

# 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 <sup>iec-</sup>  
continu) – Résistance volumique et résistivité volumique – Méthode générale**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Recherche de publications IEC -

##### [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

# 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 volumique et résistivité volumique – Méthode générale**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

---

ICS 17.220.99; 29.035.01

ISBN 978-2-8322-6359-4

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	3
1 Scope.....	5
2 Normative references .....	5
3 Terms and definitions .....	5
4 Significance.....	6
4.1 General.....	6
4.2 Power supply and voltage .....	6
4.3 Equipment .....	7
4.3.1 Accuracy .....	7
4.3.2 Guarding .....	7
4.3.3 Electrodes .....	9
4.4 Calibration .....	11
4.5 Test specimen .....	11
4.5.1 General .....	11
4.5.2 Manufacturing of test specimens.....	11
4.5.3 Number of test specimens .....	11
4.5.4 Conditioning and pre-treatment of test specimens .....	11
4.6 Procedures for specific materials .....	12
5 Test procedure .....	12
5.1 General.....	12
5.2 Measurement of volume resistance.....	12
5.3 Calculation of volume resistivity.....	12
6 Test report.....	12
7 Repeatability and reproducibility .....	13
Bibliography.....	14
Figure 1 – Basic connection for guarded electrodes.....	8
Figure 2 – Electrode arrangement.....	8
Figure 3 – Specimen with liquid electrodes .....	10
Table 1 – Typical electrode dimensions for electrode arrangement (examples).....	9

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**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

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://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](http://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.

[IEC 62631-3-1:2023](https://standards.iteh.ai/catalog/standards/sist/b2158850-76cd-43e9-b7ee-876be277e2de/iec-62631-3-1-2023)

<https://standards.iteh.ai/catalog/standards/sist/b2158850-76cd-43e9-b7ee-876be277e2de/iec-62631-3-1-2023>

## 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  $\Omega$ .

##### 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

Note 1 to entry: Volume resistivity is expressed in  $\Omega \cdot \text{m}$ .

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  $10^{10} \Omega \cdot \text{m}$ , 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  $10^{12} \Omega \cdot \text{m}$ , 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.



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:

- $\pm 10\%$  for resistances below  $10^{10}\ \Omega$ ,
- $\pm 20\%$  for resistances between  $10^{10}\ \Omega$  and  $10^{14}\ \Omega$ ,
- $\pm 50\%$  for resistances higher than  $10^{14}\ \Omega$ .

### 4.3.2 Guarding

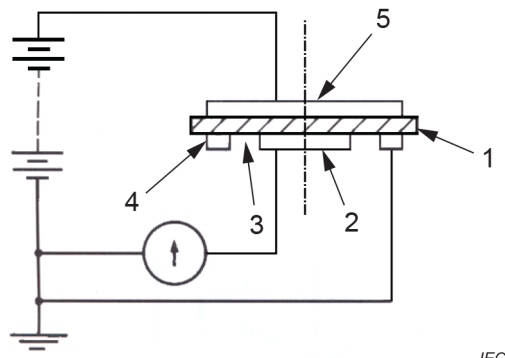
The insulation of the measuring circuit is composed of materials which, at best, have properties comparable with those of the material under test. Errors in the measurement of the specimen can arise from:

- 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.

[IEC 62631-3-1:2023](#)

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 M $\Omega$ . 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.

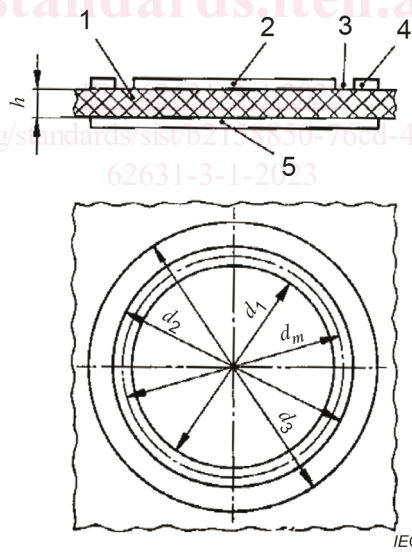


IEC

**Key**

- 1 measuring area
- 2 electrode 1
- 3 specimen
- 4 electrode 2 (guard electrode)
- 5 electrode 3

**Figure 1 – Basic connection for guarded electrodes**



IEC

**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. 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

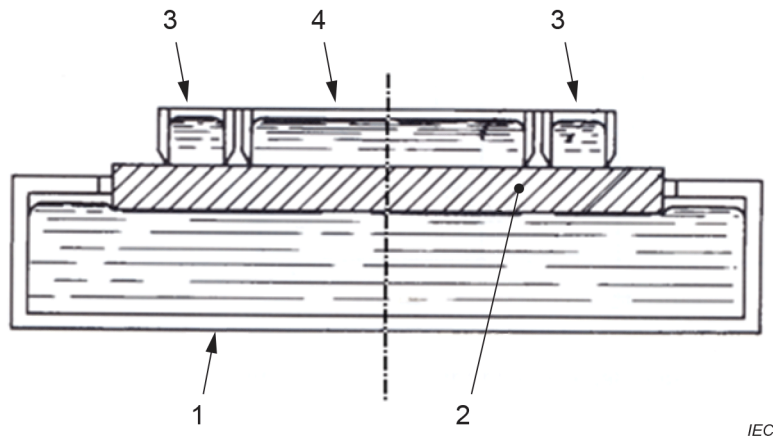
Certain types of commercially available, high-conductivity silver paints, either air-drying or low-temperature-baking varieties are sufficiently porous to permit diffusion of moisture through them and thereby allow the test specimens to be conditioned after application of the electrodes. This is a particularly 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.

#### 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<sup>2</sup>), 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.