

# **Test method to assess the suitability of materials and surfaces to avoid problems from static electricity by measurement of the ability to dissipate corona charge**

## **1 Introduction**

This document is concerned with measuring the ability of materials to avoid problems from static electricity by providing rapid dissipation of static charge. Studies have shown that the ability of materials to dissipate triboelectric charge, generated on their own surface by contact or sliding actions, is well matched by the decay of charge deposited from a high voltage corona discharge. The advantage of using corona charging for charge decay measurements is that it forms the basis of easy to use instrumentation that gives quick and repeatable assessment of a wide variety of materials (including liquids and powders) under a range of test conditions.

This document describes how to measure the dissipation of corona charge on materials. A number of papers published on the method and its application are listed in Annex 1.

It is to be noted that measurement of resistivity does not show how quickly static charge will dissipate on general materials. This is because with materials that are inhomogenous (but cannot be identified as such by simple inspection) resistivity measurements will show the fastest route available for charge migration and not the ability of the slowest dissipation rate areas to retain charge. Resistivity measurements also do not properly assess materials with non linear current voltage characteristics.

## **2 Scope**

This document describes a test method for measuring the rate of self-dissipation of static charge of insulating and static dissipative materials and surfaces.

It includes a generic description of the test instrumentation and method of measurement.

## **3 Definitions**

For the purpose of this document, the following definitions apply:

### **3.1 Charge decay**

The migration of charge across or through a material leading to a reduction of charge density or surface potential at the area where the charge was deposited.

### **3.2 Charge decay time**

The time required for the local charge density or surface potential to fall to a selected percentage of its initial value. One convenient figure for comparisons between materials is the decay time to  $1/e$  ( $e$  is the base of the natural logarithms, 2.7183). A second figure for comparison is the time to 10%.

### **3.3 Corona**

The generation of ions of either polarity by a high localised electric field.

### **3.4 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 cause an electrostatic problem.

*Note - In general applications and in operations involving manual activities the decay time from the initial peak voltage to  $1/e$  of this needs to be less than  $\frac{1}{4}$ s.*

### 3.5 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 insulating materials is generally greater than 10 s.

### 3.6 Conductive material

A material with a high mobility of charge so that charge on the surface is retained for only a very short time.

Note - The charge decay time of insulating materials is generally greater than 0.05 s.

## 4 Method of measurement of charge decay

### 4.1 Principle

The self-dissipation of static charge by a material is measured by depositing charge on the surface by means of a corona discharge and observing the decay of surface potential by means of a fieldmeter.

### 4.2 Environmental conditions

The charge decay properties of materials vary with temperature and the absorption of moisture. It is hence very important that the values of these parameters in the test environment are known, and that they are controlled to agreed values for standardised measurements.

Handle samples only well away from the area to be tested or using tweezers. Avoid breathing in the direction of the sample.

For laboratory measurements the materials and samples should be conditioned in the selected environmental conditions for at least 24 h before testing and measurements made with the following conditions in the listed sequence, or as otherwise agreed.

For measurements in practical situations the ambient temperature and relative humidity shall be recorded.

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

The surface of the material tested should be clean and free of loose dust. Remove any loose dust by gentle brushing or blowing with clean, dry air. If the surface is obviously contaminated either an alternative area or sample should be tested or measurements made with the contamination present and the condition of testing reported to be 'as received'.

Note – Solvent or chemical cleaning is not recommended as this may change surface conditions.

For measurements in practical or installed applications, the materials shall be tested without any “special” cleaning. If cleaning is part of the process, for example washing of garments, measurements should be taken before and after cleaning where practical. The materials and the method used to clean shall be reported.

### 4.3 Apparatus for using corona charging of the material

#### 4.3.1 Physical design features

A typical arrangement and relevant dimensions of the test apparatus is shown in figure 1. Other equipment fulfilling the basic design and performance requirements may be used.

The test aperture for deposition and measurement of deposited charge shall be 50 mm diameter or an equivalent area quasi-square aperture. The corona points are mounted in a 10 mm diameter circle on a movable plate 10 mm above the centre of the test aperture. The field meter sensing aperture shall be 25 mm above the centre of the test area. When the plate with the corona points is moved fully away, the test area shall be clear up to the plane of the fieldmeter sensing aperture.

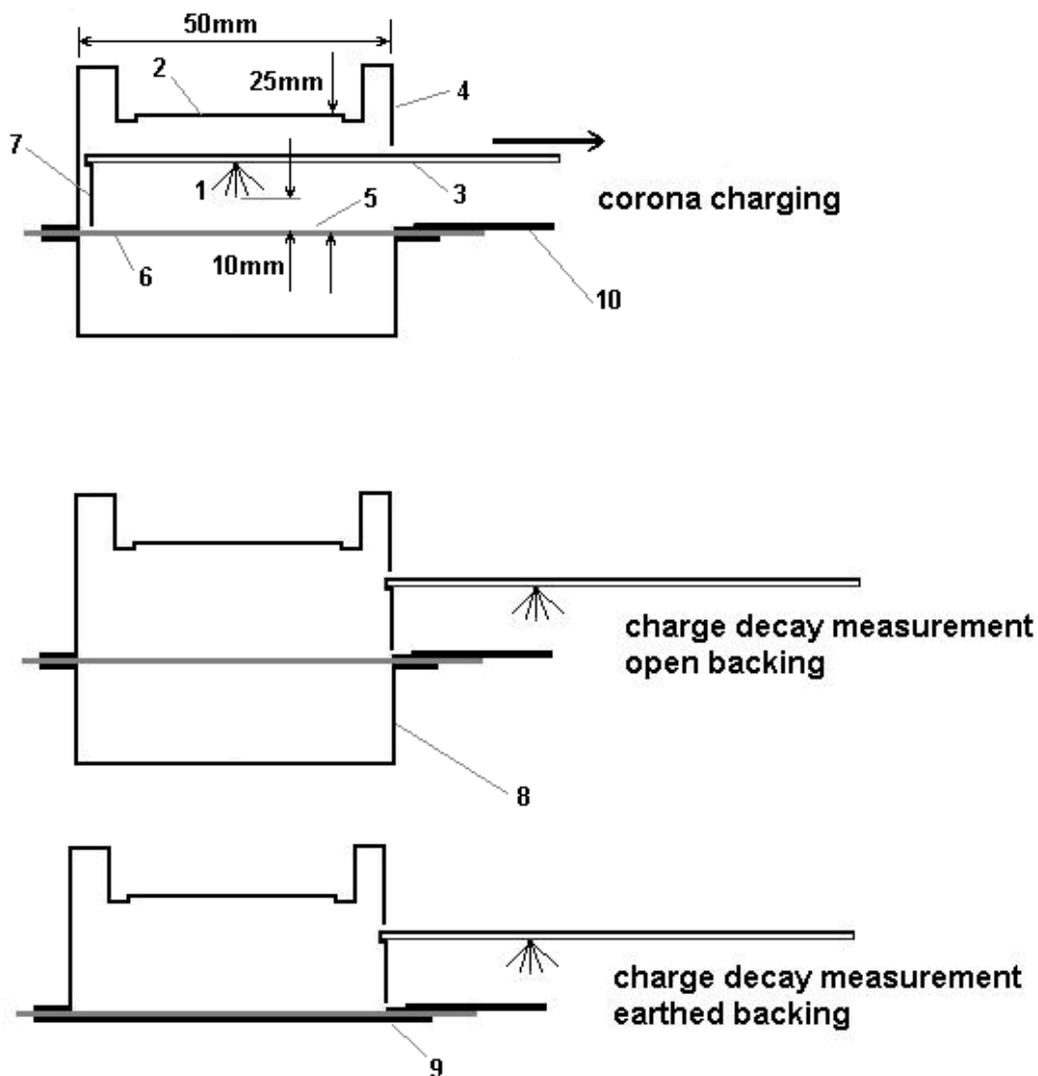


Figure 1 – Example of an arrangement for measurement of corona charge decay

Key	
1	10 mm diameter circle of corona points
2	Fieldmeter sensing aperture
3	Movable plate: - Insulating surface mounting corona points - Earthed top surface: to shield fieldmeter
4	Earthed casing
5	Test aperture – 50mm dia or 50x50mm area
6	Sample
7	Air dam to remove residual corona air ionisation
8	Open shielded backing
9	Earthed backing
10	Instrument base plate

#### 4.3.2 Containment of test material

With an installed material the test aperture in the base plate of the instrument shall be rested directly on its surface.

Sheet or flexible materials shall be tested as supported against the test aperture with both 'open backing' and 'earthed backing'. These two arrangements (shown in Figure 1) represent the extreme conditions of practical application. For both arrangements the longer of the two decay times shall be taken for comparison with general acceptance criteria.

Note - In practical terms, 'open backing' measurements represent the condition where materials are well separated from earthed surfaces, for example the bottom edge of a coat or smock hanging away from the body of the wearer. 'Earthed backing' represents the other practical extreme of a material resting in intimate contact with an earthed surface, for example a garment fitted close to the body of the wearer, or a work surface on top of a metal bench. The nature of the material used as an 'earthed backing' surface may affect measurements, so a suitable material needs to be used. For example, the insulating nature of anodised aluminium will inhibit vertical charge migration.

For testing of material with 'open backing' the material shall be supported against the base plate of the instrument by an earthed metal aperture aligned with the instrument test aperture and with at least 5mm width outside the test aperture area. The shield over the reverse side of the test area shall be earthed and at least 25 mm away over the whole test area.

For testing of materials against an 'earthed backing' the material shall be mounted between the base plate and a flat earthed metal plate.

Note - If charge moves more readily through the bulk test material than across its surface, then placing an earthed metal plate immediately behind the test area may decrease the charge decay time. On the other hand, if charge moves more readily across the surface of the test material, then charge decay time may be increased due to increased capacitive loading.

For testing thin flexible films the film needs to be well tensioned to reduce risk of flexing during decay time measurements.

Powders and liquids may be tested while supported in an earthed metal cup beneath the test aperture.

Note – When testing light powders, that may be easily dispersed into the air, precautions need to be taken to avoid powder particles becoming deposited on surfaces around and inside the fieldmeter sensing region. This may be achieved by, for example, slow retraction of the moving plate and air dam or by an appropriate increase in the separation between the powder surface and the plane of the sensing aperture.

#### 4.3.3 Corona charge deposition

The corona method provides a rapid and repeatable non-contact means of depositing charge with controllable magnitude and polarity.

Corona charging is achieved using a number of discharge points on a 10 mm diameter circle 10 mm above the middle of the test area. The exact size and distribution of charge deposited

on the material is not well defined, particularly with the more conductive surfaces, but the arrangement provides a consistent pattern of deposited charge for decay time measurement.

The corona charge deposition time shall be 20ms  $\pm$ 10ms. Longer times may be used if needed to achieve an adequate initial peak voltage for measurement. Materials should preferably be tested with both positive and negative polarity, although very similar results can be expected.

Note - Typical voltages for corona charging are between 5kV and 10kV. Corona deposition times longer than 100ms should be avoided. They will not provide any enhancement of charging and may create some damage to sensitive surfaces.

The equipment for charge deposition shall move fully away from the region of field meter observation in less than 20 ms.

Note - For corona voltages up to 10 kV the initial peak surface voltage with relatively high insulating materials will be up to about 3 kV. For materials with fast charge decay rates the initial voltage may be much lower - for example only 50 V to 100 V.

#### 4.3.4 Fieldmeter

The fieldmeter shall be able to measure the surface voltage with an accuracy of  $\pm$ 5V, or better, to below 40V with a response time (20% to 90%) below 10 ms. The stability of the zero shall allow measurement of surface voltage with this accuracy over the longest decay times to be measured.

The sensitivity of the fieldmeter shall be set according to the calibration procedure in Annex 1.

Note - A rotating vane 'field mill' type fieldmeter is to be preferred. Chopper stabilised sensors may be acceptable if the sensitivity, noise levels and zero stability are appropriate. Induction probe instruments are not likely to be suitable, even for fast charge decay measurements, because the influence of even slight residual corona air ionisation will cause zero drift – and the absence of this would need to be tested.

During corona charge deposition and decay time measurement the sensing aperture of the fieldmeter shall be well shielded from any connections or surfaces associated with corona high voltage supplies. There shall be no insulating materials in or around the region of the instrument between the fieldmeter and the test aperture able to contribute signals to fieldmeter observations.

For measurements with materials having initial peak surface voltages less than 200v it is necessary to remove residual air ionisation created by the corona discharge when the moving plate carrying the corona discharge points is moved away. An air dam on the trailing edge of the moving plate mounting the corona discharge points is a convenient way to remove this air ionisation from the region between the fieldmeter sensing aperture and the test surface. Residual ionisation shall contribute less than 30V to measurement of surface voltage. This may be tested by measurements on a fully conducting test surface

#### 4.4 Charge decay time measurements

The charge decay time is the period to reduce the initial peak voltage  $V_1$  on the charged surface to a lower voltage  $V_2$  level set as a defined fraction of the initial peak voltage. A convenient 'figure of merit' is the time from initial peak voltage to 1/e of this. It is useful to record the form of the charge decay curve because in many cases the rate of decay slows significantly during the progress of decay and appreciable levels of surface charge may be retained for long periods. For this reason it is useful to also record the decay time to 10% of the initial peak voltage.

Note – Care needs to be taken in the measurement of charge decay times on small signals where signal noise may be significant in relation to signal amplitude. Any signal averaging technique needs to take account of the need for a fast response on the fast initial transients of short decay time curves.

The performance of the decay time measuring instrumentation shall be assessed according to the calibration procedure in Annex 2.

## 5. Making measurements

The instrument is placed on the sample in a way that ensures it will remain stable and steady in position throughout the period of charge decay measurement.

Note - Movement of the test equipment relative to the surface can cause tribocharging which will affect observations.

When a sample is presented for testing the initial surface voltage on the material shall be observed before the moving plate carrying the corona discharge points is advanced to shield the fieldmeter sensing aperture. If this surface voltage is more than 50V the sample shall be left in place under the instrument until the surface voltage has fallen to below 20V.

Note – Sample surfaces may become pre-charged by handling when placed ready for testing. It is recommended that when samples are placed in position the moving plate is back, so the fieldmeter can respond to any charge on the sample surface and show these observations. This initial surface potential on relatively insulating samples may be minimised by careful handling with minimum sliding actions.

Two main options are available if there is appreciable pre-charge:

- a) to wait until the pre-charge has dissipated. This means waiting for the initial surface voltage to fall to say 10-50V, depending on the quality of observations required.
- b) to make a study on the decay of this pre-charge without adding any corona charge. This means making a measurement with the corona voltage turned off or set for zero volts. It is to be noted that the decay of such pre-charge may be rather slower than the decay of the local patch of corona charge. It is none the less a useful observation.

It is not recommended that quality measurements are attempted by putting corona charge on to an already well charged surface or material.

It is also not recommended that pre-charge the material is neutralised by any other means than waiting. Deposition of neutralising charge may only give the appearance of neutrality but give close coupled regions of charge.

There are three other possible artefacts are worth noting:

- a) that if the air dam on the leading edge of the moving plate touches the sample surface then tribocharging may occur. This may arise when testing light fabrics. The fabric surface should be stretched flat under the test aperture, but it may still rise by induced air movement. This effect may be checked by making measurements with no corona charging. It may be avoided by slightly raising the baseplate of the instrument off the sample.
- b) That with some materials a very short (1-2ms) transient peak voltage is observed before the real charge decay curve. This is usually positive. Occurrence of this transient will upset operation of software timing. This is thought to be due to vertical charge separation between front and back surfaces of the sample at sample flexing.
- c) That if static charge is retained on the surface of the moving plate facing the test surface then charge may be drawn over the sample by the induction electric field. This effect may be minimised by minimising the non-earthed area on the underside of the moving plate.

At least 2 decay time measurements shall be made in testing any material. These shall be made at different positions on the material or on different samples of the same material. Preferably at least 6 measurements shall be made, 3 with positive corona and 3 with negative corona.

Where practicable, separate sets of measurements shall be made with 'open backing' and with 'earthed backing' of the sample.

Where decay times are less than 100s it may be useful to repeat measurements at the same location and to make measurements with high and low corona voltages and with both polarities of charging. This will demonstrate consistency in measurements and material behaviour. If measurements are to be repeated at the same position on a sample the surface voltage shall be allowed to fall to below 20V or below 5% of the initial peak voltage expected before another test is made.

## 6 TEST REPORT

The Test Report shall include at least the following information:

## Measurement of corona charge decay

- a) date and time of measurements
- b) description and/or identification of material tested
- c) corona charging conditions used (e.g. polarity, corona voltage, charging duration)
- d) whether the sample is supported with an 'open backing' or an 'earthed backing'
- e) individual values of initial peak surface voltage and associated decay times – time from initial peak voltage to  $1/e$  of this and, preferably also, to 10% of this. Where multiple measurements have been made the average value and standard deviation shall be quoted separately for measurements with open and earthed backing. Different polarity measurements may be combined.
- 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

## Annex 1: INFORMATIVE REFERENCES

- [1] R. Gompf "Standard test method for evaluating triboelectric charge generation and decay" *NASA Report MMA-1985-79 Rev 2*, July 1988
- [2] J. N. Chubb "Instrumentation and standards for testing static control materials" *IEEE Trans Ind. Appl.* vol 26 (6) Nov/Dec 1990 p1182.
- [3] J. N. Chubb and P. Malinverni "Experimental comparison of methods of charge decay measurements for a variety of materials" *EOS/ESD Symposium 1992* p5A.5.1
- [4] J. N. Chubb "Dependence of charge decay characteristics on charging parameters" '*Electrostatics 1995*', York April 3-5, 1995 Inst Phys Confr Series 143 p103
- [5] J. N. Chubb "Corona charging of practical materials for charge decay measurements" *J. Electrostatics* vol 37 1996 p53
- [6] J. N. Chubb "The assessment of materials by tribo and corona charging and charge decay measurements" '*Electrostatics 1999*' Univ Cambridge, March 1999 Inst Phys Int Confr
- [7] R. Gompf, P. Holdstock, J. N. Chubb "Electrostatic test methods compared" *EOS/ESD Symposium*, Sept 26-30 1999
- [8] J. N. Chubb "Measurement of tribo and corona charging features of materials for assessment of risks from static electricity" *IEEE Trans Ind. Appl.* 36 (6) Nov/Dec 2000 p1515.
- [9] J. N. Chubb "New approaches for electrostatic testing of materials" *Proceedings ESA2000 Annual meeting*, Brock University, Niagara Falls, June 18-21, 2000 To be published in *J. Electrostatics* 51 2001

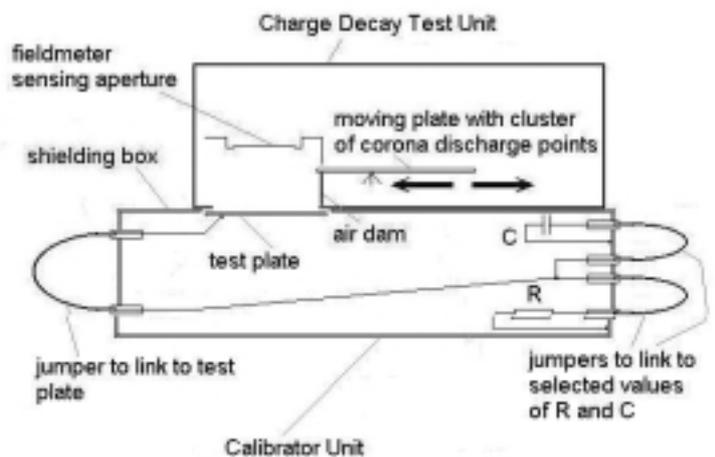
## Annex 2: CALIBRATION OF CORONA CHARGE DECAY MEASURING INSTRUMENTATION

### A2.1 Aspects to be calibrated

Calibration of charge decay measurement instrumentation involves two parts: calibration of the voltage sensitivity of the fieldmeter and calibration of the decay time measurement performance.

### A2.2 Equipment

Calibration of the charge decay measuring instrumentation is made using a plane conducting surface covering the whole test aperture area with a small separation (less than 0.5mm) below the edge of the test aperture so calibration voltages can be applied. A suitable arrangement is shown below.



### A2.3 Voltage sensitivity calibration

The voltage sensitivity calibration is made in terms of a uniform potential on the conducting surface covering the whole test aperture area.

The voltage source shall provide a stable, low ripple voltage of both polarities to at least 1000V. The voltage measuring system shall cover the measurement of both polarities and be separate from the voltage source so it may be formally calibrated independently. The accuracy of voltage measurement shall be better than 0.2%. The stability of the calibration voltage shall be 0.2%.

### A2.4 Decay time calibration

Calibrated resistors and capacitors are connected in parallel between earth and the conducting calibration plate over the test aperture. The resistors and capacitors shall be of good quality, with linear characteristics with voltage and be capable of withstanding voltages up to 3kV.

Decay time values in seconds are derived from the product of the values of the resistors (ohms) and capacitance (farads). Decay time values shall be provided for each decade of time over the main operating range of the instrument. To cover the range of interest of materials used for static control the decay time values provided should cover the range 0.1s to 100s.

Formal calibration of the resistors and capacitors shall be made in the equipment as used for calibration of the charge decay instrumentation.

#### **A2.5 Calibration procedure**

The charge decay measuring instrument is mounted on the calibration equipment, switched on and allowed to stabilise. Connect the calibration plate to earth and measure the initial 'zero' surface voltage reading by the fieldmeter. Apply calibrated voltages to the plate to give readings at well spaced voltage levels from 50V to 1000V. Repeat measurements for the other voltage polarity.

Connect a combination set of resistance and capacitance values from earth to the calibration plate. Operate the charge decay measuring instrument to apply sufficient charge to the calibration plate to achieve an initial peak surface voltage suitable for decay time measurement. Initial voltages in the range 100V to 1000V are convenient. Measure the time from the initial peak voltage to  $1/e$  of this using the normal instrument charge decay time measurement facilities. If both electronic and software decay time measurement facilities are available then both shall be used together.

At least 3 decay time measurements shall be made for each charge polarity for each decay time range. From each set of 6 readings the average decay time value and the standard deviation shall be calculated.

#### **A2.6 Results**

The results of the voltage sensitivity and the decay time calibrations shall be recorded on a Calibration Certificate.

For a new instrument supplied direct from the manufacturer the values recorded shall indicate these are 'as dispatched' values. Where an instrument is returned for recalibration then the 'as received' values shall be indicated. If no adjustments to the instrument are needed then the values shall be indicated to be 'as received and as dispatched'. If any changes or adjustments are made then the instrument is recalibrated in the sealed condition ready for dispatch and both 'as received' and 'as dispatched' values are shown.

The following information shall be shown on the Calibration Certificate:

- a) the name of the organisation issuing the Certificate
- b) Certificate number
- c) Customer identity
- d) Instrument type number
- e) Instrument serial number
- f) Date of calibration
- g) Name and signature of authorised signatory

- h) Method of calibration used and reference number of Standard
- i) Overall accuracy of calibration
- j) List of applied voltages and corresponding surface voltage values for both polarities
- k) List of measured decay time values (average values and standard deviations) and expected decay time values from resistance and capacitance values used.
- l) Reference information on the date and place of calibration of the measuring instruments used and the accuracy of their calibration