

IEEE Standard Test Procedure for Thermal Evaluation of Systems of Insulating Materials for Random- Wound AC Electric Machinery

IEEE Power and Energy Society

Sponsored by the
Rotating Machinery Committee



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USA

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IEEE Standard Test Procedure for Thermal Evaluation of Systems of Insulating Materials for Random- Wound AC Electric Machinery

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Abstract: The standard test procedure for the thermal evaluation and qualification of electrical insulation systems (EISs) for random-wound ac electric machinery, where thermal degradation is the dominating aging factor, is described. The relative thermal performance of a candidate EIS is compared to that of a reference EIS. Insulation systems for such machinery with input voltage of up to 600 V at 50/60 Hz are described in this standard. A statistical method for establishing a relative life-temperature relationship for an insulation system is also described. To have any significance, the reference insulation system must be supported with adequate field service data. Evaluation of insulation systems for use in air-cooled, random-wound ac electric machinery with “usual service conditions” is this procedure’s intent. This procedure, on its own, does not cover insulation systems such as exposure to conducting contaminants, radiation, inverter applications, or operation in oils, refrigerants, or other media that potentially degrades insulating materials.

Keywords: ac electric machinery, IEEE™, insulation system, random-wound, thermal evaluation

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Introduction

This introduction is not part of IEEE Std 117™-2015, IEEE Standard Test Procedure for Thermal Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.

This standard provides an evaluation of the thermal capability of an unsealed random-wound insulation system. Other aging factors—electrical, mechanical, and environmental—are also known to be important. Test procedures for evaluating those factors, both individually and in combination with each other, will be pursued by other working groups.

This standard was updated in 2015, with specific limitations noted here:

- Consideration of uprating for usage to 1000 V was discussed, but not implemented in the 2015 version. This was due to concerns about uprating without adequate test data. Publications and data collection of testing up to 1000 V should be completed prior to placing it into an IEEE standard.
- The use of a condensation chamber is listed herein. There is a round-robin study pending that will investigate the alternate use of a humidity chamber for testing. At present this standard remains with the wording of condensation chamber.

Comments on, and suggestions for the improvement of, this standard are welcome, and should be sent to the IEEE Standards Board (see Participants).

Acknowledgements

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Contents

1. Overview	9
1.1 Scope	9
1.2 Purpose	9
1.3 General conditions	10
1.4 Methods of evaluation	10
2. Normative references	10
3. Definitions, abbreviations, and acronyms	11
3.1 Definitions	11
3.2 Abbreviations and acronyms	11
4. History	11
4.1 Background information	11
4.2 Methods of evaluation	12
5. Motorettes	13
5.1 Insulation test specimens	13
5.2 Test exposures for motorette testing	17
5.3 Voltage checks for motorette testing	21
5.4 Failure criteria for motorette testing	22
6. Motors	22
6.1 Test procedure for motors	22
6.2 Motor models	23
6.3 Test exposures for motor testing	25
6.4 Operating cycle sequence testing	27
7. Analysis of data	28
7.1 Data	28
7.2 Analysis	28
7.3 Comparison	28
7.4 Extrapolation	28
7.5 Nonlinear or dissimilar curves	28
Annex A (informative) Thermal-class definitions	29
Annex B (informative) Bibliography	31

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IEEE Standard Test Procedure for Thermal Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery

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1. Overview

1.1 Scope

This is a standard test procedure for the thermal evaluation and qualification of electrical insulation systems (EISs) for random-wound ac electric machinery, where thermal degradation is the dominating aging factor. This procedure compares the relative thermal performance of a candidate EIS to that of a reference EIS. This standard covers insulation systems for such machinery with operating voltage of up to 600 V at 50/60 Hz. This standard provides a statistical method for establishing a relative life-temperature relationship for an insulation system. To have any significance, the reference insulation system must be supported with adequate field-service data. This procedure is intended to evaluate insulation systems for use in air-cooled, random-wound ac electric machinery with “usual service conditions.” This procedure, on its own, does not cover insulation systems such as exposure to conducting contaminants, radiation, inverter applications, or operation in oils, refrigerants, or other media that potentially degrade insulating materials.

1. Introduction

1.2 Purpose

The ~~chief~~ purpose of this ~~test~~ standard procedure is to classify insulation systems in accordance with their temperature limits by test, rather than by chemical composition. ~~The intention is, first to classify according to the recognized thermal classification A, B, F, H, and above H categories as referenced in the Appendix. The motorette procedure is intended to be used as an Industry Standard for insulation systems in that data obtained in accordance with this standard can be correlated between testing laboratories~~ This test procedure has been prepared to outline useful methods for the evaluation of systems of insulation for random-wound stators of rotating electric machines. The motorette procedure described is used for the evaluation of EISs.

1.3 General conditions

The concepts implemented in this recommended practice are based on IEEE Std 99™.¹

¹Information on references can be found in Clause 2.

The intent of this procedure is to classify candidate insulation systems by comparing them to reference insulation systems in machines with service-proven performance. Temperature classification of insulation systems are designated 105 °C, 130 °C, 155 °C, 180 °C, 200 °C, 220 °C, 240 °C, and above 240 °C, previously referred to as temperature classifications Class A, B, F, H, N, R, S or C categories, respectively (see Annex A for further information). It is expected that the several insulating materials or components that form any insulation system to be evaluated by these procedures will first be screened by the appropriate test procedures for each type of material. Thermal indices for discrete insulating materials can be obtained by following the procedures shown in IEEE Std 98™.

Thermal indices of insulating materials cannot be used to classify insulation systems. They are to be considered only as screening tests for this system test.

1.4 Methods of evaluation

This test procedure describes test models suitable for use in random-wound insulation tests. The procedure recommends a series of heat exposures to which the test models may be subjected to represent the cumulative effects of long service, using accelerated aging parameters. Procedures are given for applying periodic voltage checks preceded by periods of mechanical stress and moisture to establish the end point of insulation life by electric failure.

To obtain an acceptable statistical average, for each chosen temperature of heat exposure, an adequate number of samples should be carried through the test procedure until failure occurs. It is important that the tests on the samples be performed at a minimum of three different aging (exposure) temperatures for each insulation system to be evaluated.

After the final results of the tests are known and the test life hours have been projected to a rated temperature, the ratio of the aging (exposure) hours of the candidate EIS compared to the aging (exposure) hours of the reference EIS can provide a rough measure of the service life expectancy of the candidate system in relation to that of the reference system.

Based on the current state of the art in terms of test procedures, no accurate prediction of actual service life can be made from test results alone. This procedure will permit approximate comparisons only, and cannot be relied upon to completely determine the merits of any particular insulation system. Such information can be obtained only from the experience of extended service. By following the general procedures outlined herein, the temperature classification in which any candidate insulation system belongs can be determined.

2. Normative references

The following referenced documents are indispensable for the application of this document, i.e., they must be understood and used. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 1-~~1969~~, IEEE Recommended Practice—General Principles for Temperature Limits in the Rating of ~~Electric Machinery~~ Electrical Equipment and for the Evaluation of Electrical Insulation.^{2,3}

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IEEE Std 98-1972, ~~Guide~~ [IEEE Standard](#) for the Preparation of Test Procedures for the Thermal Evaluation ~~and Establishment of Temperature Indices~~ of Solid Electrical Insulating Materials.

IEEE Std 99-1970, ~~Guide~~ [IEEE Recommended Practice](#) for the Preparation of Test Procedures for [the](#) Thermal Evaluation of Insulation Systems for Electric Equipment.

IEEE Std 101-1972, [IEEE](#) Guide for the Statistical Analysis of Thermal Life Test Data. [NEMA MG 1, Motors and Generators.](#)⁴

3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms and Definitions*⁵ should be consulted for terms not defined in this clause.

condensation chamber: A device with an atmosphere of high (95%–100%) relative humidity that is designed to produce visible condensation on the windings.

⁴NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

⁵*IEEE Standards Dictionary Online* subscription is available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

motorette: The model suitable for use in insulation evaluation testing, with a simulated stator slot system.

3.2 Abbreviations and acronyms

EIS electrical insulation system

4. History

4.1 Background information

A wide variety of synthetic electrical insulation materials ~~is~~ are available for application in electric machinery and apparatus. As there is a growing tendency either to rely solely on these materials as electrical insulation₇ or to employ them with the ~~old-familiar~~ historic materials in novel combinations, there is a corresponding increase in the problems associated with the selection and evaluation of insulations. Consequently₄, a complete insulation system must be evaluated rather than testing only the individual insulating materials.

Many of the specifications regulating the use of insulation materials were written before the advent of the newer synthetics and were based upon experience gained with the old materials over a long period of time. Difficulties arise, therefore, when an effort is made to classify these new materials or combinations for insulation purposes under IEEE Std 1-1969 ~~General Principles for Temperature Limits in the Rating of Electric Machinery and supplementary documents~~ IEEE Std 98-1972, ~~Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indices of Solid Electric Insulating Materials,~~ as well as supplementary documents IEEE Std 98 and IEEE Std 99 ~~1970~~.

~~Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment~~ Current synthetic materials exhibit a wide range of properties ~~is available in current synthetic materials, so that,~~ but the following must be considered:

- a) It is not feasible to classify them on the basis of their chemical composition alone. ~~Secondly~~
- b) Second, it is not desirable to wait and acquire the knowledge required to classify them solely on the basis of experience.
- c) In ~~the third place~~ addition, composite systems of insulation, in which materials of different temperature classes are used in different parts of the structure, may give satisfactory service at temperatures higher than normally permitted for the lowest temperature component; and, conversely, compatibility or other problems may arise whereby the highest temperature component is rendered unsuitable for use at its classified temperature.

This test procedure has been prepared to outline useful methods for the evaluation of systems of insulation for random-wound stators of rotating electric machines. It is expected that the several insulating materials, or components, making up any insulation system to be tested will first be screened in accordance with specific test procedures for each type of material. Normally, materials that have given acceptable performance in these separate screening tests ~~would~~ are be included in the system evaluation tests outlined in this procedure.

This procedure is intended to evaluate insulation systems for use in “usual service conditions” with air cooling. It has also been a useful tool for evaluating systems for special requirements where machines are enclosed in gas atmospheres, subjected to strong chemicals, ~~to~~ or metal dusts, or ~~submersion~~ submersed in liquids. However, these special requirements are beyond the scope of this test procedure.

4.2 Methods of evaluation

The test procedure includes two principal sections.

- a) Section 2 Clause 5 describes ~~motorettes (models suitable~~ types of specimens to be used for ~~use in insulation evaluation tests) and recommends a series~~ testing as well as recommending a series of exposures to heat, vibration, and moisture, to which the specimens (motorettes) may be subjected to represent cumulative effects of long service, under accelerated conditions. Procedures for applying periodic voltage checks to establish the end point of insulation life, are also given.

b) [Clause 6](#) describes similar procedures when actual motors are used as ~~the~~ test specimens.

It is recommended that for each particular system to be evaluated, a suitable type of a specimen, namely a motorette or a complete motor, be selected; and then an adequate number of these be subjected to repeated cycles of heat, vibration, moisture, and electrical stress as outlined in ~~Sections 2 and 3~~ [5.2](#) of this procedure.

An adequate number of samples to obtain a good statistical average, in no case less than ~~ten~~ [10](#) motorettes or five motors, should be carried through the test procedure until failure occurs, for each chosen temperature of heat exposure. It is recommended that the tests be carried through on the indicated number of specimens for at least three different test temperatures, for each insulation system to be evaluated. To promote uniformity in the results ~~there are given~~, [Table 1 provides](#) six possible ranges of exposure requiring from 1 ~~day~~ [d](#) to 32 ~~days~~ [d](#) per given temperature, that are appropriate for making these tests.

The number of cycles and the total number of hours of heat aging, to the end of life for the average of each group of samples and for each of the test temperatures, are then reported as the final results of the tests. The extrapolated regression line obtained for a new insulation system is determined from these data according to the procedure in IEEE Std 101-~~1972, Guide for Statistical Analysis of Thermal Life Test Data.~~ (The motorette or motor life from an *accepted standard* [system](#) must be used as the criterion to determine the new thermal rating [for the](#) insulation system from the plot. A control set of test units using an established insulation system should be used so that a comparison of the new system to the old system can be made). As indicated in ~~Section~~ [5.2](#), the combined effects of the heat, vibration, moisture, and electrical stresses imposed on the insulation during these tests are intentionally made more severe than those normally found in service at the same temperature. Therefore, the life of any given insulation system in these tests will be shorter than that to be expected in actual service at a comparable temperature.

~~At present~~ This procedure ~~will permit~~ [permits](#) approximate comparisons only and cannot be relied upon to completely determine the merits of any particular insulation. Such information can only be obtained from extended service experience. In the course of time, however, it is expected that enough data may be obtained from tests of this kind to establish a normal number of hours of heat aging before failure that will be representative of each of the standard temperature classes of insulation [systems](#).

5. Motorettes

5.1 Insulation test specimens

[5.1.1 Motorette general construction](#)

~~2.1.1 Scope~~

This ~~section~~ [subclause](#) suggests appropriate test specimens for evaluating insulating systems that may be usefully subjected to the exposures outlined in ~~Section~~ 5.2, to simulate their behavior in service. It is considered that one type of motorette, as defined in the following, will adequately represent random-wound machines of both fractional and integral [horsepower](#) of 600-V rating or less. Other types of specimens will be required to represent machines with [operating voltages other](#) ~~more~~ than 600 V and with other than random-wound insulation systems. Procedures for evaluating such other types of insulation ~~not covered elsewhere [21.22] understudy, and will be included in future revisions of this procedure.~~ [fall outside the scope of this standard. \(See IEEE Std 1107-1996 \[B15\]⁶ and IEEE Std 1776 \[B16\].\)](#)

⁶[The numbers in brackets correspond to those of the bibliography in Annex B.](#)

5.1.2 Motorettes

The model shall be made to embody all of the elements and should be, as nearly as possible, representative of a complete winding insulation system. Specifically, it is recommended that for the purposes of testing random-wound motor insulation a motorette be employed, as shown in ~~Figs~~ [Figure 1](#), [Figure 2](#), and [Figure 3](#). At least ~~ten~~ [10](#) motorettes shall be subjected to each of a series of test exposures ~~as outlined in the following:~~ [5.2](#).

~~Fig~~ [Figure 1](#) shows typical components of a motorette before final assembly, [while Figure 2 shows the assembled motorette, and Figure 3 shows the motorette frame dimensions](#). Each of these components should be subjected to separate screening tests to establish uniformity and normality before they are assembled. For example, a number of representative samples of the wire, slot, ~~cells~~ [and](#) phase insulation, ~~and so forth,~~ [as well as wedges, all of which](#) may be broken down by ~~60-Hz ac~~ high-potential tests, or other means. It should be recognized that the number of tests [that are](#) required to establish the acceptable temperature limit in service will increase greatly, if the performance of individual components varies over a wide range. Therefore, everything possible should be done to assure that the individual components are uniform and representative of the materials used in actual service.

The finished motorette consists of a rigid supporting metal stand with four suitable stand-off porcelain insulators bolted to one end and with a slot portion, made from an inner and outer plate, bolted to the other end. The supporting stand has holes for mounting the fixture during vibration testing. The slot sections are fabricated from US Standard ~~no~~ [#16](#) gauge (1.52 mm[0.060 in]) steel sheets such as AISI 1010 cold rolled steel. The assembled slot portion contains two coils [of magnet wire](#) insulated from ground by slot insulation, insulated from each other by phase insulation, and held in place with slot wedges. These components are typical parts used in actual motors. The coils are each wound with two parallel wires ([bifilar wound](#)) so that conductor-to-conductor electrical tests may be made. They can be machine wound on pins or forms, as in ordinary shop practice.