

IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C57.12.90™-2015
(Revision of
IEEE Std C57.12.90-2010)

IEEE Std C57.12.90™-2015

(Revision of
IEEE Std C57.12.90-2010)

IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

Sponsor

**Transformers Committee
of the
IEEE Power and Energy Society**

Approved 5 December 2015

IEEE-SA Standards Board

Abstract: Methods for performing tests specified in IEEE Std C57.12.00™ and other standards applicable to liquid-immersed distribution, power, and regulating transformers are described. Instrument transformers, step-voltage and induction voltage regulators, arc furnace transformers, rectifier transformers, specialty transformers, grounding transformers, and mine transformers are excluded. Resistance measurements, polarity and phase-relation tests, ratio tests, no-load loss and excitation current measurements, impedance and load loss measurements, dielectric tests, temperature tests, short-circuit tests, audible sound level measurements, and calculated data are covered in this standard.

Keywords: IEEE C57.12.90™, tests, transformer tests, transformers

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

Copyright © 2016 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 11 March 2016. 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 978-1-5044-0769-4 STD20842
Print: ISBN 978-1-5044-0770-0 STDPD20842

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 Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

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. Volunteers 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 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 U.S. 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 ten years. When a document is more than ten 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 the IEEE-SA Website at <http://ieeexplore.ieee.org/xpl/standards.jsp> 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 all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

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 draft standard was completed, the Continuous Revision of C57.12.90 Working Group had the following membership:

Stephen Antosz, *Chair*
Peter Balma, *Vice Chair*

William Bartley
Marcel Fortin
Ramsis Girgis

Paulette Payne Powell
Mark Perkins
Bertrand Poulin
Pierre Riffon

Steven Snyder
Ed teNyenhuis
Loren Wagenaar

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

Samuel Aguirre
Gregory Anderson
Tauhid Haque Ansari
Stephen Antosz
I. Antweiler
Javier Arteaga
Roberto Asano
Donald Ayers
Roy Ayers
Robert Ballard
Peter Balma
Thomas Barnes
Paul Barnhart
William Bartley
Christopher Baumgartner
Barry Beaster
Jeffrey Benach
W.J. (Bill) Bergman
Mats Bernesjo
Enrique Betancourt
Steven Bezner
Wallace Binder
Thomas Bishop
Thomas Blackburn
Daniel Blaydon
William Bloethe
W. Boettger
Alain Bolliger
Paul Boman
Jeffrey Britton
Adam Bromley
Chris Brooks
Darren Brown
Steven Brown
David Buckmaster
Carl Bush
Thomas Callsen
Paul Cardinal
Juan Castellanos
Donald Cherry
Bill Chiu

Craig Colopy
Stephen Conrad
Jerry Corkran
John Crouse
Willaim Darovny
Alan Darwin
Frank Decesaro
Dieter Dohnal
Gary Donner
Charles Drexler
Fred Elliott
James Fairris
Jorge Fernandez Daher
Joseph Foldi
Bruce Forsyth
Marcel Fortin
Michael Franchek
Fredric Friend
George Frimpong
Jose Gamboa
Robert Ganser
Carlos Gaytan
Frank Gerleve
Ali Ghafourian
David Gilmer
Ramsis Girgis
Jalal Gohari
Edwin Goodwin
James Graham
William Griesacker
Randall Groves
Bal Gupta
Ajit Gwal
Said Hachichi
John Harley
J. Harlow
David Harris
Roger Hayes
Jeffrey Helzer
William Henning
Martin Hinow

Gary Hoffman
Timothy Holdway
Thomas Holifield
Jill Holmes
Philip Hopkinson
John Houdek
Mohammad Iman
Richard Jackson
Erwin Jauch
Brad Jensen
Song Jin
John John
Charles Johnson
Wayne Johnson
Laszlo Kadar
John Kay
Gael Kennedy
Sheldon Kennedy
Vladimir Khalin
Gary King
Joseph L. Koepfinger
Boris Kogan
Axel Kraemer
Neil Kranich
Jim Kulchisky
Saumen Kundu
John Lackey
Chung-Yiu Lam
Thomas La Rose
William Larzelere
Aleksandr Levin
Hua Liu
Mario Locarno
John Luksich
Thomas Lundquist
Richard Marek
J. Dennis Marlow
Lee Matthews
Omar Mazzoni
James McBride
Mark McNally

Susan Mcnelly	Klaus Pointner	Steve Snyder
Charles Mc Shane	Alvaro Portillo	Sanjib Som
Joseph Melanson	Bertrand Poulin	Thomas Spitzer
Tom Melle	Lewis Powell	Ronald Stahara
Michael Miller	Tom Prevost	David Stankes
Michael R. Miller	Jarrod Prince	John Sullivan
Daleep Mohla	Ulf Radbrandt	Troy Alan Tanaka
Charles Morgan	Martin Rave	Ed teNyenhuis
Daniel Mulkey	Jeffrey Ray	Malcolm Thaden
Jerry Murphy	Timothy Charles Raymond	Juan Thierry
Paul Mushill	Leslie Recksiedler	James Thompson
Ali Naderian Jahromi	Jean-Christophe Riboud	Robert Thompson
K. R. M. Nair	Johannes Rickmann	Alan Traut
Kris K. Neild	Pierre Riffon	Ajith Varghese
Dennis Neitzel	Diego Robalino	Roger Verdolin
Arthur Neubauer	Michael Roberts	John Vergis
Michael Newman	Charles Rogers	Jane Verner
Raymond Nicholas	Oleg Roizman	Richard Vongemmingen
Ryan Niemerg	John Rossetti	Loren Wagenaar
Joe Nims	Thomas Rozek	David Wallace
Robert Olen	Dinesh Sankarakurup	David Wallach
Tim Olson	Daniel Sauer	Joe Watson
David Ostrander	Roderick Sauls	Lee Welch
Lorraine Padden	Bartien Sayogo	Yingli Wen
Dwight Parkinson	Ewald Schweiger	Kenneth White
Luke Parthemore	Jeremy Sewell	Roger Wicks
Bansi Patel	Nikunj Shah	Alan Wilks
Wesley Patterson	Devki Sharma	William Wimmer
Paulette Payne Powell	Hemchandra Shertukde	Baitun Yang
Verena Pellon	Stephen Shull	Jennifer Yu
Brian Penny	Hyeong Sim	Jian Yu
Mark Perkins	Charles Simmons	Kipp Yule
Branimir Petosic	Kenneth Skinger	Shibao Zhang
Christopher Petrola	Jerry Smith	James Ziebarth
Donald Platts		Waldemar Ziomek

When the IEEE-SA Standards Board approved this standard on 5 December 2015, it had the following membership:

John D. Kulick, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Richard H. Hulett, *Past Chair*
Konstantinos Karachalios, *Secretary*

Masayuki Ariyoshi	Joseph L. Koepfnger*	Stephen J. Shellhammer
Ted Burse	David J. Law	Adrian P. Stephens
Stephen Dukes	Hung Ling	Yatin Trivedi
Jean-Philippe Faure	Andrew Myles	Philip Winston
J. Travis Griffith	T. W. Olsen	Don Wright
Gary Hoffman	Glenn Parsons	Yu Yuan
Michael Janezic	Ronald C. Petersen	Daidi Zhong
	Annette D. Reilly	

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C57.12.90-2015, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

This document is a voluntary consensus standard. Its use may become mandatory only when required by a duly constituted legal authority or when specified in a contractual relationship. To meet specialized needs and to allow innovation, specific changes are permissible when mutually determined by the purchaser and manufacturer, provided that such changes do not violate existing laws and are considered technically adequate for the function intended.

When this standard is used on a mandatory basis, the word “shall” indicates mandatory requirements, and the words “should” and “may” refer to matters that are recommended or permissive, but not mandatory. The word “must” has been removed from this revision and replaced with “shall” to conform with the *IEEE-SA Standards Style Manual*.

This standard is on a continuous revision cycle and is constantly being reviewed and updated. One can go to the website www.transformerscommittee.org to seek out information on select activities and participate in upcoming changes. The following is a brief summary of the non-editorial changes in this revision:

- Subclause 6.2, Polarity Tests for single-phase transformers, has been revised to remove the comparison method and the remaining methods have been re-arranged in order of preference.
- Subclause 6.3, Polarity and phase-relation tests for polyphase transformers, has been slightly revised.
- Subclause 7.1.4, Ratio test of three-phase transformers with inaccessible neutrals, has been rewritten.
- Subclause 9.5, Zero-sequence impedance testing, has additional notes added.
- Subclause 10.1.5.1, Dielectric Test sequence, has been revised.
- New subclause 10.2.5, Connection of neutral terminal during switching impulse tests.
- Revisions to 10.2.1, 10.3, 10.3.2.5, and 10.3.3. The number of full wave impulses applied during the test sequence has increased from one to two or three.
- Subclause 10.3.2.4, Tap connections (during lightning impulse test), has been completely rewritten.
- Subclause 11.1, Test Methods, the order of the two simulated loading methods has been reversed.
- Subclause 11.1.2.1, Loading back method, the text, Figure 29, and Figure 30 have been revised.
- Subclause 11.2.2, Hot resistance measurements, list items a) through f) have been revised.
- Clause 12, Short-circuit tests, has been revised; and a new Annex C added on connection diagrams for short-circuit testing of a three-phase transformer using single-phase source. Multiple references are added to Annex D.
- Clause 13, Audible sound testing, has been completely revised, adding: load sound measurements; sound-intensity measurement methods; new corrections for wall reflection, near-field effects, and environmental; a method to add no-load & load sound; a change in microphone locations.

Technical revisions were prepared by various groups within the IEEE Transformers Committee and have been surveyed and approved by these groups up through the subcommittee level.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	2
1.3 Word usage	2
2. Normative references	2
3. Definitions	3
4. General	4
4.1 Types of tests	4
4.2 Test requirements	4
4.3 Test sequence	4
4.4 Instrumentation	5
5. Resistance measurements	5
5.1 Determination of cold temperature	5
5.2 Conversion of resistance measurements	6
5.3 Resistance measurement methods	6
5.4 Resistance measurement connections and reporting	7
6. Polarity and phase-relation tests	8
6.1 Subtractive and additive polarity	8
6.2 Polarity tests: single-phase transformers	9
6.3 Polarity and phase-relation tests: polyphase transformers	10
7. Ratio tests	14
7.1 General	14
7.2 Tolerances for ratio	15
7.3 Ratio test methods	15
8. No-load losses and excitation current	17
8.1 General	17
8.2 No-load loss test	17
8.3 Waveform correction of no-load losses	20
8.4 Temperature correction of no-load losses	20
8.5 Determination of excitation (no-load) current	21
8.6 Frequency conversion of no-load losses and excitation current	21
9. Load losses and impedance voltage	21
9.1 General	21
9.2 Factors affecting the values of load losses and impedance voltage	22
9.3 Tests for measuring load losses and impedance voltage	23
9.4 Calculation of load losses and impedance voltage from test data	30
9.5 Zero-phase-sequence impedance	33
10. Dielectric tests	37
10.1 General	37
10.2 Switching impulse test procedures	40
10.3 Lightning impulse test procedures	41
10.4 Routine impulse test for distribution transformers	49

10.5 Low-frequency tests.....	51
10.6 Applied-voltage tests	52
10.7 Induced-voltage tests for distribution and Class I power transformers.....	52
10.8 Induced-voltage test for Class II power transformers	53
10.9 Partial discharge measurement	54
10.10 Insulation power-factor tests.....	55
10.11 Insulation resistance tests	56
11. Temperature-rise tests	58
11.1 Test methods.....	58
11.2 Resistance measurements	61
11.3 Temperature measurements.....	63
11.4 Correction of temperature-rise test results.....	65
12. Short-circuit tests.....	67
12.1 General	67
12.2 Test connections	68
12.3 Test requirements	71
12.4 Test procedure	72
12.5 Proof of satisfactory performance.....	73
13. Audible sound emissions	75
13.1 General	75
13.2 Instrumentation	76
13.3 Test conditions.....	77
13.4 Microphone positions	79
13.5 Sound pressure level measurements	80
13.6 Determination of audible sound level of a transformer	84
13.7 Presentation of results.....	87
14. Calculated data	90
14.1 Reference temperature	90
14.2 Losses and excitation current.....	90
14.3 Efficiency	90
14.4 Voltage regulation of a constant-voltage transformer.....	90
Annex A (informative) Partial discharge measurement using radio-influence voltage instrumentation and its failure detection	93
A.1 Partial discharge measurement	93
A.2 Failure detection	94
Annex B (normative) 50/60-Hz frequency conversion of measured performance parameters.....	95
B.1 No-load loss and excitation current.....	95
B.2 Load loss.....	96
B.3 Temperature-rise test.....	97
B.4 Short-circuit test.....	99
B.5 Audible sound	99
Annex C (informative) Connections diagrams for short-circuit testing of a three-phase transformer using single-phase source as an alternative (see 12.2.1.2).....	102
Annex D (informative) Bibliography	105

IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers 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.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Overview

1.1 Scope

This standard describes methods for performing tests specified in IEEE Std C57.12.00^{TM1} and other standards applicable to liquid-immersed distribution, power, and regulating transformers. It is intended for use as a basis for performance and proper testing of such transformers.

This standard applies to all liquid-immersed transformers, except instrument transformers, step-voltage and induction voltage regulators, arc furnace transformers, rectifier transformers, specialty transformers, grounding transformers, and mine transformers.

Transformer requirements and specific test criteria are not a part of this standard, but they are contained in appropriate standards, such as IEEE Std C57.12.00, IEEE Std C57.12.10TM [B17],² IEEE Std C57.12.20TM, and IEEE Std C57.12.40TM [B18], or in user specifications.

¹ Information on references can be found in Clause 2.

² The numbers in brackets correspond to those of the bibliography in Annex D