C57.12.44™

IEEE Standard Requirements for Secondary Network Protectors

IEEE Power Engineering Society

Sponsored by the
Transformers Committee

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

7 June 2006

IEEE Std C57.12.44™-2005
(Revision of
IEEE Std C57.12.44-2000)

Recognized as an
American National Standard (ANSI)

IEEE Std C57.12.44™-2005
(Revision of
IEEE Std C57.12.44-2000)

IEEE Standard Requirements for Secondary Network Protectors

Sponsor

Transformers Committee
of the
IEEE Power Engineering Society

Approved 24 April 2006

American National Standards Institute

Approved 7 December 2005

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, network, protector, spot network

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

Print: ISBN 0-7381-4882-2 SH95511
PDF: ISBN 0-7381-4883-0 SS95511

Introduction

This introduction is not part of IEEE Std C57.12.44-2005, IEEE Standard Requirements for Secondary Network Protectors.

This is the second 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 and take action as appropriate on comments held from the 2000 ballot. The revision officially started with IEEE Project Authorization Request approval on February 14, 2002. The revision was accomplished by the Network Protector Working Group under the Underground Transformers and Network Protectors Subcommittee of the of the IEEE Power Engineering Society (PES) Transformers Committee. The major changes are reintroducing the US customary measures; revising 4.1.4, 7.1, 7.2, 7.3, 10.5.14, 10.5.15, 10.5.18, and 11.4.1; and adding a new 5.2, a new Figure 6, and a new column in Table B.3 and Table B.4.

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, D. C. 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.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: http://standards.ieee.org/reading/ieee/updates/errata/index.html. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

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 with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents or patent applications for which a license may be required to implement an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Participants

The following is a list of participants in the Network Protector Working Group:

Daniel H. Mulkey, *Chair*

Dave Blew
Joseph Cultrera
Iqbal Hussain
Dennis Lee
Jock Moffat
Carl Niemann
Paul Orehek
Edwin Owen
Martin Rave
A. L. Robinson
Ken Romano
John Sullivan
W. G. Wimmer

Other individuals who have participated in the revision are as follows:

Franklin Lu
Mike Martin
Steve Schroeder

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

David Aho
Edward Bertolini
David Blew
Carl Bush
Bryan Cole
Stephen Conrad
Tommy Cooper
Jerry Corkran
R. Daubert
Matthew Davis
Gary Engmann
Rabiz Foda
Fredric Friend
Thomas Greely
Randall Groves
N. Kent Haggerty
Ken Hanus
Jeffrey Hartenberger
Edward Horgan, Jr.
James D. Huddleston III
Iqbal Hussain
Yuri Khersonsky
Stephen R. Lambert
Dennis Lee
Gregory Luri
Faramarz Maghsoodlou
Al Maguire
John Matthews
Mark McGranaghan
Nigel McQuin
G. Michel
Jock Moffat
Daniel H. Mulkey
Arun Narang
Carl Niemann
Robert Olen
T. W. Olsen
Paul Orehek
Wes Patterson
Thomas Pekarek
Alvaro Portillo
Ken Romano
Peter Risse
John Rossetti
Tarkeshwar Singh
Dinesh Sankarakurup
Michael Shirven
H. Jin Sim
John Sullivan
Tom Wandeloski
Joe Watson
James Wilson
Bill Wimmer

When the IEEE-SA Standards Board approved this standard on 7 December 2005, it had the following membership:

Steve M. Mills, *Chair*
Richard H. Hulett, *Vice Chair*
Don Wright, *Past Chair*
Judith Gorman, *Secretary*

Mark D. Bowman
Dennis B. Brophy
Joseph Bruder
Richard Cox
Bob Davis
Julian Forster*
Joanna N. Guenin
Mark S. Halpin
Raymond Hapeman
William B. Hopf
Lowell G. Johnson
Herman Koch
Joseph L. Koepfinger*
David J. Law
Daleep C. Mohla
Paul Nikolich
T. W. Olsen
Glenn Parsons
Ronald C. Petersen
Gary S. Robinson
Frank Stone
Malcolm V. Thaden
Richard L. Townsend
Joe D. Watson
Howard L. Wolfman

*Member Emeritus

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

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Alan H. Cookson, *NIST Representative*

Michelle D. Turner
IEEE Standards Project Editor

Contents

IEEE Standard Requirements for Secondary Network Protectors

1. Overview

1.1 Scope

This standard describes certain electrical, dimensional, and mechanical characteristics and takes into consideration certain 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. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C57.12.28-1999, American National Standard Pad-Mounted Equipment-Enclosure Integrity.[2]

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

[2]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

ANSI C57.12.40-2000, American National Standard for Secondary Network Transformers—Subway and Vault Types (Liquid Immersed)—Requirements.

IEEE Std C37.108™-1989 (Reaff 1994), IEEE Guide for the Protection of Network Transformers.[3, 4]

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

3. Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standard Terms* [B9] and IEEE Std C57.12.80 [B12] should be referenced for terms not defined in this clause.

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

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

3.2 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.

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

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

3.5 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.*

3.6 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.*

3.7 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.*

3.8 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.*

3.9 network protector fuse: A back-up device for the network protector.

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

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

3.10 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.

3.11 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.*

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

3.13 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, which can be rolled out of the network protector enclosure on rails for maintenance or removal.

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

3.15 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.*

3.16 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.

3.17 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.

3.18 trip-free: The capability of a switching device to have the moving contacts return to and remain in the opening 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 °C (-4 °F) and 40 °C (104° 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 must be given to these applications. IEEE Std C57.91 [B13] 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 [B11].

The insulation level at 1000 m (3300 ft) multiplied by the correction factor must 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.

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	Δ 50 °C (Δ 90 °F)
105	Δ 65 °C (Δ 117 °F)
130	Δ 90 °C (Δ 162 °F)
155	Δ 115 °C (Δ 207 °F)
180	Δ 140 °C (Δ 252 °F)
200	Δ 160 °C (Δ 288 °F)
220	Δ 180 °C (Δ 324 °F)

5.1.1 Test conditions

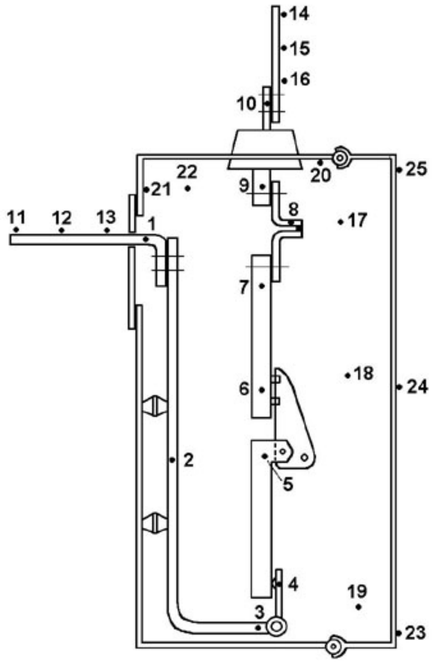
The network protector in its enclosure, with fuses, shall be connected to a balanced three-phase current source at the transformer side of the network protector with copper bus bar whose ampacity is rated to carry the full rated current. This bus bar shall extend a minimum of 1.2 m (4 ft) from the network protector. This bus bar shall have a current density range of 120 A/cm^2 (800 A/in^2) to 230 A/cm^2 (1500 A/in^2). 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 by such methods as welding, drilling and peening, or cementing. 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.

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.



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

Figure 1—Thermocouple locations

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 of the conductors shall be measured on the network protector and its enclosure, either as one unit or separately. 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.

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 [B10]. 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 must 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 (O-2 min-O). 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

After the test, the network protector must be inspected, and may be maintained. The ground fuse must 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 must 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.

After the test, the network protector must be inspected to verify that the main contacts are free of excessive burning or pitting. The ground fuse must 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.

5.2.4.1 Test conditions

All fault close current testing must 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.

5.2.4.2 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.

5.2.4.3 Performance

Directly after this test is completed, the network protector breaker shall be checked to ensure 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 must be verified to be intact.

5.2.5 Fuse interruption test for non-silver-sand fuses

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.

5.2.5.1 Test conditions

All fuse interrupting testing must 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 that 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.

5.2.5.2 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 test 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 after interruption.

5.2.5.3 Performance

Directly after each three-phase fuse interruption, the network protector shall be checked to ensure the following:

a) At least two fuses cleared successfully.

b) The 30 A ground fuse is intact.

5.2.6 Fuse interruption test for silver-sand fuses

The network protector in its enclosure with 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 silver-sand fuses are capable of clearing a three-phase fault without out-gassing, without pistoning the fuse end pieces, and without internal restrike.

5.2.6.1 Test conditions

All fuse interrupting tests must 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, three phase. The other shall energize from the network side with the transformer side shorted, three phase.

5.2.6.2 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 test shall be conducted with new fuses in all three phases. The network protector and its respective silver-sand fuse enclosure shall be inspected and may be maintained as required. However, the fuse enclosure and its surrounding bus structure shall show no signs of distress or failure.

The test circuit shall remain energized for 1 s after interruption.

It shall be determined that the fuse peak let-through current shall be below the network protector interrupting rating.

5.2.6.3 Performance

Directly after each three-phase fuse interruption, the network protector shall be checked to ensure the following:

a) At least two fuses cleared successfully.

b) The 30 A ground fuse is intact.

c) The fuse enclosure is intact, and no distress is observable to the supporting bus structure.

5.3 Mechanical endurance test

5.3.1 Test conditions

The removable breaker is to be mounted in its enclosure with the enclosure door in the closed position. Rated voltage of the network protector shall be supplied directly into the control circuitry in such a manner as to utilize as many control components as possible, such as auxiliary switch contacts, latch check contacts, auxiliary relays, closing motor, tripping device, motor seal-in contacts, resistors, rectifiers, and control transformers.

Electrical heaters shall be strategically placed throughout the network protector enclosure. The heaters shall increase the internal enclosure air temperature to 95 °C ± 5 °C (203 °F ± 9 °F). On ventilated or open types of enclosures the entire network protector shall be placed into an environment whose ambient temperature is 95 °C ± 5 °C (203 °F ± 9 °F). Three thermocouples shall be mounted at convenient locations within the network protector enclosure. One thermocouple shall be located within 152 mm (6.0 in) from the bottom of the enclosure. The second thermocouple shall be located at half the total height of the enclosure, while the third thermocouple shall be located within 152 mm (6.0 in) from the top of the enclosure. The average of the three temperature readings shall be used as the elevated temperature reading. Temperature stability must be maintained for 1.5 hr prior to proceeding with the mechanical test.

5.3.2 Operating duty

The mechanism shall be operated 10 000 consecutive times without malfunction or interim adjustment. One operation is defined as a CLOSING and OPENING of the breaker under no electrical load.

5.3.3 Rate of operation

The rate of operation shall be at least one operation every 2 min. During each operation, the network protector circuit breaker shall remain closed for no less than 1 s. The device used to control the input voltage shall have a system that controls the opening and the closing of the network protector circuit breaker and stops the test if the circuit breaker fails to OPEN or CLOSE. The control device should indicate the mode of failure.

5.3.4 Performance

At the end of this test, the network protector breaker shall be thoroughly inspected to verify and record that the critical adjustments are in tolerance. Any change or modification must be reviewed as to its impact on its thermal and/or electrical test, if previously conducted.

Any failure of the external control circuitry does not require the test counter to be reset to zero. The external control device can be replaced or repaired and the mechanical test may recommence.

Any component that has been scorched, discolored, or burned by the internal heaters shall not be considered a failure.

Any and all changes and/or modifications must be fully documented during this phase of the testing along with the starting/stopping counter readings.

6. Production tests

The production tests shall be performed on every network protector. They are divided into the following categories:

a) Operational
b) Dielectric
c) Insulation resistance
d) Current path resistance
e) Mechanical

6.1 Operational tests

The purpose of the operational test is to prove the ability of the network protector to function both in closing and opening the network protector breaker with and without relays under both nominal rated voltage and minimum voltage conditions.

6.1.1 Electrical operations

6.1.1.1 Normal voltage test

With the relays removed, the test control leads should be connected to that portion of the control circuitry that will permit a remote CLOSE and OPEN operation of the removable breaker. The test source should be connected to the rated voltage of the network protector and the removable breaker should be tested 50 operations per Table 2. The removable breaker contacts shall remain closed for a minimum of 1 s before the opening sequence is initiated.

Table 2—Operational test summary

Test subclause	Removable breaker	Relays utilized	Voltage level	Number of operations[a]
6.1.1.1	Out of enclosure	No	Rated	50
6.1.1.2	Out of enclosure	No	Minimum	5
6.1.1.3	Out of enclosure	Yes	Rated	25
6.1.1.4	Out of enclosure	No	Rated	5
6.1.1.5	In enclosure	No	None	5
6.1.1.6	In enclosure	No	Rated	5

[a]Operation is defined as one opening and one closing.

6.1.1.2 Minimum voltage tests

The voltage level should be reduced to 73% of rated voltage and initiate a CLOSE sequence. At this voltage level, the removable breaker must not close. Without changing the voltage level, the auxiliary motor relay contact should be mechanically closed. The motor must have sufficient torque at this voltage level to completely CLOSE the removable breaker. The removable breaker should be manually tripped and the input voltage increased from 73% to 80% of rated voltage. Initiate a close sequence. The removable breaker shall operate through its auxiliary motor relay supplying power to the motor. The voltage should be reduced to 7.5% of rated voltage. At this reduced level, an opening sequence should be initiated. The removable breaker must completely OPEN. Perform this sequence five times per Table 2.

6.1.1.3 Relay tests

Three-phase test leads should be connected to the transformer side bus and the network side bus connections. The ground lead should be connected to the removable breaker. The calibrated network relay(s) should be installed, and the input voltage adjusted to the rated voltage. Electrically close the removable breaker by raising the phasing voltage on the test circuit. The removable breaker shall CLOSE its contacts at a predetermined value. The removable breaker should be electrically tripped by applying reverse current on the test circuit. The removable breaker shall OPEN its contacts completely at a predetermined trip level. Perform this sequence 25 times per Table 2.

6.1.1.4 Trip free test

The trip free operation of the mechanism shall be checked by attempting to electrically CLOSE the removable breaker contacts while mechanically holding the tripping component of the removable breaker in the trip position. The removable breaker contacts shall not CLOSE under these conditions. Perform this sequence five times per Table 2.

6.1.1.5 Manual operation

On removable breakers without a stored-energy or spring close mechanism, with the removable breaker mounted in its enclosure, manually CLOSE the network protector by the use of the outside operating handle. Then, OPEN the network protector by use of the outside operating handle. The network protector shall CLOSE and OPEN its contacts through the outside operating handle. Perform this sequence five times per Table 2.

6.1.1.6 Operating handle test

On removable breakers having either stored-energy or spring closed mechanisms, the outside operating handle shall electrically complete the motor close circuit when the handle is placed in the CLOSE position. This test is performed with the removable breaker mounted in its enclosure and three-phase test leads connected to the transformer side of the network protector. Moving the outside operating handle to the CLOSE position shall complete the electrical circuit of the closing motor and the network protector shall close. Then, OPEN the network protector contacts by use of the outside operating handle. Perform this sequence five times per Table 2.

6.1.2 Performance

The operational test as defined in Table 2 shall be performed without any malfunction of the network protector.

6.2 Dielectric tests

Dielectric withstand tests shall be conducted on removable breakers and enclosures, either as one unit or separately. All barriers and insulation shall be in place. These tests prove the condition of all control wiring and bus insulation both phase-to-phase and phase-to-ground.

6.2.1 Tests conditions

The network relays are removed. The leads to the motor shall be disconnected from the circuit. Additional line to ground circuits shall be disconnected from ground. All open points on the harness, such as sockets, plugs, terminal boards, and relay connectors shall be electrically connected together and isolated from ground. Solid-state devices, such as diodes and rectifiers, shall be shorted or removed from the circuit.

The dielectric test shall be conducted at 2200 V at 60 Hz for 1 min for each of the following points of application discussed in 6.2.1.1 through 6.2.1.3.

6.2.1.1 Removable breaker

a) Between top phases and bottom phases, with the top phases grounded and the circuit breaker OPEN
b) Between all phases and ground with the circuit breaker closed
c) Between the outside phases and ground with the center phase grounded and the circuit breaker OPEN

6.2.1.2 Enclosure

a) Between all phases on the network side (including secondary disconnects) and ground
b) Between the outside phases on the network side and ground, with the center phase grounded
c) Between all phases on the transformer side and ground
d) Between the outside phases on the transformer side and ground, with the center phase grounded

6.2.1.3 Component tests

a) The motor shall be tested at 900 V at 60 Hz for 1 min.
b) The network relay(s) shall be tested at 1500 V at 60 Hz for 1 min.

6.2.2 Performance

A dielectric breakdown shall constitute a failure.

6.3 Insulation resistance tests

Insulation resistance tests shall be conducted on the removable breaker and its enclosure, with all barriers and insulation in place, either as one unit, or separately.

6.3.1 Test conditions

The network relays shall be removed. The leads to the motor shall be disconnected from the circuit. Additional line-to-ground circuits shall be disconnected from ground. All open points on the harness, such as sockets, plugs, terminal boards, and relay connectors shall be electrically connected together and isolated from ground. Solid-state devices, such as diodes and rectifiers, shall be shorted or removed from the circuit.

With the removable breaker CLOSED, the resistance should be measured at the following locations using direct current from an instrument set at 2500 V:

a) Between the main bus bars; left to center, center to right, and left to right
b) Between the main bus bars and ground; left, center, and right

6.3.2 Performance

The direct current resistance values shall be equal to or greater than 25 MΩ measured at 2500 V.

6.4 Current path resistance tests

The current path shall encompass all main current carrying conductors of both the enclosure and the removable breaker. The acceptable limits shall be established by each manufacturer for each amperage class of network protector and removable breaker, with and without fuses. These values shall be established from the continuous current thermal test (see 5.1.4). The limits shall be tabulated and subdivided into specific sections of the enclosure and the removable breaker.

6.4.1 Test conditions

With the removable breaker placed in its enclosure and all fuses and disconnect links mounted, measure the resistance on each phase of the network protector using a 100 A minimum current test set.

6.4.2 Performance

All readings shall be within the manufacturer's acceptable limits.

6.5 Mechanical tests

Mechanical tests shall be performed on network protectors to prove the mechanical fit between the removable breaker and its associated enclosure. It shall also prove the mechanical seals required on submersible types of enclosures.

6.5.1 Mechanical fit test conditions and performance

With the removable breaker out on its enclosure extension rails, roll the breaker into the enclosure. It shall

a) Roll smoothly and with no tendency for the breaker rollers to ride off the extension rails.

b) Align properly on the rails or racking device.

c) Ensure that the securing hardware aligns properly and is complete.

d) Ensure that the fuses fit properly in their designated location, and the alignment of the mating surfaces provide solid contact with the fuse to ensure proper current and heat transfer to the main conductor.

6.5.2 Submersible seal integrity test conditions and performance

On submersible enclosures, the transformer throat area shall be temporarily sealed. The leak test shall be performed by pressurizing the completed network protector to a gauge pressure of 48 kPa (7.0 lbf/in^2) and submerging it into a tank of water. Any sign of escaping air in the form of bubbles constitutes a failure. Minor leaks from the removable throat plate bolts, which do not interfere with detection of other leaks, shall be disregarded.

Alternative methods of leak detection of equivalent sensitivity may be utilized.

7. Relay characteristics

7.1 General

The relay characteristics shall be composed of the combination of the closing and tripping curves as well as the adjustment of the relay.

Network protectors shall utilize 216Y/125 V relays regardless of the three-phase, four-wire system voltage for which they are to be applied.

The purpose of the network protector relay is to trip open the protector when there is a net three-phase power flow from the network to the primary (reverse power) and to ensure automatic closure of the protector when there is a potential for a forward flow of power into the secondary network.

There are three types of network protector relays used on network systems: electromechanical (oldest), solid-state, and microprocessor (newest). Each type provides at least two automatic close functions and four automatic trip functions.

7.2 Automatic close functions

7.2.1 Dead network close function

The protector shall close when there is no network voltage and the transformer side voltage is greater than 80% of rated voltage.

7.2.2 Normal close function

The network protector shall close automatically if the net three-phase watt flow is into the network from the transformer and remains as a net three-phase watt flow into the network following the closure of the network protector.

To ensure that both the watt and var flow in the network protector are into the network from the transformer, following closure of the network protector, the phasing voltage phasor shall lie between 85° and –15° from the in-phase or 0° line.

7.2.3 Closing adjustment

The magnitude of the phasing voltage phasor shall be greater than a predetermined minimum threshold level from the network voltage, which shall serve as the reference phasor determining the network relay characteristic. This predetermined minimum level is chosen to assure that the network protector will not close when the magnitude of the phasing voltage is approaching zero. The closing adjustment threshold value shall be between 0.6 V and 2.0 V on a 216 V system. Refer to 9.6 for the closing voltage settings. The angle of the phasing voltage phasor in relation to the network voltage reference phasor shall be between 90° and –25° from the in-phase or 0° line. Any combination whereby the phasing voltage phasor exceeds the predetermined minimum value above the reference network phasor and falls within the predetermined allowable angular difference between the two phasors shall call for the relay(s) contact(s) to close (see Figure 2).

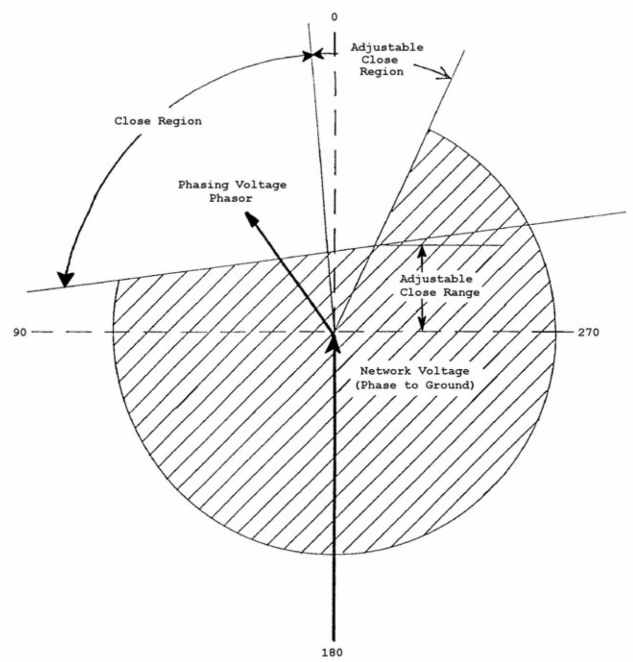


Figure 2—Close characteristics

7.3 Automatic trip functions

In all the modes of operation shown 7.3.1 through 7.3.4, the relay's trip function is primarily based on a net power flow from the network into the primary (reversed power). The reverse power condition can exist for both primary fault conditions and planned primary feeder breaker opening. The network protector shall trip automatically if the net three-phase power flow is into the transformer from the network. The network relay trip characteristic can be plotted as a function of current magnitude and the angle between the phase-to-ground voltage and phase current.

7.3.1 Sensitive trip function

The sensitive trip function is described as having a watt characteristic. In the absence of a fault, it shall trip automatically upon the reverse magnetizing current of its associated transformer. The trip is set low, on or about the losses of the associated transformer. The trip setting shall be adjustable.

7.3.2 Time delay trip function

The time delay trip function allows for a time delay for low reverse power flows and an instantaneous trip for high current during a net reverse power flow condition. Both the time delay and the high trip settings shall be adjustable. As backup protection during the time delay period, instantaneous overcurrent elements are engaged for primary feeder faults. The instantaneous overcurrent elements are adjustable from 50% to 200% of the network protector current transformer rating.

7.3.3 Insensitive trip function

The insensitive trip function only allows for tripping on an instantaneous trip for high current during a net reverse power flow condition. The instantaneous overcurrent elements are adjustable from 50% to 200% of the network protector current transformer rating.

7.3.4 Watt-var trip

The watt-var trip function allows for automatic tripping for faults on the primary feeder where the primary feeder utilizes single-phase protective devices. It may also be applied where single phase-to-ground primary fault on Δ–Y transformers may exist and the station breaker relaying may be unable to detect this level of ground current. This type of single phase-to-ground fault relay is described as having a watt-var characteristic, with a maximum response angle of 120°.

7.4 Tripping adjustment

The network relay shall make its trip contact whenever the balanced net three-phase power (watt) flow is in the reverse direction (180° from a constant network side voltage) and exceeds a predetermined threshold value. The trip adjustment threshold value shall be 0.05% to 5% of the network protector current transformer rating. Refer to 9.7 for trip current settings. For watt characteristic functions, the trip setting is the current in amperes at 180° with respect to the phase-to-ground voltage to make the relay trip contact (see Figure 3).

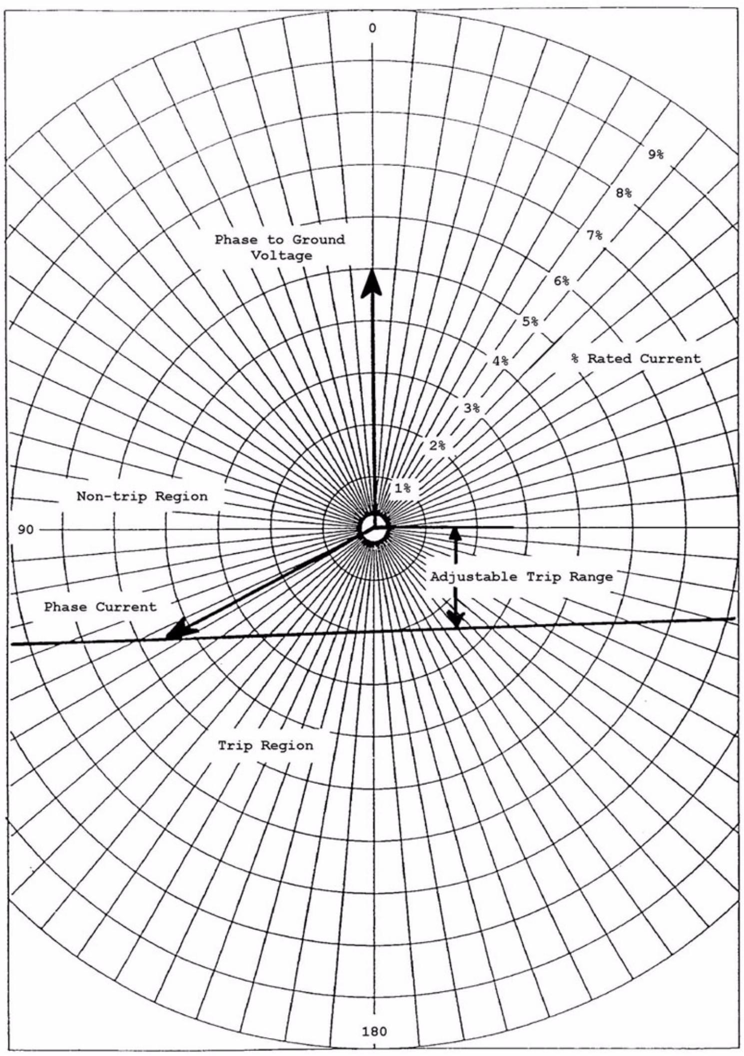
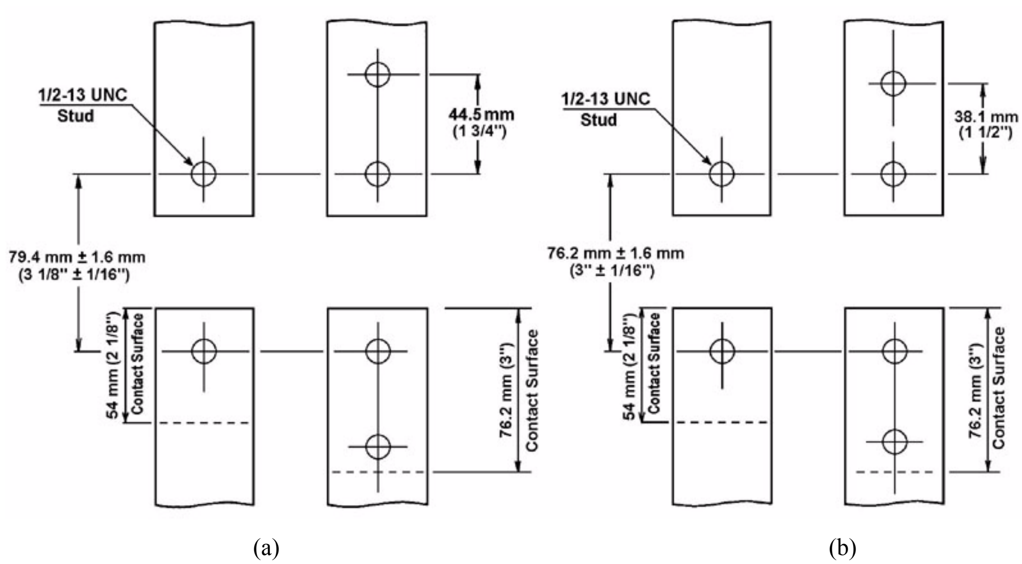


Figure 3—Watt characteristic trip

8. Fuses and fuse mountings

8.1 Fuse provisions

The network protector shall be equipped with provisions for installing three fuses mounted either internally or externally. Internal fuse mounting provisions are shown in Figure 4 and Figure 5, and are determined by the fuse selected. External fuse mountings may be in housings suitable for submersible operations, which shall be capable of being pressure tested along with the network protector enclosure per 6.5.2.



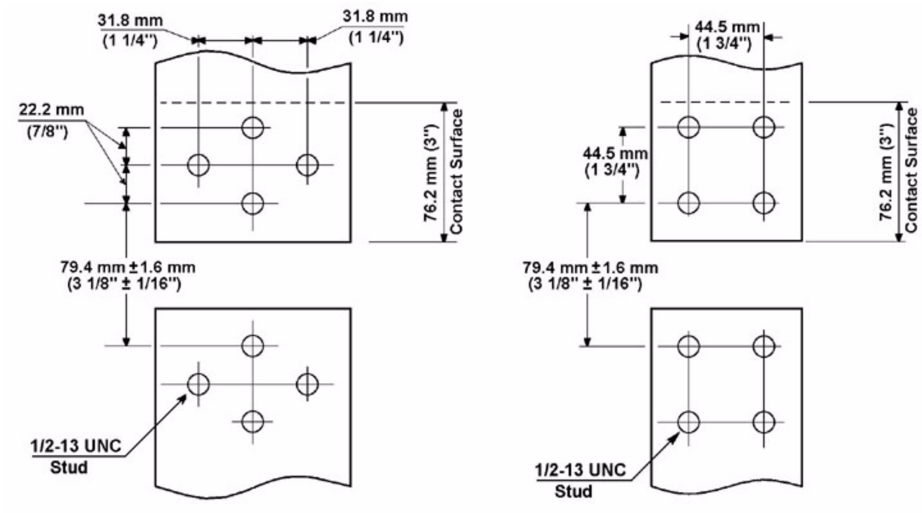
NOTE—Stud diameter is 0.5-13 Unified Coarse Thread (UNC). Stud length provided shall be of sufficient length to permit removal of fuse mounting assembly with a standard depth insulated socket. This length is determined by the fuse selected.

Figure 4—One- and two-hole internal fuse mounting patterns: (a) 800–3500 A; (b) 2250–3500 A

8.2 Functional performance specifications

Fuses used in network protectors shall be specified by the user.

Fuses shall be selected with time-current characteristics (corrected to fuse's operating ambient temperature) to provide maximum protection when compared to the thermal damage curve of its associated transformer. The minimum acceptable crossover point between the two curves should be no less than three times rated current. The maximum acceptable crossover point between the two curves should be no greater than seven times rated current. Under no circumstances are fuses to be applied whose average melting curve is faster than the network protector relay tripping response.



(a) (b)

NOTE—Stud diameter is 0.5-13 UNC. Stud length provided shall be of sufficient length to permit removal of fuse mounting assembly with a standard depth insulated socket. This length is determined by the fuse selected.

Figure 5—Four-hole internal fuse mounting patterns: (a) 2500–3500 A; (b) 4500–5000 A

8.3 Fuse types

Fuses for network protectors are not normal fuses and are specially designed for use in network protectors. They fall into the following four general categories:

a) Copper
b) Low loss
c) Alloy
d) Silver-sand current-limiting

9. Rating requirements

9.1 Nameplates

Nameplates shall contain the following minimum information for the removable breaker and the enclosure:

a) Manufacturer
b) Place of manufacture
c) Name of device (automatic network protector)
d) Model of device (example: MG-8; CM-22)
e) Identification serial number
f) Rated system voltage
g) Rated continuous current
h) Rated symmetrical interrupting current
i) Frequency

j) Current transformer ratio
k) Wiring diagram
l) Weight (total and removable breaker)
m) Submersible or nonsubmersible
n) Installation and operating instructions reference
o) Month and year of manufacture (uncoded)

9.2 Interrupting rating

Network protectors shall have continuous current, interrupting, and close and latch ratings as indicated in Table 3. As an aid in selection, the table shows recommended transformer sizes as well as the protector continuous current rating expressed as a percentage of the transformer nameplate current.

Table 3—Network protector ratings

Network protector			Network transformer		
Continuous rms current rating (A)	Interrupting rating, rms symmetrical (A)[a, b]	Close and latch rating, rms symmetrical (A)[c]	Nameplate rating (kVA)	Nameplate rms current (A)	Protector rating as % of transformer nameplate current
System voltage 216Y/125					
800	30 000	25 000	225	600	133
1200	30 000	25 000	300	800	150
1600	30 000	25 000	500	1333	120
1875	30 000	25 000	500	1333	141
2000	35 000	35 000	500	1333	150
2250	35 000	35 000	500	1333	169
2500	60 000	40 000	750	2000	125
2825	60 000	40 000	750	2000	141
3000	60 000	40 000	1000	2667	112
3500	60 000	40 000	1000	2667	131
4500	60 000	40 000	1000	2667	169

Table 3—Network protector ratings *(continued)*

Network protector			Network transformer		
Continuous rms current rating (A)	Interrupting rating, rms symmetrical (A)[a, b]	Close and latch rating, rms symmetrical (A)[c]	Nameplate rating (kVA)	Nameplate rms current (A)	Protector rating as % of transformer nameplate current
System voltage 480Y/277					
800	30 000	25 000	500	600	133
1200	30 000	25 000	750	900	133
1600	30 000	25 000	1000	1200	133
1875	30 000	25 000	1000	1200	156
2000	35 000	35 000	1000	1200	167
2250	35 000	35 000	1000	1200	188
2500	45 000	40 000	1500	1800	139
2825	45 000	40 000	1500	1800	157
3000	45 000	40 000	2000	2400	125
3500	45 000	40 000	2000	2400	146
4500	60 000	40 000	2500	3000	150
5000	60 000	40 000	2500	3000	167

[a] Interrupting rating shall exceed the through fault rating of its associated transformer.
[b]Short-time rating of network protectors without fuses shall be equal to the interrupting rating.
[c]Applies only to network protectors having spring close or stored energy mechanisms.

9.3 AC voltage ratings

The ac ratings shall be as indicated in Table 4.

Table 4—Alternating current voltage ratings

Rated voltage (V)	Maximum design voltage (V)
216Y/125	250
480Y/277 or 480 Δ	500
575Y/332 or 575 Δ	600

9.4 Dielectric test voltage

The 60 Hz dielectric test voltage shall be 2200 V except for the motor, relays, and solid-state devices. The motor and solid-state devices shall be tested at 900 V. The network relays shall be tested at 1500 V. For equipment that has been in service, test voltages shall not be greater than 75% of the foregoing values.

The test voltage shall be applied continuously for 1 min.

9.5 Control voltage

When measured line-to-line (L-L) or line-to-ground (L-G), at the protector terminals, the range of voltage for operation of the control mechanisms shall be as indicated in Table 5.

Table 5—Control voltage

Rated voltage (V)	Connect between	Closing relay range 80–106% (V)	Closing motor range 73–106% (V)	Trip range 7.5–106% (V)
216Y/125	L–G	100–135	90–135	10–135
216Y/125	L–L	170–230	157–230	16–230
480Y/277	L–G	220–295	200–295	20–295
480Y/277	L–L	385–510	350–510	36–510
480 Δ	L–L	385–510	350–510	36–510
575Y/332	L–G	265–351	242–351	25–351
575Y/332	L–L	460–610	420–610	43–610
575 Δ	L–L	460–610	420–610	43–610

9.6 Closing voltage

Network protectors shall have provisions for adjusting the closing voltage as indicated in Table 6. The closing voltage shall be the median value.

Table 6—Closing voltages

Rated voltage (V)	Available closing voltages (volts in-phase with network voltage)		
	Low	Median	High
216Y/125	1.0	1.5	2.0
480Y/277	2.2	3.3	4.4
480 Δ	2.2	3.3	4.4
575Y/332	2.7	4.0	5.4
575 Δ	2.7	4.0	5.4

9.7 Tripping currents

Network protectors shall have provisions for adjusting the tripping current as indicated in Table 7. The tripping current shall be the nominal value.

Table 7—Tripping currents

Rated current (A)	Current transformer rating (A)	Tripping currents (primary A)		
		Low 0.05% (CT secondary =2.5 mA)	Nominal 0.2% (CT secondary =10 mA)	High 5% (CT secondary =250 mA)
800	800	0.4	1.6	40
1200	1200	0.6	2.4	60
1600	1600	0.8	3.2	80
1875	1600	0.8	3.2	80
2000	1600	0.8	3.2	80
2000	2000	1.0	4.0	100
2250	1600	0.8	3.2	80
2250	2000	1.0	4.0	100
2500	2500	1.25	5.0	125
2875	2500	1.25	5.0	125
3000	3000	1.5	6.0	150
3500	3000	1.5	6.0	150
3500	3500	1.75	7.0	175
4500	3000	1.5	6.0	150
4500	3500	1.75	7.0	175

10. Mechanical performance specifications

Network protectors shall be submersible, nonsubmersible, or open frame.

10.1 Submersible type

A submersible network protector removable breaker shall be mounted in a sealed enclosure.

10.2 Nonsubmersible type

A nonsubmersible network protector removable breaker shall be mounted in an enclosure to prevent contact with internal live parts.

10.3 Open-frame type

A open-frame network protector removable breaker shall be mounted on a freestanding open frame.

10.4 Mounting application

Submersible and nonsubmersible network protectors may be either separately mounted or transformer mounted. Open-frame network protectors are mounted separately from transformers.

10.5 General requirements

The following shall apply to the removable breaker and the submersible and nonsubmersible network protector enclosures unless noted.

10.5.1 Network protector barriers

The network protector shall include barriers, of insulating material, between phases and between phases and ground. After the removable breaker has been rolled out of its enclosure, its interphase barriers shall be readily removable.

10.5.2 Studs, bolts, and screws

All studs, bolts, and screws shall be secured to prevent loosening under normal service conditions and transportation.

10.5.3 Inspection windows

Inspection windows shall be provided in the door of the enclosure so that the operation counter and position indicator can be seen without opening the door.

10.5.4 Operating handle

An external operating handle shall be provided. Provisions shall be made with a latch to prevent accidental movement and means to padlock the handle with an 11.1 mm (0.4375 in) shackle padlock in each position: OPEN, AUTO, and CLOSE for manually operated protector; OPEN and AUTO for electrically operated protector. An electrically operated protector may have a NULL position for padlocking. This is the spring return position from the CLOSE position of the switch. The position of the operating handle shall be clearly indicated by nameplates visible from the front of the enclosure. An interlock shall be provided so that the removable breaker cannot be rolled into or out of the enclosure unless the removable breaker is open.

10.5.4.1 OPEN position

Placing the handle in the OPEN position shall cause the network protector to open and remain open.

10.5.4.2 AUTO position

Placing the handle in the AUTO position shall cause the network protector to be controlled by the relay(s).

10.5.4.3 CLOSE position

Moving the handle to the CLOSE position shall close the protector and shall permit the relay(s) to open the network protector.

10.5.4.4 NULL position

This is the spring return from the CLOSE position; all contacts are open.

10.5.4.5 Submersible network protector operating handle

If the external handle is mounted on the side, mountings shall be provided on both the right-hand and left-hand sides of the network protector enclosure so that the handle can be transferred from one side of the enclosure to the opposite side whenever the need arises. The handle shall be connected to the network protector through the submersible enclosure by means of a watertight assembly. The seals used in this assembly shall be replaceable from outside the enclosure.

10.5.4.6 Submersible network protector hinged door

The enclosure door shall be provided with hinges on the left-hand side. The door and hinges shall be designed so the hinging can be easily changed to the right-hand side without modification to the enclosure.

10.5.4.7 Submersible enclosure air test fitting

Air test provisions shall be provided. This consists of a 0.5-in National Pipe Thread (NPT) female fitting on the enclosure with a sampling device, made of corrosion resistant material, installed into the fitting using a suitable thread sealer.

10.5.4.8 Nonsubmersible network protector operating handle

If the external handle is mounted on the side, it shall be provided on the left-hand side of the network protector enclosure.

10.5.4.9 Nonsubmersible network protector hinged door

The enclosure door shall be provided with hinges on the right-hand side.

10.5.5 Lifting facilities

The network protector enclosure and the removable breaker shall each include two lifting eyes with a minimum inside diameter of 25 mm (1.0 in) and shall be located on opposite sides of the unit, in a vertical plane approximately through the center of gravity.

10.5.6 Rollout rails

Means shall be provided for rolling the removable breaker from its enclosure after it has been disconnected. This shall be accomplished by means of self-contained, or detachable rails, or the equivalent, provided in the enclosure.

10.5.6.1 Rollout rail stops

Stops shall be provided to prevent the removable breaker from rolling off the rails. When extended, the rails shall not extend beyond the open enclosure door.

10.5.6.2 Rollout rail storage

Provision shall be made for safely storing the rollout rails within the enclosure.

10.5.7 Special tools

If the removable breaker requires the removal and replacement of hardware, for its removal from the enclosure, the hardware shall be a 0.5-in and/or 0.75-in hexagon head. An insulated straight "T" socket wrench for the appropriate 0.5-in and/or 0.75-in hexagon hardware shall be available.

10.5.8 Ground pad

Enclosure-grounding provisions shall consist of a copper-faced-steel or stainless-steel pad with two holes horizontally spaced on 44.5 mm (1.75 in) centers and drilled and tapped for 0.5-13 UNC thread (refer to ANSI B1.1 [B1]). The ground pad shall be welded to the enclosure. The minimum thickness of the copper facing shall be 0.38 mm (0.015 in). The minimum threaded depth of holes shall be 12.7 mm (0.5 in). Thread protection for the ground pad shall be provided.

10.5.9 Materials

Submersible enclosures shall be constructed of corrosion resistant 4.76 mm (0.1875 in) minimum stainless or 6.35 mm (0.25 in) copper bearing steel. When required to avoid excessive temperature, nonmagnetic stainless of equal thickness shall be used adjacent to and surrounding the terminals and bus structure. All hardware shall be silicone-bronze or 300 series stainless steel or functional equivalent.

Nonsubmersible enclosures shall be constructed of 3.04 mm (11 gauge or 0.1196 in) thick minimum steel.

10.5.10 Nameplates

A metal corrosion-resistant nameplate shall be affixed by corrosion resistant screws to the network protector enclosure and the removable breaker. It shall bear the rating and other essential operating data as specified in 9.1.

10.5.11 Cover plate

Submersible network protectors shall be provided with a gasketed cover plate to seal off and protect the network protector throat area, suitable for outdoor storage.

10.5.12 Internal main bus

The network protector main bus structure shall consist of a copper bus bar of adequate size to provide the specified ampere rating.

10.5.13 Secondary disconnect

A secondary disconnect shall be provided to connect and disconnect the auxiliary and control circuits between the removable breaker and its enclosure.

10.5.14 Spare auxiliary contacts

Spare contacts rated at 20 A and 600 V and mechanically driven shall be provided as follows:

a) One contact to be closed, known as an "a" contact, when the network protector is closed, and one contact to be closed, known as a "b" contact, when the network protector is open having a common side of both switch contacts tied to a single phase of the network potential side of the network protector breaker.
b) One contact to be closed, known as an "a" contact, when the network protector is closed. This is to be an available "dry" contact.

c) One contact to be closed, known as a “b” contact, when the network protector is open. This is to be an available “dry” contact.

10.5.15 Remote monitoring provisions

The network protector housings must have at least one 1-in NPT half coupling with a pipe plug located near the placement of the internal secondary disconnects or the secondary disconnect termination points, which will permit egress of the remote monitoring wiring. To ensure a pressure tight seal between the inside of the network protector enclosure and the outside environment, the wires must be sealed in such a fashion to ensure that no leakage occurs along the outside or inside of each conductor.

10.5.16 Operation counter

A nonresettable operation counter shall be provided that shall be easily read through the inspection window.

10.5.17 Contact position indicator

A mechanical indicator shall be provided that will indicate the OPEN and CLOSE positions of the network protector. The mechanical indicator shall be easily read through the inspection window. When the network protector is fully open, only the word OPEN shall be visible. When the network protector is fully closed, only the word CLOSE shall be visible.

NOTE—An intermediate breaker position shall be indicated by partial visibility of the word OPEN or CLOSE.

10.5.18 Spring position indicator (stored-energy breakers only)

On network protectors having stored energy mechanism closing provisions, the breaker must have an indicator flag that tells the operator the position of the mechanism closing spring. It must indicate if the closing spring is charged or discharged

10.5.19 Insulating material

All insulating materials in the network protector shall be track resistant per ASTM D2303 [B6] and UL 746A [B14]; shall be flame resistant per ASTM D229 [B7] and UL 94 [B15]; and shall be asbestos-free.

10.5.20 Grounding

The operating mechanism and relay cases shall be grounded to the enclosure through the removable breaker.

10.6 Finish

The finish shall conform to ANSI C57.12.28[5] or IEEE Std C57.12.32, as appropriate.

11. Other requirements

11.1 Submersible enclosure

This is an enclosure that is designed for outdoor or vault application subject to submersion or high humidity. It shall provide a degree of protection from unintentional contact with energized internal components when the door is closed. The enclosure shall have sealed interfaces at every entrance or exit point as well as the

[5]Information on references can be found in Clause 2.

door having a gasketed surface. It shall be capable of withstanding an internal or external static gauge pressure of 103.4 kPa (15 lbf/in^2) without rupture and shall remain watertight.

11.2 Nonsubmersible enclosure

This is an enclosure that provides a degree of protection from unintentional contact with energized internal components when the door is closed.

11.2.1 Ventilated enclosure

This is an enclosure that provides a degree of protection against limited amounts of falling dirt, but is not required to prevent the entry of dust or liquids.

11.2.2 Semi dust-tight enclosure

This is an enclosure that provides a degree of protection against falling dirt or airborne dust, but is not required to prevent the entry of liquids. This enclosure shall have no intentional openings in its design and shall have a gasketed interface between the enclosure and the door.

11.2.3 Drip-tight enclosure

This is an enclosure that provides a degree of protection against falling dirt and water, but is not required to prevent the entry of dust. It shall have provisions for drainage.

11.2.4 Drip-tight/semi dust-tight enclosure

This is an enclosure that provides a degree of protection against falling dirt or water, and airborne dust. It shall have no intentional openings in its design and shall provide a gasketed interface between the enclosure and the door.

11.3 Open frame enclosure

This is an open frame in which the removable breaker is clearly visible and offers no protection from unintentional contact with energized components. It offers minimal protection from falling debris, dirt, dust, or liquids.

11.4 Mounting configurations

Network protector enclosure mounting configurations are divided into the following two main categories:

a) Transformer mounted
b) Separately mounted

11.4.1 Transformer mounted enclosure

This is an enclosure that can be close coupled to its associated transformer through throat mounting provisions. The protector throat shall be designed to provide a minimum of 25.4 mm (1.0 in) clearance to the transformer connectors, and the termination position shall provide dimension C as indicated in Figure 6 as follows:

— 800 A through 2250 A dimension C shall be 85.7 mm (3.375 in)
— 2500 A through 4500 A dimension C shall be 101.6 mm (4.0 in)

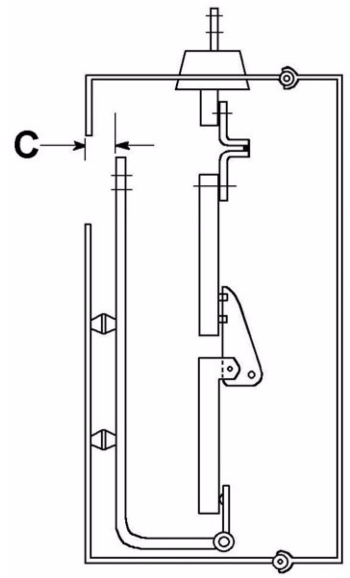


Figure 6—Termination clearance

The throat opening bolting pattern and the lower housing support shall be standardized according to the following amperage of the network protector:

- — 800 A through 2250 A shall conform to Figure 3 of IEEE Std C57.12.40.
- — 2500 A through 4500 A shall conform to Figure 4 of IEEE Std C57.12.40.

11.4.2 Separately mounted enclosure

This is an enclosure having the provisions of being supported without the aid of its associated transformer.

Separately mounted enclosures shall be divided into two categories: wall mounted or freestanding.

11.4.2.1 Wall mounted enclosure

This is an enclosure that is designed to be attached to a vertical surface.

11.4.2.2 Freestanding enclosure

This is an enclosure that is designed to be self supported with provisions for attachment to the floor.

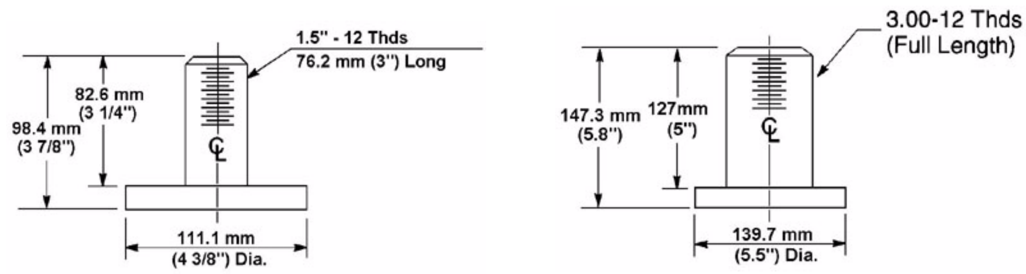
11.5 Network-side terminations

Network protector enclosures shall be supplied with terminations for connection to a secondary spot or grid network. These terminations shall be of either the stud or spade type.

11.5.1 Stud-type terminals

Stud-type terminals shall be threaded. Stud diameters and threading shall be as follows (see Figure 7):

- — 1.5-in diameter 12 threads/inch for network protectors in the 800–1875 A range
- — 3-in diameter 12 threads/inch for network protectors in the 2000–4500 A range



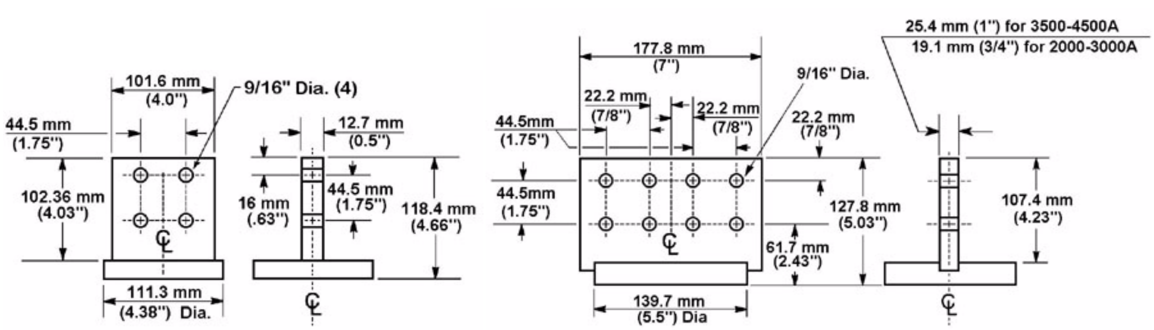
(a) (b)

**Figure 7—Typical stud type terminals
(a) 800–1875 A; (b) 2000–4500 A**

11.5.2 Spade-type terminals

Spade-type terminals shall have 0.5625-in diameter holes as follows (see Figure 8):

- — Network protectors in the 800–1875 A range shall have spades with 12.7 mm (0.5 in) thick material with two sets of two holes 44.5 mm (1.75 in) apart and each set separated by 44.5 mm (1.75 in) minimum.
- — Network protectors in the 2000–3000 A range shall have spades with 19.1 mm (0.75 in) thick material with four sets of two holes 44.5 mm (1.75 in) apart and each set separated by 44.5 mm (1.75 in) minimum.
- — Network protectors in the 3500–4500 A range shall have spades with 25.4 mm (1 in) thick material with four sets of two holes 44.5 mm (1.75 in) apart and each set separated by 44.5 mm (1.75 in) minimum.



(a) (b)

**Figure 8—Typical spade type terminals:
(a) 800–1875 A; (b) 2000–4500 A**

Annex A

(normative)

Classification of insulating materials

A.1 General

The temperature limits and ratings of electrical equipment are influenced significantly by the characteristics of the insulation systems used. It is important to recognize the distinction between insulating materials and insulation systems.

Insulating materials include processed compositions of nonconductive materials and combinations thereof, before they are fabricated into shapes and structures for use in specific electrical equipment. Electric conductivity is very small, approaching zero, and electric isolation is provided.

Insulation systems include fabricated and processed combinations of insulating materials specifically designed to perform the insulation functions needed in the associated electrical equipment. Such equipment may contain more than one insulation system.

A.2 Insulating materials

There are many different kinds of materials used for insulation purposes. Rapid advances in polymer chemistry have produced insulating materials, which are so numerous and complex that simple chemical description has become virtually impossible. Consequently, the traditional procedure of dividing insulating materials into several thermal classes, based upon broad descriptive statements of chemical composition, is no longer meaningful, adequate, or appropriate.

By means of thermal aging tests and evaluation of service experience, an insulating material may be assigned a temperature index (TI). The TI provides a technical basis for comparing the thermal capability of insulating materials, but should not be related directly to the appropriate operating or service temperature for the equipment in which they are used. The latter depends on many factors including environment, service severity, mechanical stresses, geometry of materials (e.g., thickness), and the design of the insulation system in which the material is used.

To promote standardization and to provide continuity with past procedures, it is desirable that the TI for insulating materials be grouped in material temperature classes as given in Table A.1.

As an example, if a particular material is given a TI of 140 °C by thermal aging test or service experience, it is in the TI range of 130–154 and, therefore, is a Class 130 material.

The TI of an insulating material is a value obtained by test or from service experience, and may be used as a guide, but does not imply an equipment thermal classification or a limitation on use in equipment. Temperature classification for the purpose of rating electrical equipment should be defined in terms of the thermal endurance of the total insulation system.

Table A.1—Material temperature classes

Material temperature class	Former class designation	Range of the temperature index (°C)	Temperature rise (°C)
90	O	90–104	50
105	A	105–129	65
130	B	130–154	90
155	F	155–179	115
180	H	180–199	140
200	—	200–219	160
220	—	220–249	180

An insulating material may be assigned more than one TI based upon different properties, environmental conditions, or material geometry. For example, a material can be assigned a TI based upon retention of mechanical properties and a different TI for retention of electrical properties. Thus, the TI describes performance characteristics that provide the designer with information for the selection of materials based upon engineering data rather than arbitrary classification.

A.3 Insulation systems

The temperature limits for electric equipment should be selected so that the equipment will provide a satisfactory service life under normal operating conditions. The temperature limit for an insulation system may not be directly related to the TI of the individual material included in it. In an insulation system, the thermal performance of insulating materials may be improved by the protective character of other materials used with them. A specific material as part of a system may be satisfactory for use at different limiting temperatures depending upon the type and design of equipment in which it is used and the kind of service to which the equipment is subjected.

The ability of an insulation system to perform its function is also affected by the presence of other factors in addition to thermal stresses. These include electrical stresses, mechanical stresses, and environmental stresses, e.g., moisture, dirt, chemicals, or other contaminants.

The limiting insulation temperature consists of the sum of limiting ambient temperature plus the limiting temperature rise. For most purposes, the temperature of the outdoor air is taken as the ambient, and 40 °C is normally chosen as the limiting ambient temperature. Other values for ambient temperature may be chosen in special circumstances.

The temperature rise values generally used for electrical equipment are the results of long experience and have been proven reasonably satisfactory. This suggests that any changes in existing standards should be made only if they are clearly indicated in light of new test data, new or improved materials, additional operating experience, new measurement techniques, or changes in service requirements. Only carefully evaluated service experience and/or adequately accepted tests provide the bases for rational thermal classification of electrical equipment and the temperature limit of insulation systems.

Based upon such an evaluation of the insulation system in a particular type of electrical equipment, the temperature rise value may be selected from Table A.1. These suggested temperature rise values have a numerical relationship to the material temperature classes but are not necessarily directly related to the TI of the materials used.

As indicated previously, a material with a given TI may be acceptable for a different limiting temperature, either higher or lower, based on acceptable tests and/or service experience on the equipment in which it is used.

A.4 Insulation service stresses

For the expected service life of the equipment, the electrical and mechanical properties of the insulation system must not be impaired by the application of the limiting insulation temperature permitted by the particular limiting temperature rise specified. The word "impaired" implies any change that would disqualify the insulating material from performing its intended function whether creepage spacing, mechanical support, or dielectric barrier action.

During the service life of the equipment, the insulation system may be exposed to stress factors that can ultimately impair its ability to perform its intended function. Usually service stresses that degrade the insulation result in a gradual deterioration over time. In A.4.1 through A.4.4 are brief comments on the major service stresses.

A.4.1 Thermal aging

Thermal aging of insulating materials is the progressive deterioration in electrical and mechanical properties as a result of prolonged exposure to high temperatures. The process of thermal aging is complex, and the mechanisms vary with different materials and under different service conditions.

Typical mechanisms include the following:

a) Loss of volatile constituents
b) Oxidation leading to molecular changes and embrittlement
c) Molecular polymerization (softening, melting) leading to embrittlement
d) Hydrolytic degradation (moisture reacts with the insulation)
e) Chemical breakdown of constituents

Different insulating materials react in different ways to the various aging processes, and it is essentially impossible to predict thermal performance from chemical composition.

A.4.2 Electrical stresses

The normal electrical stress results from exposure to high voltages. Insulation deterioration can result in flashovers. Arcing fault currents can cause immediate damage or destruction of the insulation system, whether or not deterioration has occurred.

A.4.3 Mechanical stresses

Typical mechanical stresses result from supporting other components of the equipment, vibration from any cause, and differential thermal expansion. Insulation deterioration can cause mechanical failure leading to an electrical fault.

A.4.4 Environmental stresses

Environmental stresses result from exposure to oxygen, moisture, dust, dirt, and chemicals. Some insulating materials will be more vulnerable to such exposure than others. The life of the equipment will be longer if the insulation system is suitably protected than if it were freely exposed to industrial atmospheres or the weather. The design and utilization of equipment should take appropriate account of the characteristics and capabilities of the insulating materials used.

Annex B

(informative)

Network fuse application

B.1 General

The purpose of this tutorial is to furnish the application engineer with some guidance for the selection of network protector fuses.

The selection of a protector fuse is still an art. There are trade-offs in selecting a fuse which may make one fuse better than another depending on how the application engineer views the tradeoffs available. The experience each engineer has had may differ and may suggest different practices than those outlined here.

Reference should be made to the IEEE Std C37.108 for an overall system view of protection.

B.2 Protector fuse

The protector fuse is selected to allow for normal load current to flow and to provide backup for the protector in the case where the protector fails to open on reverse current. The fuse clearing time should be long enough to allow for

a) Normal load current
b) Downstream limiter operation
c) Coordination with customer fuses
d) Coordination with protector breaker operation

The minimum melt curve of the protector fuse should fall to the right of

a) Normal load current
b) Total clear curve of the limiter
c) Total clear curve of the customer fuse
d) The total tripping time of the protector relay and breaker

The fuse clearing time should also be short enough to protect its associated transformer. The total clear curve of the fuse should coordinate with the thermal damage curve of the transformer. The interrupting capability of the fuses should be higher than the expected available fault. Some utilities use the maximum through current as the maximum fault current that the fuse will have to interrupt. Some utilities, because of the remote chance that the protector can fail internally, use the maximum fault current of the network as the interrupting current that the fuse will have to interrupt.

B.3 Types of fuses

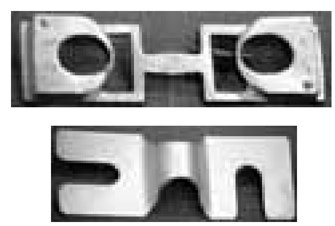
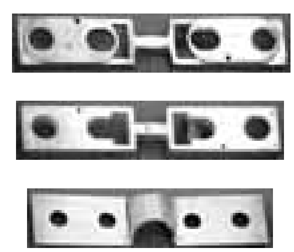
The following are network protector fuse types:

a) **Copper link fuses with or without covers:** (See Table B.1.) Fuses of this type have a relatively steep time-current characteristic, which makes this type of fuse hard to coordinate with cable limiters. These fuses are normally used on 216Y/125 V networks with covers and on the 480Y/277 V networks without covers (see Figure B.1 for typical characteristic curves).

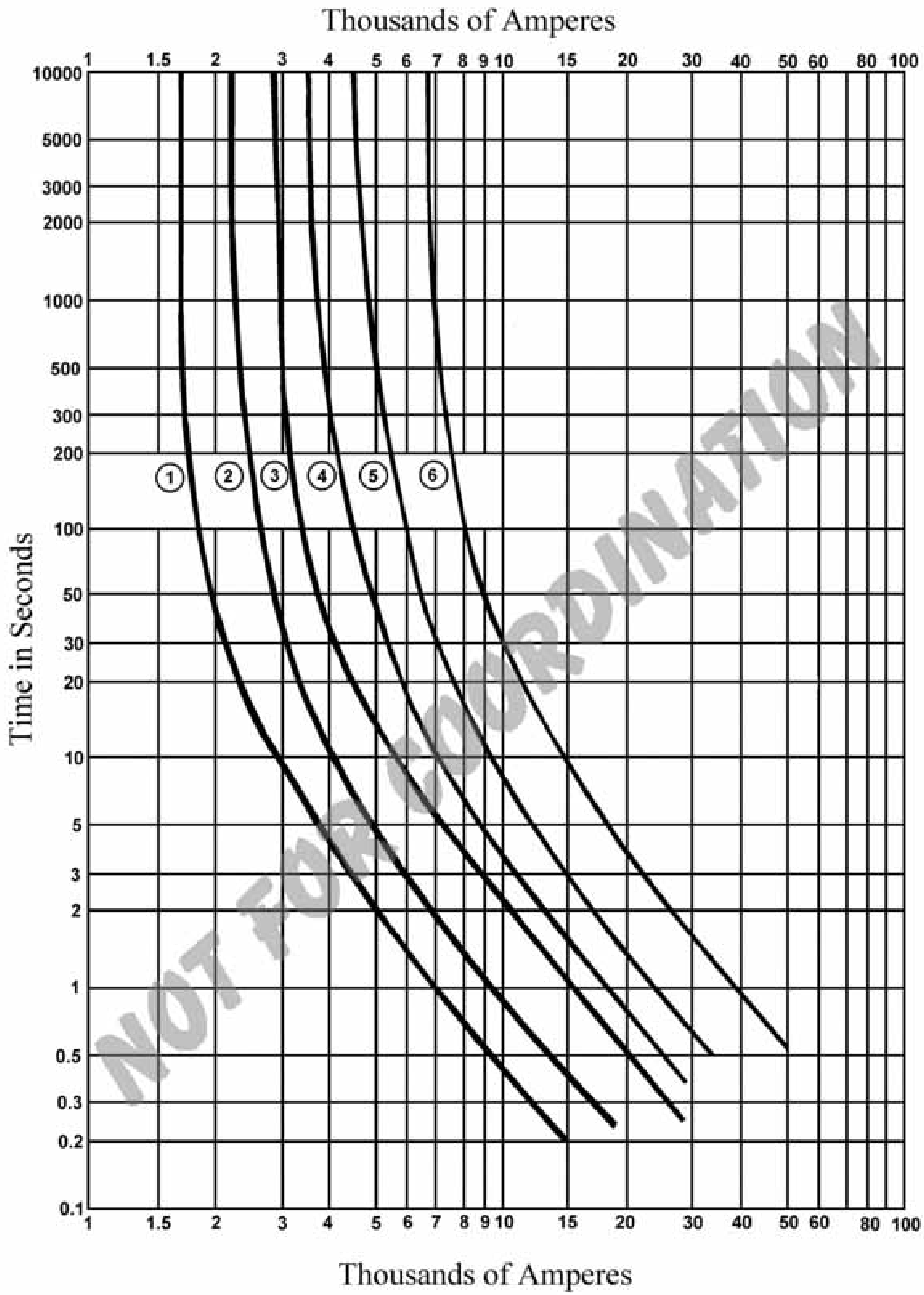
CAUTIONS:

1) Fuse characteristic curves vary with whether they are enclosed or external.
2) Fuse characteristic curves will vary with the manufacturer, and the curves in this standard are representative only and should not be used for coordination.

Table B.1—Copper fuses

Fuse curve	Protector rating (open or submersible)[a]	Typical fuse style[b]
#1	800 A	
#2	1200 A	
#3	1600 A & 1875 A	
#4	2000 A & 2250 A	
#5	2500 A & 2825 A	
#6	3000 A & 3500 A	

[a]Ratings are those of the manufacturer. IEEE does not represent or warrant the accuracy of these ratings.
[b]Fuse styles are illustrative only of this type of fuse and do not constitute an endorsement by the IEEE of these products.

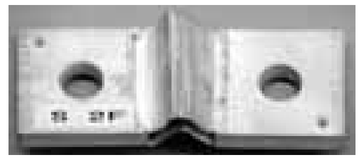
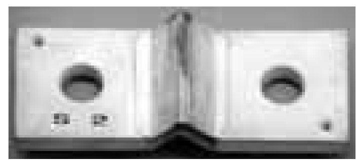
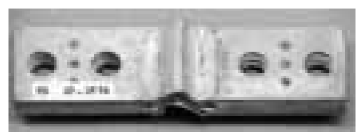
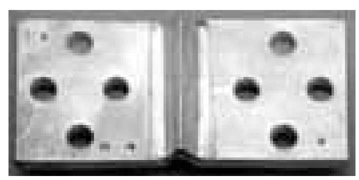
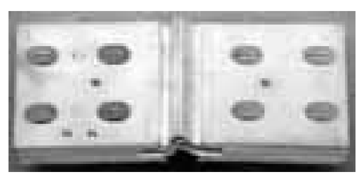


NOTE—These are typical characteristic curves and should not be used for coordination.

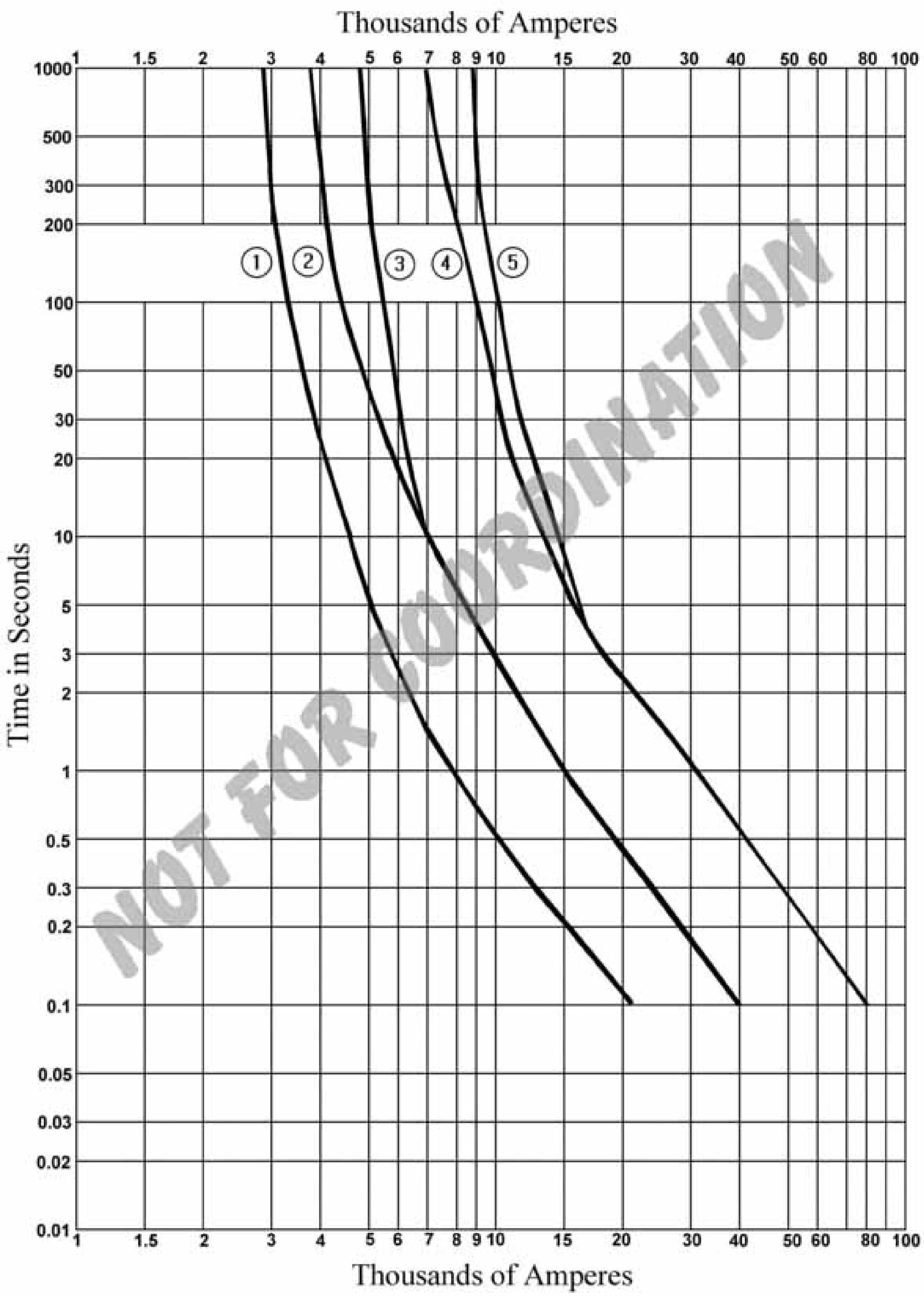
Figure B.1—Copper fuse curves

b) **Low loss fuses:** (See Table B.2.) Fuses of this type have time-current characteristics similar to the copper link fuses, except that the heat loss is approximately half of the losses in ordinary copper fuses. This allows increased loading of the network protector under contingency conditions. They are for 216Y/125 V network applications only (see Figure B.2 for typical characteristic curves).

Table B.2—Low loss fuse

Fuse curve	Protector rating (open or submersible)[a]	Typical fuse style[b]
#1	1875 A	
#2	2000 A	
#3	2250 A	
#4	4000 A	
#5	5000 A	

[a]Ratings are those of the manufacturer. IEEE does not represent or warrant the accuracy of these ratings.
[b]Fuse styles are illustrative only of this type of fuse and do not constitute an endorsement by the IEEE of these products.

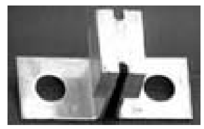
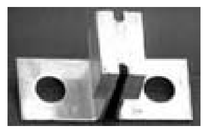
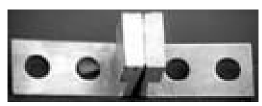
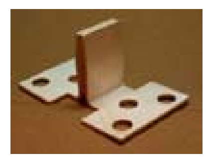
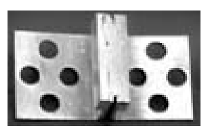
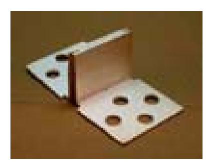


NOTE—These are typical characteristic curves and should not be used for coordination.

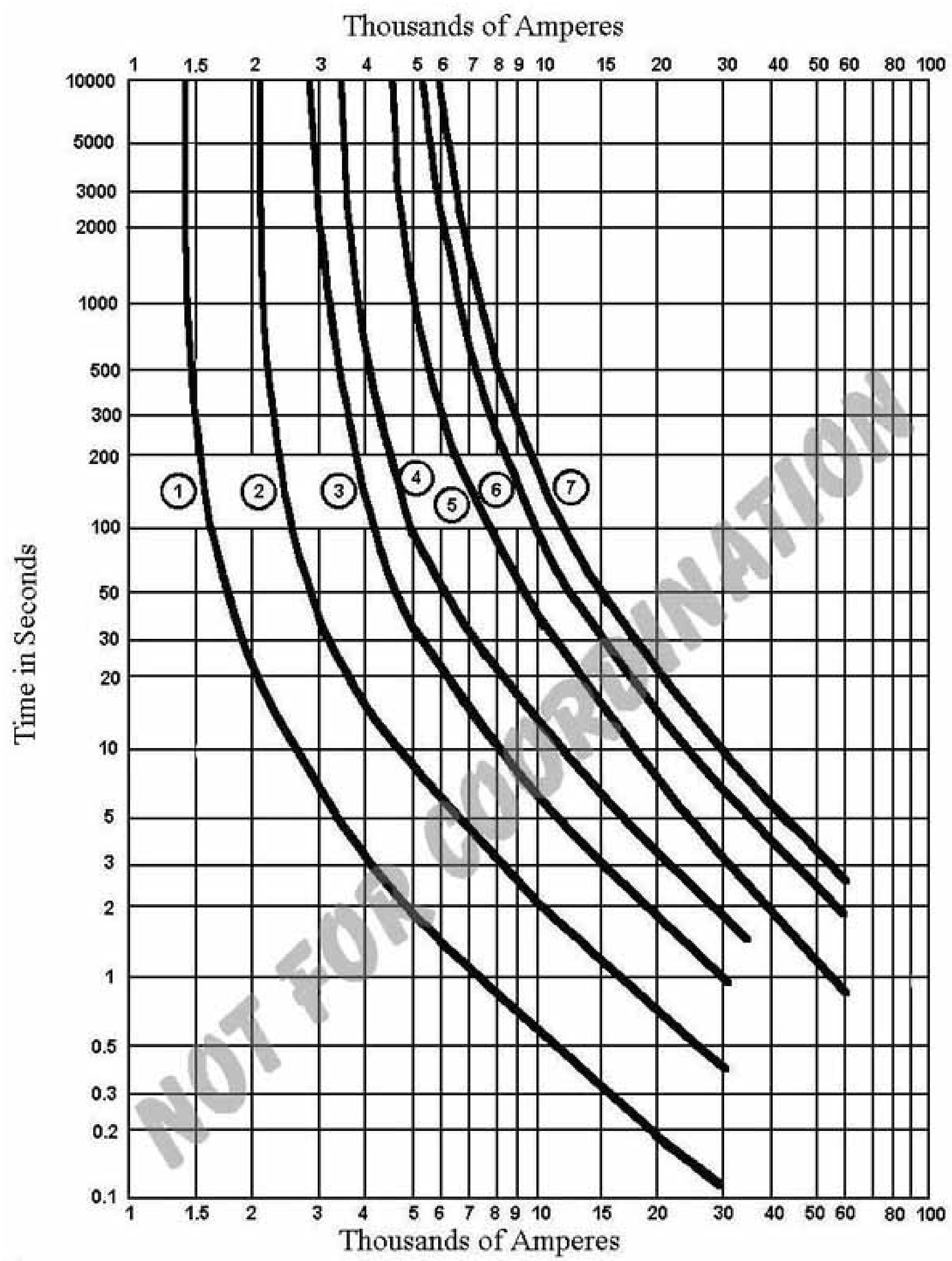
Figure B.2—Low loss fuse curves

c) **Alloy fuses:** (See Table B.3.) Fuses of this type have a much longer time delay at higher currents and allow more time to burn secondary faults clear. They have a low melting temperature, making them more sensitive to unwanted fuse blowing where high ambient temperatures occur. Because of their longer time delay on higher currents, they will coordinate well with cable limiters and protectors (see Figure B.3 for typical characteristic curves).

Table B.3—Alloy fuse

Fuse curve	Protector rating (open or submersible)[a]	Typical fuse style[b]	
#1	800 A		
#2	1200 A		
#3	1600 A		
#4	1875 A, 2000 A		
#5	2250 A, 2500 A		
#6	2825A, 3000 A		
#7	3500 A		

[a]Ratings are those of the manufacturer. IEEE does not represent or warrant the accuracy of these ratings.
[b]Fuse styles are illustrative only of this type of fuse and do not constitute an endorsement by the IEEE of these products.



NOTE—These are typical characteristic curves and should not be used for coordination.

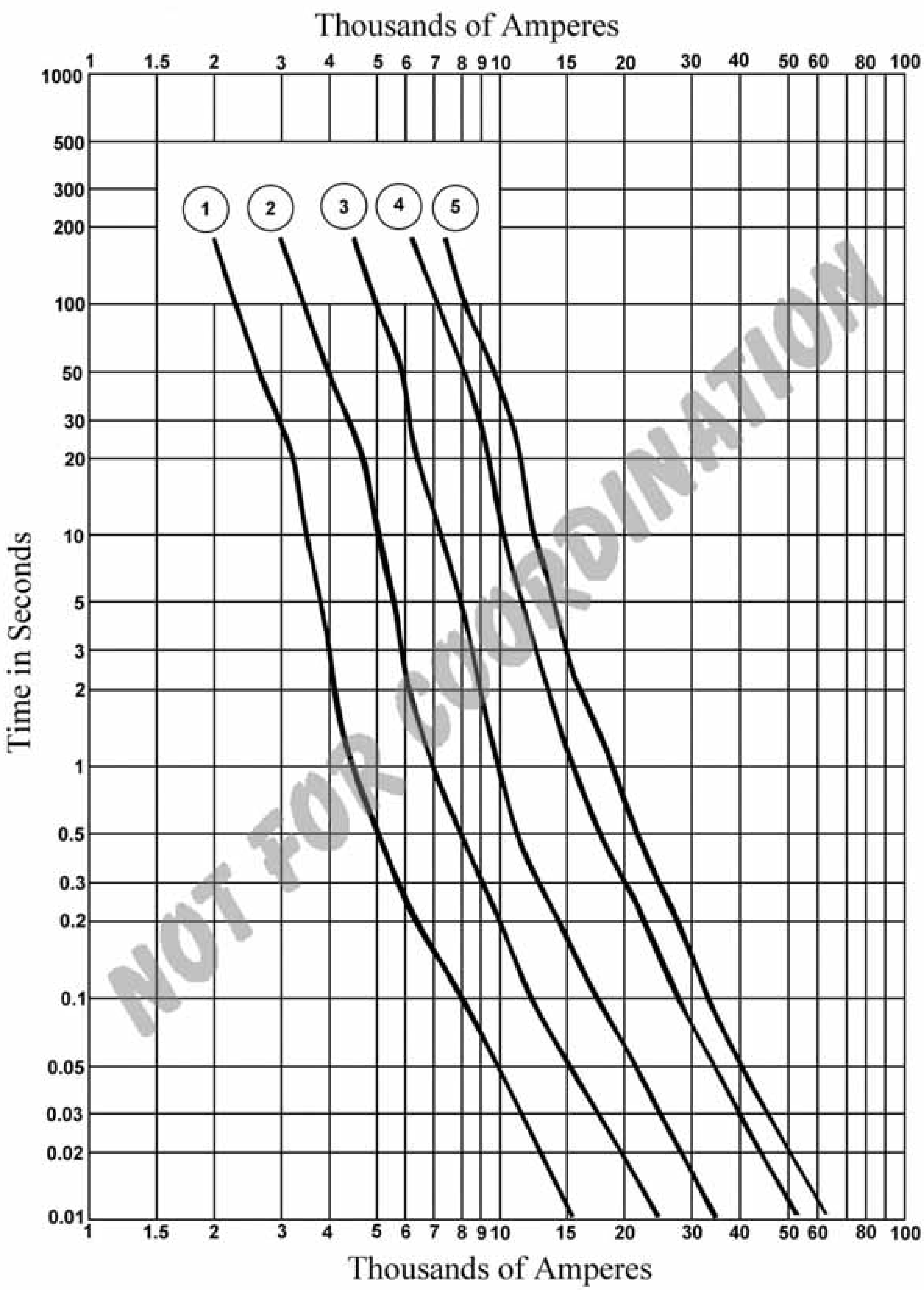
Figure B.3—Alloy fuse curves

d) **Silver-sand current-limiting fuses:** (See Table B.4.) Fuses of this type are used primarily for 480Y/277 V applications. They have steep time-current characteristic and are sensitive to changes in ambient temperatures. They should be located where the vault ambient temperature does not exceed 32 °C and the ambient inside the fuse enclosure does not exceed 15 °C rise over the vault ambient. Silver-sand fuses are not physically interchangeable with other types of fuses and must therefore, be located external to the network protector. Silver-sand fuses are not waterproof in themselves; therefore, a separate waterproof enclosure must be supplied if the fuses are subjected to water. At low levels of overcurrent, these fuses may become damaged without complete melting. Subsequent transformer loading can then cause them to overheat, open, or catch fire (see Figure B.4 for typical characteristic curves).

Table B.4—Silver-sand current-limiting fuse

Fuse curve	Protector rating[a]	Typical fuse style[b]
#1	800 A	
#2	1200 A	
#3	1875 A	
#4	2825 A	
#5	3000 A	

[a]Ratings are those of the manufacturer. IEEE does not represent or warrant the accuracy of these ratings.
[b]Fuse styles are illustrative only of this type of fuse and do not constitute an endorsement by the IEEE of these products.



NOTE—These are typical characteristic curves and should not be used for coordination.

Figure B.4—Silver-sand current-limiting fuse

B.4 History

Secondary networks first came into existence as fused secondaries of distribution transformers. Networks later became more sophisticated when special relayed circuit breakers replaced the fuse. Evidently, early relays and circuit breakers did not have the desired degree of reliability. Therefore, fuses were used in series with circuit breakers for secondary network service. The sole purpose of the fuse was to act as backup protection should the network relay or circuit breaker fail to operate. Even though present network equipment has a high degree of reliability, users have been reluctant to eliminate fuses.

Before the 1940s, most network protectors were rated 216Y/125 V. Since then, the growth of 480Y/277 V spot networks has been steadily increasing. At present, a large percentage of protectors sold are of the 480Y/277 V class. Fusing practice was generally perfected and coordinated for the 216Y/125 V systems, so with the introduction of higher rated networks, the same philosophy of fusing for 216Y/125 V systems was transferred to the 480Y/277 V systems.

The most common types of network fuses (alloy and copper) were tested up to 600 V. The 216Y/125 V alloy fuse had to have arc horns and flash barriers added before it would successfully clear at 600 V. Before the copper fuse would clear, the customary enclosure cover had to be removed. Another characteristic that required investigation before applying network fuses to 480 V systems was the condensing of metal vapors when a fuse clears. When either an alloy or copper fuse interrupts, a portion of the metal is vaporized and condenses throughout the enclosed network protector. The greater the current, the more vapor. From a theoretical standpoint, it would not be good practice to disperse metal vapor over insulated parts and expect those insulated parts to provide adequate insulation. In a 216Y/125 V system where electric arcs are self-extinguishing, one would give little thought to metal vapors. However, 480Y/277 V arcs are typically self-sustaining, so one should consider the possibility of metal vapors causing general arcing throughout an enclosed protector.

In reality, every time a network protector interrupts, a small amount of vapor is liberated. A good portion of it is confined in the arc chute, but over a period of time, insulated parts become contaminated. Fuses liberate a great deal more metal vapor than breakers during interruption; thus, after each fuse operation, all insulated parts should be cleaned before the protector is placed back into service.

Metal vapor from tin alloy fuses is essentially nonconductive. Insulation resistance of a protector before and after fuse operation does not significantly change. Conversely, copper vapor is conducting and will lower the insulation resistance.

Silver-sand current-limiting fuses are heat generators and therefore, can only be used for applications where they are external to the protector steel enclosure. Some types of silver-sand fuses are difficult to coordinate with the transformer and network relay. Silver-sand fuses are not of waterproof construction.

Alloy fuses are used for internal applications. They are the easiest to coordinate with the transformer.

Annex C

(informative)

Pumping

C.1 General

Pumping is defined as the unintentional cyclical tripping and closing of a network protector. Pumping usually occurs because the network protector is improperly allowed to close when system conditions will cause reverse current to flow after closure. The reverse current immediately trips the protector, and the cycle is repeated. Pumping may also occur because the network protector properly attempts to close, and a mechanical defect causes immediate trip. Some of the typical causes of pumping are described below.

C.2 Causes

C.2.1 Incorrect relay setting

The most common case occurs when an electromechanical phasing relay setting allows closure with a lagging phasing voltage. The ensuing power flow is in the reverse direction and pumping is established. With electromechanical relays, the phasing relay is in a separate package from the network master relay. With solid-state relays, the phasing relay function is normally included as part of a single network relay package. Thus, the solid-state phasing relay is less vulnerable to an incorrect setting.

C.2.2 Transient system conditions

One typical case occurs when nondedicated feeders from different substations supply a spot network. This situation can result in the primary voltages being slightly different in both level and phase angle. With light network load and cyclical non-network load (e.g., frequent motor starting), the network protector can trip and reclose many times over a short period. This condition results in excessive frequency of operation and in extreme cases, can develop into pumping. A solution to this problem is to apply time delays and/or increase the reverse current trip level.

C.2.3 Breaker mechanical failure

The most common condition occurs when the breaker mechanism has some defect that prevents successful closure. This is breaker trip-free operation, where attempts to close result in immediate trip. In this case, system voltage conditions may be correct for proper closing, but the breaker mechanism prevents successful closure. Hence, pumping is established.

C.3 Effects of pumping

The net effect of pumping is to raise the temperature of the closing motor. Excessive pumping can raise the temperature to the point where the insulation fails and a short circuit develops in the motor winding.

Annex D

(informative)

The unprotected zone in network protectors

The unprotected zone in a network protector is that section of bus from the secondary terminals of the network transformer to, and including, the moving contact assembly of the network protector. On transformer mounted protectors, this path would extend from the secondary terminals of the transformer via the transformer bus down the back of the network protector, through the lower disconnect point, and back up to the lower network protector breaker stationary bus, which is connected to the moving contact assembly. This path becomes longer on separately mounted network protectors.

This path is considered unprotected because the substation relays, both phase overcurrent and ground, are typically set in such a fashion that they do not respond to faults that are initiated on the low voltage side of the transformer. Faults that originate in the unprotected zone, in theory, would produce reverse currents sufficient to operate the master relay. However, because such faults are very likely to be high resistance arcing faults, it may become a race as to whether the network protector will trip before the control wiring is destroyed. Even if the network protector successfully opens its circuit, the fault is still supplied from the transformer, and it will continue to supply fault current until the station breaker is operated remotely, or until the fault has migrated far enough into the low-voltage windings to permit the primary feeder ground or phase overcurrent relays to operate.

Annex E

(informative)

Contact surface oxidation

The continuous current rating of a network protector is based on maximum conductor temperatures, as confirmed in a thermal test. The matching contact surfaces of breaker contacts, disconnecting contacts, and fuses are subject to oxidation over a period of time in service. This can increase contact resistance and result in a decrease in the amount of current that can be carried without exceeding the rated temperature. Therefore, the continuous current rating of a network protector is based on the assumption that maintenance will be sufficient to keep the temperature rise within specified limits.

Annex F

(informative)

Reverse current sensitivity

F.1 General

For faults on a network primary feeder, with one exception, the power flow, in terms of current, in the associated network protectors will be relatively high and always in the reverse direction, after the primary feeder breaker opens. Under these fault conditions, the reverse current trip setting of the network master relay is not an issue, as the reverse power flows are much higher than the available settings. This includes the case of a single line to ground fault, with network transformers connected grounded wye-grounded wye.

The one exception to the above is a single line to ground fault on a network primary feeder, with network transformers connected Δ-grounded Y. For this case, the reverse power flow is of relatively low magnitude, after the primary feeder breaker has opened. To assure that a protector will open for this single line to ground fault, the reverse power flow after feeder breaker opening must be greater than the reverse current trip setting.

Similarly, when the primary feeder breaker is opened in the absence of a fault, the power flows in the network protectors will be relatively low. To assure that all network protectors on that feeder will open, the reverse power flow in at least one network protector must exceed its trip setting. The remaining protectors on the feeder will then cascade open to clear the feeder.

Cascading occurs when a primary feeder is opened, because the network transformer units associated with the protectors already tripped continue to be energized by the network units not yet tripped, via the primary interconnections. Hence, the exciting current of the transformers with open protectors is added to the reverse exciting current supplied by the closed protectors. The last protector to trip on any one feeder sees the sum total of no-load losses on all transformers connected to that feeder.

F.2 Reverse power levels

When a primary feeder breaker is opened in the absence of a fault, there will be some variation in the voltage at each network protector, in both magnitude and phase angle. This results from small differences in cable impedances and transformer turns ratios. Hence, there will be a circulating current in the primary cable interconnections. Just after the primary feeder breaker opens, there will be "circulating" reverse power flows in some protectors and forward power flows in others. A phase angle difference of 0.5 electrical degrees on half of the transformers can produce a power flow in each protector as high as 7% of the protector rating. A voltage difference of ± 0.5% of nominal on all transformers can produce a power flow in each protector as high as 1% of protector rating.

There are also I^2R losses in the network transformer due to the circulating current and I^2R losses in the transformer due to the flow of primary cable charging current. In most cases, these losses are small in comparison to transformer no-load losses and the circulating power.

In summary, the reverse power through at least some of the network protectors on an open primary feeder consists of the following:

a) Transformer no-load losses
b) Reverse circulating power due to voltage differences

c) Transformer I^2R losses due to circulating current and primary cable charging current

Another factor that will result in higher reverse watt flow in the network protector when the primary feeder breaker is open is the effect of voltage rise on the no-load transformer loss. Under many backfeed conditions, there will be voltage rises due to primary cable capacitance. With a 10% voltage rise, no-load loss in the back feeding network transformer will increase 15% to 30%.

Reverse power flows with open primary breaker, single line to ground fault, and Δ-Y network transformers will be relatively low. If the primary feeder cables are very short, the power flows in each network protector at the instant of breaker opening will be almost the same as if the fault were not present.

F.3 Relay settings

The network master relay is calibrated at rated three-phase voltage in terms of balanced three-phase current, leading network line to ground voltage by 180°. The relay responds to the direction and magnitude of net (equivalent) three-phase power flow.

References to protector current rating herein should be considered as referring to protector current transformer rating. On some protectors, the current transformer (CT) primary rating is lower than the protector current rating. For example, the 1875 A protector uses 1600-5 A CTs.

As seen from previous paragraphs, network protectors can trip on reverse current even though their relay setting is above no-load transformer losses. This applies whether the reverse current setting is at a minimum value of 0.05% to 0.1%, or the more commonly used values of 0.15% to 0.2%, of protector rating. However, if the reverse current settings are too high, i.e., above 2% to 3% of the protector rating, the network protectors may not cascade open, when the primary feeder breaker is opened in the absence of a fault.

For many years, transformer no-load losses were at levels high enough such that network relay sensitivity was not a major concern. For example, a typical 500 kVA 216 V transformer would have no-load losses in the range of 1200–1500 W. For the normal 1600 A or 1875 A protector used with the 500 kVA transformer, these no-load loss levels are 0.2% to 0.25% of protector rating. Hence, a normal relay setting of 0.2% would be acceptable.

Transformer losses have declined in recent years so that no-load losses in the 500 kVA transformers can now be as low as 500–600 W. These loss levels are 0.08% to 0.1% of protector rating (1600 A–216 V). When such low loss transformers are added to existing grid networks, there is no need to revise previously established acceptable network relay setting levels for these new units. Even though the relay setting may be above the no-load losses for these units, they will still trip out because of the additional reverse power contributions and the cascading effect previously described. The example described above is generally representative of the higher network unit ratings as well.

The only cases where a network protector would be required to trip only on the no-load losses of its associated transformer are where a primary feeder supplies only one transformer or where the transformer has a primary breaker or load break switch, which isolates the transformer from the rest of the primary circuit. Under these conditions, the protector will trip when the primary breaker is opened only if the transformer no-load losses are greater than the network relay setting. These conditions should rarely occur.

These rare cases may require a relay setting down near minimum levels of 0.05% or 0.1%, depending on transformer losses. The electromechanical network relay is normally provided with a minimum setting value of 0.1% of protector rating. The newer solid state or microprocessor network relays are normally provided with a minimum setting value of 0.05% of protector rating.

Network protector reverse current trip settings should be only as low as required to assure automatic opening when the primary feeder breaker is opened. Settings of 0.15% of protector current transformer rating will usually yield satisfactory performance, even with low loss network transformers. Extremely sensitive reverse current trip settings can cause unnecessary protector operations due to transient reverse power flows.

Occasionally, system conditions may occur where sensitive reverse current tripping must be time delayed. Typically, this occurs on new construction sites, where the network load is light and elevators being lowered act as generators to create a temporary reverse current. To prevent excessive and/or undesirable trip operations, a time delay is required for sensitive tripping, in the order of 1 min to 5 min. When this time delay is introduced, a three-phase instantaneous overcurrent element must also be provided to trip for reverse fault currents. This element is typically set in the range of 50% to 250% of protector current rating. For electromechanical relays, the time delay and instantaneous overcurrent functions are normally combined in one package separate from the other network relaying functions. For solid state or microprocessor relays, all network relaying functions, including the above, are normally combined in one package.

Annex G

(informative)

Network protector enclosures

All network protector enclosures, whether submersible or nonsubmersible, will withstand all design and production tests. It is not to be inferred that the enclosure shall be capable of withstanding internal arcing faults, without incurring structural damage and/or complete destruction of the network protector.

Annex H

(informative)

Bibliography

[B1] ANSI B1.1-1989, American National Standard for Unified Inch Screw Threads (UN and UNR Thread Forms).[6]

[B2] ANSI B1.20.1-1983, American National Standard for Pipe Threads, General Purpose (Inch).

[B3] ANSI C57.12.57-1987, American National Standard for Transformers—Ventilated Dry-Type Network Transformers 2500 kVA and Below, Three-Phase with High-Voltage 34 500 Volts and Below, Low-Voltage 216Y/125 and 480Y/277 Volts–Requirements.

[B4] ANSI C57.12.70-1978 (Reaff 1992), American National Standard Terminal Markings and Connections for Distribution and Power Transformers.

[B5] ANSI C84.1-1995, American National Standard Voltage Ratings (60 Hz) for Electric Power Systems and Equipment.

[B6] ASTM D2303, Standard Test Methods for Liquid-contaminant, Inclined-plane Tracking and Erosion of Insulating Materials.[7]

[B7] ASTM D229, Standard Test Methods for Rigid Sheet and Plate Materials Used in Electrical Insulation.

[B8] IEEE Std 1™-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation. [8, 9]

[B9] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.

[B10] IEEE Std C37.09™-1999, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

[B11] IEEE Std C57.12.00™-2000, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

[B12] IEEE Std C57.12.80™-1978 (Reaff 1992), IEEE Standard Terminology for Power and Distribution Transformers.

[B13] IEEE Std C57.91™-1995, IEEE Guide for Loading Mineral-Oil-Immersed Overhead and Pad-Mounted Distribution Transformers Rated 500 kVA and Less with 65 ºC or 55 ºC Average Winding Rise.

[6]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[7]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

[8]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

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

[B14] UL 746A, Polymeric Materials—Short Term Property Evaluation.[10]

[B15] UL 94, Test for Flammability of Plastic Materials for Parts in Devices and Appliances.

[10]UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).