

IEEE Standard Requirements for Secondary Network Protectors

IEEE Power and Energy Society

Sponsored by the

Transformers Committee

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

IEEE Std C57.12.44™-2014
(Revision of
IEEE Std C57.12.44-2005)

IEEE Standard Requirements for Secondary Network Protectors

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

Approved 27 March 2014

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 © 2014 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 13 June 2014. 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 978-0-7381-9072-3 STD98625
Print: ISBN 978-0-7381-9073-0 STDPD98625

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 IEEE standard was completed, the Network Protectors Working Group had the following membership:

William Wimmer, *Co-Chair*
Mark Faulkner, *Co-Chair*

Edward Bertolini
Joseph Cultrera

Cory Morgan
Daniel Mulkey
Carl Niemann

Kenneth Romano
Terry Turvey

Other individuals who participated in the revision are as follows:

Douglas Craig

Larry Dix

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

William Ackerman
Satish Aggarwal
Carlo Arpino
Adam Bagby
Peter Balma
Edward Bertolini
Wallace Binder
Thomas Blackburn
Chris Brooks
William Bush
Paul Cardinal
Stephen Conrad
John Crouse
Chuanyou Dai
Randall Dotson
Brian Escott
Mark Faulkner
David Gilmer
Jalal Gohari
James Graham
Randall C. Groves
John Harley
J. Harlow
Jeffrey Hartenberger
Timothy Hayden

Jeffrey Helzer
Philip Hopkinson
Laszlo Kadar
Yuri Khersonsky
James Kinney
Jim Kulchisky
Chung-Yiu Lam
Deni Lee
Greg Luri
Bruce Mackie
Richard Marek
Nigel Mcquin
John Miller
Charles Morgan
Daniel Mulkey
Daniel Mungovan
Michael Newman
Charles Ngethe
Carl Niemann
Lorraine Padden
Bansi Patel
Wesley Patterson
Alvaro Portillo
Peter Risse

Michael Roberts
Charles Rogers
Kenneth Romano
John Rossetti
Marnie Roussel
Bartien Sayogo
Gil Shultz
Veselin Skendzic
James Smith
Jerry Smith
Gary Stodter
John Sullivan
John Teixeira
David Tepen
Sylvester Toe
Joe Uchiyama
Eric Udren
John Vergis
Jane Verner
Carl Wall
Lee Welch
Kenneth White
James Wilson
William Wimmer
Daidi Zhong

When the IEEE-SA Standards Board approved this standard on 27 March 2014, it had the following membership:

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

Peter Balma
Farooq Bari
Ted Burse
Clint Chaplain
Stephen Dukes
Jean-Phillippe Faure
Gary Hoffman

Michael Janezic
Jeffrey Katz
Joseph L. Koepfinger*
David J. Law
Hung Ling
Oleg Logvinov
Ted Olsen
Glenn Parsons

Ron Peterson
Adrian Stephens
Peter Sutherland
Yatin Trivedi
Phil Winston
Don Wright
Yu Yuan

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Don Messina
IEEE-SA Content Publishing

Erin Spiewak
IEEE-SA Standards Technical Community

Introduction

This introduction is not part of IEEE Std C57.12.44-2014, IEEE Standard for Requirements for Secondary Network Protectors.

This is the third revision of IEEE Std C57.12.44, which was originally published in 1994. The main purpose of this revision was to make changes as required to improve the standard. The revision officially started with IEEE Project Authorization Request approval on June 17, 2010. The revision was accomplished by the Standard Requirements for Secondary Network Protectors Working Group under the Underground Transformers and Network Protectors Subcommittee of the IEEE Power and Energy Society (PES) Transformers Committee.

A task force consisting of EEI, National Electrical Manufacturers Association (NEMA), and IEEE PES delegates developed the original document. The first working group meeting was held 24 February 1988, in Washington, DC. 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. R. B. Robertson chaired the Working Group during the preparation and balloting of the original standard.

This IEEE standard is a voluntary consensus standard. Its use becomes 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 user and the producer, provided such changes do not violate existing laws and are considered technically adequate for the function intended.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 Word usage	1
2. Normative references	2
3. Definitions	2
4. Service conditions	4
4.1 Usual service conditions	4
4.2 Unusual service conditions	4
5. Design tests	5
5.1 Continuous current thermal test	5
5.2 Electrical tests	7
5.3 Mechanical endurance test	11
6. Production tests	12
6.1 Operational tests	12
6.2 Dielectric tests	13
6.3 Insulation resistance tests	14
6.4 Current path resistance tests	15
6.5 Mechanical tests	15
7. Relay characteristics	16
7.1 General	16
7.2 Automatic close functions	16
7.3 Automatic trip functions	17
7.4 Tripping adjustment	18
8. Fuses and fuse mountings	19
8.1 Fuse provisions	19
8.2 Functional performance specifications	21
8.3 Fuse types	21
9. Rating requirements	21
9.1 Nameplates	21
9.2 Interrupting rating	22
9.3 AC voltage ratings	22
9.4 Dielectric test voltage	23
9.5 Control voltage	23
9.6 Closing voltage	23
9.7 Tripping currents	24
10. Mechanical performance specifications	24
10.1 Submersible type	24
10.2 Non-submersible type	24
10.3 Open-frame type	25
10.4 Mounting application	25
10.5 General requirements	25
10.6 Finish	29

11. Other requirements	29
11.1 Submersible enclosure	29
11.2 Non-submersible enclosure	29
11.3 Open frame enclosure	30
11.4 Mounting configurations	30
11.5 Network-side terminations.....	31
 Annex A (normative) Classification of insulating materials	33
 Annex B (informative) Network fuse application	36
 Annex C (informative) Pumping	46
 Annex D (informative) Unprotected zone in network protectors	47
 Annex E (informative) Contact surface oxidation	48
 Annex F (informative) Reverse current sensitivity.....	49
 Annex G (informative) Network protector enclosures	52
 Annex H (informative) Bibliography	53

IEEE Standard Requirements for Secondary Network Protectors

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 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

As used in this standard, the word “shall” indicates mandatory requirements. The words “should” and “may” refer to matters that are recommended and permissive, respectively, but not mandatory.

NOTE—The introduction of this standard describes the circumstances under which the document may be used on a mandatory basis.¹

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 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.

All characteristics, definitions, tests, and voltage designations, except as specifically covered in this standard, shall be in accordance with the following standards.

IEEE Std C57.12.28™-2005, IEEE Standard for Pad-Mounted Equipment-Enclosure Integrity.^{2, 3}

IEEE Std C57.12.32™-2002, IEEE Standard for Submersible Equipment—Enclosure Integrity.

IEEE Std C57.12.40™-2011, IEEE Standard for Network, Three-Phase Transformers, 2500 kVA and Smaller; High Voltage, 34 500 GrdY/19 920 and Below; Low Voltage, 600 V and Below; Subway and Vault Types (Liquid Immersed).

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* [B7] should be consulted for terms not defined in this clause.^{4, 5}

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, which 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.

¹ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

² IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

³ The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

⁴ The numbers in brackets correspond to those of the bibliography in Annex H.

⁵ *IEEE Standards Dictionary Online* subscription is available at:

http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

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.

NOTE—The *network protector* is usually arranged to connect automatically 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 back-up 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 re-lays, auxiliary panels, current transformers, control devices, other attachments, and all interconnecting wiring, which 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 voltage. *Syn:* **shunt trip.**

NOTE—The voltage 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 5.2, are intended to be applied to a system with power generation only on the high-voltage side of the transformer that supplies networked secondary without any secondary power generation.

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™ [B14] 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™-2010 [B11].

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

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

For the tests specified in 5.1 through 5.3, 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 5.1 (while the protector is at temperature as defined in 5.1.2) shall be used as the limit for the circuit resistance values measured at the conclusion of tests in 5.2 and 5.3. Units with higher circuit resistances shall require an additional continuous current thermal test (5.1) after type testing unless the manufacturer can demonstrate that the resistance recorded will not cause the protector to exceed temperature in Table 1.

5.1 Continuous current thermal test

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—Temperature rise

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

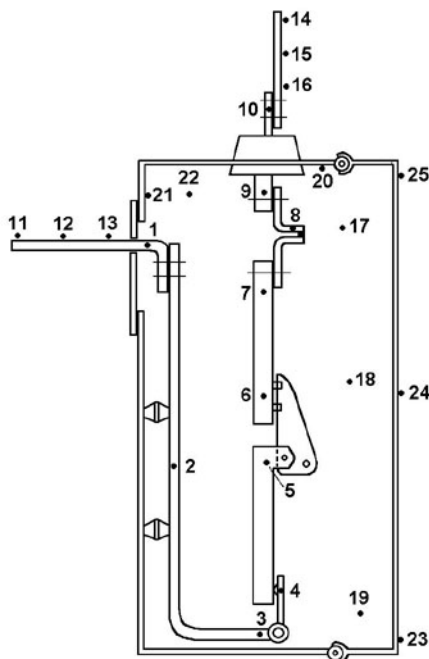
5.1.1 Test conditions

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 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 an insulating 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.

Thermocouples shall be used to measure the temperature. Thermocouples 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. Thermocouples 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. Thermocouples shall be held in intimate contact with the conductor surface. Thermocouples 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 thermocouples 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 thermocouples 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 thermocouples required.



NOTE—Thermocouples 1–16 shall be duplicated on all three phases.

Figure 1—Thermocouple locations

5.1.2 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 ± 1.0 °C (± 1.8 °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.

5.1.3 Ambient temperature

The network protector shall be tested at an ambient temperature between 10 °C (50 °F) and 40 °C (104 °F). No correction factors need 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 thermocouples placed horizontally 300 mm (12 in) from the projected periphery of the network protector enclosure and approximately on a vertical line as follows:

- a) One approximately 300 mm (12 in) above the network protector or enclosure (including bushings).
- b) One approximately 300 mm (12 in) below the network protector enclosure. In the case of a floor mounted network protector enclosure, it shall be 305 mm (12 in) above the floor or mounting base.
- c) 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 thermocouples 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.

5.1.4 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 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 5.2 and 5.3.

5.2 Electrical tests

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 [B9]. 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.

5.2.1 Interrupting rating test

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.

5.2.2 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.

5.2.2.1 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-1sec-Open). For each opening operation, the network protector shall carry its rated interrupting current for 1 s before opening.

5.2.2.2 Performance

At the end of the 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 of 5.1.

After the test, the network protector shall be inspected, and may be maintained. The ground fuse shall be verified to be intact.

5.2.3 Short-time current test

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.

5.2.3.1 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.

5.2.3.2 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.

5.2.3.3 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 of 5.1. 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.

5.2.4 Fault close test

For network protectors having 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.