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Test procedures for determining physical properties of brush materials

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC 60413 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This second edition cancels and replaces the first edition published in 1972. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Title modified.
b) Addition of definitions in Clause 3.
c) Clause 5 on test specimen: Nomenclature and addition of the different types of test specimen, specification on their dimensions, tolerances and preparation.
d) Improvement of test procedures of the properties already disclosed in the previous edition (Clause 6 to Clause 11).

e) Separation of apparent density and apparent porosity (respectively Clause 6 and Clause 10).

f) Resistivity (Clause 7): Addition of the eddy current method.

g) Rebound hardness (Clause 9): Addition of a new model of scleroscope and addition of Leeb method, as a possible alternative to the traditional scleroscope method.

h) Common elements of the test report in a dedicated Clause 12.

i) Addition of Annex A (normative): introduction of tests categories (serial/type tests), list of properties to be tested for each test category of test according to their purpose.

j) Addition of Annex B: test procedures for other mechanical properties than flexural strength and hardness: tensile, compressive and impact strength.

k) Addition of Annex C: test procedures for thermal properties (coefficient of linear expansion, specific heat capacity and thermal conductivity).

l) Addition of Annex D: supplement to density and porosity.

m) Addition of Annex E: recommendations on methods for elements analysis.

n) Addition of Annex F: supplement of information concerning scleroscope hardness.

The text of this International Standard is based on the following documents:

Draft	Report on voting
2/2286/FDIS	2/2298/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.

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, or

– revised.

1 Scope

This document concerns graphite-based grades that are used for sliding electrical contacts, such as carbon brushes or pantograph strips.

By extension, it is possible to apply the test procedures of this document to all electrical sliding contacts for electrical transmission appliances and to other appliances of graphite-based materials (heat exchangers, bearings, etc.).

This document specifies uniformized procedures for determining their following properties:

– density and porosity;
– resistivity;
– flexural strength;
– hardness;
– ash content.

In addition, it provides recommendations on test procedures for other properties:

– Mechanical properties: Charpy impact test, compressive strength, tensile strength (Annex B).
– Thermal properties: coefficient of thermal expansion, specific heat capacity, thermal conductivity (Annex C).

The properties determined by these tests are inherent to the graphite-based materials and it is therefore important to distinguish them from performance characteristics in operation on electrical equipment (carbon brush in an electrical rotating machine, contact strips on a pantograph, etc.).

Since these materials are generally brittle, porous materials, it is reasonable that their properties vary much more than the same properties in metals.

Some test methods are suitable for use in production quality control (routine tests), others only for more thorough investigations, using precise laboratory techniques (see Annex A).

WARNING — The use of this document can involve hazardous substances, operations and equipment. It does not purport to address all of the safety or environmental problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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 60276, *Carbon brushes, brush holders, commutators and slip-rings - Definitions and nomenclature*

ISO 148-1, *Metallic materials - Charpy pendulum impact test - Part 1: Test method*

ISO 179-1:2023, *Plastics - Determination of Charpy impact properties - Part 1: Non-instrumented impact test*

ISO 6508-2, *Metallic materials - Rockwell hardness test - Part 2: Verification and calibration of testing machines and indenters*

ISO 22007-2:2022, *Plastics - Determination of thermal conductivity and thermal diffusivity - Part 2: Transient plane heat source (hot disc) method*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in IEC 60276 and the following apply.

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

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

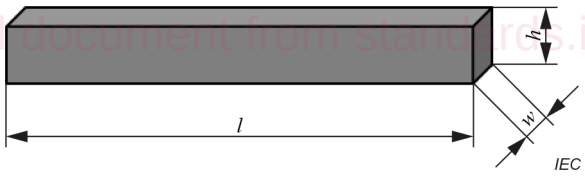
– ISO Online browsing platform: available at https://www.iso.org/obp

3.1
sample
one or more items taken from a lot and intended to provide information on the lot and possibly to serve as a basis for a decision on the lot or the process which had produced it

Note 1 to entry: One lot is constituted of one or several batches of production, see ISO 2859-1.

[SOURCE: ISO 5022:1979, 2.3, modified – "population" replaced by "lot" and Note 1 to entry added.]

3.2
test specimen
one or more blocks, drawn from an item of the sample, with dimensions $h \times w \times l$ as specified in Figure 1



Key:

h height

w width

l length

Figure 1 – Dimensions of a test specimen

Note 1 to entry: Types, dimensions and preparation the solid test specimen are defined in Clause 5.

3.3
parallelism
difference between the dimensions of the two opposite sides at any cross-section perpendicular to the length of the test specimen

3.4
anisotropy
material's directional dependence of a physical property, linked to an orientation of grains obtained during the forming process of the material

Note 1 to entry: Such material is called anisotropic. The orientation of grains during a one-directional forming process gives two main directions, defined in 3.5 and 3.6.

3.5
with-grain
WG
configuration of the material where the grains orientation is parallel to the longest dimension of the test specimen during a test

Note 1 to entry: This configuration is further explained in 5.3.2 (especially Table 2).

3.6
across-grain
AG
configuration of the material where the grains orientation is perpendicular to the longest dimension of the test specimen during a test

Note 1 to entry: This configuration is further explained in 5.3.2 (especially Table 2).

3.7
anisotropic grade
brush grade having a difference of minimum 20 % between configuration WG and configuration AG for almost one of its main properties

3.8
apparent density
bulk density
δ_a
mass per unit volume of the material (including pores) divided by the mass per unit volume of water

Note 1 to entry: The mass per unit volume of water μ_w at standardized temperature is 1 g.cm^{-3}. That is why the apparent density of the material is often related to its volumetric mass, which is expressed in g.cm^{-3}.

Note 2 to entry: The terms bulk density and bulk volume (see 3.25) are often used for granular materials.

3.9
total volume
V_t
geometrical volume of the test specimen, calculated from its dimensions h, w and l

Note 1 to entry: It is expressed in cm^3.

3.10
ambient temperature
room temperature
average temperature of air (or another medium) in the vicinity of the equipment

3.11
test temperature
ϑ, T
average temperature inside the equipment where the test specimen is under test

Note 1 to entry: Symbol T is used for thermodynamic temperature [IEV 113-04-14], in K, and ϑ for Celsius temperature [IEV 113-04-16], in °C.

3.12
resistivity
specific resistance
ρ
measured volume electrical resistance calculated to apply to a cube of unit side

Note 1 to entry: It is expressed in μΩ.m (microohm metres) or μΩ.cm (microohm centimetres).

3.13
potential span
electrodes span
d_e
distance between the extremities (or edges) of the potential electrodes (during a resistivity test)

Note 1 to entry: It is expressed in mm.

3.14
flexural strength
bending strength
σ_f
flexural stress at break of the test specimen during a three-point bending test, the test specimen being loaded by a loading knife, at a location midway between two supporting knives (see Figure 13)

Note 1 to entry: It is commonly expressed in MPa.

3.15
supports span
d_s
distance between the two points of contact between the test specimen and the supporting knives (during a flexural strength test)

Note 1 to entry: It is expressed in mm.

3.16
test speed
rate of relative movement between the test specimen support or holding device and the loading piece (during a mechanical test)

Note 1 to entry: It is expressed in mm.min^{-1}.

3.17
hardness
number characterizing the ability of a material to resist penetration or impact by a solid body, determined by a specific test method

3.18
indentation hardness
HR
hardness (number) determined from the final and initial indentation depths resulting from the application of a load by a ball indenter onto the material

Note 1 to entry: This number is an integer and is dimensionless.

3.19
rebound hardness
hardness (number) characterizing the amount of energy absorbed by the test specimen after a collision of a moving impact body at normal incidence

Note 1 to entry: This number is an integer and is dimensionless.

3.20
scleroscope hardness
Shore hardness
HSc
HSd
rebound hardness measured by a scleroscope instrument

Note 1 to entry: The scleroscope instrument is commonly named Shore, from the name of the inventor of the instrument, although other manufacturers exist. Two models exist (Type C and D), leading to two different symbols *HSc* and *HSd* – see 9.2.

Note 2 to entry: This number is an integer and is dimensionless.

3.21
Leeb hardness
HLD
rebound hardness measured by a Leeb hardness tester equipped with a D-type impact device

Note 1 to entry: This number is an integer and is dimensionless.

3.22
impact velocity
v_A
speed (or velocity) of the impact body measured before impact, at a specified position

Note 1 to entry: Impact velocity is expressed in $m.s^{-1}$.

3.23
rebound velocity
v_R
speed (or velocity) of the impact body measured after impact at a specified position

Note 1 to entry: Rebound velocity is expressed in $m.s^{-1}$.

3.24
open pore
void of the material that can be penetrated by an impregnation liquid, or that is connected to the atmosphere (liquid or gas), either directly or via one another

Note 1 to entry: By opposition, a closed pore is not penetrated by either gas or liquid.

3.25
apparent volume
bulk volume
V_a
volume of the test specimen, including all pores (open and closed)

Note 1 to entry: It corresponds to the sum of the solid, the open pores and closed pores of the material.

Note 2 to entry: It is expressed in cm^3.

3.26
open pores volume
V_o
total volume of the open pores of the material

Note 1 to entry: It is expressed in cm^3.