Designation: D4470 – 97 (Reapproved 2010)

Standard Test Method for Static Electrification[1]

1. Scope

1.1 This test method covers the generation of electrostatic charge, the measurement of this charge and its associated electric field, and the test conditions which must be controlled in order to obtain reproducible results. This test method is applicable to both solids and liquids. This test method is not applicable to gases, since a transfer of a gas with no solid impurities in it does not generate an electrostatic charge. This test method also does not cover the beneficial uses of static electrification, its associated problems or hazards, or the elimination or reduction of unwanted electrostatic charge.[2]

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D618 Practice for Conditioning Plastics for Testing

D5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

3. Terminology

3.1 *Definitions:*

3.1.1 *conducting material (conductor), n*—a material within which an electric current is produced by application of a voltage between points on or within the material.

3.1.1.1 *Discussion*—The term "conducting material" is usually applied only to those materials in which a relatively small potential difference results in a relatively large current since all materials appear to permit some conduction current. Metals and strong electrolytes are examples of conducting materials.

3.1.2 *electric field strength, n*—the magnitude of the vector force on a point charge of unit value and positive polarity.

3.1.3 *excess electrostatic charge, n*—the algebraic sum of all positive and negative electric charges on the surface of, or in, a specific volume.

3.1.4 *insulating material (insulator), n*—a material in which a voltage applied between two points on or within the material produces a small and sometimes negligible current.

3.1.5 *resistivity, surface*—the surface resistance multiplied by that ratio of specimen surface dimensions (width of electrodes defining the current path divided by the distance between electrodes) which transforms the measured resistance to that obtained if the electrodes formed the opposite sides of a square.

3.1.5.1 *Discussion*—Surface resistivity is expressed in ohms. It is popularly expressed also as ohms/square (the size of the square is immaterial). Surface resistivity is the reciprocal of surface conductivity.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent contact area, n*—the area of contact between two flat bodies.

3.2.1.1 *Discussion*—It is the area one would calculate by measuring the length and width of the rectangular macroscopic contact region.

3.2.2 *dissipative material, n*—a material with a volume resistivity greater than 10^4 ohm-cm and less than 10^{12} ohm-cm, a resistivity range between conductive and insulating material as defined in this test method.

3.2.3 *real contact area, n*—the regions of contact between two bodies through which mechanical actions or reactions are transferred.

3.2.3.1 *Discussion*—Since real bodies are never perfectly

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[1] This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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[2] Vosteen, R. E., and Bartnikas, R., Chapter 5, "Electrostatic Charge Measurements," *Engineering Dielectrics, Vol. IIB, Electrical Properties of Solid Insulating Materials, Measurement Techniques*, R. Bartnikas, Editor, *ASTM STP 926*, ASTM, Philadelphia, 1987.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] *Annual Book of ASTM Standards*, Vol 11.03.

smooth, at least on a microscopic scale, the real contact area of apparently flat materials is always less than the apparent contact area.

3.2.4 *triboelectric charge generation*—the formation, with or without rubbing, of electrostatic charges by separation of contacting materials.[5]

4. Significance and Use

4.1 Whenever two dissimilar materials are contacted and separated, excess electrostatic charge (triboelectric charge) will be found on these materials if at least one of the materials is a good insulator. This excess charge gives rise to electric fields which can exert forces on other objects. If these fields exceed the breakdown strength of the surrounding gas, a disruptive discharge (spark) may occur. The heat from this discharge may ignite explosive atmospheres, the light may fog photosensitized materials, and the current flowing in a static discharge may cause catastrophic failure of solid state devices. Electric forces may be used beneficially, as in electrostatic copying, spray painting and beneficiation of ores. They may be detrimental as when they attract dirt to a surface or when they cause sheets to stick together. Since most plastic materials in use today have very good insulating qualities, it is difficult to avoid generation of static electricity. Since it depends on many parameters, it is difficult to generate static electricity reliably and reproducibly.

5. Apparatus

5.1 *Charging Mechanisms*—The charging mechanisms can be constructed in a variety of ways, and should preferably be made as analagous to the particular application as possible. Some examples of charging mechanisms are described in 5.1.1, 5.1.2, and 5.1.3.

5.1.1 *Powder or Liquids Transported Through Tubes or Down Troughs*—Contact between the specimen and wall of the tube will charge the specimen or the tube, or both. Either the specimen or the tube must be insulating, or partially insulating. When the specimen is separated from the tube, electrostatic charge will be generated. This charge may be measured by catching a known amount of the specimen in a Faraday cage, or the charge remaining on the tube may be measured. A trough may be substituted for the tube and gravity used to effect the movement of the specimen along the trough.

5.1.2 *Webs Transported Over Rollers*—Contact between the web and the roller surface will charge the web if it is an insulator or partial insulator. If the rollers are insulators or partial insulators they will become charged thus lowering, or eliminating, the charge transfer to the web after a period of time. The electric field on the web may be measured with a fieldmeter, or the charge on the web can be measured with a cylindrical Faraday cage if the width of the web is not too large.

5.1.3 *Transport of Insulating or Partially Insulating Sheet Material*—Sheet materials may be transported on air layers, by sliding down chutes, by vacuum platens, and by pinch rollers. Of these types of transport, pinch rollers and sliding down chutes generate the largest amount of charge. Generally, the better the contact (larger real contact area), the greater will be the charge generated. Pinch rollers are usually a high pressure, small apparent area of contact, leading to a relatively large real area of contact between the sheet and rollers. Sliding serves to multiply the real area of contact over that which would be obtained with a contact without sliding.

5.2 *Electrostatic Charge Measurements*—Fig. 1 shows a block diagram of the typical components necessary for this measurement while Fig. 2 shows a schematic diagram.

5.2.1 *Faraday Cage*—The Faraday cage consists of two conducting enclosures, one enclosed and insulated from the other. The inner enclosure is electrically connected to the shunt capacitors and the electrometer input. It is insulated from the outer enclosure by rigid, very high resistance, insulators which have resistance practically independent of relative humidity (an example is polytetrafluoroethylene (PFTE). The inner enclosure should be of such construction that the test specimen can be substantially surrounded by it. The outer enclosure is connected to ground and serves to shield the inner enclosure from external fields which could affect the measurement.

5.2.2 *Shunt Capacitors*—Shunt capacitors may be necessary to reduce the measured voltage to a range where it can be read by the electrometer. Such shunt capacitors must have very low leakage insulation relatively unaffected by relative humidity changes (for example, polystyrene). They should be kept short-circuited when not in use and should be protected from high relative humidity.

5.2.3 *Electrometer*—The electrometer voltmeter measures the voltage developed on the Faraday cage and shunt capacitors. The electrometer must have a high impedence (such as 100 TΩ or higher) and a low drift rate concordant with the time of measurement. Electrometers are available with built-in shunt capacitors selected by a range switch. Electrometers are also available with negative feedback circuits which minimize the effect of input capacity. These circuits reduce the input voltage drop to nearly zero minimizing the effects of leakage of charge to ground and polarization of insulators.

5.2.4 *Display Unit*—The display unit indicates the voltage developed on the electrometer. If the input capacitance is known and does not vary, or if negative feedback is used, the display unit may be calibrated to measure the charge on the Faraday cage directly. The unit may be a meter showing the instantaneous value or it may be more complicated equipment, such as a strip chart recorder giving a reading as a function of time. The electrometer and display unit may be combined in one instrument.

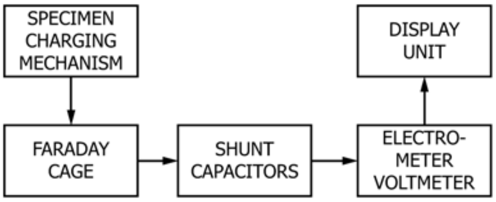

FIG. 1 Block Diagram of Apparatus for Measurement of Electrostatic Charge

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[5] Shashoua, V. E., "Static Electricity in Polymers: Theory and Measurement," *Journal of Polymer Science*, Vol XXXIII, 1958, pp 65–85.

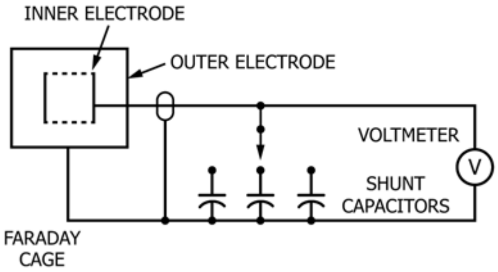

FIG. 2 Schematic Diagram

5.2.5 *Electrical Connections:*

5.2.5.1 *Connections to Faraday Cage*—Connections from the inner enclosure of the Faraday cage to the shunt capacitors and the electrometer must be highly insulated and well shielded from external electric fields. They should be stable in time and in the different ambient conditions in which measurements are made. Preferably, they should be rigid, although shielded cable may be used if it is low noise cable where flexing will not lead to the generation of static charge between the shield and the insulation of the cable. When using cable or rigid connections, the capacitance of these must be taken into account when calculating or measuring the capacitance of the input system, unless using an electrometer with negative feedback.

5.2.5.2 *Connections to Display Unit*—No special connecting wires are normally necessary between the electrometer output and the display unit. Manufacturer's recommendations should be followed when connecting an external display unit to the electrometer output.

5.3 *Electric Field Strength Measurements*—The diagram of Fig. 3 illustrates the major parts of a commercially available rotating vane fieldmeter. A commercially available vibrating plate fieldmeter is illustrated in Fig. 4. The setup required for calibration of a fieldmeter is shown in Fig. 5.

5.3.1 *Rotating Vane Fieldmeter*—In Fig. 1 an electrostatically charged material placed at a known distance from the sensing unit will induce electrostatic charge in the face of the sensing unit, the rotating vane, and the fixed sensor plate. When the rotating vane covers the sensor plate, the induced charge in the sensor is small. When the opening in the rotating vane is opposite the sensor, the induced charge in the sensor is a maximum. Thus the rotating vane produces a periodically varying electrical signal on the sensor plate. This signal is amplified, processed, and read on a suitable display unit. These fieldmeters can be made polarity-sensitive by inducing a charge of known polarity on the sensor with an internal source or by phase detection circuitry. Efforts must be made to adequately shield the sensor and associated circuits from noise generated by the motor driving the rotating vane.

5.3.2 *Vibrating Plate Fieldmeter*—In Fig. 2 a vibrating sensor plate is enclosed in a sensing unit. A charged material placed in front of the sensing unit induces a charge in the face plate and in the sensor. As the sensor moves away from the charged material, less charge is induced on the sensor. As it moves toward the charged material, more charge is induced on the sensor. This produces a periodically varying electrical signal on the sensor plate. This signal is amplified, processed, and read on a suitable display unit. Charge polarity is determined by phase detection circuits. Again, the sensor and associated circuits must be adequately shielded from noise generated by the driving mechanism.

5.3.3 *Display Unit*—The display unit may contain the power switch, circuits to process the signal (amplifiers, rectifiers, phase detectors, and the like), and a meter showing the instantaneous value of the electric field. Alternatively, a strip chart recorder giving a reading as a function of time may be used.

6. Test Conditions

6.1 Static electrification depends upon many parameters. To obtain reproducible results apparatus must be constructed to control all the measurable parameters and to keep all the unmeasurable parameters constant. The known parameters are as follows:

6.1.1 *Cleanliness of Material Surfaces*—Static electrification of contacting materials is a surface phenomenon. Thus, the surfaces must be kept in an uncontaminated state. Since contamination is very difficult to measure, efforts should be made to keep the surfaces clean. Storing samples under constant ambient conditions, such as temperature and relative humidity, is a must. Introduction of different gases into the air where they can be adsorbed on the surfaces has been known to change the results of an electrification test. Dirt particles settling on one or more surfaces can alter the results. Even contact to another surface during a test can alter a surface and give nonreproducible results in subsequent tests. Sometimes, it is better to use new samples from a sufficiently uniform material than to re-use samples. "Cleaning" of a surface with solvents rarely cleans the surface. It probably produces a uniform, reproducible, state of contamination, however. Thus, cleaning with solvents should be considered as a means of obtaining reproducibility in a test.

6.1.2 *Real Area of Contact*—Charge is transferred only at the points of real contact. Any test parameter that affects the

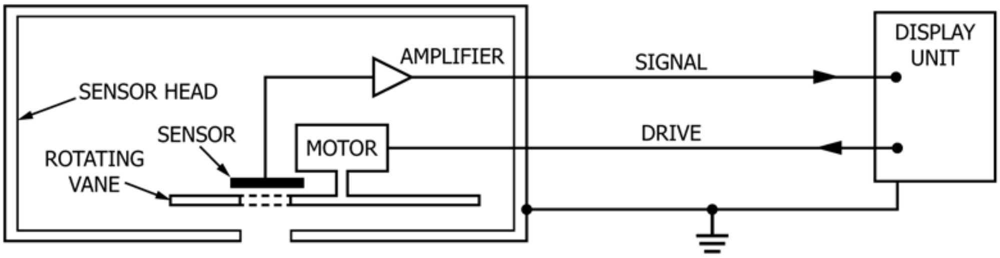

FIG. 3 Rotating Vane Fieldmeter