IEC TS 60479-2

Edition 4.0 2017-10

TECHNICAL SPECIFICATION

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BASIC SAFETY PUBLICATION

Effects of current on human beings and livestock – Part 2: Special aspects

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EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 2: Special aspects

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60479-2, which is a Technical Specification, has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

This fourth edition cancels and replaces the third edition, published in 2007. This edition constitutes a technical revision.

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

- Changes reflecting the change in applicability of frequency from 1 kHz to 150 kHz have been added.
- The examination of random complex irregular waveforms has been added.
- The handling of successive DC pulses has been clarified.

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

Draft TS	Report on voting
64/2143/DTS	64/2166/RVDTS

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

This Technical Specification has the status of a basic safety publication in accordance with IEC Guide 104.

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 publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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.

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EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 2: Special aspects

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1 Scope

This part of IEC 60479 describes the effects on the human body when a sinusoidal alternating current in the frequency range above 100 Hz passes through it.

The effects of current passing through the human body for:

– alternating sinusoidal current with DC components;
– alternating sinusoidal current with phase control;
– alternating sinusoidal current with multicycle control

are given but are only deemed applicable for alternating current frequencies from 15 Hz up to 100 Hz.

Means of extending the frequency of applicability of pure sinusoids to a frequency of 150 kHz are given, supplementing the data in IEC TS 60479-1.

Means of examining random complex irregular waveforms are given.

This document describes the effects of current passing through the human body in the form of single and multiple successive unidirectional rectangular impulses, sinusoidal impulses and impulses resulting from capacitor discharges.

The values specified are deemed to be applicable for impulse durations from 0,1 ms up to and including 10 ms.

This document only considers conducted current resulting from the direct application of a source of current to the body, as does IEC TS 60479-1 and IEC TS 60479-3. It does not consider current induced within the body caused by its exposure to an external electromagnetic field.

This basic safety publication is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51. It is not intended for use by manufacturers or certification bodies.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication will not apply unless specifically referred to or included in the relevant publications.

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.

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IEC TS 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*
IEC TS 60479-1:2005/AMD1:2016

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

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

IEC Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 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
frequency factor
F_f
ratio of the threshold current for the relevant physiological effects at the frequency f to the threshold current at 50/60 Hz.

Note 1 to entry The frequency factor differs for perception, let-go and ventricular fibrillation.

3.2
phase control
process of varying the instant within the cycle at which current conduction in an electronic valve device or a valve arm begins

[SOURCE: IEC 60050-551:1998, 551-16-23]

3.3
phase control angle
current delay angle
time expressed in angular measure by which the starting instant of current conduction is delayed by phase control

[SOURCE: IEC 60050-551:1998, 551-16-32, modified — the term "phase control angle" has been added.]

3.4
multicycle control
process of varying the ratio of the number of cycles which include current conduction to the number of cycles in which no current conduction occurs

[SOURCE: IEC 60050-551:1998, 551-16-31]

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3.5
multicycle control factor
p
ratio between the number of conducting cycles and the sum of conducting and non-conducting cycles in the case of multicycle control

SEE Figure 13.

[SOURCE: IEC 60050-551:1998, 551-16-37, modified — the symbol and reference to Figure 13 have been added.]

3.6
specific fibrillating energy
F_e
minimum $I^2 \cdot t$ value of a unidirectional impulse of short duration which under given conditions (current-path, heart-phase) causes ventricular fibrillation with a certain probability

Note 1 to entry: F_e is determined by the form of the impulse as the integral

$$\int_0^{t_i} i^2 dt$$

where t_i is defined in Figure 20 and Figure 21. F_e multiplied by the body resistance gives the energy dissipated in the human body during the impulse.

Note 2 to entry: F_e is expressed in Ws/Ω or A^2s.

3.7
specific fibrillating charge
F_q
minimum $I \cdot t$ value of unidirectional impulse of short duration which under given conditions (current-path, heart-phase) causes ventricular fibrillation with a certain probability

Note 1 to entry: F_q is determined by the form of the impulse as the integral

$$\int_0^{t_i} i dt$$

where t_i is defined in Figure 20 and Figure 21.

Note 2 to entry: F_q is expressed in C or As.

3.8
time constant
time required for the amplitude of an exponentially decaying quantity to decrease to

$$\frac{1}{e} = 0{,}3679$$

times an initial amplitude

[SOURCE: IEC 60050-801:1994, 801-21-45, modified — the definition has been revised.]

3.9
shock-duration of a capacitor discharge
t_i
time interval from the beginning of the discharge to the time when the discharge current has fallen to 5 % of its peak value

Note 1 to entry: When the time constant of the capacitor discharge is given by T the shock-duration of the capacitor discharge is equal to $3T$. During the shock-duration of the capacitor discharge practically all the energy of the impulse is dissipated.

Note 2 to entry: See Figure 20 and Figure 21.

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3.10
shock-duration for complex asymptotic waveform
t_i
shortest duration of that part of the impulse that contains 95 % of the energy over the total impulse

3.11
threshold of perception
minimum value for the charge of electricity which under given conditions causes any sensation to the person through whom it is flowing

3.12
threshold of pain
minimum value for the charge ($I \cdot t$) or specific energy ($I^2 \cdot t$) that can be applied as an impulse to a person holding a large electrode in the hand without causing pain

3.13
pain
unpleasant experience such that it is not readily accepted a second time by the subject submitted to it

EXAMPLE: Electric shock above the threshold of pain described in 11.3, the sting of a bee or burn of a cigarette.

4 Effects of alternating currents with frequencies above 100 Hz

NOTE Values for 50/60 Hz are given in IEC TS 60479-1. For frequencies up to 100 Hz the provisions of IEC TS 60479-1 are used.

4.1 General

Electric energy in the form of alternating current at frequencies higher than 50/60 Hz is increasingly used in modern electrical equipment, for example aircraft (400 Hz), power tools and electric welding (mostly up to 450 Hz), electrotherapy (using mostly 4 000 Hz to 5 000 Hz) and switching mode power supplies (20 kHz to 1 MHz).

Little experimental data is available for Clause 4, therefore the information given herein should be considered as provisional only but may be used for the evaluation of risks in the frequency ranges concerned (see Bibliography).

Recent experiments in governmental funded projects are ongoing to exploit and investigate the effects of higher frequencies using the latest technologies and methods to justify existing extrapolation of the frequency factor for ventricular fibrillation (VF) threshold.

Attention is also drawn to the fact that the impedance of human skin decreases approximately inversely proportional to the frequency for touch voltages in the order of some tens of volts, so that the skin impedance at 500 Hz is only about one-tenth of the skin impedance at 50 Hz and may be neglected in many cases. This impedance of the human body at such frequencies is therefore reduced to its internal impedance Z_i (see IEC TS 60479-1).

NOTE Use of peak measurements: at current levels that produce physiological responses of perception, startle reaction and inability of let-go, the physiological response from non sinusoidal and mixed frequency periodic current is best indicated by the peak value of an output signal from measuring circuits containing a frequency-weighting network such as those described in IEC 60990.

These frequency weighting networks attenuate the signal according to the frequency factors given in IEC TS 60479-1:2005 and IEC TS 60479-1:2005/AMD1:2016, Clause 4 so that the output signal corresponds to a constant level of physiological response. Attenuation is provided for narrow impulses of current that would produce less physiological response because of the short duration of their peak value. The network output allows a fixed value to be read independent of waveshape or mix of frequencies to be provided for ease of determination of the leakage current and evaluation of the level of hazard present.

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Comparable physiological effects are produced by non sinusoidal and sinusoidal current producing the same peak value by this measurement method.

Representative network can be found in IEC 60990 and in bibliographic reference [16][1].

4.2 Effects of alternating current in the frequency range above 100 Hz up to and including 1 000 Hz

4.2.1 Threshold of perception

For the threshold of perception the frequency factor is given in Figure 1.

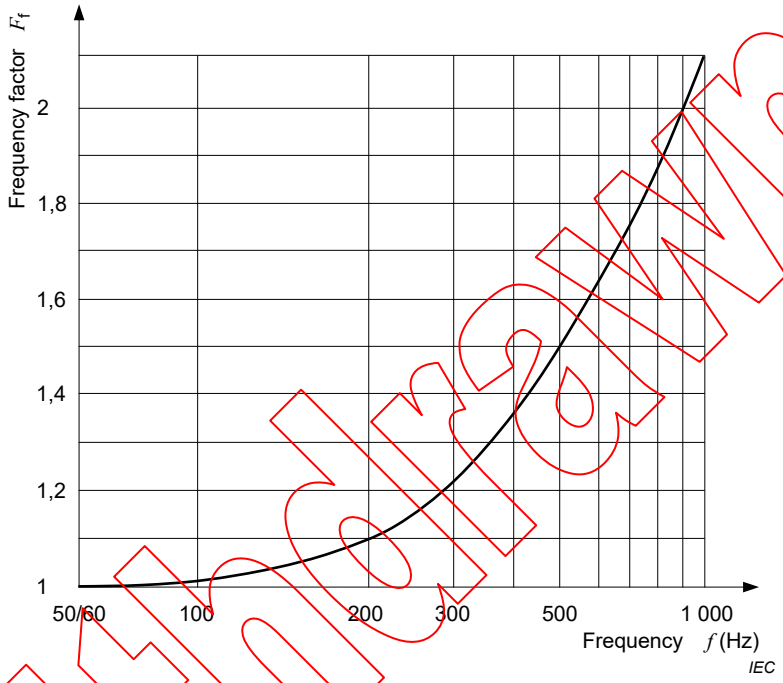

Figure 1 – Variation of the threshold of perception within the frequency range 50/60 Hz to 1 000 Hz

4.2.2 Threshold of let-go

For the threshold of let-go the frequency factor is given in Figure 2.

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

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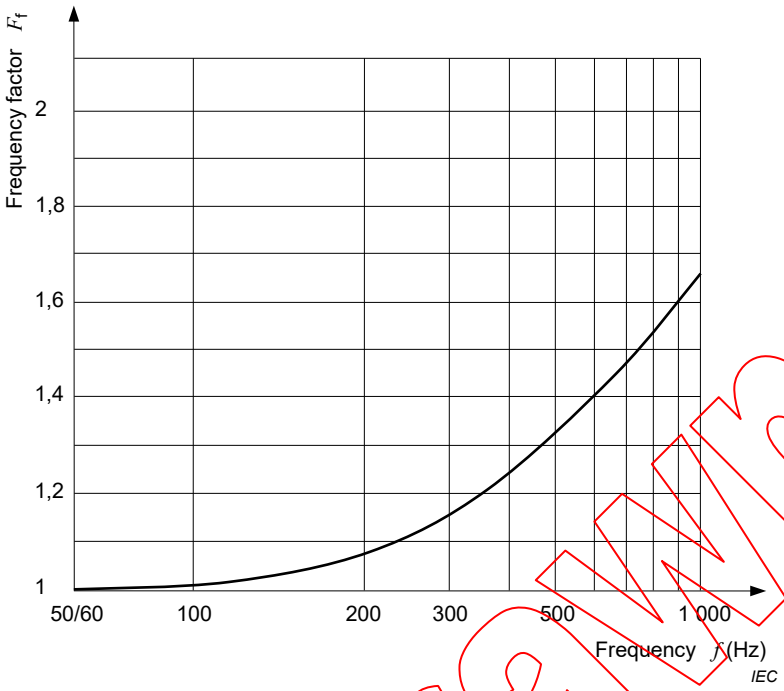

Figure 2 – Variation of the threshold of let-go within the frequency range 50/60 Hz to 1 000 Hz

4.2.3 Threshold of ventricular fibrillation

For shock durations longer than the cardiac cycle, the frequency factor for the threshold of fibrillation for longitudinal current paths through the trunk of the body is given in Figure 3.

For shock durations shorter than the cardiac cycle no experimental data is available on the effects of frequency.

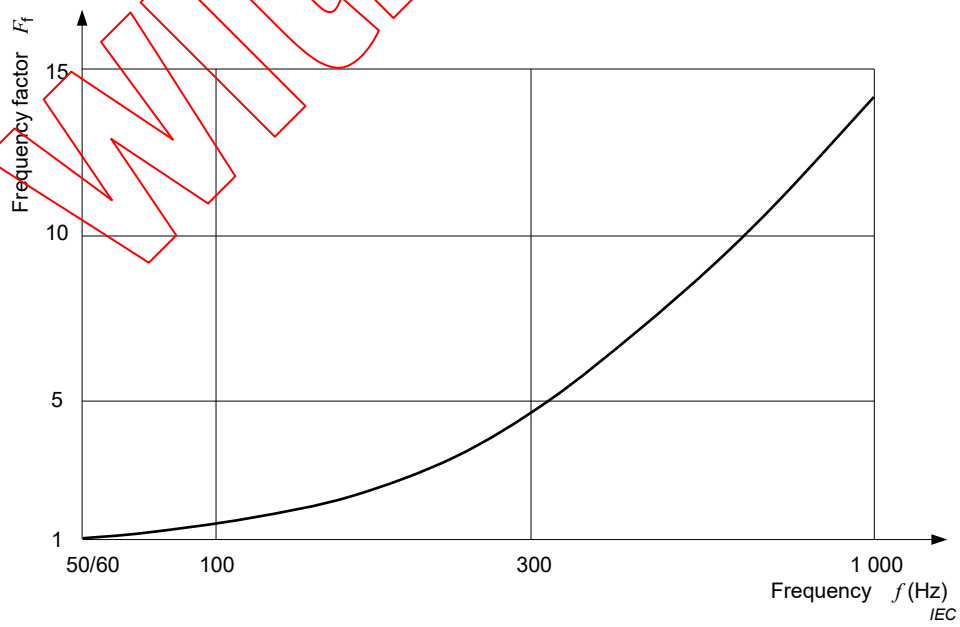

Figure 3 – Variation of the threshold of ventricular fibrillation within the frequency range 50/60 Hz to 1 000 Hz, shock durations longer than one heart period and longitudinal current paths through the trunk of the body

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4.3 Effects of alternating current in the frequency range above 1 000 Hz up to and including 10 000 Hz

4.3.1 Threshold of perception

For the threshold of perception the frequency factor is given in Figure 4.

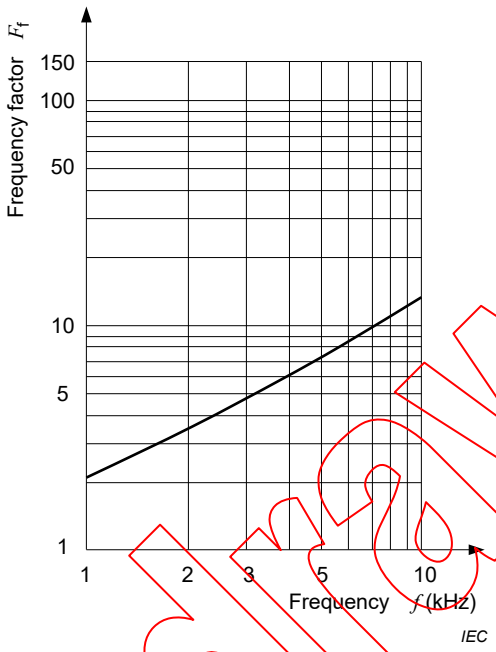

Figure 4 – Variation of the threshold of perception within the frequency range 1 000 Hz to 10 000 Hz

4.3.2 Threshold of let-go

For the threshold of let-go the frequency factor is given in Figure 5.

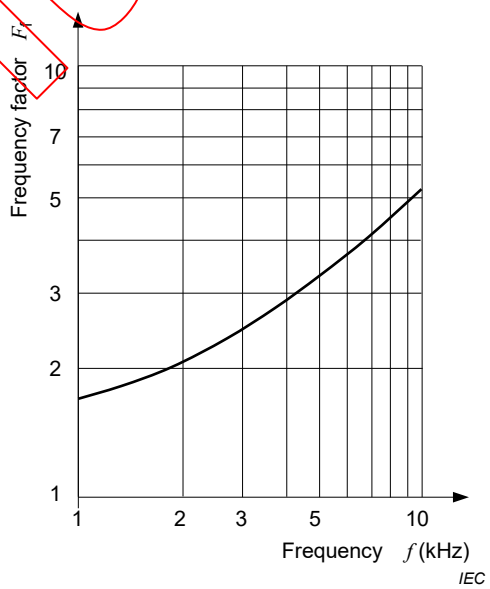

Figure 5 – Variation of the threshold of let-go within the frequency range 1 000 Hz to 10 000 Hz

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4.3.3 Threshold of ventricular fibrillation

For frequencies between 1 000 Hz and 10 000 Hz the provisions of 4.4.4 are used.

4.4 Effects of alternating current in the frequency range above 10 000 Hz

4.4.1 General

In 4.4, changes have not been made to the threshold of perception, or the threshold of let-go for higher frequencies. While these are important thresholds, the most dangerous is that of ventricular fibrillation. The fibrillation threshold is therefore given up to 150 kHz. The remaining thresholds may be considered as in the paragraphs below up to the frequency limits shown.

4.4.2 Threshold of perception

For frequencies between 10 kHz and 100 kHz the threshold rises approximately from 10 mA to 100 mA (RMS values).

For frequencies above 100 kHz the tingling sensation characteristic for the perception at lower frequencies changes into a sensation of warmth for current intensities in the order of some hundred milliamperes.

4.4.3 Threshold of let-go

For frequencies above 100 kHz there is neither experimental data nor reported incidents concerning the threshold of let-go.

4.4.4 Threshold of ventricular fibrillation

For shock durations longer than the cardiac cycle, the frequency factor for the threshold of fibrillation for longitudinal current paths through the trunk of the body for the frequency range above 1000 Hz up to and including 150 kHz is given in Figure 6.

For frequencies above 1 kHz, thermal effects are more likely to become dominant.

For shock durations shorter than the cardiac cycle, no experimental data is available.

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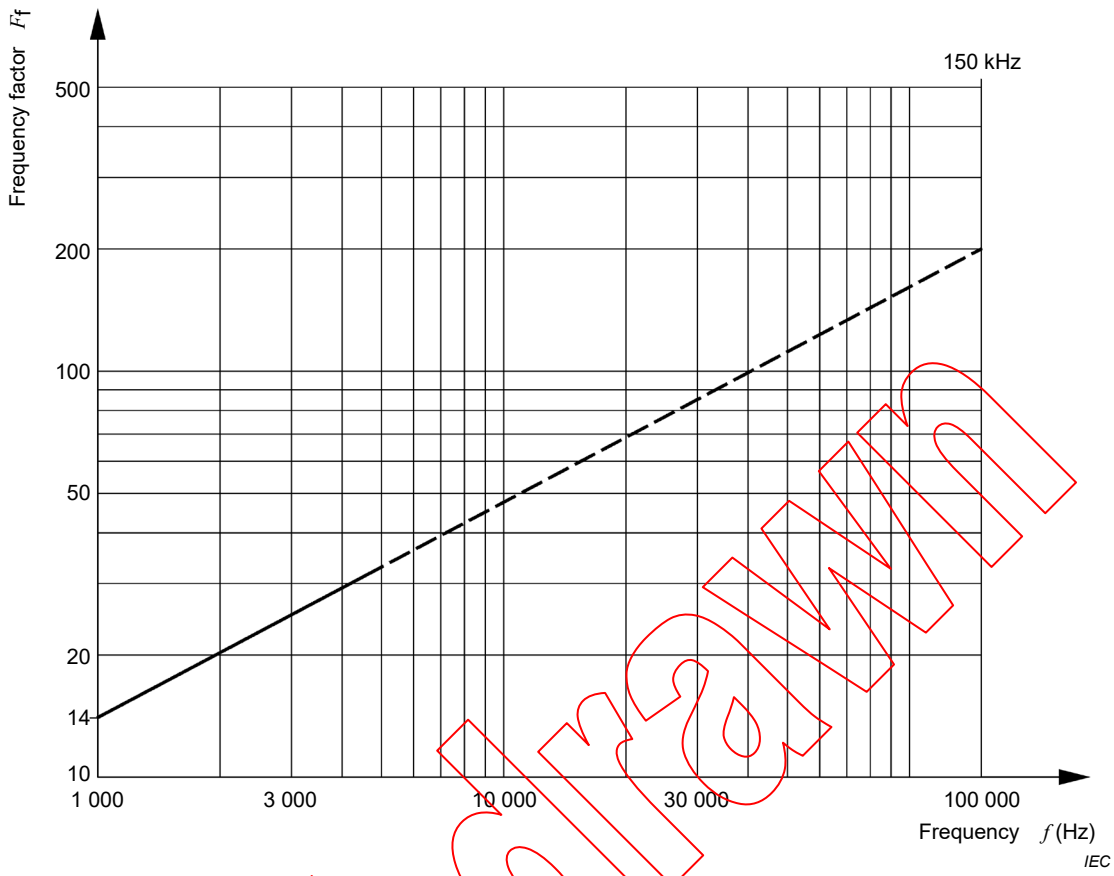

Figure 6 – Variation of the threshold of ventricular fibrillation for continuous sinusoidal current for use from 1 000 Hz to a maximum of 150 kHz

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4.4.5 Other effects

Burns may occur at frequencies above 100 kHz and current magnitudes in the order of amperes depending on the duration of the current flow.

5 Effects of special waveforms of current

5.1 General

As is to be expected, the effects of such currents on the human body are between those caused by direct and by alternating current; therefore equivalent current magnitudes with regard to ventricular fibrillation can be established.

Clause 5 describes the effects of current passing through the human body for:

– alternating sinusoidal current with DC components,
– alternating sinusoidal current with phase control,
– alternating sinusoidal current with multicycle control.

NOTE Other waveforms are under consideration.

The information given is deemed applicable for alternating current frequencies from 15 Hz up to 100 Hz.

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