

IEEE Standard Requirements for Secondary Network Protectors

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.12.44™-2024
(Revision of IEEE Std C57.12.44-2014)

STANDARDS

IEEE Standard Requirements for Secondary Network Protectors

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 11 December 2024

IEEE SA Standards Board

Abstract: The performance, electrical and mechanical interchangeability, and the safety of the equipment are covered. The proper selection of such equipment is established as a basis for use in this standard. Certain electrical, dimensional, and mechanical characteristics are described; and certain safety features of three-phase, 60 Hz, low-voltage (600 V and below) network protectors are taken into consideration. This equipment is used for automatically connecting and disconnecting a network transformer from a secondary spot or grid network.

Keywords: grid network, IEEE C57.12.44, network, protector, spot network

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

Copyright © 2025 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 18 June 2025. 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 979-8-8557-1667-2 STD27613
Print: ISBN 979-8-8557-1668-9 STDPD27613

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <https://www.ieee.org/about/corporate/governance/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 Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers.html>), appear in all IEEE standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

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

IEEE Standards documents are developed within IEEE Societies and subcommittees of IEEE Standards Association (IEEE SA) Board of Governors. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers involved in technical working groups are not necessarily members of IEEE or IEEE SA 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 makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning all standards, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. IEEE Standards documents do not guarantee safety, security, health, or environmental protection, or compliance with law, or guarantee against interference with or from other devices or networks. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. 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 their 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: THE NEED TO PROCURE 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 balloting process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English language version published by IEEE is the approved IEEE standard.

Use by artificial intelligence systems

In no event shall material in any IEEE Standards documents be used for the purpose of creating, training, enhancing, developing, maintaining, or contributing to any artificial intelligence systems without the express, written consent of IEEE SA in advance. “Artificial intelligence” refers to any software, application, or other system that uses artificial intelligence, machine learning, or similar technologies, to analyze, train, process, or generate content. Requests for consent can be submitted using the Contact Us form.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual is not, and 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 or IEEE SA. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that the presenter’s views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group. Statements made by volunteers may not represent the formal position of their employer(s) or affiliation(s). News releases about IEEE standards issued by entities other than IEEE SA should be considered the view of the entity issuing the release rather than the formal position of IEEE or IEEE SA.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, 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 subcommittees of the IEEE SA Board of Governors 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 evaluating comments or revisions to an IEEE standard is welcome to join the relevant IEEE SA working group. You can indicate interest in a working group using the Interests tab in the Manage Profile & Interests area of the [IEEE SA myProject system](#).¹ An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.²

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 constitute compliance to any applicable

¹ Available at: <https://development.standards.ieee.org/myproject-web/public/view.html#landing>.

² Available at: <https://standards.ieee.org/about/contact/>.

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.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

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, neither IEEE nor its licensors waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate licensing fees, 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; <https://www.copyright.com/>. 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](#) or [contact IEEE](#).³ For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#).⁴ Search for standard number and year of approval to access the web page of the published standard. Errata links are located

³ Available at: <https://ieeexplore.ieee.org/browse/standards/collection/ieee>.

⁴ Available at: <https://standards.ieee.org/standard/index.html>.

under the Additional Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE standards are developed in compliance with the [IEEE SA Patent Policy](#).⁵

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 <https://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.

IMPORTANT NOTICE

Technologies, application of technologies, and recommended procedures in various industries evolve over time. The IEEE standards development process allows participants to review developments in industries, technologies, and practices, and to determine what, if any, updates should be made to the IEEE standard. During this evolution, the technologies and recommendations in IEEE standards may be implemented in ways not foreseen during the standard's development. IEEE standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, data privacy, and interference protection practices and all applicable laws and regulations.

.

⁵ Available at: <https://standards.ieee.org/about/sasb/patcom/materials.html>.

Participants

At the time this IEEE standard was completed, the IEEE Standard Requirements for Secondary Network Protectors Working Group had the following membership:

Mark Faulkner, *Chair*
Alex Macias, *Vice Chair*

Jason Attard
Douglas Craig
Thomas Dauzat
William Elliott
Brad Kittrell
Brian Klaponski

Charles Morgan
Daniel Mulkey
George Payerle
James Ratty
Pedro Salgado
Dan Schwartz
Jeremy Sewell

Adam Sewell
Avijit Shingari
Igor Simonov
Travis Spoone
Robert Stinson
John Vartanian

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

Peter Balma
Barry Beaster
Steven Bezner
Wallace Binder
Thomas Blackburn
Jon Brasher
Paul Cardinal
Stephen Conrad
Randall Cunico
Thomas Dauzat
Neal Dowling
Thomas Dunmore II
Paul Elkin
William Elliott
Mark Faulkner
Carl Fredericks
David Gilmer
Jalal Gohari
Said Hachichi
John Harley
Werner Hoelzl
Philip Hopkinson

Richard Jackson
Jack Jester
John John
John Kay
Yuri Khersonsky
James Kinney
Brian Klaponski
Steven Klecker
John Lackey
Ting Li
Alejandro Macias
Bruce Mackie
Tapan Manna
Adi Mulawarman
Daniel Mulkey
Daniel Mungovan
Dennis Neitzel
James Niemira
Lorraine Padden
Dwight Parkinson
Bansi Patel
Alvaro Portillo
Benito Ramos

Charles Rogers
Steven Sano
Bartien Sayogo
Jeremy Smith
Jerry Smith
Gary Smullin
Sanjib Som
Travis Spoone
Gary Stuedter
David Tepen
Michael Thompson
Sylvester Toe
Eric Udren
John Vartanian
John Vergis
Quintin Verzosa
David Wallace
John Webb
Lee Welch
Daniel Weyer
Kenneth White
Peter Zhao

When the IEEE SA Standards Board approved this standard on 11 December 2024, it had the following membership:

David J. Law, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Gary Hoffman, *Past Chair*
Alpesh Shah, *Secretary*

Sara R. Biyabani
Ted Burse
Stephen Dukes
Doug Edwards
J. Travis Griffith
Guido R. Hiertz
Ronald W. Hotchkiss

Hao Hu
Yousef Kimiagar
Joseph L. Koepfinger*
Howard Li
Xiaohui Liu
John Haiying Lu
Kevin W. Lu
Hiroshi Mano

Paul Nikolich
Robby Robson
Lei Wang
F. Keith Waters
Sha Wei
Philip B. Winston
Don Wright

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C57.12.44™-2024, IEEE Standard Requirements for Secondary Network Protectors.

IEEE Std C57.12.44 was first published in 1994. It was subsequently revised in 2000, 2005, and 2014.

This standard was first issued in 1994 and was developed by a task force consisting of EEI, National Electrical Manufacturers Association (NEMA), and IEEE PES delegates. The document was completed in late 1994 by the Working Group on Requirements for Secondary Network Protectors under the Underground Transformers and Network Protectors Subcommittee of the IEEE PES Transformers Committee.

The current revision has been updated to current IEEE styles, has been revised to reflect the current state of the art, expanded to include network protector ratings for system voltages of 600Y/346 ac, and clarifies terminal base mounting requirements.

Contents

1. Overview	12
1.1 Scope	12
1.2 Purpose	12
1.3 Word usage	12
2. Normative references	12
3. Definitions, acronyms, and abbreviations	13
3.1 Definitions	13
4. Service conditions	14
4.1 Usual service conditions	14
4.2 Unusual service conditions	15
5. Design tests	15
5.1 General	15
5.2 Continuous current thermal test	16
5.3 Electrical tests	18
5.4 Mechanical endurance test	22
6. Production tests	23
6.1 General	23
6.2 Operational tests	23
6.3 Dielectric tests	25
6.4 Insulation resistance tests	26
6.5 Current path resistance tests	26
6.6 Mechanical tests	26
7. Relay characteristics	27
7.1 General	27
7.2 Automatic close functions	27
7.3 Automatic trip functions	28
7.4 Tripping adjustment	29
8. Fuses and fuse mountings	30
8.1 Fuse provisions	30
8.2 Functional performance specifications	33
8.3 Fuse types	33
9. Rating requirements	33
9.1 Nameplates	33
9.2 Interrupting rating	34
9.3 AC voltage ratings	36
9.4 Dielectric test voltage	36
9.5 Control voltage	36
9.6 Closing voltage	36
9.7 Tripping currents	37
10. Mechanical performance specifications	37
10.1 General	37
10.2 Submersible type	37
10.3 Non-submersible type	38
10.4 Open-frame type	38

10.5 Mounting application.....	38
10.6 General requirements.....	38
10.7 Finish.....	42
11. Other requirements.....	42
11.1 Submersible enclosure.....	42
11.2 Non-submersible enclosure.....	42
11.3 Open frame enclosure.....	42
11.4 Mounting configurations.....	43
11.5 Network-side terminations.....	44
Annex A (informative) Classification of insulating materials.....	47
A.1 General.....	47
A.2 Insulating materials.....	47
A.3 Insulation systems.....	48
A.4 Insulation service stresses.....	49
Annex B (informative) Network fuse application.....	50
B.1 General.....	50
B.2 Protector fuse.....	50
B.3 Types of fuses.....	50
B.4 History.....	59
Annex C (informative) Pumping.....	60
C.1 General.....	60
C.2 Causes.....	60
C.3 Effects of pumping.....	60
Annex D (informative) The unprotected zone in network protectors.....	61
Annex E (informative) Contact surface oxidation.....	62
Annex F (informative) Reverse current.....	63
F.1 General.....	63
F.2 Reverse power levels.....	63
F.3 Relay settings.....	64
Annex G (informative) Network protector enclosures.....	66
Annex H (informative) Bibliography.....	67

IEEE Standard Requirements for Secondary Network Protectors

1. Overview

1.1 Scope

This standard describes the electrical, dimensional, and mechanical characteristics and takes into consideration the safety features of three-phase, 60 Hz, low-voltage (600 V and below) network protectors. They are used for automatically connecting and disconnecting a network transformer from a secondary spot or grid network.

1.2 Purpose

This standard is intended for use as a basis for establishing the performance, electrical and mechanical interchangeability, and safety of the equipment covered and to assist in the proper selection of such equipment.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6, 7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

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

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

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.

IEEE Std C57.12.28™, IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity.^{8,9}

IEEE Std C57.12.32™, IEEE Standard for Submersible Equipment—Enclosure Integrity.

IEEE Std C57.12.40™, IEEE Standard for Network, Three-Phase Transformers, 2500 kVA and Smaller; High Voltage, 34 500 V and Below, Low Voltage, 600 V and Below; Subway and Vault Types (Liquid Immersed).

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁰

NOTE—An asterisk (*) following a definition indicates that the definition was originally extracted from IEEE Std 100™.¹¹

arcing contacts: The contacts of a switching device on which the arc is drawn after the main (and intermediate, where used) contacts have parted.*

desensitizing relay: A relay that prevents tripping of a network protector on transient power reversals that neither exceed a predetermined value nor persist for a predetermined time.

intermediate contacts: Contacts in the main circuit that part after the main contacts and before the arcing contacts have parted.*

main contacts: Contacts that carry all or most of the main current.*

network limiter: An enclosed fuse for disconnecting a faulted cable from a low-voltage network distribution system and for protecting the unfaulted portions of that cable against serious thermal damage.*

network master relay: A relay that functions as a protective relay by opening a network protector when power is back fed into the supply system and as a programming relay by closing the protector in conjunction with the network phasing relay when polyphase voltage phasors are within prescribed limits.*

network phasing relay: A monitoring relay that has as its function to limit the operation of a network master relay so that the network protector may close only when the voltages on the two sides of the protector are in a predetermined phasor relationship.*

network protector: An assembly comprising an air circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electrical conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control responsive to predetermined electrical conditions on the feeder and the secondary network.

⁸ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

⁹ The IEEE standards or products referred to in Annex H are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

¹⁰ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹¹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

NOTE—The network protector is usually arranged to automatically connect its associated transformer to the network when conditions are such that the transformer, when connected, will supply power to the network, and to automatically disconnect the transformer from the network when power flows from the network to the transformer.*

network protector fuse: A backup device for the network protector.

network secondary distribution system: A system of alternating current distribution in which the secondaries of the distribution transformers are connected to a common network for supplying light and power directly to consumers' services.

phasing voltage: The voltage across the open contacts of a selected phase.

NOTE—This voltage is equal to the phasor difference between the transformer voltage and the corresponding network voltage.*

pumping: The unintentional cyclical tripping and closing of a network protector.

removable breaker: An assembly that consists of the circuit breaker, disconnecting provisions, network relays, auxiliary panels, current transformers, control devices, other attachments, and all interconnecting wiring, that can be rolled out of the network protector enclosure on rails for maintenance or removal.

short-time current: The current carried by a device, an assembly, or a bus for a specified short time interval.*

shunt release: A release energized by a source of power. *Syn:* **shunt trip.**

NOTE—The power may be derived either from the main circuit or from an independent source.*

solid-state or microprocessor network relay: A relay with no mechanical parts, using solid-state components, that performs the combined functions of the master and phasing relays, and that may include a time delay function.

spot network: A small network, usually at one location, consisting of two or more primary feeders, with network units and one or more load service connections.

trip-free: The capability of a switching device to have the moving contacts return to and remain in the open position when the opening operation is initiated after the initiation of the closing operation, even if the closing force and command are maintained.*

4. Service conditions

4.1 Usual service conditions

4.1.1 General

Network protectors conforming to this standard shall be suitable for operation at rated current under the following conditions.

4.1.2 Temperature

The ambient temperature shall be between $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$) and $40\text{ }^{\circ}\text{C}$ ($104\text{ }^{\circ}\text{F}$).

4.1.3 Altitude

The altitude shall not exceed 1000 m (3300 ft).

4.1.4 Generation

Network protectors designed and tested in accordance with this standard, in particular with 5.3, are intended to be applied to a system with power normally flowing only from the high-voltage side of the transformer that supplies a secondary network. Special precautions must be taken with generation or energy storage on a secondary network that could result in reverse power flow as this will create an undesired and possibly unsafe condition.

4.2 Unusual service conditions

4.2.1 General

Conditions other than those described in 4.1 are considered unusual service, and when prevalent, shall be brought to the attention of those responsible for the design and application of the apparatus. Examples of some of these conditions are listed in 4.2.2 and 4.2.3.

4.2.2 Unusual temperature and altitude conditions

Network protectors may be used at higher or lower ambient temperatures or at higher altitudes than those specified in 4.1, but special consideration shall be given to these applications. IEEE Std C57.91™ [B12]¹² provides information on recommended practices for the accompanying transformer.

4.2.3 Insulation at high altitude

The dielectric strength of network protectors, which depend primarily on air for insulation, decreases as the altitude increases due to the effect of decreased air density. Network protectors design voltage shall be derated using the correction factors of Table 1 in IEEE Std C57.12.00™ [B9].

The insulation level at 1000 m (3300 ft) multiplied by the correction factor shall not be less than the required insulation level at the required altitude.

5. Design tests

5.1 General

The design tests shall be divided into three separate categories designated as continuous current thermal, electrical, and mechanical endurance.

For the tests specified in 5.2 through 5.4, the circuit resistance of each phase shall be measured in its entirety with a dc current of at least 100 A.

The circuit resistance values measured at the conclusion of test 5.2 (while the protector is at temperature as defined in 5.2.3) shall be used as the limit for the circuit resistance values measured at the conclusion of tests in 5.3 and 5.4. Units with higher circuit resistances shall require an additional continuous current thermal test (5.2) after type testing unless the manufacturer can demonstrate that the resistance recorded will not cause the protector to exceed the temperature listed in Table 1.

¹² The numbers in brackets correspond to those of the bibliography in Annex H.

5.2 Continuous current thermal test

5.2.1 General

The continuous current test shall be performed to demonstrate that the network protector can carry its rated continuous current at its rated frequency in an ambient temperature range between 10 °C (50 °F) and 40 °C (104 °F) without attaining a temperature rise in excess of those listed in Table 1 (see Annex A for more information). The network protector shall be tested with the highest loss fuse that would normally be applied with that network protector rating.

Table 1—Maximum allowable temperature rise

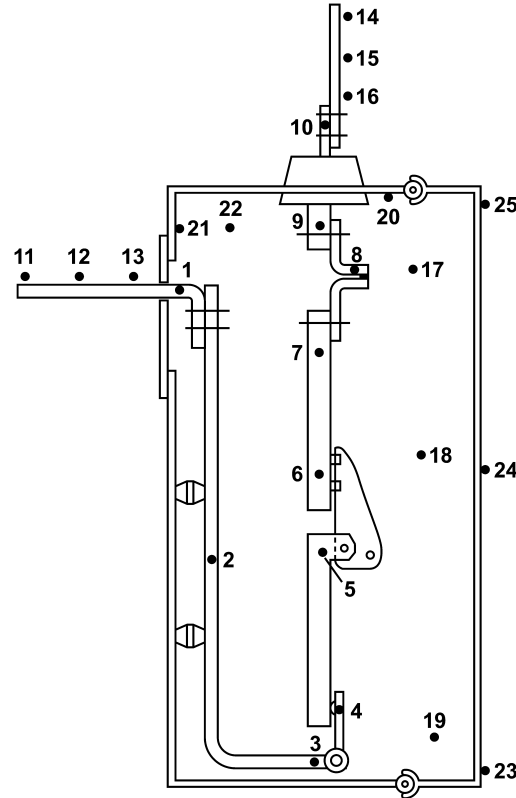
Material temperature class	Maximum allowable temperature rise
90 °C	50 °C (90 °F)
105 °C	65 °C (117 °F)
130 °C	90 °C (162 °F)
155 °C	115 °C (207 °F)
180 °C	140 °C (252 °F)
200 °C	160 °C (288 °F)
220 °C	180 °C (324 °F)

5.2.2 Test conditions

The network protector in its enclosure, with fuses, shall be connected to a balanced three-phase current source at the transformer side of the network protector with a copper bus bar whose ampacity is rated to carry the full rated current. This bus bar shall extend a minimum of 1.2 m (4 ft) from the network protector. This bus bar shall have a current density range of 120 A/cm² (800 A/in²) to 230 A/cm² (1500 A/in²). The transformer throat openings shall be suitably enclosed with a thermal panel permitting the transformer extension bus to exit, but to seal all openings at the throat area. The network side terminals shall be short-circuited with the same size bus bar as used on the transformer side connection and shall extend a minimum of 1.2 m (4 ft) from the network side terminals.

Temperature sensors shall be used to measure the temperature. Temperature sensors used for measuring the temperatures of insulation shall be located on the current-carrying member or other metal part at a point as close as practical to the accessible junction of the insulation and the current-carrying member or other metal part. Temperature sensors used for measuring the temperature of the transformer or network side terminal connections and other conducting joints shall be located approximately 13 mm (0.5 in) from the terminal or other conducting joints on the current-carrying member. Temperature sensors shall be held in intimate contact with the conductor surface. Temperature sensors may be used to determine the internal air temperature within the network protector enclosure by suspending the unmounted thermocouple bulbs in air.

The bus entering or leaving the network protector shall not be used to add or remove heat during the continuous current thermal test. To determine this, three temperature sensors shall be placed 300 mm (12 in) apart along the bus attached to the network protector. The bus is then shielded from air convection flow such that the three temperature sensors along the bus bar are within 5 °C (9 °F) of the adjacent thermocouple on the bus bar. These readings are only applicable to the final three readings taken at 30 min intervals and are not subject to the temperature variation criteria of the internal parts of the network protector. Refer to Figure 1 for the minimum number of temperature sensors required.



NOTE—Temperature sensors 1 through 16 shall be duplicated on all three phases.

Figure 1—Thermal sensor locations

5.2.3 Test duration

The rated continuous current of the network protector at rated frequency shall be applied continuously until the temperature rise stabilizes. The temperature rise shall be considered stable when three successive readings taken at 30-min intervals vary no more than $\pm 1.0\text{ }^{\circ}\text{C}$ ($\pm 1.8\text{ }^{\circ}\text{F}$). If the temperature rise at the end of the third interval is equal to the established limit (see Table 1) and if the temperature rise has increased since the previous reading, the test shall be continued one more interval.

5.2.4 Ambient temperature

The network protector shall be tested at an ambient temperature between $10\text{ }^{\circ}\text{C}$ ($50\text{ }^{\circ}\text{F}$) and $40\text{ }^{\circ}\text{C}$ ($104\text{ }^{\circ}\text{F}$). No correction factors need to be applied. The temperature rise shall, in no case, exceed those specified in Table 1. The ambient temperature shall be determined by taking the average of the readings of the three temperature sensors placed horizontally 300 mm (12 in) from the projected periphery of the network protector enclosure and approximately on a vertical line as follows:

- One approximately 300 mm (12 in) above the network protector or enclosure (including bushings).
- One approximately 300 mm (12 in) below the network protector enclosure. In the case of a floor-mounted network protector enclosure, it shall be approximately 300 mm (12 in) above the floor or mounting base.
- One approximately midway between the above two positions.

All reasonable precautions shall be taken to reduce errors caused by the time lag between the temperature rise of large apparatus and variations in the ambient temperature. Therefore, the ambient sensing

temperature sensors shall be immersed in a suitable liquid, such as oil, in a suitable metal cup. The size of the metal cup should be determined by the size of the apparatus being tested, but in no case shall the cup be any smaller than 25.4 mm (1.0 in) in diameter and 50.8 mm (2.0 in) high.

5.2.5 Performance

Network protectors shall be considered to have passed this test if the limits of observable temperature rise as listed in Table 1, for every point measured per Figure 1, are not exceeded. The resistance values recorded should be representative of the values recorded after the continuous current thermal test and serve as a basis for quality control monitoring of the production of the individual designs and establishing the maximum acceptable limits of the individual designs and configurations. These values shall also be used as the resistance limit in the tests of 5.3 and 5.4.

5.3 Electrical tests

5.3.1 General

The test circuit conditions shall be verified by measuring the current in the test circuit by short-circuiting the supply side of the test circuit at the network protector. For the purpose of determining the X/R ratio, the ac current shall be measured in the first half cycle after the short circuit is initiated, this current being calculated in accordance with IEEE Std C37.09™ [B7]. The test circuit shall have an X/R ratio between 6.6 and 8 with X and R in series. Any reactor used in the test circuit shall be an air-cored reactor. The test circuit impedances shall be such that the three-phase symmetrical currents are essentially equal. The time at which the magnitude of the symmetrical current is required to meet a rating level of the network protector is specified for each test separately.

In all cases, the network protector enclosure shall be insulated from ground and shall be connected to ground through a 30 A current-limiting fuse, having an interrupting rating capacity not less than the interrupting rating of the network protector.

5.3.2 Interrupting rating test

5.3.2.1 General

The interrupting rating of the network protector, without fuses, shall be expressed in root-mean-square (rms) symmetrical amperes at the maximum design voltage of the network protector.

5.3.2.2 Test conditions

All interrupting testing shall be three-phase with the removable breaker installed in its enclosure. The test circuit impedance shall be such that the average symmetrical phase current at the end of 1 s is not less than the interrupting rating of the network protector.

Two separate tests shall be performed. One test shall energize from the transformer side with the network side shorted; the other test shall energize from the network side with the transformer side shorted.

5.3.2.3 Operating duty

The operating duty of the network protector shall consist of an opening operation, followed by a 2 min interval, and another opening operation (OPEN 2 min, CLOSE 1 s, OPEN). For each opening operation, the network protector shall carry its rated interrupting current for 1 s before opening.

5.3.2.4 Performance

At the end of each test, the network protector shall be in substantially the same mechanical condition as before the test. It shall be capable of withstanding rated voltage in the OPEN position, and it shall be capable of carrying rated current without exceeding the temperature rise limit.

The circuit resistance of each phase shall not exceed the circuit resistance measured at the end of the heat run test described in 5.2. Each test shall consist of the operating sequence specified in 5.3.3.2.

After each test, the network protector shall be inspected. The ground fuse shall be verified to be intact. Maintenance shall not be performed until after completion of both tests. After completion of both tests, maintenance may be performed.

5.3.3 Short-time current test

5.3.3.1 General

A network protector without fuses shall be given a short-time current rating, expressed in rms symmetrical amperes at the maximum design voltage of the network protector.

5.3.3.2 Test conditions

All short-time current testing shall be three-phase, with the test circuit impedance being such that the average symmetrical phase current at the end of 1 s is not less than the short-time rating of the network protector. The maximum peak current at the initiation of current shall not be less than 2.3 times the short-time symmetrical current rating. The test shall be performed energized from either the transformer side or the network side.

5.3.3.3 Operating duty

The rated short-time current shall be maintained for a period of 1 s without the network protector breaker's contacts parting. The test circuit is to be energized and de-energized only by the action of the test station breakers.

5.3.3.4 Performance

At the end of the test, the network protector shall be capable of meeting its interrupting rating and capable of carrying rated continuous current without exceeding the temperature rise limit.

The circuit resistance of each phase shall not exceed the circuit resistance measured at the end of the heat run test described in 5.2. After the test, the network protector shall be inspected to verify that the main contacts are free of excessive burning or pitting. The ground fuse shall be verified to be intact.

5.3.4 Fault close test

5.3.4.1 General

For network protectors with either spring-close mechanisms or stored-energy mechanisms, fault close levels shall be tested to verify the network protector's ability, less the fuses, to close and latch its contacts.

5.3.4.2 Test conditions

All fault close current testing shall be three-phase, with the test circuit impedance being such that the rms total current of the maximum phase during the first half cycle is not less than 1.35 times the fault close and

latch symmetrical current rating of the network protector. The maximum peak current at the initiation of current shall not be less than 2.3 times the fault close and latch symmetrical current rating.

5.3.4.3 Operating duty

The fault closing shall consist of electrically closing the network protector breaker into the test circuit. The test circuit is then de-energized by the action of the test station breaker after 10 cycles.

5.3.4.4 Performance

Directly after this test is completed, the network protector breaker shall be checked to verify the following:

- a) The spring-closing mechanism has completed its closing cycle successfully.
- b) The main contacts are free from excessive burning or pitting.
- c) The network protector breaker can be tripped manually.

At the end of this test, the network protector shall be capable of carrying rated continuous current without exceeding its rated temperature rise and shall be capable of meeting its interrupting rating. The ground fuse shall be verified to be intact.

The circuit resistance of each phase shall not exceed the circuit resistance measured at the end of the heat run test described in 5.2.

5.3.5 Fuse interruption test for non-silver-sand fuses

5.3.5.1 General

The network protector in its enclosure with non-silver-sand fuses installed shall be subjected to fault currents that are a minimum of the interrupting rating to a maximum of 110% of the interrupting rating of the network protector. The trip circuit of the network protector shall be made inoperable for this test. This test is intended to show that the fuses are capable of clearing a three-phase fault without arcing to ground.

5.3.5.2 Test conditions

All fuse interrupting testing shall be three-phase with the removable breaker installed in its enclosure. The test circuit impedance shall be such that the average symmetrical phase current at the end of 1 s is not less than the interrupting rating of the network protector.

Two separate tests shall be performed. One test shall energize from the transformer side with the network side shorted. The other test shall energize from the network side with the transformer side shorted. Each test shall consist of the operating duty specified in 5.3.5.3.

5.3.5.3 Operating duty

The operating duty cycle of the network protector fuse test shall consist of three separate three-phase fuse interruptions at the maximum interrupting rating and maximum design voltage of the network protector. Each interruption shall be conducted with new fuses. The network protector shall be inspected and may be maintained as required. The test circuit shall remain energized for 1 s following each interruption.