IEC/TR 60479-5

Edition 1.0 2007-11

TECHNICAL REPORT

RAPPORT TECHNIQUE

Effects of current on human beings and livestock – Part 5: Touch voltage threshold values for physiological effects

Effets du courant sur l'homme et les animaux domestiques – Partie 5: Valeurs des seuils de tension de contact pour les effets physiologiques

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: 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 corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC/TR 60479-5

Edition 1.0 2007-11

TECHNICAL REPORT

RAPPORT TECHNIQUE

Effects of current on human beings and livestock –
Part 5: Touch voltage threshold values for physiological effects

Effets du courant sur l'homme et les animaux domestiques –
Partie 5: Valeurs des seuils de tension de contact pour les effets physiologiques

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX XA

ICS 13.200; 29.020

ISBN 2-8318-9346-1

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 5: Touch voltage threshold values for physiological effects

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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
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 60479-5, which is a technical report, has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
64/1585/DTS	64/1611/RVC

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

A list of all the parts in the IEC 60479 series, 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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

The contents of the corrigendum of July 2013 have been included in this copy.

INTRODUCTION

This technical report provides a methodology for estimating voltage thresholds which are intended to give guidance to IEC technical committees on the selection and application of voltage limits with regard to protection against electric shock. Technical committees may use this methodology to recalculate proposed voltage thresholds or to determine new voltage threshold values based on different pathways, other current threshold values, different alternating current frequencies, other skin capacitances values, etc.

To estimate the type and severity of physiological effects that might be caused by electricity, the magnitude and pathway of current through a person's body needs to be determined. However, from an equipment design point of view, it is advantageous to be able to predict whether unwanted physiological effects are possible or probable, given only information about voltage levels on accessible conductive surfaces. If the maximum available voltage is sufficiently low under the expected circumstances to be unable to cause enough touch current to cause unwanted physiological effects, then the safeguards normally required to avoid the occurrence of these physiological effects may be reduced or eliminated. Voltages below critical levels that are unlikely to be hazardous in this respect have normally been called extra-low voltage (ELV). Based on this information technical committees may wish to review their defined values of extra-low voltage.

The objective of this technical report being to derive touch voltage threshold values corresponding to zones of physiological effects (as presented in Figures 20 and 22 of IEC/TS 60479-1), the introduction of such techniques gives designers the ability to provide a larger variety of circuits that give the expected level of user protection under a broader set of circumstances than previously considered.

The physiological effects corresponding to the threshold voltage values should be the same as those for touch current that appear in IEC/TS 60479-1. Physiological effects considered in this technical report are startle reaction of current, effects involving muscular contractions such as inability to let-go and ventricular fibrillation. Current thresholds are based on curves a, b and c_1 in IEC/TS 60479-1 which remains the prime standard. The touch voltage thresholds are related to the touch current thresholds by the body impedance according to Ohm's law. However, in this case, the application of Ohm's law is not straightforward. Body impedance is a function of a number of variables including the voltage across the body, the current pathway, the area of contact between the skin and the conductive surface, the level of moisture in the contact area, and the duration of voltage across (or current through) the body. When voltage is applied to the body and current begins to flow, the resistive component of the skin impedance changes to a lower value within a few tens of milliseconds.

This technical report discusses 50/60Hz sinusoidal alternating voltage and pure direct voltage having no significant alternating component. Higher frequency alternating voltage is not included in this type of analysis as this would require a more complex body impedance model and would require the use of frequency factors for the current thresholds for the unwanted physiological effects. As this technical report does not cover frequencies above 50/60Hz, technical committees are requested to inform IEC/TC 64 about experience gained on this subject. Suggestions for modifications and additions to the report should be submitted to IEC/TC 64.

This work does not relieve the responsibility of IEC technical committees to consider the usual touch current commonly measured in product evaluations.

EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 5: Touch voltage threshold values for physiological effects

1 Scope

IEC/TR 60479-5, which is a technical report, provides touch voltage-duration combination thresholds based on analysis of information concerning body impedances and current thresholds of physiological effects, as given in IEC/TS 60479-1. Such threshold combinations relate to specific environmental and contact conditions that determine body impedance for particular current pathways.

This technical report considers only

(i) 50/60 Hz sinusoidal alternating voltage having no other frequency components and no significant direct voltage component, and

(ii) direct voltage with no significant alternating component.

This technical report provides thresholds as a result of calculations based on values from IEC/TS 60479-1, with uncertainties. Therefore thresholds proposed in this report also correspond to values with uncertainties.

This technical report does not consider immersion of body parts and medical application.

Touch voltage-duration combination thresholds are for use by technical committees as guidance for the determination of limits for touch voltage and touch voltage durations in various environmental situations.

Determination of limits needs to be based on risk assessment. Factors that are part of risk assessment include voltage threshold values (taking into account contact area, skin moisture condition, body current pathway) provided by this technical report, as well as other factors not covered such as:

– reduction of the likelihood of contact (by obstacles, barriers, warnings, placing out of reach, training, etc.); or

– reduction of touch voltage compared to the fault voltage (such as by equipotential bonding); or

– additional resistance in series with the human body (such as gloves, shoes, carpet, etc.).

2 Normative references

The following referenced documents are indispensable for the application 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 60050-195, *International Electrotechnical Vocabulary – Part 195: Earthing and protection against electric shock*

IEC/TS 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60990, *Methods of measurement of touch current and protective conductor current*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
touch current
electric current passing through a human body or through an animal body when it touches one or more accessible parts of an installation or of equipment

[IEV-195-05-21]

3.2
touch voltage
voltage between conductive parts when touched simultaneously by a person or an animal

[IEV 195-05-11]

NOTE The touch voltage may be different from the open-circuit voltage between those conductive parts.

3.3
threshold
level of stimulus just strong enough to produce a response

NOTE A threshold is not the same as a limit which includes risk assessment, safety margins, etc.

3.3.1
voltage threshold for startle reaction
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing

3.3.2
voltage threshold for strong muscular reaction
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let-go from an electrode (a.c.), but not including startle reaction

3.3.3
voltage threshold for ventricular fibrillation
minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause ventricular fibrillation

3.4
long duration
duration corresponding to the vertical asymptote of the “b” and “c_1” curves of IEC/TS 60479-1 (e.g. 10 s)

3.5
short duration
any duration less than long duration

4 Conditions and threshold values

4.1 General

Physiological effects of electricity through the human body are caused by current passing through the body. In order to estimate the type and severity of physiological effects that might be caused by electricity, the magnitude and pathway of current through a person’s body must be determined. However, from an equipment design point of view, it is advantageous to be

able to predict whether unwanted physiological effects are possible or probable, armed only with information concerning voltage levels on accessible conductive surfaces. If the maximum available voltage is sufficiently low to be unable to cause enough touch current to cause unwanted physiological effects, then the safeguards normally required to avoid the occurrence of these physiological effects may be reduced or eliminated.

NOTE This technical report only estimates the touch voltage and not the effect of the source impedance. This results in the worst case situation. In this report the prospective touch voltage is considered as equal to the effective touch voltage, as defined in IEC 60050-195.

4.2 Physiological effects of touch current

Thresholds for the physiological effects associated with electric current through a human body are reported in IEC/TS 60479-1.

This technical report addresses startle reaction from current, strong involuntary muscular reaction such as inability to let go an electrode in a.c. and ventricular fibrillation. Other effects, such as perception of current, might be important for some applications but are not addressed. It should be noted that current thresholds corresponding to strong muscular reaction and to ventricular fibrillation depend on touch current magnitude, while current threshold corresponding to startle reaction depends more on current density. Nevertheless, IEC/TS 60479-1 addresses a current startle reaction threshold in mA which contributes to considerations in this report that the current startle reaction threshold only depends on the current magnitude.

For the purposes of this report, the threshold of physiological effects of greatest interest are curves a, b and c_1. Curve a is the level beyond which startle reaction of current becomes possible. Curve b is the lower boundary of current levels beyond which more serious and undesirable physiological effects begin to occur. Curve c_1 is the level beyond which the likelihood of ventricular fibrillation begins to become a concern.

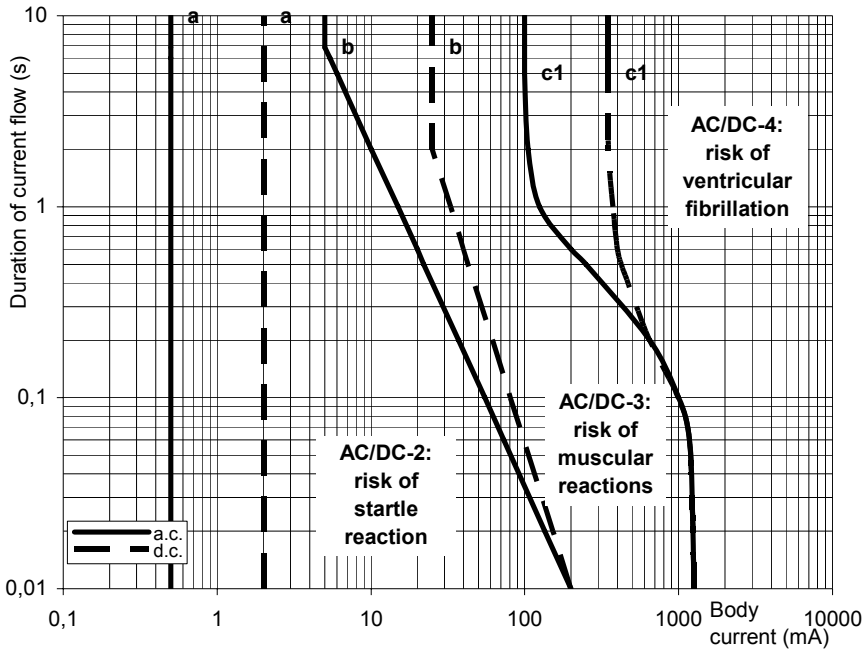
Figures 1 to 3 below show the thresholds for touch current on which the voltage thresholds are based. These figures are based only on information from IEC/TS 60479-1. Figures 1, 2 and 3 respectively show the threshold current values for hand-to-hand; both-hands-to-feet or hand-to-seat (longitudinal) current.

Figure 2 directly reproduces Figures 20 and 22 from IEC/TS 60479-1. Other figures are derived from IEC/TS 60479-1 using the appropriate factors of Table 5 to adapt the threshold current to the hand-to-hand pathway.

The values in Table 1 refer to long duration current passing through the torso. For a.c., the main concern is the inability to let go with reference to current passing through each arm. Therefore, the a.c. current value in Table 1 and in Figure 2 has been doubled for the ‘both-hands-to-feet’ pathway for longer current duration (only above the intersection with the d.c. line). For d.c. and for shorter a.c. duration, the value is not doubled because continuous d.c. and short duration a.c. current do not cause inability to let go (which results in coincidence of both lines) (see note 1 of Table 1).

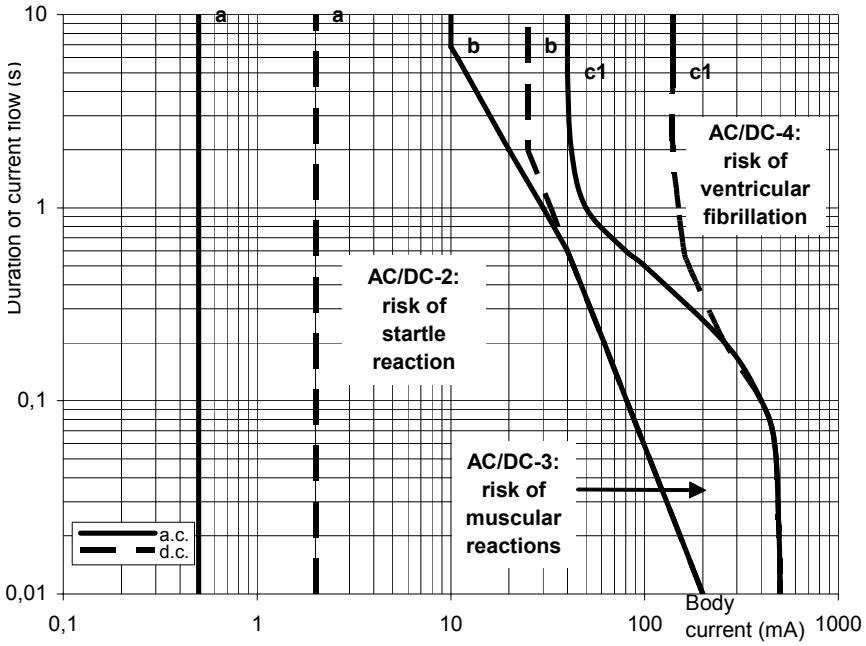
For direct current, a lower magnitude of current is needed to produce ventricular fibrillation when the current flows upward from feet to hands (feet positive with respect to the upper body) through the torso rather than downward. This technical report assumes upward current in all cases involving direct current. The ventricular fibrillation current threshold for a d.c. downwards current is about twice that of the current threshold corresponding to the upward current.

Short duration currents (less than one heart cycle) are always assumed to coincide with the vulnerable portion of the heart beat cycle.



NOTE The "c_1" curve is modified according to Table 12 of IEC/TS 60479-1; see also last paragraph of 4.1 of that standard.

Figure 1 – Physiological thresholds for a.c. (50/60 Hz) and d.c. flowing hand-to-hand (transversely) through the human body



NOTE Modifications to Figures 20 and 22 of IEC/TS 60479-1 include:

– doubling of threshold corresponding to curve "b" for a.c., explained in note 1 of Table 1;

– below the intersection of the double a.c. curve and the d.c. curve, both curves were made coincident with the more conservative d.c. curve; see explanation in the 4th paragraph of 4.1 of IEC/TS 60479-1.

Figure 2 – Physiological thresholds for a.c. (50/60 Hz) and d.c. flowing from both hands to both feet (longitudinally) through the human body

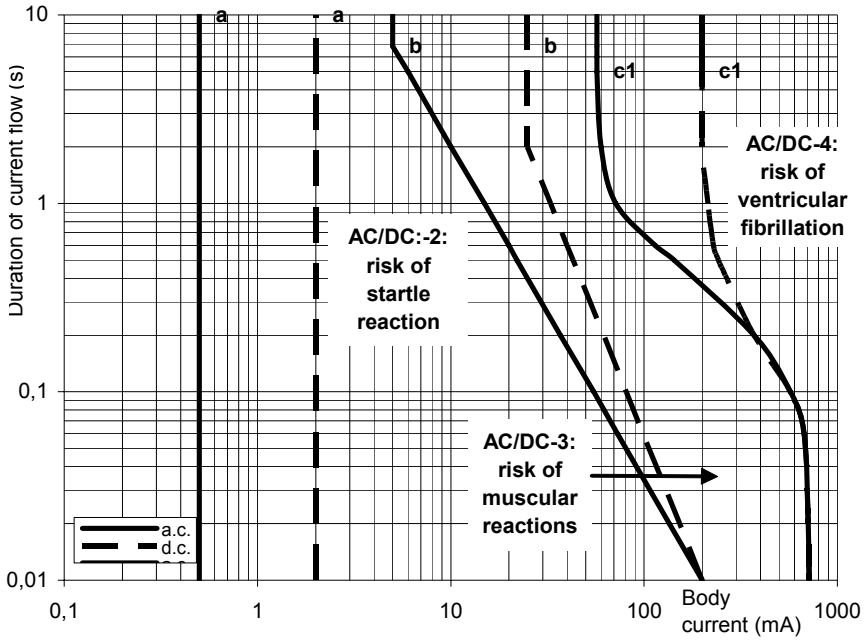


Figure 3 – Physiological thresholds for a.c. (50/60 Hz) and d.c. flowing from hand-to seat (longitudinal) through the human body

For the determination of voltage threshold, the following long duration current thresholds have been considered. They have been determined from Figures 20 and 22 and Table 12 of IEC/TS 60479-1 which correspond to the upper end of the b or c_1 curves in Figures 1 to 3 above.