SLOVENSKI STANDARD
oSIST prEN IEC 60216-1:2024

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Električni izolacijski materiali - Lastnosti toplotne vzdržljivosti - 1. del: Postopki staranja in vrednotenje rezultatov preskušanja

Electrical insulating materials - Thermal endurance properties - Part 1: Ageing procedures and evaluation of test results

Elektroisolierstoffe - Eigenschaften hinsichtlich des thermischen Langzeitverhaltens - Teil 1: Warmlagerungsverfahren und Auswertung von Prüfergebnissen

Matériaux isolants électriques - Propriétés d'endurance thermique - Partie 1: Méthodes de vieillissement et évaluation des résultats d'essai

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ICS:

17.220.99	Drugi standardi v zvezi z elektriko in magnetizmom	Other standards related to electricity and magnetism
29.035.01	Izolacijski materiali na splošno	Insulating materials in general

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2003-01.Slovenski inštitut za standardizacijo. Razmnoževanje celote ali delov tega standarda ni dovoljeno.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSULATING MATERIALS - THERMAL ENDURANCE PROPERTIES - PART 1: AGEING PROCEDURES AND EVALUATION OF TEST RESULTS –

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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IEC 60216-1 has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems. It is an International Standard.

This seventh edition cancels and replaces the sixth edition published in 2013. This edition constitutes a technical revision.

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

a) Update the definition for temperature index (3.1.1)

b) Add requirements for selection of related materials used e.g. in different colors (5.1.2)

c) Test procedure for thickness sensitivity (5.5 and 6.6)

d) Removal of Annex C "Concepts in earlier editions"

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

Draft	Report on voting
XX/XX/FDIS	XX/XX/RVD

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

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The language used for the development of this International Standard is English.

A list of all parts in the IEC 60216 series, published under the general title *Electrical insulating materials - Thermal endurance properties*, can be found on the IEC website.

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.

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INTRODUCTION

The listing of the thermal capabilities of electrical insulating materials, based on service experience, was found to be impractical, owing to the rapid development of polymer and insulation technologies and the long time necessary to acquire appropriate service experience. Accelerated ageing and test procedures were therefore required to obtain the necessary information. The IEC 60216 series has been developed to formalize these procedures and the interpretation of their results.

Physico-chemical models postulated for the ageing processes led to the almost universal assumption of the Arrhenius equations to describe the rate of ageing. Out of this arose the concept of the temperature index (3.1.1) as a single-point characteristic based upon accelerated ageing data. This is the numerical value of the temperature in °C at which the time taken for deterioration of a selected property to reach an accepted end-point is that specified (usually 20 000 h).

NOTE: The term Arrhenius is widely used (and understood) to indicate a linear relationship between the logarithm of a time and the reciprocal of the thermodynamic (absolute or Kelvin) temperature. The correct usage is restricted to such a relationship between a reaction rate constant and the thermodynamic temperature. The common usage is employed throughout this standard.

The large statistical scatter of test data which was found, together with the frequent occurrence of substantial deviations from the ideal behavior, demonstrated the need for tests to assess the validity of the basic physico-chemical model. The application of conventional statistical tests, as set out in IEC 60493-1, fulfilled this requirement, resulting in the "confidence limit (3.1.14) ", of temperature index (3.1.1) , but the simple, single-point temperature index (3.1.1) was found inadequate to describe the capabilities of materials. This led to the concept of the "Thermal Endurance Profile" (TEP), incorporating the temperature index, its variation with specified ageing time, and a confidence limit.

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A complicating factor is that the properties of a material subjected to thermal ageing may not all deteriorate at the same rate, and different end-points may be relevant for different applications. Consequently, a material may be assigned more than one temperature index, derived, for example, from the measurement of different properties and the use of different end-point times.

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It was subsequently found that the statistical confidence index included in the TEP was not widely understood or used. However, the statistical tests were considered essential, particularly after minor modifications to make them relate better to practical circumstances: the concept of the halving interval (3.1.2) was introduced to indicate the rate of change of ageing time with temperature. TEP was then abandoned, with the temperature index (3.1.1) and halving interval (3.1.2) being reported in a way which indicated whether or not the statistical tests had been fully satisfied. At the same time, the calculation procedures were made more comprehensive, enabling full statistical testing of data obtained using a diagnostic property of any type, including the particular case of partially incomplete data. Simultaneously with the development of the IEC 60216 series, other standards were being developed in ISO, intended to satisfy a similar requirement for plastics and rubber materials. These are [1: ISO 2578:1993] and [2: ISO 11346] respectively, which use less rigorous statistical procedures and more restricted experimental techniques. A simplified calculation procedure is described in IEC 60216-8.

Further reading:

IEC 60216-1:1974, *Guide for the determination of thermal endurance properties of electrical insulating materials - Part 1: General procedures for the determination of thermal endurance properties, temperature indices and thermal endurance profiles*

ISO 291:2008, *Plastics — Standard atmospheres for conditioning and testing*

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ELECTRICAL INSULATING MATERIALS - THERMAL ENDURANCE PROPERTIES - PART 1: AGEING PROCEDURES AND EVALUATION OF TEST RESULTS –

1 Scope

This part of IEC 60216 specifies the general ageing conditions and procedures to be used for deriving thermal endurance characteristics and gives guidance in using the detailed instructions and guidelines in the other parts of the standard.

Although originally developed for use with electrical insulating materials and simple combinations of such materials, the procedures are considered to be of more general applicability and are widely used in the assessment of materials not intended for use as electrical insulation.

In the application of this standard, it is assumed that a practically linear relationship exists between the logarithm of the time required to cause the predetermined property change and the reciprocal of the corresponding absolute temperature (Arrhenius relationship).

For the valid application of the standard, no transition, in particular no first-order transition should occur in the temperature range under study.

Throughout the rest of this standard the term "insulating materials" is always taken to mean "insulating materials and simple combinations of such materials".

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2 Normative references

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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 60212*, Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216-2*, Electrical insulating materials - Thermal endurance properties - Part 2: Determination of thermal endurance properties of electrical insulating materials - Choice of test criteria*

IEC 60216-3:2021*, Electrical insulating materials - Thermal endurance properties - Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60216-4-1*, Electrical insulating materials - Thermal endurance properties - Part 4-1: Ageing ovens - Single-chamber ovens*

IEC 60216-4 (all Parts 4)*, Electrical insulating materials - Thermal endurance properties - Part 4: Ageing ovens*

IEC 60216-8*, Electrical insulating materials - Thermal endurance properties - Part 8: Instructions for calculating thermal endurance characteristics using simplified procedures*

IEC 60493-1:2011*, Guide for the statistical analysis of ageing test data - Part 1: Methods based on mean values of normally distributed test results*

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3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
temperature index
TI
numerical value of the temperature in degrees Celsius determined by test by itself

Note 1 to entry: This rating is based on 20 000 h life, unless otherwise specified, based on one of the end-of-life criteria listed in IEC 60216-2.

3.1.2
halving interval
HIC
numerical value of the temperature interval in Kelvin which expresses the halving of the time to end-point taken at the temperature equal to **temperature index** (3.1.1)

[SOURCE: IEC 60050-212:2010, definition 212-12-13, modified - "equal to TI" replaces "corresponding to the temperature index or the relative temperature index"]

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3.1.3
thermal endurance graph
graph in which the logarithm of the time to reach a specified end-point in a thermal endurance test is plotted against the reciprocal thermodynamic (absolute) test temperature

[SOURCE: [3: IEC 60050-212:2010], definition 212-12-10, modified - "insertion of word "(absolute)"]

3.1.4
thermal endurance graph paper
graph paper having a logarithmic time scale as the ordinate, graduated in powers of ten (from 10 h to 100 000 h is often a convenient range)

Note 1 to entry: Values of the abscissa are proportional to the reciprocal of the thermodynamic (absolute) temperature. The abscissa is usually graduated in a non-linear (Celsius) temperature scale oriented with temperature increasing from left to right.

3.1.5
ordered data
set of data arranged in sequence so that, in the appropriate direction through the sequence, each member is greater than, or equal to, its predecessor

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Note 1 to entry: Ascending order in this standard implies that the data is ordered in this way, the first order-statistic being the smallest.

3.1.6
order-statistics
each individual value in a set of ordered data is referred to as an order-statistics identified by its numerical position in the sequence

3.1.7
incomplete data
ordered data, where the values above and/or below defined points are not known

3.1.8
censored data
incomplete data, where the number of unknown values is known

Note 1 to entry: If the censoring is begun above/below a specified numerical value, the censoring is of type 1. If above/below a specified order-statistic, it is of type 2. This standard is concerned only with type 2.

3.1.9
degrees of freedom
number of data values minus the number of parameter values

3.1.10
variance of a data set
sum of the squares of the deviations of the data from a reference level defined by one or more parameters, divided by the number of degrees of freedom

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Note 1 to entry: The reference level may for example, be a mean value (one parameter) or a line (two parameters, slope and intercept).

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3.1.11
covariance of data sets
for two sets of data with equal numbers of elements where each element in one set corresponds to one in the other, the sum of the products of the deviations of the corresponding members from their set means, divided by the number of degrees of freedom

3.1.12
regression analysis
process of deducing the best-fit line expressing the relation of corresponding members of two data groups by minimizing the sum of squares of deviations of members of one of the groups from the line

Note 1 to entry: The parameters are referred to as the regression coefficients.

3.1.13
correlation coefficient
number expressing the completeness of the relation between members of two data sets, equal to the covariance divided by the square root of the product of the variances of the sets

Note 1 to entry: The value of its square is between 0 (no correlation) and 1 (complete correlation).

3.1.14

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confidence limit
TC
statistical parameter, calculated from the test data, which with 95 % confidence constitutes a lower limit for the true value of the temperature index estimated by **temperature index** (3.1.1)

Note 1 to entry: 95 % confidence implies that there is only 5 % probability that the true value of the temperature index is actually smaller than **confidence limit** (3.1.14) .

Note 2 to entry: In other connections, confidence values other than 95 % may sometimes be used; for example, in the linearity test for destructive test data.

3.1.15
destructive test
diagnostic property test, where the test specimen is irreversibly changed by the property measurement, in a way which precludes a repeated measurement on the same specimen

3.1.16
non-destructive test
diagnostic property test, where the properties of the test specimen are not permanently changed by the measurement, so that a further measurement on the same specimen may be made after appropriate treatment

3.1.17
proof test
diagnostic property test, where each test specimen is, at the end of each ageing cycle, subjected to a specified stress, further ageing cycles being conducted until the specimen fails on testing

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3.1.18
temperature group
test group of specimens
number of specimens being exposed together to the same temperature ageing in the same oven

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Note 1 to entry: Where there is no risk of ambiguity, either temperature groups or test groups may be referred to simply as groups.

3.1.19
test group
test group of specimens
number of specimens removed together from a temperature group (as above) for destructive testing

3.1.20
end point
property level that is effected by practical application to the equipment in the thermal endurance test

3.2 Symbols and abbreviations

a, b Regression coefficients

$n_{a,b,c,d}$ Numbers of specimens for destructive tests

n Number of *y*-values