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Paints and varnishes — Determination of electrical conductivity and resistance

Peintures et vernis — Détermination de la conductivité et de la résistance électriques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This second edition cancels and replaces the first edition (ISO 15091:2012), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

— the conductivity of the aqueous potassium chloride solution with a molality of 0,001 mol/kg has been corrected to 146,71 µS/cm to correct a mistake in conductivity;

— the text has been editorially revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Paints and varnishes — Determination of electrical conductivity and resistance

1 Scope

This document specifies a method for determining the electrical conductivity and the electrical resistance of coating materials. The conductivity is usually measured for water-borne paints and varnishes, including electrodeposition coating materials, and the resistance is usually measured for solvent-borne paints and varnishes. If required, the resistivity of the coating material is calculated from either of these measurements. The method is applicable to products having a conductivity less than 5 µS/cm, corresponding to a resistivity greater than 200 kΩ·cm.

The conductivity of coating materials influences their processibility in the presence of an electric field. This is particularly important for electrodeposition paints and coating materials which are processed electrostatically.

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.

ISO 1513, *Paints and varnishes — Examination and preparation of test samples*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 4618, *Paints and varnishes — Terms and definitions*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
electrical resistance
R
ratio of the potential difference along a conductor and the current through the conductor

Note 1 to entry: Resistance is given by Ohm's law shown in Formula (1):

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$$R = \frac{U}{I} \quad (1)$$

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Field Code Changed

where

U is the potential difference;

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I is the current.

The unit of electrical resistance is the ohm (Ω), given by:

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

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The electrical resistance depends on the material of the conductor, its dimensions (length and cross-section) and its temperature.

3.2
resistivity
ρ
resistance per unit length of a material of unit cross-sectional area

Note 1 to entry: Resistivity is given by Formula (2):

$$\rho = R \times \frac{A}{l} \quad (2)$$

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Field Code Changed

where

A is the cross-sectional area of the conductor;

l is the length of the conductor.

The unit of resistivity is the ohm metre (Ω·m).

3.3
conductance
G
reciprocal of the resistance

Note 1 to entry: Conductance is given by Formula (3):

$$G = \frac{1}{R} = \frac{I}{U} \quad (3)$$

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Field Code Changed

The unit of conductance is the siemens (S):

$$1 \text{ S} = \frac{1}{\text{ohm}} = \frac{1 \text{ ampere}}{1 \text{ volt}}$$

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3.4
electrical conductivity
γ
reciprocal of the *resistivity* (3.2)

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Note 1 to entry: Electrical conductivity is given by Formula (4):

$$\gamma = \frac{1}{\rho} = \frac{1}{R} \times \frac{l}{A} \qquad (4)$$

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The unit of electrical conductivity is the siemens reciprocal metre (S·m^{-1}).

3.5
cell constant
c
quotient of the length and the cross-sectional area of a conductor

Note 1 to entry: It is given by Formula (5):

$$c = \frac{l}{A} \qquad (5)$$

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From Formula (2), it can be seen that it corresponds to the ratio of the resistance to the resistivity of the conductor material.

For the determination of the resistivity by resistance measurement, this geometrical factor, i.e. the cell constant of the measurement assembly, will need to be known.

Cell constants are given in reciprocal centimetres (cm^{-1}).

4 General

4.1 Measurement of the resistance

The resistance may be determined by;

a) the measurement of the current through a sample and the voltage acting on the sample, or;

b) comparison of the measured resistance with a reference resistance.

For the current/voltage measurement, usually a constant pre-determined voltage is applied to the sample, and the current is measured with a suitable measuring instrument (e.g. a moving-coil instrument or a digital instrument). The resistance is then calculated from Formula (1). See Figures 1 to 3.

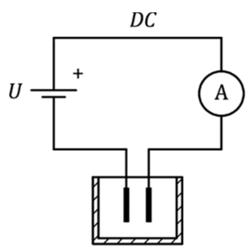

Figure 1 — Direct-current measurement

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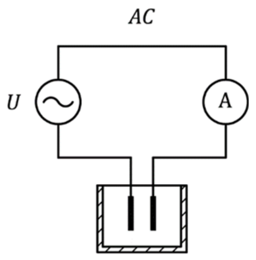


Figure 2 — Alternating-current measurement — Two-electrode cell

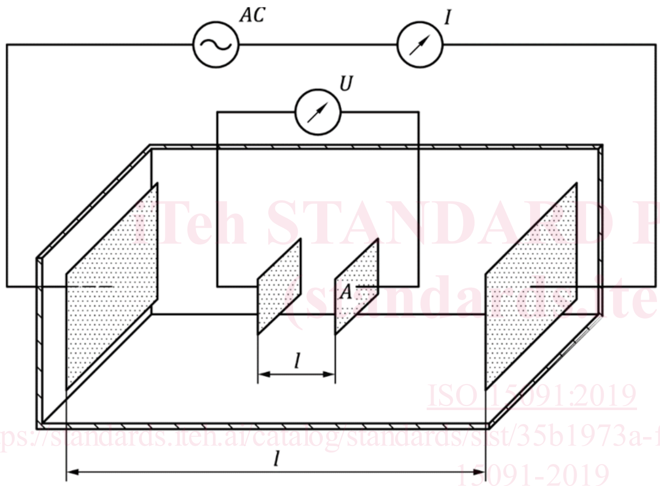
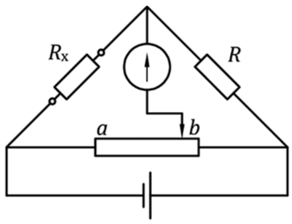


Figure 3 — Alternating-current measurement — Four-electrode cell

To compare the resistance of the sample with a reference resistance, a bridge circuit is used in which the resistances are balanced so that the bridge current becomes zero. The resistance of the sample is calculated from the ratio of the resistances of the bridge circuit. Because the bridge current is zero, errors which can result from the existence of a load on the voltage source when the voltage/current measurement method is used are avoided. The only contributions to the overall measurement error are any uncertainty in the reference resistance and any uncertainty in the adjustable resistance. See Figure 4.



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$$R_x = R \times \frac{a}{b}$$

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Figure 4 — Wheatstone bridge

4.2 Avoidance of electrolysis and polarization effects

In order to avoid electrolysis or polarization effects which would falsify the measurement, measurements of the resistance are usually carried out using alternating current. The frequency of the voltage applied to the measuring cell should, however, be as low as possible in order to minimize the contribution made by the reactance of the measuring cell, which acts as a capacitor.

5 Apparatus

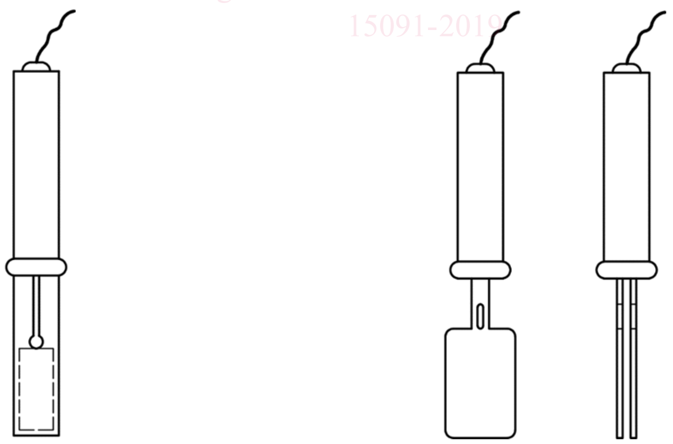
5.1 Measuring instrument

Use a resistance- or conductivity-measuring instrument calibrated as described in Annex A.

5.2 Measuring cell

The measuring cell consists of electrodes insulated from each other, with a known cell constant. The electrodes should preferably consist of a material that is easy to clean and inert (e.g. stainless steel, platinum, graphite, titanium) in order to make sure that the measurement will not be invalidated by changes in the electrodes. For examples of suitable electrodes, see Figure 5. It is important to ensure that the measuring cell is completely immersed in the liquid. The exact depth will depend on the type of electrode.

The cell geometry shall be chosen so that the possibility of contamination by dirt is minimized.



a) Measuring cell with cylinder electrodes **b) Measuring cell with plate electrodes**

Figure 5 — Examples of measuring cells

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6 Sampling

Take a representative sample of the product to be tested, as described in ISO 15528.

Examine and prepare each sample for testing, as described in ISO 1513.

7 Procedure

7.1 Test conditions

Carry out the test at a temperature of (25 ± 1) °C, unless otherwise agreed. The deviation from any agreed temperature shall also be not more than ±1 °C.

The dependence of the conductivity on the measurement temperature is shown in Annex B.

7.2 Viscosity of test sample

The test is usually carried out at the same viscosity as that of the product under test when it is ready for use. The solvent used to adjust the viscosity, if this is necessary, shall be agreed between the interested parties.

7.3 Number of determinations

Make at least three individual measurements on the product under test.

7.4 Measurement of the electrical resistance or the electrical conductivity

Take the required quantity of the paint sample and immerse the electrodes in it, avoiding the formation of bubbles. If required, homogenize the material before doing this.

Prior to the measurement, check the measuring cell for cleanliness and remove any particles of dirt. Connect the measuring cell to the measuring instrument. For measurements using a direct-current measuring instrument, e.g. a Wheatstone bridge, read the value after a waiting time of 10 s in order to allow the electrical potential to become constant. For measurements using an alternating-current measuring instrument, read the value after an agreed waiting time.

When using continuously measuring instruments, the value shall only be read if it is constant for more than 20 s.

Immediately after the test, thoroughly clean the measuring cell.

8 Expression of results

Calculate the mean of the at least three individual measurements made of the resistance or conductivity. If required, calculate the resistivity from this mean value, using Formula (2) if resistance measurements were made or Formula (4) if conductivity measurements were made. Examples of the calculation of the resistivity from the measurements are given below, using typical values.

EXAMPLE 1 Calculation of the resistivity from resistance measurements

Mean resistance reading, R	MΩ	1,22
Mean resistance reading, R	kΩ	1 220
Cell constant, c	cm^{-1}	$7,55 \times 10^{-3}$
Resistivity, ρ	MΩ·cm	161,6
Resistivity, ρ	MΩ·m	1,62

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