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REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROSTATICS –

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

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 61340-2-3 has been prepared by IEC technical committee 101: Electrostatics.

This second edition cancels and replaces the first edition published in 2000. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) a distinction has been introduced between instrumentation used for laboratory evaluations, instrumentation used for acceptance testing and instrumentation used for compliance verification (periodic testing);
b) an alternative electrode assembly is described, which can be used on non-planar products or when the dimensions of the product under test are too small to allow the larger electrode assembly to be used;
c) the formulae for calculating surface and volume resistivity have been modified to correspond with common industry practice in the main areas of application for the IEC 61340 series.

The text of this standard is based on the following documents:

CDV	Report on voting
101/470/CDV	101/494/RVC

Full information on the voting for the approval of this standard 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 2.

A list of all the parts in the IEC 61340 series, published under the general title *Electrostatics*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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INTRODUCTION

Measurements of resistances and related calculations of resistivities belong to the fundamental objectives of electrical measuring techniques along with measurements of voltage and current.

Resistivity is the electrical characteristic having the widest range, extending over some thirty orders of magnitude from the most conductive metal to almost perfect insulators.

The basis is Ohm's law and is valid for DC current and instantaneous values of AC current in electron conductors (metals, carbon, etc.). Values of resistance measurements using AC current can be influenced by capacitive/inductive reactance, depending on the frequency. Thus, existing national and international standards dealing with resistance measurements of solid materials normally require the application of DC current.

Most non-metal materials such as plastics are classified as polymers and ion conductors. The transport of charges can be dependent upon the applied electrical field strength during the measurement. Beside the measuring current, there exists a charging current that polarizes and/or electrostatically charges the material, indicated by an asymptotic decay of the measuring current with time and causing an apparent change in resistance. If this effect is observed, it will be advisable to repeat the measurement immediately after a definite electrification time has elapsed using the reverse polarity for the measuring current and averaging both obtained values.

ELECTROSTATICS –

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

1 Scope

This part of IEC 61340 describes test methods for the determination of the electrical resistance and resistivity of solid materials used to avoid electrostatic charge accumulation, in which the measured resistance is in the range 10^4 Ω to 10^{12} Ω.

It takes account of existing IEC/ISO standards and other published information, and gives recommendations and guidelines on the appropriate method.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60093:1980, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*~~

~~IEC 60167:1964, *Methods of test for the determination of the insulation resistance of solid insulating materials*~~

~~IEC 60212:1971, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*~~

~~IEC 60260:1968, *Test enclosures of non-injection type for constant relative humidity*~~

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials – Part 3-1: Determination of resistive properties (DC Methods) – Volume resistance and volume resistivity – General method*

IEC 62631-3-2, *Dielectric and resistive properties of solid insulating materials – Part 3-2: Determination of resistive properties (DC Methods) – Surface resistance and surface resistivity*

IEC 62631-3-3, *Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC Methods) – Insulation resistance*

ISO 1853~~:1998~~, *Conducting and ~~antistatic~~ dissipative rubbers, vulcanized or thermoplastic – Measurement of resistivity*

ISO 2951~~:1974~~, *Rubber, vulcanized or thermoplastic – Determination of insulation resistance*

ISO 3915~~:1981~~, *Plastics – Measurement of resistivity of conductive plastics*

ISO 7619-1, *Rubber, vulcanized or thermoplastic – Determination of indentation hardness – Part 1: Durometer method (Shore hardness)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
electrode
conductor of defined shape, size and configuration being in contact with the specimen to be measured

3.2
resistance
R
ratio of a DC voltage (V) applied between two points and the steady-state current (A) between the two points

Note 1 to entry: Resistance is expressed in ohms.

3.3
resistance to ground
R_g
resistance measured between an electrode placed on the surface of a test specimen and a local ground

Note 1 to entry: Resistance to ground is expressed in ohms.

3.4
resistance to groundable point
R_{gp}
resistance measured between an electrode placed on the surface of a test specimen and a groundable point fitted to the test specimen

Note 1 to entry: Resistance to groundable point is expressed in ohms.

3.5
point-to-point resistance
R_{pp}
resistance measured between two electrodes placed a specified distance apart on the same surface of a test specimen

Note 1 to entry: Point-to-point resistance is expressed in ohms.

3.6
surface resistance
R_s
~~the ratio of a d.c. voltage (V) applied between two electrodes on a surface of a specimen and the current (A) between the electrodes~~
resistance measured between a central disc electrode and a surrounding concentric ring electrode placed on the surface of a test specimen

Note 1 to entry: Surface resistance is expressed in ohms.

3.7
surface resistivity
ρ_s
resistivity equivalent to the surface resistance of a square area, having the electrodes at two opposite sides

Note 1 to entry: The SI unit of surface resistivity (Ω) is sometimes referred to as Ω/sq (ohms per square), to distinguish resistivity values from resistance values. However, the use of Ω/sq is deprecated because it may imply a resistance per unit area, which is not correct.

3.8
volume resistance
R_v
~~the ratio of a d.c. voltage (V) applied between two electrodes placed on two (opposite) surfaces of a specimen and the steady-state current (A) between the electrodes~~
resistance measured between two electrodes placed on opposite surfaces of a test specimen

Note 1 to entry: Volume resistance is expressed in ohms.

3.9
volume resistivity
ρ_v
ratio of a DC field strength (V/m) and the steady-state current density (A/m^2) within the material

Note 1 to entry: In practice, it is equivalent to the volume resistance of a cube with unit length, having the electrodes at two opposite surfaces.

Note 2 to entry: Volume resistivity is not an appropriate characteristic for materials that are electrically inhomogeneous.

Note 3 to entry: Volume resistivity is expressed in ohm meters.

~~**3.5**~~
~~**measuring electrode**~~
~~a conductor of defined shape, size and configuration being in contact with the specimen to be measured~~

4 Conditioning and test environment

The electrostatic behaviour of materials is influenced by environmental conditions, such as relative humidity and temperature.

For this reason, measurements shall be performed under controlled conditions. The selection of the appropriate conditions for testing shall be decided according to the type of material (product specification) and the intended application, based on the most severe conditions expected to occur during usage (e.g. lowest humidity and highest humidity).

Unless otherwise agreed, the atmosphere for conditioning and testing shall be (23 ± 2) °C and (12 ± 3) % relative humidity, and the conditioning time prior to testing shall be at least 24 h.

If it is required to test that the measured resistance is not below a minimum limit, additional testing at high humidity is required. Unless otherwise agreed, the atmosphere for conditioning and testing at high humidity shall be (23 ± 2) °C and (60 ± 10) % relative humidity, and the conditioning time prior to testing shall be at least 24 h.

Specimens shall normally be conditioned and measured in the same climate, if not specified differently. However, preconditioning ~~can~~ may be necessary in order to eliminate the effects of stress appearing after the moulding process of some plastic materials or as a drying treatment before the test procedure starts. Preconditioning ~~shall~~ is normally ~~handled~~ done in a different environment.

Adequate devices are a desiccator in an oven or a climate chamber preferably equipped with forced circulation and interchange of air. ~~Additional guidance may be taken from IEC 60212 and IEC 60260.~~

5 Selection of test method

For planar materials, the following procedure shall be used to select the test method:

a) if the range of electrical resistance of a material to be tested is known, then use the relevant clause (Clause 6, 7, 8 or 10) where appropriate standards are listed or methods described;

b) for a material of initially unknown resistivity, start the measurements by using methods for conductive materials according to Clause 6.

If the measurement is not possible or the obtained result exceeds the given range for the application of the test method, it shall be regarded as being inadequate and the result shall not be taken into account. The measurement shall be repeated according to Clause 8 or Clause 10 for electrostatic dissipative materials. If the situation described above occurs again, the measurement shall be repeated according to Clause 7 for insulating materials.

For non-planar materials and for products with structures that are too small to allow the use of the electrode assemblies specified in 8.2, the method described in Clause 10 shall be used.

If the measurement result using the method described in Clause 10 is less than 10^4 Ω or greater than 10^{12} Ω, and the shape or dimensions of the material under test do not allow measurements according to Clause 6 or Clause 7, the test result shall be reported as either "<10^4 Ω" or ">10^{12} Ω".

6 Resistance measurements ~~of~~ for solid conductive materials

The resistance of solid conductive materials (non-metals) shall be measured in accordance with ISO 3915 for plastics or ISO 1853 for rubbers. If the measured resistance is greater than or equal to 10^4 Ω, use the methods described in Clause 7, 8 or 10.

~~For highly conductive materials, the contact resistances necessitate the method of a quadrupole measurement in order to avoid a non-linear potential distribution over the specimen. The most important parameter is the current injected through the specimen or, even more precisely, the dissipated power in order to avoid significantly heating the material.~~

7 Resistance measurements ~~of~~ for solid insulating materials

The resistance of solid insulating materials shall be measured in accordance with ~~IEC 60093, IEC 60167~~ IEC 62631-3-1, IEC 62631-3-2 or IEC 62631-3-3 for plastics, or ISO 2951 for rubbers.

~~For highly insulating materials, the resistance along the surface can be much lower compared to the resistance through the material due to the effect of adsorbed contaminants such as water. Furthermore, there can exist a non-linear functional correlation between the applied voltage and the conducted current. Thus, the surface and volume resistance of solid insulating materials are conventionally measured under specified conditions (generally 500 V and 1 min time of electrification) with guarded electrodes.~~

~~Liquid, painted or sprayed contact electrodes could modify the behaviour of the specimen under test and shall not be applied. The use of conductive rubber as contact material is strongly recommended instead.~~

8 Resistance measurements ~~of~~ for planar electrostatic dissipative materials (used to avoid electrostatic charge accumulation)

~~The resistance of materials used to avoid electrostatic charge accumulation shall be measured according to the instructions given in the subclauses below.~~

8.1 Instrumentation

8.1.1 General

The instrumentation may consist of either a DC power supply and an ammeter, or an integrated instrument (ohmmeter). National safety regulations shall be followed.

~~If an ohmmeter without current reading facility is used for volume resistance measurements, a separate ammeter is required capable of reading at least from 10 pA to 10 mA with an accuracy of ±5 %.~~

8.1.2 Instrumentation for laboratory evaluation

The ~~open circuit~~ output voltage under load shall be (100 ± 5) V for measurements of 1×10^6 Ω and higher, and (10,0 ± 0,5) V for less than 1×10^6 Ω.

If an ohmmeter is used, readings shall be possible at least from 1×10^3 Ω to 1×10^{13} Ω, with an accuracy of ±10 %.

If a DC power supply and ammeter are used, readings shall be possible at least from 10 pA to 10 mA. The combined accuracy of the DC power supply and ammeter shall be ±10 %.

8.1.3 Instrumentation for acceptance testing

Instrumentation for laboratory evaluation or instrumentation meeting the following requirements shall be used for acceptance testing.

The open circuit voltage shall be (100 ± 5) V for measurements of 1×10^6 Ω and higher, and (10,0 ± 0,5) V for less than 1×10^6 Ω.

If an ohmmeter is used, readings shall be possible at least from 1×10^3 Ω to 1×10^{13} Ω, with an accuracy of ±20 %.

If a DC power supply and ammeter are used, readings shall be possible at least from 10 pA to 10 mA with an accuracy of ±20 %.

In case of dispute, instrumentation for laboratory evaluations shall be used.

8.1.4 Instrumentation for compliance verification (periodic testing)

Instrumentation meeting the requirements for laboratory evaluations or acceptance testing, or instrumentation meeting the following requirements shall be used.

Compliance verification instrumentation shall be capable of making measurements one order of magnitude above and below the intended measurement range. The output voltage of compliance verification instrumentation may vary from laboratory evaluation or acceptance testing instrumentation, and may be rated under load or open circuit. Compliance verification instrumentation shall be checked against laboratory evaluation or acceptance testing instrumentation to ensure there is correlation between measurement results.

In case of dispute, instrumentation for acceptance testing or laboratory evaluation shall be used.

8.2 Electrode assemblies

8.2.1 General

The electrodes shall consist of a material that allows intimate contact with the specimen surface and introduces no appreciable error because of electrode resistance or contamination of the specimen. The electrode material shall be corrosion resistant under test conditions and shall not cause a chemical reaction with the material being tested.

The assemblies described in the subclauses below are recommended to be suitable, but other configurations complying with national or international standards may also be used, if appropriate. Especially for volume resistance measurements of electrostatic dissipative materials, it is important that applied probes of the guarded ring type have sufficient space between the centre (measuring) and ring (guard) contact electrode in order to minimize stray currents falsifying the readings. It is recommended, that the gap g shall be at least 10 mm. In cases of dispute, the assemblies described in this standard shall be applied.

8.2.2 Assembly for the measurement of surface resistance

The electrode assembly (probe 1) contains a central disc surrounded by a concentric ring made of conductive materials which make contact with the material under test (see Figure 1). The total mass of the electrode assembly shall be (2,5 ± 0,25) kg.

The contact surface material shall have a volume resistance of less than 10^3 Ω when tested on a stainless, non-corrosive metal plate (not aluminium) as the counter electrode by applying (10,0 ± 0,5) V, and shall have a Shore A hardness of 50 to 70 when tested according to ISO 7619-1.

Insulating materials used in the electrode assembly shall have volume and/or surface resistance greater than 10^{13} Ω when tested according to IEC 62631-3-1 and/or IEC 62631-3-2 respectively.

The material under test ~~should~~ shall be placed on an insulating support as described in 8.2.5.

Dimensions in millimetres

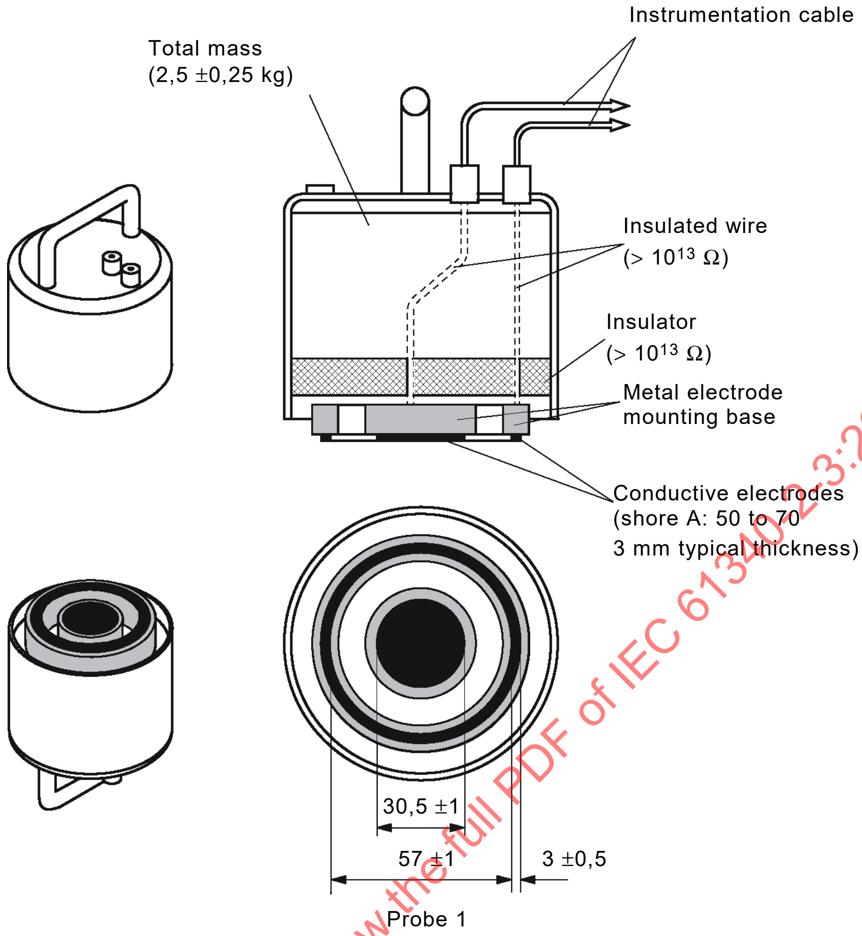


Figure 1 – Example of an assembly for the measurement of surface and volume resistance

8.2.3 Assembly for the measurement of volume resistance

The assembly consists of two electrodes placed on either side of the material under test (see Figure 4). The top electrode assembly (probe 1) shall be as described in 8.2.2 and shown in Figure 1.

The bottom electrode (probe 2) shall be a stainless, non-corrosive metal plate (not aluminium) sufficiently large to support the specimen under test. Probe 2 shall be equipped with a permanent connecting terminal (e.g. plug hole, riveted connector).

~~NOTE~~ Crocodile clips ~~can~~ should not be used.

It should be placed either on an insulating support as described in 8.2.5 prior to test or be equipped with equivalent insulating feet.

8.2.4 Assembly for the measurement of resistance to ground/groundable point and point-to-point resistance

The assembly consists of one (resistance to ground/groundable point) or two (point-to-point resistance) electrodes (probe 3) containing a disk made of conductive material which makes contact with the material under test (see Figure 2). The total mass of the electrode assembly shall be (2,5 ± 0,25) kg.

The contact surface material shall be conductive enough that two probes placed on a metal surface (e.g. probe 2) have a point-to-point resistance of less than 10^3 Ω when tested with (10,0 ± 0,5) V, and shall have a Shore A hardness of 50 to 70 when tested according to ISO 7619-1.

Insulating materials used in the electrode assembly shall have volume and/or surface resistance greater than 10^{13} Ω when tested according to IEC 62631-3-1 and/or IEC 62631-3-2 respectively.

The material under test ~~should~~ shall be placed on an insulating support as described in 8.2.5.

Dimensions in millimetres

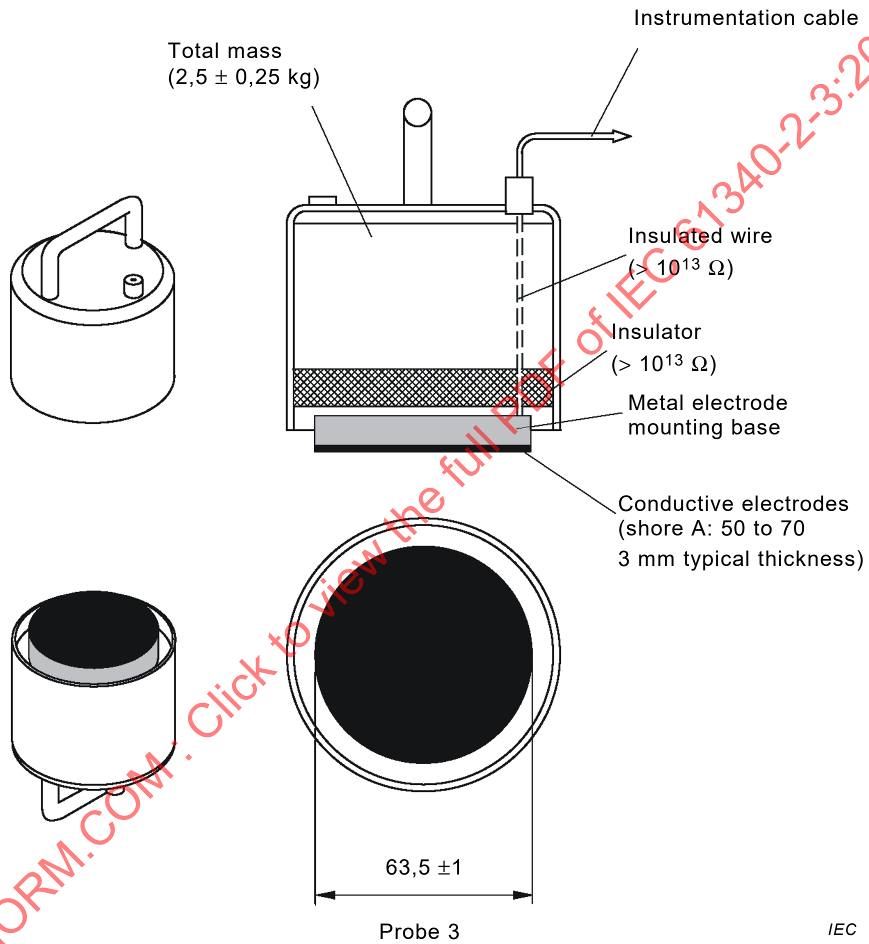


Figure 2 – Example of an assembly for the measurement of resistance to ground/groundable point and point-to-point resistance

8.2.5 Test support

The material shall be tested on a smooth flat support having a surface resistance ~~of more~~ greater than 1 × 10^{13} Ω ~~when tested with 500 V in compliance with IEC 60093 and IEC 60167~~ measured according to IEC 62631-3-2. The size shall be at least 10 mm more in length and width compared to the size of the specimen under test. The minimum thickness shall be 1 mm.

8.3 Sample preparation and handling

Refer to applicable material specifications for sampling instructions. The specimens shall not be handled or marked in areas where measurements will be performed. If the areas where the electrodes make contact have been reworked, this shall be stated in the test report. When the surface resistance is to be measured, the surface shall not be cleaned unless agreed on or specified. Care shall be taken in applying the electrodes and also in handling and mounting the specimens for the measurements in order to minimize the possibility of creating electrical paths due to contamination that may adversely affect the test results.

Specimens shall preferably have a simple geometric shape in the form of sheets with a minimum size of at least 80 mm × 120 mm or 110 mm diameter.

If no other regulation is given, a minimum of three representative specimens of the sample material shall be prepared. The sample should be clearly marked in order to identify The surface to be tested shall be clearly marked or otherwise identified.

8.4 System verification fixtures for surface resistance

8.4.1 Procedure for lower resistance range

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.1 and have 20 individual metal surfaces or pads which make contact with the centre (inner) electrode surface, and 20 identical pads which make contact with the ring (outer) electrode surface. The fixture shall consist of 20 each, 10 MΩ, 1 % resistors. Each resistor shall be individually connected between an inner and outer pad (see figure 5). The material for the fixture shall have a volume resistance of 10^8 Ω at least between the two rows of pads when not connected by resistors, and tested with 100 V.

Prior to the test, the system shall be checked for proper operation as follows:

The assembly described in 8.2.1 is connected to the instrumentation according to figure 2 and then placed onto the fixture. A voltage of 10 V shall be applied and a reading taken after 15 s. The result shall be $5{,}0 \times 10^5$ Ω ± 5 %. The check is then repeated after having the assembly rotated through 90°.

NOTE Rotation of the electrode assembly checks the flatness of the fixture and electrode containing surfaces.

8.4.2 Procedure for upper resistance range and determination of electrification period

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.1 and have metal surfaces or pads which make contact with the electrode surfaces. They are connected via a single resistor of $1{,}0 \times 10^{12}$ Ω ± 5 % between the centre (inner) and ring (outer) contact surfaces (see figure 6). When tested with 500 V in compliance with IEC 60093 and IEC 60167, the material for the fixture shall have a volume resistance of at least 10^{14} Ω between the two rows of pads when not connected by a resistor.

The following procedure confirms the capability of the system to measure $1{,}0 \times 10^{12}$ Ω and offers a method to determine the electrification period as follows:

The assembly described in 8.2.1 is connected to the instrumentation according to figure 2 and then placed onto the fixture. A voltage of 100 V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.

8.5 System verification for volume resistance measurements

8.5.1 Procedure for lower resistance range

Prior to the test, the system shall be checked for proper operation as follows.

~~Connect the electrodes (probes 1 and 2) to the instrumentation according to figure 3 but without a specimen between them. Then insert a 500 kΩ, 1 % resistor between the voltage source output and probe 2. A voltage of 10 V shall be applied and a reading taken after 15 s. The result shall be 5,0 × 10^5 Ω ± 5 %.~~

~~**8.5.2 Procedure for upper resistance range and determination of electrification period**~~

~~The following procedure confirms the capability of the system to measure 1,0 × 10^{12} Ω and offers a method to determine the electrification period as follows:~~

~~Connect the electrodes (probes 1 and 2) to the instrumentation according to figure 3 but without a specimen between them. Then insert a 1,0 × 10^{12} Ω, 5 % resistor between the voltage source output and probe 2. A voltage of 100 V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.~~

8.4 Test procedures

8.4.1 Surface resistance measurements

The electrode assembly described in 8.2.2 is connected to the instrumentation (see Figure 3). The specimen shall be placed onto the test support with the surface to be tested facing up. The electrode assembly is then positioned onto the approximate centre of the specimen or at least 10 mm away from the edges.

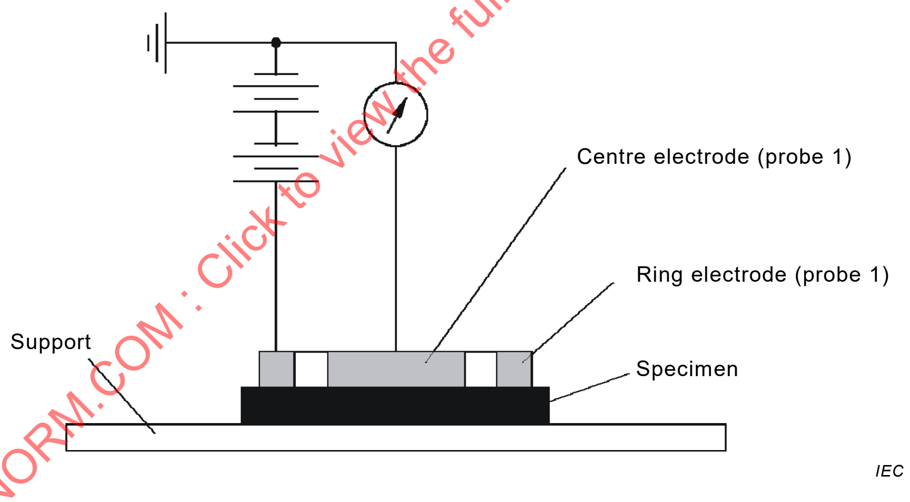


Figure 3 – Basic connections of the electrodes for surface resistance measurements

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s, unless otherwise specified. If the indicated resistance is less than 1,0 × 10^6 Ω, report the value and proceed to the next specimen. If the indicated resistance is equal to or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V. Record the indicated resistance after the electrification period determined in A.1.2.

8.4.2 Volume resistance measurements

The electrode assemblies described in 8.2.2 are connected to the instrumentation (see Figure 4). The bottom electrode (probe 2) is then placed onto the test support first and the specimen laid onto it. Afterwards, the top electrode (probe 1) is ~~then~~ positioned onto the approximate centre of the specimen or at least 10 mm away from the edges.

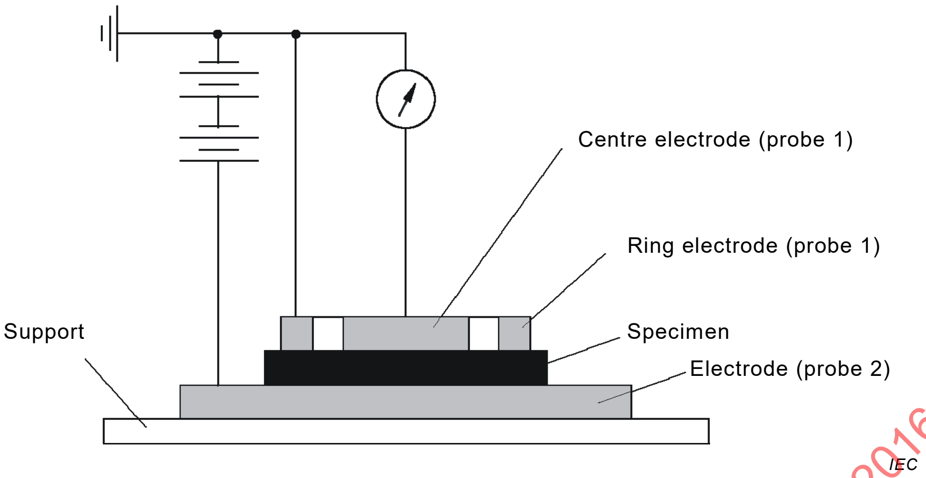


Figure 4 – Basic connections of the electrodes for volume resistance measurements

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s, unless otherwise specified. If the indicated resistance is less than 1,0 × 10^6 Ω, record the value and proceed to the next specimen. If the indicated resistance is equal to or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V. Record the indicated resistance after the electrification period determined in A.2.2.

If an evaluation of the volume resistivity is required, the average thickness h of each specimen shall be determined prior to any measurement following the instructions given in the relevant product specification.

8.4.3 Resistance to groundable point measurements

8.4.3.1 Measurements on laboratory specimens

The test specimens shall be fitted with a representative groundable point. Place the specimens onto the test support with the surface to be tested facing up. Put the electrode assembly (probe 3) onto the surface of the specimen in a position such that the centre of the electrode assembly is at least 50 mm away from the specimen edges or groundable point (see Figure 5). Connect the electrode assembly to one lead of the instrumentation and the groundable point to the other lead.

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than 1,0 × 10^6 Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

Dimensions in millimetres

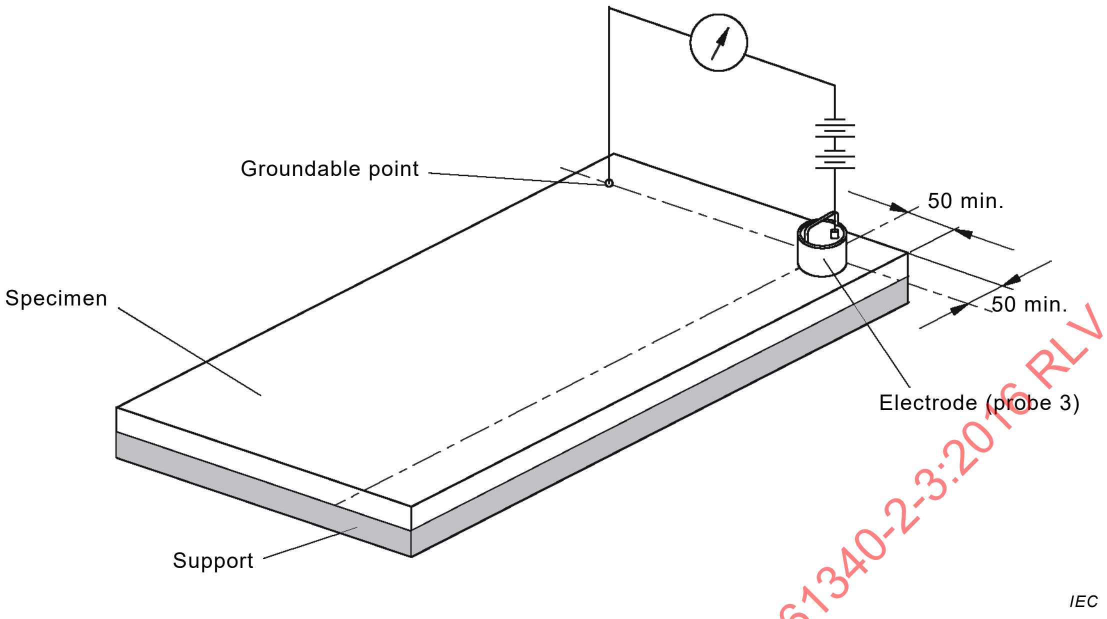


Figure 5 – Principle of resistance to groundable point measurements

8.4.3.2 Measurements on installed materials

Put the electrode assembly (probe 3) onto the surface of the specimen in a position at least 50 mm away from the specimen edges or groundable point (see Figure 5). Connect the electrode assembly to one lead of the instrumentation and the groundable point to the other lead.

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than 1,0 × 10^6 Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

~~NOTE~~ Line-powered instruments ~~may~~ can require an alternate test lead set up to properly measure grounded items. The equipment grounding conductor should be insulated from signal ground. Additionally, the high-potential test lead ~~may~~ can require connection to the ground side of the item under test. Consult the instrument manufacturer's instructions for test lead arrangement.

8.4.4 Point-to-point resistance measurements

Connect two electrode assemblies (probes 3) described in 8.2.4 to the instrumentation. The specimen shall be placed onto the test support with the surface to be tested facing up. The probes shall be then placed onto the surface of the specimen in a specified or, if appropriate, otherwise chosen position at least 250 mm in distance from their longitudinal axes, and at least 50 mm away from the edges of the specimen (see Figure 6).

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than 1,0 × 10^6 Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

Dimensions in millimetres

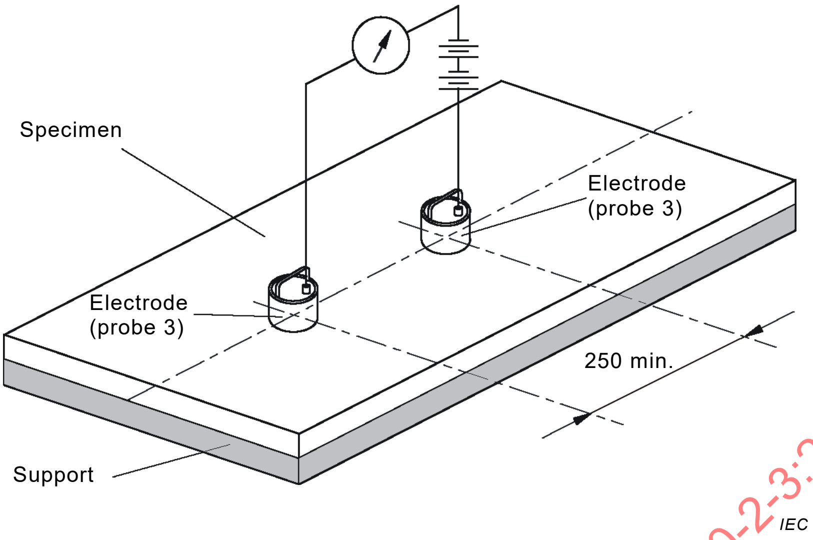


Figure 6 – Principle of point-to-point measurements

9 Conversion to resistivity values

~~When it is appropriate to convert a suface or volume resistance obtained by the test methods described in 8.6.1 or 8.6.2 to an equivalent resistivity, proceed as follows in compliance with IEC 60093.~~

9.1 Surface resistivity ρ_s

Take the following formula according to Figure 7:

~~$$\rho_s = R_x (d_1 + g) \cdot \pi / g$$~~

$$\rho_s = 2\pi \cdot R_s / \log_e(d_2/d_1)$$

$$d_2 = d_1 + 2g$$

where

ρ_s is the surface resistivity (Ω);

~~R_x~~ R_s is the measured surface resistance (Ω);

d_1 is the diameter of the ~~inner~~ centre contact electrode (m);

d_2 is the inner diameter of the outer ring contact electrode (m);

g is the distance (gap) between the contact electrodes (m).

9.2 Volume resistivity ρ_v

Take the following formula according to Figure 7:

~~$$\rho_v = R_x (d_1 + g)^2 \cdot \pi / 4 h$$~~

$$\rho_v = R_v (d_1)^2 \cdot \pi / 4h$$

where

ρ_v is the volume resistivity (Ωm);

~~R_x~~ R_V is the measured volume resistance (Ω);

d_1 is the diameter of the ~~inner~~ centre contact electrode (m);

~~g is the distance (gap) between the contact electrodes (m);~~

h is the specimen thickness (m).

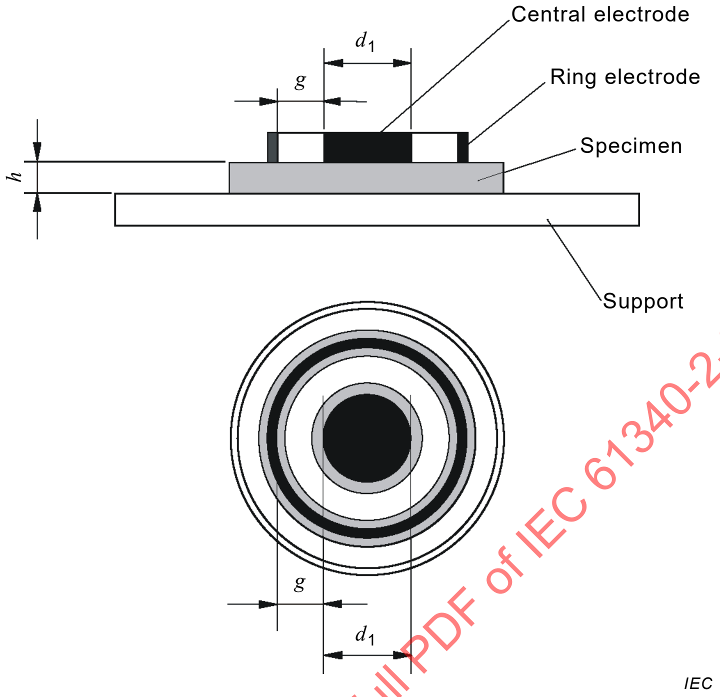


Figure 7 – Configuration for the conversion to surface or volume resistivity

10 Resistance measurements for non-planar materials and products with small structures

10.1 General considerations

This method is recommended for testing items with irregularly shaped surfaces. Conventional concentric ring and parallel bar electrode configurations are used for testing planar items only. However, most packaging items are not planar. Examples include shipping tubes, trays, tote boxes and carrier tapes. This probe employs springs to apply consistent contact pressure between the electrode and the item. Force created by springs is subject to variance from wear, contamination and manufacturing tolerance. This variance is acceptable for this application. Elastomeric electrodes compensate for uneven item surfaces. These features yield consistent results between laboratories and test operators.

10.2 Equipment

10.2.1 Probe

Refer to Table 1 and Figure 8.

This two-point probe consists of an insulated metal body with a polytetrafluoroethylene (PTFE) insulator inserted into each end. One insulator holds test leads; the other holds receptacles that accept spring-loaded pins. One receptacle is surrounded by a cylindrical insulator, which is surrounded by a metal shield. The pins are gold plated and have a spring force of (4,6 ± 0,5) N at a travel of (4,3 ± 0,1) mm. The pin tips are machined to accept friction fitted (3,2 ± 0,1) mm diameter electrically conductive rubber electrodes. The rubber has a Shore A durometer hardness of 50 to 70 (see ISO 7619-1). The electrodes are (3,2 ± 0,1) mm long. The electrode material shall be conductive enough that when tested on a stainless, non-corrosive metal plate (not aluminium) the point-to-point resistance is less than 10^3 Ω at (10,0 ± 0,5) V.

Table 1 provides a list of the key components in Figure 8.

Table 1 – Material for two-point probe

Item	Detail	Example [a]
PTFE insulators	Approximately 25,4 mm length and 12,7 mm diameter	
Electrode shield	Metal tubing approximately 31,8 mm length and 4,75 mm diameter	
Electrode insulator	Heat shrinkable PTFE or other insulator	
Receptacles	Receptacle – with solder cup	Interconnect Devices Inc., R-5-SC
Pins	Spring pin force is (4,6 ± 0,5) N at (4,3 ± 0,1) mm of travel; tip machined to accept electrode	Interconnect Devices Inc., S-5-F-16.4-G
Electrodes	(3,2 ± 0,1) mm long, (3,2 ± 0,1) mm diameter conductive material, Shore A durometer hardness between 50 and 70 (ISO 7619-1)	Vanguard Products, VC-7815
NOTE This is not intended to be a complete materials list for probe construction, but does provide key elements that enable performance replication. Refer to Figure 8 for part placement.		
[a] The parts listed are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of these products. Equivalent products may be used if they can be shown to lead to the same results.		

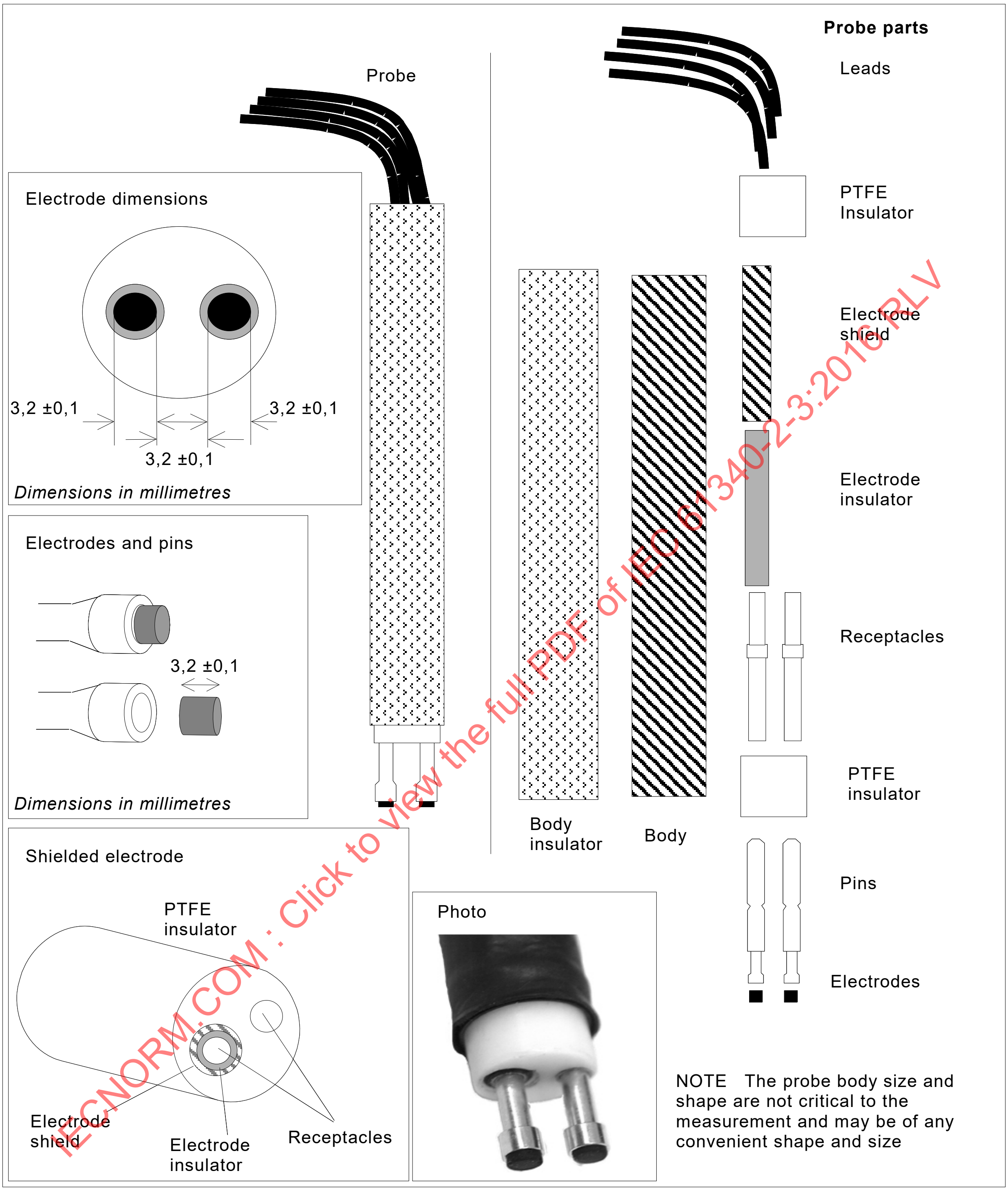


Figure 8 – Two-point probe configuration

10.2.2 Sample support surface

An insulating surface, when used for specimen support, shall have a surface resistance greater than 1×10^{13} Ω, measured according to IEC 62631-3-2.

10.2.3 Resistance measurement apparatus

Resistance measurement apparatus as specified in 8.1 shall be used.

NOTE A constant output meter as specified in 8.1.2 was used to collect all data used to validate this standard test method. Data was not collected to validate this equipment configuration.

10.2.4 Test leads

Test leads appropriate for the meter are required. A shielded lead from the probe body to the instrument will greatly reduce electrical interference (see Figure 9).

NOTE Measurements for the validation of this test method were made using a shielded lead.

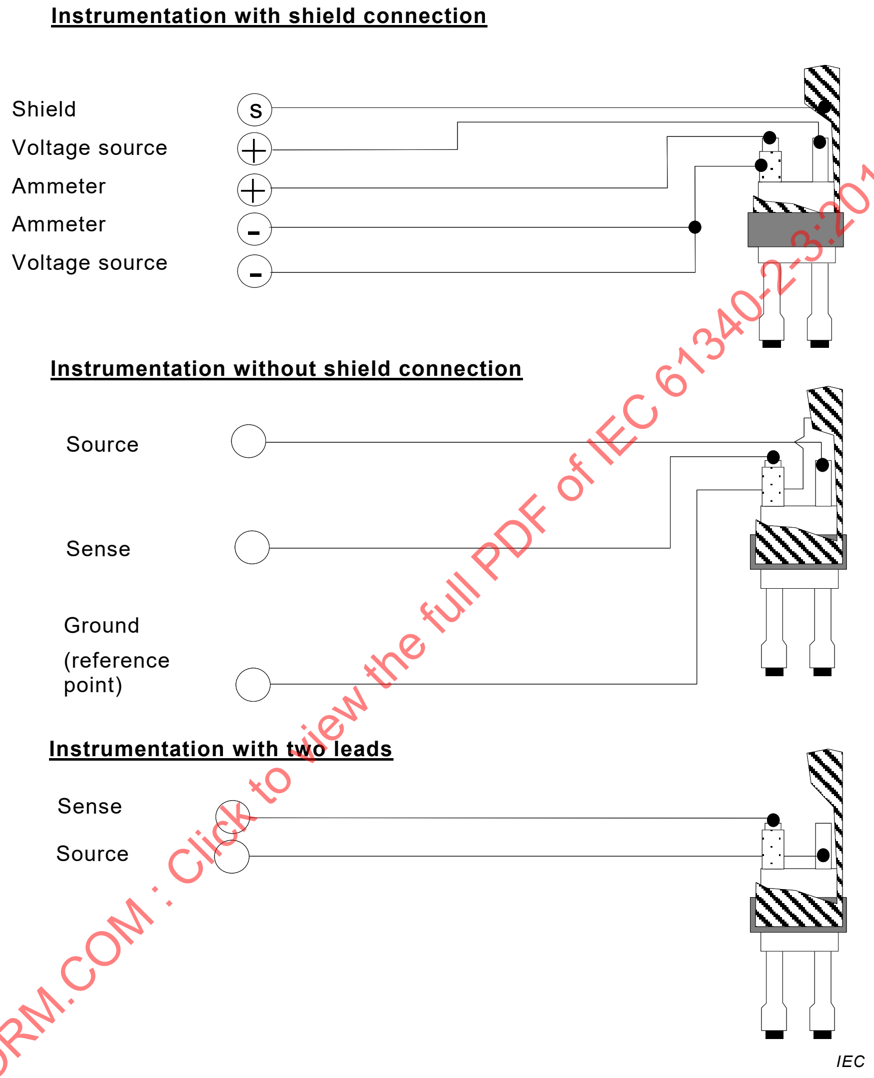


Figure 9 – Probe to instrumentation connection

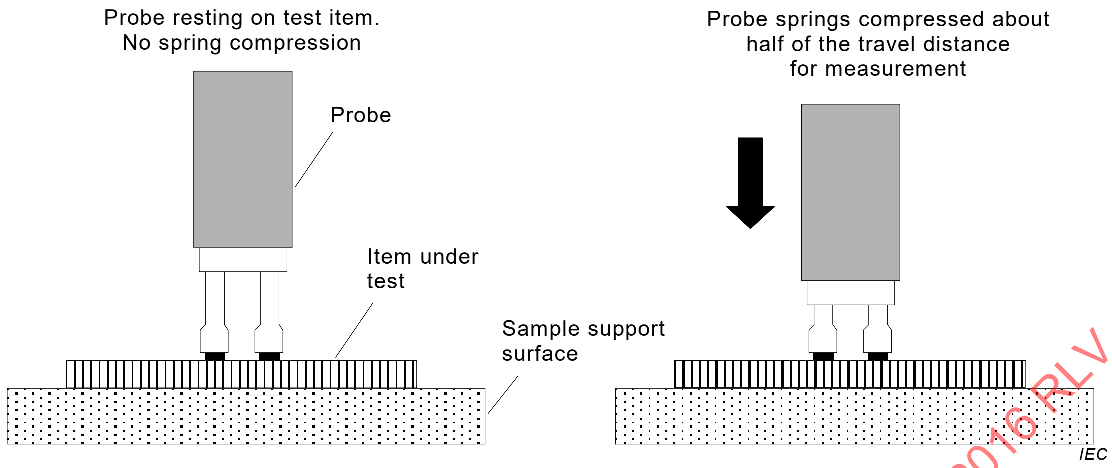


Figure 10 – Spring compression for measurement

10.3 Test procedure

The test procedure is as follows.

a) Connect the probe to the meter as shown in Figure 9.

b) Place the specimen on the sample support surface.

c) Compress the spring-loaded pins downward approximately half of the length of travel (see Figure 10).

d) Apply (10,0 ± 0,5) V for (15 ± 1) s and observe the resistance. If the resistance reading is less than $1{,}0 \times 10^6$ Ω, record the resistance value and proceed to list item f). If the resistance is greater than or equal to $1{,}0 \times 10^6$ Ω, proceed to list item e).

e) If the observed resistance in list item d) is greater than or equal to $1{,}0 \times 10^6$ Ω, change the voltage to (100 ± 5) V and repeat the measurement. Record the resistance value.

f) Repeat the test for each remaining specimen.

NOTE 1 A change in the size of the specimen can affect the measurements.

NOTE 2 Resistance measurements can be affected by the size and spacing between electrodes. The 3,2 mm diameter and 3,2 mm spacing of the electrodes was selected to test a wide range of packaging types and sizes.

NOTE 3 Resistance measurements of a particular sample material can vary due to:

a) variations in sample surface composition or thickness;

b) compression of the sample by the force of the electrodes;

c) variations of the resistance in the electrode material;

d) change in material properties due to the measurement current;

e) cleanliness of electrodes or sample.

NOTE 4 Testing of various electrode materials indicates that the use of harder rubber materials than specified creates greater variation in readings.

11 Repeatability and reproducibility

The resistance of a given specimen varies with the test conditions and it is normal for the materials to be non-uniform. Because of this, determinations are usually not more reproducible than ±10 % and are often even more widely divergent (a range of values of one order of magnitude may be obtained under apparently identical conditions). The comparability of measurements on similar specimens requires a test performance with similar voltage gradients.

The repeatability of these test methods can be assumed to be in the range of approximately one half order of magnitude. If the average value for a series of laboratory tests is 5×10^{10} Ω, the spread of values can be expected from $2,5 \times 10^{10}$ Ω to $7,5 \times 10^{10}$ Ω.

12 Test report

The test report shall include the following information:

a) description and identification of the material (name, grade, colour, manufacturer, manufacturing date, etc.);
b) shape, dimensions and number of the specimens;
c) type, material and dimensions of the probes (electrodes), if different from those specified in this standard;
d) conditioning of the specimens ~~including cleaning procedures~~ (temperature, relative humidity, duration);
e) cleaning procedures;
f) test conditions~~, if different from the product specification~~ (temperature and relative humidity at the time of measurement);
g) instrumentation (type, calibration information, etc.);
h) test voltage and electrification time with additional information, if these parameters are fixed or specified differently;
i) number of measurements, individual results and average value;
j) surface resistivity as individual results with average value, if relevant;
k) volume resistivity as individual results with average value, if relevant;
l) resistance-to-ground/groundable point with identification of test positions, if relevant;
m) point-to-point resistance with identification of test positions and whether the method specified in Clause 8 or Clause 10 is used, if relevant, and applied distance between the longitudinal axes of the probes, if different from this standard;
n) dates of specimen preparation and test performance;
o) any specific observations during test (e.g. polarization effects).

In the absence of instructions from product standards or other requirements, consideration shall be given to the way in which average values are calculated. It is common for arithmetic mean to be used to calculate the average value, i.e. the sum of n values divided by n:

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

where

$\bar{x}$ is the average value;

x_i is an individual value;

n is the number of values to be averaged.

Geometric mean may be of more practical significance than arithmetic mean when averaging values that vary by orders of magnitude, as is often the case when making resistance measurements. For example, five resistance measurements may include four measurements of the order of 1×10^9 Ω and one measurement of 1×10^{12} Ω. The arithmetic mean is weighted by the 1×10^{12} Ω measurement, whereas the geometric mean is not and may more closely represent the overall way in which a material is likely to perform in practice. Geometric mean is calculated by taking the nth root of the product of n values:

$$\bar{x} = \left(\prod_{i=1}^{n} x_i \right)^{1/n}$$

where

$$\bar{x}$$

is the average value;

x_i is an individual value;

n is the number of values to be averaged.

The test report shall state if arithmetic or geometric mean has been used to calculate average values.

Annex A
(normative)

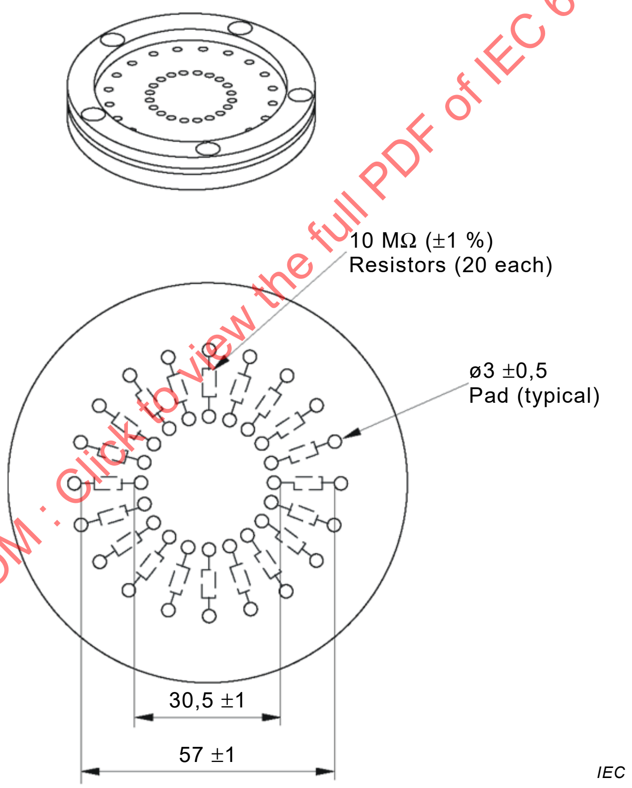
System verification

A.1 System verification for surface resistance measurements

A.1.1 Fixture and procedure for lower resistance range

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.2 and have 20 individual metal surfaces or pads which make contact with the centre (inner) electrode surface, and 20 identical pads which make contact with the ring (outer) electrode surface. Pads shall be flat without any protrusions and be mounted on a flat surface. The fixture shall consist of 20 each, (1,00 ± 0,01) × 10^6 Ω resistors. All resistors to be mounted on bottom side. Each resistor shall be individually connected between an inner and outer pad (see Figure A.1). The material for the fixture shall have a volume resistance of at least 10^8 Ω between the two rows of pads when not connected by resistors, and tested with (100 ± 5) V.

Dimensions in millimetres



~~NOTE 1~~

~~NOTE 2~~

Figure A.1 – Lower resistance range verification fixture for surface resistance measurements

Prior to a test, the system shall be checked for proper operation as follows:

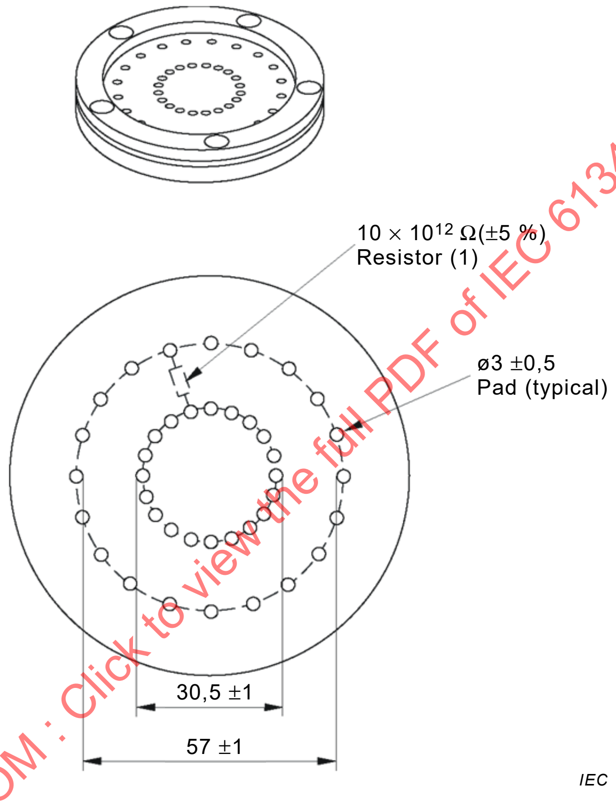
The assembly described in 8.2.2 is connected to the instrumentation according to Figure 3 and then placed onto the fixture. A voltage of (10,0 ± 0,5) V shall be applied and a reading taken after (15 ± 1) s. The result shall be (5,00 ± 0,25) × 10^5 Ω. The check is then repeated after having the assembly rotated through 90°.

NOTE Rotation of the electrode assembly checks the flatness of the fixture and electrode containing surfaces.

A.1.2 Fixture and procedure for upper resistance range and determination of electrification period

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.2 and have metal surfaces or pads which make contact with the electrode surfaces. Pads shall be flat without any protrusions and be mounted on a flat surface. Pads may be tied together with wire or complete circular rings may be used.They are connected via a single resistor of (1,00 ± 0,05) × 10^{12} Ω between the centre (inner) and ring (outer) contact surfaces (see Figure A.2). The resistor and wiring shall be mounted on the bottom side. When tested with (500 ± 25) V in compliance with IEC 60167, the material for the fixture shall have an insulation resistance of at least 10^{14} Ω between the two rows of pads when not connected by a resistor.

Dimensions in millimetres



~~NOTE 1~~

~~NOTE 2~~

~~NOTE 3~~

Figure A.2 – Upper resistance range verification fixture for surface resistance measurements

The following procedure confirms the capability of the system to measure 1,0 × 10^{12} Ω and offers a method to determine the electrification period as follows:

The assembly described in 8.2.2 is connected to the instrumentation according to Figure 3 and then placed onto the fixture. A voltage of (100 ± 5) V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.

A.2 System verification for volume resistance measurements

A.2.1 Fixture and procedure for lower resistance range

Prior to the test, the system shall be checked for proper operation as follows:

Connect the electrodes (probes 1 and 2) to the instrumentation according to Figure 4 but without a specimen between them. Then insert a (5,00 ± 0,05) × 10^5 Ω resistor between the voltage source output and probe 2. A voltage of (10,0 ± 0,5) V shall be applied and a reading taken after (15 ± 1) s. The result shall be (5,00 ± 0,25) × 10^5 Ω.

A.2.2 Fixture and procedure for upper resistance range and determination of electrification period

The following procedure confirms the capability of the system to measure 1,0 × 10^{12} Ω and offers a method to determine the electrification period as follows:

Connect the electrodes (probes 1 and 2) to the instrumentation according to Figure 4 but without a specimen between them. Then insert a (1,00 ± 0,05) × 10^{12} Ω resistor between the voltage source output and probe 2. A voltage of (100 ± 5) V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.

A.3 System verification for resistance measurements for non-planar materials and products with small structures

A.3.1 Verification fixtures

The low resistance verification fixture shall consist of a (1,00 ± 0,01) × 10^5 Ω resistor bonded to two metal contact plates. The plates shall be of size and shape so that each probe electrode contacts only one plate, and so that the plates are not in contact with each other. The plates may be affixed to a material with the same properties as the sample support surface. Figure A.3 illustrates one possible configuration of a resistance verification fixture.

The high resistance verification fixture shall consist of a (1,00 ± 0,05) × 10^9 Ω resistor bonded to two metal contact plates. The plates shall be of a size and shape so that each probe electrode contacts only one plate, and so that the plates are not in contact with each other. The length and width of each plate shall be at least 3,3 mm (for rectangular plates) or shall be at least 3,3 mm diameter (for circular plates), and the minimum gap between plates shall not exceed 3,1 mm. The plates may be affixed to a material with the same properties as the sample support surface. Figure A.3 illustrates one possible configuration of a resistance verification fixture.

The actual value of the resistors shall be measured periodically. This measured value shall be used to verify probe operation.

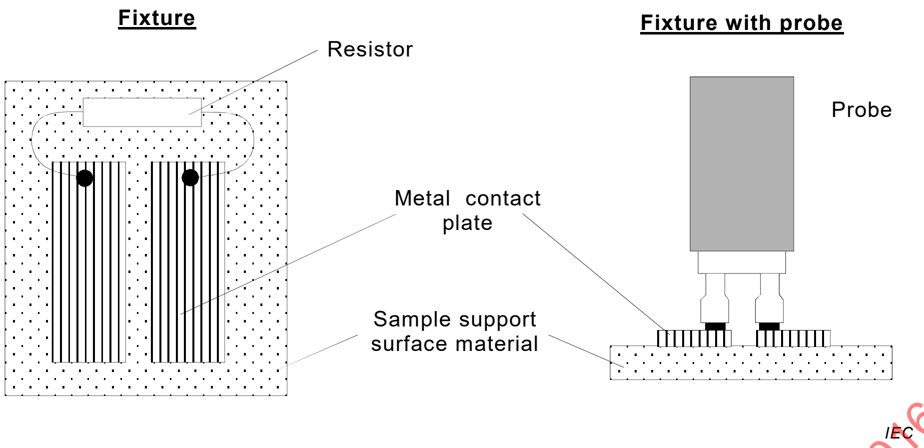


Figure A.3 – Resistance verification fixture

A.3.2 Verification procedure

The verification procedure is as follows:

a) Correct probe operation shall be verified by measuring known resistance values.
b) Connect the probe to the meter as shown in Figure 9.
c) Place the probe electrodes onto the low resistance verification fixture as shown in Figure A.3.
d) Compress the spring-loaded pins downward approximately half of the length of travel (Figure 10).
e) Apply (10,0 ± 0,5) V for (15 ± 1) s and observe the resistance.
f) Record the resistance value. The value should be within 10 % of the actual resistor value.
g) Repeat the procedure using the high resistance verification fixture at (100 ± 5) V.

Bibliography

The following publications contain information adopted or used in this standard.

ANSI/ESD *Association Standards for Protection of Electrostatic Discharge Susceptible Items:*

ANSI/ESD S4.1-1990: *Worksurfaces – Resistive Characterization*

ANSI/ESD S7.1-1991: *Floor Materials – Resistive Characterization of Materials*

ANSI/ESD S11.11-1993: *Surface Resistance Measurements of Static Dissipative Planar Materials*

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IEC 61340-2-3

Edition 2.0 2016-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Électrostatique –
Partie 2-3: Méthodes d'essais pour la détermination de la résistance et de la résistivité des matériaux solides destinés à éviter les charges électrostatiques

IEC 61340-2-3:2016-06(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROSTATICS –

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

FOREWORD

International Standard IEC 61340-2-3 has been prepared by IEC technical committee 101: Electrostatics.

This second edition cancels and replaces the first edition published in 2000. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) a distinction has been introduced between instrumentation used for laboratory evaluations, instrumentation used for acceptance testing and instrumentation used for compliance verification (periodic testing);

b) an alternative electrode assembly is described, which can be used on non-planar products or when the dimensions of the product under test are too small to allow the larger electrode assembly to be used;

c) the formulae for calculating surface and volume resistivity have been modified to correspond with common industry practice in the main areas of application for the IEC 61340 series.

The text of this standard is based on the following documents:

CDV	Report on voting
101/470/CDV	101/494/RVC

Full information on the voting for the approval of this standard 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 2.

A list of all the parts in the IEC 61340 series, published under the general title *Electrostatics*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

INTRODUCTION

Measurements of resistances and related calculations of resistivities belong to the fundamental objectives of electrical measuring techniques along with measurements of voltage and current.

Resistivity is the electrical characteristic having the widest range, extending over some thirty orders of magnitude from the most conductive metal to almost perfect insulators.

The basis is Ohm's law and is valid for DC current and instantaneous values of AC current in electron conductors (metals, carbon, etc.). Values of resistance measurements using AC current can be influenced by capacitive/inductive reactance, depending on the frequency. Thus, existing national and international standards dealing with resistance measurements of solid materials normally require the application of DC current.

Most non-metal materials such as plastics are classified as polymers and ion conductors. The transport of charges can be dependent upon the applied electrical field strength during the measurement. Beside the measuring current, there exists a charging current that polarizes and/or electrostatically charges the material, indicated by an asymptotic decay of the measuring current with time and causing an apparent change in resistance. If this effect is observed, it will be advisable to repeat the measurement immediately after a definite electrification time has elapsed using the reverse polarity for the measuring current and averaging both obtained values.

ELECTROSTATICS –

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

1 Scope

This part of IEC 61340 describes test methods for the determination of the electrical resistance and resistivity of solid materials used to avoid electrostatic charge accumulation, in which the measured resistance is in the range 10^4 Ω to 10^{12} Ω.

It takes account of existing IEC/ISO standards and other published information, and gives recommendations and guidelines on the appropriate method.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials – Part 3-1: Determination of resistive properties (DC Methods) – Volume resistance and volume resistivity – General method*

IEC 62631-3-2, *Dielectric and resistive properties of solid insulating materials – Part 3-2: Determination of resistive properties (DC Methods) – Surface resistance and surface resistivity*

IEC 62631-3-3, *Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC Methods) – Insulation resistance*

ISO 1853, *Conducting and dissipative rubbers, vulcanized or thermoplastic – Measurement of resistivity*

ISO 2951, *Rubber, vulcanized or thermoplastic – Determination of insulation resistance*

ISO 3915, *Plastics – Measurement of resistivity of conductive plastics*

ISO 7619-1, *Rubber, vulcanized or thermoplastic – Determination of indentation hardness – Part 1: Durometer method (Shore hardness)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
electrode
conductor of defined shape, size and configuration being in contact with the specimen to be measured

3.2
resistance
R
ratio of a DC voltage (V) applied between two points and the steady-state current (A) between the two points

Note 1 to entry: Resistance is expressed in ohms.

3.3
resistance to ground
R_g
resistance measured between an electrode placed on the surface of a test specimen and a local ground

Note 1 to entry: Resistance to ground is expressed in ohms.

3.4
resistance to groundable point
R_{gp}
resistance measured between an electrode placed on the surface of a test specimen and a groundable point fitted to the test specimen

Note 1 to entry: Resistance to groundable point is expressed in ohms.

3.5
point-to-point resistance
R_{pp}
resistance measured between two electrodes placed a specified distance apart on the same surface of a test specimen

Note 1 to entry: Point-to-point resistance is expressed in ohms.

3.6
surface resistance
R_s
resistance measured between a central disc electrode and a surrounding concentric ring electrode placed on the surface of a test specimen

Note 1 to entry: Surface resistance is expressed in ohms.

3.7
surface resistivity
ρ_s
resistivity equivalent to the surface resistance of a square area, having the electrodes at two opposite sides

Note 1 to entry: The SI unit of surface resistivity (Ω) is sometimes referred to as Ω/sq (ohms per square), to distinguish resistivity values from resistance values. However, the use of Ω/sq is deprecated because it may imply a resistance per unit area, which is not correct.

3.8
volume resistance
R_v
resistance measured between two electrodes placed on opposite surfaces of a test specimen

Note 1 to entry: Volume resistance is expressed in ohms.

3.9
volume resistivity
ρ_V
ratio of a DC field strength (V/m) and the steady-state current density (A/m^2) within the material

Note 1 to entry: In practice, it is equivalent to the volume resistance of a cube with unit length, having the electrodes at two opposite surfaces.

Note 2 to entry: Volume resistivity is not an appropriate characteristic for materials that are electrically inhomogeneous.

Note 3 to entry: Volume resistivity is expressed in ohm meters.

4 Conditioning and test environment

The electrostatic behaviour of materials is influenced by environmental conditions, such as relative humidity and temperature.

For this reason, measurements shall be performed under controlled conditions. The selection of the appropriate conditions for testing shall be decided according to the type of material (product specification) and the intended application, based on the most severe conditions expected to occur during usage (e.g. lowest humidity and highest humidity).

Unless otherwise agreed, the atmosphere for conditioning and testing shall be (23 ± 2) °C and (12 ± 3) % relative humidity, and the conditioning time prior to testing shall be at least 24 h.

If it is required to test that the measured resistance is not below a minimum limit, additional testing at high humidity is required. Unless otherwise agreed, the atmosphere for conditioning and testing at high humidity shall be (23 ± 2) °C and (60 ± 10) % relative humidity, and the conditioning time prior to testing shall be at least 24 h.

Specimens shall normally be conditioned and measured in the same climate, if not specified differently. However, preconditioning may be necessary in order to eliminate the effects of stress appearing after the moulding process of some plastic materials or as a drying treatment before the test procedure starts. Preconditioning is normally done in a different environment.

Adequate devices are a desiccator in an oven or a climate chamber preferably equipped with forced circulation and interchange of air.

5 Selection of test method

For planar materials, the following procedure shall be used to select the test method:

a) if the range of electrical resistance of a material to be tested is known, then use the relevant clause (Clause 6, 7, 8 or 10) where appropriate standards are listed or methods described;

b) for a material of initially unknown resistivity, start the measurements by using methods for conductive materials according to Clause 6.

If the measurement is not possible or the obtained result exceeds the given range for the application of the test method, it shall be regarded as being inadequate and the result shall not be taken into account. The measurement shall be repeated according to Clause 8 or Clause 10 for electrostatic dissipative materials. If the situation described above occurs again, the measurement shall be repeated according to Clause 7 for insulating materials.

For non-planar materials and for products with structures that are too small to allow the use of the electrode assemblies specified in 8.2, the method described in Clause 10 shall be used.

If the measurement result using the method described in Clause 10 is less than 10^4 Ω or greater than 10^{12} Ω, and the shape or dimensions of the material under test do not allow measurements according to Clause 6 or Clause 7, the test result shall be reported as either "<10^4 Ω" or ">10^{12} Ω".

6 Resistance measurements for solid conductive materials

The resistance of solid conductive materials (non-metals) shall be measured in accordance with ISO 3915 for plastics or ISO 1853 for rubbers. If the measured resistance is greater than or equal to 10^4 Ω, use the methods described in Clause 7, 8 or 10.

7 Resistance measurements for solid insulating materials

The resistance of solid insulating materials shall be measured in accordance with IEC 62631-3-1, IEC 62631-3-2 or IEC 62631-3-3 for plastics, or ISO 2951 for rubbers.

8 Resistance measurements for planar electrostatic dissipative materials (used to avoid electrostatic charge accumulation)

8.1 Instrumentation

8.1.1 General

The instrumentation may consist of either a DC power supply and an ammeter, or an integrated instrument (ohmmeter). National safety regulations shall be followed.

8.1.2 Instrumentation for laboratory evaluation

The output voltage under load shall be (100 ± 5) V for measurements of 1 × 10^6 Ω and higher, and (10,0 ± 0,5) V for less than 1 × 10^6 Ω.

If an ohmmeter is used, readings shall be possible at least from 1 × 10^3 Ω to 1 × 10^{13} Ω, with an accuracy of ±10 %.

If a DC power supply and ammeter are used, readings shall be possible at least from 10 pA to 10 mA. The combined accuracy of the DC power supply and ammeter shall be ±10 %.

8.1.3 Instrumentation for acceptance testing

Instrumentation for laboratory evaluation or instrumentation meeting the following requirements shall be used for acceptance testing.

The open circuit voltage shall be (100 ± 5) V for measurements of 1 × 10^6 Ω and higher, and (10,0 ± 0,5) V for less than 1 × 10^6 Ω.

If an ohmmeter is used, readings shall be possible at least from 1 × 10^3 Ω to 1 × 10^{13} Ω, with an accuracy of ±20 %.

If a DC power supply and ammeter are used, readings shall be possible at least from 10 pA to 10 mA with an accuracy of ±20 %.

In case of dispute, instrumentation for laboratory evaluations shall be used.

8.1.4 Instrumentation for compliance verification (periodic testing)

Instrumentation meeting the requirements for laboratory evaluations or acceptance testing, or instrumentation meeting the following requirements shall be used.

Compliance verification instrumentation shall be capable of making measurements one order of magnitude above and below the intended measurement range. The output voltage of compliance verification instrumentation may vary from laboratory evaluation or acceptance testing instrumentation, and may be rated under load or open circuit. Compliance verification instrumentation shall be checked against laboratory evaluation or acceptance testing instrumentation to ensure there is correlation between measurement results.

In case of dispute, instrumentation for acceptance testing or laboratory evaluation shall be used.

8.2 Electrode assemblies

8.2.1 General

The electrodes shall consist of a material that allows intimate contact with the specimen surface and introduces no appreciable error because of electrode resistance or contamination of the specimen. The electrode material shall be corrosion resistant under test conditions and shall not cause a chemical reaction with the material being tested.

The assemblies described in the subclauses below are recommended to be suitable, but other configurations complying with national or international standards may also be used, if appropriate. Especially for volume resistance measurements of electrostatic dissipative materials, it is important that applied probes of the guarded ring type have sufficient space between the centre (measuring) and ring (guard) contact electrode in order to minimize stray currents falsifying the readings. It is recommended, that the gap g shall be at least 10 mm. In cases of dispute, the assemblies described in this standard shall be applied.

8.2.2 Assembly for the measurement of surface resistance

The electrode assembly (probe 1) contains a central disc surrounded by a concentric ring made of conductive materials which make contact with the material under test (see Figure 1). The total mass of the electrode assembly shall be (2,5 ± 0,25) kg.

The contact surface material shall have a volume resistance of less than 10^3 Ω when tested on a stainless, non-corrosive metal plate (not aluminium) as the counter electrode by applying (10,0 ± 0,5) V, and shall have a Shore A hardness of 50 to 70 when tested according to ISO 7619-1.

Insulating materials used in the electrode assembly shall have volume and/or surface resistance greater than 10^{13} Ω when tested according to IEC 62631-3-1 and/or IEC 62631-3-2 respectively.

The material under test shall be placed on an insulating support as described in 8.2.5.

Dimensions in millimetres

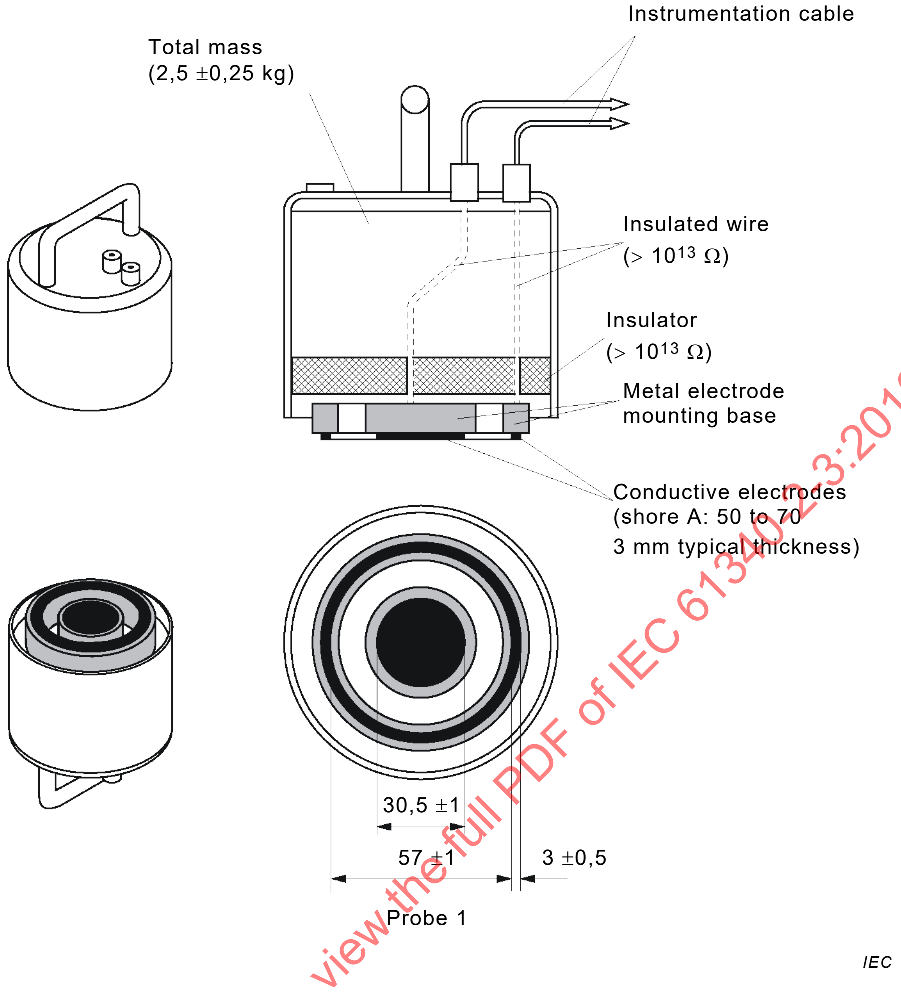

Figure 1 – Example of an assembly for the measurement of surface and volume resistance

8.2.3 Assembly for the measurement of volume resistance

The assembly consists of two electrodes placed on either side of the material under test (see Figure 4). The top electrode assembly (probe 1) shall be as described in 8.2.2 and shown in Figure 1.

The bottom electrode (probe 2) shall be a stainless, non-corrosive metal plate (not aluminium) sufficiently large to support the specimen under test. Probe 2 shall be equipped with a permanent connecting terminal (e.g. plug hole, riveted connector). Crocodile clips should not be used.

It should be placed either on an insulating support as described in 8.2.5 prior to test or be equipped with equivalent insulating feet.

8.2.4 Assembly for the measurement of resistance to ground/groundable point and point-to-point resistance

The assembly consists of one (resistance to ground/groundable point) or two (point-to-point resistance) electrodes (probe 3) containing a disk made of conductive material which makes contact with the material under test (see Figure 2). The total mass of the electrode assembly shall be (2,5 ± 0,25) kg.

The contact surface material shall be conductive enough that two probes placed on a metal surface (e.g. probe 2) have a point-to-point resistance of less than 10^3 Ω when tested with (10,0 ± 0,5) V, and shall have a Shore A hardness of 50 to 70 when tested according to ISO 7619-1.

Insulating materials used in the electrode assembly shall have volume and/or surface resistance greater than 10^{13} Ω when tested according to IEC 62631-3-1 and/or IEC 62631-3-2 respectively.

The material under test shall be placed on an insulating support as described in 8.2.5.

Dimensions in millimetres

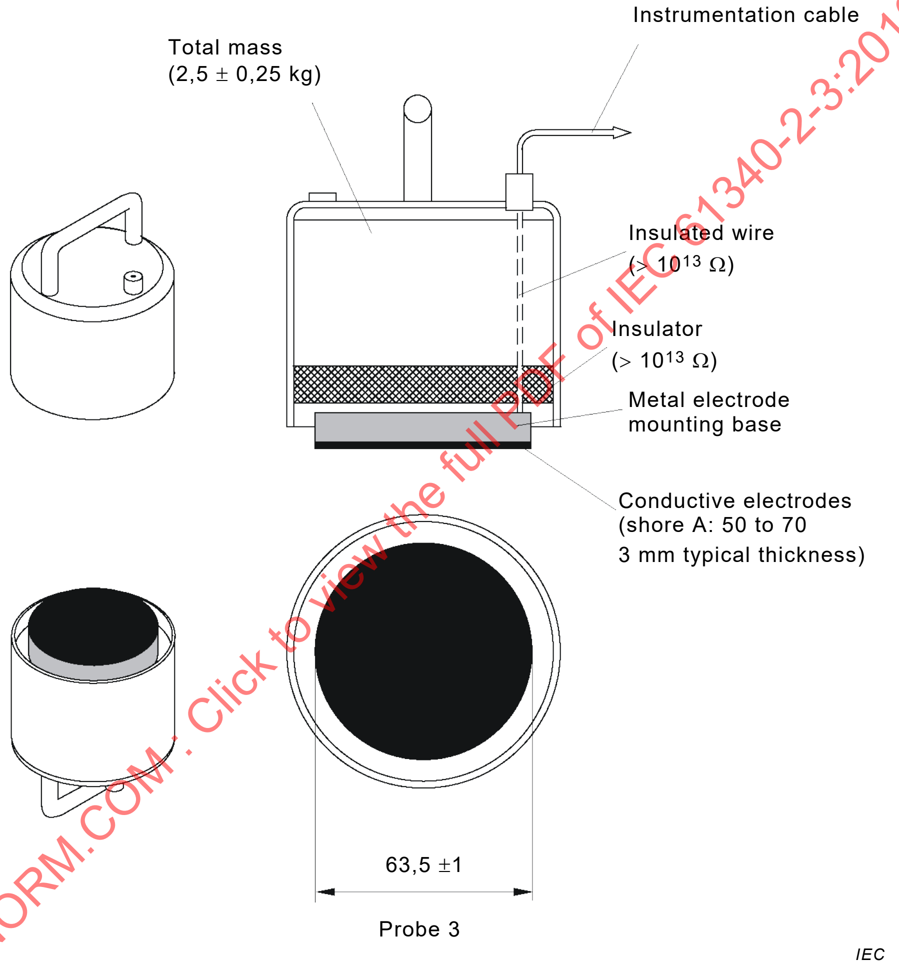

Figure 2 – Example of an assembly for the measurement of resistance to ground/groundable point and point-to-point resistance

8.2.5 Test support

The material shall be tested on a smooth flat support having a surface resistance greater than 1×10^{13} Ω, measured according to IEC 62631-3-2. The size shall be at least 10 mm more in length and width compared to the size of the specimen under test. The minimum thickness shall be 1 mm.

8.3 Sample preparation and handling

Refer to applicable material specifications for sampling instructions. The specimens shall not be handled or marked in areas where measurements will be performed. If the areas where the electrodes make contact have been reworked, this shall be stated in the test report. When the surface resistance is to be measured, the surface shall not be cleaned unless agreed on or specified. Care shall be taken in applying the electrodes and also in handling and mounting the specimens for the measurements in order to minimize the possibility of creating electrical paths due to contamination that may adversely affect the test results.

Specimens shall preferably have a simple geometric shape in the form of sheets with a minimum size of at least 80 mm × 120 mm or 110 mm diameter.

If no other regulation is given, a minimum of three representative specimens of the sample material shall be prepared. The surface to be tested shall be clearly marked or otherwise identified.

8.4 Test procedures

8.4.1 Surface resistance measurements

The electrode assembly described in 8.2.2 is connected to the instrumentation (see Figure 3). The specimen shall be placed onto the test support with the surface to be tested facing up. The electrode assembly is then positioned onto the approximate centre of the specimen or at least 10 mm away from the edges.

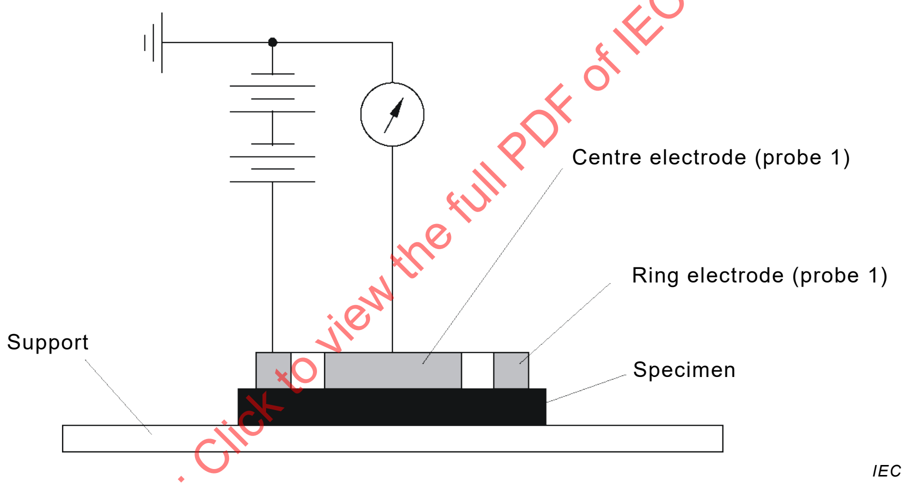

Figure 3 – Basic connections of the electrodes for surface resistance measurements

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s, unless otherwise specified. If the indicated resistance is less than 1,0 × 10^6 Ω, report the value and proceed to the next specimen. If the indicated resistance is equal to or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V. Record the indicated resistance after the electrification period determined in A.1.2.

8.4.2 Volume resistance measurements

The electrode assemblies described in 8.2.2 are connected to the instrumentation (see Figure 4). The bottom electrode (probe 2) is then placed onto the test support first and the specimen laid onto it. Afterwards, the top electrode (probe 1) is positioned onto the approximate centre of the specimen or at least 10 mm away from the edges.

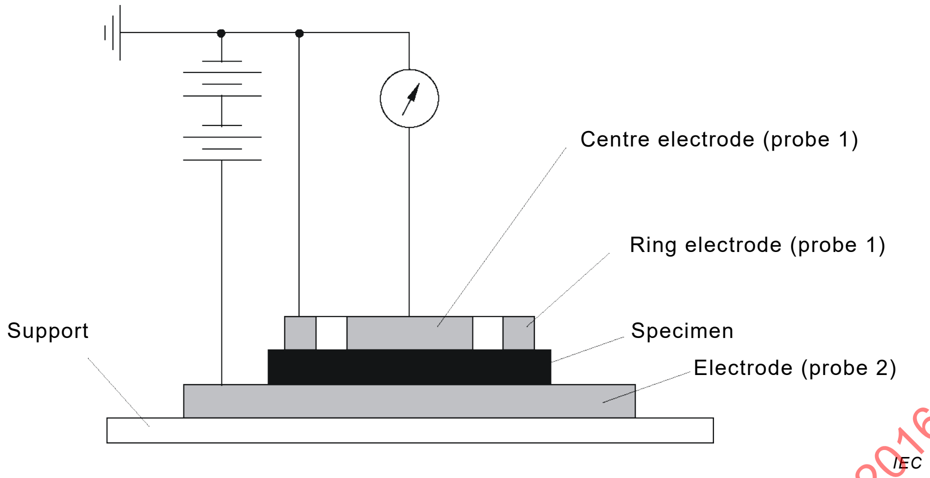

Figure 4 – Basic connections of the electrodes for volume resistance measurements

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s, unless otherwise specified. If the indicated resistance is less than 1,0 × 10^6 Ω, record the value and proceed to the next specimen. If the indicated resistance is equal to or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V. Record the indicated resistance after the electrification period determined in A.2.2.

If an evaluation of the volume resistivity is required, the average thickness h of each specimen shall be determined prior to any measurement following the instructions given in the relevant product specification.

8.4.3 Resistance to groundable point measurements

8.4.3.1 Measurements on laboratory specimens

The test specimens shall be fitted with a representative groundable point. Place the specimens onto the test support with the surface to be tested facing up. Put the electrode assembly (probe 3) onto the surface of the specimen in a position such that the centre of the electrode assembly is at least 50 mm away from the specimen edges or groundable point (see Figure 5). Connect the electrode assembly to one lead of the instrumentation and the groundable point to the other lead.

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than 1,0 × 10^6 Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than 1,0 × 10^6 Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

Dimensions in millimetres

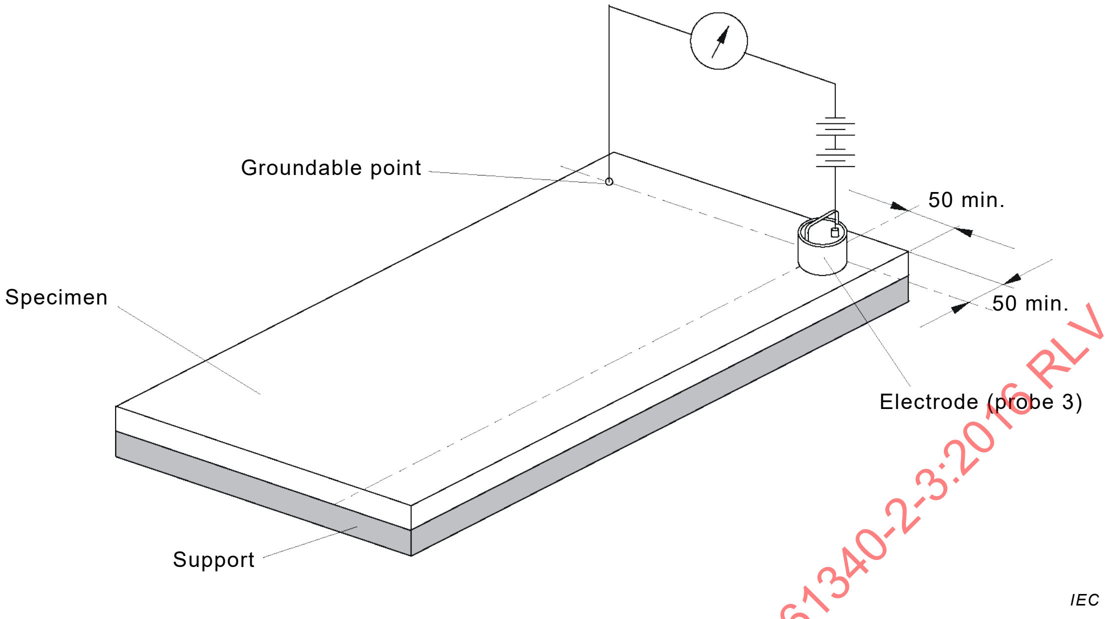

Figure 5 – Principle of resistance to groundable point measurements

8.4.3.2 Measurements on installed materials

Put the electrode assembly (probe 3) onto the surface of the specimen in a position at least 50 mm away from the specimen edges or groundable point (see Figure 5). Connect the electrode assembly to one lead of the instrumentation and the groundable point to the other lead.

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than $1{,}0 \times 10^6$ Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than $1{,}0 \times 10^6$ Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

Line-powered instruments can require an alternate test lead set up to properly measure grounded items. The equipment grounding conductor should be insulated from signal ground. Additionally, the high-potential test lead can require connection to the ground side of the item under test. Consult the instrument manufacturer's instructions for test lead arrangement.

8.4.4 Point-to-point resistance measurements

Connect two electrode assemblies (probes 3) described in 8.2.4 to the instrumentation. The specimen shall be placed onto the test support with the surface to be tested facing up. The probes shall be then placed onto the surface of the specimen in a specified or, if appropriate, otherwise chosen position at least 250 mm in distance from their longitudinal axes, and at least 50 mm away from the edges of the specimen (see Figure 6).

Energize the instrumentation at (10,0 ± 0,5) V and record the reading after (15 ± 1) s if the indicated resistance is less than $1{,}0 \times 10^6$ Ω. Then proceed to the next position or specimen. If the indicated resistance is equal or higher than $1{,}0 \times 10^6$ Ω, de-energize the instrumentation and repeat the procedure using (100 ± 5) V.

Dimensions in millimetres

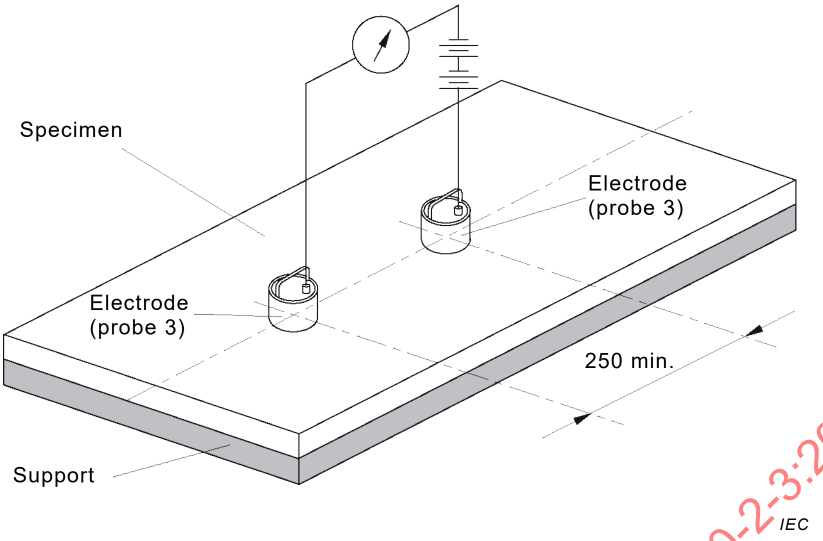

Figure 6 – Principle of point-to-point measurements

9 Conversion to resistivity values

9.1 Surface resistivity ρ_s

Take the following formula according to Figure 7:

$$\rho_s = 2\pi \cdot R_s / \log_e(d_2/d_1)$$

$$d_2 = d_1 + 2g$$

where

ρ_s is the surface resistivity (Ω);

R_s is the measured surface resistance (Ω);

d_1 is the diameter of the centre contact electrode (m);

d_2 is the inner diameter of the outer ring contact electrode (m);

g is the distance (gap) between the contact electrodes (m).

9.2 Volume resistivity ρ_v

Take the following formula according to Figure 7:

$$\rho_v = R_v\,(d_1)^2 \cdot \pi / 4h$$

where

ρ_v is the volume resistivity (Ωm);

R_v is the measured volume resistance (Ω);

d_1 is the diameter of the centre contact electrode (m);

h is the specimen thickness (m).

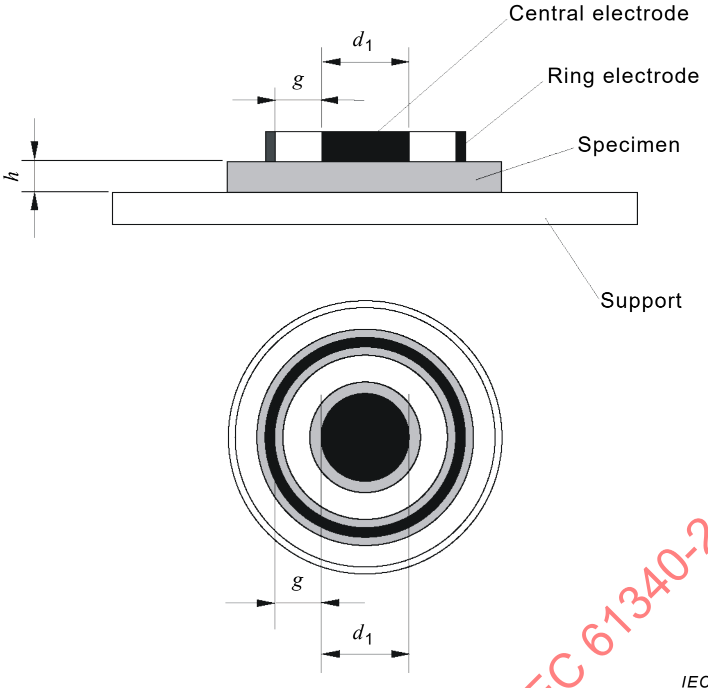

Figure 7 – Configuration for the conversion to surface or volume resistivity

10 Resistance measurements for non-planar materials and products with small structures

10.1 General considerations

This method is recommended for testing items with irregularly shaped surfaces. Conventional concentric ring and parallel bar electrode configurations are used for testing planar items only. However, most packaging items are not planar. Examples include shipping tubes, trays, tote boxes and carrier tapes. This probe employs springs to apply consistent contact pressure between the electrode and the item. Force created by springs is subject to variance from wear, contamination and manufacturing tolerance. This variance is acceptable for this application. Elastomeric electrodes compensate for uneven item surfaces. These features yield consistent results between laboratories and test operators.

10.2 Equipment

10.2.1 Probe

Refer to Table 1 and Figure 8.

This two-point probe consists of an insulated metal body with a polytetrafluoroethylene (PTFE) insulator inserted into each end. One insulator holds test leads; the other holds receptacles that accept spring-loaded pins. One receptacle is surrounded by a cylindrical insulator, which is surrounded by a metal shield. The pins are gold plated and have a spring force of (4,6 ± 0,5) N at a travel of (4,3 ± 0,1) mm. The pin tips are machined to accept friction fitted (3,2 ± 0,1) mm diameter electrically conductive rubber electrodes. The rubber has a Shore A durometer hardness of 50 to 70 (see ISO 7619-1). The electrodes are (3,2 ± 0,1) mm long. The electrode material shall be conductive enough that when tested on a stainless, non-corrosive metal plate (not aluminium) the point-to-point resistance is less than 10^3 Ω at (10,0 ± 0,5) V.

Table 1 provides a list of the key components in Figure 8.

Table 1 – Material for two-point probe

Item	Detail	Example [a]
PTFE insulators	Approximately 25,4 mm length and 12,7 mm diameter	
Electrode shield	Metal tubing approximately 31,8 mm length and 4,75 mm diameter	
Electrode insulator	Heat shrinkable PTFE or other insulator	
Receptacles	Receptacle – with solder cup	Interconnect Devices Inc., R-5-SC
Pins	Spring pin force is (4,6 ± 0,5) N at (4,3 ± 0,1) mm of travel; tip machined to accept electrode	Interconnect Devices Inc., S-5-F-16.4-G
Electrodes	(3,2 ± 0,1) mm long, (3,2 ± 0,1) mm diameter conductive material, Shore A durometer hardness between 50 and 70 (ISO 7619-1)	Vanguard Products, VC-7815
NOTE This is not intended to be a complete materials list for probe construction, but does provide key elements that enable performance replication. Refer to Figure 8 for part placement.		
[a] The parts listed are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of these products. Equivalent products may be used if they can be shown to lead to the same results.		

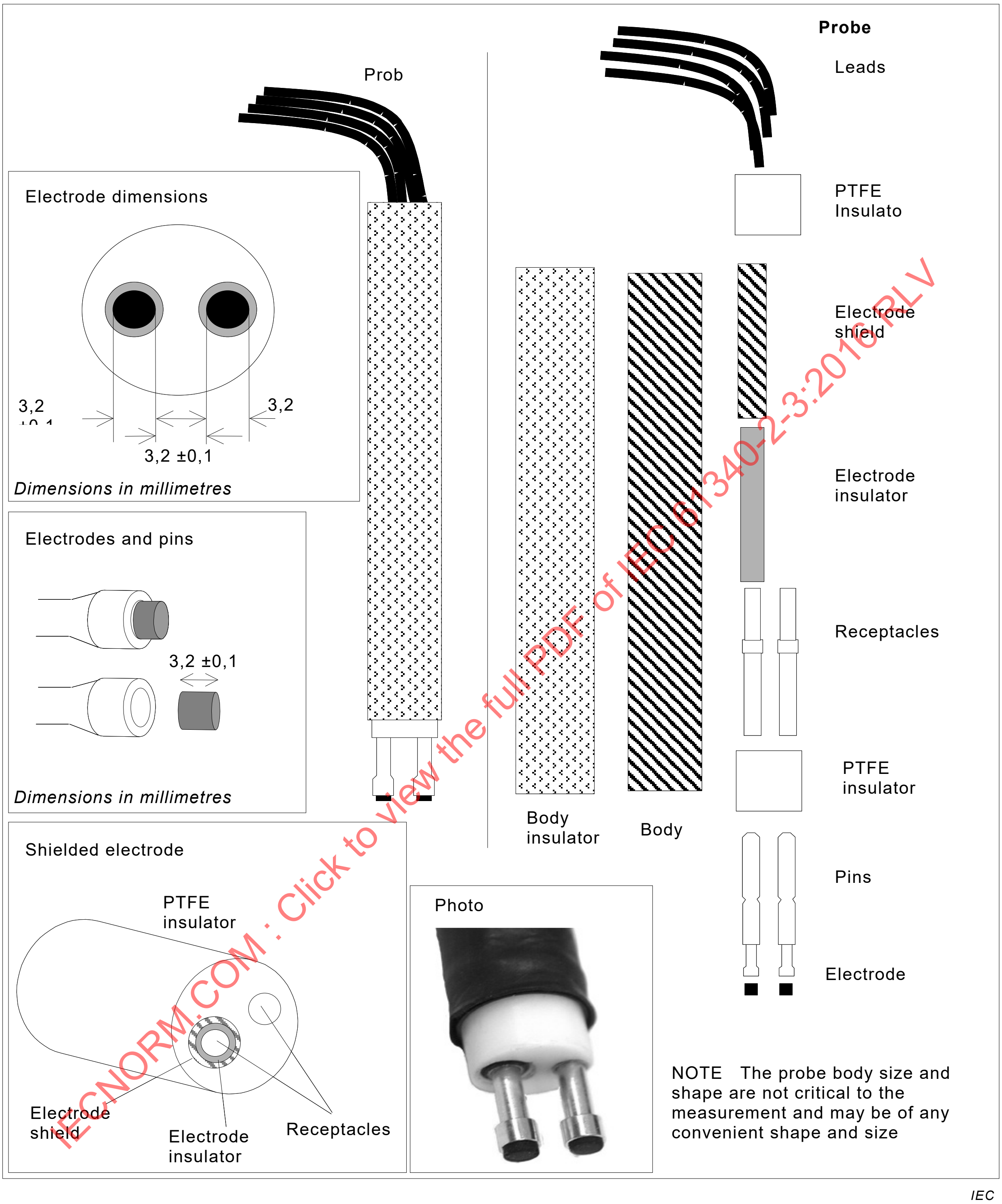

Figure 8 – Two-point probe configuration

10.2.2 Sample support surface

An insulating surface, when used for specimen support, shall have a surface resistance greater than 1×10^{13} Ω, measured according to IEC 62631-3-2.

10.2.3 Resistance measurement apparatus

Resistance measurement apparatus as specified in 8.1 shall be used.

NOTE A constant output meter as specified in 8.1.2 was used to collect all data used to validate this standard test method. Data was not collected to validate this equipment configuration.

10.2.4 Test leads

Test leads appropriate for the meter are required. A shielded lead from the probe body to the instrument will greatly reduce electrical interference (see Figure 9).

NOTE Measurements for the validation of this test method were made using a shielded lead.

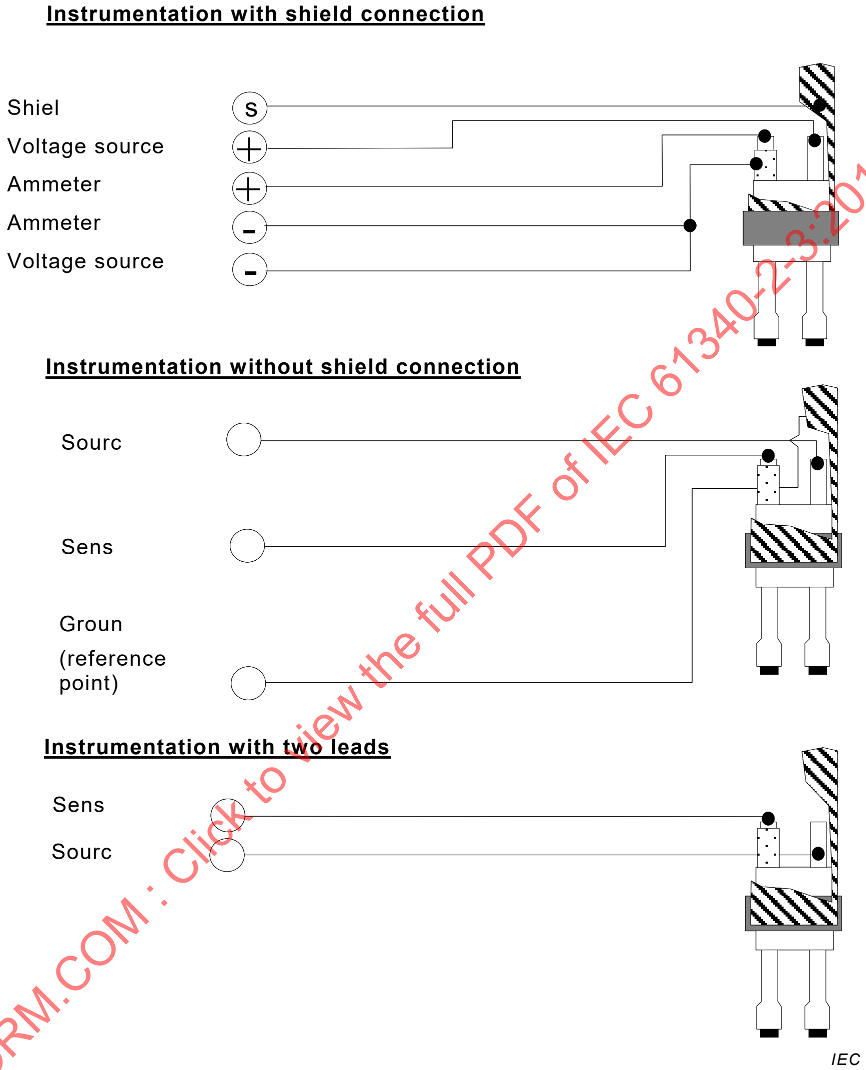

Figure 9 – Probe to instrumentation connection

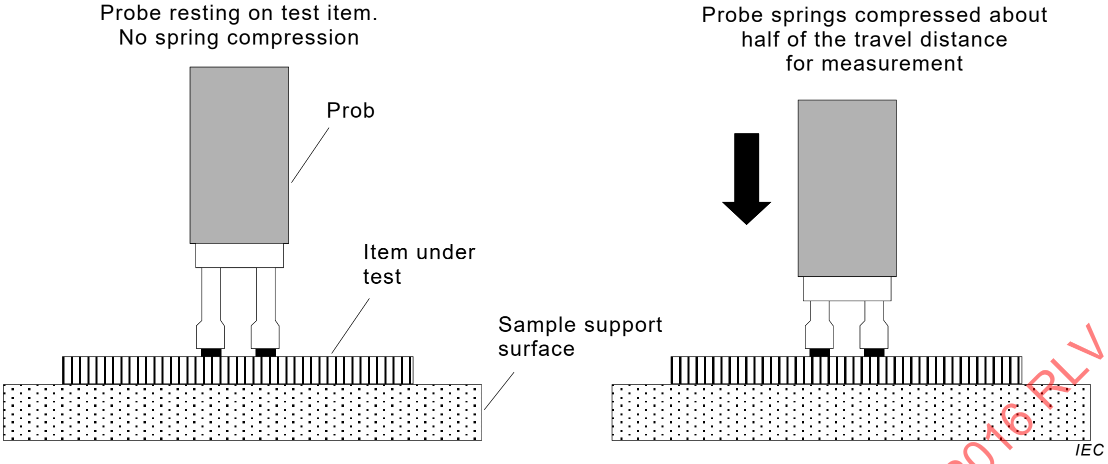

Figure 10 – Spring compression for measurement

10.3 Test procedure

The test procedure is as follows.

a) Connect the probe to the meter as shown in Figure 9.

b) Place the specimen on the sample support surface.

c) Compress the spring-loaded pins downward approximately half of the length of travel (see Figure 10).

d) Apply (10,0 ± 0,5) V for (15 ± 1) s and observe the resistance. If the resistance reading is less than $1,0 \times 10^6\ \Omega$, record the resistance value and proceed to list item f). If the resistance is greater than or equal to $1,0 \times 10^6\ \Omega$, proceed to list item e).

e) If the observed resistance in list item d) is greater than or equal to $1,0 \times 10^6\ \Omega$, change the voltage to (100 ± 5) V and repeat the measurement. Record the resistance value.

f) Repeat the test for each remaining specimen.

NOTE 1 A change in the size of the specimen can affect the measurements.

NOTE 2 Resistance measurements can be affected by the size and spacing between electrodes. The 3,2 mm diameter and 3,2 mm spacing of the electrodes was selected to test a wide range of packaging types and sizes.

NOTE 3 Resistance measurements of a particular sample material can vary due to:

a) variations in sample surface composition or thickness;

b) compression of the sample by the force of the electrodes;

c) variations of the resistance in the electrode material;

d) change in material properties due to the measurement current;

e) cleanliness of electrodes or sample.

NOTE 4 Testing of various electrode materials indicates that the use of harder rubber materials than specified creates greater variation in readings.

11 Repeatability and reproducibility

The resistance of a given specimen varies with the test conditions and it is normal for the materials to be non-uniform. Because of this, determinations are usually not more reproducible than ±10 % and are often even more widely divergent (a range of values of one order of magnitude may be obtained under apparently identical conditions). The comparability of measurements on similar specimens requires a test performance with similar voltage gradients.

The repeatability of these test methods can be assumed to be in the range of approximately one half order of magnitude. If the average value for a series of laboratory tests is 5×10^{10} Ω, the spread of values can be expected from $2{,}5 \times 10^{10}$ Ω to $7{,}5 \times 10^{10}$ Ω.

12 Test report

The test report shall include the following information:

a) description and identification of the material (name, grade, colour, manufacturer, manufacturing date, etc.);

b) shape, dimensions and number of the specimens;

c) type, material and dimensions of the probes (electrodes), if different from those specified in this standard;

d) conditioning of the specimens (temperature, relative humidity, duration);

e) cleaning procedures;

f) test conditions (temperature and relative humidity at the time of measurement);

g) instrumentation (type, calibration information, etc.);

h) test voltage and electrification time with additional information, if these parameters are fixed or specified differently;

i) number of measurements, individual results and average value;

j) surface resistivity as individual results with average value, if relevant;

k) volume resistivity as individual results with average value, if relevant;

l) resistance-to-ground/groundable point with identification of test positions, if relevant;

m) point-to-point resistance with identification of test positions and whether the method specified in Clause 8 or Clause 10 is used, if relevant, and applied distance between the longitudinal axes of the probes, if different from this standard;

n) dates of specimen preparation and test performance;

o) any specific observations during test (e.g. polarization effects).

In the absence of instructions from product standards or other requirements, consideration shall be given to the way in which average values are calculated. It is common for arithmetic mean to be used to calculate the average value, i.e. the sum of n values divided by n:

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

where

$\bar{x}$ is the average value;

x_i is an individual value;

n is the number of values to be averaged.

Geometric mean may be of more practical significance than arithmetic mean when averaging values that vary by orders of magnitude, as is often the case when making resistance measurements. For example, five resistance measurements may include four measurements of the order of 1×10^{9} Ω and one measurement of 1×10^{12} Ω. The arithmetic mean is weighted by the 1×10^{12} Ω measurement, whereas the geometric mean is not and may more closely represent the overall way in which a material is likely to perform in practice. Geometric mean is calculated by taking the nth root of the product of n values:

$$\bar{x} = \left(\prod_{i=1}^{n} x_i \right)^{1/n}$$

where

$\bar{x}$ is the average value;

x_i is an individual value;

n is the number of values to be averaged.

The test report shall state if arithmetic or geometric mean has been used to calculate average values.

Annex A
(normative)

System verification

A.1 System verification for surface resistance measurements

A.1.1 Fixture and procedure for lower resistance range

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.2 and have 20 individual metal surfaces or pads which make contact with the centre (inner) electrode surface, and 20 identical pads which make contact with the ring (outer) electrode surface. Pads shall be flat without any protrusions and be mounted on a flat surface. The fixture shall consist of 20 each, $(1,00 \pm 0,01) \times 10^6$ Ω resistors. All resistors to be mounted on bottom side. Each resistor shall be individually connected between an inner and outer pad (see Figure A.1). The material for the fixture shall have a volume resistance of at least 10^8 Ω between the two rows of pads when not connected by resistors, and tested with (100 ± 5) V.

Dimensions in millimetres

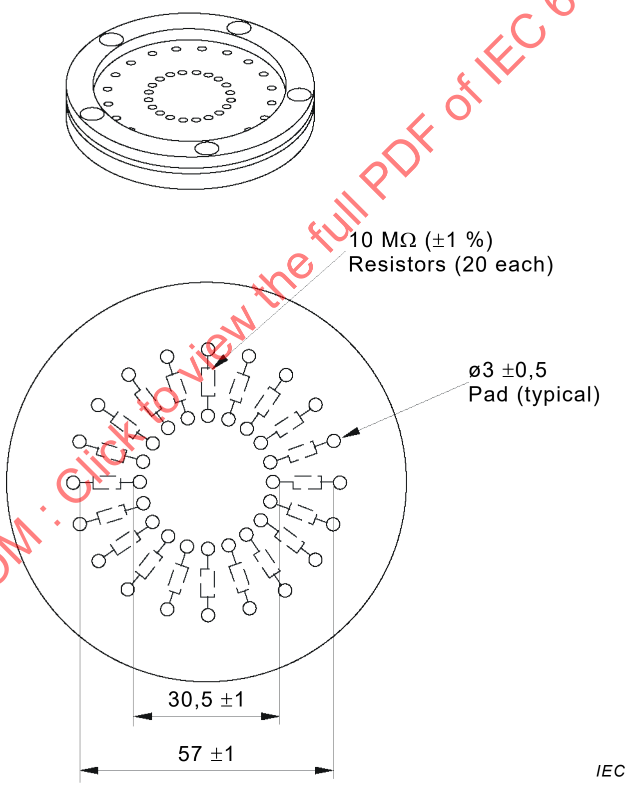

Figure A.1 – Lower resistance range verification fixture for surface resistance measurements

Prior to a test, the system shall be checked for proper operation as follows:

The assembly described in 8.2.2 is connected to the instrumentation according to Figure 3 and then placed onto the fixture. A voltage of (10,0 ± 0,5) V shall be applied and a reading taken after (15 ± 1) s. The result shall be $(5,00 \pm 0,25) \times 10^5$ Ω. The check is then repeated after having the assembly rotated through 90°.

NOTE Rotation of the electrode assembly checks the flatness of the fixture and electrode containing surfaces.

A.1.2 Fixture and procedure for upper resistance range and determination of electrification period

The fixture shall conform to the electrode dimensions of the assembly described in 8.2.2 and have metal surfaces or pads which make contact with the electrode surfaces. Pads shall be flat without any protrusions and be mounted on a flat surface. Pads may be tied together with wire or complete circular rings may be used.They are connected via a single resistor of $(1,00 \pm 0,05) \times 10^{12}$ Ω between the centre (inner) and ring (outer) contact surfaces (see Figure A.2). The resistor and wiring shall be mounted on the bottom side. When tested with (500 ± 25) V in compliance with IEC 60167, the material for the fixture shall have an insulation resistance of at least 10^{14} Ω between the two rows of pads when not connected by a resistor.

Dimensions in millimetres

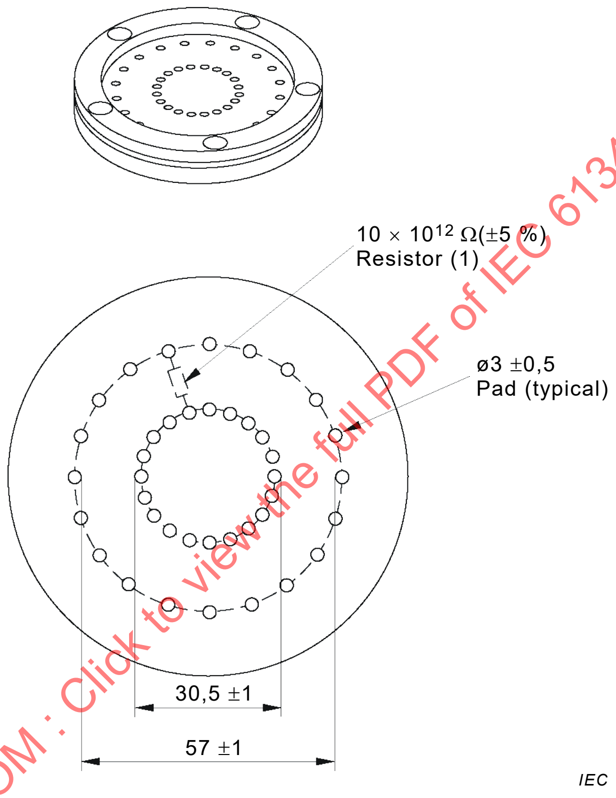

Figure A.2 – Upper resistance range verification fixture for surface resistance measurements

The following procedure confirms the capability of the system to measure $1,0 \times 10^{12}$ Ω and offers a method to determine the electrification period as follows:

The assembly described in 8.2.2 is connected to the instrumentation according to Figure 3 and then placed onto the fixture. A voltage of (100 ± 5) V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.

A.2 System verification for volume resistance measurements

A.2.1 Fixture and procedure for lower resistance range

Prior to the test, the system shall be checked for proper operation as follows:

Connect the electrodes (probes 1 and 2) to the instrumentation according to Figure 4 but without a specimen between them. Then insert a (5,00 ± 0,05) × 10^5 Ω resistor between the voltage source output and probe 2. A voltage of (10,0 ± 0,5) V shall be applied and a reading taken after (15 ± 1) s. The result shall be (5,00 ± 0,25) × 10^5 Ω.

A.2.2 Fixture and procedure for upper resistance range and determination of electrification period

The following procedure confirms the capability of the system to measure 1,0 × 10^{12} Ω and offers a method to determine the electrification period as follows:

Connect the electrodes (probes 1 and 2) to the instrumentation according to Figure 4 but without a specimen between them. Then insert a (1,00 ± 0,05) × 10^{12} Ω resistor between the voltage source output and probe 2. A voltage of (100 ± 5) V shall be applied and a reading taken when the displayed value has reached the steady-state. If the reading is within the tolerance range of the resistor, repeat the procedure five times while recording the required time for the instrument to indicate a steady-state value. The average of the five recordings is the electrification time. An addition of 5 s to this time results in the electrification period that will be used to measure specimens higher than 10^6 Ω.

A.3 System verification for resistance measurements for non-planar materials and products with small structures

A.3.1 Verification fixtures

The low resistance verification fixture shall consist of a (1,00 ± 0,01) × 10^5 Ω resistor bonded to two metal contact plates. The plates shall be of size and shape so that each probe electrode contacts only one plate, and so that the plates are not in contact with each other. The plates may be affixed to a material with the same properties as the sample support surface. Figure A.3 illustrates one possible configuration of a resistance verification fixture.

The high resistance verification fixture shall consist of a (1,00 ± 0,05) × 10^9 Ω resistor bonded to two metal contact plates. The plates shall be of a size and shape so that each probe electrode contacts only one plate, and so that the plates are not in contact with each other. The length and width of each plate shall be at least 3,3 mm (for rectangular plates) or shall be at least 3,3 mm diameter (for circular plates), and the minimum gap between plates shall not exceed 3,1 mm. The plates may be affixed to a material with the same properties as the sample support surface. Figure A.3 illustrates one possible configuration of a resistance verification fixture.

The actual value of the resistors shall be measured periodically. This measured value shall be used to verify probe operation.

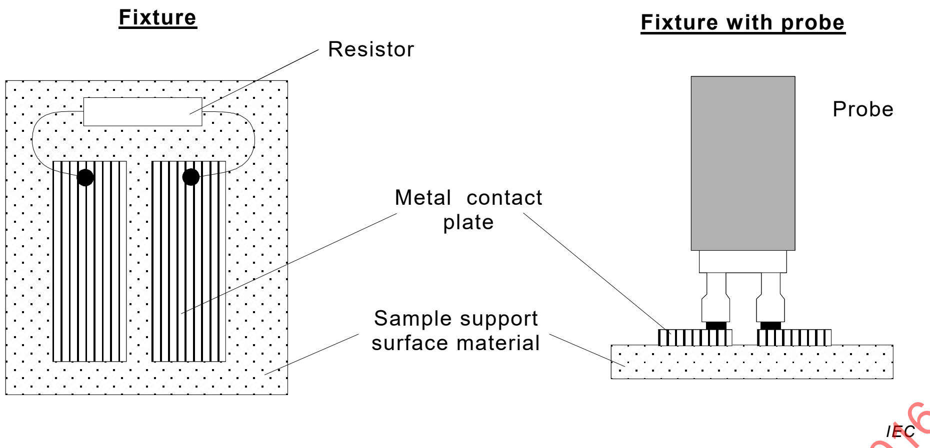

Figure A.3 – Resistance verification fixture

A.3.2 Verification procedure

The verification procedure is as follows:

a) Correct probe operation shall be verified by measuring known resistance values.

b) Connect the probe to the meter as shown in Figure 9.

c) Place the probe electrodes onto the low resistance verification fixture as shown in Figure A.3.

d) Compress the spring-loaded pins downward approximately half of the length of travel (Figure 10).

e) Apply (10,0 ± 0,5) V for (15 ± 1) s and observe the resistance.

f) Record the resistance value. The value should be within 10 % of the actual resistor value.

g) Repeat the procedure using the high resistance verification fixture at (100 ± 5) V.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ÉLECTROSTATIQUE –

Partie 2-3: Méthodes d'essais pour la détermination de la résistance et de la résistivité des matériaux solides destinés à éviter les charges électrostatiques

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La Norme internationale IEC 61340-2-3 a été établie par le comité d'études 101 de l'IEC: Electrostatique.

Cette deuxième édition annule et remplace la première édition parue en 2000. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) une distinction a été introduite entre l'instrumentation utilisée pour les évaluations en laboratoire, l'instrumentation utilisée pour les essais d'approbation et l'instrumentation utilisée pour la vérification de la conformité (essais périodiques);

b) un autre ensemble d'électrodes est décrit, qui peut être utilisé sur les produits non planaires ou lorsque les dimensions du produit à l'essai sont trop petites pour permettre l'utilisation de l'ensemble d'électrodes plus grand;

c) les formules de calcul de la résistivité transversale et de la résistivité superficielle ont été modifiées afin de correspondre à la pratique courante du secteur dans les principaux domaines d'application de la série IEC 61340.

Le texte de la présente norme est issu des documents suivants:

CDV	Rapport de vote
101/470/CDV	101/494/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 61340, publiées sous le titre général *Electrostatique*, peut être consultée sur le site web de l'IEC.

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- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

INTRODUCTION

Les mesures des résistances et les calculs afférents des résistivités font partie des objectifs fondamentaux des techniques de mesure électrique de même que les mesures de tension et de courant.

La résistivité est la caractéristique électrique qui a la plage la plus large; elle s'étend sur quelque trente ordres d'amplitude, du métal le plus conducteur aux isolateurs presque parfaits.

La base est la loi d'Ohm, et elle est valable pour le courant continu et les valeurs instantanées du courant alternatif dans les conducteurs par électrons (métaux, carbone, etc.). Les valeurs des mesures de résistance à l'aide du courant alternatif peuvent être influencées par la réactance inductive/capacitive, en fonction de la fréquence. De ce fait, les Normes nationales et internationales traitant de mesures de résistance des matériaux solides exigent normalement l'application de courant continu.

La plupart des matériaux non métalliques tels que le plastique sont classés parmi les polymères et les conducteurs d'ions. Le transport de charges peut être dépendant de l'intensité du champ électrique appliquée pendant la mesure. Hormis le courant de mesure, il existe un courant de charge qui polarise et/ou charge électrostatiquement le matériel, indiqué par une décroissance asymptotique du courant de mesure avec le temps, et qui est la cause d'un changement apparent de la résistance. Si cet effet est observé, il est recommandé de renouveler la mesure immédiatement après écoulement d'un laps de temps d'application de la tension défini, en utilisant la polarité inverse pour le courant de mesure et en établissant la moyenne des deux valeurs obtenues.

ÉLECTROSTATIQUE –

Partie 2-3: Méthodes d'essais pour la détermination de la résistance et de la résistivité des matériaux solides destinés à éviter les charges électrostatiques

1 Domaine d'application

Cette partie de l'IEC 61340 décrit les méthodes d'essai permettant de déterminer la résistance électrique et la résistivité des matériaux solides utilisés pour éviter les charges électrostatiques, pour lesquels la résistance mesurée se trouve dans la plage comprise entre 10^4 Ω et 10^{12} Ω.

Elle prend en compte les normes IEC/ISO existantes et autres publications applicables. Elle fournit aussi des recommandations et des lignes directrices sur la méthode appropriée.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 62631-3-1, *Propriétés diélectriques et résistives des matériaux isolants solides – Partie 3-1: Détermination des propriétés résistives (méthodes en courant continu) – Résistance transversale et résistivité transversale – Méthode générale*

IEC 62631-3-2, *Propriétés diélectriques et résistives des matériaux isolants solides – Partie 3-2: Détermination des propriétés résistives (méthodes en courant continu) – Résistance superficielle et résistivité superficielle*

IEC 62631-3-3, *Propriétés diélectriques et résistives des matériaux isolants solides – Partie 3-3: Détermination des propriétés résistives (méthodes en courant continu) – Résistance d'isolement*

ISO 1853, *Conducting and dissipative rubbers, vulcanized or thermoplastic – Measurement of resistivity* (disponible en anglais seulement)

ISO 2951, *Rubber, vulcanized or thermoplastic – Determination of insulation resistance* (disponible en anglais seulement)

ISO 3915, *Plastiques – Mesurage de la résistivité des plastiques conducteurs*

ISO 7619-1, *Caoutchouc vulcanisé ou thermoplastique – Détermination de la dureté par pénétration – Partie 1: Méthode au duromètre (dureté Shore)*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent:

3.1
électrode
conducteur de forme, de taille et de configuration définies en contact avec les éprouvettes soumises à la mesure

3.2
résistance
R
rapport d'une tension en courant continu (V) appliquée entre deux points et du courant en régime établi (A) entre les deux points

Note 1 à l'article: La résistance est exprimée en ohms.

3.3
résistance de mise à la terre
R_g
résistance mesurée entre une électrode placée sur la surface d'une éprouvette d'essai et une terre locale

Note 1 à l'article: La résistance de mise à la terre est exprimée en ohms.

3.4
résistance de point de mise à la terre
R_{gp}
résistance mesurée entre une électrode placée sur la surface d'une éprouvette d'essai et un point de mise à la terre fixé sur l'éprouvette d'essai

Note 1 à l'article: La résistance de point de mise à la terre est exprimée en ohms.

3.5
résistance point à point
R_{pp}
résistance mesurée entre deux électrodes placées à une distance spécifiée l'une de l'autre sur la même surface d'une éprouvette d'essai

Note 1 à l'article: La résistance point à point est exprimée en ohms.

3.6
résistance superficielle
R_s
résistance mesurée entre une électrode en forme de disque central et une électrode en forme d'anneau concentrique autour de la précédente, placées sur la surface d'une éprouvette d'essai

Note 1 à l'article: La résistance superficielle est exprimée en ohms.

3.7
résistivité superficielle
ρ_s
résistivité équivalente à la résistance superficielle d'une surface carrée dotée d'électrodes aux deux côtés opposés

Note 1 à l'article: L'unité SI de la résistivité superficielle (Ω) est parfois désignée Ω/sq (ohms par carré), afin de distinguer les valeurs de résistivité des valeurs de résistance. Toutefois, l'utilisation de Ω/sq est déconseillée car elle peut suggérer une résistance par surface unitaire, ce qui est incorrect.

3.8
résistance transversale
R_v
résistance mesurée entre deux électrodes placées sur les surfaces opposées d'une éprouvette d'essai

Note 1 à l'article: La résistance transversale est exprimée en ohms.

3.9
résistivité transversale
ρ_v
rapport d'une intensité de champ en courant continu (V/m) et de la densité du courant en régime permanent (A/m^2) dans le matériau

Note 1 à l'article: En pratique, il est équivalent à la résistance transversale d'un cube de longueur unitaire, ayant des électrodes aux deux surfaces opposées.

Note 2 à l'article: La résistivité transversale n'est pas une caractéristique appropriée pour les matériaux électriquement non homogènes.

Note 3 à l'article: La résistivité transversale est exprimée en ohmmètres.

4 Environnement d'essai et de conditionnement

Le comportement électrostatique des matériaux est influencé par les conditions environnementales telles que la température et l'humidité relative.

C'est pourquoi les mesures doivent être exécutées dans des conditions contrôlées. La sélection des conditions appropriées pour les essais doit être décidée en fonction du type de matériau (spécification de produit) et de l'application prévue, sur la base des conditions les plus sévères susceptibles d'intervenir à l'usage (par exemple, humidité la plus faible et humidité la plus élevée).

Sauf accord contraire, l'atmosphère pour le conditionnement et les essais doit être de (23 ± 2) °C de température et de (12 ± 3) % d'humidité relative, et le temps de conditionnement avant les essais doit être de 24 h au moins.

S'il est nécessaire de vérifier que la résistance mesurée n'est pas inférieure à une limite minimum, un essai supplémentaire dans des conditions de forte humidité doit être effectué. Sauf accord contraire, l'atmosphère pour le conditionnement et les essais dans des conditions de forte humidité doit être de (23 ± 2) °C de température et de (60 ± 10) % d'humidité relative, tandis que le temps de conditionnement avant les essais doit être de 24 h au moins.

Sauf spécification contraire, les éprouvettes doivent normalement être conditionnées et mesurées sous le même climat. Le préconditionnement peut toutefois être nécessaire afin d'éliminer les effets de contrainte apparaissant après le procédé de moulage de certains matériaux en plastique ou en tant que traitement de séchage avant le début de la procédure d'essai. Le préconditionnement s'effectue normalement dans un environnement différent.

Les dispositifs adéquats sont les suivants: un dessiccateur dans un four ou une chambre climatique, de préférence équipés de circulation et d'échange forcés d'air.

5 Sélection de la méthode d'essai

Pour les matériaux planaires, la procédure suivante doit être utilisée en vue de la sélection de la méthode d'essai:

a) si la plage de la résistance électrique d'un matériau est connue, utiliser l'article applicable (Article 6, 7, 8 ou 10), où figure la liste des normes appropriées ou bien la description des méthodes;

b) pour un matériau de résistivité initialement non connue, commencer les mesures à l'aide des méthodes pour matériaux conducteurs conformément à l'Article 6.

Si la mesure n'est pas possible ou si le résultat obtenu excède la plage donnée pour l'application de la méthode d'essai, elle doit être considérée comme inadéquate et le résultat ne doit pas être pris en compte. La mesure doit être renouvelée conformément à l'Article 8 ou à l'Article 10 pour les matériaux dissipatifs électrostatiques. Si la situation décrite ci-dessus se produit de nouveau, la mesure doit être renouvelée conformément à l'Article 7 pour les matériaux isolants.

Pour les matériaux non planaires et les produits dont les structures sont trop petites pour permettre d'utiliser les ensembles d'électrodes décrits en 8.2, la méthode décrite à l'Article 10 doit être utilisée.

Si le résultat de la mesure réalisée à l'aide de la méthode décrite à l'Article 10 est inférieur à 10^4 Ω ou supérieur à 10^{12} Ω, et si la forme ou les dimensions du matériau à l'essai n'autorisent pas les mesures selon l'Article 6 ou l'Article 7, le résultat de l'essai doit être indiqué sous la forme "$<10^4$ Ω" ou "$>10^{12}$ Ω".

6 Mesures de la résistance des matériaux conducteurs solides

La résistance des matériaux conducteurs solides (non métalliques) doit être mesurée conformément à l'ISO 3915 pour les plastiques, ou à l'ISO 1853 pour les élastomères. Si la résistance mesurée est supérieure ou égale à 10^4 Ω, utiliser les méthodes décrites aux Articles 7, 8 ou 10.

7 Mesures de la résistance des matériaux isolants solides

La résistance des matériaux isolants solides doit être mesurée conformément à l'IEC 62631-3-1, l'IEC 62631-3-2 ou l'IEC 62631-3-3 pour les plastiques, et à l'ISO 2951 pour les élastomères.

8 Mesures de résistance de matériaux dissipatifs électrostatiques planaires (destinés à éviter la charge électrostatique)

8.1 Instrumentation

8.1.1 Généralités

L'instrumentation peut comprendre soit une alimentation continue et un ampèremètre, soit un instrument intégré (ohmmètre). Les réglementations de sécurité nationales doivent être respectées.

8.1.2 Instrumentation utilisée pour les évaluations en laboratoire

La tension de sortie en charge doit s'élever à (100 ± 5) V pour les mesures de 1×10^6 Ω et supérieures, et à (10,0 ± 0,5) V pour celles inférieures à 1×10^6 Ω.

Si un ohmmètre est utilisé, les relevés doivent être possibles au moins de 1×10^3 Ω à 1×10^{13} Ω, avec une précision de ±10 %.

Si une alimentation continue et un ampèremètre sont utilisés, les lectures doivent être possibles au moins de 10 pA à 10 mA. La précision combinée de l'alimentation continue et de l'ampèremètre doit être de ±10 %.

8.1.3 Instrumentation utilisée pour les essais d'approbation

Une instrumentation pour les évaluations en laboratoire ou une instrumentation respectant les exigences suivantes doit être utilisée pour les essais d'approbation.

La tension de circuit ouvert doit s'élever à (100 ± 5) V pour les mesures de 1×10^6 Ω et supérieures, et à (10,0 ± 0,5) V pour celles inférieures à 1×10^6 Ω.

Si un ohmmètre est utilisé, les relevés doivent être possibles au moins de 1×10^3 Ω à 1×10^{13} Ω, avec une précision de ±20 %.

Si une alimentation continue et un ampèremètre sont utilisés, les relevés doivent être possibles au moins de 10 pA à 10 mA avec une précision de ±20 %.

En cas de litige, l'instrumentation pour les évaluations en laboratoire doit être utilisée.

8.1.4 Instrumentation utilisée pour la vérification de la conformité (essais périodiques)

Une instrumentation respectant les exigences relatives aux évaluations en laboratoire ou aux essais d'approbation, ou une instrumentation respectant les exigences suivantes doit être utilisée.

L'instrumentation utilisée pour la vérification de la conformité doit être capable d'effectuer des mesures d'un ordre d'amplitude au-dessus et au-dessous de la plage de mesure prévue. La tension de sortie de l'instrumentation utilisée pour la vérification de la conformité peut varier de celle de l'instrumentation utilisée pour les évaluations en laboratoire ou pour les essais d'approbation, et peut être définie en charge ou en circuit ouvert. L'instrumentation utilisée pour la vérification de la conformité doit être vérifiée par rapport à l'instrumentation utilisée pour les évaluations en laboratoire ou pour les essais d'approbation afin de s'assurer de la corrélation entre les résultats de mesure.

En cas de litige, l'instrumentation pour les essais d'approbation ou pour les évaluations en laboratoire doit être utilisée.

8.2 Ensembles d'électrodes

8.2.1 Généralités

Les électrodes doivent comprendre un matériau permettant un contact intime avec la surface de l'éprouvette et n'introduisant aucune erreur significative du fait de la résistance de l'électrode ou de la contamination de l'éprouvette. Le matériau de l'électrode doit être résistant à la corrosion dans des conditions d'essai et ne doit causer aucune réaction chimique avec le matériau à l'essai.

Les ensembles décrits dans les paragraphes ci-après sont recommandés, mais d'autres configurations répondant aux Normes nationales et internationales peuvent aussi être utilisées, si applicables. En particulier, pour les mesures de la résistance transversale des matériaux dissipatifs électrostatiques, il est important que les sondes appliquées de type anneau gardé contiennent un espace suffisant entre l'électrode de contact (garde) à anneau et l'électrode centrale (de mesure), et ce afin de réduire le plus possible les courants de fuite qui faussent les lectures. Il est recommandé que l'intervalle g soit au minimum de 10 mm. En cas de litige, les ensembles décrits dans cette norme doivent être appliqués.

8.2.2 Ensemble pour la mesure de la résistance de surface

L'ensemble d'électrodes (sonde 1) contient un disque central et un anneau concentrique autour de ce dernier en matériaux conducteurs qui établissent le contact avec le matériau à l'essai (voir Figure 1). La masse totale de l'ensemble d'électrodes doit être de (2,5 ± 0,25) kg.

Le matériau de la surface de contact doit avoir une résistance transversale inférieure à 10^3 Ω au moment de l'essai sur une plaque de métal inoxydable non corrosive (sans aluminium) utilisée comme contre-électrode en appliquant (10,0 ± 0,5) V, et doit avoir une dureté Shore A de 50 à 70 au moment de l'essai réalisé conformément à l'ISO 7619-1.