PUBLISHED DOCUMENT

PD IEC 61340-2-2:2000
IEC TR 61340-2-2:2000

Electrostatics —

Part 2-2: Measurement methods — Measurement of chargeability

ICS 29.020

National foreword

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The UK participation in its preparation was entrusted to Technical Committee GEL/101, ELectrostatics, which has the responsibility to:

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Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

Summary of pages

This document comprises a front cover, an inside front cover, the IEC title page, pages 2 to 16, an inside back cover and a back cover.

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This Published Document having been prepared under the direction of the Electrotechnical Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 November 2000

ISBN 0 580 36666 9

Amendments issued since publication

Amd. No.	Date	Comments

RAPPORT TECHNIQUE

TECHNICAL REPORT

CEI IEC TR 61340-2-2

Première édition
First edition
2000-07

Electrostatique –

Partie 2-2: Méthodes de mesure – Mesure de l'aptitude à la charge

Electrostatics –

Part 2-2: Measurement methods – Measurement of chargeability

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROSTATICS –

Part 2-2: Measurement methods – Measurement of chargeability

FOREWORD

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IEC 61340-2-2, which is a technical report, has been prepared by IEC technical committee 101: Electrostatics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
101/56/CDV	101/72/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

IEC 61340 consists of the following parts, under the general title: Electrostatics

Part 1: Guide to the principle of electrostatic phenomena [1]

Part 2-1: Measurement methods – Methods for testing insulating and static dissipative materials and surfaces by direct measurement of the rate of dissipation of static charge [1]

Part 2-2: Measurement methods – Measurement of chargeability

Part 2-3: Measurement methods – Methods of test for determining the resistance and resistivity of solid planar materials used to avoid electrostatic charge accumulation

Part 3-1: Methods for simulation of electrostatic effects – Human body model (HBM) – Component testing [2]

Part 3-2: Methods for simulation of electrostatic effects – Machine model (MM) – Component testing [2]

Part 3-3: Methods for simulation of electrostatic effects – Charged device model (CDM) – Component testing [1]

Part 4-1: Standard test methods for specific applications – Electrostatic behaviour of floor coverings and installed floors

Part 4-2: Standard test methods for specific applications – Test methods for garments [1]

Part 4-3: Standard test methods for specific applications – Footwear [2]

Part 4-4: Electrostatic properties of flexible intermediate bulk containers (FIBC) – Test methods and requirements [1]

Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements

Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide

Part 5-3: Protection of electronic devices from electrostatic phenomena – Test methods for packagings intended for electrostatic discharge sensitive devices [1]

The committee has decided that the contents of this publication will remain unchanged until 2010. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

This document which is purely informative is not to be regarded as an International Standard.

[1] Under consideration.

[2] In preparation.

ELECTROSTATICS –

Part 2-2: Measurement methods – Measurement of chargeability

1 General

1.1 Scope

This technical report describes the equipment, arrangements and procedures for measurement of electrostatic charge caused by contact and relative motion between materials and presents examples of model experiments to simulate practical processes.

1.2 Reference document

IEC 61340-4-1, *Electrostatics – Standard test methods for specific applications – Electrostatic behaviour of floor coverings and installed floors*

2 Fields of application

Charge is generated on contact between materials of differing electronic or ionic nature. Charge is subsequently retained on breaking the contact and separation of the surfaces if at least one of the materials is an electrical insulator or isolated conductor. In general, relative motion or rubbing is unavoidable in most practical contact and separation events, the effect of rubbing being to increase real contact area and local heating. Excessive increase in temperature can influence the charging process and ultimately, of course, material transfer can occur between violently abraded surfaces. The polarity of the charge is governed by the relative electronic properties (work function) of the contacting surfaces. In most practical situations, however, the magnitude of the retained charge is limited by electrical breakdown of the medium between the separating surfaces.

Despite contact charging being greatly influenced by surface contamination, surface temperature and local electric fields, the charge produced on a material in a continuously operating plant, under reasonably constant environmental conditions, can be fairly consistent in both magnitude and polarity. Ideally, the measurements using the methods described in clause 4 should be made on the actual practical system. The test arrangements described here are intended as essentially illustrative but can be used to estimate chargeability if measurements on the real plant are not possible.

This technical report describes appropriate test methods for the estimation of charge generation when materials are rubbed, rub or flow on other materials. Typical practical charge generating situations include:

a) semiconductor devices sliding out of shipping tubes and devices and kitted circuit boards sliding out of transport bags;
b) materials sliding across surfaces;
c) pneumatic transport of powders;
d) flow of liquids through pipes and filters;
e) rubbing of material;
f) web and film materials passing over rolling surfaces and peeling of tape;
g) individuals walking across floor surfaces.

Typically, for example

– a Faraday pail (see 4.1) can be used for measurements involving a), b), c) and d);
– a fieldmeter (see 4.2) for e) and f);
– an electrostatic voltmeter (see 4.3) for g);
– and a charge plate monitor for e), f) and g).

3 Test specimens and conditioning

NOTE The electrical properties of insulating materials vary with temperature and water content which is dependent on relative humidity.

The temperature and relative humidity should be recorded at the time and location of measurement. Preconditions should be recorded where appropriate. Materials for testing in a laboratory should be conditioned and tested under the environmental extremes expected in practice. Examples of test conditions for such laboratory measurements are given in table 1 of IEC 61340-4-1.

4 Methods of measurement

4.1 Faraday pail measurements

4.1.1 Principle

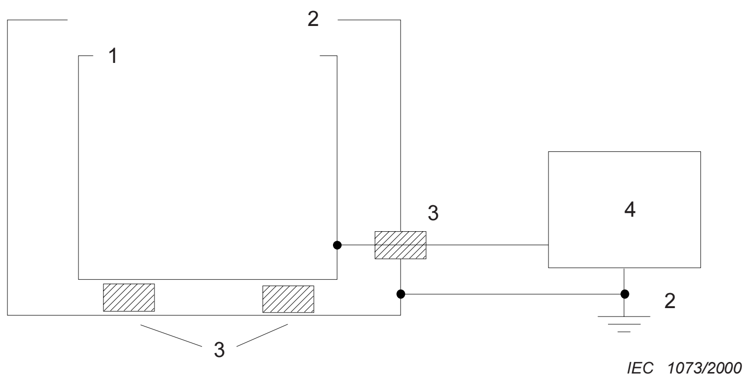
The excess of positive or negative electrostatic charge on an item or on a quantity of material is measured by placing it in an isolated conducting chamber, known as a Faraday pail. If all the charge introduced couples to the inside of the pail with no residual coupling to external surroundings, then the quantity of charge introduced appears as induced charge of the same sign and magnitude on the outside of the pail and can be measured.

NOTE It is not necessary that the charge placed in the pail is actually conducted to the inside walls. So the Faraday pail method is equally effective for insulating materials and for conductors.

4.1.2 Apparatus

4.1.2.1 The Faraday pail

The basic form of a Faraday pail system for measurement of charge is shown in figure 1. It consists of two concentric containers, the inner container being electrically insulated from the outer which is connected to earth. The latter is necessary to provide electrical shielding from external fields and protection for the sensitive charge measuring system.



Key

1 Inner container
2 Shield
3 Insulation
4 Detector

Figure 1 – Example of a Faraday pail

The insulation on which the pail is mounted and the connections and cabling to any external charge measurement circuits are designed and constructed to avoid charge leakage and trapped charge effects. The choice of insulation takes into account mechanical rigidity, leakage resistance, moisture absorption and piezo-electric characteristics. Typically, the resistance should be > 10^{15} Ω.

NOTE For satisfactory charge measurement, computer modelling calculations show that for less than 1 % leakage of the total flux from charged items introduced into a simple cylindrical pail form and filling it to no more than 30 %, the pail must have a depth to diameter ratio greater than 1,3. For less than 5 % leakage, the depth to diameter ratio must be greater than 0,8.

4.1.2.2 Measurement circuit

The charge induced on the outside of the inner container can be measured with an electrometer amplifier in the "virtual earth" mode, see figure 4. Alternatively, the increase in voltage of the pail can be measured, using a fieldmeter or electrostatic voltmeter, and the charge calculated in relation to the known capacitance of the pail. In this mode, additional capacitors may be added in parallel to that of the pail to limit the change in pail voltage. Figure 2 shows alternative configurations.

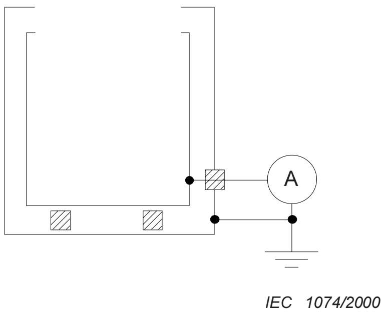


Figure 2a – Current mode

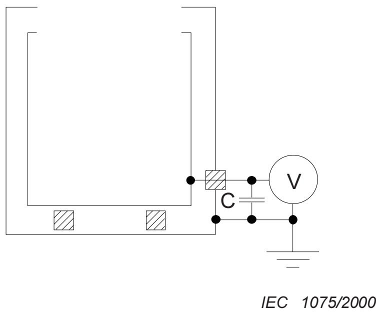


Figure 2b – Potential mode

Components

A Amperemeter
C Capacitor
V Voltmeter

Figure 2 – Examples of Faraday cage configuration

4.1.3 Procedure

Connect the outer case to ground and ground the inner pail. Then observe the measuring system response on re-isolating the latter from ground.

NOTE 1 Care should be taken when grounding a charged Faraday pail in a flammable environment since a substantial energy may be stored on the system which can be released in a spark between the closing contacts. In these circumstances a vacuum or gas-filled relay should be used.

Remove the ground from the inner pail and, then introduce the samples into the pail without contact to any other surfaces. The total charge is measured directly. In the case of a flowing product, the current to ground can be recorded and the charge obtained by integration over the measurement period. The mass of powder or volume of liquid collected can also be recorded and the charge per unit mass (or volume) calculated.

NOTE 2 It is important to use the minimum area of contact in the pick-up arrangement and to avoid any sliding action at pick-up or release of items into the pail. Checks should be made, that the method of transfer introduces negligible charge by careful measurement when the charge transferred is expected to be zero.

4.1.4 Results

The charge Q (in coulombs, C) is read directly from the electrometer or, in the case of measurement of the pail potential, given by the following equation:

$$Q = C \times U$$

where

C is the total capacitance in farads (F);

U is the voltage in volts (V).

NOTE $C = C1 + C2 + C3$, where $C1$ is the Faraday pail capacitance, $C2$ is the input capacitance of the measuring instrument and $C3$ is the capacitance of the connecting wires.

If the current to ground is measured, the charge is obtained by integrating the current over the duration of the measurement and is given by the following equation:

$$Q = \int_0^t I \times \mathrm{d}t$$

where

I is the current in amperes (A);

t is the time of measurement in seconds (s).

The mass of the powder or volume of liquid sample should be determined and the charge per unit mass in ($C \times \mathrm{kg}^{-1}$) or charge per unit volume in ($C \times \mathrm{m}^{-3}$) calculated, where C is the charge in coulombs

4.2 Electrostatic field measurements

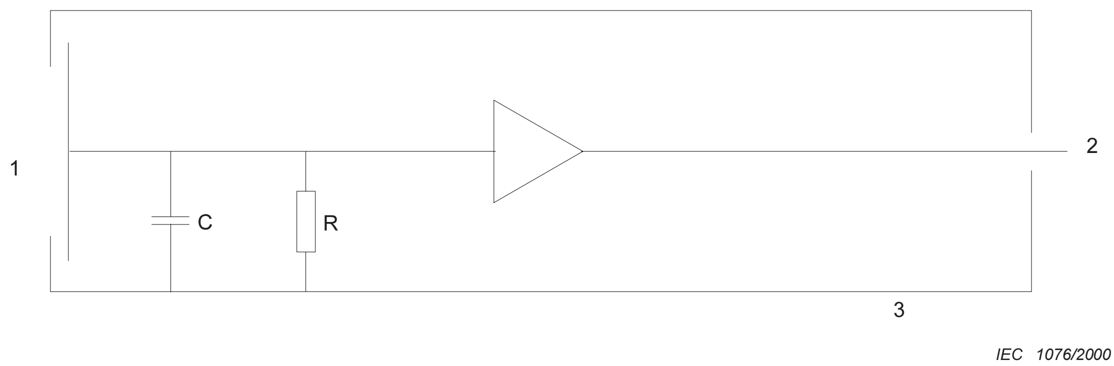
4.2.1 Principle

Electrostatic fields are determined by measuring the potential or charge induced on an isolated sensing surface placed in the field. The two main types are respectively, induction probe and field mill instruments. It should be noted that the reading of an instrument may be influenced by the test geometry.

4.2.2 Apparatus

4.2.2.1 Induction probes

Induction probe instruments are simple and relatively low in cost. They consist of a sensing surface with a defined capacitance to ground connected to an amplifier as shown in figure 3. Since the input impedance is not infinite, these devices are best suited for rapid scanning of charged surfaces with reference to a ground plane.

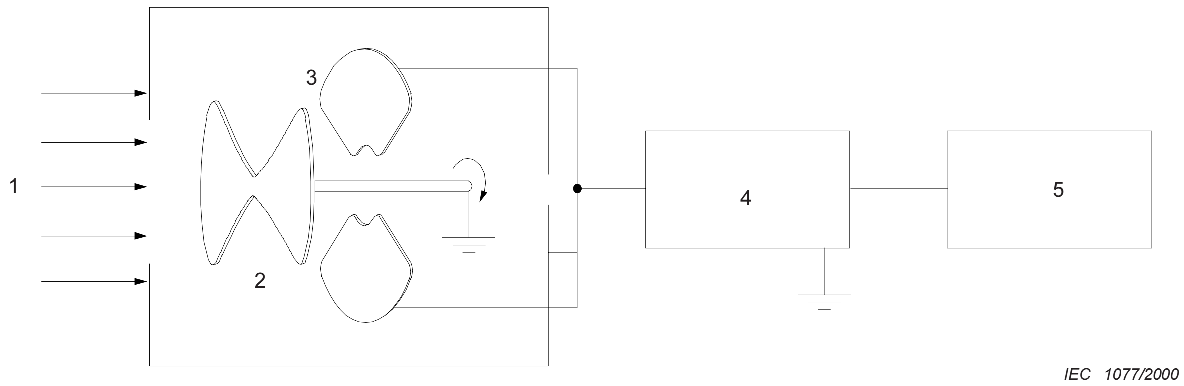


Components	**Key**
C Capacitance	1 Sensor area
R Input resistance	2 Output
	3 Shield

Figure 3 – Induction probe field meter

4.2.2.2 Field mill instruments

Field mill type fieldmeters overcome the zero stability limitations of induction probes by using a rotating or oscillating chopper to modulate the electric field observed at the sensing surface of the instrument. The general arrangement is shown in figure 4.



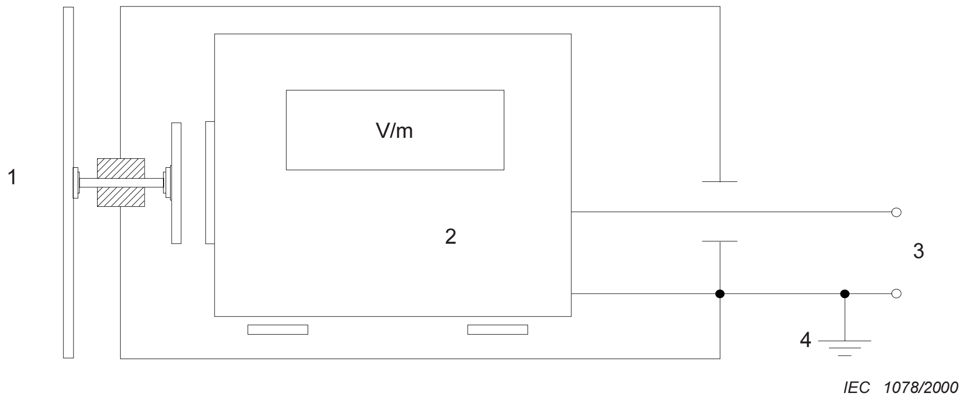
Key

1 Electric field
2 Rotating shutter
3 Fixed sensor electrode
4 Phase sensitive detector
5 Display

Figure 4 – Field mill with rotating shutter

4.2.2.3 Charge plate monitor

An instrument comprising an isolated electrode connected to a second electrode viewed by a fieldmeter is shown in figure 5.



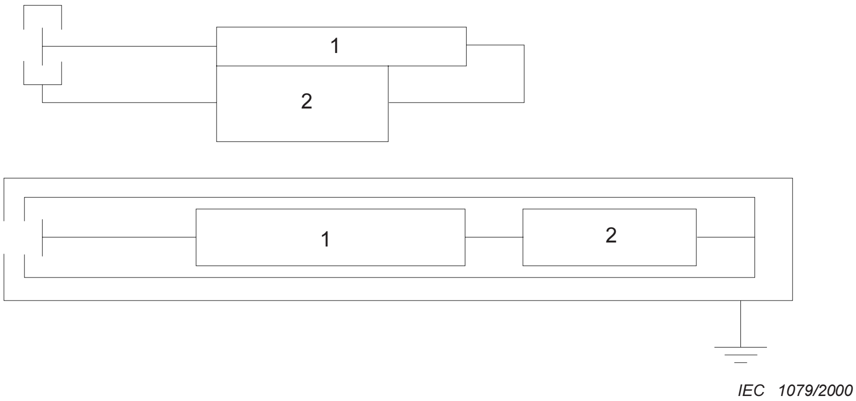
Key

1 Isolated electrode
2 Fieldmeter
3 External output
4 Shield

Figure 5 – Charge plate monitor

4.2.2.4 Feedback fieldmeter

Feedback fieldmeters overcome the zero stability limitations of induction probes by using a chopper to modulate the electric field at a sensing electrode and by feedback of voltage to a second electrode to null the input field. This is illustrated in figure 6.



Key

1 Electrometer

2 Feedback

Figure 6 – Illustrations of feedback fieldmeters

4.2.3 Construction

The sensing surface of the instrument is a flat conducting surface or boundary within a case which is made from conductive or a static dissipative material, and connected to ground via a clearly identified ground bonding point.

The instrument display, and signal output, should give a linear response to electric field, symmetrical with polarity and with no hysteresis. The display should show electric field values with polarity in volts per meter or kilovolts per meter.

Battery powered instruments shall provide an indication when the battery voltage level is low since accuracy can be compromised.

Signal output connection facilities are often convenient, allowing observations to be continuously recorded or transferred into a plotter or a microcomputer.

NOTE Some instruments used for electrostatic field measurement display values only for volts and not for volts per meter. These display values are calibrated at a fixed distance from the charged surface being measured. Care must be taken to assure accurate distance from the measurement instrument to the charged surface when using these instruments.

4.2.4 Procedure

4.2.4.1 Zero adjustment and stability check

Induction probes and fieldmeters should be switched on or 'zeroed' in a region free of electric fields, such as close to an earthed metal surface, ideally a Faraday enclosure, having connected the case of the instrument to ground. The stability of the zero reading should be observed in a field-free region over times comparable to the expected time needed for measurement. The fieldmeter is then moved to observe a constant high value of electric field obtained by applying a steady voltage to a metal plate at a known, fixed distance from the fieldmeter aperture, ensuring that no insulating materials or charged surfaces are in the vicinity.

The rate of change of reading is observed to estimate the input decay time constant. After a time that is short (less than 2 %) compared to the input time constant, the instrument is returned to a field-free region and any change in the zero reading noted.

4.2.4.2 Measurement of electric field

The fieldmeter is connected to ground before any measurements can be taken. The measurements should be completed, at the specified distance, within a time determined as being short compared to the input decay time constant and without re-zeroing. Check the fieldmeter zero periodically and record the reading.

NOTE Ensure that the surfaces around the sensing region are clean. Insulating particles readily become charged and any such particles deposited in or around the sensing region will offset the instrument zero. Air purging helps prevent particle deposition.

4.2.5 Results

The result is the value of the individual readings in volts per meter.

4.3 Measurement of potential

4.3.1 Principle

The potential on a conducting object may be measured by connection to an electrostatic voltmeter.

NOTE For small objects (of low capacity) allowance must be made for the reduction in measured potential caused by connecting the test capacitance and meter capacitance in parallel.

Potentials on surfaces or in a space may also be measured by a non-contacting method.

4.3.2 Apparatus

4.3.2.1 Contact electrostatic voltmeters

A contact electrostatic voltmeter presents a very high – greater than 10^{14} Ω – input resistance and low capacitance to ground and measures potential directly by connection to the object under test.

4.3.2.2 Induction probes and field mills

These instruments are described in 4.2.2.1 and 4.2.2.2.

The potential U (V) of a surface distant d (m) from the aperture of a field meter measuring a field E (V/m) is given by:

$$U = f \times E \times d$$

where f is a correction factor (see note 1 in 4.3.3.2).

4.3.2.3 Non-contact electrostatic voltmeter

A voltage follower probe (figure 6) comprises a field meter in which the output voltage is fed back to null the observed field. An unearthed, battery-driven, fieldmeter can be used in the same mode by applying an external potential to the fieldmeter case to reduce the observed field to zero.

4.3.3 Procedure

4.3.3.1 Contact electrostatic voltmeter

The contact electrostatic voltmeter is connected directly to the electrically conducting object. It should be noted that this method is only appropriate for objects whose capacitance to ground is much greater than that of the total measuring system.

NOTE The influence of the capacitance of the instrument should be allowed for when the capacitances of both the instrument and the object under test are known (see 4.1.4).

4.3.3.2 Fieldmeter

A fieldmeter is placed at a known distance from the surface under test and the measured field recorded.

NOTE 1 The field between the surface and the fieldmeter aperture may be non-uniform and a correction factor *f*, obtained by calibration for the particular geometric arrangement, must be applied.

NOTE 2 The presence of a grounded fieldmeter may significantly increase the capacitance to ground of the surface or body and so affect the measured potential. A large separation is used to avoid spark discharges but care must be taken to eliminate the effects of extraneous local charges.

4.3.3.3 Non-contact voltmeter

The voltage required to null the input field is recorded via the voltage follower probe (see figure 6). The result is largely independent of the meter-to-surface separation.

4.3.4 Results

The result is recorded as the value of the individual readings in volts.

5 Chargeability tests

5.1 On-site measurements

The charge accumulation on electrically isolated plant or people can be determined by measuring the potential directly using the method described in 4.3 or by measurement of the electric field at the surface as described in 4.2.

5.2 Model tests

5.2.1 General

All tests should start with a measurement to ensure that the two components to be placed in contact are not initially charged. The two components to be placed in contact should not be influenced by contact with a third component.

5.2.2 Rubbing tests

The charging of samples of material or items by rubbing, during and directly after cessation of rubbing, if there is sufficient charge retention can be measured by any of these methods. Rubbing shall be such that the whole area of the sample over which the measurement is to be made can be uniformly rubbed at prescribed speed, direction, pressure and for a known duration.

Rubbing shall be performed using materials which are representative of those found in practice. Care should be taken to ensure that the rubbing item or material only touches the sample and not any parts of the support, as contact with material other than the sample may considerably influence the result.

The condition of the sample influences the results. Care should be taken that the sample is not contaminated in any way. The test surface, for example, should not be touched by fingers but should be handled only with tweezers or with clean gloves in such a manner that charging of the surface is avoided.

A new rubbing material and sample should be used for each test.

5.2.3 Product sliding tests

Where pieces of material, items or articles slide over surfaces and a number of orientations are possible with different combinations of surfaces, the measurements shall be made with each orientation. For example, an electronic device should be tested legs up and legs down.

Measurements are made with the items or samples sliding down the normal associated practical surface to the maximum normal travel distance. The item is placed at the maximum normal travel distance and the surface then inclined until the item slides down the surface and into the Faraday pail under gravity.

Tests should be conducted at a constant angle, having established the angle at which free movement is achieved.

A powder or liquid shall be allowed to flow freely into the Faraday pail using conveying materials representative of the practical circumstances. Measurements are made over a convenient time for continuous manufacturing or material feed operations, both the quantity of charge and quantity of material collected being recorded. Data shall be reported on a 'per item', 'per unit mass' or 'per unit volume' basis.

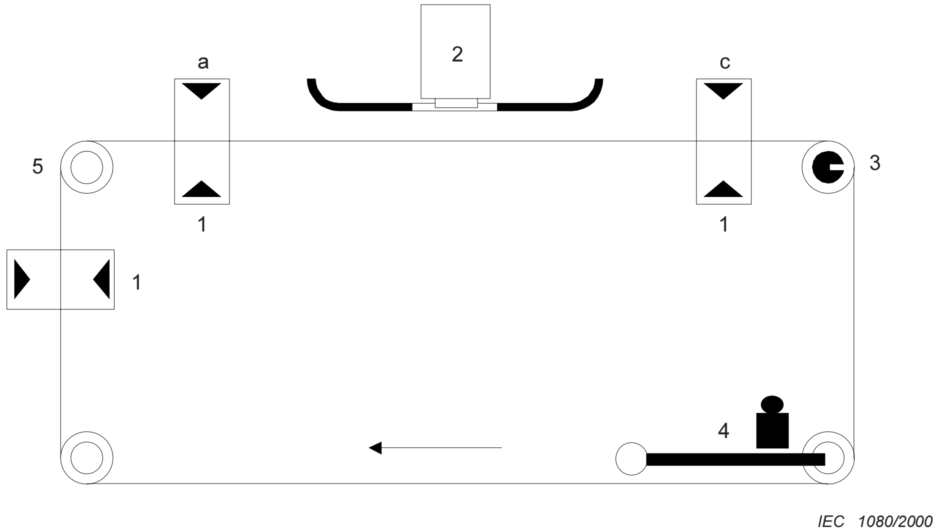
Items are tested in their normal condition and are not specially cleaned in advance. If either surface could be modified by rubbing, or if there could be transfer of material between the surfaces then fresh areas of material should be used for each measurement. This is particularly important where one material may have been surface treated to be low charging or static dissipative.

Hand contact with the surfaces and items shall be avoided. Clean metal tweezers or tools shall be used for any handling or manipulation required.

The length of sliding distance (or flow), chute profile, pipe diameter and sample characteristics should be recorded.

5.2.4 Film charging over rollers

An automatic apparatus to test the chargeability of thin, flexible sheet materials passing over rolls is shown in figure 7, but alternative configurations such as a linear track between an unwind and wind-up roller can be used. It comprises an approximately square array of four rollers. Two of the rollers are free running, one is driven, and the last can be either free running or fixed. One of the free-running rollers is mounted on a dancer arm to allow specific tension to be applied to the test loop. All roller surfaces are of materials and finish representative of practical circumstances.



Components

a Testing of neutralizer effectiveness
b Observation of free roller charging
c Single-pass charging

Key

1 Neutralizer
2 Fieldmeter
3 Driven roller
4 Dancer arm for specific tension in the loop
5 Free running roller

NOTE Locations a, b and c represent neutralizer locations for testing of neutralizer effectiveness, observation of free roller charging and single-pass charging, respectively. For the measurement of continuous loop charging, all neutralizers are off.

Figure 7 – Simulation of roller charging of film under test

Alternative positions are provided for mounting fieldmeters close to the moving film surface. The fieldmeter is connected to a device for recording observations during tests. Two neutralizer (ionization devices) bars are provided for neutralizing charge on both sides of the moving film. Checks should be made to ensure that the ioniser does not influence the fieldmeter reading.

The above apparatus is mounted inside an environment with facilities to allow control of temperature and relative humidity.

After cleaning the rollers with a suitable solvent, a loop of film is mounted over the roller system. Check that film motion is satisfactory up to full test speed. Allow sufficient time for the environment and the film to reach equilibrium (see clause 3).

NOTE The readings obtained for the overlapping areas of film may be significantly different from the mean.

The initial level of fieldmeter reading shall be recorded. The neutralizers are energized and a continuous recording of the variation of reading made as the film speed is increased to test speed. This shows the effectiveness of charge neutralization. The neutralizers are switched off with the film continuing to run and the rate of build up of fieldmeter reading recorded until it reaches a maximum level.

The fieldmeter readings shall be interpreted in terms of field intensity ($V \cdot m^{-1}$), potential (V) or charge density on the film ($C \cdot m^{-2}$) using appropriate calibration factors as described in the manufacturer's literature. The charge build-up per roll contact is calculated from the rate of increase of readings. The arithmetic mean value of the results and the standard deviation value of the result shall be calculated.

6 Reporting

The test report for all the above test methods shall record at least the following information:

a) date of measurements;

b) description and/or identification of sample tested and other materials involved;

c) nature of test performed, all test parameters being recorded;

d) individual values of parameters measured;

e) ambient temperature and relative humidity at start and end of measurements;

f) identification of instrumentation used and date of most recent calibration.

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