



# Tribocharging studies on inhabited cleanroom garments

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## ABSTRACT

Studies are reported on the surface voltages created on inhabited cleanroom garments when these are subject to tribocharging actions. It is shown that the voltage created per unit of charge does not depend on whether the garment fabrics include core conductive threads, giving very high surface resistivity values, or surface conductive threads, which show resistivity values well within the requirements of formal electrostatic Standards. Lower surface voltages per unit of charge are observed for the closer spacing of the conductive threads. These results call into question whether measurement of resistivity is the most appropriate basis for assessing the suitability of materials.

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## 1. Introduction

Standard methods to assess the electrostatic suitability of materials have been based on measurement of surface resistivity [1,2]. The present studies have been concerned with testing how well this approach applies to cleanroom garments.

Cleanroom garments are based on tightly woven fabrics of polyester that include patterns of conductive threads to control the risks from static electricity that can be expected on simple polyester fabrics. It is the surface voltage created by tribocharging actions that presents the major source of risk from static. The main objective of the studies to be described was to examine whether surface voltages created on practical inhabited cleanroom garments related directly to surface resistivity. If it did not, then to see whether they relate to another measurable parameter.

## 2. Test methods

### 2.1. Inhabited garments

The surface voltages created on inhabited cleanroom garments have been measured by the test subject standing on an insulated charge measurement support plate and having a region of the upper arm rubbed by a wool surface while the surface voltage is measured by an electrostatic fieldmeter [3,4].

The cleanroom garment is worn over normal clothing with just a shirt covering the arm. To stabilize the position of the upper arm, the lower arm is rested on an insulated support. The fieldmeter is mounted from the arm support tripod to maintain a 100 mm

spacing between the sensing aperture of the fieldmeter (a JCI 140 Static Monitor) and the rubbed area of the sleeve. The physical arrangement is shown in Fig. 1.

Tribocharging was achieved using a wooden kitchen spoon covered with a wool sock wrapped round and held in place with an elastic band. This was held by the test operator who was clothed in a cleanroom garment known to provide low surface voltages, and the operator was bonded to earth. The arrangement is shown in Fig. 1.

Use of a wool surface on a wooden spoon provided a much simpler test arrangement than the Teflon rod used in previous studies [3,4]. With the Teflon rod it was necessary to charge neutralize it before each test and to swing it well away into an electrostatically shielded region immediately after rubbing the test area to avoid influencing the readings of the fieldmeter. The wool surface on the wooden spoon provided an easy path for charge to dissipate to earth via hand contact with the test operator. This meant that the charging surface was charge neutral just before the test and then had little influence on fieldmeter readings after the rubbing action.

The quantities of charge transferred are likely to depend on the pressure and speed of the rubbing action. With manual operation it is difficult to achieve consistent charging in successive tests or between different testers. It is hence appropriate to measure the quantity of charge transferred at each test and to express the surface voltage observations in terms of the surface voltage per unit of charge transferred –  $V\text{ nC}^{-1}$ . The charge received on the garment was measured using a virtual earth charge measurement circuit (JCI 178 Charge Measurement Unit) connected to the support plate. The test subject stood on the support plate in socks so there would be good connection to the plate surface (see Fig. 1).

The signal from the fieldmeter showing surface voltage and the signal from the charge measurement circuit were recorded using an ADC-212 Picoscope linked to a Dell Inspiron 8200 microcomputer

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**Fig. 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 JCI 140 Static Monitor.

running Picoscope software. Observations were recorded in the single shot mode triggered from the rise in the charge measurement signal. A few seconds of pre-test observations were displayed so that readiness for a test could be observed and pre-test 'zero' values recorded. An example of a signal record is shown in Fig. 2.

The area of fabric on the sleeve charged by the rubbing action is of modest size. It can be expected that the readings and analogue output from the JCI 140 will hence be somewhat less than they would be for the large plane conducting surface that is used for setting up and calibrating JCI 140 instruments [5]. This means that the surface voltage values reported will be somewhat less than the actual local peak surface voltage. If the area charged was say 100 mm diameter then the actual local voltage would be about twice the reading recorded if that area was well away from an earthed backing surface and four times the reading if the area rested close against an earthed surface. In practice something between these can be expected. Some additional comments on the interpretation of surface voltage readings are presented in Annex 1.

The test procedure was for the test subject in the selected cleanroom garment to stand on the support plate, to rest the lower arm on the insulated support, to check that separation to the fieldmeter was close to 100 mm and to observe that the fieldmeter surface voltage reading was suitably low. The charge measurement

circuit was then zeroed. When pre-test observations were suitably stable the upper arm was rubbed by a single swipe of the wool surface on the wooden spoon which was swung well out of the way. The test subject remained steady on the support plate and the arm rest so that both the increase in surface voltage and the dissipation of the charge from the charged area could be recorded. Ten tests were made for each garment so there was opportunity to have confidence in the averaging and calculation of errors for each set of tests.

An example of the recorded charge and voltage signals is shown in Fig. 2. The sensitivity for charge was 1.0 V of signal per 100 nC of charge. For surface voltage the sensitivity was 1 mV of signal per 1 V of surface voltage.

## 2.2. Fabric sample studies

Studies of tribocharging on samples of the various fabrics used for the inhabited cleanroom garment studies have been made with a strip of the test material about 300 × 600 mm clipped over the upper arm area of a cotton shirt to simulate the sleeve area of a full cleanroom. The test procedure was that as established in previous inhabited garment tests [3,4] and as described above. The test fabric was charged by a single swipe by a woollen sock fitted over

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