

IEEE

No. 259

JAN. 1965

*Proposed
Test Procedure
for*

EVALUATION OF SYSTEMS OF INSULATION

for

SPECIALTY TRANSFORMERS

(Published for Trial Use)

IEEE No. 259



PUBLISHED BY

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Inc.

BOX A, LENOX HILL STATION, NEW YORK, N. Y. 10021



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Full document details: IEEE 259-1965

PREFACE

In specialty transformers, as in any electric machinery, insulation must be provided, the electrical and mechanical strength of which will remain adequate throughout the expected life under expected conditions of loading and operation. The choice and placement of insulating materials to provide such adequacy and at the same time furnish maximum utilization of material properties becomes an important problem.

Experience has shown that the thermal life characteristics of composite insulation systems cannot be reliably inferred solely from information concerning component materials. To assure satisfactory service life, insulation specifications need to be supported by service experience or life tests. Accelerated life tests are being used increasingly to evaluate the many new synthetic insulating materials that are available, thus shortening the period of service experience required before they can be used with confidence. Tests on complete insulation systems, representative of each type of equipment are necessary to confirm the performance of materials for their specific functions in the equipment.

ACKNOWLEDGMENT

Acknowledgment and thanks are extended to those who have so freely given of their time and knowledge and have conducted experimental work on which this Test Procedure is based.

This Test Procedure was prepared by the Working Group on Application of Insulating Materials to Specialty Transformers for the Subcommittee on Insulation Life of the Transformers Committee.

The personnel of the Working Group are, or have been

P. A. Vance, *Chairman*

E. E. Aldrich	W. T. Sackett, Jr.
G. I. Duncan	T. F. Saffold
W. G. Fockler	C. F. Salt
P. K. Goethe	M. W. Sims
A. V. Hughes	R. O. Truemner
L. W. Kirkwood	G. E. Walter
E. W. Lindsay	B. A. Wise

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INTRODUCTION

The object of this Test Procedure is to establish a method for estimating by comparison the life expectancy of specialty transformer insulation systems under actual operating conditions.

The electrical insulation of specialty transformers is made up of many different components selected to withstand the widely different electric, mechanical, and thermal stresses occurring in different parts of the structure. How long an insulation system will be serviceable depends on the effectiveness of the physical support for the insulation, and the severity of the forces acting on it, as well as on the materials themselves and the service environment. Therefore, the length of useful life of the insulation system will depend on the way that its individual components are arranged, their interactions upon each other, and the contribution of each component to the electrical and mechanical integrity of the system.

It is the intent of this Test Procedure to have each component of the composite structure operate and perform during the test under conditions which are similar to actual operating conditions in the transformer, modified only as necessary to accelerate failure. Prolonged exposure to high temperature is the principal aging factor employed in these tests. Other tests such as mechanical stress, exposure to moisture, and voltage have been chosen in such a way as to develop and disclose promptly any significant weakness or deterioration of the insulation system.

The Test Procedure includes three principal sections:

Section 1—Insulation Test Samples. This section describes the types of insulation samples suitable for use in the evaluation tests.

Section 2—Test Cycle. This section recommends the test cycle for use in the insulation evaluation tests. This cycle consists of a series of exposures to heat, vibration, moisture, and voltage to which the test samples may be subjected to represent cumulative effects of long service, under accelerated conditions.

Section 3—Interpretation of Data. This section establishes the criteria of failure, recommends a method for analyzing and presenting the test results and for determining the insulation life expectancy at the desired temperature under the test conditions, and provides a guide for applying specific life test data to other transformers, models and ratings.

This procedure will permit 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. For the present time at least, it will be necessary for each user of this procedure to establish test data on insulating systems of known reliability for comparison with new or unknown systems. 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 the standard temperature classes of insulation 105C, 130C, and 180C, for each type of specimen. It may also be feasible to specify the number of hours before failure that will be appropriate as indications of satisfactory performance under special service conditions, such as short-time or intermittent and high-temperature exposures.

Proposed

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SECTION 1

Insulation Test Samples

I. Whenever economically practicable, actual transformers shall be used for the thermal evaluation of insulation systems. (See Section 3, IV).

II. When size and convenience require that models rather than complete transformers be used for evaluation of insulation systems, the models should be made to embody all the essential elements, and should be as nearly as possible representative of a complete winding system and its structural supports.

Since no standard model can be established for all the types and sizes of transformers employing the insulation systems to be evaluated by this Test Procedure, it shall be the responsibility of each test laboratory to use suitable models. Full and complete design information on the model shall be published at the time of presenting test data.

The coils shall contain all the elements employed in the coils they simulate and should be considered only as smaller replicas. Insulation thicknesses and creepages shall be appropriate for the voltage class and industry or equipment standards or practices. The arrangement of the different components, such as conductors, insulations, supporting members,

spacers, and ground shall duplicate electrically, thermally, and mechanically the conditions existing in the transformer. The electric components shall be so arranged as to permit a dielectric test on the various insulation components.

Each designer of a specific model shall select the over-all design and components carefully with the objective of truly evaluating the insulation system as a whole. It is recommended that only insulating materials on which life data is available be used in system evaluations. Each component used should be subjected to separate screening tests, to establish uniformity and normality before assembly. Everything possible should be done to assure that the individual components are uniform and representative of the materials used in actual service.

SECTION 2

Test Cycle

The test specimens shall be subjected to a repeated test cycle, consisting of the following parts, in the order given in Table I. Where indicated, specific values for some of the test conditions will be found in Table III, which provides varying degrees of severity for different applications.

Table I—Test Schedule

<i>Purpose</i>	<i>Part</i>	<i>Test</i>	<i>Remarks</i>
Initial Test	I	Dielectric Proof Test	Beginning of first cycle only
Basic Test Cycle	II	Temperature Aging	Four 20-hour periods
	III	Mechanical Stress	See Table III
	IV	Thermal Shock (when specified)	See Table III
	V	Moisture Exposure (or special atmosphere)	See Table III
Continual Testing		Repeat the basic test cycle until failure occurs (Parts II, III, IV, and V)	

It is recognized that for some equipment there may be special requirements, other than those represented in this Test Procedure, such as ability to withstand surge tests, direct-current polarizing voltages during moisture exposure, etc. For these cases, special tests should be formulated and added to the test cycle recommended herein.

It is also recognized that, depending on the test facilities available, the type of specimen employed, and other factors, slight variations in the methods of exposing the specimen may be necessary. It is all-important that, when any two different materials or insulation systems are compared, the test specimens of each shall be subjected to precisely the same

exposures and other conditions of test. Unless otherwise specified, tests shall be carried out at normal room temperature and humidity.

I. Dielectric Proof Test

Prior to the exposure to an elevated temperature on the first test cycle a dielectric proof test shall be made on all test specimens.

The dielectric proof test shall consist of applied-potential and induced-potential tests under the conditions of and at the voltages recommended by applicable Standards for the type of specialty transformers involved.

Equipment for which no acceptable standard test is available may be tested according to the following recommended procedure at approximately room temperature and in normal humidity.

A. Applied-Potential Test

1. The applied-potential test shall be made by applying between each winding separately, and all other windings and ground, a 60-cycle-per-second voltage from an external source. The winding under test shall be shorted on itself during the test. All other circuits and metal parts shall be grounded during the test.
2. The duration of the applied-potential test shall be for one minute at the value specified in 3 below:
3. The rms test voltage shall be $\sqrt{2}$ times normal working voltage¹ plus 1000 volts. The rms test voltage shall be applied at a rate not to exceed 1000 volts per second.

B. Induced-Potential Test

1. The induced-potential test shall be made by applying across the terminals of any suitable winding a voltage that will stress the turn and layer insulation at a peak value twice their normal working voltage¹ but will not stress inter-winding, winding-to-core, or other insulation to voltages higher than that specified in IA-3 above. A frequency twice normal is usually required to avoid core saturation.
2. The induced-potential test shall be applied for 7200 cycles. The duration shall not exceed 60 seconds. Example of equivalent tests are as follows:

<i>Frequency, cycles per second</i>	<i>Duration of Test, seconds</i>
120 or less	60
180	40
240	30
360	20
400	18
900	8

II. Temperature Aging

The temperature aging portion of the cycle shall include 80 hours of "on" time in accordance with the following:

- A. Temperature aging shall be done by exciting the transformers or test models at rated voltage and causing current to pass through the conductors until the desired test temperature is attained. When conservation of power and simplification of the test setup is important, the transformers may be loaded in a buck-boost or opposition arrangement.
- B. The test temperature is that of the hottest spot in the windings. The relationship of the hottest spot temperature to the winding temperature, determined by change of resistance, or to the temperature of an embedded detector, shall be determined for the specimen under test. (It is recommended that a formula be derived relating hottest-spot temperature rise above average winding temperature to unit size, etc.)
- C. During thermal aging, the movement of air at the surface of the specimen shall be substantially only the convection caused by the specimen itself, and shall not constitute forced or restricted cooling. The ambient temperature shall be between 20C and 40C.² After the test temperature defined in II-B, above, has been reached and made stable by the adjustment of current described in II-A, above, further control of the test temperature may be obtained (1) by controlling the current in the conductors to maintain the temperature of the hottest winding within $\pm 5C$ as indicated by the change of resistance method,³ (2) by controlling the current in the conductors to maintain the temperature of a high-temperature location in or on the specimen within $\pm 5C$, as indicated by a suitable temperature-sensing means, or (3) by controlling the ambient temperature within $\pm 2C$ and the applied voltages within ± 1 percent, while the loading means is fixed. Regardless of the method of temperature control used, the temperature of the hottest winding shall be determined by the change of resistance method³ or by the embedded detector at the conclusion of the 80-hour thermal aging portion of the test cycle described in II-D.

¹ The working voltage is defined as the maximum peak voltage stress that may occur under normal rated operation across the insulation being considered. This insulation may be between windings or between winding and case or core.

² It is felt that transformers to operate in ambient temperatures above 40C should be tested in their normal operating ambients for a more accurate determination of life. More data is needed to verify this point.

³ Permanent changes in wire resistance may be caused by aging at temperatures (above about 250C for copper), any such effect should be compensated for when using the change of resistance method of temperature measurement.