# IEC 62631-3-1

Edition 2.0 2023-01
REDLINE VERSION

# INTERNATIONAL STANDARD

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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

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

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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

INTERNATIONAL
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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 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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# 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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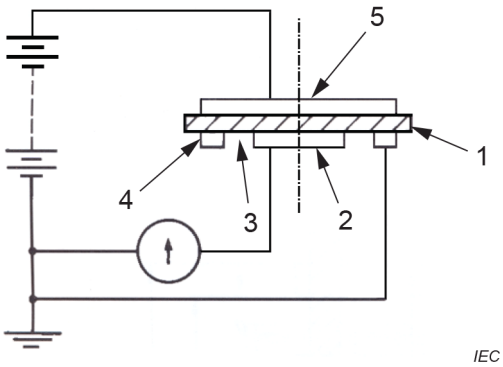
### 4.3.2 Guarding

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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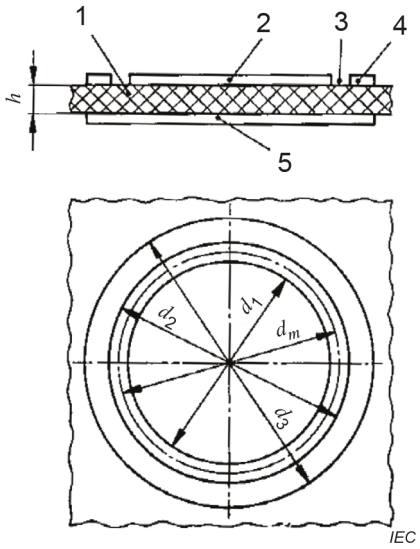


**Key**

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**

**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.

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### 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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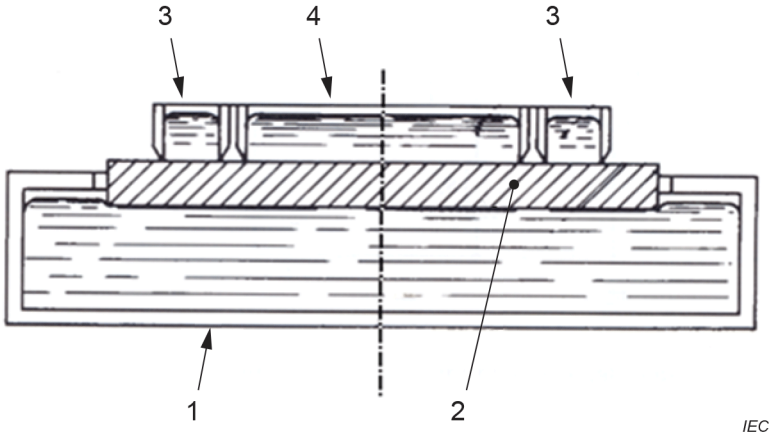


**Key**

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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