IEC TR 60479-4

Edition 3.0 2020-02

TECHNICAL REPORT

colour inside

Effects of current on human beings and livestock – Part 4: Effects of lightning strokes

Documents
Document Sharing Hub

IEC TR 60479-4:2020-02(en)

Full document details: IEC TR 60479-4-2020

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2020 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

IEC TR 60479-4

Edition 3.0 2020-02

TECHNICAL REPORT

colour inside

Effects of current on human beings and livestock – Part 4: Effects of lightning strokes

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.200; 29.020

ISBN 978-2-8322-7888-8

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms and definitions 7
3.1 Definitions of technical terms 7
3.2 Definitions of interactions 9
4 Basic physics of lightning 9
4.1 General 9
4.2 Lightning occurrence 11
4.3 Lightning flash characteristics 12
4.4 Primary and secondary injuries 12
4.5 Summary 13
5 Interaction of strokes with human beings and livestock 13
5.1 General 13
5.2 Strike mechanisms 14
5.2.1 Description of direct strike 14
5.2.2 Description of contact voltage 15
5.2.3 Description of side flash 16
5.2.4 Description of step voltage 16
5.2.4 Description of streamer current 17
5.3 Specific matters regarding body response 19
6 Effects of lightning strokes on the body of living beings 20
6.1 General comments on effects on the body 20
6.2 Comments on specific syndromes 23
6.2.1 Keraunoparalysis 23
6.2.2 Burns 23
6.2.3 Comparison between effects of electric shock derived from electrical systems and lightning 24
7 Present considerations of causation 26
7.1 Under investigation 26
7.2 Electrical effects 26
7.3 Thermal, field and radiation effects 26
7.4 Traumatic injury 26
7.5 Barotrauma 27
7.6 Release of hormones 27
8 Individual and crowd safety procedures 27
8.1 General – "No place outdoors is safe" 27
8.2 Individual actions 27
8.3 Basic principles 27
8.3.1 General 27
8.3.2 Individual lightning safety in the outdoors (NOAA recommendations) 28
8.3.3 Safe practice indoors 28
8.4 Safety procedures for crowds 29
Bibliography 30

AVA Documents
Document Sharing Hub
Full document details: IEC TR 60479-4-2020

Figure 1 – Categorization of lightning types [4] 10
Figure 2 – High resolution full climatology (HRFC) 12
Figure 3 – Direct strike 14
Figure 4 – Direct strike with no flashover and then with flashover 15
Figure 5 – Contact potential 15
Figure 6 – Side flash 16
Figure 7 – Earth potential versus distance from the stroke base – 10 kA stroke, with earth resistivity 100 Ωm 17
Figure 8 – Examples of step voltages, assuming a uniform earth of constant resistivity, and no surface flashover 18
Figure 9 – Upward streamer 19
Figure 10 – Current in establishment and in collapse of upward streamer 19

Table 1 – Lightning injury and physical symptoms [8], [9], [10], [11], [12], [13], [17] 22
Table 2 – Comparison of electrical and lightning injury [30], [34], [35], [40] 25

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 4: Effects of lightning strokes

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 60479-4, which is a Technical Report, has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) lightning occurence and climatory effects around the world are depicted;
b) direct strike description is extended;
c) step voltage effects are expanded;
d) upward streamer explanation is enhanced;

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

e) other direct or indirect related effects to lightning injuries to the human body are specified;

f) various safety procedures and related possibilities with respect to the personsal danger of lightning are presented.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
64/2369/DTR	64/2398/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60479 series, published under the general title *Effects of current on human beings and livestock*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

INTRODUCTION

IEC 60479-1 and IEC 60479-2 deal with the effect of electric shock derived from electrical systems on the bodies of human beings and livestock. This document describes the influence and effect of electricity in the form of lightning strikes. Lightning current can consist of several uni-polar and/or bi-polar impulses with different peak values and durations; IEC 60479-2:2019, Clause 6 does not cover these effects.

The interaction of a lightning stroke with the body is often different from that of electric shock derived from electrical systems. If the head is struck, the electrical path may include the brain stem, which includes the respiratory centre.

IEC 60479-2 includes information related to the effects of short duration impulses which extend to the magnitude and duration of lightning impulses.

It is accepted that more than 70 % of lightning accidents involving humans are not fatal [36], [47][1]. Corresponding reliable data for livestock is not known. There is a large variation in outcome due to different environments, different activities of people and knowledge of first aid and quality of medical care [40],[47].

It has been necessary, therefore, to create a separate document concerning the special effects of lightning strokes. The physical behaviour of lightning is shown as a basis. The interaction with a living body is then described, followed by the ongoing life consequences.

[1] Numbers in square brackets refer to the bibliography.

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 4: Effects of lightning strokes

1 Scope

This part of IEC 60479 summarizes the basic parameters for lightning and its variability insofar as they apply to human beings and livestock.

The possible direct and indirect interactions of strikes with bodies of living beings are indicated.

The resulting effects caused by lightning currents for the organism are described.

This document shows the differences of effects on human beings and livestock due to lightning strokes versus those effects of electric shocks derived from electrical systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60479-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Definitions of technical terms

3.1.1
lightning flash
<to earth> electrical discharge of atmospheric origin between cloud and earth consisting of one or more lightning strokes

3.1.2
lightning stroke
lightning impulse
single electrical discharge in a lightning flash to earth

3.1.3
lightning channel
conducting path of the lightning current

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

3.1.4
stepped leader
faintly luminous channel of generally less than 10 C of charge with associated branches that develops in virgin air and progresses towards the earth in discrete steps

3.1.5
return stroke
bright highly visible channel carrying the impulse current of the stroke, which is initiated when the stepped leader and upward connecting streamers meet to form the channel

3.1.6
upward flash
lightning flash initiated by an upward leader from earth to cloud

3.1.7
continuing current
current with a magnitude of tens to hundreds of amperes and a duration up to hundreds of milliseconds often following a return stroke

Note 1 to entry Continuing currents with duration in excess of 40 ms are traditionally termed "long continuing currents".

3.1.8
lightning current
current flowing at the point of strike

3.1.9
current peak value
maximum value of the lightning current

3.1.10
upward streamer
pre-discharge phenomena induced by the stepped leader, one of which will connect with the stepped leader opening a lightning channel which becomes a lightning stroke

3.1.11
average steepness of impulse current
average rate of change of lightning current within a time interval bounded by the 10 % and 90 % values of the peak impulse current front

3.1.12
stroke duration
time in microseconds between the time the return stroke exceeds 2 kA and the time to half peak value on the tail of the current pulse

3.1.13
flash duration
time for which the lightning current flows at the point(s) of attachment

3.1.14
point(s) of attachment
point(s) at which the successful upward streamer was launched

EXAMPLE Object, human or otherwise.

3.1.15
remote earth
ideal earth of zero resistance and zero potential

Documents
Document Sharing Hub

Full document details: IEC TR 60479-4-2020

3.1.16
physical earth
earth as contact by objects

Note 1 to entry The difference between remote earth and physical earth allows the modelling of an earth resistance between the two, creating ground potential.

3.1.17
lightning ground flash density
measurement of the number of lightning strikes to ground, over a period of one year, per km^2

3.2 Definitions of interactions

3.2.1
direct strike
interaction whereby the lightning attaches directly to an object (including a living object)

3.2.2
contact voltage
potential difference between contacted points on an object, on which currents generated by a lightning event are present, or between an accessible point and an independent object (including earth) which could result in current flow through a living being

Note 1 to entry In some texts this has been referred to as "contact potential" or "touch voltage".

3.2.3
side flash
electric arc between two objects (including living objects), at least one of which is subject to partial lightning current

3.2.4
step voltage
step potential
potential difference between two points on the earth's surface due to a lightning stroke current being conducted through the earth

3.2.5
flashover
electric arc over the surface of an object carrying a significant proportion of the stroke current

3.2.6
streamer current
current, passing through an object, to establish an upward streamer, but which ultimately will not become a point of attachment

4 Basic physics of lightning

4.1 General

The explanation of the basic physical mechanisms for the onset and the dynamics of lightning is very complicated. Within a cloud, three layers are recognized, each with identifiable charges (see Figure 1). They are generated by microscopic charge transfer between soft hail particles (also called graupel) and ice crystals. The basal layer is normally negatively charged, with the layers successively positively and negatively charged in ascending order.

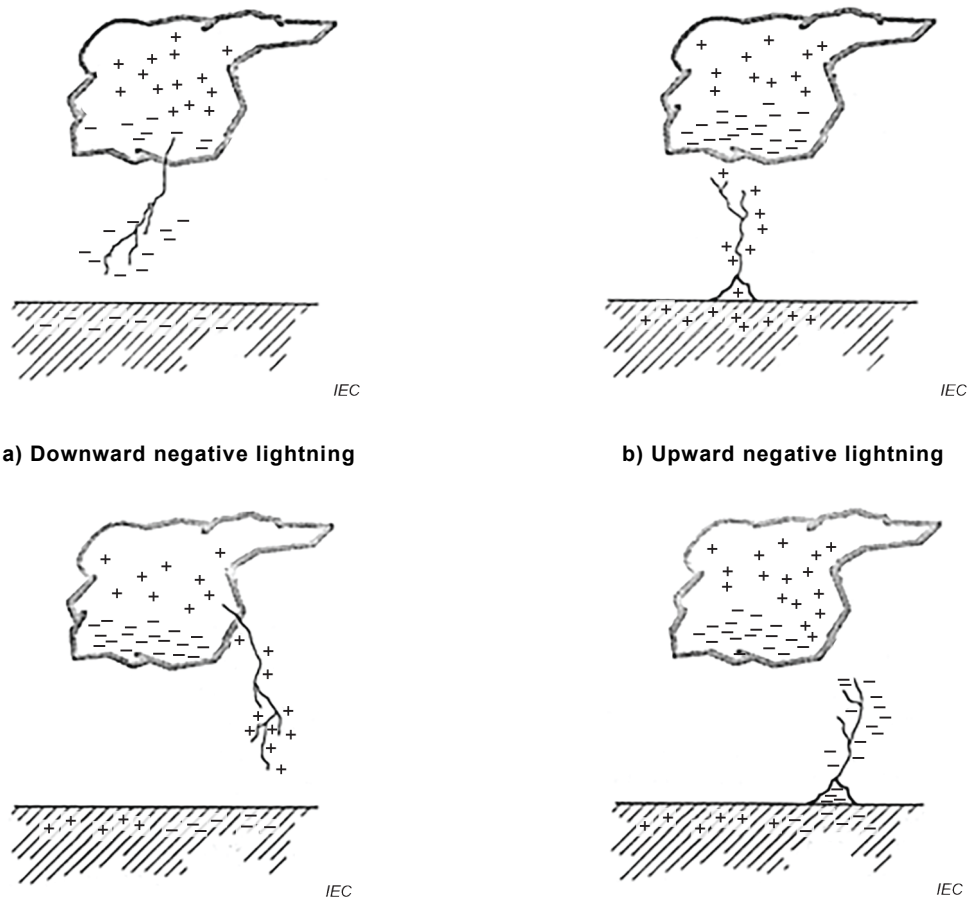
Lightning is a transient, high-current discharge whose path length is measured in kilometres. A lightning flash is a current phenomenon, and not a voltage phenomenon. More correctly, it is a "charge dumping" phenomenon, which occurs when the increasing electric field between two statically charged points exceeds a threshold.

AVA Documents
Document Sharing Hub
Full document details: IEC TR 60479-4-2020

Well over half of all flashes occur wholly within the cloud and are called intra-cloud (IC) discharges. Cloud-to-ground (CG) lightning has been studied more extensively than other forms of lightning because of its practical importance (for instance, as a cause for injuries and death, disturbances in power and communication systems, damage to structures and installed equipment, and the ignition of forest fires). Cloud-to-cloud and cloud-to-air discharges have begun to be quantified more easily as a result of space and high altitude experimentation. Upward flashes from a cloud to the ionosphere have also been identified. All discharges other than those between cloud and ground (CG), are often combined under the general term cloud discharges.

Four different types of discharges between cloud and earth have been identified (Figure 1). Negative CG flashes probably account for about 90 % of the CG discharges world-wide, and less than 10 % of lightning discharges are initiated by a downward-moving positive leader [57]. Ground-to-cloud discharges are initiated by leaders that move upward from the earth. These upward-initiated flashes are relatively rare and usually occur from mountain peaks and tall man-made structures [56], [59].

Other important physical parameters of the lightning environment have been characterized. Examples are the peak current per return stroke, the charge transferred in a return stroke, the average steepness of impulse current rise, as well as the stroke duration and total flash duration where there is more than one stroke in a flash.



a) Downward negative lightning

b) Upward negative lightning

c) Downward positive lightning

d) Upward positive lightning

Figure 1 – Categorization of lightning types [4]

Thunder accompanies lightning and is generated by superheated air at the channel, which causes air pressure waves.

Documents
Document Sharing Hub
Full document details: IEC TR 60479-4-2020