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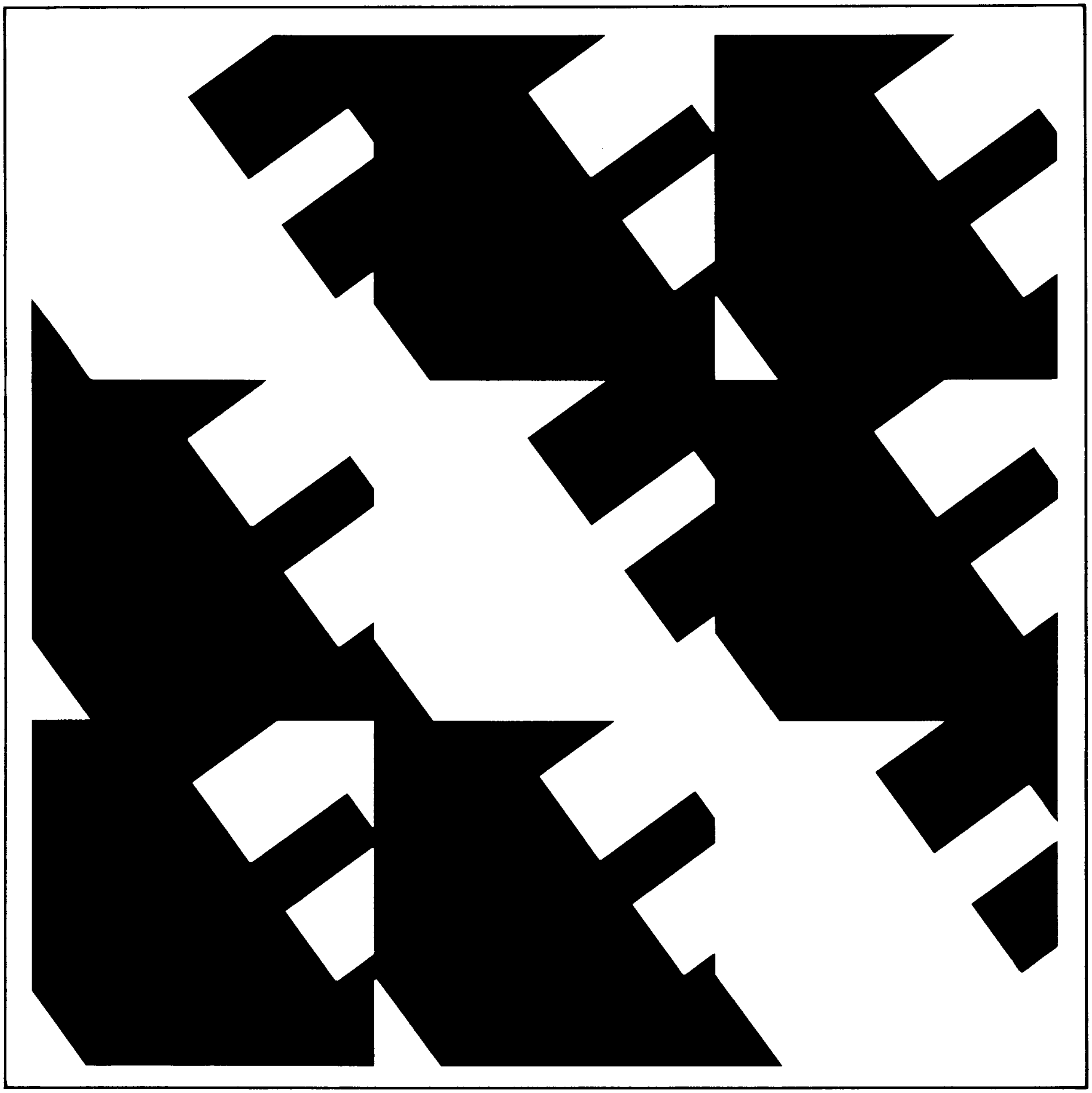
IEEE Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment



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1. Object and Scope

The purpose of this recommended practice is to provide a general form for the preparation of test procedures and to suggest the points to be considered by technical committees in the preparation of specific instructions for the thermal evaluation of insulation systems for equipment. The thermal evaluation of an insulation system involves the thermal (*T*) factor of influence as described in IEC 505 (1975), Guide for the Evaluation and Identification of Insulation Systems of Electrical Equipment.

These test procedures involve accelerated thermal aging of insulation systems and specify tests which the committees deem pertinent, based on conditions of use. The objective of these test procedures is to provide for the functional evaluation, by test, of insulation systems for electric equipment. The evaluation of insulating materials and simple combinations thereof is provided for by a separate material test guide, IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indexes of Solid Electrical Insulating Materials.

For a detailed discussion of the principles on which IEEE Std 98-1972 and IEEE Std 99-1980 are based, see IEEE Std 1969, General Principles for Temperature Limits in the Rating of Electrical Equipment. Tests based on IEEE Std 98-1972 may be considered as preliminary tests for insulation system evaluation, but should not be used as accepted tests for the classification of systems.

2. References

[1] IEC 505 (1975), Guide for the Evaluation and Identification of Insulation Systems of Electrical Equipment[1]

[2] IEC 610 (1978), Principal Aspects of Functional Evaluation of Insulation Systems; Aging Mechanisms and Diagnostic Procedures

[3] IEC 611 (1978), Guide for the Preparation of Test Procedures for Evaluating the Thermal Endurance of Electrical Insulation Systems

[4] IEEE Std 1-1969, General Principles for Temperature Limits in the Rating of Electric Equipment

[5] IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indexes of Solid Electrical Insulating Materials

[6] IEEE Std 101-1972, Guide for the Statistical Analysis of Thermal Life Test Data, including IEEE Std 101A-1974, Simplified Method for Calculation of the Regression Line (Appendix to IEEE Std 101-1972)

[1] IEC documents are available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

3. Identification of Insulation Systems

Similar insulation systems may be used in different equipment and under varying exposure conditions. It is imperative for the sake of clarity that the test results be identified with the conditions of use and failure criteria as well as the temperature classification and desired life expectancy.

An insulation system is an assembly of insulating materials in a particular type, and sometimes size, of equipment. In general, a specific piece of equipment has one insulation system, but for some types of equipment having two or more subassemblies, it may be desirable to consider that there are a corresponding number of insulation systems.

For classification purposes, the insulation systems being considered for specific equipment procedures should be prepared using the following for the definition of each class:

"Class ______. A class ______ insulation system is one that by experience or accepted test can be shown to have suitable thermal endurance when operating at the limiting class ______ temperature specified in the temperature rise standard for the equipment under consideration."

Experience, as used above, means successful operation for a long time under actual operating conditions of the equipment, designed with temperature rise at or near the temperature rating limit.

Accepted test, as used above, means a test on a system or model system that simulates the thermal aging occurring in service and correlates with service experience.

4. Test Procedures

Test procedures for the thermal evaluation of insulation systems for electric equipment should include descriptive remarks providing a clear understanding of the objectives of the particular tests with respect to the industry served and of the special requirements that exist.

The committees should ensure that each test procedure:

(1) Gives statistically consistent results

(2) Provides data free from bias of the tester

(3) Results in information that correlates with field experience in a generally acceptable manner

(4) Includes, if models are used, descriptions of these models (the equipment itself may be evaluated where feasible).

5. Test Objects

Wherever practicable, the equipment itself should be used for the thermal evaluation of insulation systems. However, when size and convenience require their use, insulation systems may be evaluated by models rather than by full-size equipment. Models should be made to embody the essential elements of the equipment they represent, and the process used for making them should approximate that used for manufacturing the equipment.

A model may include more than one insulation component or test specimen. Test procedures should specify the minimum number of models and test specimens that are to be tested under each particular aging condition to obtain reasonable statistical accuracy. The wider the spread in failure times among the specimens exposed at each temperature, the larger the number of test specimens required to achieve an acceptable degree of accuracy. The number of test specimens used at each exposure temperature should, therefore, be determined by a statistical analysis of the scatter in failure times and by the degree of accuracy desired in the determination of specimen life.

Preliminary tests should be included to assure that models are typical of the systems being tested and are capable of passing the diagnostic tests prior to the aging.

6. Thermal Aging

6.1 Choice and Control of Temperatures. Evaluation tests involve accelerated thermal aging in the specified ambient with exposures to diagnostic factors, either periodically or continuously. A primary objective of the test procedure is the determination of changes in the essential characteristics of insulation systems under various degrees of thermal aging. If cyclic exposure is used, each cycle shall include a temperature exposure period. The

Table 1
Illustrative Exposure Temperatures and Cycle Durations (°C)

Anticipated Service Temperature Range (°C)								Temperature Exposure Time per Cycle
80–104	105–129	130–154	155–179	180–204	205–229	230–254	255–279	
175	200	225	250	275	300	325	350	6 hours
165	190	215	240	265	290	315	340	12 hours
155	180	205	230	255	280	305	330	1 day (24 h)
145	170	195	220	245	270	295	320	2 days (48 h)
135	160	185	210	235	260	285	310	4 days (96 h)
125	150	175	200	225	250	275	300	8 days (192 h)
115	140	165	190	215	240	265	290	16 days (384 h)
105	130	155	180	205	230	255	280	32 days (768 h)
95	120	145	170	195	220	245	270	64 days (1536 h)

NOTES:
(1) This table is considered to be illustrative only, and other tables are in use. The appropriate equipment technical committee can choose test ranges, exposure temperatures, and length of cycles to be suitable for their particular equipment problems. They may find it convenient, for example, to replace the temperature range by a specific limiting temperature, or to make the time per cycle in weekly multiples, or to adjust the aging temperature for laboratory convenience.
(2) The end of insulation life is assumed to have occurred at the midpoint of the exposure time between two consecutive applications of diagnostic factors: the one during which failure was observed, and the last prior application of diagnostic factors with no failures (see Section 8).

service, it may be necessary to consider the additional stress which may be introduced in this fashion. Periodic temperature changes within each test cycle may be required to meet the functional needs for some type of service. In such cases the exposure time at a temperature is not the equivalent of a steady temperature (see also 8.4).

8. Diagnostic Factors

When making functional tests for the thermal evaluation of insulation systems, other stresses, such as electrical, mechanical, and environmental, are frequently used as diagnostic factors to determine end points. Diagnostic tests are tests which are applied to determine if thermal degradation has occurred, but in themselves should cause little, if any, degradation. Preliminary testing should be done to ascertain that the diagnostic tests can detect significant changes. Models should be subjected to the diagnostic tests before starting the thermal aging procedure.

IEC 610 (1978), gives a good review of considerations when establishing an equipment test procedure.

8.1 Humidification. Humidification in varying degrees, not causing irreversible changes, can be used as a diagnostic factor to make electric tests more discerning of physical and thermal damage to electrical insulation systems. The presence of condensed moisture on insulation permits overvoltages to seek out and discern cracks and porosities in insulation, whether such openings are the result of faulty construction, physical damage, or thermal aging.

Humidity, in most cases, it recognized as a major cause of variation in the properties of electrical insulation and may cause several different types of insulation failure under electric stress. The absorption of moisture by solid insulation has a gradual effect of increasing dielectric loss, reducing insulation resistance, and may contribute to a change in electric strength.

It may be desirable to use 100% relative humidity for periodic moisture exposure. Condensation, its presence or absence, should be specified. In some cases lesser degrees of humidification may be suitable (for example, on random wound motorettes and some models it has proven to be more effective to prevent condensation during the humidification cycle). When humidification is selected as a diagnostic factor, the time of exposure, temperature, relative humidity, and temperature difference between insulation and environment should be specified. If the testing cannot be performed while the specimen is exposed to humidification, specification should be made of the maximum time between removal from humidification and testing.

8.2 Mechanical Stress. For equipment usually subjected to vibration, physical shock, thermal cycling, or other mechanical stress, the test procedure may include exposure to such conditions as a diagnostic factor. The mechanical stress should be of such magnitude that it does not introduce significant additional aging. For models, as well as some types of equipment, the most practical way of introducing mechanical stress is by means of vibration, shock, short circuit, or running the model. The type, severity, and duration of the forces should be specified.

8.3 Electrical Stress. When electrical stress is used as a diagnostic factor, the test voltage is usually selected to be of a level similar to that used in normal acceptance or maintenance testing of the equipment so as to ascertain when any portion of the insulation system has deteriorated to a condition such that it is unreliable for continued service. The voltage test should not be of such duration as to introduce significant additional aging.

8.4 Stress Caused by Extreme Temperatures. For those applications which may involve temperature extremes, short-time exposure to either very low or very high temperatures may be used as a diagnostic factor. In some cases it may be desirable to change the temperature rapidly so as to introduce a thermal *shock* which is characteristic of service conditions. An extreme high temperature should be of limited duration to avoid the introduction of significant additional thermal aging.

9. End-Point Criteria

Each test procedure should be specific in describing the various criteria for the determination of the end point. The selected end point should be directly or indirectly relatable to serviceability. The life, at the test temperature, of an insulation system specimen is defined as the total test temperature exposure time minus one half of the exposure time of the cycle during which failure occurred. Normally the cycles of temperature exposure and application of diagnostic factors are repeated until all the specimens have failed.

10. Interpretation of Thermal Endurance Data

The method for analyzing and reporting the data should be described in detail in the test procedure.

It is important for uniformity of interpretation that the test procedure specify the following:

(1) The temperature range over which the endurance values of insulation systems may be extrapolated. This extrapolation should be limited. When data are used to evaluate thermal endurance under service conditions, it is recommended that extrapolation from the lowest exposure temperature be not greater than 20°C.

(2) The mathematical treatment of data, including expressions of confidence limits. A treatment of data of this kind may be found in [6].[2]

(3) The special limitations regarding extrapolation and spread of data for the case in which the thermal endurance curves being compared are quite dissimilar and are not reasonably linear, coincident, or parallel.

(4) The values of time or temperature to be taken from thermal endurance curves to be used for the comparison of insulation systems.

[2] Numbers in brackets correspond to those of the Bibliography, Section 2 of this Recommended Practice.