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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

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IEC 62631-3-1:2023-01 RLV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONTENTS

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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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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62631-3-1:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) following the withdrawal of IEC 60093 and its partial replacement with the first edition of IEC 62631-3-1, the missing editorial and technical texts have been added and incorporated into this second edition of IEC 62631-3-1;

b) the alignment of normative texts and informative notes have been addressed as well as the normative references and bibliography.

The text of this International Standard is based on the following documents:

Draft	Report on voting
112/597/FDIS	112/604/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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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

1 Scope

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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 60455-2, *Resin based reactive compounds used for electrical insulation – Part 2: Methods of test*

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

IEC 60464-2, *Varnishes used for electrical insulation – Part 2: Methods of test*

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

IEC 61212-2, *Industrial materials – Industrial rigid round laminated tubes and rods based on thermosetting resins for electrical purposes – Part 2: Methods of test*

~~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.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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

quotient of a direct voltage applied between two electrodes in contact with an insulating medium and the current through it at a given duration of voltage application

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

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

quotient of a DC electric field system and the current density within an insulating medium at a given time of voltage application

Note 1 to entry: Volume resistivity is expressed in Ω · m.

~~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~~ 2 to entry: According to IEC 60050-121~~: Electromagnetism~~, "conductivity" (IEV 121-12-03) 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" (IEV 121-12-04) 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 into the earth or into metallic structures ~~buried in the ground and resulting from their intended or unintended earthing~~ at earth potential resulting in unintended energy losses

4 Significance

4.1 General

Insulating materials are used in general to electrically isolate components of an electrical system from each other and from earth. 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~~ insulation resistance. Solid insulating material ~~may~~ can also provide mechanical support.

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~~ can be ~~great~~ high and has to be known when designing for operation conditions.

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

NOTE 1 For very high electric field strengths different behaviours can occur.

NOTE 2 For materials with volume resistivity of not more than 10^{12} Ω · m, a period of 1 h after voltage application can be sufficient to prevent electric shock.

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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.

~~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.~~

4.2 Power supply~~,~~ and 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 required degree of stability 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 $< 5 \times 10^{-5}$ 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 depending on the thicknesses of samples.

A test voltage selected divided by the thickness of the specimen under test shall not exceed 3 kV/mm.

~~If otherwise stipulated, a voltage of 100 V is to be used.~~

Unless otherwise specified, a voltage of 100 V shall be used.

NOTE 2 The maximum voltage expected in the final product application can be used. If it is unknown, 100 V can be used.

NOTE 3 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.

4.3 Equipment

4.3.1 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~~ resistances higher than 10^{14} Ω.

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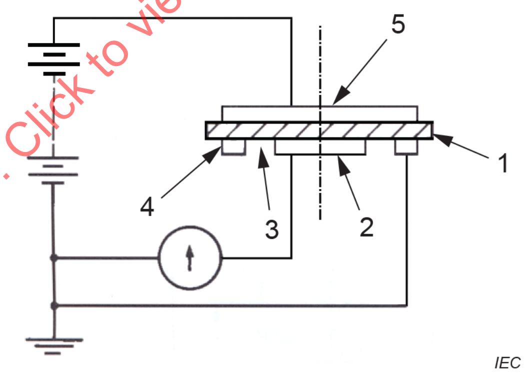
4.3.2 Guarding

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~~ can 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~~ that can 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~~ can 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~~ can 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 resistance of the specimen constitutes the only direct path between the measuring terminals. With this technique the probability of error is considerably reduced. The basic connections for guarded electrodes used for volume resistance is shown in Figure 1. The three-electrode arrangement is shown in Figure 2 and the typical dimensions of the electrodes are given in Table 1.



Key

1 measuring area

2 electrode 1

3 specimen

4 electrode 2 (guard electrode)

5 electrode 3

Figure 1 – Basic connection for guarded electrodes

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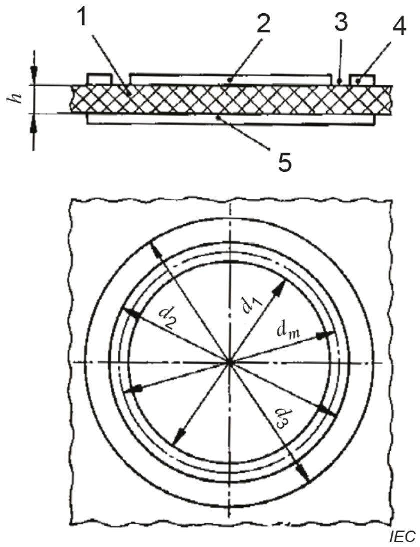

Key

1 specimen

2 electrode 1

3 measuring area

4 electrode 2 (guard electrode)

5 electrode 3

h average thickness of the specimen

d_1, d_2, d_3, d_m See Table 1 for examples of electrode dimensions.

Figure 2 – Electrode arrangement

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Table 1 – Typical electrode dimensions for electrode arrangement (examples)

	d_1 mm	d_2 mm	d_3 mm
Example 1	50	54	74
Example 2	50	60	80
Example 3	50	52	72
Example 4	25	27	47

NOTE 1 Dimensions of specimens are given in 4.5.

NOTE 2 Besides the electrodes in Figure 1 (i.e. the passive guarded electrodes), other types of active guarded electrodes, which have become popular in recent years, can be used. The active guarded electrode system can reduce stray current almost to zero by driving the guard conductor with an operational amplifier which keeps the same potential as the lead (signal) carrying the measured current.

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

Errors in the measurement of current ~~may~~ can 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.

4.3.3 Electrodes

4.3.3.1 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~~ can be advantageous to use two different electrode materials or two methods of application to see if any significant error is introduced. The following subclauses 4.3.3.2 to 4.3.3.7 list typical electrode materials that may be used.

4.3.3.2 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.

4.3.3.3 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.

4.3.3.4 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 3 shows the electrode arrangement. Alloys for example containing gallium, indium and tin, which are liquid at room temperature, have been proved suitable. Mercury is not recommended.

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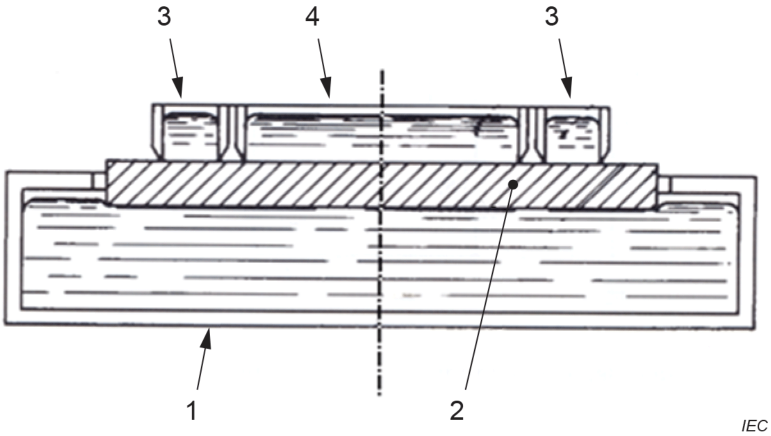

Key

1 ~~Measurement~~ liquid metal electrode

2 specimen

3 guard electrode

4 ~~Liquid metal~~ measuring electrode

Figure 3 – Specimen with liquid electrodes

4.3.3.5 Colloidal graphite

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

4.3.3.6 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~~ ISO 48-4 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 per cent) in comparison to those obtained for metallic electrodes.

4.3.3.7 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~~ can be of influence to the measurement results and their use 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.

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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.

4.4 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.

4.5 Test specimen

4.5.1 General

The specimen under test shall have a thickness close to that of its application.

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

Unless otherwise specified in the relevant product standard, a plate ≥ 100 mm × ≥ 100 mm × (1,00 mm ± 0,1 mm) is recommended.

NOTE 1 A plate thickness of 3 mm is preferred for elastomeric materials, and a plate thickness range between 3 mm and 5 mm is preferred for long fibre reinforced polyester resin or vinyl ester resin moulding components (SMB BMC).

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

~~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~~	

4.5.2 Manufacturing of test specimens

The production and shape of the test specimens shall be determined by the relevant standards for the material. During ~~removal and~~ the production of the specimens, the condition of the material shall not be changed and the specimen shall not be damaged.

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If the surface of the test specimen is machined at the contact areas of the electrodes, the type of machining shall be specified in the test report. The test specimens shall have a geometrically simple shape (e.g. plate with parallel measuring areas, cylinder ~~etc.~~).

The specimens from products shall be prepared ~~with~~ by using the product thickness, if ~~possible~~ known.

4.5.3 Number of test specimens

The number of specimens to be tested shall be determined by the relevant product standards. If no such data is available, at least three specimens shall be tested.

4.5.4 Conditioning and pre-treatment of test specimens

Conditioning and any other pre-treatment of the test specimens shall be carried out in accordance with the relevant product standard. If no product standard exists, conditioning shall be done for at least four days at (23 ± 2) °C and (50 ± 5) % RH in accordance with IEC 60212 (standard climate B) waiting the weight stability of the test specimen (less than 0,1 % of weight variation assessed with high resolution weighing machine).

4.6 Procedures for specific materials

Specific materials are described in material specifications. IEC 60455-2, IEC 60464-2 and IEC 61212-2 contain methods of test. If a specific procedure for a specified material exists, this specification shall be used.

5 Test procedure

5.1 General

A number of specimens as described in the relevant specification shall be prepared. If not otherwise specified, three specimens shall be tested. The thickness of the sample should be measured at least at five points before application of the electrodes. The thickness of the specimens and electrode dimensions shall be measured with an accuracy of ±1 %.

5.2 Measurement of volume resistance

Before measurement, the specimen shall be brought into an electrically stable condition. To obtain this, short-circuit the measuring electrodes of the specimen through the measuring device and observe the changing short-circuit current, while increasing the sensitivity of the current measuring device. The short-circuit current shall attain a fairly constant value. ~~If not~~ Unless otherwise ~~stipulated~~ specified, the volume resistance shall be determined after a fixed time of electrification of 1 min. Before the measurement, the specimen shall be stored for at least 24 h under climate conditions.

NOTE Quality control measurements are typically measured after 1 min.

It is not allowed to repeat the measurement unless the specimen is brought into a stable condition again.

As the time-dependent behaviour of the material under test is of interest, apply the specified direct voltage and start a timing device simultaneously. Unless otherwise specified, a measurement is taken after each of the following times of electrification: 1 min, 2 min, 5 min, 10 min, 50 min and 100 min. If two successive measurements give the same results, the test shall be terminated.

5.3 Calculation of volume resistivity

The volume resistivity shall be calculated from the following formula:

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$$\rho = R_{\text{x}} \times \frac{A}{h}$$

where

ρ is the volume resistivity in Ω · m;

R_{x} is the volume resistance measured in Ω;

A is the effective area of the electrode in m^2;

h is the thickness of the specimen in m (average).

6 Test report

The test report shall include the following:

- complete identification and description of the material tested, including source and manufacturer's code;
- shape, thickness and number of test specimens;
- test voltage;
- description of electrodes, test set-up and instrument used for the test;
- accuracy of the instrument and calibration method, depending on the measured values of resistance, if necessary;
- curing conditions of the material and any pre-treatment;
- conditioning of ~~samples and climatic conditions under test~~ test specimens and ambient conditions during testing;
- number of samples;
- date of test;
- each single value and the median of volume resistance and volume resistivity, respectively;
- ~~ambient conditions during testing;~~
- any other important observations if applicable.

7 Repeatability and reproducibility

Measurements of volume resistance and volume resistivity are dependent on numerous aspects. The experience has shown that the reproducibility ~~is in the range of >~~ can be more than 50 % (of the measured value).

The repeatability is typically between 20 % and 50 %.

NOTE Repeatability and reproducibility are under consideration. IEC TC 112 intends to perform a round robin test to specify the repeatability and reproducibility with more precision.

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ISO 48-4, *Rubber, vulcanized or thermoplastics – Determination of hardness – Part 4: Indentation hardness by durometer method (Shore hardness)*

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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

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

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IEC 62631-3-1:2023-01(en-fr)

CONTENTS

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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

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FOREWORD

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

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) following the withdrawal of IEC 60093 and its partial replacement with the first edition of IEC 62631-3-1, the missing editorial and technical texts have been added and incorporated into this second edition of IEC 62631-3-1;

b) the alignment of normative texts and informative notes have been addressed as well as the normative references and bibliography.

The text of this International Standard is based on the following documents:

Draft	Report on voting
112/597/FDIS	112/604/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
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- amended.

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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

1 Scope

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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 60455-2, *Resin based reactive compounds used for electrical insulation – Part 2: Methods of test*

IEC 60464-2, *Varnishes used for electrical insulation – Part 2: Methods of test*

IEC 61212-2, *Industrial materials – Industrial rigid round laminated tubes and rods based on thermosetting resins for electrical purposes – Part 2: Methods of test*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
volume resistance
quotient of a direct voltage applied between two electrodes in contact with an insulating medium and the current through it at a given duration of voltage application

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

3.2
volume resistivity
quotient of a DC electric field system and the current density within an insulating medium at a given time of voltage application

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Note 1 to entry: Volume resistivity is expressed in Ω · m.

Note 2 to entry: According to IEC 60050-121, "conductivity" (IEV 121-12-03) 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" (IEV 121-12-04) 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 into the earth or into metallic structures at earth potential resulting in unintended energy losses

4 Significance

4.1 General

Insulating materials are used in general to electrically isolate components of an electrical system from each other and from earth. 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 insulation resistance. Solid insulating material can also provide mechanical support.

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 can be high and has to be known when designing for operation conditions.

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

NOTE 1 For very high electric field strengths different behaviours can occur.

NOTE 2 For materials with volume resistivity of not more than 10^{12} Ω · m, a period of 1 h after voltage application can be sufficient 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.

4.2 Power supply and 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 required degree of stability 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 $< 5 \times 10^{-5}$ peak to peak.

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

A test voltage selected divided by the thickness of the specimen under test shall not exceed 3 kV/mm.

Unless otherwise specified, a voltage of 100 V shall be used.

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NOTE 2 The maximum voltage expected in the final product application can be used. If it is unknown, 100 V can be used.

NOTE 3 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.

4.3 Equipment

4.3.1 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 resistances higher than 10^{14} Ω.

4.3.2 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 can 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 that can 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 can 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 can 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 resistance of the specimen constitutes the only direct path between the measuring terminals. With this technique the probability of error is considerably reduced. The basic connections for guarded electrodes used for volume resistance is shown in Figure 1. The three-electrode arrangement is shown in Figure 2 and the typical dimensions of the electrodes are given in Table 1.

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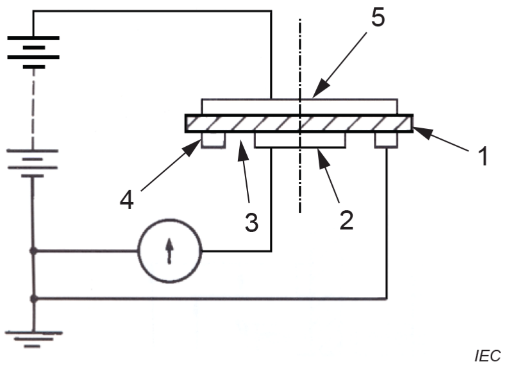


Key

1 measuring area

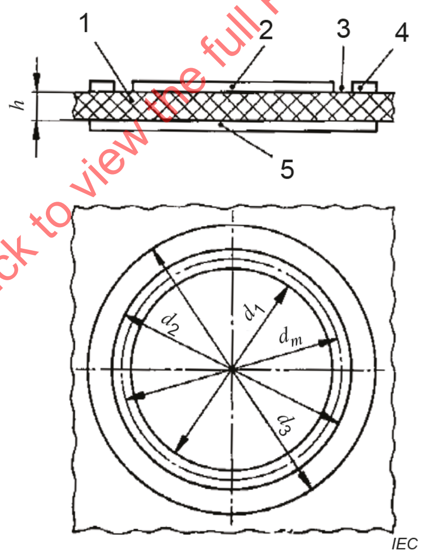
2 electrode 1

3 specimen

4 electrode 2 (guard electrode)

5 electrode 3

Figure 1 – Basic connection for guarded electrodes



Key

1 specimen

2 electrode 1

3 measuring area

4 electrode 2 (guard electrode)

5 electrode 3

h average thickness of the specimen

d_1, d_2, d_3, d_m See Table 1 for examples of electrode dimensions.

Figure 2 – Electrode arrangement

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Table 1 – Typical electrode dimensions for electrode arrangement (examples)

	d_1 mm	d_2 mm	d_3 mm
Example 1	50	54	74
Example 2	50	60	80
Example 3	50	52	72
Example 4	25	27	47

NOTE 1 Dimensions of specimens are given in 4.5.

NOTE 2 Besides the electrodes in Figure 1 (i.e. the passive guarded electrodes), other types of active guarded electrodes, which have become popular in recent years, can be used. The active guarded electrode system can reduce stray current almost to zero by driving the guard conductor with an operational amplifier which keeps the same potential as the lead (signal) carrying the measured current.

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

Errors in the measurement of current can 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.

4.3.3 Electrodes

4.3.3.1 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 can be advantageous to use two different electrode materials or two methods of application to see if any significant error is introduced. The following subclauses 4.3.3.2 to 4.3.3.7 list typical electrode materials that may be used.

4.3.3.2 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.

4.3.3.3 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.

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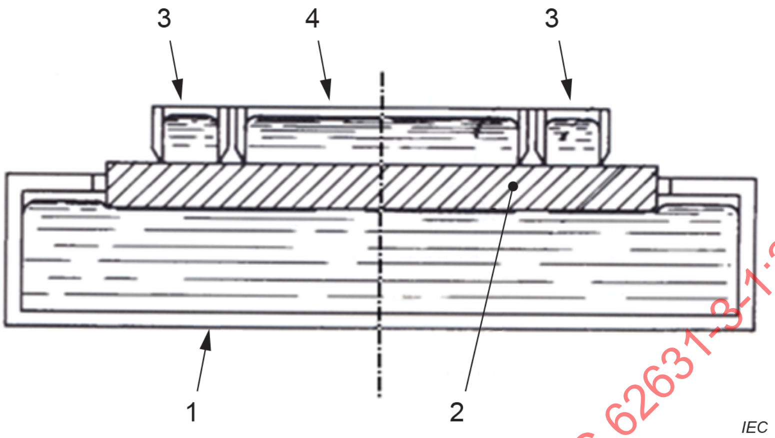
4.3.3.4 Liquid electrodes

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 3 shows the electrode arrangement. Alloys for example containing gallium, indium and tin, which are liquid at room temperature, have been proved suitable. Mercury is not recommended.



Key

1 liquid metal electrode

2 specimen

3 guard electrode

4 measuring electrode

Figure 3 – Specimen with liquid electrodes

4.3.3.5 Colloidal graphite

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

4.3.3.6 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 48-4 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 per cent) in comparison to those obtained for metallic electrodes.

4.3.3.7 Metal foil

Metal foil can be applied to specimen surfaces as electrodes for volume 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 can be of influence to the measurement results and their use should be minimized.

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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. The adhesive film can be reduced to 0,002 5 mm or less.

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4.4 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.

4.5 Test specimen

4.5.1 General

The specimen under test shall have a thickness close to that of its application.

Unless otherwise specified in the relevant product standard, a plate ≥ 100 mm × ≥ 100 mm × (1,00 mm ± 0,1 mm) is recommended.

NOTE 1 A plate thickness of 3 mm is preferred for elastomeric materials, and a plate thickness range between 3 mm and 5 mm is preferred for long fibre reinforced polyester resin or vinyl ester resin moulding components (SMB BMC).

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

4.5.2 Manufacturing of test specimens

The production and shape of the test specimens shall be determined by the relevant standards for the material. During the production of the specimens, the condition of the material shall not be changed and the specimen shall not be damaged.

If the surface of the test specimen is machined at the contact areas of the electrodes, the type of machining shall be specified in the test report. The test specimens shall have a geometrically simple shape (e.g. plate with parallel measuring areas, cylinder).

The specimens from products shall be prepared by using the product thickness, if known.

4.5.3 Number of test specimens

The number of specimens to be tested shall be determined by the relevant product standards. If no such data is available, at least three specimens shall be tested.

4.5.4 Conditioning and pre-treatment of test specimens

Conditioning and any other pre-treatment of the test specimens shall be carried out in accordance with the relevant product standard. If no product standard exists, conditioning shall be done for at least four days at (23 ± 2) °C and (50 ± 5) % RH in accordance with IEC 60212 (standard climate B) waiting the weight stability of the test specimen (less than 0,1 % of weight variation assessed with high resolution weighing machine).

4.6 Procedures for specific materials

Specific materials are described in material specifications. IEC 60455-2, IEC 60464-2 and IEC 61212-2 contain methods of test. If a specific procedure for a specified material exists, this specification shall be used.

5 Test procedure

5.1 General

A number of specimens as described in the relevant specification shall be prepared. If not otherwise specified, three specimens shall be tested. The thickness of the sample should be measured at least at five points before application of the electrodes. The thickness of the specimens and electrode dimensions shall be measured with an accuracy of ±1 %.

5.2 Measurement of volume resistance

Before measurement, the specimen shall be brought into an electrically stable condition. To obtain this, short-circuit the measuring electrodes of the specimen through the measuring device and observe the changing short-circuit current, while increasing the sensitivity of the current measuring device. The short-circuit current shall attain a fairly constant value. Unless otherwise specified, the volume resistance shall be determined after a fixed time of electrification of 1 min. Before the measurement, the specimen shall be stored for at least 24 h under climate conditions.

NOTE Quality control measurements are typically measured after 1 min.

It is not allowed to repeat the measurement unless the specimen is brought into a stable condition again.

As the time-dependent behaviour of the material under test is of interest, apply the specified direct voltage and start a timing device simultaneously. Unless otherwise specified, a measurement is taken after each of the following times of electrification: 1 min, 2 min, 5 min, 10 min, 50 min and 100 min. If two successive measurements give the same results, the test shall be terminated.

5.3 Calculation of volume resistivity

The volume resistivity shall be calculated from the following formula:

$$\rho = R_x \times \frac{A}{h}$$

where

ρ is the volume resistivity in Ω · m;

R_x is the volume resistance measured in Ω;

A is the effective area of the electrode in m^2;

h is the thickness of the specimen in m (average).

6 Test report

The test report shall include the following:

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- complete identification and description of the material tested, including source and manufacturer's code;
- shape, thickness and number of test specimens;
- test voltage;
- description of electrodes, test set-up and instrument used for the test;
- accuracy of the instrument and calibration method, depending on the measured values of resistance, if necessary;
- curing conditions of the material and any pre-treatment;
- conditioning of test specimens and ambient conditions during testing;
- number of samples;
- date of test;
- each single value and the median of volume resistance and volume resistivity, respectively;
- any other important observations if applicable.

7 Repeatability and reproducibility

Measurements of volume resistance and volume resistivity are dependent on numerous aspects. The experience has shown that the reproducibility can be more than 50 % (of the measured value).

The repeatability is typically between 20 % and 50 %.

NOTE Repeatability and reproducibility are under consideration. IEC TC 112 intends to perform a round robin test to specify the repeatability and reproducibility with more precision.

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IEC 60050-121, *International Electrotechnical Vocabulary (IEV) – Part 121: Electromagnetism,* available at https://www.electropedia.org

IEC 62631-3-11, *Dielectric and resistive properties of solid insulating materials – Part 3-11: Determination of resistive properties (DC methods) – Volume resistance and volume resistivity – Method for impregnation and coating materials*

ISO 48-4, *Rubber, vulcanized or thermoplastics – Determination of hardness – Part 4: Indentation hardness by durometer method (Shore hardness)*

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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PROPRIÉTÉS DIÉLECTRIQUES ET RÉSISTIVES DES MATÉRIAUX ISOLANTS SOLIDES –

Partie 3-1: Détermination des propriétés résistives (méthodes en courant continu) – Résistance volumique et résistivité volumique – Méthode générale

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AVANT-PROPOS

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L'IEC 62631-3-1 a été établie par le comité d'études 112 de l'IEC: Évaluation et qualification des systèmes et matériaux d'isolement électrique. Il s'agit d'une Norme internationale.

Cette seconde édition annule et remplace la première édition parue en 2016. Cette édition constitue une révision technique.

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

a) à la suite du retrait de l'IEC 60093 et à son remplacement partiel par la première édition de l'IEC 62631-3-1, des éléments rédactionnels et techniques manquants ont été ajoutés et intégrés dans la seconde édition de l'IEC 62631-3-1;

b) un alignement des textes normatifs et des notes informatives a été réalisé ainsi qu'une mise à jour des références normatives et de la bibliographie.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
112/597/FDIS	112/604/RVD

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

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 62631, publiées sous le titre général *Propriétés diélectriques et résistives des matériaux isolants solides*, se trouve sur le site web de l'IEC.

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PROPRIÉTÉS DIÉLECTRIQUES ET RÉSISTIVES DES MATÉRIAUX ISOLANTS SOLIDES –

Partie 3-1: Détermination des propriétés résistives (méthodes en courant continu) – Résistance volumique et résistivité volumique – Méthode générale

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1 Domaine d'application

La présente partie de l'IEC 62631 spécifie une méthode d'essai pour déterminer la résistance volumique et la résistivité volumique de matériaux isolants électriques par application d'une tension continue.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. 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 60212, *Conditions normales à observer avant et pendant les essais de matériaux isolants électriques solides*

IEC 60455-2, *Composés réactifs à base de résines utilisés comme isolants électriques – Partie 2: Méthodes d'essai*

IEC 60464-2, *Vernis utilisés pour l'isolation électrique – Partie 2: Méthodes d'essai*

IEC 61212-2, *Matériaux isolants – Tubes et barres industriels rigides, ronds, stratifiés, à base de résines thermodurcissables à usages électriques – Partie 2: Méthodes d'essai*

3 Termes et définitions

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

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
résistance volumique
quotient d'une tension continue appliquée entre deux électrodes en contact avec un milieu isolant et le courant qui traverse celui-ci à un instant donné de la durée de mise sous tension

Note 1 à l'article: La résistance volumique s'exprime en Ω.

3.2
résistivité volumique
quotient d'un système à champ électrique en courant continu et la densité du courant qui traverse un milieu isolant à un instant donné de la durée de mise sous tension

Note 1 à l'article: La résistivité volumique s'exprime en Ω.

Note 2 à l'article: Selon l'IEC 60050-121, la "conductivité" (IEV 121-12-03) est définie comme "la grandeur scalaire ou tensorielle dont le produit par le champ électrique dans un milieu est égal à la densité de courant électrique" et la "résistivité" (IEV 121-12-04) est définie comme "l'inverse de la conductivité lorsque cet inverse existe". Lorsqu'elle est mesurée de cette façon, la résistivité volumique est une moyenne de la résistivité sur les hétérogénéités éventuelles dans le volume incluses dans la mesure, et comprend l'effet d'éventuels phénomènes de polarisation au niveau des électrodes.

3.3
courant vagabond
courant de fuite dans la terre ou dans des structures métalliques au potentiel de la terre, qui génère des pertes en énergie imprévues

4 Signification

4.1 Généralités

Des matériaux isolants sont en général utilisés pour isoler électriquement les composants d'un système électrique les uns par rapport aux autres et par rapport à la terre. Pour ces utilisations, il est généralement souhaitable que la résistance d'isolement soit aussi élevée que possible et qu'elle présente des propriétés mécaniques, chimiques et de résistance à la chaleur acceptables. La résistance volumique est un élément de la résistance d'isolement. Un matériau isolant solide peut également servir de support mécanique.

La résistivité volumique peut être utilisée pour choisir un matériau isolant destiné à une application spécifique. La variation de la résistivité en fonction de la température et de l'humidité peut être élevée; elle doit être connue lors de la conception pour prévoir les conditions de fonctionnement.

Lorsqu'une tension continue est appliquée entre les électrodes en contact avec une éprouvette, le courant qui traverse cette éprouvette diminue de manière asymptotique vers une valeur en régime établi. La diminution du courant en fonction du temps peut être due à la polarisation diélectrique et au déplacement des ions mobiles vers les électrodes. Pour des matériaux dont la résistivité volumique est inférieure à environ 10^{10} Ω · m, la valeur en régime établi est en général atteinte dans un délai de 1 min et la résistance est déterminée après cette durée de mise sous tension. Pour les matériaux de résistivité volumique supérieure, le courant peut continuer à décroître pendant plusieurs minutes, heures, jours, voire des semaines. Par conséquent, des durées de mise sous tension plus longues peuvent être nécessaires pour de tels matériaux.

NOTE 1 Les comportements peuvent être différents lorsque les champs électriques sont très élevés.

NOTE 2 Pour des matériaux dont la résistivité volumique est inférieure ou égale à 10^{12} Ω · m, un laps de temps de 1 h après l'application de la tension peut être suffisant pour éviter les chocs électriques.

Les effets de la polarisation peuvent avoir une influence sur les valeurs mesurées. Il n'est donc pas acceptable de mesurer deux fois la résistance dans deux expériences consécutives sans respecter un intervalle de temps suffisant entre les deux mesurages.

4.2 Alimentation et tension

Une source de tension continue très stable est exigée. Cette condition peut être obtenue soit par l'emploi de batteries, soit par une alimentation redressée et stabilisée. Le degré de stabilité exigé est tel que la variation de courant liée aux variations de tension demeure négligeable par rapport au courant à mesurer.

NOTE 1 L'ondulation de la source de tension est importante. Une valeur type pour 100 V est $< 5 \times 10^{-5}$ crête à crête.

Les tensions d'essai couramment spécifiées à appliquer à l'éprouvette complète sont généralement égales à 100 V, 500 V, 1 000 V et 10 000 V, selon l'épaisseur des échantillons.

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