

IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Liquid-Immersed Distribution and Power Transformers

IEEE Power & Energy Society

Sponsored by the
Transformers Committee



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IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Liquid-Immersed Distribution and Power Transformers

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Transformers Committee
of the
IEEE Power & Energy Society

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Abstract: A test procedure to provide a uniform method for investigating the effect of operating temperature on the life expectancy of liquid-immersed transformers is provided. The test procedures are intended to provide data for the selection of a limiting hottest-spot temperature for rating purposes, provide data which may serve as the basis for a guide for loading, and permit the comparative evaluation of a proposed insulation system with reference to a system that has proven to be acceptable in service.

Keywords: aging, distribution transformers, IEEE C57.100, life tests, liquid immersed, power transformers, test procedures, thermal evaluation

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Introduction

This introduction is not part of IEEE Std C57.100-2011, IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Liquid-Immersed Distribution and Power Transformers.

This standard is intended to establish test procedures for evaluating the insulation systems of liquid-immersed transformers. The electrical insulation of transformers is subject to electrical, mechanical, and thermal stresses occurring in different parts of the structure. How long the insulation system will be serviceable depends on the transformer design and the severity of the stresses acting on it, as well as on the materials themselves and the service environment. Therefore, the length of useful life of the insulation system depends on the way that its individual components are arranged, their interactions upon each other, the contribution of each component to the electrical and mechanical integrity of the system, and the way the transformer is manufactured and operated.

Experience has shown that the thermal life characteristics of composite insulation systems cannot be reliably inferred solely from information concerning individual component materials. To assure satisfactory service life, transformer designs need to be verified by service experience or accelerated life tests. Tests on complete insulation systems, representative of each transformer design, are necessary to confirm the performance of materials for their specific functions in the transformer.

During the preparation of prior editions of this standard, manufacturers built and tested more than one hundred complete distribution transformers. The results of these tests, while not specifically published, confirmed the practicality of the test procedures in this standard for liquid-immersed distribution transformers. Subsequent to this work, it was recognized by prior working groups that a need existed for a similar test procedure for power transformers. To fulfill this need, two projects on “Basic Transformer Life Characteristics” were completed by the Electric Power Research Institute (EPRI) in 1982 [B6], [B7].^a Limited testing was performed on insulated coils, models, and model assemblies. The information obtained from these EPRI projects was used to extend the test procedures in this standard to power transformers.

Manufacturers occasionally make changes in the insulation used in transformers. This occurs due to the development of a new material or a change in vendors. In some cases, a preferred material will no longer be available, or a preliminary evaluation of the potential of a new insulation system is needed. It is reasonable to permit a reduced scale thermal test to determine that the change will not reduce the life of the transformer. For this situation, a single point aging test described in Annex A is specified using the procedure outlined in Annex B (similar to the Annex A from IEEE Std C57.100-1999). In situations where more than a minor change to the insulation system is made, a comparison to the industry-proven system must be made. This revision deals with how such a comparison is to be conducted.

In addition to the use of a comparison test to the industry-proven system, this revision of IEEE Std C57.100 deals with issues raised during the ballot for the 1999 revision of this document, as well as issues that have developed during the intervening time period. These issues included the need for a simplified model test for power transformers, as well as the need for evaluation methods for materials of dissimilar thermal capability. The old Annex A from IEEE Std C57.100-1999 has been modified to become part of the materials testing section in the new annex, which will also include a new dual-temperature sealed tube test method in Annex C. In the case of the distribution transformer and power transformer model test, the difference in performance between the candidate system and the industry-proven system can be compared directly by test. In the case of the materials tests described in Annex B and Annex C, the difference between the industry-proven system and the candidate system are also obtained, but the correlation of this difference to transformer life may require confirmation from industry experience. The scope of this document notes that the dielectric liquid is part of the insulation system, but evaluations of the fluid portion of the insulation system are not part of this test procedure. While fluids are a critical part of the insulation system, since they can be reprocessed or exchanged, this document only investigates the solid insulation components as the limiting factor of the insulation system.

^a The numbers in brackets correspond to those of the bibliography in Annex E.

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1. Overview

1.1 Scope

This ~~test procedure is intended~~ standard applies to ~~give a direct evaluation of the thermal aging characteristics of the composite-~~ the insulation systems used in all liquid-immersed distribution and power transformers. This standard provides test procedures to evaluate the thermal aging characteristics of insulation systems used in liquid-immersed distribution or power transformers. The ~~evolution of bubbles or their effect on~~ dielectric ~~strength is not considered. It is to be noted that the liquid in which the transformer is immersed is to be considered a~~ liquid is part of the insulation system.

~~It is the intent of the procedure to provide that each component of the insulation structure operate during the test under conditions that are, as nearly as possible, the same as those that it would encounter in service. Thus, it is intended that each component be evaluated in accordance with its actual function.~~

1.2 Purpose

The objective of this test procedure is to establish uniform methods for investigating the effects of operating temperature on the life expectancy of liquid-immersed transformer insulation systems. The results of these test procedures are expected to

a) Provide the basis for the selection of a limiting hottest-spot temperature for rating purposes

~~Acceptable thermal aging performance may be assumed if the hottest-spot temperature, at rated load as defined in IEEE Std C57.12.00-1993,¹ demonstrates a minimum life expectancy of at least 20.5 y (180 000 h) as determined by this test procedure;~~

b) Provide life curves that may serve as the basis for a guide for loading

c) Permit the comparative evaluation of a proposed insulation system with reference to an industry-proven system that has been shown to be acceptable in service. ~~The minimum life expectancy curve to be used for comparison purposes is given by Equation (1) and displayed in Figure 1.~~

~~¹Information on references can be found in Clause 2.~~

~~where~~

~~*LIFE* is the life in hours~~

~~*T* is the hottest-spot temperature in °C~~

2. Normative references

~~This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.~~

~~ASTM D 4243-86 (Reaff 1993), Standard Method for Measurement of Average Viscometric Degree of Polymerization of New and Aged Electrical Papers and Boards.~~

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

IEC TS 62332-1— Electrical Insulation Systems (EIS) — Thermal Evaluation of Combined Liquid and Solid Components—Part 1: General Requirements.¹

~~IEEE Std 1-1986 (Reaff 1992), IEEE General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.~~³

~~IEEE Std 99-1980 (Reaff 1992), IEEE Recommended Practice for the Preparation of Test Procedure for the Insulation Systems for Electric Equipment.~~

~~IEEE Std 101-1987 (Reaff 1995), IEEE Guide for the Statistical Analysis of Thermal Life Test Data.~~

²~~ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).~~

³~~IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.standards.ieee.org/>).~~

IEEE Std C57.12.00-~~1993~~,TM IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.^{2, 3}

IEEE Std C57.12.90-~~1999~~,TM IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.91-~~1995~~,TM IEEE Guide for Loading Mineral-Oil-Immersed Transformers.

IEEE Std 1TM, IEEE General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation.

[IEEE Std 99™, IEEE Recommended Practice for the Preparation of Test Procedure for the Thermal Evaluation of Insulation Systems for Electric Equipment.](#)

[IEEE Std 101™, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.](#)

3. Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be referenced for terms not defined in this clause.⁴

3.1 Industry-proven insulation system

Decades of operating equipment manufactured using an insulation system including thermally upgraded kraft paper, cellulosic pressboard, and mineral oil has shown that a minimum life expectancy of at least 20.5 years (180 000 hours) may be assumed if the hottest-spot temperature, at rated load as defined in IEEE Std C57.12.00, is maintained. This proven insulation system includes a manufacturing process, which provides initial drying to a moisture content of 0.25% to 0.50% moisture by weight, and after processing, the insulation system will be sealed to prevent the ingress of air (oxygen) and moisture.

The minimum life expectancy curve from IEEE Std C57.12.00 to be used for comparison purposes is repeated here by Equation (1) and displayed in Figure 1.

$$LIFE = EXP^{\left[\frac{15000}{T+273} - 27.064 \right]} \quad (1)$$

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