American National Standard

for Switchgear –

Metal-Enclosed Low-Voltage AC Power-Circuit-Breaker Switchgear Assemblies – Conformance Test Procedures

ANSI American National Standards Institute
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Revision of
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Secretariat
National Electrical Manufacturers Association
Institute of Electrical and Electronics Engineers

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American National Standard

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Foreword

(This Foreword is not part of American National Standard C37.51-1989.)

This standard is a revision of American National Standard for Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies, ANSI C37.51-1979. This revision describes selected tests and procedures to demonstrate conformance in accordance with Section 5, Tests, of American National Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear, ANSI/IEEE C37.20.1-1987. It is being published separately from ANSI/IEEE C37.20-1987 to facilitate its use and to permit timely revisions based on experience.

This standard is one of several in a series of test procedure standards for conformance testing switchgear products. While this standard is written for general guidance, performance criteria are established so that this standard can be adopted as the basis for certification of metal-enclosed low-voltage alternating-current power-circuit-breaker switchgear assemblies for use in nonutility installations subject to regulation by public authorities and similar agencies concerned with laws, ordinances, regulations, administrative orders, and similar instruments.

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

This 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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Working Group Number 2 on Conformance Test Procedures, which prepared this revision, and which was sponsored by the C37 Subcommittee on Conformance Test Procedures, had the following members:

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Contents

American National Standard
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Metal-Enclosed Low-Voltage AC Power-Circuit-Breaker Switchgear Assemblies – Conformance Test Procedures

1. Scope

This standard applies to metal-enclosed low-voltage power-circuit-breaker switchgear assemblies and covers the conformance test procedures for the basic switchgear section that includes the structure, circuit-breaker compartments, instrument compartments, buses, and internal connections (see American National Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear, ANSI/IEEE C37.20.1-1987 for assigned ratings and usual service conditions).

This standard does not apply to installations under the exclusive control of electric utilities for the purposes of communication or metering or for the generation, control, transformation, transmission and distribution of electric energy located in buildings used exclusively by utilities for such purposes, or located outdoors on property owned or leased by the utility or on public highways, streets, roads, and the like, or located outdoors by established rights on private property.

Low-voltage switchgear assemblies usually include control and instrumentation components that are unique for the application and are not individually evaluated under this standard. However, these components when utilized in circuits that obtain their energy from primary sources within the low-voltage switchgear shall be suitably protected as specified in 3.2.

NOTE: In this standard, the use of the term "low-voltage switchgear" shall be considered to mean "metal-enclosed low-voltage alternating-current power-circuit-breaker switchgear assemblies." The use of the term "circuit breaker" shall be considered to mean "low-voltage alternating-current power circuit breaker," unless qualified by other descriptive terms.

This standard specifies the tests that shall be performed to demonstrate that the low-voltage switchgear being tested conforms with the ratings assigned to it in accordance with American National Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear, ANSI/IEEE C37.20.1-1987, and American National Standard for Switchgear — Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors — Preferred Ratings, Related Requirements, and Application Recommendations, ANSI C37.16-1988.

2. Referenced American National Standards

This standard is intended to be used in conjunction with the following publications. When the referenced 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 C37.50-1989, Switchgear — Low-Voltage AC Power Circuit Breakers Used in Enclosures — Test Procedures

ANSI/IEEE C37.09-1979 (R1989), C37.09c-1984, and C37.09e-1985, 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 C37.20.1-1987, Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear

ANSI/IEEE C37.26-1972 (R1978), Guide for Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits[1]

ANSI/IEEE 4-1978, Standard Techniques for High Voltage Testing

3. General Test Conditions

3.1 Ambient Conditions. The conditions prevailing at the test site during tests on low-voltage switchgear shall be those usual service conditions given in Section 3 of ANSI/IEEE C37.20.1-1987, except that the temperature of the air surrounding the assembly (ambient) for the continuous current test shall be within the range of 10°C to 40°C.

3.2 Protection and Conditions — Control and Instrumentation

3.2.1 General. All voltage circuits used for control, relaying, or metering shall be protected within the low-voltage switchgear as follows:

(1) All circuits supplied from external sources (alternating current or direct current) shall have short-circuit protection within the control source incoming section. This may be provided by a single set of short-circuit protective devices.

(2) All circuits supplied from internal sources (alternating current or direct current) shall have short-circuit protection within the same section as the supply source. If these circuits are supplied by a control power transformer, this protection may be in the primary circuit only.

Overcurrent protection of voltage circuits may be provided in addition to the required short-circuit protection.

Other circuits supplying loads such as heaters, lights, or receptacles, shall have overload and short-circuit protection.

Current transformers shall be of the proper voltage class. Overcurrent protection is not permitted in current transformer secondary circuits.

Voltage transformers or control power transformers are required whenever the nominal primary voltage is greater than 240 volts alternating current.

3.2.2 Control Power Transformers. Short-circuit protection of control power transformers shall be provided in accordance with Table 1.

[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 C37.51-1989.

Table 1
Control Power Transformer Short-Circuit Protection

Single-Phase kVA Rating	Primary Maximum Current-Limiting Fuse Rating — Amperes 240 V	480 V	600 V
Up to 1 kVA	10*	10*	6*
2	20	10*	10*
3	30	15*	15*
5	50	25	20
7.5	80	40	30
10	100	50	40
15	150	80	60

*Due to inrush currents, certain types of current-limiting fuses may require larger ratings than those shown, but the ratings shall not exceed 20 amperes.

3.2.3 Voltage Transformers. Voltage transformers shall be protected in the primary circuit with current-limiting fuses not larger than 10 amperes.

4. Conformance Test Requirements

4.1 General. Tests shall be made on representative test arrangements of low-voltage switchgear, as described in 4.3, to demonstrate the capability of the low-voltage switchgear to meet its assigned ratings and to operate under usual service conditions, as outlined in Section 3 of ANSI/IEEE C37.20.1-1987.

For each frame size of the circuit-breaker compartment to be tested, the test arrangement designated in 4.3 shall be used.

4.2 Test Requirements. All test arrangements shall be subjected to the following tests (in accordance with the subsections indicated in parentheses) to prove the adequacy of the design:

(1) Alternating-current dielectric withstand test (4.4)

(2) Mechanical performance test (4.5)

(3) Continuous current test (4.6)

(4) Short-time current withstand test (4.7)

(5) Short-circuit current withstand test (4.8)

(6) Alternating-current dielectric withstand test (repeated) (4.4)

4.3 Test Arrangements. The test arrangement construction shall consist of an indoor vertical section of circuit-breaker compartments plus an additional representative structure to simulate actual installation of two adjacent sections so that the main bus extends through both sections and includes a main bus splice.

If the low-voltage switchgear is manufactured in both stationary and drawout designs and the bus design is identical for both, either design shall be tested, except for test 4.2(2), which shall be conducted on the drawout design.

For tests 4.2(1) and 4.2(2), the circuit breaker may be in any compartment.

Test 4.2(3) shall be conducted with a single circuit breaker in the uppermost circuit-breaker compartment of any arrangement used by the manufacturer for the rating being tested, with all other compartments in that vertical section bussed to receive circuit breakers, but with circuit breakers, if installed in these compartments, disconnected for the test. Tests 4.2(4) and 4.2(5) shall be made with a circuit breaker in the uppermost compartment, unless it is determined that circuit breakers need not be included in the short-time and short-circuit current withstand tests (see 4.7 and 4.8).

The section bus (riser) shall be the minimum size furnished by the manufacturer for the frame size of the circuit breaker used in the test arrangement.

Test Arrangement Number 1
1-600 A Frame Size Circuit-Breaker
Compartment — 1600 A Main Bus

Test Arrangement Number 2
1-800 A Frame Size Circuit-Breaker
Compartment — 1600 A Main Bus

Test Arrangement Number 3
1-1600 A Frame Size Circuit-Breaker
Compartment — 1600 A Main Bus

Test Arrangement Number 4
1-2000 A Frame Size Circuit-Breaker
Compartment — 2000 A Main Bus

Test Arrangement Number 5
1-3000 A Frame Size Circuit-Breaker —
Compartment – 3000 A Main Bus

Test Arrangement Number 6
1-3200 A Frame Size Circuit-Breaker
Compartment — 3200 A Main Bus

Test Arrangement Number 7
1-4000 A Frame Size Circuit-Breaker
Compartment — 4000 A Main Bus

4.4 Alternating-Current Dielectric Withstand Tests. Alternating-current dielectric withstand tests on low-voltage switchgear shall be made to determine the ability of the insulation to withstand overvoltage.

Alternating-current test voltages shall be measured in accordance with ANSI/IEEE 4-1978. The potential shall be increased gradually from zero so as to reach the required test value in 5 seconds to 10 seconds and shall be held at that value for 1 minute.

The test voltage 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 percent of the rated frequency of the low-voltage switchgear being tested. If a test transformer of less than 500 volt-amperes is used, a suitable voltmeter shall be provided to measure the applied output potential directly.

A dielectric test voltage of 2200 volts, 60 hertz, shall be applied for a period of 1 minute to the primary circuit of the low-voltage switchgear in the following manner:

(1) With the circuit breaker in the connected position, apply the test voltage between primary circuits and ground as follows:

(a) *With the circuit-breaker contacts closed.* Between each phase of the test arrangement with the metal frame of the switchgear structure and the other phases and the neutral bus grounded.

(b) *With the circuit-breaker contacts open.* Between each terminal of the test arrangement with the metal frame of the switchgear structure and all other terminals grounded.

(2) With the circuit breaker in the test position and contacts closed, apply the test voltage as follows:

(a) *With the lower terminals of the circuit-breaker compartment connected to the metal frame of the switchgear structure and to ground.* Between the upper terminals of the compartment and ground.

(b) *With the upper terminals of the circuit-breaker compartment connected to the metal frame of the switchgear structure and to ground.* Between the lower terminals of the compartment and ground.

(3) Between neutral and ground, except at 1800 volts instead of 2200 volts.

Dielectric tests are not required for fused circuit-breaker equipment (1) when the fused circuit-breaker compartment in the low-voltage switchgear is physically equivalent to the circuit-breaker test enclosure previously tested in accordance with ANSI C37.50-1989, and (2) when the connectors from the section bus (riser) to the fused circuit-breaker compartment are physically equivalent to the unfused connectors.

4.5 Mechanical Performance Tests — Removable Circuit Breakers

4.5.1 Test Procedure. When low-voltage switchgear includes drawout circuit breakers, mechanical performance tests shall be performed on each frame size to demonstrate proper operation of the following elements with all external primary connections removed:

(1) Separable primary contacts

(2) Separable control contacts

(3) Circuit-breaker removable element position interlocks

(4) Stored-energy mechanism interlocks, as applicable

(5) Housing-mounted breaker position switches

Mechanical performance tests of fused circuit breakers are not required when the five elements specified in 4.5.1(1) through 4.5.1(5) are of equivalent design on fused and unfused circuit breakers.

The tests shall be performed either with an electrically operated circuit breaker or with a manually operated circuit breaker having a stored-energy closing mechanism and equipped with separable control contacts, if the design of the drawout mechanism and the interlocks are the same for both. If they are not, both manually and electrically operated designs shall be tested.

The test shall consist of ten complete cycles of operation as described in 4.5.2 without repair or replacement of any functional parts. Proper operation of housing-mounted breaker position switches shall be verified by the tests specified in 4.5.2, as applicable.

The circuit breaker shall be open and in the disconnected position with the stored-energy mechanism discharged. Separable contacts shall be lubricated according to the manufacturer's recommendations.

4.5.2 Cycles of Operation. Each complete cycle of operation shall consist of the following six steps:

Step 1. Move the circuit breaker to the test position and, if required, install a secondary test coupler.

NOTE: The test position may correspond to the disconnect position.

(a) Close the circuit breaker.

(b) Check to assure that the circuit breaker cannot be moved to the connected position while closed.

(c) Open the circuit breaker.

Step 2. Move the circuit breaker to a position approximately midway between the test and connected positions or as close to a midposition as the removable secondary test coupler (if required) will permit. Check to assure that the circuit breaker cannot be closed, either electrically or mechanically.

Step 3. Remove the secondary test coupler, if present, and move the circuit breaker to the connected position.

(a) Close the circuit breaker.

(b) Check to assure that the circuit breaker cannot be moved out of the connected position while closed.

Step 4. Move the circuit breaker to a position approximately midway between the test and connected positions or as close as possible to a midposition as the removable secondary test coupler (if required) will permit. Check to assure that the circuit breaker cannot be closed, either electrically or mechanically.

Step 5. Move the circuit breaker to the test position and, if required, install a secondary test coupler.

(a) Close the circuit breaker.

(b) Check to assure that the circuit breaker cannot be moved to the connected position while closed.

(c) Open the circuit breaker.

Step 6. Remove the secondary test coupler, if present, and move the circuit breaker to the disconnect position.

NOTE: The disconnect position may correspond to the test position.

After completion of ten cycles of operation, a check shall be carried out to assure that, when the mechanism is in the fully charged condition, either the closing function is blocked or the interlocks ensure mechanism discharge before or during withdrawal of the circuit breaker from the housing. (Automatic discharge is a commonly accepted method.)

NOTE: The discharge or close blocking feature is not required if the stored-energy mechanism and contact assembly are fully enclosed within the breaker element and access for service is not possible.

4.5.3 Performance. At the completion of these tests, the mechanism parts and interlocks shall be in essentially the same condition as before the test, and there shall be no galling of the separable primary or control contacts.

4.6 Continuous Current Test. The continuous current test shall be performed to ensure that the low-voltage switchgear test arrangement can carry the rated continuous current of the circuit breaker at rated frequency without exceeding the allowable temperature rises specified in 4.5 of ANSI/IEEE C37.20.1-1987 and 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 during the test.

The low-voltage switchgear test arrangement shall be tested using a three-phase source of power of any convenient voltage at a test frequency no less than rated frequency. The average of the three-phase currents shall be maintained at no less than the rated continuous current of the circuit breaker, and the current in any one phase shall be at least 95 percent of the rated continuous current of the circuit breaker. A single-phase source of power (all phases in series with flow of current reversed with adjacent phases) may be used at the option of the manufacturer.

Continuous current tests of fused circuit breakers are not required when the actual temperature rises of the fused circuit-breaker test enclosure terminal connections are: (1) not greater than the comparable rises of unfused terminal connections, or (2) if greater, but the actual temperature rises of the low-voltage switchgear buses and connections demonstrate sufficient margin to prevent exceeding maximum allowable temperature rises.

If testing in accordance with ANSI C37.50-1989 clearly demonstrates that either the fused or unfused terminal connections have higher temperature rises, continuous current testing of the unit with the lower temperature rises is not required.

4.6.1 Duration of Tests. The continuous current test shall be performed for such a period of time that the temperature rise of any monitored point in the test arrangement has not increased by more than 1.0°C 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 had increased since the previous reading, the test shall be continued.

4.6.2 Measurement of Ambient Air Temperature. Indoor ambient air temperatures shall be determined by taking the average of the readings of three temperature-measuring devices such as thermometers or thermocouples, placed as follows:

(1) One level with the top of the structure

(2) One 12 inches (305 mm) above the bottom of the structure

(3) One midway between the two positions indicated in 4.6.2(1) and 4.6.2(2)

All temperature-measuring devices shall be placed 12 inches (305 mm) from the structure, not in front of ventilators, and in locations unaffected by drafts caused by the structure or appreciable radiation from the equipment. When the ambient air temperature is subject to variations that might result in errors in measuring the temperature rise, the temperature-measuring devices should be immersed in suitable liquid such as oil in a suitable container, or reliably attached to a suitable mass of metal.

NOTE: A convenient form for such a container consists of a metal cylinder with a hole drilled partly through it. This is filled with liquid and the temperature-measuring device placed therein.

A glass bottle may also be used as a container. The size of the container should be at least 1 inch (25.4 mm) in diameter and 2 inches (50.8 mm) high.

4.6.3 Method of Measuring Temperature. Thermocouples shall be used to measure the temperature at the required locations on the low-voltage switchgear test arrangement. The thermocouple, when used for measuring the temperature of insulation, shall be located on the current-carrying member or other metal part adjacent to the insulation.

Thermocouples used for measuring the temperature of the circuit-breaker separable primary disconnect contacts shall be located approximately 0.5 inch (13 mm) from the contacts on the current-carrying member. For cable terminations, the thermocouples shall be located at the junction of the conductor and its insulation.

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

4.6.4 Copper Conductors for Use in Continuous Current Tests. Bus bars as described in Table 2 shall be utilized for connection to the main bus. Cables or bus bars as specified in Table 3 shall be utilized for connection to the feeder-circuit-breaker outgoing terminals or extensions. If test arrangement internal bus sizes differ from those specified in Tables 2 and 3, external bus sizes equal to internal bus sizes may be substituted at the option of the manufacturer.

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

Table 2
Copper Conductors for Connection to the Main Bus for Use in Continuous Current Tests

	*Copper Bus per Terminal		
		Size	
Main Bus Rating Amperes	Quantity	inch	mm
1600	2	1/4 × 3	6.35 × 76.2
2000	2	1/4 × 4	6.35 × 101.6
3000	3	1/4 × 5	6.35 × 127.0
3200	3	1/4 × 5	6.35 × 127.0
4000	4	1/4 × 5	6.35 × 127.0

*Where multiple bus bars are used, they shall be spaced 1/4 inch (6.35 mm) apart. The 4000-ampere group shall be two sets of two bars with not more than 4 inches (101.6 mm) between pair centers. Configurations shall be vertical unless the design of the circuit-breaker enclosure terminals requires them to be horizontal. The determination of the configuration shall be at the option of the manufacturer.

Table 3
Copper Conductors for Connection to Feeder Circuit-Breaker Outgoing Terminals or Extensions for Use in Continuous Current Tests

	Size of Copper Conductor			
		*Bus per Terminal		
			Size	
Circuit-Breaker Frame Size	AWG or Circular-Mil	Quantity	inch	mm
600	2-350M	—	—	—
800	2-500M	—	—	—
1600	4-600M	—	—	—
2000	5-600M	—	—	—
3000	—	3	1/4 × 5	6.35 × 127.0
3200	—	3	1/4 × 5	6.35 × 127.0
4000	—	4	1/4 × 5	6.35 × 127.0

*Where multiple bus bars are used, they shall be spaced 1/4 inch (6.35 mm) apart. The 4000-ampere group shall be two sets of two bars with not more than 4 inches (101.6 mm) between pair centers. Configurations shall be vertical unless the design of the circuit-breaker enclosure terminals requires them to be horizontal. The determination of the configuration shall be at the option of the manufacturer.

4.6.5 Performance. The low-voltage switchgear test arrangement shall be considered as having passed this test if temperature rises specified in 4.5 of ANSI/IEEE C37.20.1-1987 and Table 2 of ANSI/IEEE C37.13-1981 are not exceeded. The terminal connection limit of 55°C rise is not applicable.

The results of previous design tests may be used to establish points of temperature measurement and the phase with the greatest temperature rise. The temperature rises of that phase only and the hot spot of the other phases shall be measured.

4.7 Short-Time Current Withstand Test. A short-time current duty cycle test shall be made to demonstrate the ability of each low-voltage switchgear test arrangement to carry the current resulting from a short circuit having an available current equal to the short-time rating of the applicable circuit-breaker frame size. See Table 2 in ANSI C37.16-1988 for preferred values.

The circuit breaker shall be of a type that has previously met the design test requirements for short-time current performance as specified in ANSI C37.50-1989. When the circuit-breaker compartment in the low-voltage switchgear is physically equivalent to the circuit-breaker test enclosure, no additional testing of the circuit breaker, circuit-breaker compartment, or associated conductors is required. The circuit-breaker compartment incoming terminals shall be connected together by a shorting bar(s) or the connection may be in accordance with 4.8.2.

If the circuit-breaker compartment is not physically equivalent to the circuit-breaker test enclosure, the three-phase short-time current test shall include a circuit breaker of the construction used when supplied without direct acting trip devices. The main bus terminals shall be connected to the test circuit power source, and the circuit-breaker compartment outgoing terminals shall be connected together by a shorting bar(s).

Fused circuit-breaker compartments do not require short-time current testing.

4.7.1 Test Circuit Conditions. The test circuit shall conform to the requirements listed in 4.8.2.

4.7.2 Short-Time Current Duty Cycle. The available short-time current shall be applied within the limitations stated in 4.8.2 and maintained for two periods of 1/2 second each, with a 15-second interval of zero current between the 1/2-second periods.

At the option of the manufacturer a single period of 1-second duration may be used if the circuit breakers are not included in the test enclosure.

4.7.3 Performance. After a short-time current duty cycle, the low-voltage switchgear test arrangement shall show no physical damage and shall be in a condition to continue the test sequence without repair or replacement of parts.

4.8 Short-Circuit Current Withstand Tests. Short-circuit current withstand tests shall be made to demonstrate the mechanical adequacy of the structure, buses, and connections to withstand the maximum short-circuit stresses that would occur when properly applied on systems when the available short-circuit current is equal to the short-circuit current rating of the circuit breakers in the low-voltage switchgear. Refer to Table 1 of ANSI C37.16-1988 for the preferred current levels at 480 volts and 240 volts. However, the 600-volt ratings do not have to be proven, since the prior short-time test was conducted at the specified current levels.

The circuit breaker shall be of a type that has previously met the design test requirements for short-circuit performance as specified in ANSI C37.50-1989. When the circuit-breaker compartment in the low-voltage switchgear is physically equivalent to the circuit-breaker test enclosure, no additional testing of the circuit breaker, circuit-breaker compartment, or associated conductors is required.

If the circuit-breaker compartment is not physically equivalent to the circuit-breaker test enclosure, the test shall be made under the same conditions that resulted in the highest let-through current during the circuit-breaker short-circuit current tests described in ANSI C37.50-1989. The circuit-breaker outgoing terminals shall be connected together by a shorting bar(s).

For the short-circuit current withstand test, the main bus terminals of the low-voltage switchgear arrangement shall be connected to the test circuit power source and three-phase tests shall be made with a short circuit at the following locations:

(1) At the opposite end of the main bus from the terminals to cause a short-circuit current to pass through the main bus and splice

(2) If a circuit breaker is not required, at a location on the section bus (riser) so that a short-circuit current will pass through the greatest possible length of the section bus (riser)

Single-phase tests shall be made to prove the strength of the ground bus and the neutral bus with respect to the nearest phase bus. A three-phase test source shall be used with an available short-circuit current as defined in 4.8.2.

Tests for the neutral bus shall be made by connecting the neutral bus to the source neutral and connecting the nearest phase bus to one phase of the source. Tests for the ground bus shall be made by connecting the ground bus to one phase of the source and connecting the nearest phase bus to another phase of the source. The short-circuit connection shall be made between the ends of the main and neutral or ground bus bars at the end opposite the test source connection.

The short-circuit connections shall be made with bolted bars of minimum length and cross section equal to the bus being tested. Insofar as possible, they shall not add intentional bracing to the bus structure being tested.

The incoming bus structure used in a low-voltage switchgear shall be considered as meeting the short-circuit current requirements if its construction is physically equivalent to that of the main bus structure that was tested and found to meet the short-circuit current requirements.

The short-circuit current withstand tests shall be conducted on each low-voltage switchgear test arrangement specified in 4.3. However, it is not required to test the main bus specified in test arrangements 1 and 2 if it has the same construction as the main bus specified in test arrangement 3.

If it can be demonstrated that the maximum peak let-through current of the fuse is less than the peak let-through current for which the low-voltage switchgear has been tested, then testing with fused circuit breakers is not required. When it is necessary to test fused circuit-breaker compartments, the short-circuit current connections shall be made on the ongoing side of the fused circuit breaker. The fuses shall be the maximum current rating supplied by the manufacturer for the circuit-breaker frame size.

4.8.1 Test Duration. The duration of current flow during the short-circuit current withstand test shall be for no less than four cycles on a 60-hertz basis (0.067 seconds), unless the bus is protected by a current-limiting device, in which case the duration shall be for the time permitted by that device.

NOTE: Four cycles is the maximum duration of short-circuit current when circuit breakers with instantaneous trip devices are installed on 600-volt alternating-current systems.

4.8.2 Test Circuit Conditions. The test circuit conditions shall be as follows:

(1) The three-phase root-mean-square (rms) symmetrical value of current that verifies the short-time or short-circuit current rating shall be determined by calibrating the test circuit with the low-voltage switchgear test arrangement omitted. The current shall be measured one-half cycle after the inception of current flow in the test circuit. The symmetrical rms value of current in each phase shall be calculated in accordance with 7.1 in ANSI/IEEE C37.09-1979. For three-phase circuits, the symmetrical current value shall be the average of the phase currents.

(2) The power factor of the test circuit shall be 15-percent lagging or less (X/R ratio of 6.6 or greater) with X and R in series connection. The power factor shall be determined in accordance with ANSI/IEEE C37.26-1972.[1] (Power factor 20 percent or less, X/R ratio of 5 or greater for fused circuit-breaker equipment.)

(3) The rms value of the alternating component of current at the end of four cycles shall be not less than 90 percent of the value measured at one-half cycle after initiation of the current. For the short-time test, the alternating component of the current at the end of 1/2 second shall be not less than 80 percent of the alternating component measured at one-half cycle after initiation of the current.

(4) The current shall be initiated in the test circuit in such a manner as to ensure that the peak current available will 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. (For fused circuit breakers, the multiplying factor shall be 2.16.)

(5) The frequency of the test circuit shall be 60 hertz ±20 percent.

(6) The tests shall be performed at the maximum design voltage.

4.8.3 Performance. The low-voltage switchgear test arrangement shall be considered as having passed this test if there is no breakage of the bus supports and the equipment can withstand the dielectric requirements of 4.4. Permanent deformation of bus bars and supports that does not prevent the dielectric requirements from being met is permissible. Permanent deformation of bus bars and supports shall not impair mechanical performance as specified in 4.5.

5. Treatment of Failures

When failures occur during testing, the failures shall be evaluated and corrected, and the equipment shall be retested. A design change made to the low-voltage switchgear to correct a test failure shall be evaluated for its effect on other tests.

6. Accessory Devices

6.1 Cell-mounted functional components, such as circuit-breaker position switches, that have passed the requirements of device standards are not required to be retested electrically or mechanically other than as is specified in 4.5.

6.2 When accessory devices are mechanical only, such as key interlocks, mechanical interlocks, and the like, which are operated rather infrequently, normal production tests shall be the criteria for proving the operational tests of these devices.

7. Production Tests

Unless otherwise specified, all production tests shall be made by the manufacturer at the factory on the complete low-voltage switchgear or its component parts for the purpose of checking the correctness of manufacturing operations and materials (see ANSI/IEEE C37.20.1-1987).

Production tests shall include the following:

(1) Alternating-current dielectric withstand tests

(2) Mechanical operation tests

(3) Grounding of instrument transformer cases test (if instrument transformers are of metal case design)

(4) Electrical operation and wiring tests

7.1 Alternating-Current Dielectric Withstand Tests. Alternating-current dielectric withstand tests shall be made at the factory in accordance with the general requirements of 4.4 and the following instructions:

(1) Drawout circuit-breaker removable elements are not required to be tested in the assembly if they are tested separately. Control devices that are connected to the primary circuit may be disconnected during the test.

(2) With the circuit-breaker contacts open or with the circuit breaker omitted, apply the test voltage:

(a) *Between each phase of the main bus and ground.* The other two phases of the main bus and the switchgear frame shall be grounded.

(b) *Between each phase of all circuit-breaker compartment outgoing terminals (and incoming line terminals) and ground.* All other phases of these terminals, the main bus, and the low-voltage switchgear frame shall be connected together and to ground.

(3) Apply a test voltage of 1800 volts between neutral and ground.

7.2 Mechanical Operation Tests. Mechanical operation tests shall be performed to ensure the proper functioning of removable compartment operating mechanisms, mechanical interlocks, and the like. These tests shall ensure the interchangeability of removable circuit breakers designed to be interchangeable.

7.3 Grounding of Instrument Transformer Cases Test. The effectiveness of grounding of each instrument transformer case or frame shall be checked with a low potential source, such as 10 volts or less, by using bells, buzzers, or lights. This test shall be performed when instrument transformers are of metal case design, and is not required otherwise.

7.4 Electrical Operation and Wiring Tests

7.4.1 Control Wiring Continuity. The correctness of the control wiring of a low-voltage switchgear shall be verified by either (1) actual electrical operation of the component control devices, or (2) individual circuit continuity checks by electrical circuit testers.

7.4.2 Control Wiring Insulation Test. A 60-hertz test voltage, 1500 volts to ground, shall be applied for 1 minute after all circuit grounds have been disconnected and all circuits have been connected with small bare wire to short-circuit the coil windings. The duration of the test shall be 1 second if a voltage of 1800 volts is applied. At the option of the manufacturer, switchgear-mounted devices that have been individually tested may be disconnected during this test.

7.4.3 Polarity Tests. Tests or inspections shall be made to ensure that connections between instrument transformers and meters or relays, and the like, are correctly connected with proper polarities in accordance with circuit diagrams. Instruments shall be checked to ensure that pointers move in the proper direction. It is not required that primary voltage and current be used to satisfy any of the requirements in 7.4.3.

7.4.4 Sequence Tests. Low-voltage switchgear involving the sequential operation of devices shall be tested to ensure that the devices in the sequence function properly and in the order intended.

This sequence test need not include remote equipment controlled by the low-voltage switchgear; however, this equipment may be simulated where necessary.

8. Retesting

Retesting is not required if the design has not changed. A design change made to the low-voltage switchgear shall be evaluated for its effect on rated performance. If it is determined that performance may be affected by the change, the relevant conformance tests shall be repeated.

Appendix (This Appendix is not part of ANSI C37.51-1989, 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 C37.51-1989.

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	Circuit Power Factor 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.

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

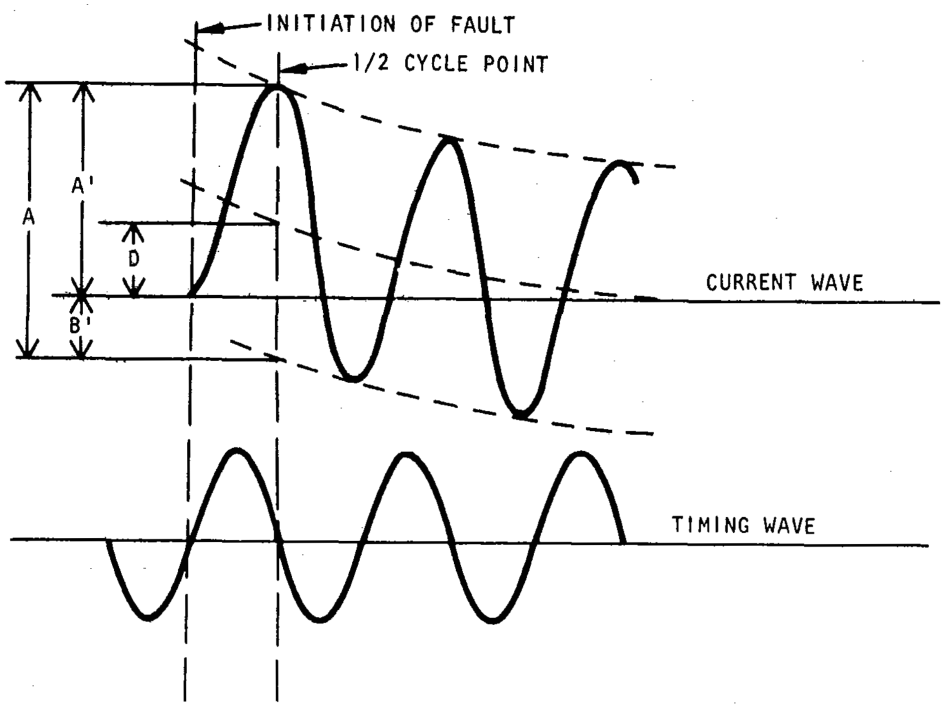
B' = minor ordinate

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

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

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

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



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

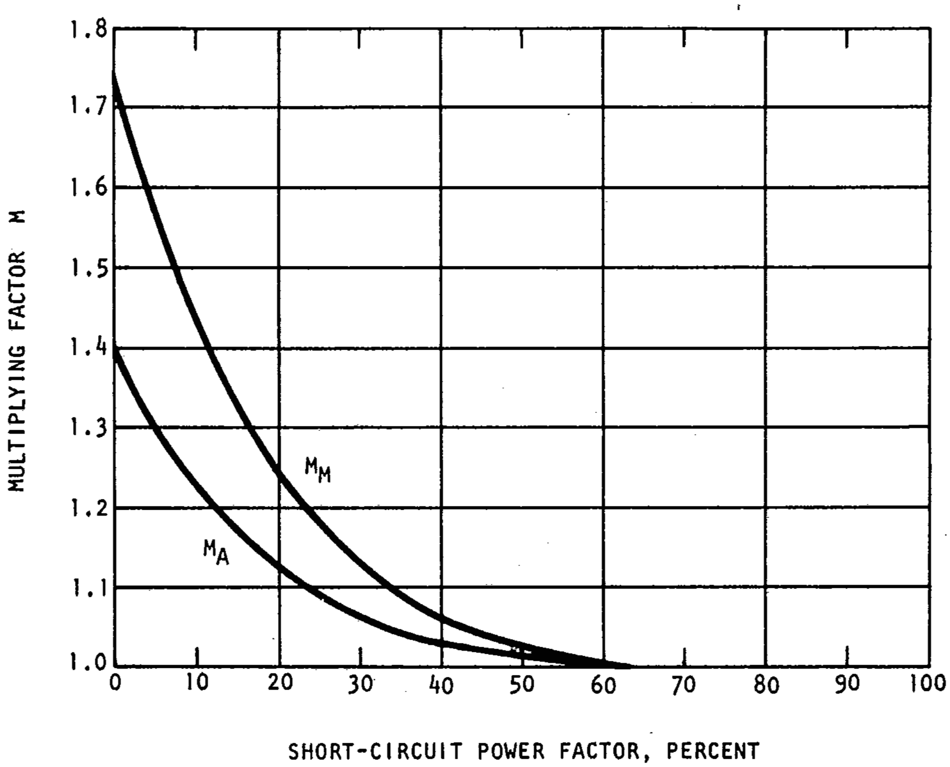
t = time interval, in seconds, between i_d and I_{d0}

e = base of Napierian logarithms (2.7183)

Fig. 2
Multiplying Factor vs Power Factor

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

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



APPENDIX

Multiplying Factors

Table 2

Power Factor Percent	X/R Ratio	Multiplying Factor		Power Factor Percent	X/R Ratio	Multiplying Factor	
		Maximum Single Phase rms Current at ½ Cycle (Curve M_M)	Average Three Phase rms Current at ½ Cycle (Curve M_A)			Maximum Single Phase rms Current at ½ Cycle (Curve M_M)	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

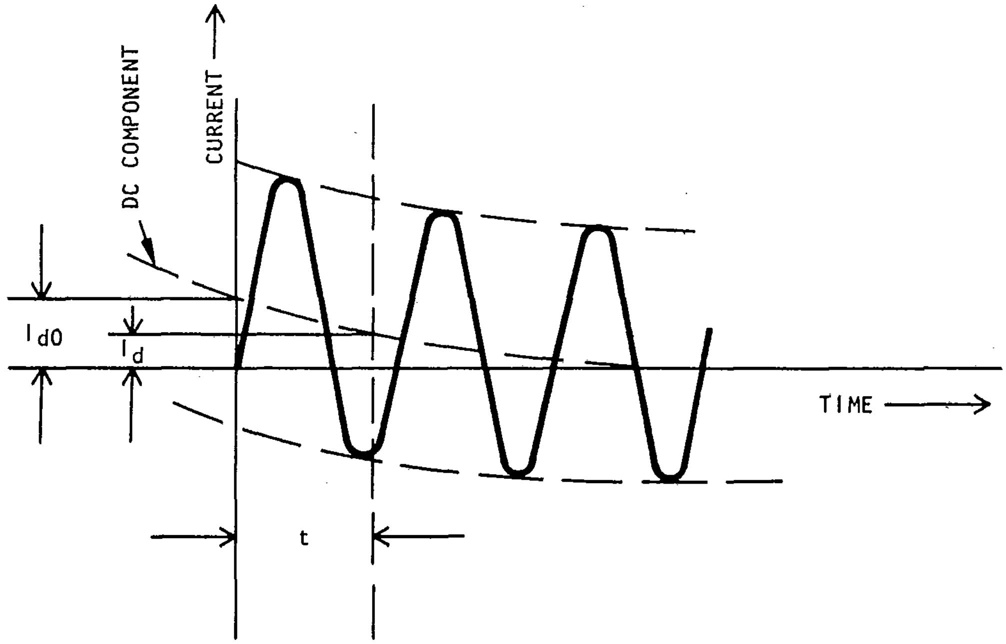


Fig. 3
DC Decrement Method

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.

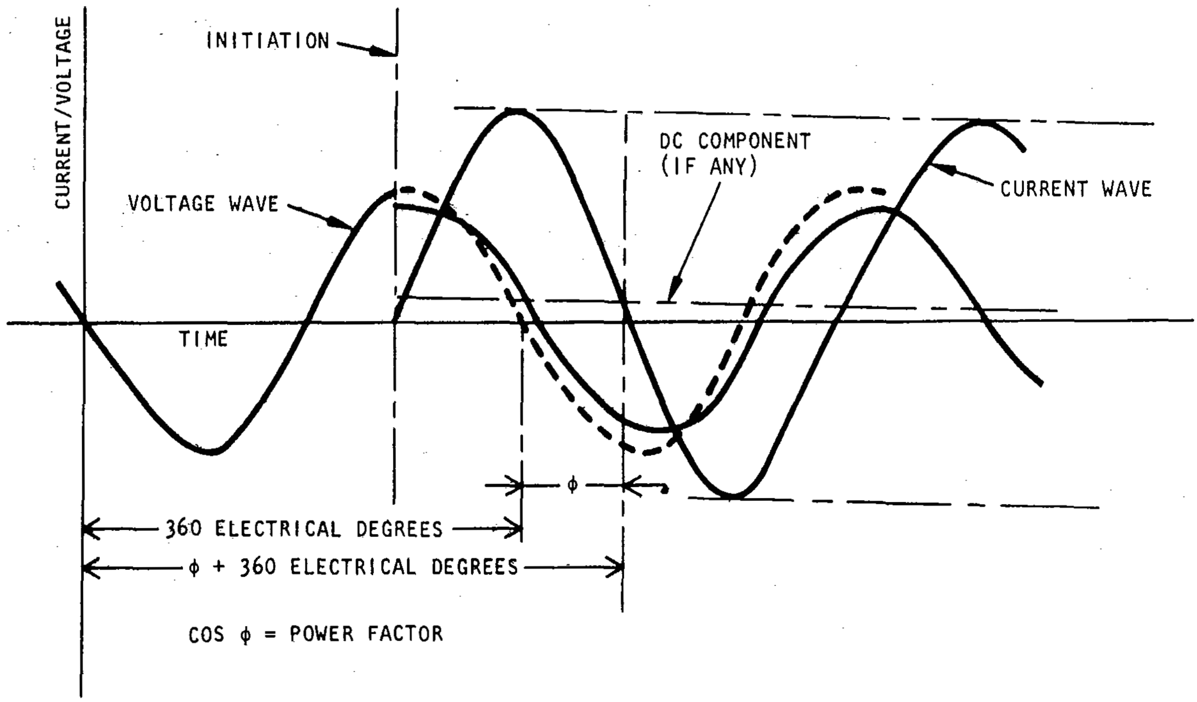


Fig. 4
Phase Relationship Method

[5] Farquhar, W. A.; Schall, G. E.; Plate, G. H. *Comparison of Power Factor Measurement Methods.* Presented at IEEE Winter Power Meeting, New York, N. Y., Jan 29, 1968, 68CP168-PWR.

[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.