

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

BASIC SAFETY PUBLICATION
PUBLICATION FONDAMENTALE DE SÉCURITÉ

**Effects of current on human beings and livestock –
Part 1: General aspects**

**Effets du courant sur l'homme et les animaux domestiques –
Partie 1: Aspects généraux**

WITNOGAMN



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CONTENTS

FOREWORD.....	6
INTRODUCTION.....	9
1 Scope.....	11
2 Normative references	12
3 Terms and definitions	12
3.1 General definitions	12
3.2 Effects of sinusoidal alternating current in the range 15 Hz to 100 Hz	13
3.3 Effects of direct current	14
4 Electrical impedance of the human body.....	14
4.1 Internal impedance of the human body (Z_i)	14
4.2 Impedance of the skin (Z_s).....	15
4.3 Total impedance of the human body (Z_T).....	15
4.4 Factors affecting initial resistance of the human body (R_O).....	15
4.5 Values of the total impedance of the human body (Z_T).....	15
4.6 Value of the initial resistance of the human body (R_O).....	23
5 Effects of sinusoidal alternating current in the range of 15 Hz to 100 Hz.....	23
5.1 Threshold of perception.....	23
5.2 Threshold of reaction.....	23
5.3 Immobilization	23
5.4 Threshold of let-go	23
5.5 Threshold of ventricular fibrillation.....	24
5.6 Other effects related to electric shocks.....	24
5.7 Effects of current on the skin.....	25
5.8 Description of time/current zones (see Figure 20).....	26
5.9 Application of heart-current factor (F).....	26
6 Effects of direct current.....	27
6.1 Threshold of perception and threshold of reaction	27
6.2 Threshold of immobilization and threshold of let-go	27
6.3 Threshold of ventricular fibrillation.....	27
6.4 Other effects of current	28
6.5 Description of time/current zones (see Figure 22).....	29
6.6 Heart factor	29
Annexes	48
Annex A (normative) Measurements of the total body impedances Z_T made on living human beings and on corpses and the statistical analysis of the results	49
Annex B (normative) Influence of frequency on the total body impedance (Z_T)	52
Annex C (normative) Total body resistance (R_T) for direct current	53
Annex D (informative) Examples of calculations of Z_T	54
Bibliography.....	58

Figure 1 – Impedances of the human body.....	29
Figure 2 – Internal partial impedances Z_{ip} of the human body	30
Figure 3 – Simplified schematic diagram for the internal impedances of the human body	31
Figure 4 – Total body impedances Z_T (50 %) for a current path hand to hand, for large surface areas of contact in dry, water-wet and saltwater-wet conditions for a percentile rank of 50 % of the population for touch voltages $U_T = 25$ V to 700 V, a.c. 50/60 Hz.....	32
Figure 5 – Dependence of the total impedance Z_T of one living person on the surface area of contact in dry condition and at touch voltage (50 Hz)	33
Figure 6 – Dependence of the total body impedance Z_T on the touch voltage U_T for a current path from the tips of the right to the left forefinger compared with large surface areas of contact from the right to the left hand in dry conditions measured on one living person, touch voltage range $U_T = 25$ V to 200 V, a.c. 50 Hz, duration of current flow max. 25 ms	34
Figure 7 – Dependence of the total body impedance Z_T for the 50 th percentile rank of a population of living human beings for large, medium and small surface areas of contact (order of magnitude 10 000 mm ² , 1 000 mm ² and 100 mm ² respectively) in dry conditions at touch voltages $U_T = 25$ V to 200 V a.c. 50/60 Hz	35
Figure 8 – Dependence of the total body impedance Z_T for the 50 th percentile rank of a population of living human beings for large, medium and small surface areas of contact (order of magnitude 10 000 mm ² , 1 000 mm ² and 100 mm ² respectively) in water-wet conditions at touch voltages $U_T = 25$ V to 200 V, a.c. 50/60 Hz.....	36
Figure 9 – Dependence of the total body impedance Z_T for the 50 th percentile rank of a population of living human beings for large, medium and small surface areas of contact (order of magnitude 10 000 mm ² , 1 000 mm ² and 100 mm ² respectively) in saltwater-wet conditions at touch voltages $U_T = 25$ V to 200 V, a.c. 50/60 Hz	37
Figure 10 – Values for the total body impedance Z_T measured on 10 living human beings with a current path hand to hand and large surface areas of contact in dry conditions at a touch voltage of 10 V and frequencies from 25 Hz to 20 kHz.....	38
Figure 11 – Values for the total body impedance Z_T measured on one living human being with a current path hand to hand and large surface areas of contact in dry conditions at a touch voltage of 25 V and frequencies from 25 Hz to 2 kHz.....	38
Figure 12 – Frequency dependence of the total body impedance Z_T of a population for a percentile rank of 50 % for touch voltages from 10 V to 1 000 V and a frequency range from 50 Hz to 2 kHz for a current path hand to hand or hand to foot, large surface areas of contact in dry conditions	39
Figure 13 – Statistical value of total body impedances Z_T and body resistances R_T for a percentile rank of 50 % of a population of living human beings for the current path hand to hand, large surface areas of contact, dry conditions, for touch voltages up to 700 V, for a.c. 50/60 Hz and d.c.....	40
Figure 14 – Dependence of the alteration of human skin condition on current density i_T and duration of current flow (for detailed description of zones, see 5.7)	41
Figure 15 – Electrodes used for the measurement of the dependence of the impedance of the human body Z_T on the surface area of contact	42

Figure 16 – Oscillograms of touch voltages U_T and touch currents I_T for a.c., current path hand to hand, large surface areas of contact in dry conditions taken from measurements 43

Figure 17 – Occurrence of the vulnerable period of ventricles during the cardiac cycle 44

Figure 18 – Triggering of ventricular fibrillation in the vulnerable period – Effects on electro-cardiogram (ECG) and blood pressure 44

Figure 19 – Fibrillation data for dogs, pigs and sheep from experiments and for persons calculated from statistics of electrical accidents with transversal direction of current flow hand to hand and touch voltages $U_T = 220\text{ V}$ and 380 V a.c. with body impedances Z_T (5 %) 45

Figure 20 – Conventional time/current zones of effects of a.c. currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (for explanation see Table 11)..... 46

Figure 21 – Oscillogram of touch voltages U_T and touch current I_T for d.c., current path hand to hand, large surface areas of contact in dry conditions 46

Figure 22 – Conventional time/current zones of effects of d.c. currents on persons for a longitudinal upward current path (for explanation see Table 13)..... 47

Figure 23 – Let-go currents for 60 Hz sinusoidal current 47

Table 1 – Total body impedances Z_T for a current path hand to hand a.c. 50/60 Hz, for large surface areas of contact in dry conditions 16

Table 2 – Total body impedances Z_T for a current path hand to hand a.c. 50/60 Hz, for large surface areas of contact in water-wet conditions 17

Table 3 – Total body impedances Z_T for a current path hand to hand a.c. 50/60 Hz, for large surface areas of contact in saltwater-wet conditions 18

Table 4 – Total body impedances Z_T for a current path hand to hand for medium surface areas of contact in dry conditions at touch voltages $U_T = 25\text{ V}$ to 200 V a.c. 50/60 Hz (values rounded to $25\ \Omega$) 19

Table 5 – Total body impedances Z_T for a current path hand to hand for medium surface areas of contact in water-wet conditions at touch voltages $U_T = 25\text{ V}$ to 200 V a.c. 50/60 Hz (values rounded to $25\ \Omega$) 20

Table 6 – Total body impedances Z_T for a current path hand to hand for medium surface areas of contact in saltwater-wet conditions at touch voltages $U_T = 25\text{ V}$ to 200 V a.c. 50/60 Hz (values rounded to $5\ \Omega$) 20

Table 7 – Total body impedances Z_T for a current path hand to hand for small surface areas of contact in dry conditions at touch voltages $U_T = 25\text{ V}$ to 200 V a.c. 50/60 Hz (values rounded to $25\ \Omega$) 20

Table 8 – Total body impedances Z_T for a current path hand to hand for small surface areas of contact in water-wet conditions at touch voltages $U_T = 25\text{ V}$ to 200 V a.c. 50/60 Hz (values rounded to $25\ \Omega$) 21

Table 9 – Total body impedances Z_T for a current path hand to hand for small surface areas of contact in saltwater-wet conditions at touch voltages $U_T = 25$ V to 200 V a.c. 50/60 Hz (values rounded to 5 Ω)	21
Table 10 – Total body resistances R_T for a current path hand to hand, d.c., for large surface areas of contact in dry conditions	22
Table 11 – Time/current zones for a.c. 15 Hz to 100 Hz for hand to feet pathway : Summary of zones of Figure 20	26
Table 12 – Heart-current factor F for different current paths.....	27
Table 13 – Time/current zones for d.c. for hand to feet pathway – Summary of zones of Figure 22	29
Table A.1 – Total body impedances Z_T , electrodes type A for dry condition and deviation factors F_D (5 % and 95 %)	49
Table A.2 – Total body impedances Z_T , electrodes type B for dry, water-wet and saltwater-wet conditions and deviation factors F_D (5 % and 95 %)	49
Table A.3 – Total body impedances Z_T for dry, water-wet and saltwater-wet conditions and deviation factors F_D (5 % and 95 %).....	50
Table A.4 – Deviation factors F_D (5 %) and F_D (95 %) for dry and water-wet conditions in the touch voltage range $U_T = 25$ V up to 400 V for large, medium and small surface areas of contact.....	51
Table D.1 – 50 th percentile values for the total body impedance for a current path hands-feet medium surface area of contact for hands, large for feet, reduction factor 0,8, dry conditions, touch currents I_T and electrophysiological effects.....	56

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**EFFECTS OF CURRENT ON HUMAN BEINGS
AND LIVESTOCK –****Part 1: General aspects**

FOREWORD

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

IEC 60479-1, 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 as a technical report in 1994, and constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

- Dependence of the total body impedance Z_T for 50th percentile rank of a population of living human beings for large, average and small surface areas of a contact in dry, water-wet and saltwater-wet conditions at touch voltage $U_T = 25$ V to 200 V a.c. 50/60 Hz.
- Oscillograms of touch voltages U_T and touch currents I_T for a.c., current path hand-to-hand, large surface areas of contact in dry condition taken from measurements given in Figure 16 with the relevant explanations in the main text.
- Fibrillation data for dogs, pigs and sheep obtained from experiments and for persons calculated from statistics of electrical accidents with transversal direction of current flow, hand-to-hand and touch voltages $U_T = 220$ V to 380 V a.c. with body impedances Z_T (5%) given in Figure 19 with the relevant explanations in the main text.
- Change of Curve B in Figure 20 from 10 mA to 5 mA: conventional time/current zones of effects of a.c. current (15 Hz to 100 Hz) on persons with the relevant explanations in the main text.
- Let-go currents for 60 Hz sinusoidal current given in Figure 23 with the relevant explanations in the main text.
- new structure to the body of the standard.

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

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

Enquiry draft	Report on voting
64/1427/DTS	64/1463/RVC

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

IEC 60479 consists of the following parts under the general title *Effects of current on human beings and livestock*

- Part 1: General aspects
- Part 2: Special aspects:
 - Chapter 4: Effects of alternating current with frequencies above 100 Hz
 - Chapter 5: Effects of special waveforms of current
 - Chapter 6: Effects of unidirectional single impulse currents of short duration
- Part 3: Effects of currents passing through the bodies of livestock
- Part 4: Effects of lightning strokes on human beings and livestock

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

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

The contents of the corrigendum of October 2006 and June 2013 have been included in this copy.

Withdrawn

INTRODUCTION

This technical specification provides basic guidance on the effects of shock current on human beings and livestock, for use in the establishment of electrical safety requirements.

In order to avoid errors in the interpretation of this specification, it must be emphasized that the data given herein is mainly based on experiments with animals as well as on information available from clinical observations. Only a few experiments with shock currents of short duration have been carried out on living human beings.

On the evidence available, mostly from animal research, the values are so conservative that the standard applies to persons of normal physiological conditions including children, irrespective of age and weight.

There are, however, other aspects to be taken into account, such as probability of faults, probability of contact with live or faulty parts, ratio between touch voltage and fault voltage, experience gained, technical feasibilities, and economics. These parameters have to be considered carefully when fixing safety requirements, for example, operating characteristics of protective devices for electrical installations.

The form of the specification as has been adopted summarizes results so far achieved which are being used by technical committee 64 as a basis for fixing requirements for protection against shock. These results are considered important enough to justify an IEC publication which may serve as a guide to other IEC committees and countries having need of such information.

This technical specification applies to the threshold of ventricular fibrillation which is the main cause of deaths by electric current. The analysis of results of recent research work on cardiac physiology and on the fibrillation threshold, taken together, has made it possible to better appreciate the influence of the main physical parameters and, especially, of the duration of the current flow.

IEC 60479-1 contains information about body impedance and body current thresholds for various physiological effects. This information can be combined to derive estimates of a.c. and d.c. touch voltage thresholds for certain body current pathways, contact moisture conditions, and skin contact areas. Information about touch voltage thresholds for physiological effects is contained in the IEC 61201.

This specification refers specifically to the effects of electric current. When an assessment of the harmful effects of any event on human beings and livestock is being made, other non-electric phenomena, including falls, heat, fire, or others should be taken into account. These matters are beyond the scope of this specification, but may be extremely serious in their own right.

Recent research work has also been conducted on the other physical accident parameters, especially the waveform and frequency of the current and the impedance of the human body. This fourth revision of IEC 60479-1 should be viewed as the logical development and evolution of the third edition.

Clause 2 of IEC 60479-1 (third edition) on the impedance of the human body contained little information on the dependence of the impedance on the surface area of contact and then only for dry conditions.

Therefore measurements were carried out on 10 persons using medium and small surface areas of contact in dry, water-wet and saltwater-wet conditions, current path hand to hand, at a touch voltage of 25 V a.c. 50 Hz. The impedance values for a percentile rank of 5 %, 50 % and 95 % have been calculated from these measurements.

Due to unpleasant sensations and the possibility of inherent danger, measurements using large surface areas of contact (order of magnitude 10 000 mm²) in dry, water-wet and saltwater-wet conditions and with medium and small surface areas of contact (order of magnitude 1 000 mm² and 100 mm²) in dry condition at touch voltages from 25 V up to and including 200 V a.c. have only been carried out on one person. By the use of deviation factors it was nevertheless possible to derive values of the total body impedance Z_T for a percentile rank of 5 %, 50 % and 95 % of a population of persons. With the same one person measurements were also made with still smaller surface areas of contact (10 mm² and 1 mm²) and between fingertips.

For the calculation of total body impedance Z_T for a percentile rank of 5 %, 50 % and 95 % of a population of persons for large surface areas of contact for touch voltages above 200 V up to 700 V and higher up to the asymptotic values the method to adapt values of Z_T measured on corpses to those of persons used for the second edition of IEC 60479-1 was improved by taking account of the different temperature of the corpses during measurements and the temperature of 37 °C for persons.

The present state of knowledge of a.c. impedance Z_T of the human body for large, medium and small surface areas of contact in dry, water-wet and salt-water-wet conditions and of the d.c.-resistance R_T of the human body for large areas of contact in dry conditions are presented.

It should be mentioned that the thresholds as order of magnitude are valid for all persons (men, women and children) independent of their state of health. Often concerns are expressed in that respect but if the background of such objections is examined it is found that such objections represent just opinions without experimental evidence. Some measurements indicate that the thresholds of perception and let-go for women are lower than for men. This may also be the case for children.

Furthermore in Clause 5 a heart-current factor F for the current path foot to foot has been introduced. This is important for electrical risks caused by step voltages.

EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

Part 1: General aspects

1 Scope

For a given current path through the human body, the danger to persons depends mainly on the magnitude and duration of the current flow. However, the time/current zones specified in the following clauses are, in many cases, not directly applicable in practice for designing measures of protection against electrical shock. The necessary criterion is the admissible limit of touch voltage (i.e. the product of the current through the body called touch current and the body impedance) as a function of time. The relationship between current and voltage is not linear because the impedance of the human body varies with the touch voltage, and data on this relationship is therefore required. The different parts of the human body (such as the skin, blood, muscles, other tissues and joints) present to the electric current a certain impedance composed of resistive and capacitive components.

The values of body impedance depend on a number of factors and, in particular, on current path, on touch voltage, duration of current flow, frequency, degree of moisture of the skin, surface area of contact, pressure exerted and temperature.

The impedance values indicated in this technical specification result from a close examination of the experimental results available from measurements carried out principally on corpses and on some living persons.

Knowledge of the effects of alternating current is primarily based on the findings related to the effects of current at frequencies of 50 Hz or 60 Hz which are the most common in electrical installations. The values given are, however, deemed applicable over the frequency range from 15 Hz to 100 Hz, threshold values at the limits of this range being higher than those at 50 Hz or 60 Hz. Principally the risk of ventricular fibrillation is considered to be the main mechanism of death of fatal electrical accidents.

Accidents with direct current are much less frequent than would be expected from the number of d.c. applications, and fatal electrical accidents occur only under very unfavourable conditions, for example, in mines. This is partly due to the fact that with direct current, the let-go of parts gripped is less difficult and that for shock durations longer than the period of the cardiac cycle, the threshold of ventricular fibrillation is considerably higher than for alternating current.

NOTE The IEC 60479 series contains information about body impedance and body current thresholds for various physiological effects. This information can be combined to derive estimates of a.c. and d.c. touch voltage thresholds for certain body current pathways, contact moisture conditions, and skin contact areas. Information about touch voltage thresholds for physiological effects is contained in IEC 61201.

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 61201:1992, *Extra-low voltage (ELV) – Limit values*

Guide 104:1997, *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 following terms and definitions apply.

3.1 General definitions

3.1.1

longitudinal current

current flowing lengthwise through the trunk of the human body such as from hand to feet

3.1.2

transverse current

current flowing across the trunk of the human body such as from hand to hand

3.1.3

internal impedance of the human body

Z_i

impedance between two electrodes in contact with two parts of the human body, neglecting skin impedances

3.1.4

impedance of the skin

Z_s

impedance between an electrode on the skin and the conductive tissues underneath

3.1.5

total impedance of the human body

Z_T

vectorial sum of the internal impedance and the impedances of the skin (see Figure 1)

3.1.6

initial resistance of the human body

R_0

resistance limiting the peak value of the current at the moment when the touch voltage occurs

3.1.7

dry condition

condition of the skin of a surface area of contact with regard to humidity of a living person being at rest under normal indoor environmental conditions

3.1.8**water-wet condition**

condition of the skin of a surface area of contact being exposed for 1min to water of public water supplies (average resistivity $\rho = 3\,500\ \Omega\text{cm}$, pH = 7 to 9)

3.1.9**saltwater-wet condition**

condition of the skin of a surface area of contact being exposed for 1 min to a 3 % solution of NaCl in water (average resistivity $\rho = 30\ \Omega\text{cm}$, pH = 7 to 9)

NOTE It is assumed that saltwater-wet condition simulates the condition of the skin of a sweating person or a person after immersion in seawater. Further investigations are necessary.

3.1.10**deviation factor** F_D

total body impedance Z_T for a given percentile rank of a population divided by the total body impedance Z_T for a percentile rank of 50 % of a population at a given touch voltage

$$F_D (X\%, U_T) = \frac{Z_T (X\%, U_T)}{Z_T (50\%, U_T)}$$

3.2 Effects of sinusoidal alternating current in the range 15 Hz to 100 Hz**3.2.1****threshold of perception**

minimum value of touch current which causes any sensation for the person through which it is flowing

3.2.2**threshold of reaction**

minimum value of touch current which causes involuntary muscular contraction

3.2.3**threshold of let-go**

maximum value of touch current at which a person holding electrodes can let go of the electrodes

3.2.4**threshold of ventricular fibrillation**

minimum value of touch current through the body which causes ventricular fibrillation

3.2.5**heart-current factor** F

relates the electric field strength (current density) in the heart for a given current path to the electric field strength (current density) in the heart for a touch current of equal magnitude flowing from left hand to feet

NOTE In the heart, the current density is proportional to the electric field strength.

3.2.6**vulnerable period**

comparatively small part of the cardiac cycle during which the heart fibres are in an inhomogeneous state of excitability and ventricular fibrillation occurs if they are excited by an electric current of sufficient magnitude

NOTE The vulnerable period corresponds to the first part of the T-wave in the electrocardiogram which is approximately 10 % of the cardiac cycle (see Figures 17 and 18).

3.3 Effects of direct current

3.3.1

total body resistance

R_T

sum of the internal resistance of the human body and the resistances of the skin

3.3.2

d.c./a.c. equivalence factor

k

ratio of direct current to its equivalent r.m.s. value of alternating current having the same probability of inducing ventricular fibrillation

NOTE As an example for shock durations longer than the period of one cardiac cycle and 50 % probability for ventricular fibrillation, the equivalence factor for 10 s is approximately:

$$k = \frac{I_{\text{d.c.-fibrillation}}}{I_{\text{a.c.-fibrillation (r.m.s.)}}} = \frac{300 \text{ mA}}{80 \text{ mA}} = 3,75 \text{ (see Figures 20 and 22)}$$

3.3.3

upward current

direct touch current through the human body for which the feet represent the positive polarity

3.3.4

downward current

direct touch current through the human body for which the feet represent the negative polarity

4 Electrical impedance of the human body

The values of body impedance depend on a number of factors and, in particular, on current path, on touch voltage, duration of current flow, frequency, degree of moisture of the skin, surface area of contact, pressure exerted and temperature.

A schematic diagram for the impedance of the human body is shown in Figure 1.

4.1 Internal impedance of the human body (Z_i)

The internal impedance of the human body can be considered as mostly resistive. Its value depends primarily on the current path and, to a lesser extent, on the surface area of contact.

NOTE 1 Measurements indicate that a small capacitive component exists (dashed lines in Figure 1).

Figure 2 shows the internal impedance of the human body for its different parts expressed as percentages of that related to the path hand to foot.

For current paths hand to hand or hand to feet, the impedances are mainly located in the limbs (arms and legs). If the impedance of the trunk of the body is neglected, a simplified circuit diagram can be established which is shown in Figure 3.

NOTE 2 In order to simplify the circuit diagram, it is assumed that the impedance of arms and legs have the same values.