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AMERICAN NATIONAL STANDARD

ANSI C37.50-1989 (R1995, R2000)

American National Standard

Switchgear Low Voltage AC Power Circuit Breakers Used in Enclosures— Test Procedures

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
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Low-Voltage AC Power Circuit Breakers Used in Enclosures— Test Procedures

Secretariat

Institute of Electrical and Electronics Engineers
National Electrical Manufacturers Association

Approved 02/11/00

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American National Standard

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Foreword

(This Foreword is not part of American National Standard C37.50-1989.)

This standard was first published in 1973 as a replacement for Section 9 (Test Requirements) of American National Standard for Low-Voltage AC Power Circuit Breakers (600-Volt Insulation Class), ANSI C37.13-1969. In 1975 a supplement, American National Standard Test Procedures for Low-Voltage AC Integrally Fused Power Circuit Breakers, ANSI C37.50a-1975, was published as a replacement for Section 8 (Test Requirements) of ANSI C37.28-1969 and Section 8 of ANSI C37.13a-1975. The contents of ANSI C37.50-1973 and C37.50a-1975 were combined in ANSI C37.50-1981 in accordance with the IEEE Low-Voltage Switchgear Devices Subcommittee revision and combination of ANSI C37.13-1969 and ANSI C37.13a-1975 into ANSI/IEEE C37.13-1981. This (1989) revision of the 1981 standard was developed to clarify miscellaneous areas of interpretation within the document.

This standard was originally written as a description of design test requirements and the performance criteria outlined established the basis for certification of low voltage ac-power circuit breakers used in enclosures for use in nonutility installations subject to regulation by public authorities and similar agencies concerned with laws, ordinances, regulations, administrative orders, and similar instruments. It was established as a separate document to facilitate its use by test laboratories and its timely revision based on experience. This revision supports that original proposition.

Experience has also indicated that there have been misinterpretations regarding the testing requirements for field design-change modifications. This has resulted in circuit breaker modifications by manufacturers other than the original manufacturer without sufficient testing to properly recertify the modified products. Any change to a basic design should be coordinated with the original manufacturer. Otherwise, the original certification responsibility cannot be continued.

This revision was prepared by the NEMA Power Switchgear Assemblies, Low- and Medium-Voltage Power Circuit Breaker, Medium-Voltage Load-Interrupter Switches Technical Committee, NEMA/SG/V, which has assumed responsibility for its maintenance.

Suggestions for improvement of this standard will be welcome. They should be sent to: National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

The standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Power Switchgear, C37. Committee approval of the standard does not necessarily imply that all Committee members voted for its approval. At the time it approved this standard, the C37 Committee had the following members:

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The Power Switchgear Assemblies, Low- and Medium-Voltage Circuit Breaker, Medium-Voltage Load-Interrupter Switches Technical Committee (NEMA/SG/V) of the NEMA Switchgear Section, which developed this standard, had the following members:

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American National Standard for Switchgear –

Low-Voltage AC Power Circuit Breakers Used in Enclosures – Test Procedures

This standard constitutes Section 9 of American National Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures, ANSI/IEEE C37.13-1981.

1. General

1.1 Scope. This standard covers the test procedures for enclosed low-voltage ac power circuit breakers as follows:

(1) Stationary or drawout circuit breakers of two- or three-pole construction, with one or more rated maximum voltages of 635 (600 for units incorporating fuses), 508, and 254 V for application on systems having nominal voltages of 600, 480, and 250 V.

(2) (a) Unfused circuit breakers

(b) Fused circuit breakers

(3) Manually operated or power-operated circuit breakers with or without electromechanical or solid-state trip devices.

NOTE: In this standard the words "circuit breaker" shall mean "enclosed low-voltage ac power circuit breaker," either fused or unfused. The words "unfused circuit breaker" shall mean a "circuit breaker without integral fuses" and the words "fused circuit breaker" shall mean a "circuit breaker incorporating current-limiting fuses as an integral part of the unit."

1.2 Referenced American National Standards. This standard is intended for use with the following American National Standards. When these standards are superseded by a revision approved by the American National Standards Institute, Inc, the revision shall apply.

ANSI C37.16-1988, Switchgear – Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors – Preferred Ratings, Related Requirements, and Application Recommendations

ANSI C37.17-1979 (R1988), Trip Devices for AC and General-Purpose DC Low-Voltage Power Circuit Breakers

ANSI/IEEE 4-1982, Techniques for High-Voltage Testing

ANSI/IEEE C37.09-1979 (R1989), Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI/IEEE C37.13-1981, Low-Voltage AC Power Circuit Breakers Used in Enclosures

ANSI/IEEE C37.26-1972 (R1978), Guide for Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits (see Appendix)

ANSI/UL 198C-1986, High Interrupting-Capacity Fueses, Current-Limiting Types

2. General Test Conditions and Requirements

The conditions prevailing at the test site during tests on circuit breakers shall be as stated in Section 2 of ANSI/IEEE C37.13-1981, except that continuous-current tests and trip-device calibration check tests shall be conducted at an ambient air temperature between 10°C (50°F) and 40°C (104°F).

3. Design Test Requirements

3.1 General. Design tests are performed on representative circuit breakers to demonstrate the capability of a particular frame size of a circuit breaker to meet its assigned ratings and to operate under service conditions given in Section 2 of ANSI/IEEE C37.13-1981.

Although the tests described in this standard cover the performance of complete low-voltage power circuit breakers, it should be recognized that they may not cover some of the component parts of circuit breakers such as wire, insulation materials, and the like. Additional evaluation in accordance with applicable standards covering these components may be necessary.

When major design changes (such as contact structure) are made, a complete sequence retest shall be made. Minor design changes that affect only a specific area shall be retested within the applicable sequence (for example, an electrical operator change needs only an endurance test, or an arc chute change needs only an interrupting test).

3.2 Specific Test Requirements

3.2.1 Test Requirements for Unfused Circuit Breakers. Each circuit breaker frame size, including functional components as listed in Table 1 of ANSI/IEEE C37.13-1981 and accessory devices as given in Section 4 of this standard, with which it is equipped, shall successfully complete all of the following tests, utilizing the applicable sequences as outlined in Table 1 of this standard.

(1) Trip-device calibration check test (see 3.4)
(2) AC dielectric withstand-voltage test (see 3.5)
(3) Continuous-current test (see 3.6)
(4) Overload switching test (see 3.7)
(5) Endurance tests (see 3.8)
(6) Short-circuit current tests (see 3.9)
(7) Short-time current test (see 3.10)

NOTE: Where there is close similarity between frame size designs or where duplicate ratings (such as short-circuit current) exist, certain tests may be combined in order to obviate duplicate testing.

3.2.2 Test Requirements for Fused Circuit Breakers. The circuit breaker element of the fused circuit breaker shall have met the test requirements of 3.2.1 for unfused circuit breakers. Each fused circuit breaker frame size shall be equipped with direct-acting trip devices with long-time-delay and instantaneous elements. The trip device may be either electromechanical or solid-state as required by the circuit-breaker design except that when the circuit breaker design will accept either type, the solid-state type shall be used. When power and manually operated fused circuit breakers have stored-energy closing mechanisms that differ only in the means of supplying the energy to be stored, the sequence of tests shall be performed as outlined on the power-operated fused circuit breaker only.

When a manually operated fused circuit breaker is not essentially the same as the power-operated fused circuit breaker or does not have any power-operated equivalent, all test sequences shall also be performed on the manually operated fused circuit breaker.

The fused circuit breaker shall be equipped with the functional components listed in Table 1 of ANSI/IEEE C37.13-1981 and shall complete all of the tests in sequence V of Table 1 of this standard.

3.3 Test Conditions

3.3.1 Test Enclosure. All tests listed in 3.2, with the exception of the trip-device calibration check test and the ac dielectric withstand-voltage test, shall be made with a drawout circuit breaker in its test enclosure.

The test enclosure for circuit breakers of a particular frame size shall be the minimum-dimension single-unit enclosure with the smallest electrical spacings recommended by the manufacturer and with enclosure terminals exposed to the ambient air. The manufacturer's test enclosure description shall include minimum clearance to ground, location of ventilation openings and their effective area, total enclosure dimensions, and configuration of connections for the enclosure terminals.

3.3.2 Circuit Breakers Using Only One Type of Trip Device. Circuit breakers that are designed to be equipped only with solid-state, direct-acting trip devices (or only electromechanical devices) shall be completely tested in accordance with the test sequences given in Table 1; that is, test sequences I–IV for unfused circuit breakers and the additional test sequence V for fused circuit breakers.

3.3.3 Circuit Breakers Using More than One Type of Trip Device. Circuit breakers that are designed to be equipped with more than one type of direct-acting trip device, either electromechanical or solid-state, shall be tested in accordance with the requirements given in 3.3.3.1, 3.3.3.2, and 3.3.3.3.

3.3.3.1 Each circuit-breaker frame size, with the electromechanical trip device installed, shall be tested for all applicable tests in accordance with the test sequences I, II, III, and IV of Table 1.

NOTE: Contingent upon review of construction differences between circuit breakers using alternate tripping devices, test 3 of sequence II(c) may be omitted for the alternate configurations, based on successful testing of one of the configurations.

3.3.3.2 Each circuit-breaker frame size, with the solid-state trip device installed, shall be tested in accordance with test sequence II given in Table 1, except that under (c), only short-circuit current test 3 need be performed.

When the basic design of the solid-state trip device does not vary substantially between frame sizes, the required tests just mentioned need be performed only on the 1600- and 3000/3200-ampere frame sizes.

3.3.3.3 Each fused circuit breaker frame size shall be equipped with a solid-state trip device and shall be tested in accordance with sequence V of Table 1.

3.4 Trip-Device Calibration Check Test

3.4.1 Direct-Acting Overcurrent Trip Devices. Calibration check tests shall be made on direct-acting overcurrent trip devices, both before and after applicable

Table 1
Test Sequences

Sequence I (Power-Operated Circuit Breaker with Selective Trip Device)
(a) Trip-Device Calibration Check Test (3.4)
(b) AC Dielectric Withstand-Voltage Test (3.5)
(c) Continuous-Current Test (3.6)
(d) Overload Switching Test (3.7)
(e) Short-Circuit Current Tests (Table 3, test 8)
(f) Trip-Device Calibration Check Test (3.4)
(g) AC Dielectric Withstand-Voltage Test (3.5)

Sequence II (Power-Operated Circuit Breaker with Dual Trip Device)
(a) Trip-Device Calibration Check Test (3.4)
(b) AC Dielectric Withstand-Voltage Test (3.5)
(c) Short-Circuit Current Tests (Table 3, tests 1, 2, 3, 4, 5, and 6)
(d) Trip-Device Calibration Check Test (3.4)
(e) AC Dielectric Withstand-Voltage Test (3.5)

Sequence III (Power-Operated Circuit Breaker with Dual Trip Device)
(a) Trip-Device Calibration Check Test (3.4)
(b) AC Dielectric Withstand-Voltage Test (3.5)
(c) Endurance Tests (3.8)
(d) Short-Circuit Current Tests (Table 3, test 7)
(e) Trip-Device Calibration Check Test (3.4)
(f) AC Dielectric Withstand-Voltage Test (3.5)

Sequence IV (Manually Operated Circuit Breaker without Direct-Acting Trip Device, with Shunt Trip)
(a) AC Dielectric Withstand-Voltage Test (3.5)
(b) Short-Time Current Test (3.10)
(c) Short-Circuit Current Tests (Table 3, test 8)
(d) AC Dielectric Withstand-Voltage Test (3.5)

Sequence V (Power-Operated Fused Circuit Breaker with Dual Trip Device)
(a) Trip-Device Calibration Check Test (3.4)
(b) AC Dielectric Withstand-Voltage Test (3.5)
(c) Continuous-Current Test (3.6)
(d) Short-Circuit Current Tests (Table 3, tests 9, 10, 11, and 12)
(e) Trip-Device Calibration Check Test (3.4)
(f) AC Dielectric Withstand-Voltage Test (3.5)

NOTES:

(1) **Power-Operated and Manually Operated Circuit Breakers.** When power-operated and manually operated circuit breakers have stored-energy closing mechanisms that differ only in the means of supplying the energy to be stored, the sequence of tests shall be performed as outlined on the power-operated circuit breaker only.

When a manually operated circuit breaker is not essentially the same as the power-operated circuit breaker or does not have any power-operated equivalent, all test sequences shall also be performed on the manually operated circuit breaker.

(2) **Number of Samples.** Use one circuit breaker per frame size, either new or rebuilt, to complete each test sequence: I, III, and IV.

(3) **Sequence II.** Use one new or rebuilt circuit breaker per frame size to perform as many short-circuit duty cycles per set of contacts as the manufacturer chooses. Contacts and arc chutes may be dressed or cleaned between short-circuit tests (c), provided that test (e) is performed before arc chutes are dressed and cleaned. The manufacturer may rebuild or provide a new circuit breaker after any short-circuit test provided that tests (d) and (e) are performed prior to rebuilding or replacing the circuit breaker. All trip-device calibration check tests and dielectric withstand tests shall be performed on each new or rebuilt circuit breaker.

(4) **Sequence IV.** The direct-acting trip device is to be made inoperative or removed if this is the construction used when the circuit breaker is supplied without a direct-acting trip device. For test (c), the shunt trip circuit is to be energized at the same instant (± 3 ms) as fault-current inception. If the total clearing time is 83 ms or less, short-circuit current test 1 in sequence II (c) may be omitted. In the event that an independent manually operated circuit breaker is not manufactured in a particular frame size, this test sequence is to be performed on a power-operated circuit breaker.

(5) **Sequence V.** Use one new or rebuilt circuit breaker per frame size to perform as many short-circuit duty cycles per set of contacts as the manufacturer chooses. Contacts and arc chutes may be dressed or cleaned between short-circuit tests (d) provided that test (f) is performed before arc chutes are dressed and cleaned. The manufacturer may rebuild or provide a new circuit breaker after any short-circuit test provided that tests (e) and (f) are performed prior to rebuilding or replacing the circuit breaker. All trip-device calibration check tests and dielectric withstand tests shall be performed on each new or rebuilt circuit breaker.

(6) When a rating is to be changed subsequent to completing sequences in Table 1 only those tests needed to demonstrate the changed rating need to be performed. For example:

Increased 635-V instantaneous short-circuit rating can be demonstrated by performing Sequence II of Table 1 with short-circuit current tests 1 and 4 of Table 3 at the increased rating.

Increased short-circuit current ratings with selective trip devices can be demonstrated by performing sequence I at the increased rating.

Increased short-time or nonautomatic short-circuit current ratings (both ratings shall be of equal value) can be demonstrated by performing sequence IV at the different current and voltage rating.

test sequences as given in Table 1 to demonstrate the stability of the trip devices. Tests shall be conducted on the trip devices using a 60-Hz current supply of sinusoidal wave shape at any appropriate voltage. Tests on trip devices may be conducted with the trip device(s) removed from the circuit breaker.

Solid-state trip devices may be tested as described in 3.4.1.1, 3.4.1.2, and 3.4.1.3, or, alternatively, by applying directly to the solid-state trip devices current or voltage values equal to the output of the overcurrent sensing device for the specified value of primary test current. The trip device shall function to open the circuit breaker within the specified time limits. When the alternate method is employed, the overcurrent sensing device(s) shall be checked separately to verify that its output is within the manufacturer's standards.

The tripping times shall be in accordance with the requirements of ANSI C37.17-1979, and the appropriate table depending upon whether the device is of electromechanical or solid-state design, as well as with the manufacturer's time-current characteristic curve for the particular device.

3.4.1.1 Long-Time-Delay Trip Elements. The long-time-delay trip element of the direct-acting trip device shall be set at the 100% long-time pickup setting and at the marked minimum time setting (band). The element shall be tested once to determine the time of operation by applying a test current equal to 150%–300% of the 100% setting for electromechanical devices, and 200% of the 100% setting for solid-state devices. The test current shall be initiated at the test value or shall be increased from a lower value to the test value as quickly as possible, but not longer than 5 seconds, and shall be maintained at the test value.

3.4.1.2 Instantaneous Trip Elements. The instantaneous trip element of the direct-acting trip device shall be set at any marked pickup setting and shall be tested once to determine that the element operates within the allowable tolerance. Compliance with this requirement may be determined by initiating the test current at approximately 70% of the instantaneous trip setting and quickly raising the current at a uniform rate and as rapidly as consistent with an accurate determination of the trip value or by using a symmetrical current pulse of such magnitude and duration at both limits of the allowable tolerance that operation of the trip element only within the allowable tolerance can be determined.

3.4.1.3 Short-Time-Delay Trip Elements. The short-time-delay trip element of the direct-acting trip device shall be set at any marked short-time-delay pickup setting and at the marked maximum time setting (band) and shall be tested once to determine the time of operation when a test current equal to 250% of that setting is applied to the trip device. The test current shall be initiated and maintained at the test value for the time necessary to establish performance criteria.

In addition, each short-time-delay trip element is to be tested to determine that it will not trip the circuit breaker when a current less than the pickup setting (minus the allowable tolerance) is applied. This current should not be maintained for longer than 1 second.

3.4.1.4 Alternate Test Method. If the calibrating test currents specified in 3.4.1.1 and 3.4.1.3 are not readily available, test currents as low as 150% of the pickup setting may be used.

3.5 AC Dielectric Withstand-Voltage Test

3.5.1 General. Dielectric withstand tests shall be conducted on completely assembled circuit breakers, including secondary control wiring, at voltages and under the conditions given in 3.5.2 and 3.5.3.

All voltages shall be measured in accordance with ANSI/IEEE 4-1982. The potential shall be increased gradually from zero so as to reach the required test value in 5 to 10 seconds, and shall be held at that value for 1 minute, except 3.5.2(4), which is to be a momentary voltage test to verify the solid-state control device's integral surge-protection features.

The test voltages shall be essentially sinusoidal and applied with a minimum crest value equal to 1.414 times the specified values. The frequency of the test voltage shall be within ±20% of the rated frequency of the circuit breaker being tested. If a test transformer of less than 500 VA is used, a suitable voltmeter shall be provided to measure the applied output potential directly.

3.5.2 Test Voltages. The dielectric withstand test voltage shall be not less than the following:

(1) 2200 V for the primary circuit of a new, completely assembled circuit breaker.

(2) 1500 V for secondary control wiring and control devices including current sensors and magnetic latch, except (3), (4), and (5).

(3) 1000 V for new motors.

(4) 500 V momentary for control devices and circuitry operating at 80 V ac rms (110 V dc) or less that are not connected directly to the primary circuit or external secondary control circuits.

(5) Twice rated voltage plus 1000 V for undervoltage trip devices operating at a voltage above 250 V ac.

(6) 60% of the values given in (1), (2), (3), (4), and (5) after completion of any of the test sequences in Table 1.

3.5.3 Points of Application of Test Voltage

3.5.3.1 With the circuit breaker in the open position, apply the primary-circuit test potential between:

(1) The primary circuit, including both upper and lower terminals, and metal parts that are normally grounded.

(2) The primary circuit and the secondary control wiring.

(3) The upper terminals and lower terminals of the primary circuit.

For convenience, tests (1) and (2) above may be combined by connecting secondary terminals to metal parts that are normally grounded.

3.5.3.2 With the circuit breaker in the closed position, apply the primary-circuit test potential between:

(1) The primary circuit and metal parts that are normally grounded.

(2) The primary circuit and secondary control wiring.

(3) Primary terminals of different phases.

For convenience, tests (1) and (2) above may be combined by connecting secondary terminals to metal parts that are normally grounded.

3.5.3.3 With the circuit breaker in either the open or closed position, apply the secondary control wiring test potential between the secondary control wiring terminals and metal parts that are normally grounded.

If the circuit-breaker control circuit includes a motor, the motor may be disconnected during the dielectric withstand test on the control circuit and subsequently tested at the potentials specified in 3.5.2(3).

Undervoltage trip devices operating at a potential above 250 V shall be tested separately as specified in 3.5.2(5).

3.6 Continuous-Current Test

3.6.1 General. The continuous-current test is performed to ensure that circuit breakers can carry 100% of their rated continuous current at rated frequency within a test enclosure without exceeding the allowable temperature limits specified in Table 2 of ANSI/IEEE C37.13-1981. Circuit breakers shall be equipped with overcurrent trip devices having a continuous-current rating equal to the continuous-current rating of the circuit-breaker frame size. The overcurrent trip device shall be prevented from opening the circuit breaker.

See Section 4 for information concerning accessory devices.

Three-pole circuit breakers may be tested using either a three-phase circuit or single-phase circuit (all poles in series) at the option of the manufacturer.

The fused circuit breaker shall be equipped with the minimum-rating fuse recommended by the manufacturer for use with an overcurrent trip device having a continuous-current rating equal to the fused circuit-breaker frame size.

Table 2
Copper Conductors for Use in Continuous-Current Tests

Circuit-Breaker Frame Size (amperes)	Bus Bars* per Terminal: Quantity	Bus Bars* per Terminal: Size (inches)
600	1	1/4 × 2 (6.35 × 50.8 mm)
800	1	1/4 × 3 (6.35 × 76.2 mm)
1600	2	1/4 × 3 (6.35 × 76.2 mm)
2000	2	1/4 × 4 (6.35 × 101.6 mm)
3000/3200	3	1/4 × 5 (6.35 × 127.0 mm)
4000	4	1/4 × 5 (6.35 × 127.0 mm)

*Where multiple bus bars are used, they are to be spaced 1/4 inch (6.35 mm) apart. The 4000-ampere group is to be two sets of two bars with not more than 4 inches (101.6 mm) between pair centers. When testing nonpreferred ratings above 4000 amperes, the bus bar groups and sizes should be adapted to the particular terminal designs, and so may not necessarily have 1/4-inch spacings and may vary from 4 inches maximum between sets.

3.6.2 Duration of Test. The continuous-current test shall be performed for such a period of time that the temperature rise of the terminals of the test enclosure will not have increased by more than 1.0°C (1.8°F) during each of two successive 30-minute intervals as indicated by three successive readings. If the temperature rise at the end of the second interval is equal to the established limits and if the temperature rise has increased since the previous reading, the test shall be continued.

3.6.3 Method of Measuring Temperature of the Air Surrounding the Enclosure (Ambient). The temperature of the air surrounding the enclosure (ambient) shall be determined by one thermometer or thermocouple having a heat sink attached and placed approximately 12 inches (304.8 mm) from the side surface of the enclosure and midway between the top and bottom of the enclosure.

3.6.4 Copper Conductors for Use in Continuous-Current Tests. Specifications for copper bus bars are given in Table 2.

Configurations shall be vertical unless the design of the test enclosure requires them to be horizontal.

The conductors connected to the enclosure terminals shall be a minimum of 4 feet (1.2 m) long.

If the test enclosure terminal configuration is not compatible with the number of bars listed in Table 2, then the test bus size and number may be changed to match the enclosure terminals, provided that the cross-sectional area is not increased and a 1/4-inch minimum thickness is used.

If continuous current ratings other than those listed in Table 2 are tested, determine the test bus size by interpolation using the nearest standard bus bar sizes. For example, the size for a 2500-A breaker rating is found as follows:

2000 A: $2 \times 1/4 \times 4 = 2\ \text{in}^2$

3000 A: $3 \times 1/4 \times 5 = 3.75\ \text{in}^2$

2500 A: $2 + \frac{(3.75 - 2)}{2} = 2.875\ \text{in}^2$

3.6.5 Method of Measuring Device Temperatures. Thermocouples shall be used to measure the temperatures on the circuit breaker.

Thermocouples used for measuring the temperature 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 test enclosure terminal connections and other conducting joints shall be located approximately 1/2 inch (12.7 mm) from the terminal or other conducting joints on the current-carrying member.

Thermocouples may be used to determine the air temperature of the areas within the circuit breaker where accessory devices are mounted as a means of establishing the required ambient temperature for separate accessory device testing.

Thermocouples shall be held in intimate contact with the conductor surface by such methods as welding, drilling and peening, or cementing.

3.6.6 Performance. Circuit breakers shall be considered to have passed this test if the limits of observable temperature rise specified in Table 2 of ANSI/IEEE C37.13-1981 are not exceeded.

3.7 Overload Switching Test

3.7.1 General. The overload switching test shall be performed at not less than the rated maximum voltage, any rated control voltage, and at a current level no less than 600% of rated continuous current of the circuit-breaker frame size.

3.7.2 Test Circuit. The three-phase test circuit shall have a maximum power factor of 50% lagging with X and R in series connection. The frequency of the test circuit shall be 60 Hz ± 20%. The power factor shall be determined in accordance with ANSI/IEEE C37.26-1972.[1]

The open-circuit voltage of the supply circuit shall be not less than 100% or more than 105% of the rated maximum voltage of the circuit breaker, except that a higher voltage may be employed at the option of the manufacturer. The maximum fault current available at the circuit-breaker terminals shall not exceed the rated short-circuit current of the circuit breaker.

The closed-circuit voltage as measured at the test terminals to which the supply side of the circuit breaker is connected shall be not less than 65% of the rated maximum voltage for which the circuit breaker is being tested.

The enclosure and the frame of the circuit breaker shall be insulated from ground and shall be connected through a 30-ampere fuse of adequate interrupting rating to the supply side of the phase judged least likely to strike to the enclosure. As an alternate configuration, at the manufacturer's option, the 30-ampere fuse may be replaced by a minimum No. 10 AWG copper wire. The configuration may be changed at any time during the test. Metallic contact between the circuit-breaker frame and the enclosure shall be considered a connection.

3.7.3 Rate of Operation. Rate of operation shall be not less than one operation every minute for a group of five operations. Groups of operations may be separated by intervals of up to 15 minutes maximum.

3.7.4 Opening of Circuit Breaker. The circuit breaker shall be opened by a separately energized shunt trip device.

3.7.5 Duration of Current. The circuit breaker shall carry the current for not less than one cycle before opening for each operation.

3.7.6 Number of Operations. Circuit breakers in each frame size shall make and break the circuit not less than the number of times given in Table 3 of ANSI C37.16-1988. For frame sizes not listed in Table 3, the tests shall be conducted based on the values specified for the next-lower preferred frame-size rating.

3.7.7 Performance. At the conclusion of this test, the circuit breaker shall be in a condition to continue the applicable test sequence without repair or replacement of parts, and the grounding means (either wire or fuse) mentioned in 3.7.2 shall not have opened.

3.8 Endurance Tests

3.8.1 General. All endurance tests shall be performed on the same circuit breaker to determine compliance with specified mechanical and electrical requirements as given in Table 4 of ANSI C37.16-1988. Servicing shall be permitted at the intervals given in the table.

For frame sizes not listed in Table 4, the tests shall be conducted based on the values specified for the next-lower preferred frame-size rating.

[1] ANSI/IEEE C37.26-1972 has been withdrawn as an American National Standard (pending review or reaffirmation), but is reproduced in the Appendix to aid in the completion of the requirements of ANSI C37.50-1989.

3.8.1.1 Power-operated circuit breakers shall be subjected to all endurance tests.

3.8.1.2 Manually operated circuit breakers having stored-energy mechanisms that differ from the power-operated equivalent only in the means of supplying the energy to be stored need not be subjected to endurance tests.

3.8.1.3 Manually operated circuit breakers, not essentially the same as power-operated circuit breakers or not having any power-operated equivalent, shall be subjected to all endurance tests except that the number of mechanical endurance operations performed shall be 50% of the number specified in Table 4 of ANSI C37.16-1988.

3.8.2 **Rate of Operation.** The rate of operation shall be one operation every 2 minutes. At the option of the manufacturer, the rate may be increased. During each operation, the circuit breaker shall remain closed for no less than 1/6 second.

Due to the large total number of operations required, both electrical and mechanical endurance tests may be conducted in groups at the option of the manufacturer. However, at least one group shall consist of not less than 120 electrical endurance operations.

3.8.3 **Electrical Endurance Test.** The electrical endurance test shall be performed with not less than rated continuous current, at not less than rated maximum voltage, and at any rated control voltage.

3.8.3.1 **Test Circuit.** The test circuit shall have a maximum power factor of 85% lagging with the X and R in series connection. The frequency of the test circuit shall be 60 Hz ± 20%. The power factor shall be determined in accordance with ANSI/IEEE C37.26-1972.[1]

The open-circuit voltage of the supply circuit shall be not less than 100% or more than 105% of the rated maximum voltage of the circuit breaker, except that a higher voltage may be employed at the option of the manufacturer. The maximum fault current available at the circuit-breaker terminals shall not exceed the rated short-circuit current of the circuit breaker.

The closed-circuit voltage as measured at the test terminals to which the supply side of the circuit breaker is connected shall be not less than 80% of the rated maximum voltage for which the circuit breaker is being tested.

The enclosure and the frame of circuit breakers for which the overload switching test is not required shall be insulated from ground and connected through a 30-ampere fuse of adequate interrupting rating to the supply side of the phase judged least likely to strike to the enclosure. As an alternate configuration, at the manufacturer's option, the 30-ampere fuse may be replaced by a minimum No. 10 AWG copper wire. The configuration may be changed at any time during the test. Metallic contact between the circuit-breaker frame and enclosure shall be considered a connection.

For circuit breakers for which the overload switching test is required, the 30-ampere fuse or alternate ground connection may be omitted.

3.8.4 **Mechanical Endurance Test.** The mechanical endurance test shall be performed at no load and at any rated control voltage.

3.8.5 **Performance.** At the conclusion of these tests, the circuit breakers shall be in a condition to continue the applicable test sequence without repair or replacement of parts that affect short-circuit performance, charging of the mechanism, opening of the breaker, or closing of the breaker, and the grounding means (either wire or fuse) mentioned in 3.8.3.1 shall not have opened.

3.9 Short-Circuit Current Tests

3.9.1 **General.** Short-circuit current tests as described in 3.9.2 and given in Table 3, shall be performed on circuit breakers to determine their ability to close, carry, and interrupt currents within their ratings, and to demonstrate that fused breakers with maximum-rated fuses will provide short-circuit interruption at current values at and above ratings given for the 600-V system nominal voltages given in Table 1 of ANSI C37.16-1988. Short-circuit current ratings are given in ANSI C37.16-1988, Tables 1 and 2 for unfused breakers and Table 17 for fused breakers. For frame sizes not listed in these tables, the ratings shall be based on the next-higher preferred frame-size rating or the maximum-preferred frame-size rating, whichever is less.

3.9.2 **Types of Tests.** Types of short-circuit current tests are described in 3.9.2.1 through 3.9.2.4.

3.9.2.1 Single-phase tests with a line-to-line voltage not less than each rated maximum voltage applied across any pole and with the available rms symmetrical current not less than 87% of the applicable rated three-phase short-circuit current. See Table 3, tests 4, 5, and, 6 for unfused breakers and test 9 for fused breakers.

3.9.2.2 Three-phase tests with a line-to-line voltage not less than each rated maximum voltage and the average of the available rms symmetrical components of the available three-phase currents not less than the applicable rated short-circuit current. See Table 3, tests 1, 2, 3, 7, and 8 for unfused breakers and test 10 for fused breakers.

3.9.2.3 For fused breakers, a three-phase test with a line-to-line voltage not less than rated maximum voltage and the average of the available rms symmetrical components of the available three-phase currents between 90% and 100% of the rated short-circuit current values given for the 600-V system nominal voltages of the circuit-breaker element as listed in Table 1 of ANSI C37.16-1988. See test 11 of Table 3 of this standard.

Table 3
Short-Circuit Current Tests

Test	Duty Cycle	Type of Test (No. of Phases)	Rated Maximum Voltage	Current
1	O–15 s–C-O	3	635	I_1
2	O–15 s–C-O	3	508	I_2
3	O–15 s–C-O	3	254	I_3
4	O–15 s–C-O	1	635	$0.87I_1$
5	O–15 s–C-O	1	508	$0.87I_2$
6	O–15 s–C-O	1	254	$0.87I_3$
7	O	3	635	I_1
8	O–15 s–C-O	3	635	I_8
9	O	1	600	174 000
10	O + t + C-O	3	600	200 000
11	O	3	600	See 3.9.2.3
12	O	3	600	See 3.9.2.4

NOTES:

(1) O = opening operation; C-O = close-open; t = time necessary for the test procedures, including replacement of fuses and resetting of the open-fuse trip device; I_1 = rated short-circuit current at rated maximum voltage of 635 V; I_2 = rated short-circuit current at rated maximum voltage of 508 V; I_3 = rated short-circuit current at rated maximum voltage of 254 V (see Table 1 of ANSI C37.16-1988; I_8 = rated short-circuit current at rated maximum voltage of 635 V (see Table 2 of ANSI C37.16-1988).

(2) Tests 1 and 2 are to be performed with opposite terminals energized. (For example, if upper terminals are used for test 1, then lower terminals are used for test 2, and vice versa.)

(3) Test 2 is to be performed in sequence II given in Table 1, using a circuit breaker equipped with the minimum-rated continuous-current electromechanical overcurrent trip device for the circuit-breaker frame size being tested.

(4) Tests 4, 5, and 6 may be performed on the same circuit breaker, one test per pole.

(5) For tests 9 and 10 the current is in rms symmetrical amperes.

(6) For tests 11 and 12 see the referenced sections of this standard.

(7) At the option of the manufacturer, test 11 may be omitted if the total clearing time of the maximum fuse is equal to or less than the minimum total clearing time of the circuit-breaker element, at the short-circuit test current value. If the circuit breaker's time-current characteristic data are for the maximum clearing time, subtract 0.016 second to obtain a value for the minimum total clearing time of the circuit-breaker element.

3.9.2.4 For fused breakers, a three-phase test with a line-to-line voltage not less than rated maximum voltage and the average of the available rms symmetrical components of the available three-phase currents equal to approximately twice (±10%) the rated short-circuit current values given for the 600-V system nominal voltages of the circuit-breaker element as listed in Table 1 of ANSI C37.16-1988. See test 12 of Table 3 of this standard.

3.9.3 Test Circuit Conditions

3.9.3.1 The rms symmetrical current that verifies the short-time or the short-circuit rating shall be determined by calibrating the test circuit with the circuit breaker short-circuited or omitted and shall be measured one-half cycle after inception of the current flow in the test circuit. This current shall be calculated in accordance with ANSI/IEEE C37.09-1979.

For three-phase circuits the symmetrical-current value shall be the average of the phase currents.

3.9.3.2 The power factor of the test circuit for unfused circuit breakers shall be 15% lagging or less (X/R ratio or 6.6 or greater) with X and R in series connection. Any reactor used in the test circuit shall be an air-core reactor. The power factor for fused circuit breakers shall be 20% lagging or less (X/R ratio of 4.9 or greater) with X and R in series connection. The power factor shall be determined in accordance with ANSI/IEEE C37.26-1972.[1]

3.9.3.3 Transient current characteristics of the test circuit shall be as given in 3.9.3.3.1 through 3.9.3.3.4.

3.9.3.3.1 For circuit breakers with instantaneous trip elements the rms value of the alternating component of the current at the end of three cycles shall be not less than 90% of the value measured at one-half cycle after initiation of the current.

3.9.3.3.2 For unfused circuit breakers without instantaneous trip elements the rms value of the alternating components of the current at the end of 1/2 second shall be not less than 80% of the value measured at one-half cycle after initiation of the current.

3.9.3.3.3 For the first opening operation (unfused circuit breakers) on each duty cycle, the current shall be initiated in the test circuit in such a manner as to ensure that the peak current available would be not less than 2.3 times the single-phase rms symmetrical value for the single-phase test and 2.3 times the three-phase rms symmetrical value in one phase for three-phase tests.

3.9.3.3.4 For the first opening operation (fused circuit breakers) on each duty cycle, the current shall be initiated in the test circuit in such a manner as to ensure that the peak current available would be not less than 2.16 times the single-phase rms symmetrical value for the single-phase test and 2.16 times the three-phase rms symmetrical value in one phase for three-phase tests.

3.9.3.4 The test-circuit voltage prior to the inception of current flow shall be not less than the rated maximum voltage for the short-circuit current rating being verified.

3.9.3.5 The frequency of the test circuit shall be 60 Hz ± 20%.

3.9.3.6 On three-phase tests, either the power source or fault connections shall be grounded, but not both.

3.9.3.7 The power-frequency recovery voltage shall be not less than 95% of the rated maximum voltage of the circuit breaker when testing with instantaneous trip elements. When testing circuit breakers without instantaneous trip elements, the recovery voltage shall be not less than 80% of the rated maximum voltage of the circuit breaker.

The peak value of the power-frequency recovery voltage within the first full half-cycle after clearing and for the next five successive peaks shall be not less than 1.343 ($\sqrt{2} \times 0.95$) times the rated maximum voltage of the circuit breaker for tests conducted with instantaneous trip elements; and not less than 1.131 ($\sqrt{2} \times 0.800$) times the rated maximum voltage of the circuit breaker for tests conducted without instantaneous trip elements. Each of the peaks shall be displaced not more than ± 10 electrical degrees from the peaks of the open-circuit voltage wave prior to current flow. When making this comparison, it will be necessary to compensate for any frequency change that may occur during the test. This may be done by comparing the positions of the zero crossing points of the voltage wave when referred to a timing wave, before and after the test. For tests performed at 60 Hz, the average of the instantaneous value of the recovery voltage of each of the first six half-cycles measured at the 45-degree and 135-degree points on the wave shall be not less than 85% of the rms value of the recovery voltage. The instantaneous value of the recovery voltage measured at the 45-degree and 135-degree points of each of the first six half-cycles shall be not less than 75% of the rms value of the recovery voltage.

For tests performed at 50 Hz (which are intended to establish a 60-Hz rating) the instantaneous value of recovery voltage measured at the 45-degree and 135-degree points of each of the first six half-cycles shall be not less than 90% of the rms value of the recovery voltage.

If, in a test circuit that employs secondary closing, there is no attenuation of phase displacement of the first full cycle of the recovery-voltage wave when compared with the open-circuit secondary-voltage wave before current flows, the detailed measurement of the recovery-voltage characteristics indicated in the preceding paragraphs is not required.

3.9.3.8 For three-phase testing, the enclosure and the frame of the circuit breaker shall be insulated from ground and shall be connected through a 30-ampere fuse of adequate interrupting rating to the line side of the phase judged least likely to strike to the enclosure. As an alternate configuration, at the manufacturer's option, the 30-ampere fuse may be replaced by a minimum No. 10 AWG copper wire. The configuration may be changed at any time during the test. Metallic contact between the circuit breaker frame and the enclosure shall be considered a connection. During the opening test of a duty cycle the maximum current offset shall not exist in the phase to which the fuse is connected.

3.9.3.9 For single-phase testing, the test enclosure and circuit-breaker frame shall be insulated from ground and shall be connected through a 30-ampere fuse of adequate interrupting rating to the unused phase of the three-phase source. As an alternate configuration, at the manufacturer's option, the 30-ampere fuse may be replaced by a minimum No. 10 AWG copper wire. The configuration may be changed at any time during the test.

3.9.4 Circuit-Breaker Direct-Acting Trip-Device Settings

3.9.4.1 Ratings and settings of unfused circuit-breaker direct-acting trip devices that shall be used for all test sequences except sequence II(c), test 2, are specified in 3.9.4.1.1 and 3.9.4.1.2.

3.9.4.1.1 For test sequences II and III, circuit breakers shall be equipped with direct-acting trip devices with long-time-delay and instantaneous elements. The continuous-current rating of the trip device shall be equal to the circuit-breaker frame size being tested. The long-time-delay element's pickup and time setting may be set as desired by the manufacturer, but the instantaneous setting shall be set at the marked maximum setting.

3.9.4.1.2 For test sequence I, circuit breakers shall be equipped with direct-acting trip devices with long-time-delay and short-time-delay trip elements. The continuous-current rating of the trip devices shall be equal to the circuit-breaker frame size being tested. The long-time-delay element's pickup and time setting may be set as desired by the manufacturer, but the short-time-delay element shall be set at the marked maximum pickup setting and maximum time setting.

3.9.4.2 Ratings and setting of unfused circuit-breaker direct-acting trip devices that shall be used for test sequence II(c), test 2, to demonstrate withstandability of the minimum-rated trip devices are specified in 3.9.4.2.1 and 3.9.4.2.2.

3.9.4.2.1 The circuit breakers shall be equipped with direct-acting trip devices with long-time-delay and instantaneous trip elements. The continuous rating of the trip device shall be the minimum continuous-current rating at 480 V for the circuit-breaker frame size being tested. The long-time-delay element's pickup and time setting may be set as desired by the manufacturer, but the instantaneous element shall be set at the marked maximum pickup setting.

3.9.4.2.2 Where no change of the integral series conductor is involved, only the maximum rating of the frame size need be checked as stated in 3.9.4.1.1. However, for solid-state trip devices, the lowest-ratio current-transformer (sensor) shall be used.

3.9.4.3 For solid-state trip devices an additional interrupting test (not required to be part of Sequence I) shall be conducted as indicated in Table 3, Test 8, with the lowest-ratio current-transformer (sensor), short time-delay element set at maximum pickup and maximum time-delay, to demonstrate the thermal capability of the solid-state trip-device system with the maximum energy input during Test Duty Cycle 8. If the actual energy input to the trip device at another voltage rating is greater than 635 volts, the test shall be conducted at that rating. This test is required for solid-state trip device qualification and is in addition to Table 1. After this test the trip device shall be in a condition to continue any test without repair or replacement of parts.

3.9.4.4 Fused circuit breakers shall be equipped with direct-acting trip devices with long-time-delay and instantaneous elements. The long-time-delay element's pickup and time setting may be set as desired by the manufacturer, but the instantaneous setting shall be set at the marked maximum setting. The continuous-current rating of the trip device shall be equal to the fused circuit-breaker frame size being tested. The fuses shall be the maximum current rating supplied by the manufacturer for the circuit-breaker frame size.

3.9.4.5 When a solid-state trip device of new design is added to existing qualified circuit breakers, the following tests shall be conducted:

(1) Sequence I(e) with 1600- and 3000/3200-ampere frame sizes

(2) Sequence II(c), Table 3, Test 2, with 1600- and 3000/3200-ampere frame sizes

(3) Maximum energy input as indicated in 3.9.4.3

Each test may be conducted on a separate trip device. After these tests the trip devices shall be in a condition to continue any test sequence without repairs or replacement of parts.

3.9.5 Short-Circuit Current Duty Cycle. Each duty cycle shall consist of an opening operation followed by an interval as specified in Table 3 followed by a close-open operation. When short-time-delay tripping devices are used, the tripping on each opening shall be delayed by these tripping devices, except when equipped with instantaneous tripping elements effective only during closing.

3.9.6 Test Procedure. The circuit breaker shall be inserted into the test circuit and the designated short-circuit current tests performed (see Tables 1 and 3).

3.9.7 Emission Indicators for Short-Circuit Current Tests. An indicator consisting of three layers of cheesecloth shall be employed to detect any excessive emission of flame, hot gases, or molten particles during the short-circuit current test. The cheesecloth shall be loosely stretched on a frame at least as large as the front of the circuit-breaker enclosure and shall be located 1 inch (25.4 mm) from, and parallel to, the front door of the circuit-breaker enclosure. The cheesecloth may be displaced as necessary to accommodate projections such as handles.

3.9.8 Performance

3.9.8.1 The unfused circuit breaker at the conclusion of each test shall be in a condition to continue the applicable test sequence without repair or replacement of parts, except as permitted in Note 3 of Table 1, and the emission indicators shall not have ignited. Scorching of the cheesecloth shall not be considered as ignition. The grounding means (either wire or fuse) mentioned in 3.9.3.8 and 3.9.3.9 shall not have opened.

3.9.8.2 The fused circuit breaker at the conclusion of each test shall be in a condition to complete the test sequence (tests (e) and (f) of sequence V, Table 1) without repairs or replacement of parts other than the primary fuses and open-fuse trip-device trigger fuses if applicable, except as stated in Note 5 of Table 1. The emission indicator shall not have ignited. Scorching of the cheesecloth shall not be considered as ignition. The grounding means (either wire or fuse) mentioned in 3.9.3.8 and 3.9.3.9 shall not have opened.

The open-fuse trip device shall have functioned to open the fused circuit breaker. The fuses shall show no evidence of arcing on their exterior or that molten metal was expelled. They shall not be cracked or charred and shall not have damaged the supporting means.

3.9.9 Making Current. A circuit breaker's making-current capability is demonstrated by its ability to pass the three-phase short-circuit current duty cycle test described in 3.9.5.

3.9.10 Latching Current. Latching-current capability (for a circuit breaker not equipped with an instantaneous phase trip element) is demonstrated by the ability of the circuit breaker to pass the three-phase short-circuit current duty-cycle test described in 3.9.5.

3.10 Short-Time Current Test

3.10.1 General. The short-time current test shall be performed to verify the ability of the circuit breaker to perform a short-time current duty cycle at its rated available short-time current and any rated maximum voltage when applied without direct-acting trip devices (as described in Table 1, Note 4). See Table 2 of ANSI C37.16-1988. For frame sizes not listed in C37.16-1988, the ratings shall be based on the next-lower preferred frame-size rating.

3.10.2 Test Circuit. The test circuit shall conform to the requirements given in 3.9.3. A three-pole circuit breaker shall be tested using a three-phase circuit.

3.10.3 Test Procedure. The circuit breaker shall be inserted in the test circuit, placed in the closed position, and tested in accordance with test (b) of sequence IV, Table 1.

3.10.4 Short-Time Current Duty Cycle. The duty cycle shall consist of two periods of 1/2 second each, with a 15-second interval of zero current between the 1/2-second periods.

3.10.5 Performance. After a short-time current duty cycle, the circuit breaker shall be in a condition to continue the test sequence without repairs or replacement of parts.

4. Accessory Devices

4.1 General. Accessory devices, as contrasted with functional components, are those devices that are not basically required for proper operation of a circuit breaker but perform a secondary or minor function as an adjunct or refinement to the primary function of the circuit breaker.

Functional components are parts of the circuit breaker required during sequential testing, as outlined in 3.3.2, and successful operation of those components throughout all the test sequences shall constitute sufficient proof of their design and that no further testing of them is necessary.

Available electrical accessory devices, including alarm and auxiliary switches and undervoltage trip devices, shall be operationally tested. An accessory device shall be mounted in its normal place on the circuit breaker during the applicable testing sequence when its installation or operation may affect the performance of the circuit breaker or if the circuit breaker may affect the operation of the accessory. Servicing of functional components and accessory devices by cleaning, adjusting, or repositioning the contacts shall be permitted at the intervals specified in Table 4 of ANSI C37.16-1988 and in accordance with the manufacturer's established maintenance procedures.

4.2 Alarm and Auxiliary Switches

4.2.1 Temperature Test. An alarm or auxiliary switch shall be subjected to a temperature test. With the circuit breaker and one alarm or auxiliary switch carrying not less than rated continuous current, the switch shall not attain temperatures higher than those permitted for the materials involved, in accordance with Table 2 of ANSI/IEEE C37.13-1981. As an alternative test procedure at the manufacturer's option, temperature tests may be conducted on alarm and auxiliary switches separately mounted in an equivalent ambient temperature determined as described in 3.6.5. When more than one alarm or auxiliary switch can be installed on a circuit breaker, the temperature test shall be performed with:

(1) The maximum number of switches that can be installed.

(2) Those switches that control external circuits and are normally closed when the circuit breaker is closed carrying 50% of their rated continuous current.

(3) Those switches used in the internal control of a circuit breaker energized and carrying normal continuous control currents.

Rated continuous current of a switch rated only in inductive amperes is the highest rated inductive current listed.

4.2.2 Overload Test. Alarm and auxiliary switches shall be subjected to an overload test of 50 operations. The rate of operation shall be in accordance with 3.7.3. For an alarm switch, this test shall also be proof of the endurance capability of the switch. The appropriate test(s) shall be selected from Table 4.

4.2.2.1 Performance. At the conclusion of the overload test, an alarm switch shall be capable of making and breaking the test circuit without repairs or replacement of parts and shall withstand the dielectric test.

An auxiliary switch shall be in a condition to continue with the endurance test.

4.2.3 Endurance Test – Auxiliary Switch. An auxiliary switch that has completed the overload test shall be subjected to the number of electrical and mechanical operations specified in 3.8.1 and at the rate of operation given in 3.8.2. The endurance test on the auxiliary switch may be performed in conjunction with the endurance test performed on the circuit breaker. When the design of an auxiliary switch is common to more than one frame size of circuit breaker; the test may be made only in conjunction with the endurance test of the smallest frame size, at the option of the manufacturer. The appropriate test(s) shall be selected from Table 5.

4.2.3.1 Performance. At the conclusion of the electrical and mechanical endurance test, the switch shall be capable of making and breaking the test circuit without repairs or replacement of parts and shall withstand the dielectric test.

4.3 Undervoltage Trip Devices

4.3.1 General. An undervoltage trip device shall operate to open the circuit breaker at 30% or less of the voltage ratings of its trip coil. It shall not operate to open the circuit breaker at values above 60% of the voltage ratings of its trip coil. However, an undervoltage trip device may operate to open the circuit breaker when the voltage across the trip coil is greater than 30% but is 60% or less of the voltage rating of its trip coil.

An electrically reset undervoltage trip device shall pick up, and a mechanically reset undervoltage trip

Table 4
Overload Test Conditions

Type of Assigned Contact-Interrupting Rating	Test Conditions			
	Voltage	Current	Power Factor (ac)	Type of Load (dc)
None assigned	Maximum of applicable range*	150% continuous rating	75%–80% lagging†	Resistance
Noninductive	Maximum of applicable range*	100% assigned rating	75%–80% lagging†	Resistance
Inductive	Maximum of applicable range*	100% assigned rating	30%–35% lagging†	Electromagnet

*See Table 23 of ANSI C37.16-1988.

†At the option of the manufacturer, the power factor may be lower.

Table 5
Endurance Test Conditions

Type of Assigned Contact-Interrupting Rating	Test Conditions			
	Voltage	Current	Power Factor (ac)	Type of Load (dc)
None assigned	Rated*	100% continuous rating	75%–80% lagging†	Resistance
Noninductive	Rated*	100% assigned rating	75%–80% lagging†	Resistance
Inductive	Rated*	100% assigned rating	45%–50% lagging†	Electromagnet

*See Table 23 of ANSI C37.16-1988.

†At the option of the manufacturer, the power factor may be lower.

device shall seal in, at 85% of rated voltage. They may also pick up and seal in at any lower voltage greater than 30% of the voltage rating of its trip coil.

4.3.2 **Temperature Test.** With the undervoltage trip-device coil energized at the maximum voltage of the applicable range given in Table 23 of ANSI C37.16-1988, the maximum temperature rise of an undervoltage trip coil shall not be higher than that permitted in Table 2 of ANSI/IEEE C37.13-1981 for the materials involved. As an alternate test procedure at the manufacturer's option, temperature tests may be conducted on undervoltage trip devices separately mounted in an equivalent ambient temperature determined as described in 3.6.5.

4.3.3 **Operation Test.** To determine compliance with the requirements stated in 4.3.1 tests shall be conducted as follows, starting with the circuit breaker in the tripped position.

(1) Energize the undervoltage trip device to 85% of the rated voltage of the coil.

(2) Close the circuit breaker.

(3) Reduce the voltage to 60% of the rated voltage of the coil. The circuit breaker shall not open above this voltage.

(4) Reduce voltage to 30% of the rated voltage of the coil. The circuit breaker shall open.

4.3.4 **Endurance Test.** An undervoltage trip device shall cause the circuit breaker to trip for 10% of the electrical endurance operations and at the frequency of operation given in 3.8.2. The tests may be performed as part of the endurance test on the circuit breaker. When so tested, the number of tripping operations to be performed by the shunt trip device shall be reduced to 90%.

At the conclusion of the endurance test, the undervoltage trip device shall be capable of meeting the requirements given in 4.3.1.

With the electrical accessory device(s) installed on the circuit breaker, the accessory device(s) shall meet the requirements for ac dielectric withstand voltage set forth in 3.5.

4.4 Mechanical Accessory Devices. When accessory devices are mechanical only, such as key interlocks, mechanical interlocks, etc, which are operated relatively infrequently, normal production tests will be the criteria for proving the operational characteristics of these devices.

5. Treatment of Failures within Test Sequences

Should failures occur during performance testing, they should be evaluated and corrections should be made before retesting is carried out.

A design change made to correct a test failure shall be evaluated for its effect on any preceding test in the sequence, and retesting shall be performed as necessary.

6. Production Tests

6.1 General. All applicable production tests shall be performed by the manufacturer on each circuit breaker at the factory after final assembly, except that calibration may be performed on the individual direct-acting trip-device subassembly prior to final assembly on the circuit breaker. When the latter is carried out, the effect of the operating time of the circuit breaker shall be recognized, and the complete assembly shall be tested to ensure that the device will mechanically trip the circuit breaker.

Production tests shall include the following:

(1) Calibration

(2) Control and secondary wiring and device check test

(3) Dielectric withstand test

(4) No-load operation test

6.2 Calibration

6.2.1 General. Calibration shall include the procedures given in 6.2.2 and 6.2.3, where applicable.

6.2.2 Direct-Acting Trip Devices. Direct-acting trip devices shall be subjected to the following calibration, where applicable, for conformance to published time-current characteristic curves. Sinusoidal-wave-shape single-phase 60-Hz current at a convenient voltage shall be used. The calibration may be performed in any order deemed appropriate by the manufacturer:

(1) Long-time-delay-element pickup

(2) Short-time-delay-element pickup

(3) Instantaneous-element pickup

(4) Time delay of long-time-delay element

(5) Time delay of short-time-delay element

(6) Ground-element pickup

(7) Time delay of the ground element

6.2.3 Undervoltage Trip Devices. Each undervoltage trip device shall be calibrated to ensure that it trips the circuit breaker when the voltage drops to a value that falls within the range of 30% to 60% of rated voltage. A test shall be performed to determine that with 85% of rated voltage applied the undervoltage trip device will permit the circuit breaker to be closed.

For an undervoltage trip device equipped with time delay, the time delay shall also be checked to see that it falls within the manufacturer's specified limits and that the device resets if voltage recovers in the delay period.

6.3 Control, Secondary Wiring, and Devices Check Test. Control, secondary wiring, and devices shall be checked to make sure that all connections have been made correctly. Devices and relays, if used, shall be checked by actual operation where feasible. Those circuits for which operation is not feasible shall be checked for continuity.

6.4 AC Dielectric Withstand Test. The test shall be conducted in accordance with the requirements given in 3.5. The duration of the test may be reduced to 1 second if a voltage 20% greater than that specified in 3.5.2 is used. It is recognized that other suitable test terminal combinations than those stated in 3.5.3 may be used. These shall be permitted to be used if all of the conditions represented by 3.5.3 have been tested.

6.5 No-Load Operation Test

6.5.1 Power-Operated Circuit Breakers. Power-operated circuit breakers shall be given the following no-load operation tests:

(1) Five closing and five opening operations at minimum control voltage.

(2) Five closing, five opening, and five trip-free operations at maximum control voltage.

(3) Two operations to check antipumping, which shall be performed in the following manner:

(a) Apply uninterrupted control power to the closing circuit of the open circuit breaker as the closing signal.

(b) Trip the circuit breaker. The circuit breaker shall remain open until closing circuit power has been interrupted and then restored.

If other devices, electrical or mechanical, are applicable, they shall be checked for proper functioning. Such devices shall include key interlocks, mechanical interlocks, electrical interlocks, padlocking, racking mechanisms, etc.

6.5.2 Manually Operated Circuit Breakers. Manually operated circuit breakers shall be given the following no-load operation tests:

(1) Five closing and five opening operations.

(2) When shunt trip is used, a minimum of five openings using the shunt trip at the minimum control voltage specified for the coil.

(3) Five trip-free operations.

If other devices, electrical or mechanical, are applicable, they shall be checked for proper functioning. Such devices shall include key interlocks, padlocking, racking mechanisms, etc.

6.6 Open-Fuse Trip Device. The trip device shall be tested mechanically or by application of proper voltage to the device to establish positive tripping of the fused circuit breaker.

7. Production Monitoring and Product Retest Requirements

7.1 General. Subsequent to certification of a circuit breaker in accordance with this standard, retest intervals shall be determined either by the total number of circuit breakers produced to this standard or by the elapsed time since completion of the immediately previous test schedule, whichever occurs sooner.

7.1.1 General (Fused Circuit Breakers). Subsequent to certification of a fused circuit breaker in accordance with this standard, production units shall be monitored and retesting shall be carried out when design changes are made.

7.2 Production Monitoring. Monitoring of production units shall be done quarterly or at shorter intervals at the discretion of the certifying agency to verify that production tests are in accordance with the requirements given in Section 6 and that the product conforms to the design that was certified.

7.3 Product Retest Requirements. Retesting shall be initiated at the end of specified periods measured from time of certification. The periods are defined by elapsed time intervals or by the number of units certified, whichever comes first. However, not more than one test sequence shall be required to be started on the same frame size in the same 12-month period. Not all possible tests are required at the end of a period. The test sequences to be performed at the end of each period are specified by number in Table 6 and are described in Table 1 and the subsections to which it refers.

7.3.1 Product Retest Requirements (Fused Circuit Breakers). When fused circuit breakers covered in this standard are composed of a circuit-breaker element that is periodically retested in accordance with this standard and fuses that are periodically retested and are separately listed in, and comply with, ANSI/UL 198C-1986, no periodic retesting is required for the combination.

Where the fuses are not separately listed in, and may comply with, ANSI/UL 198C-1986, the test described in 3.2.2 of this standard shall be repeated at 5-year intervals.

When major design changes (such as contact structure) are made, a complete sequence retest shall be performed. Minor design changes that do not affect the performance of the combination and are proved by separate tests of the circuit-breaker element or fuse shall not require retest of the combination.

Table 6
Retest Series (Unfused Breakers)

Frame Size	(A) (B)	Total Units or Years	Test Sequence	(A) (B)	Total Units or Years	Test Sequence	(A) (B)	Total Units or Years	Test Sequence
600 & 800	(A)	8 800	I	(A)	17 600	II*	(A)	26 400	III & IV†
	(B)	5		(B)	10		(B)	15	
1 600 & 2 000	(A)	8 500	I	(A)	17 000	II*	(A)	25 500	III & IV†
	(B)	5		(B)	10		(B)	15	
3 000/3 200	(A)	2 100	I	(A)	3 600	II*	(A)	5 100	III & IV†
	(B)	7		(B)	12		(B)	17	
4 000	(A)	830	I	(A)	1 350	II*	(A)	1 870	III & IV†
	(B)	8		(B)	13		(B)	18	

NOTES:

(1) After completion of test sequence III and IV, the series shall be repeated.

(2) When major design changes (such as contact structure) are made, a complete sequence retest shall be made. Minor design changes that affect only a specific area shall be retested within the applicable sequence (for example, electrical operator change needs only an endurance test, or arc chute change needs only an interrupting test).

(3) For frame sizes not listed in Table 6, the tests shall be conducted based on the values specified for the next-lower preferred frame size rating.

*Under sequence II(c), Table 1, conduct test 2 only.

†For retest sequence III the short-circuit opening test (d) is to be omitted if the condition of the circuit breaker prior to the test is considered to be equivalent to that of the circuit breaker that successfuly met the original certification requirements. It is important that adequate documentation be made originally of the condition of the contacts and arc chutes by description, photographs, and measurements or by retention of representative parts so that meaningful comparisons can be made.

Appendix

(This Appendix is not part of American National Standard C37.50-1989, but is included for information only.)

Guide for Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits

ANSI/IEEE C37.26-1972 has been withdrawn as an American National Standard (pending review or reaffirmation), but is reproduced in this Appendix to aid in the completion of the requirements of ANSI C37.50-1989.

1. Scope

This standard describes three methods used to measure the power factor in 60 Hz inductive low-voltage (1000 volts and below) test circuits. Similar methods may apply at other frequencies. These methods are:

(1) Ratio method
(2) dc decrement method
(3) Phase relationship method

These preferred methods are shown in Table 1.

2. Purpose

The purpose of this standard is to recommend methods of measuring power factor for inductive test circuits by such means as oscillographic records, so that the preferred method, giving the greatest accuracy, is recommended for any particular circuit.

3. Definitions

The definitions and terms contained in this document or in other American National Standards referred to in this document, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.

For additional definitions of terms used in this standard, refer to American National Standard Definitions for Power Switchgear, C37.100-1972.

4. Ratio Method

4.1 General. Devices such as current-limiting fuses, fused circuit breakers, and similar fast clearing devices may have total interrupting times of 0.5 cycle or less. The ratio method permits measurement to be made within the operating time of these devices and generally

Table 1
Preferred Methods of Power Factor Measurement for Low-Voltage Inductive Test Circuits (See Note 1)

Test Circuit Current Range (rms symmetrical)	Interrupting Time on Test Device (Cycles)	Circuit Power Factor	
		0-30 Percent	Above 30 Percent
20 kA and below	0.5 or less	Ratio Method	Phase relationship method
	Above 0.5	dc Decrement Method	
Above 20 kA to 130 kA, inclusive	0.5 or less	Ratio Method	—
	Above 0.5	dc Decrement Method	
Above 130 kA	Any	Ratio Method (Note 2)	—

Notes:
(1) Table 1 applies to single-phase or three-phase test circuit. 60 Hz.
(2) For circuits above 130 kA, where asymmetrical closing conditions may jeopardize equipment or instrumentation, the phase relationship may be used.

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is not suitable on circuits with power factors above 30 percent.

Since this method requires closing the circuit to produce maximum current asymmetry, the resulting high mechanical forces on bus supports and circuit components may jeopardize the test equipment or instrumentation. When there is a question of jeopardy, the phase relationship method may be used.

4.2 Procedure for Determining Power Factor. The power factor is determined at an instant one-half cycle (based on the fundamental frequency timing wave) after the initiation of current flow by determining the asymmetrical and symmetrical currents at this point. (See Figs. 1 and 2, and Table 2.) Both total rms asymmetrical current and rms symmetrical current are to be measured and the ratio M_A or M_M calculated as follows: Construct the envelope of the wave as shown in Fig. 1. The rms symmetrical and rms asymmetrical currents shall be determined as indicated in the equations of Fig. 1. Having determined these values, the M_A for three-phase circuits and M_M for single-phase circuits are determined from the following:

$$\text{Ratio } M_A \text{ (for Three-Phase Tests)} \quad \frac{\text{Average of the rms Asymmetrical Current in the Phases}}{\text{Average of the rms Symmetrical Current in the Phases}}$$

$$\text{Ratio } M_M \text{ (for Single-Phase Tests)} \quad \frac{\text{rms Asymmetrical Current}}{\text{rms Symmetrical Current}}$$

Fig. 1
Ratio Method

A' = major ordinate

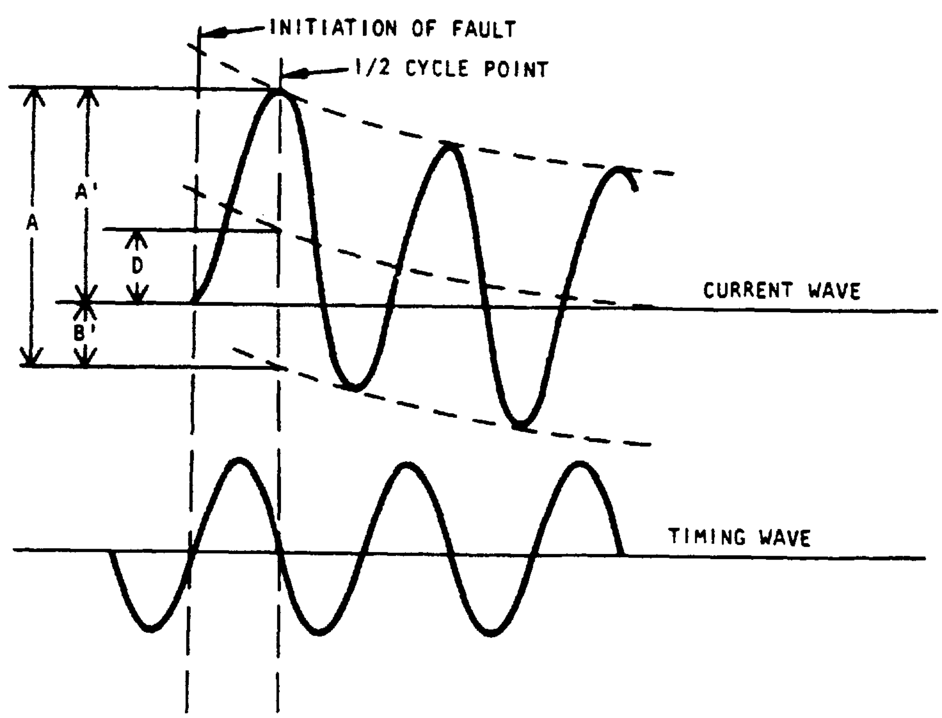
B' = minor ordinate

A = peak-to-peak value of alternating component $= A' + B'$

D = dc component $= A' - \frac{A}{2}$

I = rms symmetrical current $= \frac{A' + B'}{2.828} = \frac{A}{2.828}$

I' = rms asymmetrical current $= \sqrt{\left(\frac{A}{2.828}\right)^2 + D^2}$



Refer to Fig. 2 or Table 2 to determine the power factor of the test circuit.

5. DC Decrement Method

5.1 General. This method is recommended for circuits of 30 percent power factor or less where the device to be tested interrupts at a point in time more than one-half cycle from the initiation of the current. This method relates power factor to the rate of decay of the dc component. The current measuring method used should not introduce distortion into the dc component. Use noninductive shunts since current transformers may introduce significant error.

5.2 Procedure for Determining Power Factor. The power factor may be determined from the curve of the dc component of the asymmetrical current wave. See Fig. 3.

5.2.1 The equation for the dc component is:

$$i_d = I_{d0}\, e^{-(Rt/L)}$$

where

i_d = value of the dc component at time t

I_{d0} = initial value of the dc component

L/R = time constant of the circuit in seconds

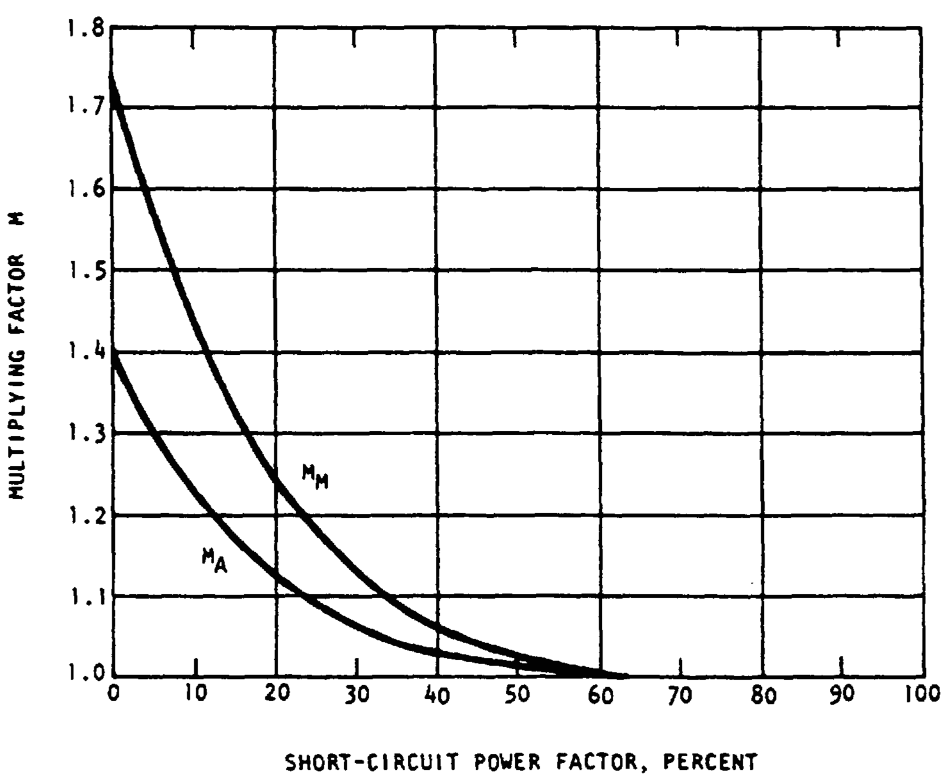
t = time interval, in seconds, between i_d and I_{d0}

e = base of Napierian logarithms (2.7183)

Fig. 2
Multiplying Factor vs Power Factor

$$M_A = \frac{\text{Average of the rms Asymmetrical Current in the Phases}}{\text{Average of the rms Symmetrical Current in the Phases}}$$

$$M_M = \frac{\text{rms Asymmetrical Current}}{\text{rms Symmetrical Current}}$$



Multiplying Factors

Table 2

Power Factor Percent	X/R Ratio	Multiplying Factor: Maximum Single Phase rms Current at ½ Cycle (Curve M_M)	Multiplying Factor: Average Three Phase rms Current at ½ Cycle (Curve M_A)	Power Factor Percent	X/R Ratio	Multiplying Factor: Maximum Single Phase rms Current at ½ Cycle (Curve M_M)	Multiplying Factor: Average Three Phase rms Current at ½ Cycle (Curve M_A)
0	∞	1.732	1.394	29	3.3001	1.139	1.070
1	100.00	1.696	1.374	30	3.1798	1.130	1.066
2	49.993	1.665	1.355	31	3.0669	1.121	1.062
3	33.322	1.630	1.336	32	2.9608	1.113	1.057
4	24.979	1.598	1.318	33	2.8606	1.105	1.053
5	19.974	1.568	1.301	34	2.7660	1.098	1.049
6	16.623	1.540	1.285	35	2.6764	1.091	1.046
7	14.251	1.511	1.270	36	2.5916	1.084	1.043
8	12.460	1.485	1.256	37	2.5109	1.078	1.039
8.5	11.723	1.473	1.248	38	2.4341	1.073	1.036
9	11.066	1.460	1.241	39	2.3611	1.068	1.033
10	9.9501	1.436	1.229	40	2.2913	1.062	1.031
11	9.0354	1.413	1.216	41	2.2246	1.057	1.028
12	8.2733	1.391	1.204	42	2.1608	1.053	1.026
13	7.6271	1.372	1.193	43	2.0996	1.049	1.024
14	7.0721	1.350	1.182	44	2.0409	1.045	1.022
15	6.5912	1.330	1.171	45	1.9845	1.041	1.020
16	6.1695	1.312	1.161	46	1.9303	1.038	1.019
17	5.7967	1.294	1.152	47	1.8780	1.034	1.017
18	5.4649	1.277	1.143	48	1.8277	1.031	1.016
19	5.1672	1.262	1.135	49	1.7791	1.029	1.014
20	4.8990	1.247	1.127	50	1.7321	1.026	1.013
21	4.6557	1.232	1.119	55	1.5185	1.015	1.008
22	4.4341	1.218	1.112	60	1.3333	1.009	1.004
23	4.2313	1.205	1.105	65	1.1691	1.004	1.002
24	4.0450	1.192	1.099	70	1.0202	1.002	1.001
25	3.8730	1.181	1.093	75	0.8819	1.0008	1.0004
26	3.7138	1.170	1.087	80	0.7500	1.0002	1.00005
27	3.5661	1.159	1.081	85	0.6128	1.00004	1.00002
28	3.4286	1.149	1.075	100	0.0000	1.00000	1.00000

The time constant L/R can be ascertained from the above formula as follows:

(1) Measure the value of I_{d0} at the time of current initiation and the value of i_d at any other time t

(2) Determine the value of $e^{-Rt/L}$ by dividing i_d by I_{d0}

(3) From a table of values of e^{-x} determine the value of $-x$ corresponding to the ratio i_d/I_{d0}

(4) The value x then represents Rt/L, from which L/R is determined

5.2.2 Determine the angle ϕ from:

$$\phi = \arctan(\omega L/R)$$

where

$\omega = 2\pi$ times the actual frequency

5.2.3 Power Factor = $\cos\phi$

6. Phase Relationship Method

6.1 General. Methods dependent upon asymmetrical values of current or the decay of the dc component generally are not suitable

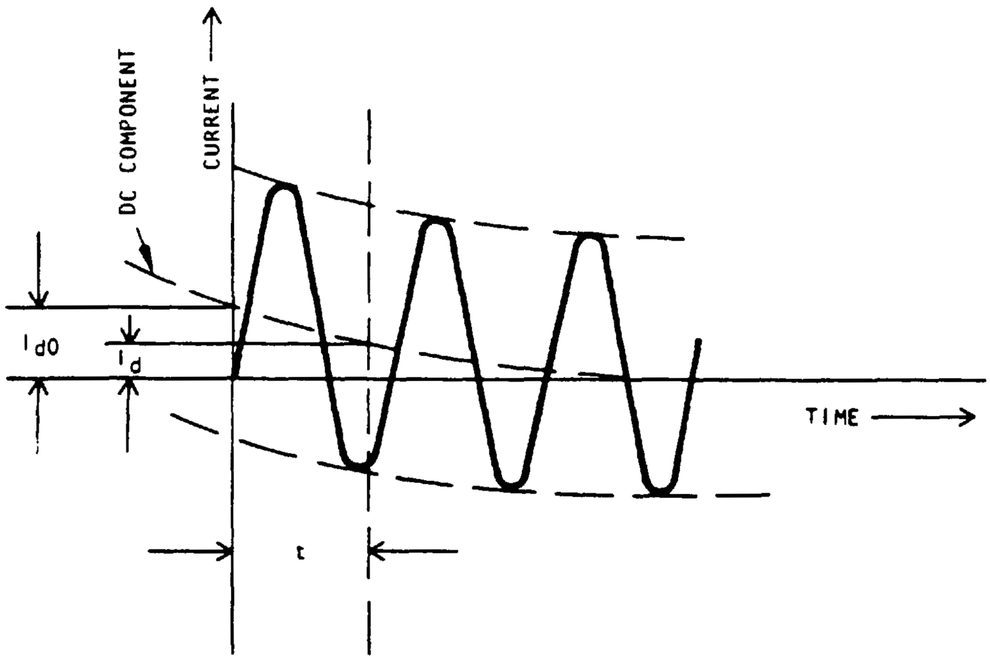


Fig. 3
DC Decrement Method

for the measurement of power factor circuits above 30 percent where the dc component is severely reduced. Therefore, the phase relationship method, using current and voltage waves, is the recommended method on circuits having power factors over 30 percent.

6.2 Procedure for Determining Power Factor. This method involves controlled closing and determines the power factor of the test circuit under essentially symmetrical closing conditions. Construct suitable straight, parallel wave envelope lines and a line midway between them to determine the "zero point" of the "true" axis of the current wave at the end of the first major half cycle. By relating this point to the open circuit voltage wave "zero point," the power factor can be determined from the difference in electrical degrees between the "zero point" of the current at the end of the first major half cycle and the corresponding "zero point" position of the circuit voltage wave. For three-phase circuits, each phase current must be related to its own phase-to-neutral voltage. Greater accuracy will result if each power factor is determined when the circuit is closed so that the phase under consideration has symmetrical characteristics. The average of the phase power factors is considered as the circuit power factor. If the voltage wave is subject to measurable phase shift upon closure of the test circuit (as shown in Fig. 4), it is necessary to determine and use the voltage zero (0) point which would have existed (indicated dash line) if the phase shift in the voltage wave had not occurred.

7. References

[1] *NEMA Standard for Molded Case Circuit Breakers*, Publication AB 1-1969.

[2] *IEC Specification for Alternating-Current Circuit Breakers*, IEC Publication 56-1-1971.

[3] Underwriters' Laboratories, Inc. *High-Interrupting-Capacity Fuses; Current-Limiting Types*, UL198.2-1970.

[4] Harder, J.E. A method of power factor measurement for circuit interrupter testing. *IEEE Transactions on Power Apparatus and Systems*, vol PAS-87, no 10, Oct 1968, TP21 PWR.

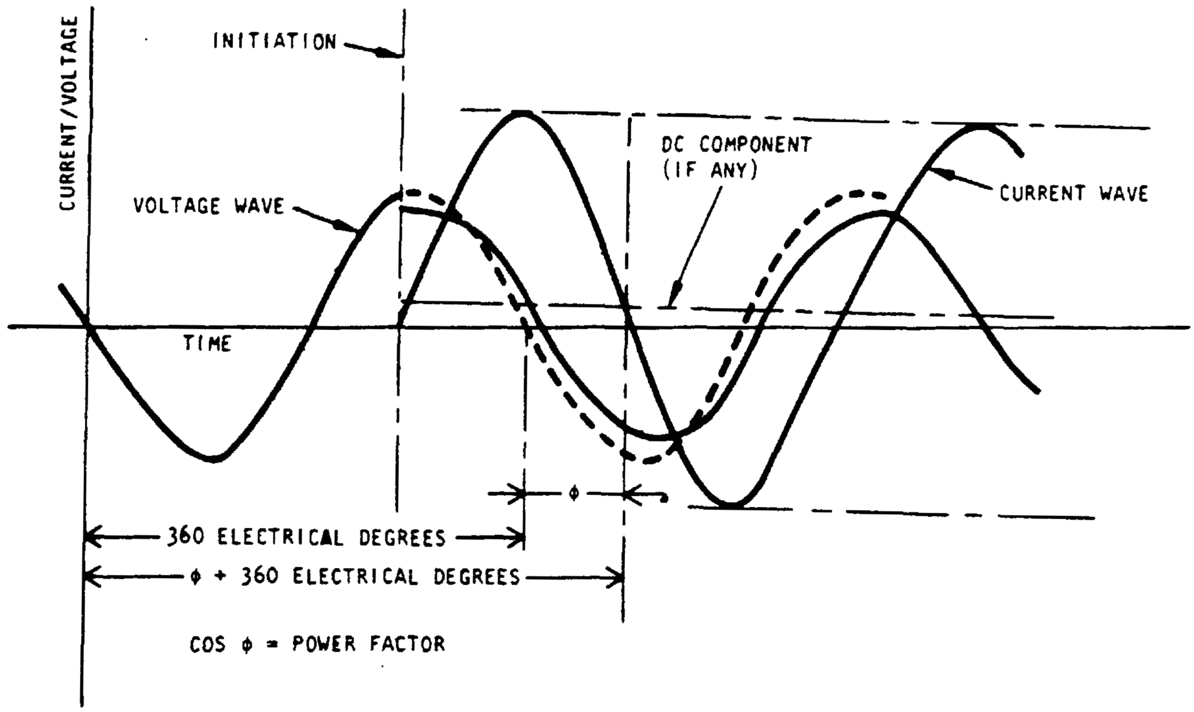


Fig. 4
Phase Relationship Method

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[6] Brandt, T. F., Jr, *Test Procedure for Determining Short-Circuit Power Factor.* Presented at IEEE Winter Power Meeting New York, N. Y., Jan 29, 1968, 68CP20-PWR.

[7] Withers, J. S. *Ammeter-Voltmeter-Wattmeter Method of Determining Short-Circuit Power Factor in a Short-Circuit Laboratory.* Presented at IEEE Winter Power Meeting, New York, N. Y., Jan 29, 1968, 68CP82-PWR.