TEST METHOD TO MEASURE SURFACE VOLTAGES CREATED ON TRIBOCHARGING INHABITED GARMENTS

Foreword:

Many of the risks and problems that arise with garments from static electricity relate to the surface voltages created by tribocharging actions. The present document describes a method of test to measure such surface voltages in a way that enables this feature of the electrostatic suitability of garments to be assessed.

INTRODUCTION:

Significant voltages may arise on the surfaces of garments when these are tribocharged by contact or rubbing actions. The level of these voltages will be affected by the nature of the garment material, by the contact or rubbing material and by the speed and pressure of the tribocharging action. To remove the influence of the material and the speed and pressure of rubbing it is appropriate to express garment performance in terms of the surface voltage created per unit of triboelectric charge transferred. The voltages expected in practical situations may then be predicted from knowledge of the charge transferred in various practical activities.

With many materials, such as those made of natural fibre, the surface voltage may fall away quite quickly after the cessation of rubbing. The present method of test hence includes measurement of both the initial surface voltage created at the moment of separation of the charging surface and the way in which this voltage subsequently decays.

The method of test is specifically aimed at measurements while garments are being worn – that is for 'inhabited garments'. This is the situation of practical relevance. Measurements on fabrics and uninhabited garments may not relate directly to results with inhabited garments.

The method of testing is equally applicable to workwear, cleanroom garments and consumer clothing.

The method of test described does not aim to give information of the ability of garments to provide shielding against the voltages that may arise on undergarments or on the risk of occurrence of energetic static discharges that might arise if the garment of a highly charged person approaches an earthed projection.

1. SCOPE

This document describes a method to measure the surface voltages created on inhabited garments by triboelectric charging. The method is equally applicable to garments made from all types of material. Materials may be homogeneous or non-homogeneous and may include surface or core conductive threads or fibres.

2. INFORMATIVE REFERENCES

References to published papers that provide relevant background information are listed in Annex A.

3. DEFINITIONS

For the purposes of this document the definitions presented in Annex B will apply.

4. TEST METHOD

4.1 Background

Garments will be suitable to avoid risk of problems from surface voltages created by static electricity if either of the following criteria are satisfied:

- if the charge separated on the garment surface by contact or rubbing actions can dissipate to a low level within the time it takes the contacting surfaces to separate
- if the capacitance experienced by charge on the surface is sufficiently high that only low surface voltages can arise. This also requires that the rate of charge dissipation is sufficient to avoid any progressive build up of surface voltage at successive charging actions.

The method of test described provides the data needed to assess the suitability of garments to both the above criteria.

4.2 Basis for test method

The test subject stands on a charge measurement support plate wearing the test garment. The selected test area is rubbed by single swipe of a suitable test material surface while the surface voltage of the rubbed area is measured by an electrostatic fieldmeter. Recordings are made of the quantity of charge transferred by the charging action, of the local surface voltage created over the area rubbed and of the way this surface voltage decays with time after charging.

4.3 Apparatus

4.3.1 Charge Measurement Support Plate:

The support plate for the person tested to stand on shall be a metal plate of at least 300x300mm supported at its corners by rigid insulators from an earthed metal under-plate.

Note: *This configuration avoids risk of charges arising by induction, piezoelectric or tribocharging at any slight changes in the standing position.*

4.3.2 Support Stand:

Physical support of the upper part of the body of the test subject is necessary to ensure stability of the fieldmeter to surface spacing for good quality measurements. This is particularly important for recording the decay of surface voltage after charging.

The support might be to the middle area of one or both arms and maybe also at the back of the neck. Support is conveniently provided by a shaped wood surface mounted on good quality insulation from the support stand. Minor body movement on the supports shall be checked to show negligible charge signals.

The Support Stand also provides rigid support for the fieldmeter at its working distance from the test area.

Note: *The mounting of the fieldmeter shall be from the back part of the fieldmeter to minimize influence of the support structure on observations.*

4.3.3 Charging Paddle:
Charge is transferred to the test area by a single swipe of an area of a suitable charging material surface. It is convenient to use a charging material such as a wool or cotton fabric wrapped around the area of a wooden spoon with the spoon handle held in the hand of the tester. The use of such a dissipative material on a dissipative support makes it easy to ensure that the charging surface is charge neutral before each test.

4.4 Instrumentation:
4.4.1 Charge transfer measurement:
A virtual earth charge measurement instrument or circuit is required able to measure quantities of charge transferred charge up to ±100nC with a resolution of 0.1nC with an accuracy better than 5%. An analogue output signal is required so the time variation of observations can be displayed and recorded.

4.4.2 Surface voltage measurement:
A 'field mill' type electrostatic fieldmeter able to measure surface voltages to ±2000V with a resolution better than 1V at a frequency response better than -3dB at 30Hz and at a separation distance of at least 50mm. An analogue output signal is required so the time variation of observations can be displayed and recorded. A relationship needs to be established between fieldmeter signal amplitude and surface voltage at the separation distance chosen for conduct of the tests.

The fieldmeter is supported from its back area by the Support Stand so that its sensing aperture is stable at the required separation distance from the garment test surface area.

The separation distance for measurement needs to be sufficiently large for the charging paddle to easily enter and leave the test area between the garment surface and the fieldmeter during test swipe operations.

4.4.3 Test environment:
The test environment shall be free of surfaces and materials that are, or may become. electrostatically charge during the conduct of tests. The environment shall be free of alternating electric fields – and be shown to be so by observations with the fieldmeter and its recording system.

The 'tester' shall be earthed and shall wear a full overall that is known will not have any significant surface voltage created on its surface by test activities that might interfere with observations at even the most sensitive level. There shall be no exposure of items of clothing that might cause such interference.

4.4.4 Signal display and recording:
Charge transfer and surface voltage signals are to be displayed and recorded on a digital storage type oscilloscope operating in 'single shot' mode. Triggering is most appropriately made from the charge measurement observations.

The display and recordings of surface voltage and charge level observations shall be easily visible to the test personnel over a period of at least a few seconds before the start of a test. This will ensure that good stability of pre-event signals can be achieved.

The relationship between surface voltage values and recorded signals needs to be established. Although the fieldmeter itself may have been formally calibrated (for example to BS7506: Part 2: 1996) this calibration may not apply because the area charged will be of limited and will be surrounded by quasi-neutral surfaces backed by the earthed surface of the test subject body. It is appropriate to make in situ calibration by applying a defined voltage (via a shielded cable) to a patch of conducting foil on the garment surface of similar area to that charged by the paddle.

4.4.5 Environmental atmospheric conditions

The electrostatic characteristics of materials often vary with temperature and relative humidity. It is hence important that the values of these parameters are measured in the test environment. Garments shall be conditioned in the selected environmental conditions for at least 24 h before testing and measurements.

For standardized measurements temperature and humidity values need to be controlled to particular combinations of values as listed in the table below:

Temperature °C			**Relative humidity %**
1	High relative humidity	23 ±2	50 ±3
2	Low relative humidity	23 ±2	12 ±3

Table 1: Environments for conditioning and testing

Note*: If garments are to be used in conditions outside this range of the above standard values (in particular at lower levels of humidity) then their characteristics must be checked under the most extreme conditions likely to be encountered and these conditions reported.*

5. TEST PROCEDURE

The test subject in the selected garment stands on the charge measurement support plate and rests on the insulated support(s). The separation to the fieldmeter from the test area surface is checked and the fieldmeter signal is checked to be suitably low and stable. The tester is clothed in a suitably good charge dissipative overall and is bonded to earth. The charge measurement circuit is then zeroed and the digital storage oscilloscope set to be ready to go in single shot mode.

When pre-test observations are suitably stable the tester positions the charging paddle near the area to be tested and then makes a single quick swipe of the paddle against the surface of the test area under the fieldmeter. As part of the swipe action the paddle is swung immediately and quickly well out of the way. The test subject remains steady on the supports so that both the increase in surface voltage and the decay of surface voltage can be recorded.

Ten tests are made for each test area so there is opportunity to have confidence in the averaging and calculation of errors for each set of tests.

The test area of the garment surface may hang close to the body or hang away from it. In such situations it will be wise to make sets of tests in both conditions. Proximity to the body surface is likely to reduce levels of surface voltage.

Measurements shall be made on a number of relevant area of the garment surface.

A photograph of a typical test set up is shown in Figure 1.

6. ANALYSIS OF OBSERVATIONS

6.1 Charge measurement:
The quantity of charge transferred to the garment surface by the swipe action is measured from the change of measured charge signal recorded from just before the swipe charging action to the level just after.

6.2 Peak voltage:
Peak voltage values are measured as the difference in surface voltage value from the average level before charging to the peak value observed following the charging action.

Note: *A very short duration pulse is often observed as the charging paddle rises from the garment surface and charge on it couples more closely to the fieldmeter than the charge transferred to the garment surface. This brief pulse is of opposite polarity to the following excursion that leads into the slow decay of surface voltage as charge dissipates over the garment surface. An example of recorded signals is shown in Figure 2.*

6.3 Decay time measurement:
Decay times are measured in seconds from the peak of the voltage excursion, observed as above, to 1/e (37%) and/or 10% of that initial peak voltage value.

Where decay times are long, more than 20s, it will be useful to estimate and record likely decay time values for each test.

6.4 Presentation of results
For each test the quantity of charge transferred, the peak voltage and the decay time shall be listed. Foe each set of charge and peak voltage measurements a value of voltage per unit charge shall be calculated as volts per nanocoulomb. For the number of tests conducted (preferably at least 10) the average standard deviation values shall be calculated for volts per nanocoulomb and decay time.

6.5 Assessment of results
The results of measurements made will be judged in relation to the practical application as to whether:
a) charge decay times are less than a set target value
b) if charge decay time is longer than the target value then whether both the surface voltage per unit of charge is below a target value and also that the decay time is at least a longer target value.

7. TEST REPORT

The test report shall include at least the following information:

a) date and time of measurements and identity of testing organization

b) description and/or identification of garment and material tested

c) description of paddle charging material and charging conditions used

d) identification of each of the areas of the garment tested

e) average values and standard deviations for volts per naoncoulomb and decay times for each of the garment areas tested

f) temperature and relative humidity at the time of testing and time for which samples were exposed to these conditions before testing

g) identification of instrumentation used (e.g. type and serial number) and date and certificate details of most recent calibration

Figure 1: Set-up for testing inhabited garments. Test subject standing on charge measurement plate with arm supported on insulated support. Test operator ready to tribocharge area of sleeve directly in front of the fieldmeter.

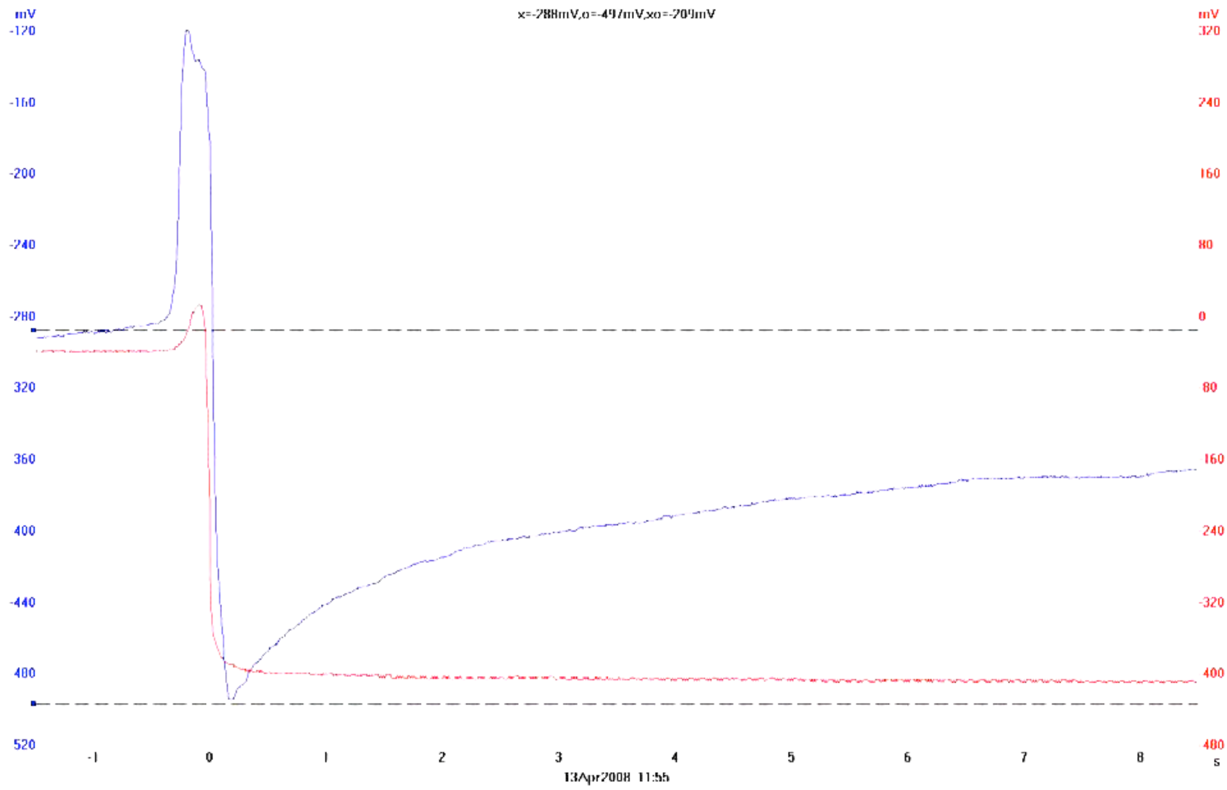

Figure 2: Example of recording of surface voltage and body charge from tribocharging sleeve area of a cleanroom garment.
Surface voltage (blue trace) 1mV = 1V surface potential. Charge (red trace) 100mV = 10nC. Initial positive excursion of JCI 140 fieldmeter is response to positively charged wool surface moving quickly away from sleeve from in front of the fieldmeter.

Annex A: REFERENCES (INFORMATIVE)

1) J. N. Chubb, P. Holdstock, M. Dyer *"Predicting the maximum voltages expected on inhabited cleanroom garments in practical use",* Institute of Physics Conference 'Electrostatics 2003' IoP Conference Series 178 2004 p131

2) J. N. Chubb, P. Holdstock M. Dyer *"Predicting the maximum surface voltages expected on inhabited cleanroom garments in practical use"* ESTECH 2003, Contamination Control Division, Phoenix, Arizona.18-21 May, 2003 Journal of the IEST Vol. 47 No. 2 2004'.

3) P Holdstock, M Dyer, J N Chubb *"Test procedures for predicting surface voltages on inhabited garments"*. EOS/ESD 25th ANNUAL SYMPOSIUM. Riviera Hotel, Las Vegas, Nevada, USA 21-25 September 2003. J. Electrostatics 62 2004

4) J N Chubb *"Tribocharging studies on inhabited cleanroom garments"* J. Electrostatics 66 2008

Annex B: (Normative)
DEFINITIONS

B1 capacitance loading
the surface potential achieved per unit quantity of charge for a thin film of a good dielectric divided by the surface potential achieved per unit of charge with a similar surface charge distribution on the test material

B2 charge decay
the migration of charge across or through a material leading to a reduction of surface potential at the area where the charge was deposited

B3 charge decay time
The time from the initial surface voltage level created by the charge put on to the surface (100%) to a selected, and a stated, end point fraction of this.

***NOTE**: Convenient decay times for comparison between materials are the time from the initial surface voltage to 1/e of this (e is the base of the natural logarithm 2,7183) and to 10% of this.*

***NOTE**: As the rate of charge decay may vary greatly during the progress of decay it is very useful to record the form of the variation of surface voltage with time.*

B4 conductive material
a material with a high mobility of charge so that the potential on the surface is retained for only a very short time

***NOTE**: The charge decay time of conductive materials is generally less than 0.05 s.*

B15 corona
the generation of ions of either polarity by a high localised electric field

B6 dissipative material
a material which allows charge to migrate over its surface and/or through its volume in a time that is short compared to the time scale of the actions creating the charge or the time within which this charge will be effective or will cause an electrostatic problem.

***NOTE**: For general avoidance of risks and problems in operations involving manual activities the decay time from the initial surface voltage at 0.1s to 10% of this needs to be less than 1.0 s. To avoid the risk of incendiary sparks the decay time needs to be longer than 0.01s.*

***NOTE**: The dissipative capability of a material does not relate to its ability to remove charge from a conducting item in contact. This ability is determined by resistivity type measurements.*

B7 insulative material
a material with very low mobility of charge so that charge on the surface is retained there for a long time

***NOTE:** The charge decay time of insulative materials is generally greater than 10 s.*

B8 relative capacitance
(see capacitance loading)