

"Can one predict the surface voltages that will arise on cleanroom garments by tribocharging?"

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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. It is shown that the performance of the variety of inhabited garments relates primarily to the 'capacitance' experienced by charge on the fabric surface - as measured using corona charging on sample areas of the fabric. Resistivity has been shown to be irrelevant.

1. INTRODUCTION

The paper describes measurements of the voltages that can arise on the surfaces of cleanroom garments during work activities. If voltages are too high and last too long then there can be risks of damage to nearby sensitive devices. It is therefore important that the choice of fabric and garment construction ensure that garment surface voltages remain suitably low.

The present work had two main objectives:

- to establish reliable methods to measure the surface voltages of inhabited cleanroom garments where these experience tribocharging
- to see if these voltages can be predicted from measurements of electrostatic performance features on sample areas of garment fabrics

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 net 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 on an earthed metal plate surface. Electrostatic charge has been 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 of limited size the reading by the fieldmeter, set up to show the voltage on an extended surface, will be an underestimate of the immediate local voltage.

To enable the charge transfer to be measured the operator stood on a metal plate insulated from an earthed support plate by localised insulators. The standing plate surface was connected by coax cable to a virtual earth charge measurement unit (JCI 178). This kept the metal standing plate at earth potential throughout measurement. Discrete insulators were used to support the standing plate to avoid risks of tribocharging at the support insulation or of signals arising from varying capacitance to nearby charged surfaces.

To enable the garment surface voltage to be measured with confidence, a robust tripod support stand was built that mounted a shaped wooden support on high quality insulation to support the arm of the operator. The JCI 140 Static Monitor used to measure garment surface voltage was mounted from the top of the tripod stand. This tripod arrangement gave good positional stability of the body and the garment surface relative to JCI 140 for good quality surface voltage measurements.

Measurements of surface and body voltages were recorded on a Picoscope (ADC-212) digital storage oscilloscope. To achieve good signal to noise ratio records the charge and surface voltage signals were passed through a filter and gain stage unit providing -3dB roll-off (70% signal) at 2Hz with a x10 gain.

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

	Grid	Thread
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
G	7.5mm grid	

1, 2 and 3 are different types of conductive thread

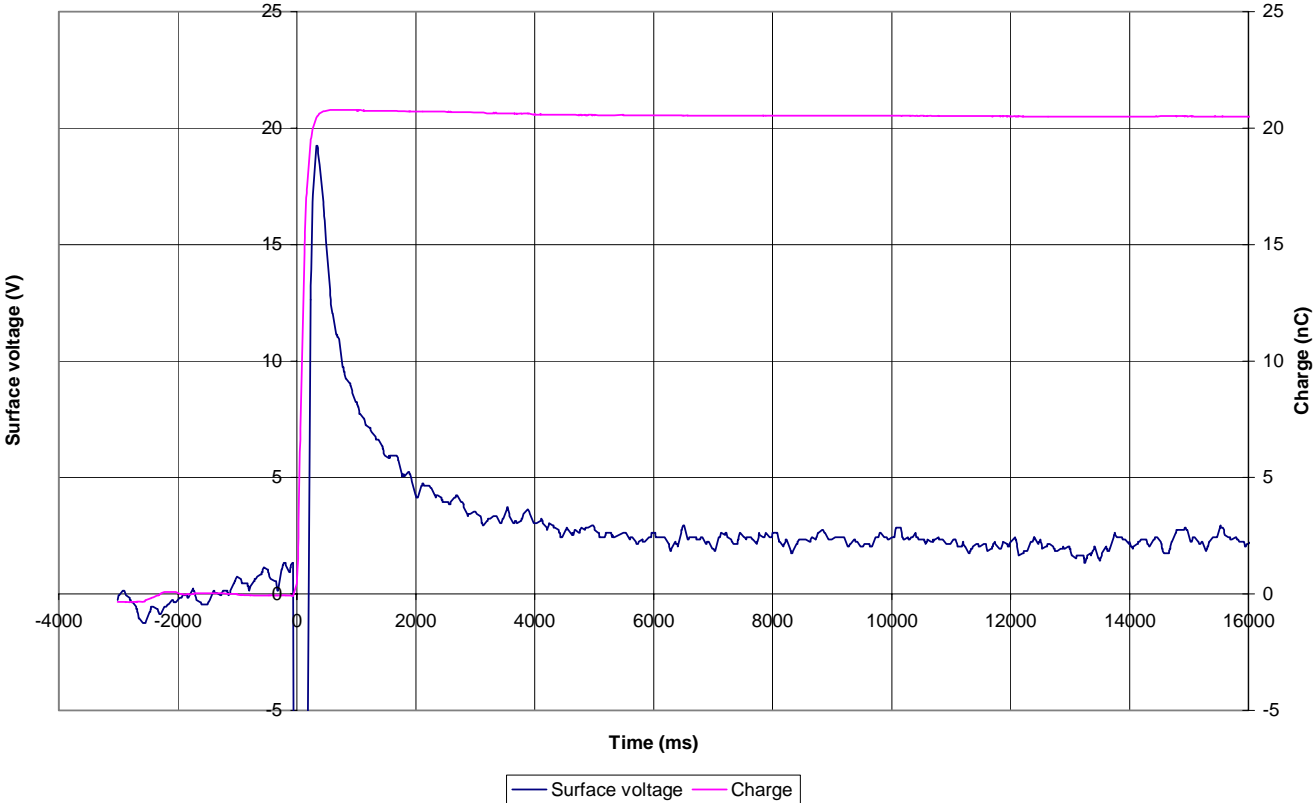
The garments were manufactured to a normal commercial design. The garments were laundered 5 cycles to ISO 6330 procedure 5A at 40C, followed by a final low temperature tumble dry.

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

The local area electrostatic characteristics of the garment fabrics were measured by corona charge decay (to IEC 61340-2-1) in combination with capacitance loading [1] and by surface resistivity (to prEN 1149). These measurements were made in the same environmental conditions at used for the electrostatic performance tests on inhabited garments.

3. RESULTS

The variation with time of surface voltage of an inhabited garment (E) is shown below (in blue) together with the charge measurement signal (in mauve).

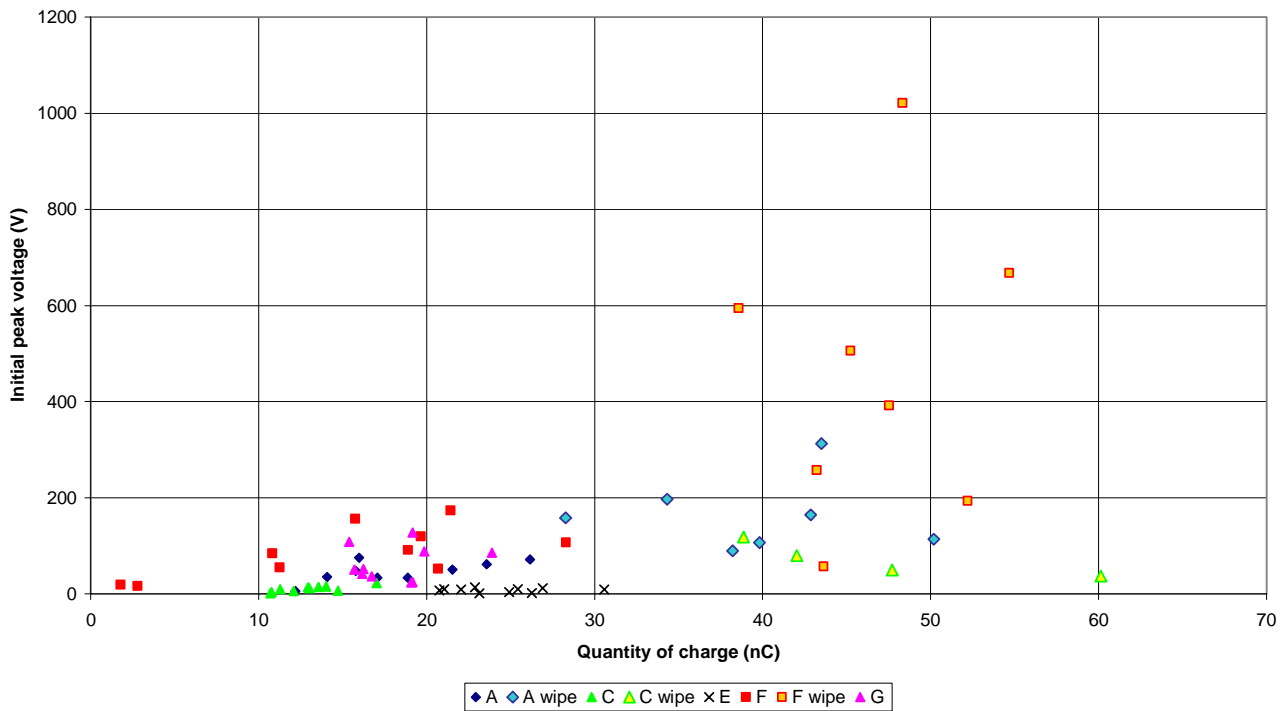


The graph below shows values for the initial peak voltages observed for garments with different fabrics as a function of the quantity of charge transferred. This graph shows that quite high surface voltages can arise on certain garments (to over 1000V), while on others surface voltages are no more than 20V. While there is quite a bit of scatter in the present measurements it seems likely that the surface voltage varies in proportion to the quantity of charge.

The electrostatic characteristics of the garments have been assessed by measurement of charge decay time and capacitance loading, based on the use of corona charging. The equipment and techniques for these measurements have been described in published papers [1,2]. The essence of this method of assessment is to use a short period of high voltage corona discharge (20ms) to deposit a local patch of electrostatic charge on the material to be tested and to measure the quantity of charge transferred. A fast response electrostatic fieldmeter is used to measure the initial peak surface voltage created by this charge and the decay of this voltage with time. The

'capacitance loading'¹ experienced by the charge on the surface is calculated from the quantity of charge deposited and the initial peak surface voltage created.

Variation of initial peak voltage with quantity of charge



Measurements were made on the various garments at quantities of charge comparable to those involved in the triboelectric charging. These showed that charge decay times were essentially independent of the quantity of charge transferred. Capacitance loading values, however, did vary with the quantity of charge. The variation was linear and had the form of an intercept at zero charge and a slope. (It is noted that materials and fabrics that do not include conductive threads seem to show no significant variation of capacitance loading with quantity of charge. The mechanism responsible for the variation with conductive threads is still unknown).

Comparison of test results shows there was a reasonable quantitative match between garment and fabric performance features if capacitance loading values were used corresponding to zero charge. This indicated that the local surface voltage V_g (volts) on an inhabited garment can be predicted from the quantity of charge q (nC) transferred by a rubbing action and the capacitance loading value $CL_{q=0}$ at $q=0$, as:

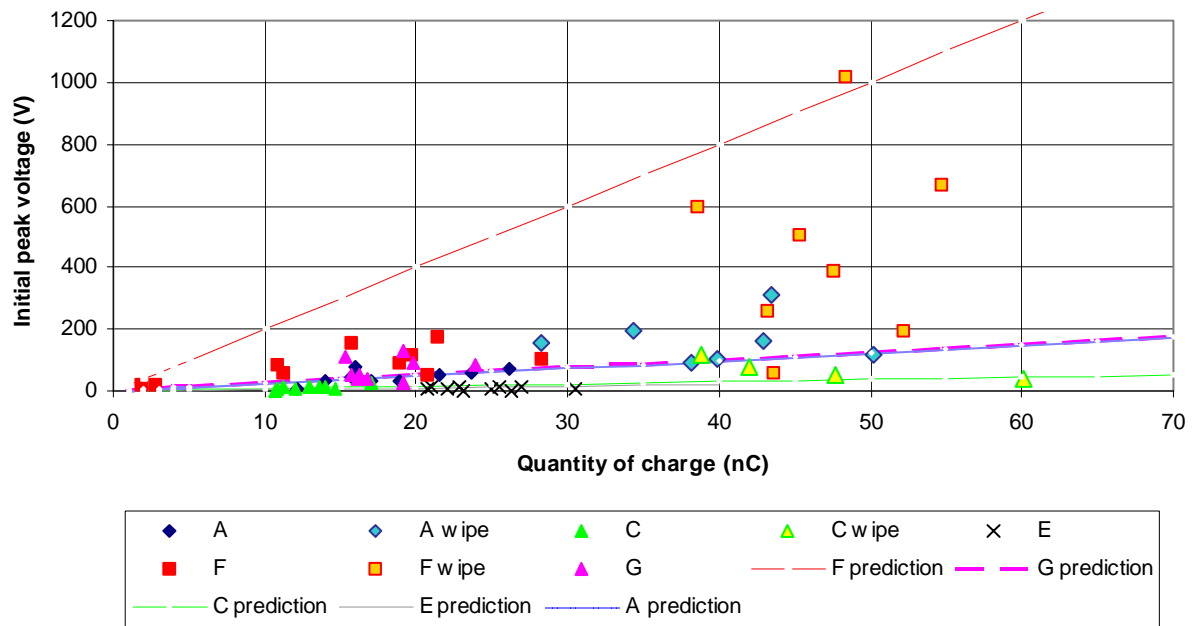
$$V_g = f q / (CL_{q=0})$$

- where f is a factor around 20. Thus there seems to be a way to predict the maximum local surface voltages expected from the maximum quantities of charge likely to be transferred at practical rubbing actions. The following graph combines the above experimental observations

¹ '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.

with predictions by the above equation using values for $CL_{q=0}$ derived from the capacitance loading measurements on sample areas of the garments.

Variation of initial peak voltage with quantity of charge



Previous studies [3] have shown that surface voltages do not relate to surface resistivity.

4. CONCLUSIONS

The present studies indicate that the surface voltage on an inhabited garment can indeed be predicted from the quantity of charge transferred by a rubbing action and knowledge of the capacitance loading experienced by charge of the surface. Capacitance loading values are measured as a characteristic of the fabric using instrumentation based on corona charging. Thus maximum surface voltages to be predicted from the maximum quantities of charge likely to be transferred at practical rubbing actions.

Further work is being pursued to confirm the present findings with a wider variety of garments and fabric materials and constructions.

The differences in performance for the garments tested related primarily to the capacitance experienced by charge on the fabric surface. It does not relate to surface resistivity – and for the present garments does not appear to be related to charge decay times.

The present work enhances knowledge on practical electrostatic risks by showing how measurements can be made on cleanroom garments ‘as used’. The results of such work are important as they provides a route for assessment of fabrics and of garments 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
- [2] J. N. Chubb “*New approaches for electrostatic testing of materials*” *J. Electrostatics* **54** March 2002 p233 (ESA Annual meeting, Brock University, Niagara Falls, June 18-21, 2000).
- [3] J. N. Chubb, P. Holdstock, M. Dyer “*Can cleanroom garments create electrostatic risks?*” ‘*Cleanroom Technology*’ **8** (3) March 2002 p38