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Premises for Practical Evaluation of the Anti-electrostatic Properties of Protective Garments

Abstract
The use of inappropriate working and protective clothing may cause significant electrical charging of both the clothing material and the wearer's body. Static charge generation on the human body is especially dangerous because of its relatively high electrical conductivity, which may result in high-energy spark discharges. The respective procedures for risk evaluation and/or protection effectiveness may sometimes be questioned, mainly because it is impossible to exactly reproduce in the laboratory the systems that appear when the clothing is worn and, which follows on, there are no sufficient reasons to make generalizations with regard to conclusions. This especially concerns some international standards as well as publications describing the measurement methods of the charge decay time and the charge transfer in electrostatic discharges from textile surfaces. These methods are recommended, first of all, for the testing of atypical textile materials, such as those containing fibres with a conductive core. A method which creates the environment for a rational evaluation of both the level of risk caused by the clothing electrification and the effectiveness of protection provided, regardless of the predicted area of application of the product in question, was developed as a result of research carried out by the Institute of Industrial Organic Chemistry. The results of tests performed, in accordance with a specific procedure in extreme laboratory conditions, simulating the situations that cause the charging of the clothing material and the wearer's body allow adequate quality classification and qualification for use of protective clothing in view of the static control requirements.

Key words: *static electricity, electrostatic charge, charging, discharge, anti-electrostatic effect, electric conductivity, resistance, protective clothing.*

Introduction

Static electricity poses a real threat to human life, health and material resources. This risk is present in many spheres of human activity, especially in working environments where electrostatic fields and discharges may cause fire or explosions, as well as disturbances in the production process [1].

Personal protective equipment, which in substance is designed to protect people, may become a source of danger itself if it is made of an inappropriate material or used in an incorrect way. Among other items, this concerns protective clothing made of material that may become electrified, and especially, which could cause the dangerous charging of the human body. However, clothing material which charges itself, especially when it is worn, causes practically no risk, because the energy of the discharge from the material surface is relatively low. Not only is it a result of the usually small conductivity of the clothing material, which entails an insignificant charge released in the discharge, but also of the large electric capacitance of the clothing-human body system which, at a given level of material charging expressed as charge *Q*, causes the reduction of the electrostatic voltage *U* produced in this system, as indicated in Figure 1. However, the generation of an electrostatic charge on the human body, is very dangerous because of its relatively high conductivity, which may cause high-energy discharges, usually in the form of sparks.

The charged human body has caused many fires and explosions, especially in the chemical industry and in the plants that process or use flammable or explosive chemical products. It cannot be ruled out, for example, that the explosion which occurred on 3 May 2003 in the fuel tank at the Gdańsk Refinery and resulted in human death and large material losses was caused by an electrostatic discharge on an employee's body, which might have been an effect of wearing the wrong kind of protective clothing. Strong fields and electrostatic discharges that occur in the same conditions may also cause accidents among the production personnel (injuries as a result of uncontrolled reactions during an electric shock) and damage the systems containing sensitive microelectronic devices (diagnostic, measuring and control apparatus, equipment used for the storage and transmission of information, etc.). An important, although seldom considered aspect is that electrostatic fields may have also a dangerous influence on humans. Many reports show that such fields are not biologically inactive. The human body's electrical charging, together with the clothing worn, causes acute discomfort (due to strong discharges), in particular during the heating season when extremely low air humidity in non-air-conditioned spaces causes a significant increase in the material's resistance, and makes it impossible for the generated charge to decay sufficiently quickly.

Whether an accident occurs with the participation of a human being (fire and/or explosion, disturbances in the technological process or in the use of products, hazardous biological effects) depends on

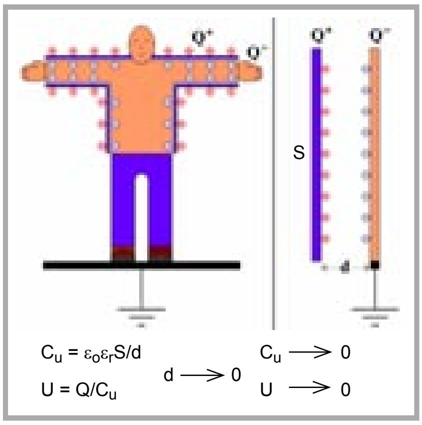

***Figure 1.** The effect of lowering the potential difference (U) in the clothing-human body system as a result of a large electric capacitance (C_u) at the constant level of material charging (charge Q), constant area of contacting surfaces (S) and constant distance (d) between them.*

the probability of the risk's occurrence, as is illustrated by the general block scheme in Figure 2.

The conditions for a potential risk arise when a material, a product, an object or a human body achieves a 'critical' charging level (the highest allowable), when a possibility of dangerous discharges or the hazardous effects of an electrostatic field must be considered. The real danger occurs only at the moment when a given state lasts long enough to result in a spark discharge of an adequately high energy. The conditions for the processes of charging and charge decay may be expressed in a descriptive (logical) way, or by means of parameters with appropriate numeric values.

The criteria for risk evaluation and the principles of protection against static electricity

The criteria for risk evaluation are the determinants of the possibility of accidents caused by electrification [3]. As a rule, these are based on the border values of parameters, i.e. the highest and the lowest allowable parameter values that define, for example:

- the properties of materials that influence their chargeability (electric conductivity and permittivity, shape, dimensions and other)
- the properties of the surrounding environment that influence the ability to maintain the charging conditions and to ignite or explode (air humidity and temperature, minimal ignition energy of gases, vapours or dusts that create explosive mixtures with air);
- the conditions of the process, or the conditions and method of performing a given technological operation (e.g. temperature and pressure, the moving speed of a material or an object, the way of generating friction) that influence the intensity of electrification;
- the maximum level of a material/product/object's charging;
- the maximum time of maintaining the condition of charging;
- the maximum charging energy for a given system or energy of electrostatic discharges.

The criteria for risk evaluation may be also applied to evaluate the effectiveness of anti-(electro) static protection. The strictest protection requirements concern hazardous explosive atmospheres, classified in accordance with standard PN-EN 1127-1:2001 p. 6.3. As a rule, meeting these requirements ensures effective protection against static electricity in any service conditions. If there is a need to eliminate other harmful effects of static electricity outside the explosion-prone areas, it is usually sufficient to meet much less demanding requirements in order to achieve effective anti-electrostatic protection. The criteria for risk evaluation and the corresponding protection requirements can be found in a series of Polish Standards under the common title 'Protection against static electricity' [5-10].

The table below contains a list of the more important requirements as regards protection against static electricity in accordance with Polish Standards. These requirements may be adopted in order, among other objectives, to define safe conditions for the use of protective clothing.

Exceeding the specific 'critical' (the highest allowable) values N_{kr} means a hazardous condition has occurred. The real danger occurs when, at the same time, one of the critical values that defines the allowable charging level of a material or an object, in accordance with items 3-6, is exceeded. as is one of the critical values in accordance with items 1-2 in Table 1 that characterise the time of maintaining the charging conditions. When there are no generalised criteria, the highest allowable values of relevant parameters are established individually, in accordance with the expected disturbances, on the basis of the information included in the relevant standards or the technical literature in question.

Following standard PN-92/E-05200 [5], the level of risk caused by static electricity is defined with the index α which expresses the ratio of the maximum value (N_{max}) measured or defined in given conditions to the relevant critical value – the highest allowable (N_{kr}), in accordance with Table 1, which, when exceeded, results in danger:

$$\alpha = \frac{N_{max}}{N_{kr}}$$

It follows that the risk occurs when $\alpha > 1$.

In accordance with standard PN-92/E-05201 [6], the level of risk is considered relatively high if $\alpha > 10$.

Standard PN–92/E-05200 also defines the index of the effectiveness of anti-

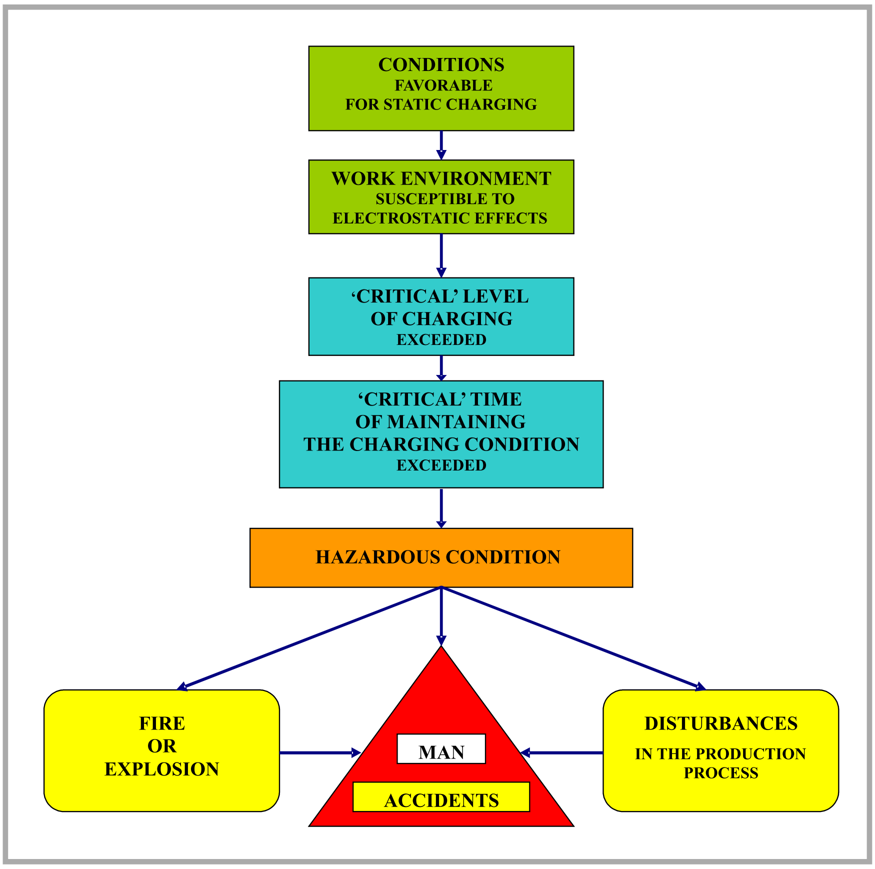

Figure 2. *Factors that determine the static electricity risk in the work environment.*

Table 1. Selected requirements of anti-static protection in accordance with the Polish Standards.

Item	Objects exposed to the explosive risk	Objects not exposed to explosive risk (but exposed to other disturbances)
1.	Leakage resistance (resistance to the ground) of the material, product or object: $R_u \leq R_{u\,kr}$; $R_{u\,kr} = 1 \cdot 10^6\ \Omega$	$R_u \leq R_{u\,kr}$; $R_{u\,kr} = 1 \cdot 10^9\ \Omega$
2.	The decay time of an electrostatic charge: $\tau \leq \tau_{kr}$; $\tau_{kr} = 1 \cdot 10^{-3}$ s	$\tau \leq \tau_{kr}$; $\tau_{kr} = 1 \cdot 10^{-1}$ s
3.	The potential of an electrostatic charge produced on the surface of a dielectric material: $V_p \leq V_{p\,kr}$; $V_{p\,kr} = 1 \cdot 10^3$ V - in the presence of the medium with minimum ignition energy $W_{z\,min} \leq 0.1$ mJ; $V_p \leq V_{p\,kr}$; $V_{p\,kr} = 3 \cdot 10^3$ V in the presence of the medium with minimum ignition energy $0.1\ \text{mJ} < W_{z\,min} \leq 0.5$ J;	$V_p \leq V_{max\ all.}$
4.	Electrostatic voltage between the conductive object (e.g. a human body) and the ground: $U \leq U_{kr}$; $U_{kr} = \sqrt{\frac{W_{z\,min}}{5C}}$	$U \leq U_{max\ all.}$
5.	Intensity of an electrostatic field: $E \leq E_{kr}$; $E_{kr} = 1 \cdot 10^5$ V/m - in the presence of the medium with minimum ignition energy $W_{z\,min} \leq 0.1$ mJ; $E \leq E_{kr}$; $E_{kr} = 3 \cdot 10^5$ V/m in the presence of the mediuma with minimum ignition energy $0.1\ \text{mJ} < W_{z\,min} \leq 0.5$ J;	$E \leq E_{kr}$; $E_{kr} = 2 \cdot 10^4$ V/m or $E \leq E_{max\ all.}$
6.	Energy of electrostatic discharges: $W_w \leq W_{z\,min}$	$W_w \leq 1$ mJ or $W_w \leq W_{w\,max\ all.}$

electrostatic protection η, which is the inverse of index α:

$$\eta = \frac{1}{\alpha} = \frac{N_{kr}}{N_{max}}$$

It follows from this relation that protection is effective if the value of index η is equal to at least ‘1’, i.e. when:

$$\eta \geq 1.$$

It seems that in the model of forecasting the risk posed by static electricity, we may apply a complex probability index of the risk level (marked as ZE) which would express the probability of an accident caused by static electricity.

For individual indexes of the risk level α assigned to the relevant values of the criteria in accordance with the cited table, we might for example adopt an event probability (P) equal to ‘1’ in the case when:

$$\alpha = \frac{N_{max}}{N_{kr}} \geq 10$$

In this way we will obtain the following:

$$ZE = P_1 \cdot P_2 \cdot P_3 \cdots P_n$$

An overview of evaluation methods as regards the anti-static properties of protective clothing material in accordance with EN standards

Currently, three Polish Standards have been harmonised with the European standards [11-13] concerning tests of the electrostatic properties of materials designed for protective clothing.

Standard PN-EN 1149-1 deals with methods of measuring surface resistivity, and standard PN-EN 1149-2 of volume resistance. The methods of testing the electric conductivity of clothing materials should be considered as reasonably justified, although there are plans to remove the evaluation criteria for the results of such tests in the 2nd edition of the European standards in question, which is currently under development, and which will make relevant product certification practically impossible. Such criteria in the form of usage requirements for anti-electrostatic protective clothing are to be formulated as late as in the fifth part of the standard developed within the EN 1149 series. So far there have been no such requirements, which will definitely complicate the interpretation of the test results and limit the practical usability of these standards. The evaluation criteria should have a clear reference to the resistance measurement method which, in turn, should be related to an adequate situation which in practice reflects the expected path of the charge leakage. From this point of view, the recently forwarded proposal to develop a standard IEC document sanctioning the method of measuring electrical resistance between the ends of sleeves or other points on the clothing surface seems unfounded.

The third part of standard PN-EN 1149 was introduced in Poland in 2005 in the original language. This standard has been translated, and there are plans to establish it in Polish at the end of this year; it is the last standard so far developed within the series. It concerns the method of measuring the charge decay time in protective clothing material when charging is achieved in two ways: by rubbing with specific materials and by induction (by the way, the term ‘induction’ is not ideal because of the kind of materials in which the charge is to be ‘inducted’). The proposed measurement methods are designed above all to evaluate a typical textile materials, and especially to test inhomogeneous materials, such as those containing fibres with a conductive core, for which the application of resistance measurement methods is limited.

The methods described in the given standard [13] and in some other publications [15, 19-22] are highly questionable because there is no unambiguous definition of the resistance R and electric capacitance C of the experimental system, and also for the following reasons:

- The time an electrostatic charge is maintained depends on the way the charge is generated, which in this case arises usually by contact and mutual friction between two materials;
- The so-called 'inductive method' is inadequate for the real conditions of protective clothing’s use. Apart from the dislocation of free charges in the material, it causes polarisation; and in this case, the charge decay time may to a great extent be conditioned by the de-polarisation time;
- It is impossible to reproduce on a the laboratory stand the variable conditions that occur when clothes are worn. This is why all generalisations made as a result of such tests seem unjustified. Under real conditions, the charge decay time on the clothing material is first of all defined by the resistance of the leakage path to the ground through the layer of outer clothing, underwear, the human body, shoes and the floor. As there is usually little air conductivity and a low level of the ionisation of the gases that air contains, the share of the charge leakage in this direction is insignificant. Also, the corona effect, due to the small charge potential on the surface of the clothing worn, is in practise very unlikely;
- The direct measurement of the charge decay time on a material is pointless,

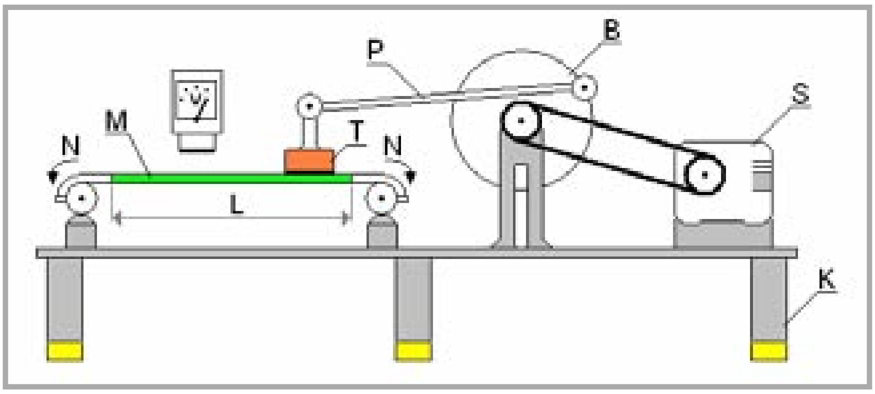

Figure 3. *A schematic diagram of the stand used to test charging caused by one-sided friction of the surface of a band of a clothing material; M – tested material, N – band tension, T – rubbing element with a guide P, S – engine to propel the rubbing element by means of an eccentric drum mechanism B, K – the bearing construction of the appliance.*

considering the fact that depolarisation and the corona effect have no significant share in it. In such a situation, the time during which charging is maintained practically depends only on the material's resistivity and the leakage resistance of the systems discussed. However, the measurement of electrical resistanceis much easier and carries a much lower risk of error than the measurement of the charge decay;

- From the point of view of protection against static electricity, it is much more important to exclude the possibility of dangerous charging of the human body than to define the charge decay time in the clothing material;
- There are no clear evaluation criteria as regards the level of risk on the basis of the test results obtained by means of the methods described above.

Similar objections may apply to the attempts of standardising (among others at IEC) the methods of evaluating the electrostatic properties of protective clothing by applying electrification with the corona effect. This method is completely extraneous to the conditions of use, and electrification means both the movement of free charge carriers and the polarisation and adsorption of gas ions. The charge decay time will undoubtedly derive from these three mechanisms, depending on their particle share. The experimental conditions would only correspond to the real conditions if their simulation was complete, which cannot be ensured by this method.

There have also been attempts to standardise the method of assessing risk caused by the electrification protective clothing, on the basis of measuring the discharge from the surface of a charged material, or defining the energy of this discharge [17, 18, 20, 23]. The application of this method is also insufficiently justified because of the ambiguity of test results caused by the difficulty of reconstructing real conditions, as well as the capacitance relations described in the initial part of this paper and which occur in the human body/material system of the garment worn. This method, when it is well designed, can play a part in basic studies aimed at establishing the allowable levels of the material's charging level. Such a parameter may be measured in an easier and more precise way than discharge energy.

Research procedure proposed by the Institute of Industrial Organic Chemistry

A concept for a method for evaluating the anti-static properties of protective clothing and the materials designed for such clothing was presented at the 5th EL-TEX Symposium 2002 [14]. The verification tests [16] performed later at the Institute of Industrial Organic Chemistry confirmed the practical usability of the procedure developed for the formal classification and qualification for the use of protective clothing, in the light of the requirements in force concerning protection against static electricity. The given procedure formed the basis of the two IEC international standard projects submitted by the Polish Committee for Standardisation in 2003.

The method proposed by the IPO follows on from the assumption that the risk caused by the charging of protective clothing in use is conditioned, first of all, by the following factors:

1. dangerous charging of the human body as a result of friction on the outer layer of the clothing material or as a result of taking off the outer clothes;
2. dangerous charging of the clothes that have been removed;
3. exceeding the 'critical' limit of the time of maintaining the charge by the human body and the clothes that have been removed.

The respective border values are defined by the criteria found in Table 1. In order to perform a correct evaluation of the product, it is sufficient to establish whether in the conditions that simulate the conditions of use it may achieve a dangerous charging level and whether the time of sustaining the electrostatic charge may be sufficient to cause danger or other disturbances. Providing solutions to these problems is, in our opinion, sufficient to develop an adequate certification system for protective clothing. The protection requirements are deemed as fulfilled when the response concerning the possibilities of dangerous charging and/or exceeding the critical time of maintaining the charge is negative.

In accordance with the adopted procedure, the first step is to measure the resistance/resistivity of the clothing material. If its value remains within the allowable limits, and especially if it is close to the human skin resistance, then further tests are unnecessary because such a result guarantees a sufficiently quick decay of charging. As a result, the product receives a positive qualification and is classified as

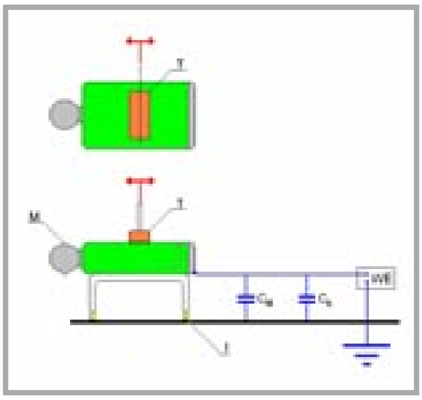

Figure 4. *A schematic diagram of the stand used to test the human body charging which occurs when mechanical friction is generated on the outer layer of clothing; M – mannequin, T – rubbing element, I – insulation ≥ 10^{14} Ω, WE – electrostatic voltmeter, C_M – electric capacity of the mannequin (100 pF÷200 pF), C_b – electric capacitance of the measuring apparatus and connections.*

'anti-electrostatic'. The charging of the clothing material with higher than allowable resistance values is tested at the test station in accordance with the schematic diagram in Figure 3. The friction parameters are selected in such a way that the maximum charging level of the material is achieved under the given conditions. The friction generating/rubbing materials should correspond to the materials that the tested clothing material may come into contact with when it is worn. The tests results are assessed in accordance with the criteria included in Table 1.

The maximum level of charging of the human body achieved as a result of friction on the outer surface of clothing may be established in a similar way. In order to do this, we used an experimental system with a mannequin, whose electrical parameters correspond to the real conditions (Figure 4).

The situations when static electricity is produced by wearing clothes are, in principle, complemented by those when charging occurs at the moment the clothes are taken off. This activity is presented in the scheme in Figure 5. In this system, it is possible to measure time the charging level of the clothes that have been removed and the charging level of the human body (mannequin trunk) of which these clothes have been removed at the same. The evaluation criteria for the tests results can be found in Table 1.

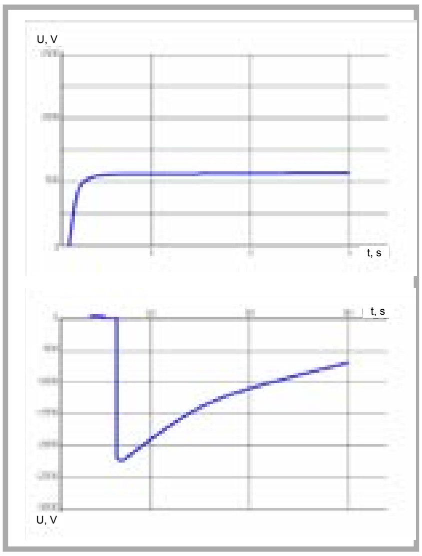

Figure 6. Typical diagrams that characterise the level of charging measured at the simulation stand with a mannequin: a – when friction is generated by natural hair on the outer surface of a work jacket made of D-44 fabrics; b – at the moment of removing the 'Sztygar' work jacket.

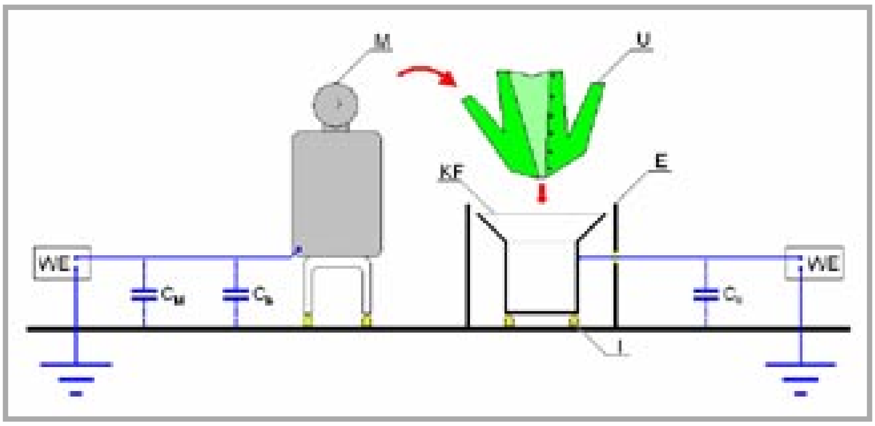

***Figure 5.** A schematic diagram of the test stand used to measure the total charge Q arising in the simulation system on the part of clothing removed from the mannequin trunk (the measurement from the Faraday cage) and the voltage produced on the mannequin trunk (contact measurement); M – mannequin, U – the item of clothing removed, KF – the Faraday cage (a cylindrical container of 50 dm^3), E – grounded screen, WE – electrostatic voltmeter, I – insulation ≥ 10^{14} Ω, C_u – electric capacitance of the system (the Faraday cage, the appliance and connections).*

Typical characteristics that illustrate the body's charging level achieved in the conditions described above on the simulation stand with a mannequin are presented in Figure 6.

Conclusions

1. Electrostatic charging caused by wearing work and protective clothes provokes the risk to human life, health and property that arises as its result of it.

2. The evaluation methods concerning the antistatic properties of protective clothing which have so far been applied are not sufficiently reliable, and so their application in the quality certification of products is limited.

3. It seems that the method proposed by the Institute of Industrial Organic Chemistry creates rational premises for classifying clothing materials with regard to their anti-electrostatic properties and the qualification for use of final goods in the light of the protection requirements concerning static electricity.

References

1. *Kowalski, J.M.: Static Electricity in Technological Processes; Designing Technological Processes – Part 3. The Safety of Chemical Processes, (in Polish), Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2001, pp. 63-84.*
2. *Kowalski, J.M, Wróblewska, M.: Developing Input Data for the Models of Accidents Caused by Static Electricity (in Polish), IPO Report No. EMC 330200014-1, Warszawa 2002.*
3. *Kowalski, J.M, Wróblewska, M.: Defining Critical Parameters Necessary to Evaluate Hazards Caused by Static Electricity in the Work Environment (in Polish), IPO Report no. EMC 330200014-1, Warszawa 2002.*
4. *Kowalski, J.M.: Protection Against Static Electricity in the Work Environment, Work Safety – Science and Practice, (in Polish), CIOP-PIB,(2004) Nr 9, pp.12-16.*
5. *PN-92/E-05200 Ochrona przed elektrycznością statyczną – Terminologia [Protection against static electricity – Terminology].*
6. *PN-92/E-05201 Ochrona przed elektrycznością statyczną – Metody oceny zagrożeń wywołanych elektryzacją materiałów dielektrycznych stałych – Metody oceny zagrożenia pożarowego i/lub wybuchowego [Protection against static electricity – The methods of the evaluation of hazards caused by the electrification of solid dielectric materials – The methods of evaluation of fire and/or explosion hazard].*
7. *PN-92/E-05202 Ochrona przed elektrycznością statyczną – Bezpieczeństwo pożarowe i/lub wybuchowe – Wymagania ogólne [Protection against static electricity – Protection against fire and/or explosion – General requirements].*
8. *PN-92/E-05203 Ochrona przed elektrycznością statyczną - Materiały i wyroby stosowane w obiektach oraz strefach zagrożonych wybuchem – Metody badania oporu elektrycznego właściwego i oporu upływu [Protection against static electricity – Materials and products for use in explosive atmospheres – The methods of tests for electrical resistivity and leakage resistance].*
9. *PN-E-05204:1994 Ochrona przed elektrycznością statyczną – Ochrona obiektów, instalacji i urządzeń – Wymagania [Protection against static electricity*

– Protection of buildings, installations and equipment – Requirements].

10. *PN-E-05205:1997 Ochrona przed elektrycznością statyczną – Ochrona przed elektrycznością statyczną w produkcji i stosowaniu materiałów wybuchowych [Protection Against Static Electricity - Protection Against Static Electricity in the Manufacturing and Use of Explosives].*
11. *PN-EN 1149-1:1999 Odzież ochronna – Właściwości elektrostatyczne – Rezystywność powierzchniowa (Metody badania i wymagania) [Protective Clothing – Electrostatic Properties Part 1: Surface Resistivity -Test methods and requirements].*
12. *PN-EN 1149-2:1999 Odzież ochronna – Właściwości elektrostatyczne – Metoda badania rezystancji skrośnej [Protective Clothing – Electrostatic Properties Part 2: Test method for measurement of the electrical resistance through a material (vertical resistance)].*
13. *PN-EN 1149-3:1995 (U) Odzież ochronna – Właściwości elektrostatyczne – Metody badań do pomiaru zaniku ładunku [Protective Clothing – Electrostatic Properties Part 3: Test methods for measurement of charge decay].*
14. *Kowalski, J.M, Wróblewska, M.: The Concept of the Quality Evaluation Method of Anti-electrostatic Properties of Materials Used in Protective Clothing, (in Polish), Proceedings 5th International EL-TEX Symposium 2002, pp. 140-148, ISBN 83-911544-2-4, Łódź, Nov. 2002, Ed. Instytut Włókiennictwa, Łódź 2002.*
15. *Holdstock P.: Electrostatic Measurements on Textile Materials, ibid. pp. 120-129.*
16. *Wróblewska, M, Kowalski, J.M.: Developing an Evaluation Method and Qualification Criteria of Use for Clothes in View of the Anti-static Protection Requirements, Part 3. Classification and Qualification Tests of the Selected Textiles and Protective Clothes in Accordance with the Procedures Included in the Developed Draft Standards: PN-E-05206 and PN-E-05207 (verification of methodology), (in Polish), unpublished IPO Report no. EMC 01600012.*
17. *Wilson N.: The Nature and Incendiary Behaviour of Spark Discharges from Textile Surfaces, J. Electrostatics, vol. 16, 231-245 (1985).*
18. *Haase I., Loebel W.: The Problems Concerning the Evaluation and Static Behaviour of Textile Products Made of Conductive Fibres, (in Polish), Proceedings of 2nd International Symposium EL-TEX 1996, Łódź 1996, Ed. Instytut Włókiennictwa/Centralny Instytut Ochrony Pracy, Łódź/Warszawa 1996, pp. 69-83.*
19. *Holdstock P.: Assessment of the protective clothing made of conductive fibres, as regard its electrical properties, (in Polish), ibid. pp. 83-96.*
20. *Ptasiński L.: Assessment of Textile Products concerning Static Discharges, ibid. pp. 97-106.*
21. *Vogel C., Haase J.: Comparison Testing of Electrostatic and Electrodynamic Behaviour of Typical inhomogenous conductives Textile Products, (in Polish), Proceedings of 3rd International Symposium EL-TEX, Łódź 1998.*
22. *Poźniak R., Pasternak A.: Charge decay time as the way for the assessment of antistatic properties of plastics, (in Polish), ibid. 95-100.*
23. *Vogel Ch. et al.: Testing of ignitability of protection clothing textiles to static discharges,(in Polish), Proceedings 4th International Symposium EL-TEX, Łódź 2000.*

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