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**Matériaux isolants électriques –  
Propriétés d'endurance thermique –**

**Partie 2:  
Détermination des propriétés d'endurance  
thermique de matériaux isolants électriques –  
Choix de critères d'essai**

**Electrical insulating materials –  
Thermal endurance properties –**

**Part 2:  
Determination of thermal endurance  
properties of electrical insulating materials –  
Choice of test criteria**

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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### **ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –**

#### **Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria**

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International Standard IEC 60216-2 has been prepared by subcommittee 15E<sup>1</sup>: Methods of test, of IEC technical committee 15: Insulating materials.

This fourth edition of IEC 60216-2 cancels and replaces the third edition issued in 1990, and constitutes a technical revision.

The main changes from the previous edition are as follows:

- editorial,
- Table 1 has been actualized essentially by Part 3 sheets of SC 15C publications.

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<sup>1</sup> Subcommittee 15E has been merged with technical committee 98 into the new technical committee 112.

The text of this standard is based on the following documents:

FDIS	Report on voting
15E/257/FDIS	15E/259/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 60216: *Electrical insulating materials – Properties of thermal endurance*, consists of six parts:

- Part 1: Ageing procedures and evaluation of test results
- Part 2: Choice of test criteria
- Part 3: Instructions for calculating thermal endurance characteristics
- Part 4-1: Ageing ovens – Section 1: Single-chamber ovens
- Part 4-2: Ageing ovens – Precision ovens for use up to 300 °C
- Part 4-3: Ageing ovens – Multi-chamber ovens
- Part 5: Determination of relative thermal endurance index (RTE) of an insulating material
- Part 6: Determination of thermal endurance indices (TI and RTE) of an insulating material using the fixed time frame method

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## **ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –**

### **Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria**

#### **1 Scope**

This part of IEC 60216 gives guidance for the choice of test criteria for the determination of thermal endurance characteristics. It includes a list of existing published procedures which is however not exhaustive.

#### **2 Normative references**

The following referenced documents are indispensable for the application 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 60172, *Test procedure for the determination of the temperature index of enamelled winding wires*

IEC 60216-3, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60216-6, *Electrical insulating materials – Thermal endurance properties – Part 6: Determination of thermal endurance indices (TI and RTE) of an insulating material using the fixed time frame method*

IEC 60243-1, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60317 (all parts), *Specifications for particular types of winding wires*

IEC 60370, *Test procedure for thermal endurance of insulating varnishes – Electric strength method*

IEC 60371 (all parts), *Specification for insulating materials based on mica*

IEC 60394 (all parts), *Varnished fabrics for electrical purposes*

IEC 60450, *Measurement of the average viscometric degree of polymerization of new and aged cellulosic electrically insulating materials*

IEC 60454 (all parts), *Specifications for pressure-sensitive adhesive tapes for electrical purposes*

- IEC 60455 (all parts), *Resin based reactive compounds used for electrical insulation*
- IEC 60464 (all parts), *Varnishes used for electrical insulation*
- IEC 60554 (all parts), *Specification for cellulosic papers for electrical purposes*
- IEC 60626 (all parts), *Combined flexible materials for electrical insulation*
- IEC 60641 (all parts), *Specification for pressboard and presspaper for electrical purposes*
- IEC 60667 (all parts), *Specification for vulcanized fibre for electrical purposes*
- IEC 60674 (all parts), *Specification for plastic films for electrical purposes*
- IEC 60684 (all parts), *Flexible insulating sleeving*
- IEC 60763 (all parts), *Specification for laminated pressboard*
- IEC 60819 (all parts), *Non-cellulosic papers for electrical purposes*
- IEC 60893 (all parts), *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes*
- IEC 61033, *Test methods for the determination of bond strength of impregnating agents to an enamelled wire substrate*
- ISO 37, *Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain properties*
- ISO 178, *Plastics – Determination of flexural properties*
- ISO 179-1, *Plastics – Determination of Charpy impact properties – Non-instrumented impact test*
- ISO 527-2, *Plastics – Determination of tensile properties – Test conditions for moulding and extrusion plastics*
- ISO 527-3, *Plastics – Determination of tensile properties – Test conditions for films and sheets*
- ISO 1520, *Paints and varnishes – Cupping test*
- ISO 1924 (all parts), *Paper and board – Determination of tensile properties*
- ISO 2759, *Board – Determination of bursting strength*
- ISO 8256, *Plastics – Determination of tensile-impact strength*

### 3 General considerations

The determination of the thermal endurance of electrical insulating materials is described in IEC 60216-1, IEC 60216-3, IEC 60216-5 and IEC 60216-6. IEC 60216-1 gives experimental details for the ageing of test specimens and determining the gradual deterioration of the property selected as the test criterion. IEC 60216-3 gives details of the procedures for evaluation of the experimental data. IEC 60216-5 gives experimental details for determining the relative thermal endurance of a material and details of the procedures for evaluation of the experimental data. IEC 60216-6 provides an alternate experimental method for determining the thermal endurance of a material and details of the procedures for evaluation of the experimental data. This standard is concerned with the selection of the test properties and end-point levels.

The thermal endurance behaviour of a material cannot be adequately represented by a single number. At least two shall be given:

- temperature index TI (or relative thermal endurance index RTE), and
- halving interval HIC.

Even so, the values of these numbers are highly dependent on the chosen property and end-point, and may be dependent on the dimensions of the test specimen, especially the thickness.

The selection of a property should reflect the function of the material in its application, as stated in IEC 60216-1.

### 4 Guide for the choice of properties and end-points

Where an international specification exists for a particular insulating material, the property and end-point called for in that specification shall be used to determine the thermal endurance characteristic value(s) needed to claim compliance with the specification. See the current catalogue of IEC publications for an up-to-date list of specifications.

For the choice of properties and end-points, Clause 5 and Table 1 provide guidance. Further advice is given in Annex A. To evaluate thermal endurance characteristics, an end-point of 50 % of the initial value of the property is often used.

Although, on account of the high cost of thermal endurance testing, it is frequently desirable to select a single property and end-point to give a result representative of the thermal endurance behaviour of a material, this information may be inadequate for use in all applications of the material. In such cases, alternative criteria should be chosen that are more appropriate to the application and the function of the material, when, e.g. the 50 % of initial value end-point has no fundamental significance and a 25 % of initial value end-point is more indicative of the application. Alternative end-points considered likely to be valuable in such cases are also indicated in Table 1.

The information in Table 1 is given, for convenience, in relation to materials grouped according to their salient mechanical or chemical features. Annex A explains the main features of each group; this may be helpful to assign a non-listed material to the right group.



**Table 1 – Examples of insulating materials, with recommended test properties and end-points**

1	2	3	4			5
Insulating materials	Material specification Publication No.	Recommended properties	Recommended end-points			Test method Publication No.
			Preferred	Subsidiary 5)	Type 1)	
<b>Rigid materials A</b> Rigid laminates Vulcanized fibre products Preimpregnated fibre products (prepregs) Rigid mica or mica-paper products	IEC 60893 IEC 60667  IEC 60371	Flexural strength Voltage 1-min proof test Loss of mass	50 % 6 kV 5 %	25 %; 75 % 3 kV; 10 kV 3 %; 10 %	R A L  ISO 178 IEC 60243-1	
<b>Rigid materials B</b> Reinforced/filled thermosetting moulded and cast insulation Reinforced/filled thermoplastic moulded and cast insulation		Flexural strength Tensile strength Loss of mass Charpy impact strength Breakdown voltage	50 % 50 % 3 % 50 % 50 %	25 %; 75 % 25 %; 75 % 5 %; 10 % 25 %; 75 % 25 %; 75 %	R R L R R  ISO 178 ISO 527-2 IEC 60455-2 ISO 179-1 IEC 60243-1	
<b>Rigid materials C</b> Unfilled thermosetting moulded and cast insulation Unfilled thermoplastic moulded and cast insulation <sup>4)</sup>		Flexural strength Tensile strength Loss of mass Tensile impact strength Breakdown voltage	50 % 50 % 3 % 50 % 50 %	25 %; 75 % 25 %; 75 % 5 %; 10 % 25 %; 75 % 25 %; 75 %	R R L R R  ISO 178 ISO 527-2 IEC 60455-2 ISO 8256 IEC 60243-1	
<b>Elastomers</b> Vulcanized natural or synthetic rubber and combinations of them Polyolefins including cross-linked polyethylene Silicone rubber		Tensile stress at 100 % extension Elongation at break <sup>2)</sup> Breakdown voltage	50 %  50 % 50 %	25 %; 75 %  25 %; 75 % 25 %; 75 %	R  R R  ISO 37  ISO 37 IEC 60243-1	
<b>Semi-rigid sheet materials</b> Pressboards and presspapers Laminated pressboards	IEC 60641 IEC 60763	Bursting strength Tensile strength MD/CD	50 % 50 %	25 %; 75 % 25 %; 75 %	R R  ISO 2759 ISO 1924	
<b>Paper, paper-based or woven materials</b> (except: glass textile reinforced) Cellulosic paper (all types) Non-cellulosic, paper-like materials Varnished paper Varnished fabrics	IEC 60554 IEC 60819	Tensile strength Viscometric degree of polymerization Breakdown voltage	50 % 50 % 50 %	25 %; 75 % 25 %; 75 % 25 %; 75 %	R R R  IEC 60394 IEC 60450  IEC 60370	

**Table 1 (continued)**

1	2	3	4			5
Insulating materials	Material specification Publication No.	Recommended properties	Recommended end-points			Test method Publication No.
			Preferred	Subsidiary 5)	Type 1)	
Pressure-sensitive adhesive tapes Paper-based tapes Glass fabric-based tapes (Plastic film-based tapes, see the next group)	IEC 60454 IEC 60454	Breakdown voltage Loss of mass	1,0 kV 10 %	5 %; 20 %	A L	IEC 60454-2 IEC 60454-2
	IEC 60674 IEC 60454	Tensile strength Elongation at break Breakdown voltage Loss of mass	30 % 2 % 2,5 kV 10 %	10 %; 50 % 1 %; 4 % 1 kV; 4 kV 5 %; 20 %	R A A L	ISO 527-3 ISO 527-3 IEC 60454-2 IEC 60454-2
Flexible film and film based materials Plastic films Pressure-sensitive adhesive film tapes	IEC 60684 IEC 60684 IEC 60684 IEC 60684	Elongation at break Tensile stress at 100 % extension Breakdown voltage	50 % 2 times initial value 50 %	25 %; 75 % <sup>3)</sup> 25 %; 75 %	R R R	IEC 60684-2 IEC 60684-2 IEC 60684
	IEC 60626 IEC 60371	Tensile strength Breakdown voltage	50 % 50 %	25 %; 75 % 25 %; 75 %	R R	ISO 1924 IEC 60243-1
Resin based reactive compounds (embedding compounds, potting compounds, encapsulating compounds)	IEC 60455 IEC 60455	Flexural strength Loss of mass Loss of mass	50 % 10 % 3 %	3 %; 5 % 5 %; 10 %	R L	ISO 178
	IEC 60455 IEC 60455	Flexural strength	50 %		R	ISO 178
Impregnating compounds and varnishes Unsaturated polyester based impregnating resins Epoxy-based impregnating resins, unfilled Polyurethane-based impregnating resins, unfilled Hot curing impregnating varnishes	IEC 60455	Bond strength	22 N	-	A	IEC 61033, method B IEC 60172
	IEC 60464	Proof voltage Breakdown voltage Loss of mass Flexural strength	0,3 – 1,2 kV 3 kV 10 % 50 %	- - - -	A A A L R	IEC 60455-2 IEC 60455-2 ISO 178

**Table 1 (continued)**

1	2	3	4		5
Insulating materials	Material specification Publication No.	Recommended properties	Recommended end-points		Test method Publication No.
			Preferred	Subsidiary 5)	
<b>Coating compounds</b> Coating powders	IEC 60455	Loss of mass Breakdown voltage Breakdown voltage Loss of flexibility	10 % 3 kV 3 kV Cupping 1 mm	5 %; 15 % - 1 kV; 5 kV 0,5 mm	IEC 60455-2 IEC 60455-2 IEC 60370 ISO 1520
<b>Insulations on conductors</b> Enamelled winding wires	IEC 60317	Proof voltage	0,3 – 1,2 kV	-	IEC 60172
Column 1 lists the group of the material to be tested. See also Annex A.					
If in the respective material specification listed in column 2, the property(ies), end-point(s) and test method(s) are prescribed, then these instructions shall be followed. If a material specification or its testing conditions are not listed, select from the recommended properties and end-points those appropriate to the application of the material.					
The test methods in Column 5 are identified by the ISO or IEC publication where they are specified. However, in particular cases where thermal endurance data are of interest for design purposes, other properties applying national or specifically developed test methods may be more useful.					
NOTE Some of the materials listed herein may be grouped differently. In a few cases tests for determination of thermal endurance characteristics according to IEC 60216-1 may not apply to the materials listed below.					
<p>1) Percentage or other values in column 4 ("Recommended end-points") shall be interpreted according to the letter symbol as follows:</p> <p>R = abbreviation for retention (if initial tensile strength is, for example, 60 MPa, then 25 % means 15 MPa, 50 % means 30 MPa and so forth).</p> <p>L = abbreviation for loss of mass end-points to be understood as the percentage decrease of the mass related to the original organic material content (determined by burning out at approximately 500 °C).</p> <p>A = abbreviation for an absolute end-point according to item b) of 5.2 of IEC 60216-1.</p> <p>2) This property may not always be critical because in some applications, once the material is in place, it no longer will be subject to elongation.</p> <p>3) Elongation at break may not be relevant for all types of glass sleeving.</p> <p>4) Where an excessive reduction of the test specimen thickness is observed on thermoplastic moulded insulation (e.g., due to thermoplastic flow), the voltage breakdown test is not applicable.</p> <p>5) Subsidiary end-points to be used in special cases only, where the preferred end-points will not give information appropriate for special applications of the material (see Clause 3).</p>					

## **Annex A** **(informative)**

### **Additional information on the group to which new or unknown materials should be assigned**

Since it is impossible to list all insulating materials with their preferred diagnostic properties for thermal endurance testing, Table 1 shows typical representatives of each group. The grouping is essentially based on the materials' salient mechanical and chemical features. However, the supply form, the appearance or the predominant application of a material provides additional information on the group to which new or unknown materials should be assigned in order to enable the selection of adequate properties and end-points.

#### **a) Rigid materials**

Rigid materials typically exhibit a modulus of elasticity greater than 700 MPa.

Materials of Group A and thermosetting materials of Group B and C are mostly supplied in the form of plates or flat pieces, produced by moulding, pressing from granules or from two- or multi-component compounds.

Rigid thermoplastic materials are delivered as extrusion moulded plates or other semi-finished products; they may also be manufactured to prefabricated parts by injection moulding of granules.

#### **b) Elastomers**

Materials of this group are composed from natural rubber or synthetic rubber materials or thermoplastic elastomers to meet specific properties. Compositions of natural or synthetic rubber should be adequately prepared, e.g. by milling, vulcanizing, etc. and pressed or calendered in final form. Thermoplastic elastomers are typically injection or blow moulded into prefabricated parts. Elastomers are often applied in a prefabricated form to a particular part of an electrotechnical product where thermal shock resistance or sealing performance are important material features.

#### **c) Semi-rigid sheet materials**

Materials of this group are mostly supplied in sheet form, but also as strips; they have a modulus of elasticity between 70 MPa and 700 MPa. They can be punched or folded without breaking. The thickness of pressboards and presspapers ranges from 0,1 mm up to 5,0 mm. Laminated pressboards may have a thickness up to 200 mm. These materials are often applied for slot insulation.

#### **d) Paper, paper-based or woven materials**

Materials of this group are mostly supplied in roll form. The thickness ranges from 0,01 mm to 0,5 mm. Varnished cotton or glass fabrics are designated by the term "woven materials"; the varnish may consist of different kinds of coating including silicones. A significant application of materials of this group is wrapping to insulate conducting elements such as winding coils.

**e) Pressure-sensitive adhesive (PSA) tapes**

These materials form a separate group due to the adhesive's influence on the performance and on the preparation of endurance test specimens. Since the backing determines the kind of ageing and diagnostics, it is advisable to consider thoroughly the details of a thermal endurance test, depending on whether the tape is paper-based, textile-based or film-based. PSA tapes with film backing are similar to pure films with regard to their diagnostics.

**f) Plastic films**

Materials of this group consist of a wide range of distinct products with different properties, which are also applied for multiple purposes. The thickness ranges from 0,002 mm to 0,35 mm. A significant aspect of films is their transparency; for designation purposes they are often supplied in various colours.

**g) Flexible insulating sleeveings**

Materials of this group are supplied in tubular form in continuous or cut lengths. They are used in a wide range of applications; therefore, many different compositions and dimensions are available. This is pertinent to the ageing and diagnostics.

**h) Flexible material combinations**

Materials of this group are supplied in the form of sheets, tapes or full width rolls. The supply form may not be representative of the final application; additional processing is in most cases required such as wrapping and curing, punching, folding, etc. Specimens for thermal endurance testing should be made in a shape or structure representative of the intended part or product.

**i) Resin-based reactive compounds (embedding compounds, potting compounds, encapsulating compounds)**

Embedding compound:

casting compound poured into a mould completely encasing an electric or electronic component. After subsequent curing, the encased component is removed from the mould.

Potting compound:

casting compound poured into a mould completely encasing an electric or electronic component. After subsequent curing the mould remains attached to the encased component as a permanent part of the unit.

Encapsulating compound:

reactive compound applied without a mould as a protective or insulating coating to enclose an electric or electronic component by suitable means such as brushing, dipping, spraying, or spreading.

**j) Impregnating compounds and varnishes**

Compounds and varnishes are supplied in liquid form in containers. They may be solventless or contain solvent. Resinous compounds are often supplied as two separate reactive components which have to be mixed prior to application and solidification. Products of this group are suitable to provide adequate impregnation even for fine wire windings.

**k) Coating compounds**

Coating compounds are supplied as either powders or liquids. Powders of thermoplastic or chemically reactive resins, are applied by coating processes such as the fluidized bed technique, powder spraying or electrostatic coating. Generally, the powder is applied to objects heated to a temperature exceeding the melting or curing point of the powder. For final cure many coatings require post-heating. The coating thickness is normally high, up to 0,5 mm.

Fusible insulating materials, plastisols and organosols are supplied in liquid form. The coating performance depends on the ability of providing a coating on metallic substrates of sufficient integrity to ensure insulation and protection. Some materials cure under room temperature conditions.

**l) Insulated conductive elements**

Products of this group are composites and should be considered as prefabricated parts. Although the thermal endurance may be governed by the insulation, the performance depends on the entire composite. Consequently, such composites should be submitted to particular methods of thermal endurance testing, with diagnostics and end-points related to the intended technical function.

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**RÉPONSE PAYÉE**

**SUISSE**

Centre du Service Clientèle (CSC)

**Commission Electrotechnique Internationale**

3, rue de Varembé

1211 GENÈVE 20

Suisse



**Q1** Veuillez ne mentionner qu'**UNE SEULE NORME** et indiquer son numéro exact:  
(ex. 60601-1-1)  
.....

**Q2** En tant qu'acheteur de cette norme, quelle est votre fonction?  
(cochez tout ce qui convient)  
Je suis le/un:

agent d'un service d'achat ☐  
bibliothécaire ☐  
chercheur ☐  
ingénieur concepteur ☐  
ingénieur sécurité ☐  
ingénieur d'essais ☐  
spécialiste en marketing ☐  
autre(s).....

**Q3** Je travaille:  
(cochez tout ce qui convient)

dans l'industrie ☐  
comme consultant ☐  
pour un gouvernement ☐  
pour un organisme d'essais/  
certification ☐  
dans un service public ☐  
dans l'enseignement ☐  
comme militaire ☐  
autre(s).....

**Q4** Cette norme sera utilisée pour/comme  
(cochez tout ce qui convient)

ouvrage de référence ☐  
une recherche de produit ☐  
une étude/développement de produit ☐  
des spécifications ☐  
des soumissions ☐  
une évaluation de la qualité ☐  
une certification ☐  
une documentation technique ☐  
une thèse ☐  
la fabrication ☐  
autre(s).....

**Q5** Cette norme répond-elle à vos besoins:  
(une seule réponse)

pas du tout ☐  
à peu près ☐  
assez bien ☐  
parfaitement ☐

**Q6** Si vous avez répondu PAS DU TOUT à Q5, c'est pour la/les raison(s) suivantes:  
(cochez tout ce qui convient)

la norme a besoin d'être révisée ☐  
la norme est incomplète ☐  
la norme est trop théorique ☐  
la norme est trop superficielle ☐  
le titre est équivoque ☐  
je n'ai pas fait le bon choix ☐  
autre(s) .....

**Q7** Veuillez évaluer chacun des critères ci-dessous en utilisant les chiffres  
(1) inacceptable,  
(2) au-dessous de la moyenne,  
(3) moyen,  
(4) au-dessus de la moyenne,  
(5) exceptionnel,  
(6) sans objet

publication en temps opportun .....  
qualité de la rédaction.....  
contenu technique .....  
disposition logique du contenu .....  
tableaux, diagrammes, graphiques,  
figures .....  
autre(s) .....

**Q8** Je lis/utilise: (une seule réponse)

uniquement le texte français ☐  
uniquement le texte anglais ☐  
les textes anglais et français ☐

**Q9** Veuillez nous faire part de vos observations éventuelles sur la CEI:

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