Tube Arrester Low-Voltage Surge-Protective Devices

1. Scope and Introduction

This application guide applies to surge-protective devices used in systems with voltages of 1000 V rms and 1200 V dc or less. 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 gas discharge surge arresters, this manual will also provide useful information for many other protection applications. For protection under the specialized conditions found at power stations, consult ANSI/IEEE Std 487-1980 [7]¹ and ANSI/IEEE C37.90.1-1974 (R 1979) [1]. For a guide on "Surge Voltages in Low-Voltage AC Power Circuits" consult ANSI/IEEE C62.41-1980 [4].

This guide is intended to complement the IEEE Standard Test Specifications for Gas Tube Surge-Protective Devices (ANSI/IEEE C62.31-1984) [3]. The definitions used in these two standards are the same. With this guide the reader will be able to evaluate the various types of gas tube arresters in terms of his own particular applications. The guide will consider the sources and nature of transients, the characteristics of gas tube surge arresters, and the concepts necessary to choose the appropriate product.

When used in conjunction with ANSI/IEEE C62.31-1984 [3], this guide will give the user guidance in selecting the right product and interpreting its specifications.

¹ The numbers in brackets correspond to those in the references, Section 2 of this standard.

2. References

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

- [1] ANSI/IEEE C37.90.1-1974 (R 1979), IEEE Guide for Surge Withstand Capability (SWC) Tests.²
- [2] ANSI/IEEE C62.1-1984, IEEE Standard for Surge Arresters for AC Power Circuits.
- [3] ANSI/IEEE C62.31-1984 IEEE Standard Test Specifications for Gas Tube Surge-Protective Devices.
- [4] ANSI/IEEE C62.41-1980, IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits.
- [5] ANSI/IEEE Std 81-1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
- [6] ANSI/IEEE Std 367-1979, IEEE Guide for Determining the Maximum Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault.
- [7] ANSI/IEEE Std 487-1980, IEEE Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations.

² ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.

- [8] ANSI/NFPA 70-1987, National Electrical Code.³
- [9] CIANOS, N., and PIERCE, E.T. A Ground Lightning Environment for Engineering Usage, Stanford Research Institute, Menlo Park, CA 94205, Aug 1972.
- [10] SUNDE, E.D., *Earth Conduction Effects in Transmission Systems*, New York: Dover Publications, Inc, 1968, pp 268–298.
- [11] BALDWIN, J.L. Climates of the United States, of US Dept of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climate Center, Asheville, North Carolina. Available from the US Government Printing Office, Washington, DC, Stock no 003-017-00211-0, map 31, p 81.
- [12] BODLE, D.W., GHAZI, A.J., SYED, M., and WOODSIDE, R.L. *Characterization of the Electrical Environment*, Toronto and Buffalo, University of Toronto Press, 1976, pp 14–15, 85–95, 124–130.
- [13] CHANGERY, M. National Thunderstorm Frequencies for the Contiguous United States, Figure 14, US Dept of Commerce, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, North Carolina. Available from the National Technical Information Service, Springfield, Va 22161. Publication no NUREG/CR-2252.
- [14] Electrical Protection Fundamentals, Rural Electrification and Administration Telecommunications Engineering and Construction Manual Section 801, Oct 1982, Dept of Agriculture, REA, Washington, DC 20250, p 8.
- [15] KLEWE, H.R.J., by DRUKKERN HOOIBERG, N.V., EPE-Netherlands, *Interference between Power Systems and Telecommunications Lines*, London: Edward Arnold Publishers, Ltd.
- [16] Lightning and 60 Hz Disturbances at the Bell Operating Company Network Interface, Technical Reference-EOP-000001 Issue 1, June 1984, Bell Communications Research.
- [17] EMP Engineering Practices Handbook, 1977, NATO File #1460-2.
- [18] LERNER, E.J. Electromagnetic Pulses-Potential Crippler, *IEEE Spectrum*, vol 18, no 5, May 1981, pp 41–46.
- [19] VANCE, E.F. Electromagnetic Pulse Handbook for Electric Power Systems. Stanford Research Institute, Menlo Park, CA 94025.
- [20] EMP Protection for Emergency Operating Centers, TR-61-A, Defense Civil Preparedness Agency, Dept of Defense, USA, 1972.
- [21] EMP Protective Systems, TR-61-B, Defense Civil Preparedness Agency, Dept of Defense, USA July 1972.
- [22] COBINE, J.D. Gaseous Conductors, New York: Dover Publications Inc, 1958, pp 143–168.
- [23] DRUYVESTEYN and PENNING, Rev MO1 PHYS-VR no 2, Kiempere 2 Tech Pltys Van Voorhs Pay Rev 25 583.
- [24] DEMIRCIOGLU, S., DINNIN, A.J. and MORIN, P.L. Improved Electrical Protection Scheme for Digital Carrier Systems, National Telecommunications Conference, 1978, IEEE CH 1354-0/78/0000-0210.
- [25] CARROLL, R.L. Loop Transient Measurements in Cleveland, South Carolina, Bell System Technical Journal, vol 59, no 9, Nov 1980 pp 1645–1680.
- [26] CARROLL, R.L. and MILLER, P.S. Loop Transients at the Customer Station, Bell System Technical Journal, vol 59, no 9 Nov 1980, pp 1608–1643.
- [27] MARTZLOFF, F.D. and HAHN, G.J. Surge Voltage in Residential and Industrial Power Circuits, *IEEE Transactions on Power Apparatus and Systems*, vol PAS-89, July/Aug 1970, pp 1049–1056.
- [28] ANDERSON R.B. and ERIKSSON, E.J. "Lightning Parameters for Engineering Appli-

³ NFPA publications are available from the National Fire Protection Association, Publications Sales Division, Batterymarch Park, Quincy, MA 02269. Copies are also available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

cation," *CIGRE*, *Electra*, no 69, Mar 1980, pp 65-102.

3. Environment

3.1 Introduction. 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.

3.2 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 are shown in Fig 1. This concentration of charge induces a similar, but opposite, concentration of charge in 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 Fig 1.

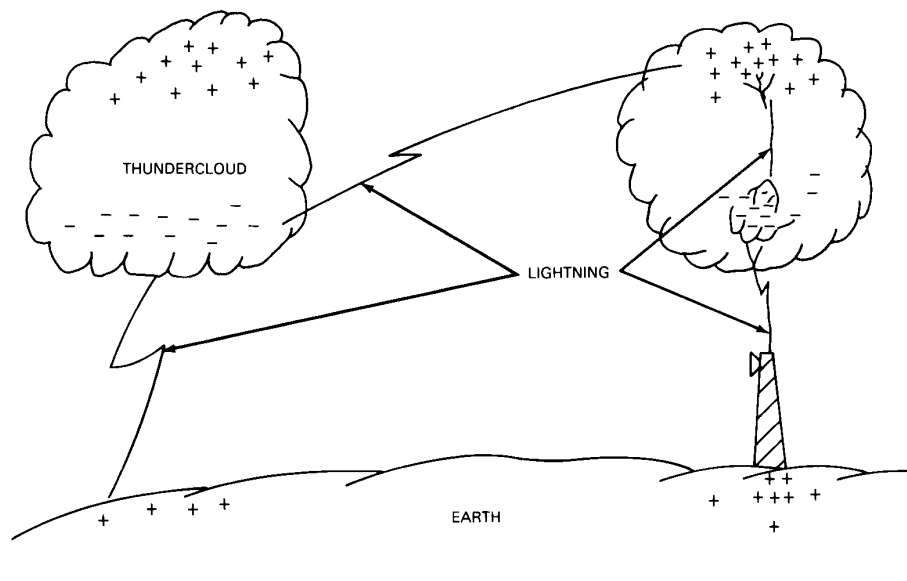
A complete lightning flash may last as long as $\frac{1}{4}$ s, and may consist of several strokes of high current discharge separated by periods of up to one tenth of a second when current flow is significantly reduced. Figure 2 illustrates a typical time history of a lightning flash [9] [28].

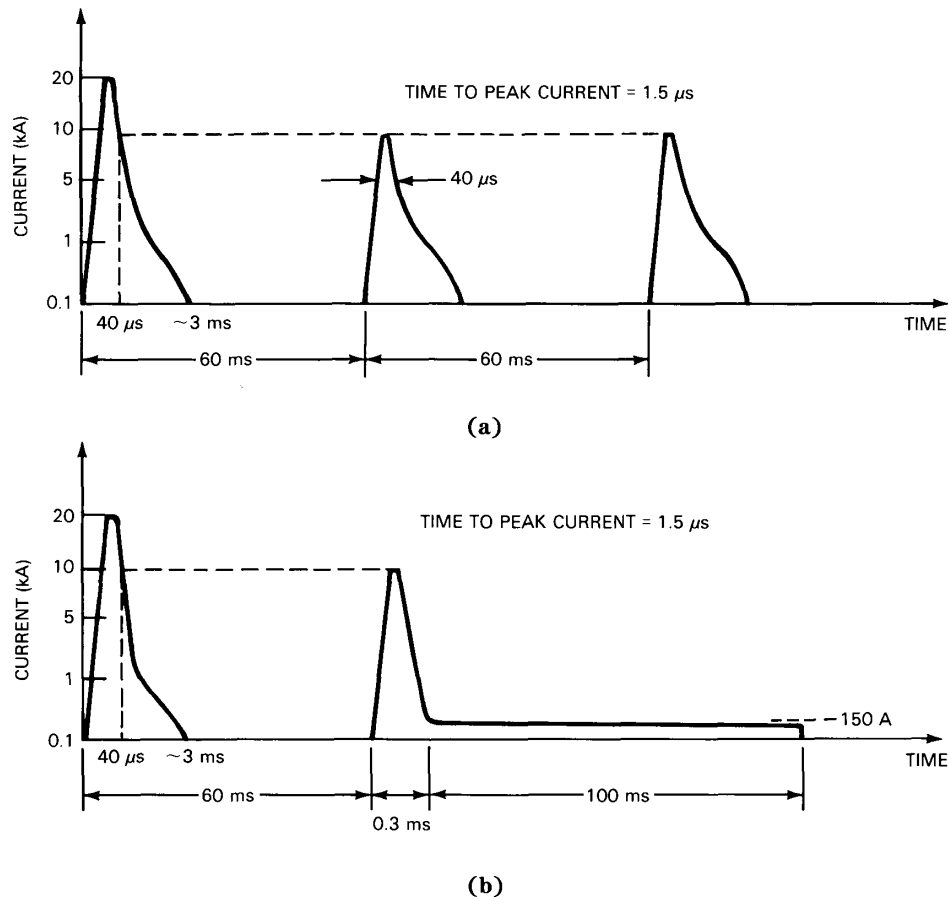
3.2.1 Direct Lightning Stroke. The crest current magnitude of an actual lightning stroke varies widely. Figure 3 illustrates the distribution of lightning stroke crest current to aerial structures [10]. Typical surges conducted or induced into wire line facilities would be considerably smaller because 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.

3.2.2 Indirect Lightning Stroke. In addition to direct strokes, facilities may be subjected to lightning caused potentials in the following manners:

- (1) Induction from nearby strokes to earth
- (2) Arcing to facilities from the earth, a tree, or a structure incurring a direct stroke

Fig 1
Source of Lightning





*See [9] and [28].

Fig 2
Time History of Typical (Basic) Lightning Models*
(a) Flash without any Continuing Current Stages
(b) Flash with Final Stage Continuing Current

(3) Lightning currents may also 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.

3.2.3 Factors Affecting the Exposure to Lightning Damage. When estimating the exposure to lightning damage, several variables must be considered. Briefly, they include:

(1) Storm Frequency or Incidence

(a) The traditional measure of storm frequency is the number of *thunderstorm days* experienced at a given location during the year. A