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INTERNATIONAL ELECTROTECHNICAL COMMISSION

THERMAL EVALUATION AND CLASSIFICATION OF ELECTRICAL INSULATION

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 15B: Endurance Tests, of IEC Technical Committee No. 15: Insulating Materials, in collaboration with IEC Technical Committee No. 63: Insulation Systems.

This publication constitutes the second edition of IEC Publication 85 and replaces the first edition.

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

Six Months' Rule	Report on Voting
15B(CO)55	15B(CO)59

Further information can be found in the Report on Voting indicated in the table above.

Other IEC publications quoted in this publication:

Publication Nos. 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.

216-2: Part 2: List of Materials and Available Tests.

216-3: Part 3: Statistical Methods.

216-4: Part 4: Instructions for Calculating the Thermal Endurance Profile.

505: Guide for the Evaluation and Identification of Insulation Systems of Electrical Equipment.

610: Principal Aspects of Functional Evaluation of Electrical Insulation Systems: Ageing Mechanisms and Diagnostic Procedures.

611: Guide for the Preparation of Test Procedures for Evaluating the Thermal Endurance of Electrical Insulation Systems.

THERMAL EVALUATION AND CLASSIFICATION OF ELECTRICAL INSULATION

1. Scope

This publication describes the recognized system of thermal classes for the insulation of electrotechnical products. It considers the thermal evaluation of insulating materials and of insulation systems, their interrelationship and the influence of service conditions. It defines the responsibility for assigning thermal identification and classification.

2. General

2.1 *Thermal classes*

The endurance of the insulation of electrotechnical products is affected by many factors such as temperature, electrical and mechanical stresses, vibration, deleterious atmospheres and chemicals, moisture, dirt and radiation.

As the temperature in electrotechnical products is very often the dominating ageing factor on insulating materials and insulation systems, certain basic thermal classes are useful and have been recognized throughout the world. These thermal classes and the temperatures assigned to them are as follows:

Thermal class	*Temperature*
Y	90 °C
A	105 °C
E	120 °C
B	130 °C
F	155 °C
H	180 °C
200	200 °C
220	220 °C
250	250 °C

Temperatures over 250 °C should increase by 25 °C intervals and classes designated accordingly.

Note. — The old Class C which was used in I E C Publication 85 (1957) for all temperatures above 180 °C is replaced by the above thermal classes.

The use of the letters is not mandatory. However, the above relationship between letters and temperatures should be adhered to. If the contents of Sub-clause 2.1.5 are applied to particular equipment, alternative systems of identification may be used.

When a thermal class describes an electrotechnical product it normally represents the maximum temperature appropriate to that product under rated load and other conditions. Thus, the insulation subjected to this maximum temperature will need to have a thermal capability at least equal to the temperature associated with the thermal class of the product (but see Sub-clause 2.1.2).

Up to now the term "class" has been used to refer to insulating materials, insulation systems and products. I E C Publication 216: Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials, has introduced the term "temperature index" for insulating materials, while I E C Publication 505: Guide for the Evaluation and Identification of Insulation Systems of Electrical Equipment, has introduced the term "identification" for insulation systems. The identification of systems is relevant only to the particular product for which the system is designed. The term "classification" may be reserved for electrotechnical products.

2.1.1 *Operating conditions*

Experience has proved that, under usual operating conditions, satisfactory economic life is obtained for electrotechnical products such as rotating machines, transformers, etc., designed and built in accordance with standards based on the temperatures in Sub-clause 2.1 making due allowance for factors peculiar to the product in question.

2.1.2 *Insulating materials in insulation systems*

The description of an electrotechnical product as being of a particular thermal class does not mean, and must not be taken to imply that each insulating material used in its construction is of the same thermal capability.

The temperature limit for an insulation system may not be directly related to the thermal capability of the individual materials included in it. In the system, the thermal performance of insulating materials may be improved by the protective character of the materials used with them. On the other hand, problems of incompatibility between materials may decrease the appropriate temperature limit of the system below that for the individual materials. Such problems should be investigated by functional tests.

2.1.3 *Temperature and temperature rise*

The temperatures quoted in this standard are the actual temperatures of the insulation and not the temperature rises of the electrotechnical product.

Standards for electrical equipment usually specify temperature rise rather than actual temperature. In establishing such standards, factors such as features of construction, thermal conductivity and thickness of insulation, accessibility of insulated parts, methods of ventilation, load characteristics etc., should be taken into account when considering the methods of measurement and the temperature rise to be permitted.

2.1.4 *Other factors of influence*

Apart from thermal factors, the ability of insulation to continue to fulfil its function is influenced by such conditions as mechanical stresses imposed upon it and its supporting structure, and by such factors as vibration and differential thermal expansion which may become of increasing importance as the size of the product increases. Moisture in the atmosphere and the presence of dirt, chemicals, or other contaminants may have injurious effects. All such factors should be taken into account when designing particular products and further guidance on this aspect may be found in I E C Publication 505.

2.1.5 *Insulation performance*

Actual performance in service depends on particular conditions, which may vary widely with, e.g., environmental exposure, duty cycles and type of product. Further, the intended performance in service depends on the relative importance of size, reliability, desired period of use of associated equipment and economic considerations.

For certain products it may be desirable to establish values of temperature rise which permit temperatures higher than those normally appropriate or which restrict the temperatures attained by the insulation to values lower than those normally appropriate. Such cases may arise because, for the purpose in question, a shorter or a longer life than normal is envisaged, or exceptional conditions of service exist.

The life of insulation is dependent to a considerable extent upon the degree of exclusion of oxygen, moisture, dirt and chemicals. Therefore, at a given temperature, the life of the insulation may be longer if it is suitably protected than if it is freely exposed to industrial atmospheres. The use of chemically inert gases, or liquids, as cooling or protective media may increase the temperature capability of insulation.

In addition to the ageing which insulation undergoes, some materials when heated above a certain temperature, soften and otherwise degrade but may recover their initial properties again on cooling. The user of such materials should satisfy himself that they are suitable in the above respect for the duties to be imposed on them.

2.2 *Responsibility for selection and assignment*

The responsibility for the selection of appropriate materials and systems lies with the manufacturer of the electrotechnical product. Only experience or adequate acceptable tests provide bases for assigning rational temperature limits for the insulation. Service experience is an important basis for the selection of materials and systems. Where new materials and systems are involved, appropriate tests are the basis for this selection (see also Clause 4).

3. Thermal evaluation of insulating materials

Many insulating materials of the same generic type are available in a number of variants of different thermal endurance capability. Therefore, the generic chemical designation of an insulating material is inadequate to characterize its thermal capability.

When applying materials for the insulation of electrotechnical products, their individual thermal endurance characteristics may be affected by the way in which they are combined with others. The thermal capability of materials used for insulation of electrotechnical products also depends strongly on the special functions they will be called upon to fulfil.

In respect of the use in electrotechnical products, material evaluation serves two purposes: one is to obtain evaluation of a material to be used as a component in an electrical insulation system, the other is to evaluate a material to be used alone or as part of a simple combination to become an insulation system.

Generally, tests and experience are recognized as the acceptable basis for the thermal evaluation of insulating materials.

When the basis of experience is used, care is required to ensure that it is relevant. Yet it may often be valid to translate experience from one type of application to another. Methods appropriate for establishing the relevance of service experience are to be prepared.

Considerable progress has been made in the development of tests to evaluate materials. Reference should be made to the following I E C publications:

216: Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials.

216-1: Part 1: General Procedures for the Determination of Thermal Endurance Properties, Temperature Indices and Thermal Endurance Profiles.

216-2: Part 2: List of Materials and Available Tests.

216-3: Part 3: Statistical Methods.

216-4: Part 4: Instructions for Calculating the Thermal Endurance Profile.

Note. — This work is continuing. New parts and amendments of the listed publications are in preparation. Please see the current catalogue of I E C publications for up-to-date list.

While the complete documents above should be considered, the following definitions may be helpful.

a) thermal endurance graph: Arrhenius graph
A graph in which the logarithm of time to reach a specified end point in a thermal endurance test is plotted versus the reciprocal thermodynamic (absolute) test temperature.

b) temperature index: TI
The number corresponding to the temperature in degrees Celsius derived from the thermal endurance relationship at a given time, normally 20 000 h.

c) relative temperature index: RTI
The temperature index of a test material obtained from the time which corresponds to the known temperature index of a reference material, when both materials are subjected to the same ageing and diagnostic procedures in a comparative test.

d) halving interval: HIC
The number corresponding to the temperature interval in degrees Celsius which expresses the halving of the time to end point taken at the temperature of the TI or the RTI.

Different temperature indices and halving intervals for a single material may be obtained when different types of test criteria and end points — electrical, mechanical, etc. — are used for the thermal endurance graph. Different temperature indices and halving intervals may indicate differing thermal capabilities and so determine the way the material is used and the function it may perform.

Tests on standard specimens may give results different from those which might be obtained from tests on the material in the form in which it is to be used. Thus, the results of insulation system tests may be used to verify the suitability of the material for the application concerned.

4. Thermal evaluation of insulation systems

The preferred basis for assessing the thermal endurance of an insulation system is relevant service experience. Where this experience does not exist, appropriately designed functional tests should be carried out. For this purpose, a service proven system is needed to be used as a reference insulation system.

A reference insulation system should be described by the responsible Technical Committee on the basis of service experience. The Committee should establish guidelines for the particular equipment to explain how an insulation system with a record of service experience can be used as a reference. The use of such guidelines should enable the Committee to replace previous definitions of classes which were based on material descriptions.

For evaluating new insulation systems by comparison with reference systems, specific test procedures will be developed by the responsible Technical Committees, when these Committees deem standardization to be necessary.

Very few test procedures have so far been standardized and in general it is the responsibility of the product manufacturer to devise and execute suitable tests where standardized tests do not exist.

Before designing suitable tests, reference should be made to the following I E C publications and documents:

505: Guide for the Evaluation and Identification of Insulation Systems for Electrical Equipment.

610: Principal Aspects of Functional Evaluation of Electrical Insulation Systems: Ageing Mechanisms and Diagnostic Procedures.

791: Performance Evaluation of Insulation Systems Based on Service Experience and Functional Tests.

More detailed recommendations concerning the design of thermal evaluation test procedures are given in:

611: Guide for the Preparation of Test Procedures for Evaluating the Thermal Endurance of Electrical Insulation Systems.

In selecting the individual components of an insulation system, some guidance may be obtained from the thermal evaluation of the materials alone (see Clause 3).

For a material to be recognized as suitable for use in a particular insulation system, it is sufficient to demonstrate satisfactory performance by appropriate system tests or by experience, irrespective of the thermal endurance of the material by itself.

For very simple and simply stressed insulation systems, the responsible Technical Committee may decide whether functional tests according to I E C Publication 611 are required or whether the simpler case of evaluation from materials' thermal endurance data according to I E C Publication 216 would produce satisfactory results. If it is necessary to evaluate the suitability of insulating materials for application in electrotechnical products then comparative tests should be performed using service proven materials as reference.

For the case of very simple and simply stressed insulation systems, it is recommended that the responsible Technical Committee provide information about service-proven materials for specific applications. Alternatively, it should provide rules on how to evaluate relevant experience which could be used to classify materials.

As long as the responsible Technical Committees do not present standardized procedures suitable for comparative evaluation, the responsibility to choose acceptable test procedures remains with the manufacturer of the product.

5. Classification

For the classification of electrotechnical products and their insulation, see Sub-clause 2.1, in particular Sub-clause 2.1.5, and Clause 4.

When an insulating material, simple combination, or an insulation system has been shown by test or from service experience to be capable of operating successfully at a particular temperature in a particular application it may be assigned the appropriate thermal class selected from the list in Sub-clause 2.1.