

IEEE Standard for Thermal Evaluation of Insulation Systems for Dry-Type Power and Distribution Transformers

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.12.60™-2020
(Revision of IEEE Std C57.12.60-2009)

IEEE Standard for Thermal Evaluation of Insulation Systems for Dry-Type Power and Distribution Transformers

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 30 January 2020

IEEE SA Standards Board

Abstract: A uniform method is established for determining the temperature classification for the insulation systems for dry-type power and distribution transformers. These insulation systems are intended for use in transformers covered by IEEE Std C57.12.01™ and IEEE Std C57.12.91™ as they apply to dry-type transformers whose highest voltages exceed nominal 600 V.

Keywords: IEEE C57.12.60™, insulation systems, model transformer coils, resin-encapsulated transformers, solid-cast transformers, thermal evaluation

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

Copyright © 2020 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 3 April 2020. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-6472-7 STD24068
Print: ISBN 978-1-5044-6473-4 STDPD24068

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.

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.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/ipr/disclaimers.html>.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

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.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive 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 comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, 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.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit IEEE Xplore at <http://ieeexplore.ieee.org/> or contact IEEE at the address listed previously. For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for IEEE standards can be accessed via <https://standards.ieee.org/standard/index.html>. Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional Resources Details section. Errata are also available in IEEE Xplore: <https://ieeexplore.ieee.org/browse/standards/collection/ieee/>. Users are encouraged to periodically check for errata.

Patents

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 by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this IEEE standard was completed, the Dry Type Transformers—Thermal Evaluation For Solid-Cast & Resin Encapsulated Insulation Working Group had the following membership:

Roger Wicks, *Chair*
David Stankes, *Vice Chair*

Casey Ballard	Charles Johnson	Juan Pablo Medina
Jagdish Burde	Ken Klein	Nam Tran Nguyen
Solomon Chiang	Moonhee Lee	Dhiru Patel
Derek Foster	Aleksandr Levin	Mark Raymond
Monty Goulkhah	Tim-Felix Mai	Michael Shannon
Mohammad Iman	Kenneth McKinney	Joseph Tedesco
Jerry Jackson		Vijay Tendulkar

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

J. Antweiler	John John	Alvaro Portillo
Robert Ballard	Sheldon Kennedy	Ion Radu
Peter Balma	James Kinney	Mark Raymond
Barry Beaster	Jim Kulchisky	Diego Robalino
Steven Bezner	Chung-Yiu Lam	Bartien Sayogo
Thomas Blackburn	Benjamin Lanz	Nikunj Shah
Demetrio Bucaneg Jr.	Moonhee Lee	Michael Sharp
Paul Cardinal	Aleksandr Levin	Hyeong Sim
Stuart Chambers	Hua Liu	Jerry Smith
Arvind Chaudhary	Colby Lovins	Gary Smullin
Solomon Chiang	Tim-Felix Mai	Sanjib Som
John Crouse	Kumar Mani	Ronald Stahara
J. Arturo DelRio	Richard Marek	David Stankes
Gary Donner	Daleep Mohla	Gary Stoedter
Donald Dunn	Rhea Montpool	Joseph Tedesco
Bruce Forsyth	Jerry Murphy	Vijay Tendulkar
Derek Foster	K. R. M. Nair	James Thompson
Randall Groves	Dennis Neitzel	James Van De Ligt
John Harley	Nam Tran Nguyen	Jason Varnell
Thang Hoчанh	Lorraine Padden	John Vergis
Werner Hoelzl	Bansi Patel	David Wallace
Mohammad Iman	Dhiru Patel	Roger Wicks
Richard Jackson	Dev Paul	Jian Yu
	Klaus Pointner	

When the IEEE SA Standards Board approved this standard on 30 January 2020, it had the following membership:

Gary Hoffman, *Chair*
Vacant Position, *Vice Chair*
Jean-Philippe Faure, *Past Chair*
Konstantinos Karachalios, *Secretary*

Ted Burse
J. Travis Griffith
Grace Gu
Guido R. Hiertz
Joseph L. Koepfinger*
John D. Kulick
David J. Law

Howard Li
Dong Liu
Kevin Lu
Paul Nikolich
Damir Novosel
Jon Walter Rosdahl

Dorothy Stanley
Mehmet Ulema
Lei Wang
Sha Wei
Philip B. Winston
Daidi Zhong
Jingyi Zhou

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C57.12.60-2020, IEEE Standard for Thermal Evaluation of Insulation Systems for Dry-Type Power and Distribution Transformers.

This standard is a revision of IEEE Std C57.12.60™-2009, and it represents the state of the art in methodology for evaluating insulation systems for dry-type power and distribution transformers with high-voltage ratings greater than 600 V. In the time since the last revision, there has been a significant amount of interest in such systems testing, and other standards bodies have developed or are developing testing standards with similar characteristics. This revision has tried to take into account the best parts of these other test methods to build on what has been developed over the years within IEEE, starting with IEEE Std 65™-1956 [B5]¹ that first lead to IEEE Std C57.12.56™-1986 [B10] and later to IEEE Std C57.12.60™-1998 [B11].

Areas of significant change from IEEE Std C57.12.60-2009 include the following:

- Modified table for suggested aging conditions
- Design screening test procedures
- Detailed dielectric testing procedures
- Detailed description for making changes to existing insulation systems

Informative annexes were also added to provide guidance on the selection of aging temperatures as well as a second annex that outlines a procedure for adding optional partial discharge testing to the testing protocol as a diagnostic tool.

NOTE—The dielectric test methods described in this standard are based on relevant IEEE standards. For customers considering use of this test methodology using different dielectric test methods, such as those outlined in IEC standards, those methods should be followed for the complete test program, and they should be agreed to in advance.²

¹The numbers in brackets correspond to those of the bibliography in [Annex A](#).

²Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
1.3 Word usage	12
2. Normative references	12
3. Definitions, abbreviations, and acronyms	13
3.1 Definitions	13
3.2 Abbreviations and acronyms	14
4. Basic considerations	14
4.1 General	14
4.2 Intent of test methods	14
4.3 Aging factors	14
4.4 Data treatment	15
4.5 Decision on intended performance	15
5. Aging program requirements—new insulation system	16
5.1 General	16
5.2 Thermal aging test coil samples	16
5.3 Design screening tests	17
5.4 Conductor size and shape	17
5.5 Conductor type	18
6. Full-size transformer coils	18
6.1 Coil design	18
6.2 Optional design screening test—full-size transformer coils	18
6.3 Coil quality screen	21
6.4 Thermal aging test procedure – full-size transformer coils	23
7. Representative small-scale model coils	25
7.1 Coil design	25
7.2 Electrical stress paths	26
7.3 Representative small-scale model coil examples	27
7.4 Design screening test—representative small-scale model coils	30
7.5 Coil quality screen	33
7.6 Thermal aging test procedure—representative small-scale model coils	34
8. Modifications to an existing system	37
8.1 Primary insulation	37
8.2 Single-point thermal evaluation	38
8.3 Varnish substitution	39
8.4 Secondary insulation	40
8.5 Magnet wire	40
8.6 Changes in voltage class	40

9. Reporting.....	41
Annex A (informative) Bibliography.....	42
Annex B (informative) Experience-based suggested techniques.....	43
Annex C (informative) Guidance on selection of aging temperatures	47
Annex D (informative) Partial discharge (PD) testing.....	56
Annex E (informative) Substitution procedure form ANSI C57.12.55.....	57

IEEE Standard for Thermal Evaluation of Insulation Systems for Dry-Type Power and Distribution Transformers

1. Overview

1.1 Scope

This test procedure for the thermal evaluation of insulation systems of dry-type power and distribution transformers is to be used for determining the temperature classification and modification of the insulation systems. This standard shall apply to all dry-type transformers with a voltage of 601 V or higher in the highest voltage winding except as follows:

- a) Instrument transformers
- b) Step- and induction-voltage regulators
- c) Arc-furnace transformers
- d) Rectifier transformers
- e) Specialty and general-purpose transformers
- f) Mine transformers
- g) Testing transformers
- h) Welding transformers

NOTE—Where IEEE standards do not exist for the transformers mentioned above or for other special transformers, this standard may be applicable as a whole or in parts subject to agreement between the parties responsible for the application and for the design of the transformer.

1.2 Purpose

The purpose of this test procedure is to establish a uniform method for the following:

- a) Acquiring data used to determine the temperature classification of an insulation system
- b) Acquiring data that may be used as a basis for a loading guide, such as IEEE Std C57.96^{TM3}
- c) Modifying an established electrical insulation system

³Information on references can be found in [Clause 2](#).