COMMENTS ON METHODS FOR CHARGE DECAY MEASUREMENT

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Abstract: Comments are made on the features of the various methods in use for measurement of charge decay. It is noted that none of the methods that start with the material charged and tested by earthing the test area boundary can be considered valid because this situation does not match practical experience. It is noted that any valid method must give results that match the behaviour of a variety of materials with tribocharging. Measurements based on corona charging have been shown to match the behaviour observed with tribocharging.

1. INTRODUCTION

Traditionally the suitability of materials to avoid risks and problems from static electricity has been judged by surface resistivity measurement. This is not appropriate for materials in general – even though the categorisation of materials in most 'standards' and in common use is still based on this [1,2]. 'Charge decay' has become accepted as a more appropriate way to assess materials and a variety of methods are described in various 'standards' [3,4,5]. The methods of measurement are quite different in philosophy and can give very different results. They therefore cannot all be right!

This paper presents some personal comments on the main methods of charge decay measurement in use. The aim is to increase understanding of the limitations of the various methods of charge decay measurement. By this it is hoped to help end users specify appropriate methods and for the preparers of 'standards' to clarify their documents.

2. BACKGROUND

Problems from static electricity arise from the surface voltage arising from charge retained on a material after it has been contacted or rubbed. It is perfectly possible to observe quite high surface voltages on materials that show low resistances and also quite low voltages on materials that are good insulators!

Resistance measurement is NOT an appropriate way to describe the ability of a material to dissipate or decay charge on its surface because:

1) Measurement of resistance shows the fastest route for charge movement on a surface. Low values will be measured where high conductivity components are held within a relatively insulating matrix. Prime examples are cleanroom garments and bulk bag material that include conductive threads with surface conductivity. 'Resistance' measurement show the resistance of the threads - but give no information on the ease of movement of charge on the fabric between the threads.

2) The use of 'resistance' measurement to categorise materials is based on the assumption that materials are both homogeneous and have linear current/voltage characteristics (Ohmic). With most materials the decay of surface voltage after local tribocharging does not follow the exponential form that would arise with simple 'resistive' charge movement.

Few modern materials involved in static control satisfy these requirements, and it is not clear to ordinary users whether or not they are satisfied.

How quickly charge moves away over the surface of the material and away to earth is a feature of major interest. If charge has moved away over the surface of a material by the time the contacting surfaces have separated there will be little influence left from retained static charge. What is now important is the method used for measurement of 'charge decay' performance.

3. COMMENTS

3.1 Introduction

Several methods for measurement of ‘charge decay’ are described in ‘standard’ documentation and in published literature [3-12]. The methods are very different, do not in general agree with each other and in general do not provide the information likely to be useful for uninitiated or unskilled users because they are susceptible to the construction of the materials tested.

Methods of charge decay measurement need to satisfy the following requirements:

- give results comparable to measurements with practical tribocharging actions for a wide variety of materials
- the material is initially at near earth potential and is subject to a charging action in a central region near a surface voltage sensor. Measurements are made of the surface voltage created by the charging action and how this decays with time
- surface voltage measurements are made without contact directly on the area charged
- measurement should be made on the same side of the material as that charged
- independent of constructions or features of materials
- minimal modification of the material and decay characteristics by the conduct of the test (and this should also apply to tribocharging methods).
- the method should be easy to use and interpret by non-specialist staff
- suitable equipment should be easy to construct and/or commercially available.
- approaches should also be backed by peer reviewed published papers describing the equipment and giving supporting experimental measurements. Where appropriate these papers should be referenced in the ‘standard’ document.

The following notes describe a number of methods of charge decay measurement in use with their strengths and limitations. It may be argued that many of the methods mentioned are ‘well established’, in common use and are specified in ‘standards’. However, this does not make them right – and it is hoped the following comments will clarify strengths and weaknesses!

3.2 Corona charge decay

The corona charging approach to charge decay measurement offers many practical advantages and has been implemented in compact easy to use instrumentation. It is in use by non-specialist staff with many types of materials in a wide variety of industries around the world. It is included in formal standards documents [4,5,6]. The method can be used in conjunction with measurement of the corona charge transferred to give values for ‘capacitance loading’ [13,14]. Corona charging gives an apparently generalised way to assess the suitability of materials, including films, layers, liquids, powders, small items and installed surfaces.

Studies have been reported that show comparability between corona and tribocharge decay times for a variety of materials [13,14,15]. Recent comparison studies have shown it is important with short decay time materials to compare decay rates at comparable times after the end of the charging action [16]. Lack of any significant modification of the surface by the action of corona ionisation has been shown [13] by constancy of charge decay performance at a single location from an initial low corona charge exposure through a high exposure and back to low exposure charging.

The method needs to be checked more extensively by different workers – in particular for different areas of sample and of charging and with comparison to tribocharging results. Suitable equipment is available commercially.

3.3 Federal Test Standard 101C

Federal Test Standard 101C Method 4046 [3] has been around for many years and has been subject to a number of comments and refinements [17,18]. The basic approach involves mounting a 5” long 3” wide strip of material between supporting clamps in front of a fieldmeter. A voltage of 5000V is applied to the clamps and the build up of fieldmeter signal observed to achieve a reading equivalent to the applied voltage. The clamps are then earthed and the decay of the fieldmeter signal observed and timed. It is noted in the specification that the method should only be used for ‘homogeneous materials’ - but no guidance is given on how to recognise such materials!

Comparative tests have shown much shorter charge decay times by FTS 101C than are observed with corona charge decay measurements with many practical materials [17]. These tests did however confirm that comparable results are obtained with truly homogeneous materials. It was concluded that FTS 101C basically responded to the fastest route for charge movement in the layer of material, whereas corona charge decay showed how charge moved on the surface of materials. The method of charging will not ensure full charging of insulating components in a relatively conductive matrix or grid. The method requires use of a cut sample area. Equipment is available commercially.

3.4 ITV Denkendorf

ITV Denkendorf developed a tribocharging method (ITV-TEV) in which a nearly vertical strip of material is held between two earthed clamps and rubbed by polythene rollers on either side nipping the strip as these are moved down the strip under tension. The rubbed area is held stably in front of a fieldmeter to observe the initial peak voltage and the rate of charge decay. The principle of the method seems sound. It is however only applicable to flexible layer materials and to materials with decay times longer than several tenths of a second. With fabrics rather different behaviour is observed in the warp and in the weft directions. The equipment is not now available commercially.

3.5 NASA

A tribocharging method for testing layer materials has been developed at NASA by Gompf [7]. This uses a rotating Teflon brush to tribocharge the sample surface that is earthed around its edge. At cessation of charging the sample is quickly dropped in front of a fieldmeter so the initial peak surface voltage and the rate of decay of this voltage can be measured. This seems a good, valid and useful approach. Results are reported to correlate well with safety experience at NASA. There also seems reasonable correlation with two other test methods [19].

As implemented at NASA the approach has been limited by using an induction probe type fieldmeter, rather than a field mill, and by the time taken to move the sample at the cessation of rubbing to the position of observation. Use of an induction probe limits the sensitivity for low surface voltages and the length of decay times that can usefully be measured. It is also, of course, limited to layer type materials that can be presented as cut samples and those not likely to be damaged by the tribocharged rubbing action. There is also a limitation in the minimum decay times that can be measured by the mechanical delay between the end of charging and the start of surface voltage observations. This equipment is not available commercially.

A modification has been proposed to the above approach [10] to try to simulate the risk from the charging of an unearthed person’s body while wearing personnel protective clothing. An isolated pick up disc has been mounted as a backing support for the sample with 220pF capacitance to earth. The idea is that the electrostatic energy picked up by this disc will represent the energy available to create risks of ignition. However, if the sample is mounted on an earthy support then the presence of conductive threads in the test fabric could diminish the quantities of charge observed because of shielding effects. It needs to be recognised that risk may also arise if there are local areas of high voltage on garment fabric surfaces relative to the body – although the incendivity of such discharges will be affected by other characteristics of the fabric.

3.6 BTTG

A corona charging method is used at British Textile Technology Group (BTTG) for testing fabrics (Shirley Method 20). A 300mm diameter disc of material is held under radial tension in a circular conducting frame. The material is charged by a cluster of corona discharge points near one side of the centre of the disc and a fieldmeter observes the surface voltage on the opposite side. After the surface has been charged the mounting frame is connected to earth.

The observed charge decay behaviour after the mounting frame is earthed needs to be assessed with caution. First, observations with the fieldmeter are made on the opposite side to that charged. For materials including relatively conducting components within their structure (for instance conductive threads) there will be a shielding effect between the charge and the observations so observations will not directly relate to the behaviour of surface charge. Second, as for FTS 101C, the initial reduction of observed signal will be strongly influenced by capacitive coupling via high conductivity components in the material. It is then a matter of judgement as to when observations relate to the decay of surface charge on the fabric itself. It is only applicable for layer type materials that can be presented as cut samples. This equipment is not available commercially.

BTTG has also developed a corona charging method for testing whole garments (Shirley Method 137 for Charge Decay Time Measurement on a Full Garment [11]). This involves using a corona discharge to charge an area of the garment, while the garment is hung up vertically from insulated supports. The variation of the potential at the charged area is observed from the time the corona charging electrode system is removed. Charge decay behaviour is observed with four test procedures: charging with the garment unearthed and then earthed via the cuff and ankle area and then charged while continuously earthed via the cuff and via the ankle area. This equipment is not available commercially. Only the later two seem appropriate.

3.7 'Scuff' tribocharging

A simple method for studying tribocharging has been developed at JCI [14,15,20]. It involves scuffing the middle of a stretched area of film or fabric with a charge neutral Teflon rod. A fieldmeter above the struck area shows the initial peak voltage created by the charging action and the rate of decay of this charge. Measurement of the quantity of charge transferred at the scuffing action is made by putting the struck end of the Teflon rod into a Faraday Pail. Values for the quantity of charge per unit of initial peak surface voltage show the capacitance effect experienced by the charge on the surface. A similar approach has been used with inhabited garments [21].

It is felt that the main value of the method is to provide a tribocharging reference against which other test methods may be compared. It is only really suitable for research type studies with film and planar surface materials. No studies have yet been reported on results with charging of large areas or with repeated charging. It is not appropriate as commercial instrumentation.

3.8 STFI

A method for assessing materials has been developed by STFI [8]. This involves observation of the form of components of the signal observed on the far side of a sample in response to a step function potential applied to an electrode on the near side. With careful interpretation these observations seem to relate to the risk of occurrence of incendive electrostatic discharges from charged surfaces.

The method is not suitable generally for measuring the surface charge decay capabilities of layer materials. For instance it will not measure the decay of charge for a plastic layer on a metal sheet.

The method is not appropriate for measuring the surface charge decay capabilities of materials. The material is 'charged' by induction so components with long decay times will only be charged to a low level. This means that only small surface voltages will be available for surface charge decay time measurements. A field mill type fieldmeter is needed, rather than an induction type, to monitor charging and charge decay. If conductive threads or internal higher conductive components are included in the material tested then their influence will depend on the resistive and capacitance coupling to the earthed mounting. This will affect observations. The response time of observations to the fast rising applied electric field gives indication of the effective conductivity within the material providing shielding performance. It seems very reasonable that this has a relation to the opportunity for drawing incendive electrostatic discharges from the material surface [23,24]. Resistive and capacitance coupling at the earthed mounting of the sample will affect observations. It was indicated that this equipment would become commercially available.

3.9 Charge plate monitor

Observations are often made using a metal electrode connected to an electrostatic voltmeter in contact with the middle of an area of test material [12,25]. A popular approach is to use a 'charge plate monitor' (an instrument designed for assessing the ability of air ionisation to remove charge from surfaces).

This approach may be useful for assessing how quickly charge may be removed from a conducting item in contact with a material - such as a person standing on flooring. It does NOT, however, measure the ability of a material to dissipate charge on its own surface. As with FTS 101C etc, the reason is that observations are strongly influenced by linkage to the fastest routes for charge migration and lack of fair representation of the influence of slow charge migration routes. There is also an uncertain influence from the capacitance loading of the contacting electrode. Equipment is available commercially from several sources.

4. CONCLUSIONS

Eight methods have been described for measurement of charge decay. Four of these are not appropriate for assessing how quickly charge can dissipate on a material itself – FTS 101C, BTTG, STFI and the Charge plate monitor. The basic problem with these methods is that their observations are dominated by the fastest route for charge migration in the material, and they do not show the behaviour of charge retained on the surface of the material - as after tribocharging. No attempts have been reported to relate such methods to tribocharging behaviour.

None of the methods that start with the material already charged and tested by earthing the test area boundary can be considered valid because this situation does not match practical experience.

Of the tribocharging methods only the NASA and 'scuff charging' approaches start with the sample with an earthed boundary. None of the three methods based on tribocharging is available commercially.

The only method that gives results shown to match tribocharging and commercially available is that based on corona charging.

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