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Electrification of human body by walking

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Abstract

The process of electrification of the human body by walking on resistive floors has been analysed and the corresponding body potential measured. A model for electric body potential caused by walking has been proposed and then verified experimentally. The model combines two main processes: an exponential increase of potential due to successive charging and potential oscillations caused by periodic changes of body capacitance during walking. The conditions for initiation of Paschen's microdischarges running in the gaps between floor and soles of walker's footwear have been specified and a corresponding relation for minimum saturated body potential causing Paschen's discharges has been derived. This saturated critical potential has been found to be much higher than that usually attained by walking on common floors which explains why the Paschen discharges did not appear in such air gaps. On the other hand, the microdischarges developed between *uncovered* parts of the human body and grounded metallic objects have been found to be likely even with common floor and sole materials.

Keywords: Triboelectrification; Charging by walking; Body potential; Electrostatic microdischarges

1. Introduction

Recent increased interest in electrostatic effects has been stimulated by a rapid development of microelectronics. Sensitive microelectronic components are often destroyed by electrostatic microdischarges. These microdischarges can appear in the air gaps between the human body charged by walking and metallic grounded objects. This is a typical situation of people moving inside the interiors of buildings. A body potential less than 100 V is usually considered as a safe potential which does not cause microdischarges. Therefore, the measurement of body potential is one of the important preventive tools which help to assess electrostatic risks in interiors of buildings.

Some authors have published [1] model studies of current pulses caused by discharging of a person coming in contact with grounded objects. The person has been simulated by the RLC circuit containing 11 segments which have represented the main anatomic parts of the human body. In other papers [2] an equivalent circuit model applied to antistatic floors has been presented and relaxation of surface potential of the floor has been analysed. Some authors [3–6] have also investigated charging of the human body during walking on a resistive floor. In paper [3] an analysis of charging due to fundamental step motions 'up' and 'down' is given while another paper [4] offers a method for visualisation of surface charge on a floor. The decay of body charge (or body potential) was studied [5] as a result of a charge leakage on the surface of the floor on which the person stood. Some attempts to model electric potential of floor by using Maxwell's equations have been published [6] as well. Some measurements [7] of body potentials have led to the conclusion that the floor bearing a surface layer of higher conductivity in combination with the footwear possessing more conductive soles ensures that the body potential reaches a 'safe' value less than 100 V. Simple model considerations concerning the increase of body potential during walking have been presented [8,9] but, to our knowledge, a rigorous theoretical model of body

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potential induced by walking on resistive floors has not been published.

When reviewing recent papers concerning electrification by walking, special attention should be paid to the two treatments [10,11] that have studied electrification experimentally by walking with insects. Both the treatments contain interesting results and ideas directly applicable to human walking.

2. Experimental arrangement

Fig. 1 shows a scheme of the measuring circuit recommended by the national Czech Standard ČSN EN 1815 and the German Standard DIN 54 345. The circuit consists of a hand electrode (a) with a capacitive bond C_2 to the rest of the circuit, capacitive voltage divider (b) and electrometer (c). The voltage divider consists of the capacitance C_2 of the hand electrode and capacitance C_3. If the input resistance R_i of the electrometer is sufficiently large, the voltage U_e read from the electrometer determines the body potential U_B as follows:

$$U_B \approx \frac{C_2 + C_3}{C_2} U_e. \tag{1}$$

A Keithley electrometer, model 6514, with the input resistance $R_i = 2 \times 10^{14}\,\Omega$ was used. Since the relation $R_i \gg 1/\omega C_3$ was well fulfilled, the voltage conversion (1) was applied with a high accuracy. The ratio $(C_2 + C_3)/C_2$ was both measured and calculated using the values $C_3 \approx 500\,\text{pF}$ and $C_2 \approx 25\text{pF}$ with the following result: $(C_2 + C_3)/C_2 = 21$. The maximum possible range of the electrometer used was 200 V but due to the voltage divider and the transformation (1), the range of the meter was extended to 4 kV.

3. Model curve of body potential

The human body is charged during walking on highly resistive floors. Under certain circumstances, the body potential can reach considerable values going to several kilovolts. Figs. 2–5 show an increase of the body potential of a person who walked on a PVC floor with shoes having rubber soles. The whole charging process of 160 steps has been plotted in four phases so that Figs. 2, 3, 4 and 5 represent 10, 30, 80 and 160 steps, respectively. In these figures, it is possible to follow a gradual increase of body potential. With the first ten steps shown in Fig. 2 an obvious *periodic* increase and decrease of the potential curve can be seen. The periodic changes are repeated with a frequency of 1 Hz which is exactly the step frequency of the walker. The local maxima on the potential curve correspond to the moments when one of the walker's feet has attained its

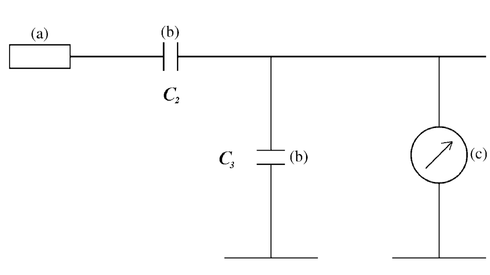

Fig. 1. Scheme of measuring circuit according to the Standards ČSN EN 1815 and DIN 54 345.

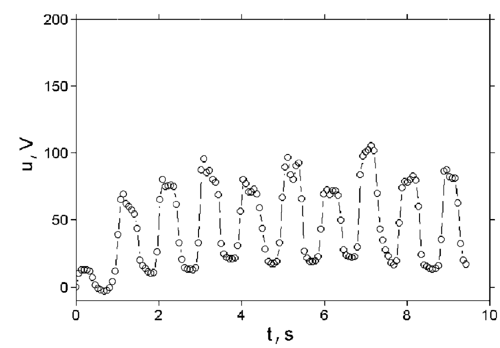

Fig. 2. Body potential after 10 steps (rubber sole—PVC floor, normal walking).

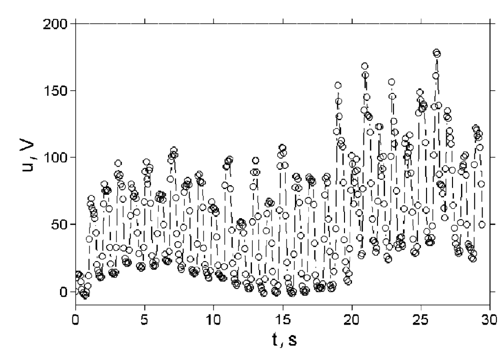

Fig. 3. Body potential after 30 steps (rubber sole—PVC floor, normal walking).

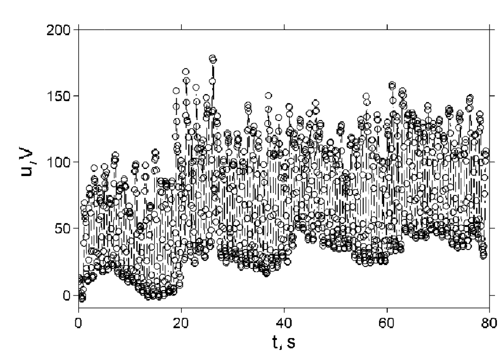

Fig. 4. Body potential after 80 steps (rubber sole—PVC floor, normal walking).