

Guide to

Effects of current passing through the human body

Part 1. General aspects

Guide aux effets du courant passant par le corps humain
Partie 1. Aspects généraux

Leitfaden zur Wirkung von elektrischem Strom im menschlichen Körper
Teil 1. Allgemeine Gesichtspunkte

National foreword

This Published Document, which has been prepared under the direction of the General Electrotechnical Engineering Standards Committee, is identical with the Report of the International Electrotechnical Commission, IEC Publication 479-1 : 1984 'Effects of current passing through the human body. Part 1: General aspects'. Although the content of the IEC Publication is not judged suitable for publication as a British Standard, its status in the IEC of 'Basic safety standard' (see IEC Guide 104 : 1984 'Guide to the drafting of safety standards and the rôle of Committees with safety pilot functions and safety group functions') is likely to result in many references to it being made in other IEC standards concerned with safety and it is therefore thought to be of interest to members of appropriate Technical Committees and to those concerned with the development of products. In particular, the number of experiments on which the data in IEC 479 were based was statistically small and there may have been a bias in respect of age, health and racial characteristics. The most conservative figures in IEC 479 cover 95 % of the adult population so, where safety of persons is a consideration, a substantial safety factor should be applied. Attention is drawn to the introduction which indicates ways in which the PD should be used.

PD 6519 is published in two Parts. The other Part is:

Part 2 Special aspects

Terminology and conventions. The text of IEC 479-1 has been approved as suitable for publication as a Published Document without deviation. Some terminology and certain conventions are not identical with those used in British Standard publications; attention is drawn especially to the following.

Except in the fifth paragraph of the introduction, referring to the method of presentation, wherever the word 'report' appears, referring to this document, it should be read as 'Published Document'.

References within the text to page numbers relate to IEC page numbers given in brackets at the bottom of each page.

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INTRODUCTION

In order to avoid errors in the interpretation of this report it must be emphasized that the data given herein are 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 report applies to persons under normal physiological conditions, including children irrespective of age and weight.

This report is intended to provide basic guidance on the effects of shock currents on the human body for use in the establishment of electrical safety requirements.

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 report has been adopted, as it summarizes results so far achieved which are being used by Technical Committee No. 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 also as a guide to other IEC Committees and countries having need of such information.

The first edition of Publication 479 was issued in 1974 and was based on an extensive search in literature and on the evaluation of replies received to a questionnaire. However, since that date, new research work has been conducted on this subject. The study of this work and a more precise analysis of preceding publications have allowed a better understanding of the effects of electric current on living organisms and, in particular, on man.

This specifically applies to the limits of ventricular fibrillation which is the main cause of deaths by electric current, and the analysis of all 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.

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 revision of Publication 479 was therefore considered necessary and should be viewed as the logical development and evolution of the first edition.

CHAPTER 1: ELECTRICAL IMPEDANCE OF THE HUMAN BODY

1. General

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 chapters are, in many cases, not directly applicable in practice for designing protection against electric shock, the necessary criterion being the admissible limit of touch voltage (i.e., the product of the current through the body 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 accordingly 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 these impedances depend on a certain number of factors and, in particular, on the current path, on the touch voltage, the duration of the current flow, the frequency, the degree of moisture of the skin, the surface area of contact, the pressure exerted and on the temperature.

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

2. Scope

This chapter indicates values for the electrical impedance of the human body as a function of the touch voltage, the frequency, the degree of moisture of the skin and the current path.

Note. — The values given in Clause 5 refer to frequencies of 50/60 Hz; values for higher frequencies and for direct current are under consideration.

3. Definitions

3.1 *Internal impedance of the human body (Z_i)*

Impedance between two electrodes in contact with two parts of the human body, after removing the skin from under the electrodes.

3.2 *Impedance of the skin (Z_p)*

Impedance between an electrode on the skin and the conductive tissues underneath.

3.3 *Total impedance of the human body (Z_T)*

Vectorial sum of the internal impedance and the impedances of the skin (see Figure 1, page 14).

3.4 *Initial resistance of the human body (R_i)*

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

4. Characteristics of the impedance of the human body

A circuit diagram for the impedances of the human body is shown in Figure 1, page 14.

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 principally on the current path and, to a lesser extent, on the surface area of the contact. However, when the surface area of contact is very small, in the order of a few square millimetres, the internal impedance is increased.

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

Figure 2, page 14, shows the internal impedance of the human body for various current paths expressed as percentages of that related to the path hand to hand.

4.2 *Impedance of the skin (Z_p)*

The impedance of the skin can be considered as a network of resistances and capacitances. Its structure is made up of a semi-insulating layer and small conductive elements (pores). The skin impedance falls when the current is increased. Sometimes current marks are observed.

The value of the impedance of the skin depends on the voltage, frequency, duration of the current flow, surface area of contact, pressure of contact, the degree of moisture of the skin and temperature.

For touch voltages up to approximately 50 V, the value of the impedance of the skin varies widely with surface area of contact, temperature, respiration etc. even for one person.

For higher touch voltages in the order of approximately 50 V to 100 V the skin impedance decreases considerably and becomes negligible when the skin breaks down.

As regards the influence of frequency, the impedance of the skin decreases when the frequency increases.

4.3 *Total impedance of the human body (Z_T)*

The total impedance of the human body consists of a resistive component and a capacitive component.

For touch voltages up to approximately 50 V, on account of considerable variations in the impedance of the skin Z_p , the total impedance of the human body Z_T similarly varies widely.

For higher touch voltages, the total impedance depends less and less on the impedance of the skin and after breakdown of the skin its value approaches that of the internal impedance Z_i .

As regards the influence of frequency, taking into account the frequency dependence of the skin, the total impedance of the human body is higher for direct current and decreases when the frequency increases.

4.4 *Initial resistance of the human body (R_i)*

At the moment when the touch voltage occurs, capacitances in the human body are not charged. Therefore skin impedances Z_p are negligible and the initial resistance R_i is approximately equal to the internal impedance of the human body Z_i (see Figure 1). R_i depends mainly on the current path and to a lesser extent on the surface area of contact.

The initial resistance R_i limits the current peaks of short impulses (e.g. shocks from electric fence controllers).

5. Values of the total impedance of the human body (Z_T)

The values of the total body impedance given in Table I are valid for living human beings and a current path hand to hand or hand to foot for large contact areas (50 cm² to 100 cm²) and dry conditions.

At voltages up to 50 V, values measured with contact areas wetted with normal water are 10% to 25% lower than in dry conditions and conductive solutions decrease the impedance considerably down to half of the values measured in dry conditions.

At voltages higher than approximately 150 V the total body impedance depends only slightly on humidity and on the surface area of contact.

The measurements have been made on adults (males and females). The range of the total body impedance for touch voltages up to 5 000 V is presented in Figure 3, page 15, and for touch voltages up to 700 V in Figure 4, page 15.

The values of Table I and Figures 3 and 4 represent at present the best knowledge on the total body impedance for living adults. On the knowledge at present available the total body impedance for children is expected to be in the same order.

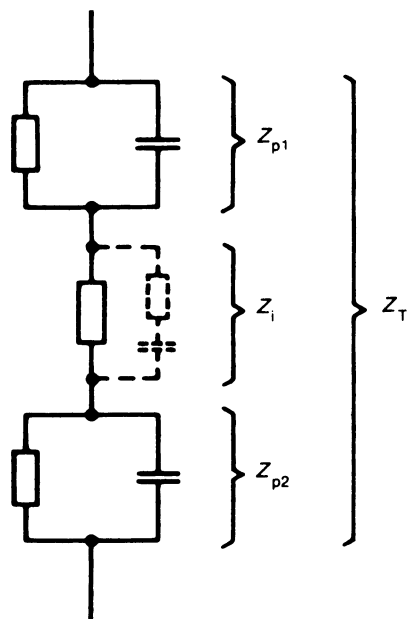
TABLE I
Total body impedance Z_T

Touch voltage (V)	Values for the total body impedance (Ω) that are not exceeded for a percentage (percentile rank) of		
	5%	50%	95%
	of the population		
25	1 750	3 250	6 100
50	1 450	2 625	4 375
75	1 250	2 200	3 500
100	1 200	1 875	3 200
125	1 125	1 625	2 875
220	1 000	1 350	2 125
700	750	1 100	1 550
1 000	700	1 050	1 500
Asymptotic value	650	750	850

Notes 1. — These values have been derived as described in Appendix A.
2. — Values for persons immersed in water are under consideration.

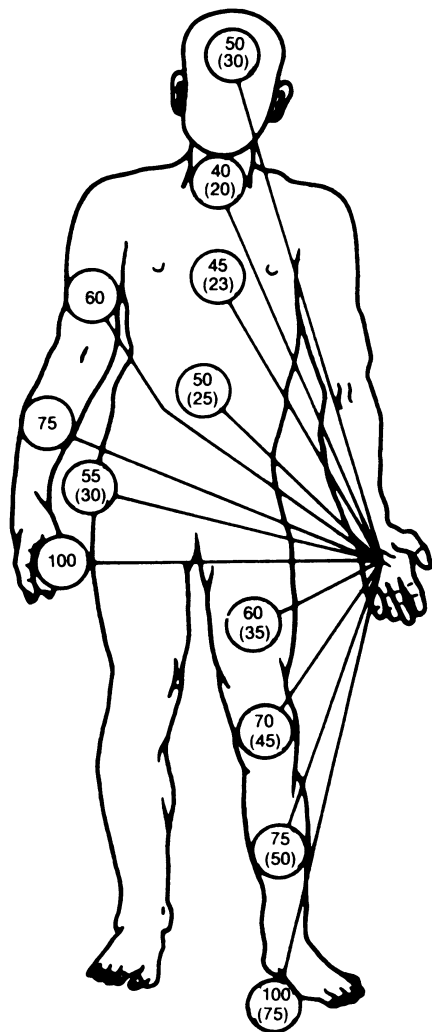
6. Value of the initial resistance of the human body (R_i)

The value of the initial resistance of the human body for a current path hand to hand or hand to foot and large contact areas can be taken as equal to 500 Ω for the 5% percentile rank.



Z_i = internal impedance
 Z_{p1}, Z_{p2} = impedances of the skin
 Z_T = total impedance

FIG. 1. — Impedances of the human body.



The numbers indicate the percentage of the impedance of the human body for the path concerned, in relation to the path hand to hand. The numbers not in brackets refer to the current paths from one hand to the part of the body in question. The numbers in brackets refer to current paths between two hands and the corresponding part of the body.

- Notes 1. — The impedance from one hand to both feet is 75% and the impedance from both hands to both feet 50% of the impedance from hand to hand.
2. — As a first approximation the percentages are also valid for the total body impedance.

FIG. 2. — Internal impedance of the human body as a function of the current path.