INTERNATIONAL STANDARD

ISO 24584

First edition
2022-06

Textiles — Smart textiles — Test method for sheet resistance of conductive textiles using non-contact type

Textiles — Textiles intelligents — Méthode d'essai de mesurage de la résistance superficielle de textiles conducteurs au moyen d'un capteur de type sans contact

Reference number
ISO 24584:2022(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 38, *Textiles*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 248, *Textiles and textile products,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

Introduction

Conductive fabrics are an important component in the design and manufacture of smart textiles. On the one hand, it is possible to use the non-destructive method for measuring the sheet resistance of fabrics of different construction and thickness described in this document for quality control of the fabrics. On the other hand, it is also suitable for quantitatively determining the sheet resistance of the conductive fabric, which is needed for the design and manufacture of electronic (smart) textile products.

The eddy current method is a method applied for the characterization of electrical properties such as sheet resistance, conductivity and local magnetization. Typically, an alternating electromagnetic field (primary field) is inducing eddy currents in the flat electrically conductive sample of interest. According to Lenz' law, the induced eddy currents generate a secondary electromagnetic field which is opposed to the primary field. The interaction of the primary field with the secondary field is a function of the sheet resistance of the present conductive layers. This principle is applied to electrically characterize layers without establishing an electrical contact. Generally, there are variants of measurements in physical contact and without physical contact of an electrically isolated eddy current sensor. The non-contacting mode allows investigating specimen without any mechanical impact as a potential source of damage or artefacts. It is possible to implement the primary field induction and the resulting field measurement at different positions. The industry is using various probe types and sizes for eddy current testing (see ISO 12718 and ISO 15549).

Textiles — Smart textiles — Test method for sheet resistance of conductive textiles using non-contact type

1 Scope

This document describes the measurement for the determination of the sheet resistance of conductive textile structures or conductive structures by using eddy current technology in reflection mode setup/arrangement.

It is applicable to conductive textile structures or conductive structures intended for application in/to textiles in the form of sheets (woven fabric, knitted fabric, nonwoven, coated fabric) where the area is formed by intersecting surfaces having conductive textile material.

It is also applicable to multilayer structures containing both insulating and conductive layers.

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 139, *Textiles — Standard atmospheres for conditioning and testing*

3 Terms and definitions

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

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

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

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

3.1
textile material
material made of textile fibres and intended to be used, as such or in conjunction with other textile or nontextile items, for the production of textile products

Note 1 to entry: textile material refers to linear textile materials (textile yarns) as well as flat textile material (e.g. knitted, woven and nonwoven fabric).

3.2
conductive textile material
textile material (3.1) intended to carry electric current

3.3
conductive fabric
fabric having electrical conductivity

Note 1 to entry: Possible applications for conductive fabrics are as signal line, power transmission line, or electromagnetic shield.

Note 2 to entry: Fabrics are for example of woven, knitted or nonwoven construction.

Note 3 to entry: Highly conductive materials like silver or copper have values for the specific resistance around 10^{-8} Ω m. Conductive fabrics do not reach these low resistance values yet.

[SOURCE: IEC 63203-101-1:2021, 3.18, modified — The examples have been moved to Note 2 to entry, Note 3 to entry has been added.]

3.4
woven fabric
fabric produced by interlacing (by weaving on a loom or a weaving machine) a set of warp threads and a set of weft threads normally at right angles to each other

[SOURCE: ISO 3572:1976, 2.1]

3.5
conductive woven fabric
woven fabric (3.4) which has contact points at interlacing with conductive material over its entire surface

Note 1 to entry: See Figure 1.

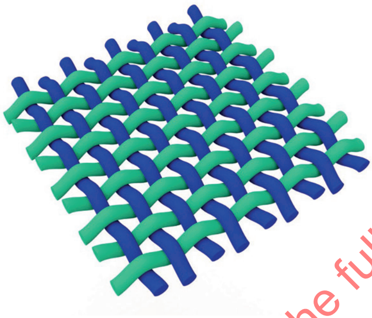


Figure 1 — Conductive woven fabric

3.6
knitted fabric
generic name applied to textile fabric in which at least one system of threads is formed into knitted loops and the knitted loops are intermeshed into stitches

[SOURCE: ISO 8388:1998, 3.0.1]

3.7
conductive knitted fabric
knitted fabric which has contact points at interlacing with conductive material over its entire surface

Note 1 to entry: See Figure 2.

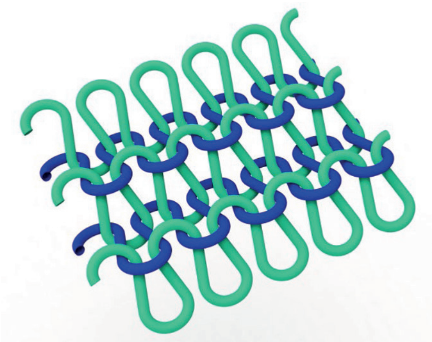


Figure 2 — Conductive knitted fabric

3.8
nonwoven
engineered fibrous assembly, primarily planar, which has been given a designed level of structural integrity by physical and/or chemical means, excluding weaving, knitting or papermaking

[SOURCE: ISO 9092:2019, 3.1.1]

3.9
conductive nonwoven
nonwoven (3.8) fabric which has contact points at interlacing with conductive material over its entire surface

Note 1 to entry: See Figure 3.

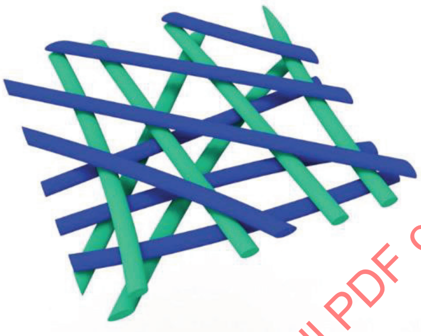


Figure 3 — Conductive nonwoven

3.10
fabric coating
coating applied to a fabric by impregnation or as a toplayer, consisting of substances such as lacquer, varnish, rubber, or polymers

3.11
conductive fabric coating
fabric coated with conductive material such as liquid or paste

3.12
sheet resistance
electrical resistance of a thin film material measured across the opposite ends of a square area

Note 1 to entry: The unit of sheet resistance is expressed in ohms (Ω). However, for the purpose of this procedure, it represents the unit of ohms per square (Ω/☐) with the thickness of the film.

[SOURCE: IEC 62899-202-3:2019, 3.1]

3.13
eddy current
electric current induced in a conductive material by a varying magnetic field

[SOURCE: ISO 12718:2019, 3.1.12, modified to use the term in singular]

3.14
sensor probe
eddy current (3.13) transducer physical device containing excitation elements and receiving elements

[SOURCE: ISO 12718:2019, 3.3.40, adapted from the definition of 'probe' with 'sensor' added to the term]

3.15
non-contact type
measurement method without contact between *sensor probe* (3.14) and sample

3.16
insulating material
insulant
material used to prevent electric conduction between conductive elements

Note 1 to entry: In the field of electromagnetism the term “insulant” is also used as a synonym for “insulating medium”.

[SOURCE: IEC 60050-151:2001/AMD3:2019]

3.17
sensor gap
distance between test specimen and *sensor probe* (3.14)

3.18
calibration
correlation in-between *eddy current* (3.13) signal and physical parameter (sheet resistance)

4 Principle

The purpose of this test method is to measure the sheet resistance of a conductive fabric, such as conductive woven fabric, conductive knitted fabric, conductive nonwoven, conductive fabric coating. During the measurement, the test specimen is placed flat on the measurement stage, i.e. without wrinkles and not being under tension. If it is not possible to measure the sheet resistances of a fabric in the standard procedure, for example due to it having a rough surface, a high thickness or it being bulky, a pre-defined pressure shall be applied to the test specimen during the measurement using a pressure plate. The sheet resistance is determined through an eddy current measurement using a non-contact sensor probe.

5 Apparatus

5.1 Apparatus for eddy current measurement

The following apparatus shall be used.

5.1.1 Eddy current instrument, which is part of an eddy current testing system.

NOTE Generally, this consists of a generator, an amplifier, a demodulator and a display unit.

5.1.2 Eddy current sensor probe.

5.1.3 Device or external software which calculates the sheet resistance from eddy current signal based on the underlying calibration.

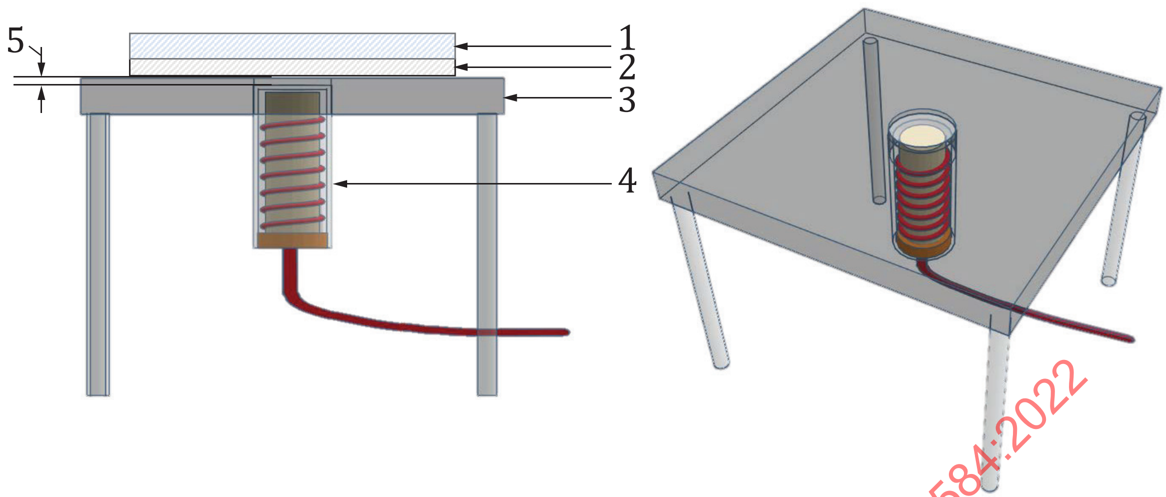
5.2 Measurement stage

The surface of the sensor probe shall not touch the specimen directly and a constant distance shall be maintained.

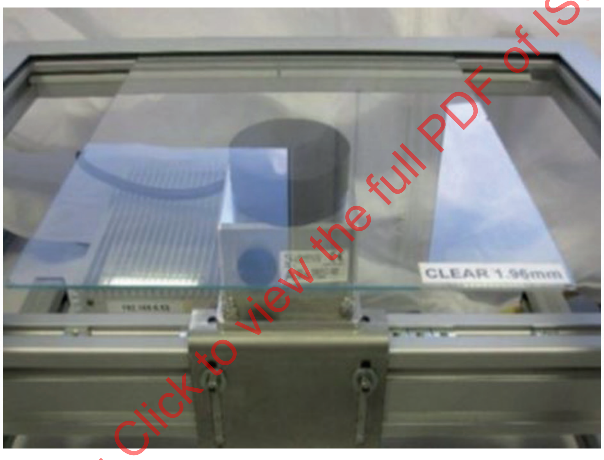
NOTE The eddy current produced by the specimen varies with the distance between the sensor probe and the test specimen.

The sensor probe and the surface of the measurement stage shall be installed perpendicular to each other. After calibration the sensor gap shall remain fixed. The measurement stage shall be made of insulating material and shall have a thickness of 50 mm to prevent affecting the test result.

Figure 4 below shows the two possible test equipment configurations, as Figure 4 a) and Figure 4 b).



a) Type 1, portable sensor probe, fixed in the measurement stage



b) Type 2, fixed sensor probe (permanently integrated into the measurement stage)

Key

1 pressure plate
2 test specimen
3 measurement stage
4 sensor probe
5 sensor gap

Figure 4 — Test equipment configuration

5.3 Pressure plate

The pressure plate shall be made of insulating material and shall be placed over the test specimen as to apply an even pressure over the complete surface area of the test specimen such that the fabric is flattened but the structure is not distorted from its normal configuration.

It is recommended to have a range of pressure plate masses or a means of applying a variable pressure, dependent on the type of fabric under test.

5.4 Stopwatch

The stop watch shall allow for reading the time to the nearest 0,01 s.

6 Sampling and preparation of test specimen

6.1 Select samples either in accordance with the procedure laid in the material specification for the fabric, or as agreed between the interested parties. An example of a suitable pattern for cutting test specimens from larger samples is given in Annex A. Avoid test specimens from areas with folds or wrinkles or having any other distortions.

6.2 The dimension of test specimens shall be (200 ± 10) mm × (200 ± 10) mm. Five test specimens per sample shall be tested.

6.3 If less sample material is available, it is possible to choose a different test specimen size, as long as the measurement conditions described in 8.1.3 are met. In this case, the dimension of test specimens shall be stated in test report.

6.4 The test specimens shall be conditioned for at least 24 h in a flat state without tensioning in a standard atmosphere as defined in ISO 139 as (20 ± 2) °C temperature and (65 ± 4) % RH.

7 Calibration

A valid calibration is essential for an accurate sheet resistance measurement. The calibration of the measurement device shall be performed with certified reference samples or materials agreed upon by the involved parties. A calibration is invalid if the sensor probe, excitation parameters, sensor gap or test specimen geometry are not identical for both calibration as well as measurement.

To ensure the highest accuracy, it is recommended to use a certified reference material (CRM) for calibration, which has a certificate of traceability and level of confidence.

NOTE Examples for recommended CRM accuracies are shown in Table 1.

Table 1 — Example of recommended CRM accuracies

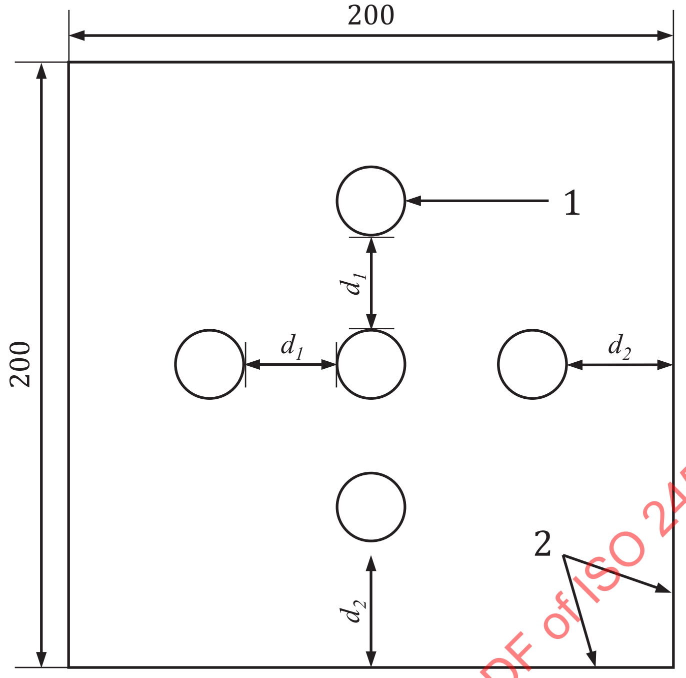
Range	Accuracy
(0,1 to 10) Ω/☐	(2 to 8) %
(1 to 100) Ω/☐	(2 to 8) %
(100 to 1 000) Ω/☐	(4 to 8) %

8 Test procedure

8.1 Measurement points

Measurement points are shown in Figure 5. Five measurements of the sheet resistance (Ω/☐) shall be taken with a distance of d_1 at least 3 cm between the measuring points (see Figure 5) and d_2 at least 1 cm from the edges.

Dimensions in millimetres



Key

1 5 measuring points with the circle of the probe
2 edge
d_1 distance between the measuring points
d_2 distance from the edge

Figure 5 — Measuring points on the test specimen

8.2 Method A: Standard procedure

8.1.1 Carry out the tests under standard atmospheric conditions described in ISO 139, see also 6.4.

8.1.2 Place the test specimen free from tension on the measurement stage.

8.1.3 Measure the sheet resistance (Ω/☐) at the measuring points shown in 8.1.

8.1.4 Calculate mean, standard deviation and coefficient of variance [CV (%)] of the five measurements. If the CV(%) is less than 10 %, the test is completed as shown in Clause B.1.

8.1.5 If the CV(%) is more than 10 %, remeasure the sheet resistance of the same specimen at the same measuring points, up to the maximum two repetitions (total three measurements).

If the CV(%) does not fall in less than 10 %, discard the test specimen.

8.1.6 Then, take the new specimen from the same sample and repeat the procedure from 8.1.2 to 8.1.5 until the test results with the CV(%) fall in less than 10 %. When the CV(%) falls in less than 10 % of the specimen, the test for the sample can be completed.

NOTE Example for test results and procedure is shown in Annex B.

8.3 Method B: Deviating procedure applying pressure to the test specimen using a pressure plate

8.2.1 Carry out the tests under the standard atmospheric conditions described in ISO 139, see also 6.4.

8.2.2 Place the test specimen free from tension on the measuring stage.

8.2.3 Position the pressure plate on the test specimen and apply a pressure of (0,10 ± 0,01) kPa to it. If a different pressure is applied, it shall be stated in test report.

8.2.4 After 10 s, carry out the procedure described in 8.1.3 to 8.1.6.

9 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 24584:2022;

b) the method used; specifying in method B if method A was followed, if applicable;

c) the identification of the test equipment;

d) the specification of the CRM;

e) the identification of the sample and the material including the direction of the track with respect to the fabric structure;

f) the orientation of the test specimen with respect to the measurement set up;

g) the standard atmosphere used for conditioning and testing;

h) the date of test;

i) the results of the measurement of the sheet resistance (in Ω/☐) obtained in Clause 8, together with the standard deviation of these results;

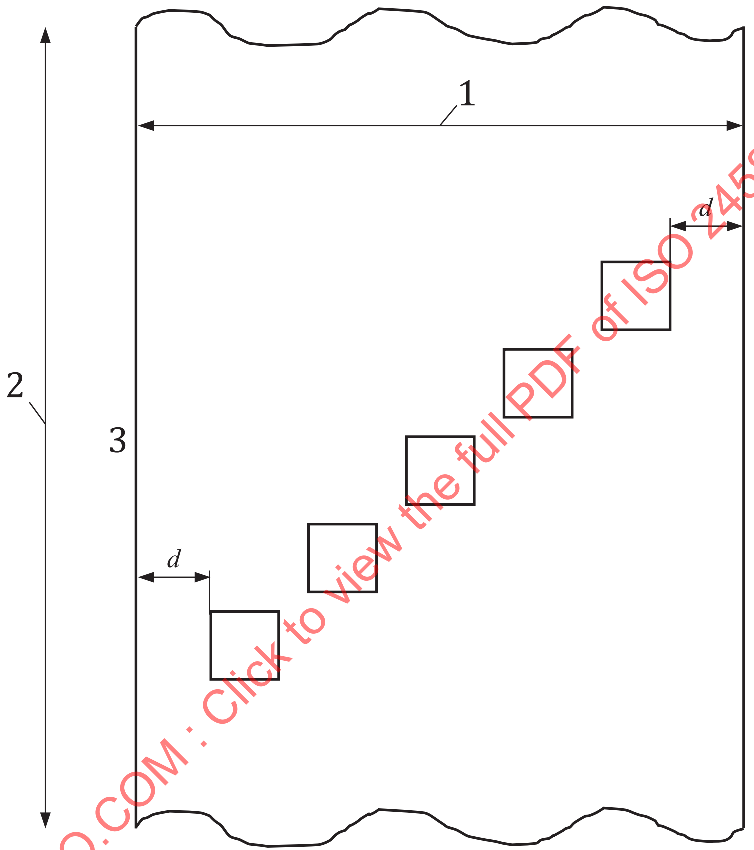
j) the dimension of test specimen;

k) the pressure value;

l) any unusual features noted during the testing, or deviations from the standard procedure.

Annex A
(informative)

Example of a pattern for cutting test specimens from a laboratory sample



Key

1 width of fabric

2 length of fabric

3 edge

d 150 mm

Figure A.1 — Example of a pattern for cutting test specimens from a laboratory sample

Annex B
(informative)

Example of test results and procedure

B.1 Case 1: CV < 10 % (below 10 %)

B.1.1 Prepare the specimen as described in Clause 6.

B.1.2 Measure the sheet resistance as described in 8.1.1 to 8.1.4.

B.1.3 If the CV(%) is less than 10 % as shown in Table B.1, the test is completed as described in 8.1.4.

Table B.1 — Measurement result on sample A

Specimen A			
Measuring point	Sheet resistance (Ω/☐)		
	1st		
1	7,80		
2	8,93		
3	8,60		
4	8,40		
5	7,77		
Mean value	8,30		
SD	0,51		
CV (%)	6,1		

B.2 Case 2: CV ≥ 10 % (more 10 %)

B.2.1 Prepare the specimen as described in Clause 6.

B.2.2 Measure the sheet resistance as described in 8.1.1 to 8.1.4.

B.2.3 The test result is shown in Table B.2 and the CV(%) is more than 10 %.

Table B.2 — Measurement result on sample B

Specimen B			
Measuring point	Sheet resistance (Ω/☐)		
	1st		
1	7,90		
2	8,25		
3	9,08		
4	10,35		
5	8,78		