
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

Guide pour la détermination des propriétés d'endurance thermique de matériaux
isolants électriques

Partie 1. Méthodes générales pour la détermination des propriétés d'endurance
thermique, des indices de température et des profils d'endurance thermique

Anleitung zur Bestimmung der Wärmedauer-eigenschaften von elektrischen
Isoliermaterialien

Teil 1. Allgemeine Verfahren zur Bestimmung der Wärmedauer-Eigenschaften, der
Temperaturzahlen und der Wärmedauer-Profile

National foreword

This British Standard is identical with IEC Publication 216-1 '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' published in 1974 by the International Electrotechnical Commission (IEC). It is published under the direction of the General Electrotechnical Engineering Standards Committee.

Other Parts of this standard are as follows.

Part 2 List of materials and available tests

Part 3 Statistical methods for the determination of thermal endurance profile (Under study by IEC technical committee)

Part 4 Instruction for calculating the thermal endurance profile (Under study by IEC technical committee)

Part 5 Examples of thermal endurance test methods for specifications (Under study by IEC technical committee)

Terminology and conventions. The text of the international standard has been approved as suitable for publication, without deviation, as a British Standard. Some terminology and certain conventions are not identical with those used in British Standards; attention is especially drawn to the following.

The comma has been used as a decimal marker in figures 3a, 3b and 4. In British Standards it is the current practice to use a full point on the baseline as the decimal marker.

Wherever the word 'recommendation' appears, referring to this standard, it should be interpreted as 'British Standard'.

Where the words 'by reference to an IEC Publication' appear in clause 12, these should be interpreted as 'by reference to a British Standard'.

Where page numbers are quoted in connection with references to figures in this standard they are IEC page numbers.

Cross-reference

International standard*	Corresponding British Standard
IEC 212 : 1971	BS 2844 : 1972 Memorandum on conditioning of solid electrical insulating materials prior to and during testing (Technically equivalent)

*Undated in the text

NOTE. *Textual errors.* When adopting the text of the international standard, the errors listed below were noted. These errors have been reported to the International Electrotechnical Commission in a proposal to amend the text of the international standard as follows:

Clause 8, paragraph 2, lines 5, 6 and 8: replace 'deg C' by '°C'.

11.1 a), line 7: replace ' $(n + 1)/2$ ' by ' $(n/2 + 1)$ '.

British Standard 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

INTRODUCTION

The revision of the first edition of IEC Publication 216, Guide for the Preparation of Test Procedures for Evaluating the Thermal Endurance of Electrical Insulating Materials, is composed of three parts:

Part 1: General procedures for the determination of thermal endurance properties, temperature indices and thermal endurance profiles.

Part 2: List of materials and available tests.

Part 3: Examples and application of statistical methods to the determination of thermal endurance. (Under consideration.)

1. Scope

This recommendation gives principles for the development of test procedures to evaluate the thermal endurance of electrical insulating materials and simple combinations of such materials.

The results of accelerated thermal endurance tests, which are conducted according to prescribed procedures, may be used to establish thermal endurance profiles and temperature indices for insulating materials.

2. Object

Thermal endurance test procedures are intended to determine the changes in properties of materials caused by long-term exposure to elevated temperature.

To perform satisfactorily, insulating materials must have the required combination of mechanical, chemical and electrical properties and retain these at an adequate level throughout the service life of the equipment.

The mechanical, chemical and electrical properties of the materials when new should be evaluated separately by test methods not within the scope of thermal endurance test procedures. The properties so determined may indicate that one or more, or combinations of these, will be the limiting factor in practice rather than thermal endurance.

The process of thermal ageing in insulating materials is complex and the mechanisms vary with different materials and under different service conditions.

Typical mechanisms include:

- a) Loss of volatile constituents such as low molecular weight components initially present or formed in the ageing process.
- b) Oxidation which causes molecular cross-linking and embrittlement.
- c) Continuing molecular polymerization which may increase physical and electric strength at first, but may subsequently lead to decreased flexibility, embrittlement and failure under mechanical stress.

- d) Hydrolytic degradation in which retained moisture reacts with the insulation under the influence of heat.
- e) Chemical breakdown of constituents with formation of harmful products such as hydrochloric acid. Such processes once started may be autocatalytic.

Rapid advances in polymer chemistry have resulted in numerous complex insulating materials, the thermal endurance of which cannot be reliably predicted from their chemical family and which often differ significantly from one another, e.g. changes in the physical nature of the polymer and/or in the type and quantity of various additives can exert an important influence on the stability of the material.

It is the present state of the art to assess the thermal endurance of insulating materials and simple combinations through accelerated tests at higher temperatures than the intended service temperature. It is a common experience that the results of thermal endurance tests can be described by an Arrhenius type of model law, i.e. a linear relationship between the logarithm of time to a certain degree of property change and the inverse thermodynamic temperature. This law is often used for estimating the times at lower temperatures by extrapolation. Performing thermal endurance tests at several temperatures serves a double purpose; first, the accuracy of the extrapolation is improved and, second, a check is provided that the basic assumption of a linear relationship between the logarithm of time and the reciprocal thermodynamic temperature is satisfied, which is not the case if the deterioration mechanism is subject to change in the range of test temperatures. An extrapolation of the results is not justified if this check is negative.

The most complete information about the result of an accelerated thermal ageing test is an ageing curve. To enable materials to be compared expeditiously and the properties tabulated, a *thermal endurance profile* (see Clause 11) is introduced as a “short hand form” of an ageing curve, indicating in a few numbers the relative stability of a material, as determined by the change in a particular property when it is subjected to prolonged heating. An even shorter form, suitable for specification purposes, is the *temperature index* (see Clause 11).

Profiles and indices, while giving guidance on materials, should not by themselves be taken to predict the relationship between temperature and life of an insulation system in service.

All the properties of a material subjected to heat ageing do not deteriorate at the same rate and, consequently, thermal endurance profiles and temperature indices are required for a number of properties related to possible modes of failure of the material in service.

Materials are normally freely exposed in an oven during ageing. Other arrangements may be used, but different thermal endurance results may then be obtained.

Thermal endurance tests provide a means for determining irreversible changes of important properties of insulating materials as a function of temperature and time.

Different test procedures are to be developed for different kinds of insulating materials such as impregnating varnishes, sheet insulation, etc. The thermal endurance of the material is determined by end-point criteria based on the material's ability to withstand a stress such as electric field, mechanical tension or flexure, etc., or is based on changes in a property of the material. A material may be assigned more than one thermal endurance profile or more than one temperature index derived from the measurement of different properties or from different tests.

3. General considerations

The test procedures covered by this guide apply to insulating materials including processed compositions of raw materials and simple combinations thereof before they are fabricated into coils or other insulating structures identified with specific parts of electric equipment.

A distinction between such material tests and tests to evaluate the performance of insulation systems is necessary because the details of the particular use of a material cannot be known to its manufacturer.

The procedures covered by this recommendation produce data on the long-time characteristics of insulating materials which provide the designer and development engineer with information for the selection of materials for further evaluation in insulation systems and equipment tests.

The results of tests on familiar, widely used materials may be compiled for convenient reference so that comparisons between new and old materials can be made.

In addition, reference specimens of well-known materials may advantageously be included in each set of test specimens in order to ensure the validity of the overall ageing conditions.

The recommended procedure for the thermal evaluation of an insulating material consists in:

- a)* Selecting suitable specimens appropriate for the intended tests.
- b)* Subjecting groups of specimens to ageing at least at three fixed elevated temperatures, either continuously or for a number of periods between which the specimens are returned to room temperature.
- c)* Subjecting specimens to a test such as electric stress, mechanical flexing or other measurement of a significant property.
- d)* Continuing the steady heat exposure or the thermal cycling until failure of specimens or a specified degree of change in the measured property is revealed.
- e)* Reporting the results of the tests in the form of time to failure versus temperature curves.
- f)* Assigning the thermal endurance profile or temperature index.

4. Selection of test procedures and specimens

Each test procedure should describe the method to be used in determining the property on which the ageing test results have to be based and state the form and number of specimens to be tested.

The test chosen should relate to a property which is likely to be of significance in practice and, when possible, use a well-established international method of test. Only when no such appropriate method exists should a national method or a specially devised method be used.

The test specimens should be chosen to simulate practical usage where possible but, since insulating materials are used in many different applications and are exposed to a complex of forces and environments, this may not always be possible. Often a test specimen as used for routine testing may be preferred.

When feasible, the test should simulate as closely as possible the function of the material in actual service. The property measured in the test should be related to property requirements in actual use.

The test procedure should specify the test methods to be applied to the specimens to obtain end points of ageing at each different temperature. The test method and the end point should be realistically selected to indicate deterioration of the insulating material.

A selection of proposed test methods for determining thermal endurance properties of electrical insulating materials is given in IEC Publication 216-2.

If the principal measuring method is a proof test, in which a specified stress is applied after successive exposures until failure occurs, it may also be helpful to obtain data on another property demonstrating the rate of deterioration of the material.

When it is desired to determine the thermal endurance of materials' aged in atmospheres other than air (such as nitrogen or other gas or liquid), the test procedure must give details of such special tests.

5. Selection of end points

The end point should be selected to indicate a degree of deterioration of the insulating material which has reduced its ability to withstand a stress encountered in actual service in an insulation system. The degree of degradation indicated at the end point of the test should be related to the allowable safe value desired for the material property in practice. The end point should not be set so high that unreasonable short time to failure values are obtained.

Each test procedure must fix a clearly defined end point. There are two ways in which the end point may be defined, both of which are equally acceptable:

a) As a percentage increase or decrease in the measured value from the original value. This method will provide comparisons among materials but bears less relationship than *b)* to the property value required in normal service.* The original value of the property is defined—unless otherwise specified—as the average value of at least 10 specimens exposed to the lowest ageing temperature for 48 h.

b) As a fixed value of the property. This value might be selected with respect to usual service requirements.

A selection of end-point criteria is given in IEC Publication 216-2. In some cases, other end-point criteria than those given may be better suited for a specific material or a specific purpose.

6. Preparation of test specimens

Test procedures should contain instructions for preparing test specimens. Drawings and photographs should be included when applicable.

The thickness of specimens is specified in the list of test methods for the determination of thermal endurance properties and should be specified in new test procedures. The thickness is important because the rate of ageing will vary with thickness. Ageing data of materials with different thickness are not always comparable

Where specimen dimensions need smaller tolerances than are normally used for general testing, these special tolerances should be given.

Screening tests should be used to ensure that specimens are of uniform quality and typical of the material to be tested.

7. Number of test specimens

The accuracy of the test results depends largely on the number of test specimens aged at each temperature. A greater number of test specimens is required to achieve an acceptable degree of accuracy if there is a wide spread in the results among specimens at each exposure temperature.

Experience with the test will help in selecting an adequate number of specimens.

* A test value based on an arbitrary percentage of the initial value of the measured property may unfairly penalize materials with high initial values when compared with materials with lower initial values.