

# "Can cleanroom garments create electrostatic risks?"

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*Measurements are reported showing that appreciable surface voltages can arise on inhabited cleanroom garments when these are locally charged by triboelectric rubbing. Surface voltages can be up to 1000V relative to the person within the garment. It is shown that the performance of the range of inhabited garments tested does relate to features that can be measured on sample areas of the fabrics. The feature of prime importance is the capacitance experienced by charge on the fabric surface. Resistivity is shown to be irrelevant.*

## 1. INTRODUCTION

The paper describes measurements of the voltages that may arise on the surfaces of cleanroom garments during work activities. If these are too high and last too long then there can be risks of damage to nearby sensitive devices. Apart from assessing voltages likely to occur the work also aimed to find what relation the surface voltages have to features of garment fabric construction and the opportunity to assess these features by localised testing.

Electrostatic charges will be separated when garment surfaces are rubbed against other surfaces around the work area. This might be a sleeve or body area of a garment. The charge left on the garment will create voltages depending on:

- the quantity of charge transferred
- how quickly charge can move away from its source area
- the capacitance experienced by the charge
- whether the garment panel rubbed has a good linkage path to earth
- whether the person's body inside the garment is bonded to earth

The quantity of charge separated will depend on the garment fabric, the material of the other surface that is rubbed and the mechanical speed and intensity of the rubbing action. It is necessary to have information on maximum likely quantities of such charge in practical work activities. However, from the point of view of assessing the suitability of garment fabrics and construction it is important to have information on a per unit charge basis:

- a) so that fair relative comparisons can be made between observations
- b) so that realistic estimates can be made on maximum voltages expected in different operating situations.

'Apparent surface voltages' may perhaps also arise from charges on clothing between the outer garment and the person's body and on the body itself. The term 'apparent surface voltage' is used because it could be that there is no actual nett electrostatic charge on the outer garment surface, but items nearby experience the influence of electric fields from charges on underlying garment surfaces that are not shielded by the outer garment. Where charge separation occurs by rubbing between the outer garment and the next inner surface this will have little external influence unless the outer garment is loose so that there can be appreciable distances between the separated charges. If the garment is bonded to earth but the person's body is not then there could be a question of shielding of body voltages by the garment material.

## 2. SURFACE VOLTAGES ON INHABITED GARMENTS

The present studies have aimed to match normal operational experience as far as practicable commensurate with making good quality electrostatic measurements. A person (operator) has

been clothed in a number of cleanroom garments and boots and stood inside a simple electrostatic cage. Electrostatic charge was separated at a local position on the surface of the garment by striking it with the end of a charge neutral Teflon rod ('scuff' charging [1]). The area chosen was the upper arm as this was convenient for striking and measurement. An electrostatic fieldmeter (JCI 140) was used to measure the surface voltage created locally at the area struck by the Teflon rod. The measurement separation distance was 100mm. This allowed the garment to be struck directly in front of the fieldmeter sensing aperture so observations related to the area over which charge was separated. It also gave opportunity for reasonable accuracy of measurement because at 100mm separation a 10% error in distance only gives 5% error in reading. It needs to be noted, of course, that as the area of initial charge is limited the reading by the fieldmeter, set up to show the voltage on an extended surface, will be an underestimate of the immediate local voltage. The quantity of charge transferred was measured by having the clothed operator stand on an isolated plate connected to an electrostatic voltmeter (JCI 148). Knowing the capacitance of the operator system (155pF) the quantity of charge can be calculated from the modest increase in body voltage when the garment is struck. Subtraction of the body voltage from the surface voltage observations gives the voltage difference between the garment surface and the body.

Measurements of surface and body voltages were recorded on a digital storage oscilloscope with a digitisation noise about 5V p-p. Signal noise was within 20V p-p and inspection of recordings allowed assessment of voltage values with confidence within a few volts. Both voltage observations had a frequency response of 30Hz.

The garments were standard cleanroom coveralls and boots worn over normal shirt and trousers - as is usual. The garments had been laundered, as would normally apply. The following table lists garment details.

**Table 1: Test garment construction**

	<b>Grid</b>	<b>Thread</b>
A	5mm grid (white)	Core conductor 1
B	5mm grid (white)	Surface conductor 1
C	2mm grid (white)	Core conductor 1
D	2.5mm grid (white)	Surface conductor 2
E	5mm grid (white)	Core conductor 1
F	20mm stripe (blue)	Surface conductor 3

The garments were manufactured to a normal commercial design. The garments were laundered 5 cycles to ISO 6330 procedure 5A at 40C, followed by a final low temperature tumble dry.

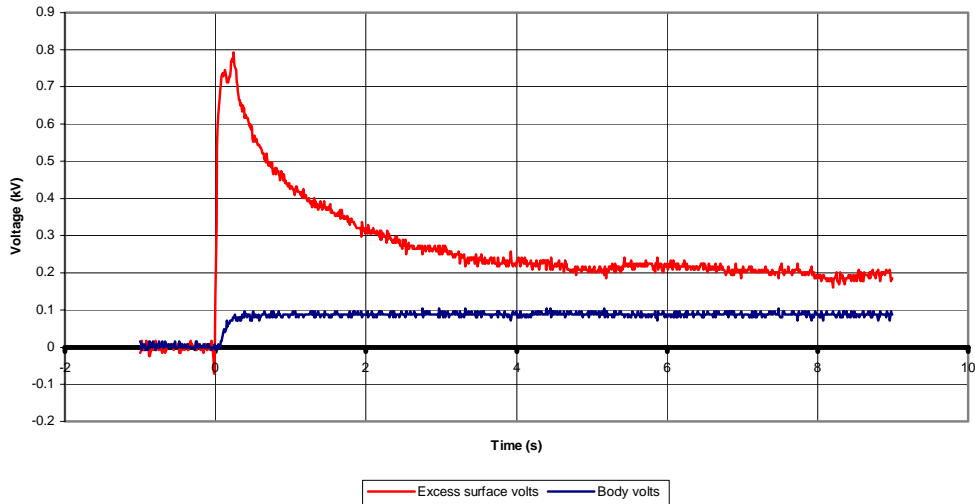
Measurements were made in a controlled environment of 23C and 40%RH in the test laboratory of British Textile Technology Group (BTTG), Manchester, UK.

The local area characteristics of the garment fabric were separately measured by surface resistivity (to prEN 1149) and by corona charge decay (to IEC 61340-2-1) in combination with capacitance loading [1].

### 3. RESULTS

An example of the variation of the voltage of the surface of an inhabited garment relative to the body within is shown below. The graph also shows (in blue) the body voltage signal that was used for measurement of the quantity of charge transferred.

### Garment F



The following table summarises the main results.

Garment	Initial peak voltage (V)	Quantity of charge (nC)	Estimated decay time (s)
A	15-110	12.7-18.6	0.6-5
B	10-80	11- 20.4	2- 5
C	12	12-15.8	3
D	20-60	25-28.5	2-3
E	10-57	19.2-31	0.5-1
F	790-1000	13-14.8	3-10

While observations covered quite a range of values it was clear that garment F shows surface voltages about 10 times higher than those observed for any of the other garments. These surface voltages are such as to provide a route to electrostatic risks – for example, via discharge of induced charges. All the other voltages seem moderately low. However, the quantities of charge transferred are modest and the dependence of surface voltage with quantity of charge at plausible maximum practical levels needs to be checked.

#### 4. MEASUREMENTS ON SAMPLE AREAS

The results of surface voltage measurements on the various inhabited garments are compared in the following histogram with the values of charge decay time, capacitance loading and resistivity measured on sample areas of the garments.

Measurements of charge decay and capacitance loading<sup>1</sup> were made with corona charging using the approach and instrumentation that has been described in published papers [1,2]. In these measurements it was observed that while charge decay times (peak voltage to 1/e of this) were fairly independent of quantity of charge the capacitance loading varied linearly with the quantity of charge above a zero charge level. The zero charge level and slope varied between materials.

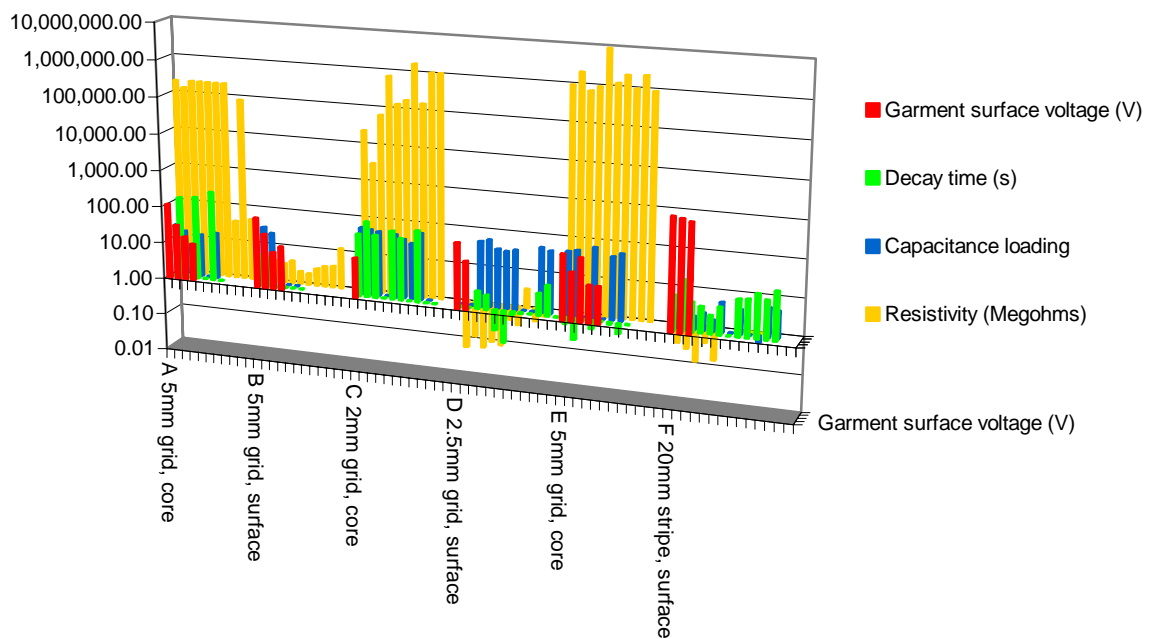
<sup>1</sup> 'Capacitance loading' is the relative capacitance experienced by charge on the material compared to that for a similar distribution and quantity of charge on a thin layer of a good dielectric - where the capacitance is essentially that of just the spatial distribution of charge and any influence of proximity of nearby earthy surfaces. The enhanced capacitance to the deposited charge probably arises from coupling of the deposited charge to some structural feature in the material. This might be a relatively conductive layer or pattern of threads or a high dielectric constant feature. Coupling may link to nearby earthy surfaces or just to a larger effective area of material.

The results shown in the histogram below were obtained with comparable quantities of charge for the tribocharging garment tests and for the corona charging studies on sample areas of the garments.

The main points that arise from the above measurements are that:

- 1) The highest surface voltage for an inhabited garment was observed with a 20mm stripe – at around 1000V. Surface voltages for 2.5 and 5mm grid pattern garments much lower (10-100V) but no clear relation is yet shown within 2.5 and 5mm grid pattern or fabric features.
- 2) Measurements on sample areas, with comparable quantities of charge, show that:
  - a) capacitance loading is much lower for 20mm stripe than for closer grid spacing of conductive threads.
  - b) capacitance loading is lower for 5mm grid patterns than for 2.5mm grid, except when an antistat treatment is present (fabric E).
  - c) the performance of the garments tested related primarily to the capacitance loading values measured on sample areas - and not to decay times
  - d) surface ‘resistivity’, as measured, is clearly not a relevant performance feature

Surface voltages on inhabited garments compared to decay times, capacitance loading and resistivity values for sample areas



## 5. CONCLUSIONS

It is shown that voltages can arise on the surfaces of cleanroom garments that could present electrostatic risks to sensitive devices nearby by the induction electric fields created.

Of the six garments tested, one garment gave surface voltages over ten times those observed with the other five garments. The differences in performance for the garments tested related primarily to the capacitance experienced by charge on the fabric surface - as shown by sample area measurements. Capacitance loading is mainly determined by such fabric design features as the spacing between conductive threads and whether the fabric has an antistat treatment. Resistivity is clearly not a relevant feature determining surface voltage performance.

This work enhances present knowledge on practical electrostatic risks by showing how measurements can be made on cleanroom garments ‘as used’. The results of such work is important as it provides a reference basis for assessment of fabrics and of garments for cleanroom use and for the design of fabrics to achieve target requirements. It will also have

relevance to the choice of materials to be used for personal protective clothing for work in flammable atmospheres.

### **References**

[1] J. N. Chubb “*Measurement of tribo and corona charging features of materials for assessment of risks from static electricity*” Trans IEEE Ind Appl 36 (6) Nov/Dec 2000 p1515-1522

[2] J. N. Chubb “*New approaches for electrostatic testing of materials*” (ESA Annual meeting, Brock Univesity, Niagara Falls, June 18-21, 2000) J. Electrostatics 54 March 2002.