

IEEE Standard Requirements for Secondary Network Protectors

Sponsor
Transformers Committee
of the
IEEE Power Engineering Society

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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

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Introduction

(This introduction is not a part of IEEE Std C57.12.44-2000, IEEE Standard for Secondary Network Protectors.)

This is the first revision of IEEE Std C57.12.44, which was originally published in 1994. The main purpose of this revision is to incorporate the many improvement ideas received during the balloting for the original standard and to expand fuse information. The revision officially started with an IEEE Project Authorization Request approval on 29 September 1995. The revision was accomplished by the Working Group on Requirements for Secondary Network Protectors under the Underground Transformers and Network Protectors Subcommittee of the IEEE PES Transformers Committee. The major changes are the addition of figures depicting the terminals in Clause 11, the addition of fuse pictures and fuse curves in Annex B, and the conversion to metric as the primary dimensional system in accordance with IEEE policy. Clauses 4, 5, 6, 8, 10, and 11 of the standard were significantly revised, as were Annexes B and C.

A task force working group consisting of EEI, 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 of the IEEE PES Transformers Committee. Mr. 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.

The Working Group on Requirements for Secondary Network Protectors had the following membership during the revision process:

D. H. Mulkey, *Chair*

A. J. Alcantara, Jr.
E. A. Bertolini
R. R. Butani
R. W. Fisher
R. D. Graham
J. L. Harper

G. Miller
M. C. Mingoia
J. R. Moffat
C. G. Niemann
P. E. Orehek

E. Owen
B. Nutt
P. G. Risse
A. L. Robinson, Jr.
K. Romano
W. G. Wimmer

Other individuals who have participated in the revision are:

A. Bartek

N. P. McQuin
R. B. Robertson

J. Somma

The following persons were on the balloting committee:

S. H. Aguirre	J. D. Huddleston, III	C. G. Niemann
G. Andersen	J. S. Hurst	P. E. Orehek
R. L. Barker	R. W. Ingham	D. S. Patel
A. Bartek	R. I. James	W. F. Patterson
E. A. Bertolini	B. Klaponski	P. A. Payne
A. Bolliger	B. Kumar	L. W. Pierce
R. R. Butani	S. R. Lambert	P. G. Risse
D. Chu	J. P. Lazar	A. L. Robinson, Jr.
P. W. Clarke	M. Loveless	J. R. Rossetti
J. L. Corkran	D. L. Lowe	H. Jin Sim
J. N. Davis	W. A. Maguire	T. Singh
R. H. Fausch	K. T. Massouda	J. E. Smith
R. D. Graham	J. W. Matthews	R. J. Stahara
R. L. Grunert	N. P. McQuin	R. E. Sullivan
N. Wayne Hansen	J. Melanson	B. Scott Wilson
P. J. Hopkinson	J. R. Moffat	W. G. Wimmer
	D. H. Mulkey	

The final conditions for approval of this standard were met on 10 August 2000. This standard was conditionally approved by the IEEE-SA Standards Board on 21 June 2000, with the following membership:

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*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaison:

Alan Cookson, *NIST Representative*
Donald R. Volzka, *TAB Representative*

Noelle D. Humenick
IEEE Standards Project Editor

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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.

2. References

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

When a standard referred to in this document is superseded by a revision, the revision shall *not* apply. The referenced standard and the specific referenced edition shall be the applicable referenced standard until the new version of the referenced document is incorporated by formal action or appropriate revision of the citing standard.

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

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

ANSI C57.12.28-1996, American National Standard for Switchgear and Transformers—Pad-Mounted Equipment-Enclosure Integrity.

ANSI C57.12.32-1994, American National Standard for Submersible Equipment—Enclosure Integrity.

ANSI C57.12.40-1994, American National Standard for Secondary Network Transformers—Subway and Vault Types (Liquid Immersed)—Requirements.

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.

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

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

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.²

IEEE Std 100, IEEE Standard Dictionary of Electrical and Electronics Terms, Sixth Edition.

ANSI C37.09-1979 (Reaff 1988), IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.108-1989 (Reaff 1994), IEEE Guide for the Protection of Network Transformers.

IEEE Std C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

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

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 °C or 55 °C Average Winding Rise.

3. Definitions

An asterisk (*) following a definition indicates that the definition is identical to that which appears in IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronics Terms*.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

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 a 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.

3.10 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: The removable breaker 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 (shunt trip): A release energized by a source of voltage.

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 and 40°C .

4.1.3 Altitude

The altitude shall not exceed 1000 m.

4.1.4 Generation

The network protector is designed 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 4.1.1 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 C57.91-1995 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 C57.12.00-1993.

The insulation level at 1000 m 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 and 40 °C 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 °C
90	50
105	65
130	90
155	115
180	140
200	160
220	180

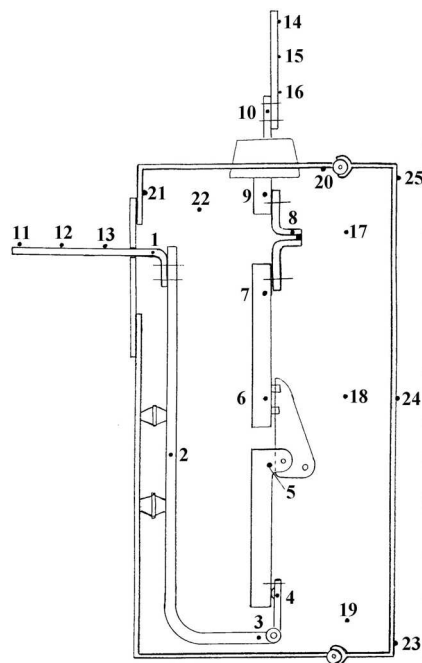
5.1.1 Test conditions

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 from the network protector. This bus bar shall have a current density range of 120 A/cm² to 230 A/cm².³ 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 from the network side terminals.

³800 A/in² to 1500 A/in².

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 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 30 cm 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 of the adjacent thermocouple on the bus bar. These readings are only applicable to the final three readings taken at 30 min intervals and are not subject to the temperature variation criteria of the internal parts of the network protector. Refer to Figure 1 for the minimum number of thermocouples required.



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

Figure 1—Thermocouple locations

5.1.2 Test duration

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

5.1.3 Ambient temperature

The network protector shall be tested at an ambient temperature between 10 °C and 40 °C. No correction factors need be applied. The temperature rise shall, in no case, exceed that specified in Table 1. The ambient

temperature shall be determined by taking the average of the readings of the three thermocouples placed horizontally 30 cm from the projected periphery of the network protector enclosure and approximately on a vertical line as follows:

- a) One approximately 30 cm above the network protector or enclosure (including bushings).
- b) One approximately 30 cm below the network protector enclosure. In the case of a floor mounted network protector enclosure, it shall be 30 cm 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 mm in diameter and 51 mm 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 C37.09-1979. 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 rms symmetrical amperes at the maximum design voltage of the network protector.

5.2.1.1 Test conditions

All interrupting testing must be three phase with the removable breaker installed in its enclosure. The test circuit impedance being 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.

5.2.1.2 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.

5.2.1.3 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.

5.2.2 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.

5.2.2.1 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.

5.2.2.2 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.

5.2.2.3 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.

5.2.3 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.

5.2.3.1 Test conditions

All fault close current testing must be three phase, with the test circuit impedance 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.

5.2.3.2 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.

5.2.3.3 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.

5.2.4 Fuse interruption test

The network protector in its enclosure with fuses 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 phase to phase fault without arcing to ground.

5.2.4.1 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 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.

5.2.4.2 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.

5.2.4.3 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

5.3 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 $95^{\circ}\text{C} \pm 5^{\circ}\text{C}$. On ventilated or open types of enclosures the entire network protector shall be placed into an environment whose ambient temperature is $95^{\circ}\text{C} \pm 5^{\circ}\text{C}$. Three thermocouples shall be mounted at convenient locations within the network protector enclosure. One thermocouple shall be located within 150 mm 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 150 mm 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 hours 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

^aOperation 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 73–80% 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.