TEST METHOD FOR MEASURING SURFACE VOLTAGES CREATED AT TRIBOCHARGING INHABITED CLEANROOM GARMENTS

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1. OBJECTIVE

To assess the surface voltages that may arise locally on cleanroom garments by tribocharging actions in practical use

2. METHOD

To strike a scuffing blow with a charge neutral Teflon rod to an area of the cleanroom garment to be tested to create local tribocharging. To measure the resulting quantity of charge transferred, the local surface voltage created and the rate of decay of the surface voltage.

3. TEST INSTRUMENTATION AND FACILITIES

Electrostatic fieldmeter to measure local surface voltage at the tribocharging location, 2000V FSD at 100mm. At 100mm separation a 10% error in distance gives 5% error in reading. The fieldmeter needs to be a 'filed mill' type instrument with a frequency response better than –3dB at 20Hz.

Charge measurement unit virtual earth charge measurement unit with 200nC FSD

Digital storage oscilloscope to display and record the variations with time of charge and surface voltage signals from several seconds before charging to between 10 and 20s after.

Operator The 'operator' is the person who wears the garment to be tested. Where the garment is normally worn with special boots or footwear this should also be worn. If these are not worn, then the operator should be in bare feet or with natural fibre socks.

Operator support plate to enable charge transfer to the operator to be measured. The operator stands on a metal plate insulated from an underlying earthed support plate by localised insulators. Discrete insulators are used to avoid risks of tribocharging at the support insulation or signals arising from varying capacitance to nearby charged surfaces. The standing plate surface is connected by coax cable to the charge measurement unit.

Operator support stand to steady the upper part of the operator body so that garment surface voltages can be measured accurately and with confidence over the period from before scuff charging to at least 10s after. A convenient support point is top of the lower arm. This provides good stability for scuff charging tests on the upper arm area or on the front of the body.

A robust tripod can provide a convenient support stand. From this, or other support, a shaped wooden rest for the arm of the operator is mounted with high quality insulation. The insulation is best shielded by earthed surfaces. The fieldmeter to measure garment surface voltage is best mounted on the same basic support. so there is good positional stability of the fieldmeter relative to the test area of the garment. A general test arrangement is shown in Figure 1 below.

Teflon tribocharging rod 300mm long and 25mm diameter with a metal handle end for holding in the hand. It may be desirable to clean the striking area of the rod from time to time. Isopropanol is a convenient cleaning solvent.

Charge neutraliser A radioactive neutraliser bar (Po) is needed to remove charge from the whole area of the Teflon rod before each test. Charge neutrality can be checked by holding the rod in front of the fieldmeter sensing aperture. If garment surfaces show significant initial surface voltages it is necessary to neutralise the test area of the garment and any other areas where retained charge will affect the stability of observations.

Tester The 'tester' needs to be dressed in an overall that will not retain any surface potential. The tester must be bonded to earth.

4. TEST CONDITIONS

Environmental conditions of 20C 40%RH are appropriate to match environmental conditions likely to apply in cleanrooms.

5. TEST PROCEDURE

Two people are needed to carry out the tests: the 'operator', who wears the test garment and stands on the charge measurement plate and the 'tester' who hold the Teflon rod and scuffs this rod against the test area immediately in front of the fieldmeter sensing aperture.

The operator wears the cleanroom garment, fully zipped up, over normal indoor clothing – for example shirt and trousers. Matching cleanroom boots (where available) are worn over normal shoes. If special boots are not worn then the operator should stand in bare feet or natural fibre socks. The tester wears a static dissipative coverall and is earth bonded via a wrist strap.

The operator stands on the charge measurement plate and stabilises the upper part of the body by resting an arm on the wood support mounted on insulation from the support stand.

The test area is chosen a) so it will remain physically stable relative to the fieldmeter during the conduct of testing, and b) so it can be struck a clean glancing blow by the end of the Teflon rod with fast and easy removal of the rod out of sensing range of the fieldmeter.

After the 'scuff charging' the Teflon rod must be swung well away from the test area into an electrostatically shielded position so that the charge on its will have no influence on the fieldmeter observations. As fieldmeter readings need to be stable to better than 1V over the whole test period the earthed shielding needs to be quite effective.

The fieldmeter is positioned with its sensing aperture 100mm from the test area. This distance allows the garment to be struck directly in front of the fieldmeter sensing aperture. It also gives reasonable accuracy of measurement because at this distance a 10% error in distance only gives 5% error in reading.

Figure 1: Operator in cleanroom garment with arm steadied on insulated rest from tripod support.

The fieldmeter is set for 2000V FSD sensitivity at 100mm and charge measurement for 200nC FSD. The digital storage oscilloscope may be initially set to display and record maximum surface voltages in the range 50 to 1000V FSD positive and maximum charge of 50nC FSD positive. A total timebase sweep of 5 to 20s is convenient with a pre-trigger display of about 5s displayed and recorded. The timebase is best triggered from the charge signal at a positive level of 2-5nC.

The Teflon rod must be charge neutralised before each and every test and its neutrality tested over the whole area of the rod by bringing it close to the sensing aperture of the fieldmeter.

A test is started by zeroing the charge measurement circuit and noting that both charge and voltage measurements on the oscilloscope displays are remaining steady.

A test is made by a single clean scuff charging impact on the test area. The surface voltage will make a large negative swing followed by a positive swing above the pre-event level and this value will decay away. The charge measurement trace will show a positive excursion and remain at a higher level. The measurements made on the recorded signals are:

- the peak voltage of the fieldmeter signal relative to the pre-event level
- the time for the fieldmeter signal to fall away to 1/e of its peak value relative to the pre-event level
- the increase in the charge measurement signal

At least 10 tests should be made for each inhabited garment. Testing should include some light and some heavy impacts. Higher quantities of charge may be transferred by coupling the impact action with some twisting the rod at the time of impact.

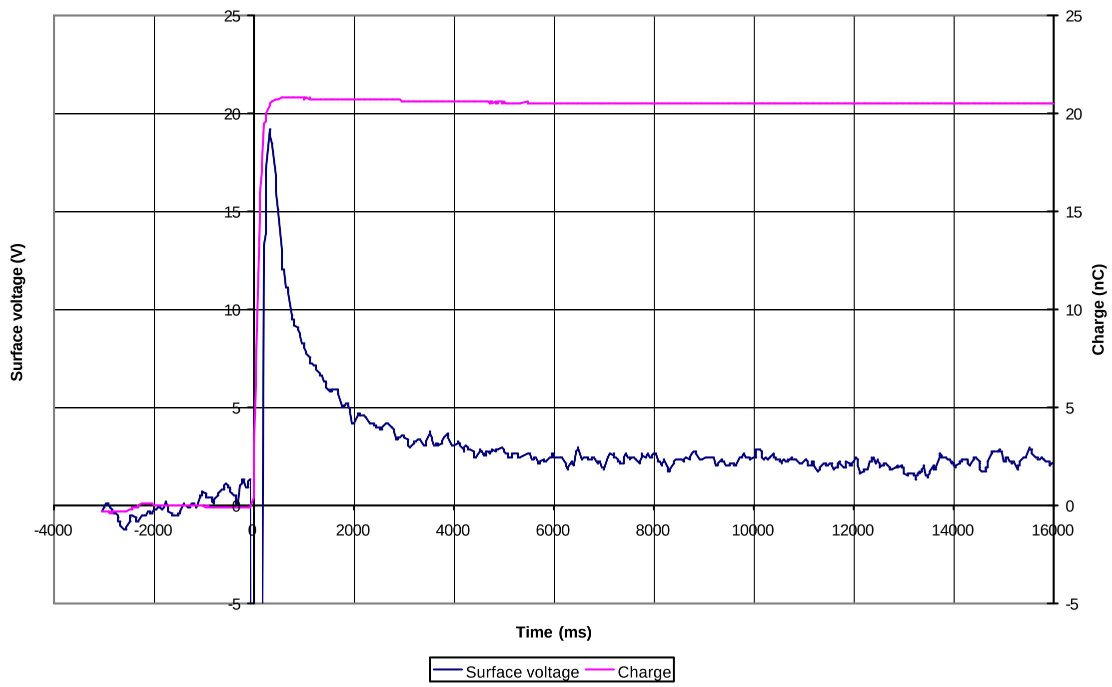

Figure 2: Example of recorded voltage and charge signals

6. PRESENTATION OF RESULTS

The performance of the garment is best expressed by both:

- the average and standard deviation of charge decay times (to 1/e)
- the average and standard deviation of the quantity of charge per unit surface voltage generated. This is equivalent to the 'apparent capacitance' exhibited by the garment surface as:

$$C_{apparent} = Q / V_{peak}$$

Where measurements have been made of corona charge decay times and capacitance loading values for sample areas of the garment fabric [1] it is useful to compare the peak voltage values observed with those predicted from the sample area tests. Comparison may be made numerically or graphically.

Studies have indicated that the maximum local surface voltage V_g (volts) that will arise locally on the surface of an inhabited garment when this is rubbed can be predicted from the quantity of charge q (nC) transferred by the rubbing action and $CL_{(q=0)}$, the capacitance loading value with open backing at q=0, according to the empirical relation:

$$V_g = f\, q / (CL_{(q=0)})$$

where the factor f is around 75. A 'Test Method' has been developed for these measurements [1].

Numerical comparison may be made from the ratio of surface voltage observed to that predicted for unit charge (Q = 1nC) as:

$$V_{(peak\ @\ 1nC)} / V_g = (CL_{(q=0)}) * f / C_{apparent}$$

The factor f has been chosen empirically to ensure that no experimental values will exceed the calculated value of V_g. To this end there should be at least one 'standard deviation' space. This means the following relation should be satisfied:

$$(V_{(peak\ @\ 1nC)} + \mathrm{St\ Dev}) / V_g < 1$$

In addition to this numerical comparison it may be useful to present individual observations on a graph of initial peak surface voltage versus corresponding quantity of charge transferred. Predicted values of maximum surface voltage can then also be displayed on the same graph.

Comparisons are also usefully made between charge decay times observed from tribocharging studies on inhabited garments and values obtained from corona charge decay tests on fabric samples.

[1] J. N. Chubb *"Test method to determine the limitation of surface potential created by electrostatic charge retained on materials"* Document going forward for consideration by IEC TC101 and available on JCI Website at: www.jci.co.uk/Measurements/RetainedCharge.pdf