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NORME INTERNATIONALE

Electrical insulating materials – Thermal endurance properties – Part 8: Instructions for calculating thermal endurance characteristics using simplified procedures

Matériaux isolants électriques – Propriétés d'endurance thermique – Partie 8: Instructions pour le calcul des caractéristiques d'endurance thermique en utilisant des procédures simplifiées

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ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –

Part 8: Instructions for calculating thermal endurance characteristics using simplified procedures

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

FDIS	Report on voting
112/236/FDIS	112/244/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.

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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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

The designation 'thermal endurance' is used here to refer to the test of thermal stress in air, excluding any other influence or stress applied to the test specimens. Thermal endurance properties evaluated in different environments and/or with different stresses applied to the test specimens require different test procedures.

In this part of IEC 60216, the study of the thermal ageing of materials is based solely on the change in certain properties resulting from a period of exposure to elevated temperature. The properties studied are always measured after the temperature has returned to ambient.

Properties of materials change at various rates on thermal ageing. To enable comparisons to be made of the thermal ageing of different materials, the criteria for judgment depend on the type of property to be studied and its acceptable limiting value.

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ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –

Part 8: Instructions for calculating thermal endurance characteristics using simplified procedures

1 Scope

This part of IEC 60216 specifies the general ageing conditions and simplified procedures to be used for deriving thermal endurance characteristics, which are shown by temperature index (TI) and/or relative temperature index (RTI) and the halving interval (HIC).

The procedures specify the principles for evaluating the thermal endurance properties of materials exposed to elevated temperature for long periods.

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 designation "insulating materials" is always taken to mean "insulating materials and simple combinations of such materials".

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60216-1:2013, *Electrical insulating materials –Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*[1]

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, *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*

[1] A sixth edition is due to be published shortly.

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

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

3 Terms, definitions, symbols and abbreviations

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

3.1 Terms and definitions

3.1.1
temperature index
TI
numerical value of the temperature in degrees Celsius derived from the thermal endurance relationship at a time of 20 000 h (or other specified time)

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 TI

[SOURCE: IEC 60050-212:2010 [1][2], definition 212-12-13, modified – omission of reference to "relative temperature index"]

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 test temperature

[SOURCE: IEC 60050-212:2010, definition 212-12-10]

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) and values of the abscissa are proportional to the reciprocal of the thermodynamic (absolute) temperature

Note 1 to entry: The abscissa is usually graduated in a non-linear (Celsius) temperature scale oriented with temperature increasing from left to right.

3.1.5
degrees of freedom
number of data values minus the number of parameter values

3.1.6
end-point
limit for a diagnostic property value based on which the thermal endurance is evaluated.

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2 Figures in square brackets refer to the Bibliography.

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3.1.7
time to end-point
failure time
time to reach the end point or conventional failure

3.1.8
square of the correlation coefficient
r^2
fraction of the variation in one variable that may be explained by the other variable

Note 1 to entry: r^2 is a square of correlation coefficient which explains the ratio of all data deviation on the regression line.

3.1.9
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

3.1.10
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

3.1.11
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

3.1.12
temperature group
temperature group of specimens
number of specimens being exposed together to the same temperature ageing in the same oven

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

3.1.13
test group
test group of specimens
number of specimens removed together from a temperature group (as above) for destructive testing

3.1.14
relative temperature index
RTI
numerical value of the temperature in degrees Celsius at which the estimated time to endpoint of the candidate material is the same as the estimated time to endpoint of the reference material at a temperature equal to its assessed temperature index

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

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N	Total number of test specimens
r	Correlation coefficient
F	Fisher distributed stochastic variable
x	Reciprocal thermodynamic temperature (1/Θ)
y	Logarithm of time to end-point
ϑ	Temperature, °C
Θ	Temperature, thermodynamic (Kelvin)
Θ_0	Value in Kelvin of 0 °C (273,15 K)
τ	Time (to end-point)
TI	Temperature index
HIC	Halving interval at temperature equal to TI
RTI	Relative temperature index

4 Thermal endurance test procedure

4.1 General

Simplified procedures, which do not test the data dispersion but only deviations from linear behaviour, are described.

It is possible, with some limitations, to evaluate the thermal endurance data graphically. In this case, statistical assessment of data dispersion is not possible, but it is considered important to evaluate any deviation of the data from the linear relationship.

Since the temperature is very often the dominant ageing factor affecting an electrical insulating material (EIM) certain basic thermal classes are useful and have been recognized as such internationally (see IEC 60085).

4.2 Number of test specimens

The accuracy of endurance test results depends largely on the number of specimens aged at each temperature. Generally, the following instructions, which influence the testing procedure, apply.

a) For a criterion requiring non-destructive testing, in most cases a group of five test specimens for each exposure temperature is adequate.

   Where the test criterion for non-destructive or proof tests is based upon the initial value of the property, this should be determined from a group of specimens of at least twice the number of specimens in each temperature group

b) For proof-test criteria, a group of at least 11 and possibly 21 specimens will be required for each exposure temperature.

   The dimensions and method of preparation of the test specimens shall be in accordance with the specifications given for the relevant test method.

c) For a criterion requiring a destructive test, the minimum total number (N) of test specimens needed is derived as follows:

$$N = n_a \times n_b \times n_c + n_d \quad (1)$$

where

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n_a is the number of specimens in a test group undergoing identical treatment at one temperature and one treatment time and discarded after determination of the property (usually five);

n_b is the number of treatments, i.e. exposure lengths, at one temperature;

n_c is the number of exposure temperature levels;

n_d is the number of specimens in the group used to establish the initial value of the property. Normal practice is to select $n_d = 2n_a$ when the diagnostic criterion is a percentage change of the property from its initial level. When the criterion is an absolute property level, n_d is usually given the value of zero, unless reporting of the initial value is required.

NOTE When there is a large number of specimens to be tested, it may be possible in certain cases to deviate from the relevant test specifications and to reduce this number. However, it should be recognized that the precision of the test result depends to a large extent on the number of specimens tested. In contrast, when the individual results are too scattered, an increase in the number of specimens may be necessary in order to obtain satisfactory precision. It is advisable to make an approximate assessment, by means of preliminary tests, of the number and duration of the ageing tests required.

4.3 Preparation of test specimens

The specimens used for the ageing test should constitute a random sample from the population investigated and are to be treated uniformly.

The material specifications or the test standards will contain all necessary instructions for the preparation of specimens.

The thickness of specimens is in some cases specified in the list of property measurements for the determination of thermal endurance (see IEC 60216-2); otherwise the thickness shall be reported. Some physical properties are sensitive even to minor variations of specimen thickness. In such cases, the thickness after each ageing period may need to be determined and reported if required in the relevant specification.

The thickness is also important because the rate of ageing may vary with thickness. Ageing data of materials with different thicknesses are not always comparable. Consequently, a material may be assigned more than one thermal endurance characteristic derived from the measurement of properties at different thicknesses.

The tolerances of specimen dimensions should be the same as those normally used for general testing; where specimen dimensions need smaller tolerances than those normally used, these special tolerances should be given. Screening measurements ensure that specimens are of uniform quality and typical of the material to be tested.

Since processing conditions may significantly affect the ageing characteristics of some materials, it shall be ensured that, for example, sampling, cutting sheet from the supply roll, cutting of anisotropic material in a given direction, moulding, curing, pre-conditioning, are performed in the same manner for all specimens.

It is good practice to keep an adequate number of test specimens separately as a reserve of the original material batch from which such specimens may subsequently be prepared. In this way, any required ageing of additional specimens in case of unforeseen complications will introduce a minimum risk of producing systematic differences between groups of specimens. Such complications may arise, for example, if the thermal endurance relationship turns out to be non-linear, or if specimens are lost due to thermal runaway of an oven. Moreover they can be used:

– for cases in which the accuracy requires heat ageing at an additional temperature;

– as reference specimens.

They shall be stored in an appropriately controlled atmosphere (see ISO 291).

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Thermosetting materials shall be conditioned for 48 h at the lowest exposure temperature of the range selected.

If necessary, thermoplastic materials should be annealed for 48 h at the lowest exposure temperature of the range selected.

4.4 Preparation of ageing processes – exposure temperature and cycle time

For TI determinations, test specimens should be exposed to not less than three, preferably at least four, temperatures covering a sufficient range to demonstrate a linear relationship between logarithms of time to end-point and reciprocal thermodynamic (absolute) temperature.

To reduce the uncertainties in calculating the appropriate thermal endurance characteristic, the overall temperature range of thermal exposure needs to be carefully selected, observing the following requirements:

a) the lowest exposure temperature shall be one which will result in a mean or median time to end-point more than 1/4 of the extrapolation time (which is generally 20 000 h) when determining TI;

NOTE 1 The mean time corresponding to TI is generally 20 000 h, thus the lowest exposure temperature corresponds to a mean time > = 5 000 h.

b) the extrapolation necessary to establish TI shall not be more than 25 K;

c) the highest exposure temperature shall be one which will result in a mean or median time to end-point of more than 100 h.

NOTE 2 For some materials, it may not be possible to achieve a time to end-point of less than 500 h while retaining satisfactory linearity. However, it is important that a smaller range of mean times to end-point will lead to a larger confidence interval of the result for the same data dispersion.

Table 1 gives guidance in making initial selections.

A number of recommendations and suggestions useful in establishing times and temperatures can be found in IEC 60216-1:2013, Annex B.

Before the heat-ageing procedure is started, an initial test shall be made at room temperature with the required number of specimens conditioned and tested in accordance with the chosen test method.

Selection of adequate exposure temperatures requires previously determined information on the material under test. If such information is not available, exploratory tests may help in selecting exposure temperatures which are suitable for evaluating the thermal endurance characteristics.

For heat ageing, ovens shall be used that meet the requirements specified in IEC 60216-4-1, in particular with respect to the temperature tolerances and ventilation rates of air exchange.

Place the required number of specimens in each of the ovens maintained at the selected temperatures.

If there is a risk of cross-contamination between test specimens originating from different materials, use separate ovens for each material.

At the end of each heat-ageing period, the required number of test specimens is removed from the oven and conditioned, if necessary, under the appropriately controlled atmosphere (see ISO 291). The test, in accordance with the selected test criterion, shall be carried out at room temperature.

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