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Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials (IEC 60093:1980)

Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials

Prüfverfahren für den spezifischen Durchgangswiderstand und den spezifischen Oberflächenwiderstand von festen, elektrisch isolierenden Werkstoffen

Méthodes pour la mesure de la résistivité transversale et de la résistivité superficielle des matériaux isolants électriques solides

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METHODS OF TEST FOR VOLUME RESISTIVITY AND SURFACE RESISTIVITY OF SOLID ELECTRICAL INSULATING MATERIALS

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BODY OF THE HD

The Harmonization Document consists of:

- IEC 93:1980; IEC/SC 15A, not appended

This Harmonization Document was approved by CENELEC on 1982-07-07.

The English and French versions of this Harmonization Document are provided by the text of the IEC publication and the German version is the official translation of the IEC text.

According to the CEN/CENELEC Internal Regulations the CENELEC member National Committees are bound:

to announce the existence of this Harmonization Document at national level by or before 1983-06-01

to publish their new harmonized national standard by or before 1984-01-01

to withdraw all conflicting national standards by or before 1984-01-01.

Harmonized national standards are listed on the HD information sheet, which is available from the CENELEC National Committees or from the CENELEC Central Secretariat.

The CENELEC National Committees are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODS OF TEST FOR VOLUME RESISTIVITY AND SURFACE RESISTIVITY OF SOLID ELECTRICAL INSULATING MATERIALS

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 15A: Short-time Tests, of IEC Technical Committee No. 15: Insulating Materials.

It forms the second edition of IEC Publication 93.

A first draft was discussed at the meeting held in Toronto in 1976. As a result of this meeting, a draft, Document 15A(Central Office)35, was submitted to the National Committees for approval under the Six Months' Rule in November 1977.

Amendments, Document 15A(Central Office)39, were submitted to the National Committees for approval under the Two Months' Procedure in October 1979.

The National Committees of the following countries voted explicitly in favour of publication:

Austria
Belgium
Brazil
Bulgaria
Canada
China
Czechoslovakia
Denmark
Egypt
France
Germany
Ireland
Italy
Korea (Republic of)
New Zealand
Norway
Poland
Spain
Sweden
Switzerland
United Kingdom
United States of America
Yugoslavia

Other IEC publications quoted in this standard:

Publications Nos. 167: Methods of Test for the Determination of the Insulation Resistance of Solid Insulating Materials.
212: Standard Conditions for Use Prior to and during the Testing of Solid Electrical Insulating Materials.
260: Test Enclosures of Non-injection Type for Constant Relative Humidity.

METHODS OF TEST FOR VOLUME RESISTIVITY AND SURFACE RESISTIVITY OF SOLID ELECTRICAL INSULATING MATERIALS

1. Scope

These methods of test cover procedures for the determination of volume and surface resistance and calculations for the determination of volume and surface resistivity of solid electrical insulating materials.

Both volume resistance and surface resistance tests are affected by the following factors: the magnitude and time of voltage application, the nature and geometry of the electrodes, and the temperature and humidity of the ambient atmosphere and of the specimens during conditioning and measurement. Recommendations are made for these factors.

2. Definitions

2.1 *Volume resistance*

The quotient of a direct voltage applied between two electrodes placed on two faces (opposite) of a specimen, and the steady-state current between the electrodes, excluding current along the surface, and neglecting possible polarization phenomena at the electrodes.

Note. — Unless otherwise specified, the volume resistance is determined after 1 min of electrification.

2.2 *Volume resistivity*

The quotient of a d.c. electric field strength and the steady-state current density within an insulating material. In practice it is taken as the volume resistance reduced to a cubical unit volume.

Note. — The SI unit of volume resistivity is the ohm metre. In practice the unit ohm centimetre is also used.

2.3 *Surface resistance*

The quotient of a direct voltage applied between two electrodes on a surface of a specimen, and the current between the electrodes at a given time of electrification, neglecting possible polarization phenomena at the electrodes.

Notes 1. — Unless otherwise specified, the surface resistance is determined after 1 min of electrification.

2. — The current generally passes mainly through a surface layer of the specimen and any associated moisture and surface contaminant, but it also includes a component through the volume of the specimen.

2.4 *Surface resistivity*

The quotient of a d.c. electric field strength, and the linear current density in a surface layer of an insulating material. In practice it is taken as the surface resistance reduced to a square area. The size of the square is immaterial.

Note. — The SI unit of surface resistivity is the ohm. In practice this is sometimes referred to as "ohms per square".

2.5 *Electrodes*

Measuring electrodes are conductors of defined shape, size and configuration in contact with the specimen being measured.

General note. — *Insulation resistance* is the quotient of a direct voltage applied between two electrodes in contact with a specimen and the total current between the electrodes. The insulation resistance depends on both volume and surface resistivity of the specimen (see IEC Publication 167: Methods of Test for the Determination of the Insulation Resistance of Solid Insulating Materials).

3. Significance

3.1 Insulating materials are used in general to isolate components of an electrical system from each other and from earth; solid insulating materials may also provide mechanical support. For these purposes it is generally desirable to have the insulation resistance as high as possible, consistent with acceptable mechanical, chemical and heat-resisting properties. Surface resistance changes very rapidly with humidity, while volume resistance changes only slowly, although the final change may be greater.

3.2 Volume resistivity can be used as an aid in the choice of an insulating material for a specific application. The change of resistivity with temperature and humidity may be great and must be known when designing for operating conditions. Volume resistivity measurements are often used in checking the uniformity of an insulating material, either with regard to processing or to detect conductive impurities that affect the quality of the material and that may not be readily detectable by other means.

3.3 When a direct voltage is applied between electrodes in contact with a specimen, the current through it decreases asymptotically towards a steady-state value. The decrease of current with time may be due to dielectric polarization and the sweep of mobile ions to the electrodes. For materials having volume resistivities less than about $10^{10}\ \Omega \cdot m$ ($10^{12}\ \Omega \cdot cm$), the steady-state is in general reached within 1 min, and the resistance is then determined after this time of electrification. For materials of higher volume resistivity the current may continue to decrease for several minutes, hours, days, or even weeks. For such materials, therefore, longer electrification times are used, and, if relevant, the material is characterized by the time dependence of the volume resistivity.

3.4 Surface resistance or surface conductance cannot be measured accurately, only approximated, because more or less volume conductance is nearly always involved in the measurement. The measured value is largely a property of the contamination of the surface of the specimen at the time of measurement. However, the permittivity of the specimen influences the deposition of contaminants, and their conductive capabilities are affected by the surface characteristics of the specimen. Thus surface resistivity is not a material property in the usual sense, but can be considered to be related to material properties when contamination is involved.

Some materials, such as laminates, may have quite different resistivities in a surface layer and in the interior. It may therefore be of interest to measure the intrinsic property of a clean surface. Cleaning procedures aimed at producing consistent results should be fully specified bearing in mind the possible effect of solvents and other factors of the cleaning procedure on the surface characteristics.

The surface resistance, especially when high, often changes in an erratic manner, and in general depends strongly on the time of electrification; for measurements, 1 min of electrification is usually specified.

4. Power supply

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

Commonly specified test voltages to be applied to the complete specimen are 100 V, 250 V, 500 V, 1 000 V, 2 500 V, 5 000 V, 10 000 V and 15 000 V. Of these the most frequently used are 100 V, 500 V and 1 000 V.

In some cases, the specimen resistance depends upon the polarity of the applied voltage.

If the resistance is polarity dependent, this should be indicated. The geometric (arithmetic mean of the logarithmic exponents) mean of the two resistance values is taken as the result.

Since the specimen resistance may be voltage dependent, the test voltage should be stated.

5. Measuring methods and accuracy

5.1 *Methods*

The methods commonly in use for measuring high resistances are either direct methods or comparison methods.

The direct methods depend upon simultaneous measurement of the direct voltage applied to the unknown resistance and the current through it (voltmeter-ammeter method).

The comparison methods establish the ratio of the unknown resistance to the resistance of a known resistor, either in a bridge circuit, or by comparison of currents through the resistances at fixed voltage.

Examples illustrating the principles are described in Appendix A.

The voltmeter-ammeter method requires a reasonably accurate voltmeter, but the sensitivity and accuracy of the method depend mainly on the properties of the current measuring device, which may be a galvanometer, an electronic amplifier instrument, or an electrometer.

The bridge method requires only a sensitive current detector as null indicator, and the accuracy is mainly determined by the known bridge arm resistors, which are obtainable with high precision and stability over a wide range of resistance values.

The accuracy of the current comparison method depends on the accuracy of the known resistor, and on the stability and linearity of the current measuring device, including associated measuring resistors, etc., whereas the exact values of current are insignificant, as long as the voltage is constant.

Determination of volume resistivity in accordance with Sub-clause 10.1 using a galvanometer in the voltmeter-ammeter method is feasible for resistances up to about 10^{11} Ω. For higher values, the use of a d.c. amplifier or electrometer is recommended.

In the bridge method, it is not possible to measure the current directly in the short-circuited specimen (see Sub-clause 10.1).

The methods utilizing current measuring devices permit automatic recording of the current to facilitate determination of the steady state (Sub-clause 10.1).

Special circuits and instruments for measuring high resistance are available. These may be used, provided that they are sufficiently accurate and stable, and that, where needed, they enable the specimen to be properly short-circuited, and the current measured before electrification.

5.2 *Accuracy*

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, and ±20% for higher values. See also Appendix A.

5.3 *Guarding*

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

a) stray current from spurious external voltages which are usually unknown in magnitude and often sporadic in character;

b) undue shunting of the specimen resistance, reference resistors, or the current measuring device by insulation, having resistance of unknown, and possibly variable magnitude.

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