

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

Sponsor

**Transformers Committee
of the
IEEE Power Engineering Society**

Approved 26 June 1999

IEEE-SA Standards Board

Abstract: A test procedure is established to provide a uniform method for investigating the effect of operating temperature on the life expectancy of liquid-immersed transformers. 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, life tests, liquid immersed, power transformers, test procedures, thermal evaluation

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 1999 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 7 October 1999. Printed in the United States of America.

Print: ISBN 0-7381-1793-5 SH94780
PDF: ISBN 0-7381-1794-3 SS94780

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

(This introduction is not part of IEEE Std C57.100-1999, IEEE Standard Test Procedure for Thermal Evaluation of 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 many electrical, mechanical, and thermal stresses occurring in different parts of the structure. How long the 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 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 maintained.

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.

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. The goal was to find a way to evaluate the effect of overload on the insulation life of power transformers. 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. It was recognized by the working group that the effect of bubbles is a factor during overloading. However, the objective of this standard is to evaluate the effect of operating temperature on the life expectancy and not to test for the effect of bubbles that may occur during, or following, overloads.

The correct value for end point dielectric tests has been a subject of debate for many years, and it is very difficult to arrive at the correct value. At one extreme are those who believe that useful life ended only when the transformer was unable to carry rated load at rated voltage. At the other extreme are those who believe that transformers that could not sustain the standard tests given to new transformers were unfit for further use, since they believe that the probability of failure on abnormal currents or voltage would then be high. For distribution transformers, the consensus was that the end point test level should be 65% of the values specified for a new transformer. For power transformer models, the consensus was that the end point test level should be 65% of the design level. Since such tests, presumably, are intended to insure serviceability of the apparatus, the 65% should be adequate for end point tests.

Manufacturers occasionally must 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. Therefore, it is reasonable to permit a reduced scale thermal test to determine that the change will not reduce the life of the transformer. For these reasons an annex to this procedure has been added defining a sealed tube aging test.

This test procedure was produced by the IEEE Working Group on Thermal Evaluation of Power and Distribution Transformers which had the following membership:

L. A. Lowdermilk, Chair

J. Akers
J. L. Corkran
V. Dahinden
D. Dohnal
R. L. Grubb

P. J. Hopkinson
K. T. Massouda
C. J. McMillan
C. K. Miller
S. K. Oklu
L. W. Pierce

R. L. Provost
J. Puri
M. P. Sampat
H. J. Sim
A. L. Wilks

The following members of the balloting committee voted on this standard:

S. H. Aguirre
David Aho
Paul Ahrens
Paul Alex
Glenn Andersen
Jim Antweiler
Javier Arteaga
Jacques Aubin
Donald E. Ballard
Peter M. Balma
Ron L. Barker
Mike Barnes
A. Bartek
William H. Bartley
Martin Baur
Edward A. Bertolini
Enrique Betancourt
Jerry H. Bishop
Thomas E. Blackburn III
John D. Borst
Donald J. Cash
Dan W. Crofts
John C. Crouse
V. Dahinden
F. David
Bob Del Vecchio
Dieter Dohnal
J. C. Duart
Stephen L. Dyrnes
John A. Ebert
Fred E. Elliott
Reto H. Fausch
Pierre T. Feghali
Michael A. Franche
Dudley L. Galloway
Donald A. Gillies
Richard D. Graham
Robert L. Grunert
Ernst Hanique
N. Wayne Hansen
Robert H. Hartgrove
R. R. Hayes
George E. Henry

Peter J. Hoefler
Philip J. Hopkinson
James D. Huddleston, III
John O. Hunt
Rowland I. James
Charles W. Johnson
Anthony J. Jonnatti
Lars-Erik Juhlin
Gene Kallaur
David Keithly
Joseph J. Kelly
Vladimir Khalin
Lawrence A. Kirchner
Brian Klaponski
Egon Koenig
Thomas M. Kurihara
J. P. Lazar
Larry A. Lowdermilk
Donald L. Lowe
Thomas Lundquist
Joe D. MacDonald
Don MacMillan
William A. Maguire
Richard P. Marek
K. T. Massouda
John W. Matthews
Charles J. McMillen
Nigel P. McQuin
Charles Patrick McShane
Joe Melanson
R. E. Minkwitz, Sr.
Daniel H. Mulkey
Carl G. Niemann
T. V. Oommen
Paul E. Orehek
Sanjay Y. Patel
Mark D. Perkins
Linden W. Pierce
Paul Pillitteri
R. Leon Plaster
Donald W. Platts
Bertrand Poulin
G. Preininger
Tom A. Prevost

Richard L. Provost
Peter G. Risse
John R. Rossetti
Thomas Rouse
Mahesh P. Sampat
V. S. N. Sankar
Subhas Sarkar
Rick Sawyer
William E. Saxon
Robert J. Schaaf
Pat Scully
Walt Seitlinger
Dilipkumar Shah
Devki Sharma
Vic Shenoy
Hyeong Jin Sim
R. William Simpson, Jr.
Tarkeshwar Singh
Kenneth R. Skinger
Jerry W. Smith
James E. Smith
Stephen D. Smith
Steven L. Snyder
Ronald J. Stahara
Peter G. Stewart
Craig L. Stiegemeier
Ron W. Stoner
John C. Sullivan
James A. Thompson
Thomas P. Traub
Al Traut
Subhash C. Tuli
Robert A. Veitch
Ralph D. Wakeam
Barry H. Ward
Joe D. Watson
Robert Whearty
Christopher Wickersham
Roger Wicks
A. L. Wilks
B. Scott Wilson
William G. Wimmer
W. E. Wrenn

When the IEEE-SA Standards Board approved this standard on 26 June 1999, it had the following membership:

Richard J. Holleman, *Chair*

Donald N. Heirman, *Vice Chair*

Judith Gorman, *Secretary*

Satish K. Aggarwal
Dennis Bodson
Mark D. Bowman
James T. Carlo
Gary R. Engmann
Harold E. Epstein
Jay Forster*
Ruben D. Garzon

James H. Gurney
Lowell G. Johnson
Robert J. Kennelly
E. G. "Al" Kiener
Joseph L. Koepfinger*
L. Bruce McClung
Daleep C. Mohla
Robert F. Munzner

Louis-François Pau
Ronald C. Petersen
Gerald H. Peterson
John B. Posey
Gary S. Robinson
Akio Tojo
Hans E. Weinrich
Donald W. Zipse

*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaison:

Robert E. Hebner

Greg Kohn
IEEE Standards Project Editor

Contents

1. Overview.....	1
1.1 Scope.....	1
1.2 Purpose.....	1
2. References.....	2
3. Aging influences	3
4. Minimum life expectancy	3
5. Criteria for end of life	3
6. Test temperatures	4
7. Test specimens and procedures.....	4
7.1 Distribution transformers	4
7.2 Power transformers	4
8. Test period	5
8.1 Hottest-spot test temperature	5
8.2 Temperature of liquid	5
8.3 Duration of test period	5
8.4 Cycling.....	6
8.5 Calculation of aging caused by heating and cooling	6
9. End-point tests	6
9.1 Distribution transformers	6
9.2 Power transformers	7
9.3 Abnormalities.....	7
10. Test results	7
11. Applicability of test results	8
12. Other tests	8
Annex A (normative) Standard test procedure for sealed tube aging of liquid-immersed transformer insulation	9
A.1 Purpose.....	9
A.2 Test samples.....	9
A.3 Test period	9
A.4 Determination of life.....	9
A.5 Comparative evaluation	10
Annex B (informative) Bibliography.....	11