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Proposed
Test Procedure
for THERMAL EVALUATION of
VENTILATED DRY-TYPE POWER and DISTRIBUTION
TRANSFORMERS

(Published for trial use)



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PREFACE

For many years, temperature limits for electric apparatus have been founded upon classification of insulating materials by broad general definitions based upon chemical composition¹. Recently, it has become apparent that this method no longer meets the needs of the industry and that a new approach is needed, based upon functional tests.^{2,3,4,5,6}

The latest revision of AIEE No. 1¹ recognizes this need by the following statement:

The electrical insulation of equipment 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. To assure satisfactory service life, therefore, insulation specifications need to be supported by service experience or life tests, on the complete insulation system. Accelerated life tests are increasingly important as a means of evaluating the many new synthetic insulating materials that are available, thus shortening the period of service experience required before they can be used with confidence. It is desirable that life tests on materials be

supplemented by tests on complete insulation systems, representative of the different types of equipment.

It is contemplated that, in the course of time, Institute Test Codes will be developed, giving procedures for such accelerated life tests, and other methods of evaluating insulating materials and systems.

Accordingly, this test procedure is intended to establish methods for evaluating the insulating systems of ventilated dry-type power and distribution transformers. It is expected that test procedures covering other classes of transformers will be prepared from time to time as the lengthy but necessary study and trials are completed.

During the preparation of this test procedure, members of the subgroup built and tested more than fifty transformer models in accordance with the recommended methods. The results demonstrated that the methods are workable, even though there were a few details on which further work will be necessary before final decisions can be made. The test procedure, therefore, is offered for trial use in order to obtain wider distribution and to encourage discussion, criticism, and trial by others.

ACKNOWLEDGEMENT

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

The major work of preparing the code and trying out its procedures was done by the Subgroup on Functional Tests for Dry-Type Transformers of the Working Group on Life of Materials, with personnel as follows:

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Proposed Test Procedure ***of the*** **American Institute of Electrical Engineers**

THERMAL EVALUATION OF VENTILATED DRY-TYPE POWER AND DISTRIBUTION TRANSFORMERS

The object of this Test Procedure is to establish a uniform method for determining operating temperature limits for ventilated dry-type power and distribution transformers, to give a reasonable life expectancy under normal operating conditions.

The subjects covered by this Test Procedure are subdivided according to the following plan:

- Sections 1 to 7—Basic considerations
- Sections 10 to 12—Specifications for test samples
- Sections 20 to 27—The test procedure
- Section 30 —Reporting

Section 1.

The test covered by this Test Procedure is intended to give a direct evaluation of the composite insulation system of a dry-type transformer, tested as an integral unit.

Section 2.

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 as nearly as possible the same as its actual operating conditions in the transformer. Thus, it is intended that each of the components is evaluated in accordance with its actual function.

Section 3.

The primary aging factors shall be temperature and time.

Section 4.

Each test shall be carried out simultaneously on a group consisting of a number of identical samples, sufficient to give the desired statistical accuracy.

Section 5.

The life of a sample, aged at one temperature, shall be equal to the duration of temperature exposure during one test cycle, multiplied by the number of cycles to failure, less one half of one cycle.

The word "failure", above, shall be construed to mean any form of dielectric breakdown of insulation or a dielectric flashover, which may occur on any of the specified electrical tests. The type of failure shall be reported.

Section 6.

If a transformer is operated continuously at the permissible maximum hottest-spot temperature, its life ex-

pectancy will be less than that obtained under usual service conditions. Consequently, and because of the severity of the test conditions specified in this test procedure, the minimum acceptable value of extrapolated life of the test sample shall be taken as 4 years (35,000 hours). Experience and experimental evidence indicate that attainment of this nominal life under test results in a service life comparable to that of dry-type transformers now in use.

Section 7.

Tests specified in this Test Procedure are of an accelerated nature. Hence, extrapolation of the life obtained at the test temperature is required in order to obtain the temperature limit for normal life expectancy.

Furthermore, a certain amount of variation in the life of individual samples tested at the same temperature is to be expected.

In order to insure valid results obtained from such data, free of bias, and suitable for comparative studies, the test data shall be reduced statistically, according to procedure given in Appendix II, and the results reported according to Section 30. Tests may be carried out in accordance with Method 2, described below, when applicable; otherwise, Method 1 shall be used.

Extrapolations indicated in Section 30 shall be applied only for failures occurring in the same part of the insulating system. Should failures be occurring in more than one part of the system, data for each mode of failure shall be treated separately from others. Likewise, the temperature class shall be determined by extrapolation separately for each mode of failure, and the lowest value obtained shall be used as representing the temperature class for the complete transformer.

a. Method 1.

This method shall be used when incomplete information is available regarding the life of the insulating materials involved, or the life-temperature dependence.

At least three groups of samples shall be tested at three (or more) different temperatures, differing, preferably, by not less than 10 percent of the maximum test temperature in degrees centigrade. The results shall be reduced as directed in Appendix II, and reported as directed in Section 30.

b. Method 2.

This method is applicable when the life (L)-tem-

perature (T) dependence is known to be expressible by the equation:

$$L = A (2.718)^{b/T}$$

in which A and b are constants, and the value of b for the type of system being tested is known from previous tests. In this case only one group of samples (n-samples) needs to be tested, at one temperature value T_2 (degrees Kelvin). Extrapolation may be carried out by equation (1).

$$T_1 = \frac{b}{\ln(L_1/L_2') + (b/T_2)} \quad (1)$$

in which:

T_1 = temperature limit, degrees Kelvin (absolute),*
to give life expectancy equal to or greater than L_1 ,
as provided in Section 6, with 95 percent confidence level.

$$^* \text{ } ^\circ\text{K} = ^\circ\text{C} + 273$$

$$L_2' = \bar{L}_2 - 1.65 \sqrt{\Sigma (L_2 - \bar{L}_2)^2/n}$$

$\bar{L}_2$ = Mean value of life obtained at test temperature, T_2 ($^\circ\text{K}$), expressed in the same units as L_1 .

b = rate factor in the life-temperature dependence of the required properties for the materials involved.

$\ln$ = natural logarithm to the base $e = 2.718$.

For many phenolic base resins, varnishes, and similar materials, value of constant b = 11,500 may be used with good approximation. When the value of 11,500 is known to be applicable, Table I, which is based on this value and on $L_1 = 4$ years (1460 days), may be used as a guide.

TABLE I						
Aging Temp. C	Accumulated Days of Aging (Life of the Samples)					Operating Temperature Limit, C
	5	10	20	40	80	
188	—	110	120	130	140	
202	110	120	130	140	150	
216	120	130	140	150	160	
230	130	140	150	160	170	
246	140	150	160	170	180	
263	150	160	170	180	190	

Section 10.

Test samples must conform to the following requirements.

- Whenever possible, actual transformers shall be used. For small transformers this may be the simplest, most direct, and least expensive form of samples.
- For larger transformers the use of test models is permissible.

Section 11.

If test models of dry-type transformers are used for

test purposes, these shall be constructed in accordance with the following principles.

- The arrangement of the different components, such as coils, supporting insulating members, spacers, electrical barriers, layer insulation, and turn insulation, should be an essential duplicate of the transformer construction. Specifically, the manner of bracing and supporting of the high- and the low-voltage coils, used in the transformer, shall be duplicated in the model.
- All of the insulating clearances, such as air clearances from the windings to grounded parts and to other windings, thickness of insulating spacers, barriers, and layer insulation, shall be no greater than in the transformer represented by the model. Smaller clearances shall be permissible in non-critical locations which would not affect the results of the tests.
- The materials used for the various components of the structure of the model shall be identical with those used in the transformer.
- The electric components shall be so arranged as to permit a dielectric test on the various insulation components, such as major insulation to ground, turn, section, and layer insulation, where such are present.

Section 12.

A recommended test model for core-form dry-type transformers, representing a typical 15-kv class insulation structure, is shown on the attached drawing, Figure 1. Although specified dimensions are given on this drawing, it is to be recognized that these should be modified to represent the regular practices of different manufacturers. The high-voltage coil of this model shall be wound of two parallel conductors to permit dielectric test of turn insulation. The leads from each pair of twin sections are to be brought out separately to permit a section-to-section dielectric test. The low-voltage coil shall be wound of two layers, to permit test of layer insulation.

Section 20.

The test procedure shall consist of subjecting the test samples to a repeated test cycle, consisting of the following parts, in the order given:

- Temperature aging period;
- Dielectric test, dry, at ambient temperature;
- Humidification;
- Dielectric test under humid condition.

Prior to the exposure to an elevated temperature on the first test cycle, dielectric screening tests shall be made on all samples, as indicated in parts (b) and (d) inclusive, above. Samples not passing this screening test shall not be included in the statistical evaluation of life.

Section 21.

- Exposure to the elevated temperature shall be done by means of electric current circulated in the windings of the test sample.

