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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 3-1: Determination of resistive properties (DC methods) – Volume resistance and volume resistivity – General method

FOREWORD

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International Standard IEC 62631-3-1 has been prepared by IEC technical committee TC 112: Evaluation and qualification of electrical insulating materials and systems.

This first edition of IEC 62631-3-1 cancels and replaces the second edition of IEC 60093, published in 1980. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the second edition of IEC 60093:

a) IEC 60093 has been completely revised, both editorially and technically, and incorporated into the new IEC 62631 series;
b) test methods have been updated to current day state of the art;
c) volume and surface resistance and resistivity are now separated to appear in this part of IEC 62631 and in IEC 62631-3-2, respectively.

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

FDIS	Report on voting
112/339/FDIS	112/350/RVD

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 parts in the IEC 62631 series, published under the general title *Dielectric and resistive properties of solid insulating materials*, 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- withdrawn,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.

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 3-1: Determination of resistive properties (DC methods) – Volume resistance and volume resistivity – General method

1 Scope

This part of IEC 62631 covers a method of test for the determination of volume resistance and volume resistivity of electrical insulation materials by applying a DC voltage.

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

IEC 60455 (all parts), *Resin based reactive compounds used for electrical insulation*

IEC 60464 (all parts), *Varnishes used for electrical insulation*

IEC 61212 (all parts), *Industrial materials – Industrial rigid round laminated tubes and rods based on thermosetting resins for electrical purposes*

ISO 868, *Plastics and ebonite – Determination of indentation hardness by means of a durometer (Shore hardness)*

3 Terms and definitions

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

3.1
volume resistance
part of the insulation resistance which is due to conduction through the volume

Note 1 to entry: Volume resistance is expressed in the unit of Ω.

3.2
volume resistivity
volume resistance of a material related to its volume

Note 1 to entry: Volume resistivity is expressed in the unit of Ωm.

Note 2 to entry: For insulating materials, the volume resistivity is usually determined by means of measuring electrodes arranged on a sheet of the material.

Note 3 to entry: According to IEC 60050-121: Electromagnetism, “conductivity” is defined as “scalar or tensor quantity, the product of which by the electric field strength in a medium is equal to the electric current density” and “resistivity” as “the inverse of the conductivity when this inverse exists”. Measured in this way, the volume resistivity is an average of the resistivity over possible heterogeneities in the volume incorporated in the measurement; it includes the effect of possible polarization phenomena at the electrodes.

3.3
stray current
leakage current in the earth or in metallic structures buried in the ground and resulting from their intended or unintended earthing

4 Significance

Insulating materials are used in general to electrically isolate components of an electrical system from each other and from earth. Solid insulating material may also provide mechanical support. For these purposes it is generally desirable to have the insulation resistance as high as possible, consistent with acceptable mechanical, chemical and heat resistance properties. Volume resistance is a part of the insulating resistance.

Volume resistivity can be used as an aid in the choice of an insulating material for a specific application. The change in resistivity with temperature and humidity may be great and has to be known when designing for operation conditions.

When a direct voltage is applied between electrodes in contact with a specimen, the current through it decreases asymptotically towards a steady-state value. The decrease of current with time may be due to dielectric polarization and the sweep of mobile ions to the electrodes. For materials having volume resistivity less than about 10^{10} Ωm the steady state is generally reached within 1 min and the resistance is determined after this time of electrification. For materials with higher volume resistivity the current may continue decreasing for several minutes, hours, days or even weeks. For such materials, therefore, longer electrification times may be necessary.

NOTE For very high electric field strengths different behaviour can occur.

5 Method of test

5.1 General

This general method describes common values for general measurements. If a method for a specific type of material is described in this standard, the specific method shall be used.

The measurement of volume resistance (and volume resistivity respectively) shall be carried out carefully and taking into account the electric properties of the measuring circuit as well as the specific electric properties of the material.

To carry out the test, in most cases the use of high voltages is necessary. Care shall be taken to prevent electric shock.

Polarization effects can influence the measurement. Therefore it is not acceptable to achieve the measured resistance twice in two consecutive experiments without a sufficient space of time in-between.

NOTE For materials with volume resistance of not more than 10^{12} Ω a period of 1 h after voltage application might be sufficient.

5.2 Power supply, voltage

A source of very steady direct voltage is required. This may be provided either by batteries or by rectified and stabilized power supply. The degree of stability required is such that the change in current due to any change in voltage is negligible compared with the current to be measured.

NOTE 1 The ripple of the voltage source is important. A typical value for 100 V is <5 × 10^{-5} peak to peak.

Commonly specified test voltages to be applied to the complete specimen are 10 V, 100 V, 500 V, 1 000 V, and 10 000 V.

If not otherwise stipulated, a voltage of 100 V is to be used.

NOTE 2 In air, below 340 V no partial discharges will occur. Partial discharge can lead to erroneous measurements of the resistance when a specific inception voltage is exceeded.

5.3 Equipment

5.3.1 Accuracy

Any suitable equipment may be used. The measuring device should be capable of determining the unknown resistance with an overall accuracy of at least

- ±10 % for resistances below 10^{10} Ω,
- ±20 % for resistances between 10^{10} Ω and 10^{14} Ω,
- ±50 % for values higher than 10^{14} Ω.

5.3.2 Guarding

The insulation of the measuring circuit is composed of materials which, at best, have properties comparable with those of the material under test. Errors in the measurement of the specimen may arise from:

- stray current from spurious external voltages which are usually unknown in magnitude and often sporadic in character;
- inadequate shunting of the specimen resistance, reference resistors or the current measuring device by insulation, having resistance of unknown, and possibly variable magnitude;

- the surface resistance may be lower than the volume resistance by one order of magnitude.

An approximate correction of these difficulties may be obtained by making the insulation resistance of all parts of the circuit as high as possible under the conditions of use. This may lead to unwieldy apparatus which is still inadequate for measurement of insulation resistances higher than the magnitude of some hundred MΩ. A more satisfactory correction is obtained by using the technique of guarding.

Guarding depends on interposing, in all critical insulated parts, guard conductors which intercept all stray currents that might otherwise cause errors. The guard conductors are connected together, constituting the guard system and forming with the measuring terminals a three terminal network. When suitable connections are made, stray currents from spurious external voltages are shunted away from the measuring circuit by the guard system, the insulation resistance from either measuring terminal to the guard system shunts a circuit element which should be of very much lower resistance, and the specimen resistance constitutes the only direct path between the measuring terminals. By this technique the probability of error is considerably reduced. The basic connections for guarded electrodes used for volume resistance is shown in Figure 1.

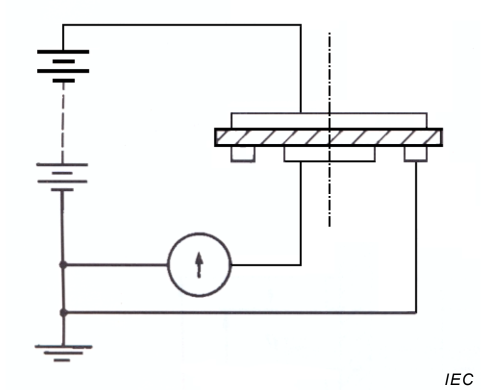


Figure 1 – Basic connection for guarded electrodes

NOTE Dimensions of specimen are given in 5.5

Voltages (e.g. electrochemically or thermally induced) between guard and guarded terminals can be compensated if they are small. Care shall be taken so that such voltages do not introduce significant errors in the measurements.

Errors in the measurement of current may result from the fact that the current-measuring device is shunted by the resistance between the guarded terminal and the guard system. To ensure satisfactory operation of the equipment, a measurement should be made with the lead from the voltage source to the specimen disconnected. Under this condition, the equipment should indicate infinite resistance within its sensitivity. If suitable standards of known values are available, they may be used to test the operation of the equipment.

5.3.3 Electrodes

5.3.3.1 General

The electrodes for insulating materials should be of a material that is readily applied, allows intimate contact with the specimen surface and introduces no appreciable error because of electrode resistance or contamination of the specimen. The electrode material should be corrosion resistant under the conditions of the test. The electrodes shall be used with suitable backing plates of the given form and dimensions. It may be advantageous to use two different electrode materials or two methods of application to see if any significant error is introduced. The following are typical electrode materials that may be used.

5.3.3.2 Conductive silver paint

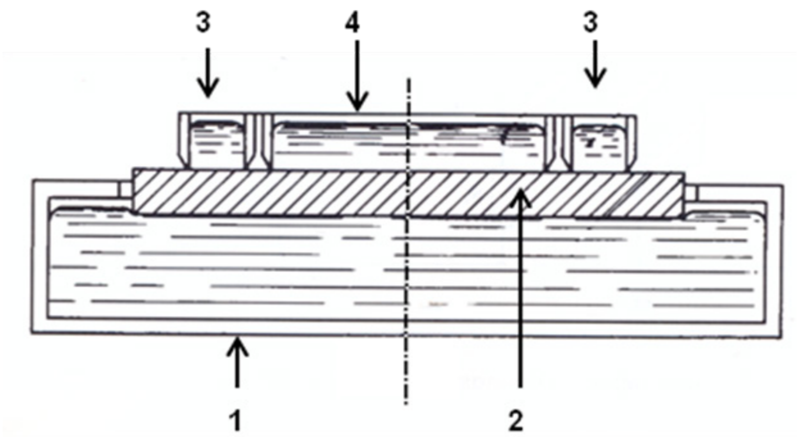
Certain types of commercially available, high-conductivity silver paints, either air-drying or low-temperature-baking varieties are sufficiently porous to permit diffusion of moisture through them and thereby allow the test specimens to be conditioned after application of the electrodes. This is a particularly useful feature in studying resistance-humidity effects as well as changes with temperature. However, before conductive paint is used as an electrode material, it should be established that the solvent in the paint does not affect the electrical properties of the specimen. Reasonably smooth edges of guard electrodes may be obtained with a fine-bristle brush. However, for circular electrodes, sharper edges may be obtained by the use of a compass for drawing the outline circles of the electrodes and filling in the enclosed areas by brush. Clamp-on masks may be used if the electrode paint is sprayed on.

5.3.3.3 Evaporated or sputtered metal

Evaporated or sputtered metal can be used where it can be shown that the material is not affected by ion bombardment, temperature stress or vacuum treatment.

5.3.3.4 Liquid electrodes

Liquid electrodes can be used and give satisfactory results. The liquid forming the upper electrode should be confined, for example, by stainless steel rings, each of which should have its lower rim reduced to a sharp edge by bevelling on the side away from the liquid. Figure 2, shows the electrode arrangement. Alloys e.g. containing gallium, indium and tin which are liquid at room temperature had been proved as suitable. Mercury is not recommended.



IEC

Key

1 Measurement electrode

2 Specimen

3 Guard electrode

4 Liquid metal electrode

Figure 2 – Specimen with liquid electrodes

5.3.3.5 Colloidal graphite

Colloidal graphite dispersed in water or other suitable medium, may be used under the same conditions as given for conductive silver paint.

5.3.3.6 Conducting rubber

Conducting rubber may be used as an electrode material. It has the advantage that it can be applied and removed from the specimen quickly and easily. As the electrodes are applied only during the time of measurement they do not interfere with the conditioning of the specimen. The resistance of the rubber electrode shall be less than 1 000 Ω.

The conducting rubber material shall be soft enough to ensure that effective contact to the specimen is obtained when a reasonable pressure, for example 2 kPa (0,2 N/cm^2), is applied. Shore A hardness according to ISO 868 in the range of 65 to 85 has been found suitable.

NOTE Results of resistivity measurements obtained with the application of electrodes made of conducting rubber are always higher (few tens to few hundreds %) in comparison to that obtained for metallic electrodes.

5.3.3.7 Metal foil

Metal foil can be applied to specimen surfaces as electrodes for volume resistance measurement, but it is not suitable for surface resistance measurement. Aluminum and tin foil are in common use. They are usually attached to the specimen by a minimum quantity of petrolatum, silicone grease, oil or other suitable material, as an adhesive.

All adhesive materials may be of influence to the measurement results and should be minimized.

NOTE A pharmaceutically obtainable jelly of the following composition is suitable as a conductive adhesive:

– anhydrous polyethylene glycol of molecular mass 600 to 800 parts by mass;
– water: 200 parts by mass;
– soft soap (pharmaceutical quality): 1 part by mass;
– potassium chloride: 10 parts by mass;

Soft soap is a non-corrosive, neutral soap used for medical purposes.

The electrodes shall be applied under a smoothing pressure sufficient to eliminate all wrinkles and to work excess adhesive towards the edge of the foil where it can be wiped off with a cleansing tissue. Rubbing with a soft material such as the finger, has been used successfully. This technique can be used satisfactorily only on specimens that have very smooth surfaces. With care, the adhesive film can be reduced to 0,002 5 mm or less.

5.4 Calibration

The equipment shall be calibrated in the magnitude of the volume resistance measured.

NOTE Calibration resistors in the range up to 100 TΩ are commercially available.

5.5 Test specimen

5.5.1 General

The specimen under test shall have a thickness close to their application.

If not otherwise specified, a plate ≥ 100 mm × ≥ 100 mm × (1 mm ± 0,5 mm) is recommended.

5.5.2 Recommended dimensions of test specimens and electrode arrangements

If not otherwise stipulated in the relevant product standard, the following dimensions, as shown in Table 1, for test specimens are recommended:

Table 1 – Test specimen

Type of product	Recommended dimensions of test specimen	Remarks
Thermoplastic moulding components		
Thermosetting moulding components		
Long fibre reinforced polyester and vinyl ester moulding components (SMB BMC)	100 mm × 100 mm × (3 to 5) mm	
Epoxy based sheets and laminates		
Impregnating resins and varnishes	See IEC 62631-3-11	Materials described in IEC 60455 and IEC 60464
Casting resins		Materials described in IEC 60455
Pipes, bars, rods		Materials described in IEC 61212
Elastomeric material	100 mm × 100 mm × 3 mm	