



DPC: 23 / 30440614 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Interested committees:

Title: BS EN 60413 Test procedures for determining physical properties of brush materials for electrical machines

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 60413 ED2	
DATE OF CIRCULATION: 2023-01-06	CLOSING DATE FOR COMMENTS: 2023-03-31
SUPERSEDES DOCUMENTS: 2/2060/RR	

IEC TC 2 : ROTATING MACHINERY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Charles Whitlock
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of

- any relevant patent rights of which they are aware and to provide supporting documentation,
- any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "in some countries" clauses. See AC/22/2007.

TITLE:

Test procedures for determining physical properties of brush materials for electrical machines

NOTE FROM TC/SC OFFICERS:

We would like to request a modification of the title, which is not necessary at this stage, and, we can take a decision during a plenary meeting.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**TEST PROCEDURES FOR DETERMINING PHYSICAL PROPERTIES
OF BRUSH MATERIALS FOR ELECTRICAL MACHINES**

FOREWORD

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IEC 60413 has been prepared by IEC technical committee TC2: 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) Compliance of the document to the ISO/IEC Directives.
- b) Addition of definitions (Clause 3)).
- c) Clause 4 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 (Clauses 5 to 10).
- e) Separation of Apparent porosity and apparent density (resp. Clauses 5 and 9).
- f) Resistivity (Clause 6): Addition of the Eddy current method.

- g) Rebound hardness (Clause 8): Addition of a new model of Scleroscope and of Leeb method, as a possible alternative to the traditional Scleroscope method.
- h) Common elements of the test report in a dedicated Clause 11.
- 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: traction, compression and impact strength.
- k) Addition of Annex C: thermal properties testing procedures (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: recommendation of 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
XX/XX/FDIS	XX/XX/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 https://www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at <https://www.iec.ch/standardsdev/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](https://wwwstore.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.

TEST PROCEDURES FOR DETERMINING PHYSICAL PROPERTIES OF BRUSH MATERIALS FOR ELECTRICAL MACHINES

1 Scope

The present document concerns carbon-based materials that are used for sliding electrical contacts, such as carbon brushes or pantograph strips.

It specifies uniformized procedures for determining the following properties:

- Density and porosity;
- Resistivity;
- Flexural strength;
- Hardness;
- Ash content;
- Thermal properties: coefficient of thermal expansion, specific heat capacity, thermal conductivity;
- Charpy impact test, compression strength, tensile strength.

By extension some tests may be relevant for other kind of sliding electrical contacts for electrical transmission appliances.

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

The properties determined by these tests are inherent in the carbon-based materials themselves as distinct from performance characteristics in operation on electrical equipment (carbon brush in an electrical rotating machine, contact strips on a pantograph, etc.).

It should be kept in mind that since these materials are generally brittle, porous materials, it is reasonable that their properties vary much more than the same properties in metals.

WARNING — The use of this International Standard can involve hazardous materials, 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 International Standard 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 60276:2018, *Carbon brushes, brush holders, commutators and slip-rings – Definitions and nomenclature*

ISO 5022:1979, *Shaped refractory products — Sampling and acceptance testing*

ISO 2859-1:1999, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 6508-2:2016, *Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines and indenters*

ASTM E 448, *Standard Practice for Scleroscope Hardness Testing of Metallic Materials*

ISO 16859-1, *Metallic materials — Leeb hardness test — Part 1: Test method*

ISO 179-1:2010, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

ISO 148-1:2016, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ASTM C749:2015, *Standard test method for tensile stress-strain of carbon and graphite*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 18515:2014, *Carbonaceous materials for the production of aluminium — Cathode blocks and baked anodes — Determination of compressive strength*

ISO 11357-1:2016, *Plastics — Differential scanning calorimetry (DSC) — Part 1: General principles*

ISO 11357-4:2016, *Plastics — Differential scanning calorimetry (DSC) — Part 4: Determination of specific heat capacity*

ISO 19628:2017, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Thermophysical properties of ceramic composites — Determination of specific heat capacity*

ASTM C714:2000, *Standard test method for thermal diffusivity of carbon and graphite by a thermal pulse method*

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 60276:2018 and the following apply.

ISO and IEC maintain terminological 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 – population replaced by lot]

3.2

test specimen

one or more blocks, drawn from an item of the sample, with dimensions h , w and l as specified on Figure 1



Key:

h height

w width

l length

Figure 1 – Dimensions of a test specimen

NOTE 1 to entry: Test specimen types and dimensions are defined in Clause 4.

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 4.3.2 (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 4.3.2 (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 3.24) are often used for granular materials.

3.8.1**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 cm³.

3.9**ambient temperature**

room temperature

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

[SOURCE: IEC 826-10-03]

3.10**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.

3.11**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 $\mu\Omega$.m (microohm metres) or $\mu\Omega$.cm (microohm centimetres).

3.12**potential span** d_e

distance between the extremity of the potential electrodes (during a resistivity test)

NOTE 1 to entry: It is expressed in mm.

3.13**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 edge, at a location midway between two supporting edges (see Figure 13)

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

3.14**supports span** d_s

distance between the points of contact between the test specimen and the supporting edges (during a flexural strength test)

NOTE 1 to entry: It is expressed in mm.

3.15**test speed**

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

NOTE 1 to entry: It is expressed in mm.min⁻¹.

3.16**hardness**

ability of a material surface to resist penetration or impact by a solid body, determined by a specific test method

3.17**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.

3.18**rebound hardness**

hardness relative to 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.

3.19**Scleroscope hardness**

Shore hardness

 HSc, HSc

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 HSc – see 8.2.

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

3.20**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.

3.21**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.

3.22**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} .

3.23**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 either by any gas nor liquid.

3.24**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. It is expressed in cm^3 .

3.25**open pores volume** V_o

total volume of the open pores of the material

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

3.26**apparent porosity**

open porosity

 Φ_o

ratio of the volume of the open pores V_o of the material to its apparent volume V_a and multiplied by 100, which is determined from equation (1):

$$\Phi_o = \frac{V_o}{V_a} \times 100 \quad (1)$$

NOTE 1 to entry: It is expressed in % (percentage by volume).

3.27**ash**

non-burnable residues of a carbon-based material

Note 1 to entry: Ash is composed of elements and their compounds from minerals or chemicals that were present initially in the raw materials. These elements occur normally, by degradation of raw materials, or be purposely added, for example silica or silicon carbide.

3.28**ash content** $ash\%$

ratio of the ash mass to the mass of the test specimen

Note 1 to entry: It is expressed in % (mass percentage).

3.29**Charpy impact strength** a_C

impact energy absorbed in breaking a test specimen, referred to the original cross-sectional area of the test specimen

Note 1 to entry: It is expressed in kJ.m^{-2} .

[SOURCE: ISO 179-1:2010]

3.30**tensile strength** σ_t

highest force that the test specimen withstands during the tensile test divided by the original cross-sectional area

Note 1 to entry: It is expressed in MPa.

[SOURCE: ISO 6892-1]

3.31**compression strength** σ_c

highest force that the test specimen withstands during a compression test divided by the original cross-sectional area

Note 1 to entry: It is expressed in MPa.

3.32**coefficient of linear expansion** α

ratio of the change in length of a specimen within a temperature interval to that temperature interval, related to the initial specimen length

Note 1 to entry: It is expressed in 10^{-6}K^{-1} .

Note 2 to entry: By applying the method and formula described in C.2, it is more commonly known as being the average coefficient of linear thermal expansion. One could refer to ISO 14420 for more details.

3.33**specific heat capacity** c_p

amount of energy per unit mass required to raise 1 kg of material of a temperature of 1 K

Note 1 to entry: The unit is $\text{J.kg}^{-1}.\text{K}^{-1}$.

3.34**thermogravimetry**

TG

technique in which the mass of a substance is measured as a function of temperature or time while the substance is subjected to a controlled temperature program

Note 1 to entry: Record is the thermogravimetric curve or TG curve. The mass should be plotted as the ordinate, decreasing downwards, and temperature or time as the abscissa, increasing from left to right.

3.35**thermal conductivity** λ

heat-transfer rate through a unit length of a material divided by the temperature gradient causing the heat transfer

288 Note 1 to entry: The unit is $\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$.

289 **3.36 Symbols**

290	
291	a_C Charpy impact strength, %
292	$ash\%$ ash content, %
293	c_p specific heat capacity, $\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$
294	d_e electrodes potential span, mm
295	d_s supports span, mm
296	E Young's modulus, GPa
297	F_{cmax} highest force that the test piece withstands during a compression strength test, N
298	F_{fmax} force measured at the instant of rupture during a flexural strength test, N
299	F_{tmax} highest force that the test piece withstands during a tensile strength test, N
300	F_0 initial test force (loading during indentation test)
301	F_1 additional test force (loading during indentation test)
302	h height of the test specimen, mm
303	h_i permanent indentation depth, mm
304	h_0 initial height of the impact body, from the surface of the test specimen, mm
305	h_r rebound height of the impact body, from the surface of the test specimen, mm
306	HR indentation hardness
307	HSc Scleroscope hardness, obtained with Model C
308	HSd Scleroscope hardness, obtained with Model D
309	HLD Leeb hardness
310	I current through the test specimen, A
311	K energy absorbed (during a Charpy impact test), J
312	l length of the test specimen, mm
313	m mass of the impact body, g
314	m_a mass of the test specimen, in air, g
315	m_{ia} mass of the test specimen after impregnation, in air, g
316	m_{il} mass of the test specimen after impregnation, in immersion liquid, g
317	m_w mass of the test specimen in water, g
318	$m_1, m_2, m_3,$ mass of the ashing dish, in g
319	T (thermodynamic) test specimen temperature, K
320	U voltage drop between the potential electrodes, V
321	S_0 initial cross-section of the test specimen in the constant cross-section region, mm^2
322	v_A impact velocity, $\text{m}\cdot\text{s}^{-1}$
323	v_R rebound velocity, $\text{m}\cdot\text{s}^{-1}$
324	V_a apparent volume of the test specimen (including pores), cm^3
325	V_l volume of liquid impregnated into the test specimen, cm^3
326	V_o volume of the open pores of the test specimen, cm^3

- 327 V_t total volume of the test specimen (geometric), cm³
 328 w width of the test specimen, mm
 329 α coefficient of linear expansion, 10⁻⁶ K⁻¹
 330 δ_a apparent (or bulk) density
 331 δ_l liquid density
 332 δ_r real density
 333 λ thermal conductivity, W.m⁻¹.K⁻¹
 334 μ_w volumic mass of water, g.cm⁻³
 335 ρ specific resistance, $\mu\Omega$.m or $\mu\Omega$.cm
 336 σ_c compression strength, MPa
 337 σ_f flexural strength, MPa
 338 σ_t tensile strength, MPa
 339 Φ_a apparent porosity, in %
 340 Φ_t total porosity, in %
 341 ν Poisson's ratio
 342 ϑ_o reference temperature, °C
 343 ϑ test specimen temperature, °C

344 **4 Test specimen**

345 **4.1 General**

346 Measurements of properties specified in clauses 5 to 10 are carried on test specimens drawn
 347 from item(s) taken from a sample.

348 Samples used for these tests must be representative of the batch of material involved using a
 349 recognized and/or agreed sampling procedure or technique.

350 The sampling plan is defined by the grade manufacturer. The number of samples (and therefore
 351 the number of test specimens) depends on the category of test (routine or type test), which is
 352 defined in Annex A. For production control (routine), it is recommended to apply the procedures
 353 specified in the standards ISO 2859-1 and/or ISO 5022.

354 The following sub-clauses define the different types of test specimen and their preparation.

355 **4.2 Types of test specimen**

356 **4.2.1 General**

357 A test specimen may be:

- 358 – an item, as is or with a surface preparation;
- 359 – a sized-block machined from an item.

360 Several types of test specimen are specified in this sub-clause. Each property's measurement
 361 method (clause 5) specifies the type(s) and the minimum number of test specimens to be tested.

362 Tests which are carried out on test specimens of different dimensions, or on specimens which
 363 are prepared under different conditions, can produce results which are not comparable. Other

factors, such as the test speed and the conditioning of the specimens, can also influence the results.

Consequently, a high number of test specimen may be required to perform measurements to determine the entire list of properties. Nevertheless, one test specimen may undergo several successive tests (for example density, resistivity and flexural strength).

4.2.2 Type A

This type of test specimen corresponds to an item taken from the sample, that is to say a block or a plate without cut-out.

Two sub-types are defined:

- Type A1: item as it is produced and cleaned from dust;
- Type A2: item machined to get a smooth and planar surface.

4.2.3 Type B

This type covers test specimen of a rectangular cross-section cut and machined from an item (which could be a block, a plate or a brush). The preparation of the test sample shall be in accordance with 4.3.

For example, a saw (or other device) for cutting the sample to a suitable size is used. In addition, a grinding wheel (or other device) for machining the test specimen may be used so that all adjacent surfaces are at right angles.

Its dimensions $h \times w \times l$ are linked to the test method and/or the grade family.

In any case, the smallest dimension shall be at least two times of the largest structural constituent (e.g. maximum grain size) of the material to be tested, but not smaller than 4 mm.

The length of the test specimen must be at least three times its width or diameter.

NOTE Form and size of the samples influence the measurement, in particular the flexural strength (statistic of Weibull).

The different sub-types and their dimensions are specified in Table 1.

Table 1 – Dimensions of test specimen of type B

Dimensions in millimetres

Type	h	w	l
B1	5	5	30
B2	4	8	32
B3	5	5	40
B4	10	10	64
B5	12	25	90

4.2.4 Type C

This type regroups test specimens without any a special shape and specific dimensions, when the determination of a property does not require a sample of type A or B.

When needed, the overall dimensions and/or mass of type C test specimen are specified in the test procedure.

4.2.5 Type D

This type is relative to blocks having smaller dimensions than test specimen of type B1. It is mainly the case when the brush is directly moulded with its final dimensions (pressed-to-size).

Some of the properties described in clauses 5 to 10 may not be possible to be tested since they absolutely require test specimen of type B (for example resistivity and flexural strength).

When it is acceptable the dimensions may be reduced. Nevertheless, it is recommended that the length is at least three times the width (or diameter). This case will be specifically included in each test procedure.

4.3 Preparation of test specimens

4.3.1 General

The present paragraph applies to test specimens of type A, B and D. It specifies the preparation and the control of test specimens:

- grain orientation to be considered during its manufacturing process (machining or moulding);
- test method for the measurement of its dimensions, with categories of tolerances, when applicable;
- requirements on parallelism and squareness, when applicable;
- requirements on roughness, when applicable.

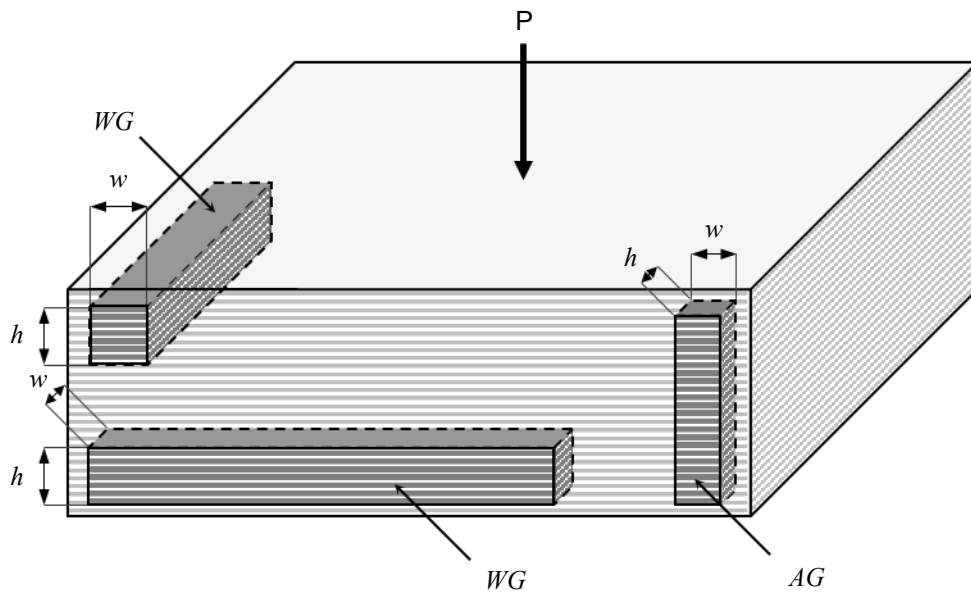
When machined from a sample, the test specimen should not be cut in the area closed to the external side (baking skin). See Figure 2 and Figure 3.

4.3.2 Relation between dimensions and grain direction

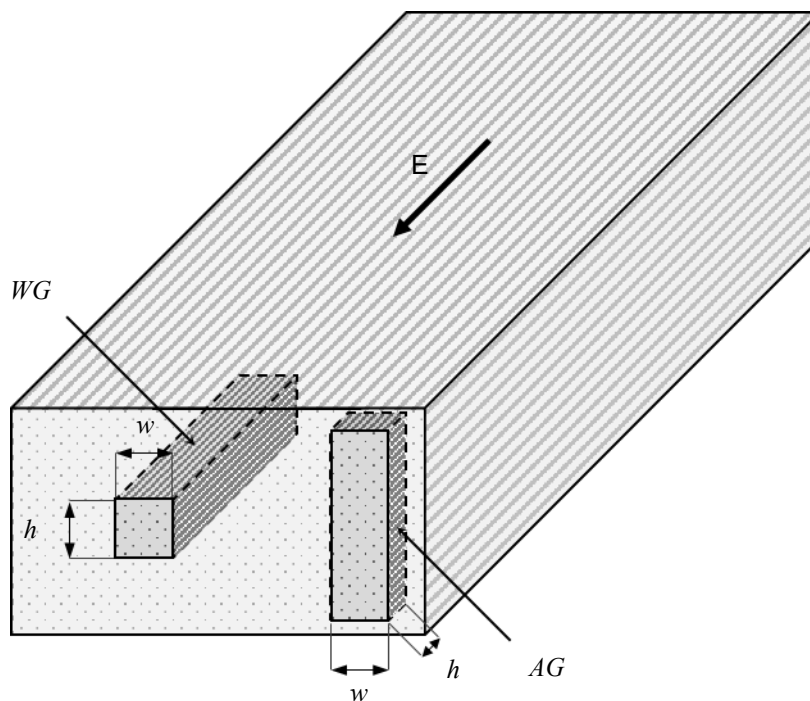
Brush grades (and by extension sliding contacts) may be anisotropic, that is to say their properties are different depending on the direction of measurement. This anisotropy is due to the orientation of agglomerated grains during the forming operation:

- for one-directional compression (uniaxial moulding): grains are oriented in a plane that is perpendicular to the pressing direction,
- for extrusion: grains are oriented in lines parallel to the extrusion direction.

Figure 2 and Figure 3 illustrate the grain orientation direction respectively for each process.

**Key:** h height w width P direction of pressing during moulding operation

White lines represent the grain orientation planes.

Figure 2 – Configuration of test specimen relative to the direction of moulding**Key:** h height w width E direction of extrusion

Grey lines represent the grain orientation lines.

Figure 3 – Configuration of test specimen relative to the direction of extrusion

The anisotropy is mainly found for bakelite-graphite (BG), carbon-graphite (CG), hard carbon (HC) and metal graphite (MG) grades, whereas, as it is commonly admitted, it is insignificant for electrographite grades (EG).

The consequence is that some of their properties, such as resistivity and flexural strength, will differ depending on how the test specimen is cut from the item.

Therefore, two configurations are specified as per Table 2 and illustrated in Figure 2 for one-directional compression and Figure 3 for extrusion.

Table 2 – Configuration type according to the forming process of the item

Configuration type	Configuration's impact on the property tested	One-directional compression	Extrusion
<i>WG</i>	the property will be measured "with-grain"	the grain orientation planes are parallel to the plane $w \times l$ of the test specimen ^a	the grain orientation lines are perpendicular to the plane $h \times w$ of the test specimen
<i>AG</i>	the property will be measured "across-grain"	the grain orientation planes are parallel to the plane $h \times w$ of the test specimen	the grain orientation lines are perpendicular to the plane $w \times l$ of the test specimen ^b
^a For this case, two possibilities are given when machining of the test specimen from a block, as shown on Figure 2. ^b Lines are also parallel to the plane $h \times l$. As for note ^a , two possibilities of machining are also possible (the second one is not represented on Figure 3 to avoid overwhelm).			

If the test specimen has a square cross-section, a mark shall be done on the test specimen (for example: a white line parallel to the orientation direction) to identify the pressing or extruding direction, so that the operator will place it correctly on the test equipment.

4.3.3 Requirements on test specimens

4.3.3.1 Dimensions measurement

The height h , width w and length l shall be measured by using either a micrometre, a digital-indicator gauge or a calliper at points lying within ± 2 mm of the centre of the specimen.

NOTE The design, characteristics and metrology (periodic calibration, etc) of above instruments are specified in respective standards ISO 3611, ISO 13102 and ISO 13385-1.

If not stated in the paragraph Test equipment of the property to be measured, the accuracy of the measuring instrument shall be in chosen in accordance with the tolerances on the dimensions to be measured (see Table 3).

When a micrometre is used, the presser foot shall have a flat, circular contact face with a diameter of minimum 4 mm and the anvil shall have a spherical contact face of radius 50 mm to avoid errors caused by misalignment with the test piece.

4.3.3.2 Tolerances on dimensions

Two categories are defined:

- category 1: when the dimensions are measured on each test specimen, and then used in the formula of the relevant property to be determined;
- category 2: when the dimensions are not measured on each test specimen, and the nominal values given in Table 2 are used in the formulae of the relevant property to be determined. As for the squareness, it is up to the brush manufacturer to define a suitable control plan for evaluating the compliance on tolerances for this category.

The tolerances on dimensions $h \times w \times l$ of the test specimen for each category shall be in accordance with Table 3.

Table 3 – Tolerances on test specimen dimensions for each category

Dimensions in millimetres

Dimension	Category 1	Category 2
h	$\pm 0,10$	$\pm 0,04$
w	$\pm 0,10$	$\pm 0,04$
l	$\pm 1,0$	$\pm 0,8$

4.3.3.3 Squareness and parallelism

The test specimen shall have all angles between adjacent sides of $90^\circ \pm 15'$. The parallelism between opposite sides shall be $\pm 0,04$ mm.

It is up to the brush manufacturer to define the control plan for the evaluation of squareness (each test specimen of a sample, test specimens randomly taken from a sample, test specimens taken periodically...).

4.3.3.4 Surface aspect

Where indicated in the paragraph relative to the test specimen for each property's test procedure, the surfaces of the test specimen that are subjected to testing shall be machined or grinded to the surface finish normally used for carbon brushes, that is to say so as to remove any surface irregularity nor traces of the process moulding (die or extrusion skin).

A maximum roughness of $5 \mu\text{m}$ is recommended.

NOTE The roughness type is arithmetical roughness (R_a) and it is measured with a roughness meter according to ISO 21920-2 or ISO 4287.

5 Apparent density

5.1 General

The method described here is used to determine the apparent density (or bulk) of moulded bodies made of carbon and graphite materials with rectangular block specimen and irregular shape test specimen.

The apparent density may be determined by one of following standard methods:

- Rectangular block specimen: Mass-and-dimensions method.

It is suitable for type test and production quality control (serial test) and should preferably be used since most of the materials are porous.

- Irregular shape test specimen: Immersion method;

The immersion method is considered to be an alternative and may be used in cases where the mass-and-dimensions method cannot be applied or is unsuitable.

All these methods are considered accurate to three significant figures, which is sufficiently accurate for checking these properties, since carbon-graphite products vary much more than metals.

5.2 Mass-and-dimensions method

5.2.1 General

This method is only applicable to rectangular parallelepipedal block specimen.

NOTE 1 The apparent density determined with this method is also called geometric density.

NOTE 2 Standards ISO 12985-1 and ASTM C559 also describe equivalent test procedures.

5.2.2 Principle of measurement

The geometry of the test specimen and its mass are measured, the apparent density is calculated according to the formula (2).

5.2.3 Test equipment

5.2.3.1 Instrument for measuring dimensions according to 4.3.3.1.

- For test specimens for which the largest dimension is ≤ 25 mm, the micrometre ($\pm 0,001$ mm) must be used;
- For test specimens with the largest dimension > 25 mm, the calliper ($\pm 0,01$ mm) is sufficient.

5.2.3.2 Scale or balance suitable for weighing the test specimen with an accuracy of:

- $\pm 0,001$ g (four significant figures) for small samples of dimensions w and h up to 5 mm;
- $\pm 0,01$ g (three significant figures) for samples of larger dimensions.

NOTE The tolerances of the measurement devices above are set to influence the measured values up to 0,5 %.

5.2.4 Test condition

All tests should be conducted at $20\text{ °C} \pm 5\text{ °C}$. The exact ambient temperature shall be recorded.

5.2.5 Test procedure

Weigh the mass of the test specimen m_a with the minimum significant figures specified in 5.2.3.2.

5.2.6 Calculation and Report

Calculate the volume V_t of the test specimen expressed in cm^3 by using formula (2):

$$V_t = h \times w \times l \quad (2)$$

where

h , w and l are expressed in cm;

V_t is expressed in cm^3 .

Then, calculate the apparent density δ_a in accordance with the following formula (3):

$$\delta_a = \frac{m_a}{V_t} \quad (3)$$

where

m_a is the mass of the test specimen, expressed in g;

δ_a is the apparent density.

Report the results for each test specimen to three decimals in the test report according to Clause 11.

5.3 Immersion method

5.3.1 General

This method is applicable to any kind of test specimen, especially of complex or irregular geometry.

NOTE 2 Standard ISO 12985-2 also describes an equivalent test procedure.

5.3.2 Principle of measurement

The principle is based on hydrostatic method, by weighing a specimen before and after immersing it into water. The volume of the test specimen is determined from the mass of the displaced water, that is why it is also known as “Archimedes’ density”. The apparent density is calculated by the formula (4) specified in 5.3.8.

5.3.3 Reagents

Distilled water, or water of equivalent purity.

5.3.4 Test equipment

5.3.4.1 Balance, with an accuracy of :

- $\pm 0,01$ g or better (three significant figures) for big specimen;
- $\pm 0,001$ g for small specimen (four significant figures).

5.3.4.2 Tank, to be filled with distilled water, with dimensions larger than those of the test specimen holder device.

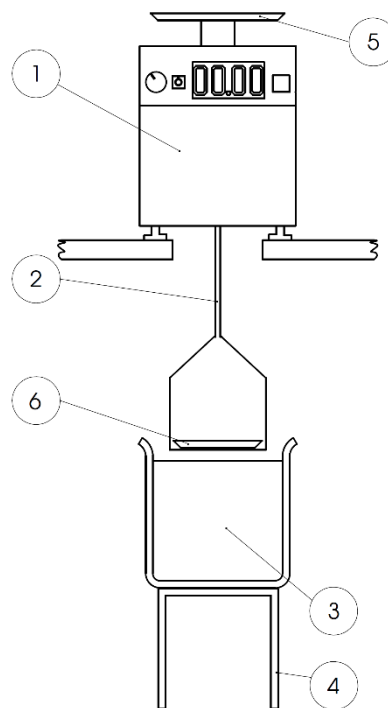
5.3.4.3 Specimen holders, to hold the test specimen in air and/or in water, for example a pan or a basket.

5.3.4.4 Specimen holder device for weighing the test specimen in air and in water.

Two types of devices, a) and b), and their corresponding test method are accordance with the size of the test specimen:

a) Type for method A : For “big” test specimen having dimensions equal or larger than specified for type B5 (see 4.2), the test equipment shall be configured as per below and Figure 4:

- a specimen holder basket 6 suspended to the balance 1, by the mean of a wire, a chain or a rod 2 (the mass of the basket and suspension mean shall be as low as possible);
- a water tank 3, filled with water, is placed under the specimen holder, with a device 4 capable to move it up and down;
- optionally, a pan 5 placed onto the balance.



569

570 **Key**

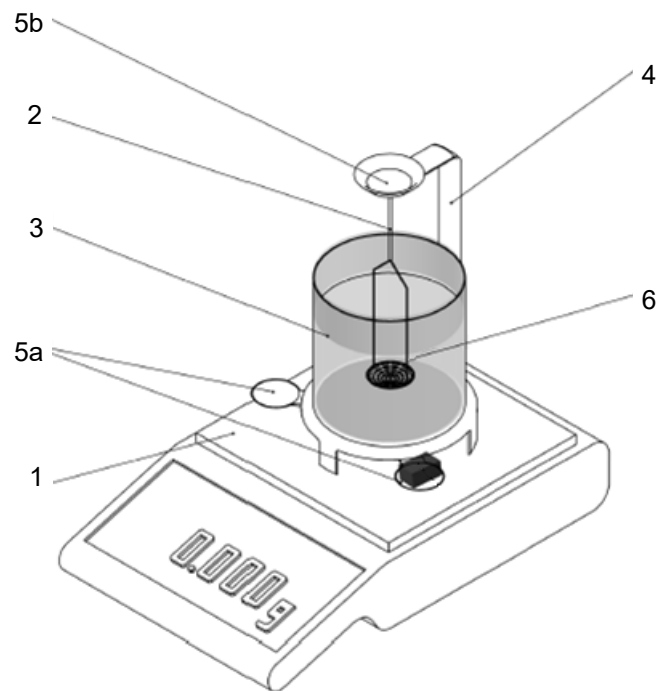
- 571 1 balance
 572 2 specimen holder
 573 3 water tank
 574 4 device to move up or down the water tank
 575 5 pan placed onto the balance 1
 576 6 basket of the specimen holder 2

577 **Figure 4 – Test equipment for the measurement of apparent density by immersion**
 578 **method A on big test specimen**

579 b) Type for method B: for “small” test specimen having dimensions lower than specified for
 580 type B5 (see 4.2), the test equipment shall be arranged as per below and as described in
 581 Figure 5:

- 582 – the water tank 3 is placed onto the balance 1;
 583 – the specimen holder comprises a basket 6 (which will be dipped in water) and is
 584 suspended thanks to a holding device 4.
 585 – a pan to weigh the test specimen in air, which may be on the top of the specimen holder
 586 (5b) or of the balance (5a).

587 NOTE Such device is known as density kit.

**Key**

- 1 balance
- 2 specimen holder
- 3 water tank
- 4 device to hold the test specimen
- 5a pan placed onto the balance 1
- 5b pan on the top of the specimen holder 2
- 6 specimen holder basket, immersed in water

Figure 5 – Test equipment for the measurement of apparent density by immersion method B on small test specimen

5.3.5 Test specimen

As this method may be used for irregular shape test specimen, no preparation is necessary beyond making sure that the sample is clean, dry and free from extraneous metal or foreign material.

As an option, for high porous materials, it is possible to coat as thinly as possible all surfaces of the test specimen with a waterproof masking material (for example vaseline). If this option is used, make sure that there is no significant influence on the measurement of mass.

5.3.6 Test condition

All tests should be conducted at $20\text{ °C} \pm 5\text{ °C}$. The exact ambient temperature shall be recorded.

5.3.7 Procedure of measurement

5.3.7.1 General

The general procedure follows the principle stated in 5.3.2.

Two different methods are to be applied depending on the test specimen dimensions, as described in 5.3.4: