Recognized as an
American National Standard (ANSI)

IEEEC37.13-1990
(Revision of IEEE C37.13-1981)

IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

Sponsor
Switchgear Committee
of the
IEEE Power Engineering Society

Secretariat

Institute of Electrical and Electronics Engineers, Inc.
National Electrical Manufacturers Association

Approved October 22, 1990
Reaffirmed September 21, 1995

IEEE Standards Board

Approved March 5, 1991
Reaffirmed April 8, 1996

American National Standards Institute

Abstract: This standard covers enclosed low-voltage ac power circuit breakers of the stationary or draw-out type of two- or three-pole construction, with one or more rated maximum voltages of 635 V (600 V for units incorporating fuses), 508 V, and 254 V for application on systems having nominal voltages of 600 V, 480 V, and 240 V; with unfused or fused circuit breakers; manually or power operated; and with or without electromechanical or solid-state trip devices. It deals with service conditions, ratings, functional components, temperature limitations and classifications of insulating materials, insulation (dielectric) withstand voltage requirements, test procedures, and application.
Keywords: circuit breaker, fused circuit breaker, low-voltage ac power circuit breaker, open-fuse trip device, unfused circuit breaker

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345 East 47th Street, New York, NY 10017-2394, USA

ISBN 1-55937-113-7

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Foreword

(This Foreword is not a part of IEEE C37.13-1990, IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.)

This revision of C37.13-1981 includes a general updating of the standard in many areas and specific changes in the classification of insulating materials. The general classification of insulating materials has been deleted, but the temperature classes have been retained with reference to IEEE Std 1-1986 for technical support. In addition, locking of a circuit breaker has been added to the functional components to reflect standard practice.

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The final conditions for approval of this standard were met on October 22, 1990. This standard was conditionally approved by the IEEE Standards Board on September 28, 1990, with the following membership:

IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

1. Scope

The scope of this standard includes enclosed low-voltage ac power circuit breakers, as follows:

1) Stationary or draw-out type of two- or three-pole construction, with one or more rated maximum voltages of 635 V (600 V for units incorporating fuses), 508 V, and 254 V for application on systems having nominal voltages of 600 V, 480 V, and 240 V.
2) Unfused or fused type
3) Manually operated or power operated, with or without electromechanical or solid-state trip devices.

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

2. Service Conditions

A circuit breaker conforming to this standard shall be suitable for operation up to and including all of its standard ratings, provided that

1) The temperature of the air surrounding the circuit breaker is not below –5 °C.
   NOTE — When properly applied in metal-enclosed switchgear or individual enclosures, a circuit breaker will operate within the limits of ambient temperature of the air surrounding the enclosure as specified in IEEE C37.20.1-1987 [4].[1]
2) The altitude does not exceed 6600 ft (2000 m).
3) The relative humidity of the air surrounding the circuit breaker is such that there will be no condensation on the circuit-breaker parts at any time.
4) None of the service conditions as listed in 10.6.2 prevail.

For application of circuit breakers under service conditions other than those above, see Section 10.

[1]The numbers in brackets correspond to those of the references listed in Section 3.

3. References

When the standards referred to in this document are superseded by an approved revision, the revision shall apply.

[1] ANSI C37.16-1988, American National Standard Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors.[2]

[2] ANSI C37.17-1979 (Reaff 1988), American National Standard for Trip Devices for AC and General Purpose DC Low-Voltage Power Circuit Breakers.

[3] ANSI C37.50-1989, American National Standard Test Procedures for Low-Voltage AC Power Circuit Breakers Used in Enclosures.

[4] IEEE C37.20.1-1987, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear (ANSI).[3]

[5] IEEE C37.100-1981 (Reaff 1989,) IEEE Standard Definitions for Power Switchgear (ANSI). (Includes supplement IEEE C37.100b-1986.)

[6] IEEE Std 1-1986, IEEE Standard General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation (ANSI).

[7] IEEE Std 4-1978, IEEE Standard Techniques for High Voltage Testing (ANSI).

[8] IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (ANSI) (IEEE Red Book).

[9] IEEE Std 241-1990, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (ANSI) (IEEE Gray Book).[4]

[10] IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (ANSI) (IEEE Buff Book).

[11] NEMA CP1-1988, Shunt Capacitors.[5]

4. Definitions

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

At the time this standard was approved, there was no corresponding definition in IEEE C37.100-1981 [5] for the definition below.

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[2]ANSI publications are available from the American National Standards Institute, Sales Department, 11 West 42nd St., 13th Floor, New York, NY 10036,(212) 642-4900.
[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331,1-800-678-4333.
[4]As this standard goes to press, IEEE Std 241-1990 is not yet published. It is, however, available in manuscript form from the IEEE Standards Department, (908) 562-3800. Anticipated publication date is July 1991, at which point IEEE Std 241-1990 will be available from the IEEE Service Center, 1-800-678-4333.
[5]NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037, (202) 457-8474.

open-fuse trip device: A device that operates to open (trip) all poles of a circuit breaker in response to the opening, or absence, of one or more fuses integral to the circuit breaker on which the device is mounted. After operating, the device shall prevent closing of the circuit breaker until a reset operation is performed.

NOTE — Since some open-fuse trip devices may operate by sensing the voltage across the fuses, they may not prevent closing of the circuit breaker with an open or missing fuse, but in most cases will cause an immediate trip if such an operation is performed. There is a practical limit of load impedance above which the device (sensing voltage across an open or missing fuse) will not function as described.

5. Ratings

5.1 General

The rating of a circuit breaker is a designated limit of operating characteristics based upon service conditions in Section 2 and shall include the following as applicable:

1) Rated maximum voltage(s)
2) Rated frequency
3) Rated continuous current
4) Rated short-time current
5) Rated short-circuit current at each rated maximum voltage
6) Rated control voltage(s)

The designated ratings in ANSI C37.16-1988 [1] are preferred, but are not considered to be restrictive.

5.2 Rated Maximum Voltage

The rated maximum voltage of a circuit breaker is the highest rms voltage, three-phase or single-phase, at which it is designed to perform. The circuit breaker shall be rated at one or more of the following maximum voltages: 635 V, 508 V, or 254 V. For fused circuit breakers, the 635 V rated maximum voltage becomes 600 V to match the fuse rating.

5.3 Rated Frequency

The rated frequency of a circuit breaker is the frequency at which it is designed to perform. The standard frequency is 60 Hz. Application at other frequencies should receive special consideration.

5.4 Rated Continuous Current

The rated continuous current of a circuit breaker is the designated limit of rms current at rated frequency that it shall be required to carry continuously without exceeding the temperature limitations designated in Section 7. The preferred continuous current ratings of the various frame sizes are listed in ANSI C37.16-1988 [1]. The rated continuous current of a circuit breaker equipped with direct-acting trip devices or fuses of a lower rating than the frame size of the circuit breaker is determined by the rating of those devices.

5.5 Rated Short-Time Current

For an unfused circuit breaker, the rated short-time current is the designated limit of available (prospective) current at which it shall be required to perform its short-time current duty cycle (two periods of 1/2 s current flow, separated by a 15 s interval of zero current) at rated maximum voltage under the prescribed test conditions. This current is expressed as the rms symmetrical value of current measured from the available current wave envelope at a time 1/2 cycle after short-circuit initiation.

Unfused circuit breakers shall be capable of performing the short-time current duty cycle with all degrees of current asymmetry produced by three-phase or single-phase circuits having a short-circuit power factor of 15% or greater (*X/R* ratio of 6.6 or less). Preferred short-time current ratings are listed in Table 2 of ANSIC37.16-1988 [1] .

Fused circuit breakers do not have a rated short-time current; only the circuit breaker element of the fused circuit breaker assembly shall have such a rating, and it shall be the same as described above.

5.6 Rated Short-Circuit Current

5.6.1 Unfused Circuit Breakers

The rated short-circuit current of an unfused circuit breaker is the designated limit of available (prospective) current at which it shall be required to perform its short-circuit current duty cycle (0 – 15 s – CO) at rated maximum voltage under the prescribed test conditions. This current is expressed as the rms symmetrical value of current measured from the available current wave envelope at a time 1/2 cycle after short-circuit initiation.

Unfused circuit breakers shall be capable of performing the short-circuit current duty cycle with all degrees of current asymmetry produced by three-phase or single-phase circuits having a short-circuit power factor of 15% or greater (*X/R* ratio of 6.6 or less).

Unfused circuit breakers with direct-acting instantaneous phase trip elements shall have short-circuit current ratings at each rated maximum voltage. When provided with instantaneous trip settings, the preferred ratings are those listed in Table 1 of ANSI C37.16-1988 [1]. When not equipped with direct-acting instantaneous phase trip elements, the preferred short-circuit current ratings are those listed in Table 2 of ANSI C37.16-1988.

When unfused circuit breakers are equipped with direct-acting short-time-delay phase trip elements in addition to direct-acting instantaneous phase trip elements, they may have the preferred short-circuit current ratings listed in Table 1 of ANSI C37.16-1988 provided that the maximum instantaneous trip setting does not exceed the preferred short-circuit current ratings listed in Table 2 of ANSI C37.16-1988.

5.6.2 Fused Circuit Breakers

The rated short-circuit current of a fused circuit breaker is the designated limit of available (prospective) current at which it shall be required to perform its short-circuit current duty cycle at rated maximum voltage under the prescribed test conditions. The short-circuit current duty cycle consists of an O followed by a CO operation. The time between the O and CO operations is the time necessary to replace fuses and to reset the open-fuse trip device. This current is expressed as the rms symmetrical value of current measured from the available current wave envelope at a time 1/2 cycle after short-circuit initiation.

Fused circuit breakers shall be capable of performing the short-circuit current duty cycle with all degrees of current asymmetry produced by three-phase or single-phase circuits having a short-circuit power factor of 20% or greater (*X*/*R* ratio of 4.9 or less).

The circuit-breaker element of a fused circuit breaker shall have a short-circuit current rating, the preferred values of which are listed in Tables 1 and 2 of ANSIC37.16-1988 [1] for the particular frame size for a system nominal voltage of 600 V. The fuses are required to operate for short-circuit currents at or below the short-circuit current ratings in Tables 1 or 2 up to those of Table 17 in ANSI C37.16-1988.

5.7 Rated Control Voltage

The rated control voltage is the voltage at which the mechanism of the circuit breaker is designed to operate when measured at the control power terminals of the operating mechanism with the highest operating current flowing. Rated control voltages and their ranges for low-voltage power circuit breakers are listed in Table 23 of ANSI C37.16-1988 [1].

Table 1— Functional Components

	Functional Component	Operating Mechanism Type	
		Manual	**Power**
(1)	Direct-acting trip device(s). Calibration in accordance with ANSIC37.17-1979 [2]	X*	X*
(2)	Manual trip device	X	X
(3)	Contact position indicator in accordance with 6.2	X	X
(4)	Independent, manually operated mechanism, trip free, with attached operating handle	X	—
(5)	Power-operated mechanism, trip free, with anti-pump feature and maintenance closing device	—	X
(6)	Shunt trip device with necessary control auxiliary switches	—	X
(7)	Stored energy indicator in accordance with 6.3	X†	X†
(8)	Nameplate(s), with markings in accordance with 6.1	X	X
(9)	Fuses, one per pole, complying with ANSI C37.16-1988 [1], Table 17, and footnotes	X‡	X‡
(10)	Open-fuse trip device	X‡	X‡
(11)	Locking in accordance with 6.4	X*	X*

* As required by the application.
† Required only on closing mechanisms that provide for stored energy operation when the mechanism can be left in the charged position.
‡ Required on fused circuit breakers only.

6. Functional Components

The functional components required are listed in Table 1. Additional accessory devices may be available. The manufacturer should be consulted for specific information.

6.1 Nameplate(s)

The following minimum information shall be given on the nameplate(s) of all circuit breakers:

1) Manufacturer's name
2) Type of circuit breaker
3) Rated continuous current of trip devices (where applicable) and type designation
4) Frame size
5) Rated maximum voltage(s)
6) Rated short-circuit current at each rated maximum voltage
7) Rated short-time current (where applicable)
8) Suitable fuse type and sizes (where applicable)
9) Rated frequency
10) Rated control voltage (where applicable)
11) Year of manufacture, by date or code
12) Identification number
13) Manufacturer's data sheets or instruction book reference

6.2 Contact Position Indicator

The following colors shall be used:

1) Red background with the word *closed* in white or aluminum (contrasting) letters to indicate closed contacts
2) Green background with the word *open* in white or aluminum (contrasting) letters to indicate open contacts

Table 2— Limits of Temperature Rise (*See 7.2*)

	Limit of Temperature Rise Over Air Surrounding Enclosure (°C)	Limit of Total Temperature (°C)
Class 90 insulation	50	90
Class 105 insulation	65	105
Class 130 insulation	90	130
Class 155 insulation	115	155
Class 180 insulation	140	180
Class 220 insulation	180	220
Circuit-breaker contacts, conducting joints, and other parts, except the following:	85	125
Fuse terminals	*	*
Series coils with over Class 220 insulation or bare	*	*
Terminal connections †	55	95

* No specified limit except to avoid damaging adjacent parts.
† Terminal connection temperatures are based on connections to bus in low-voltage metal-enclosed switchgear. If connections are made to cables, recognition must be given to possible thermal limitations of the cable insulation and appropriate measures taken.

6.3 Stored Energy Indicator

The following colors shall be used:

1) Yellow background with black lettering to indicate that the closing mechanism is charged
2) White background with black lettering to indicate that the closing mechanism is discharged

6.4 Locking

Provisions shall be made for locking the circuit breaker in the open (trip-free) position.

7. Temperature Limitations and Classification of Insulating Materials

7.1 Temperature Limits

The temperature limits on which the rating of circuit breakers is based are determined by the characteristics of the insulating materials used and the metals that are used in current-carrying parts and springs.

7.2 Limits of Temperature Rise

The temperature rise of the various parts of the circuit breaker above the temperature of the air surrounding the circuit breaker test enclosure, when subjected to temperature tests in accordance with this standard, shall not exceed the values given in Table 2. This table applies only to a circuit breaker having all contacts silver-surfaced, silver alloy, or equivalent, and in addition, having all conducting joints, moving or fixed, including terminal connection, either (1) silver-surfaced and held mechanically; or (2) brazed, welded, or silver-soldered; or (3) fixed rigid mechanical joints surfaced with suitable material other than silver.

7.3 Classification of Insulating Materials

The temperature limits on which circuit-breaker ratings are based depend on the character of the insulating materials used.

For the purpose of establishing temperature limits, insulating materials are classified in IEEE Std 1-1986 [6].

8. Insulation (Dielectric) Withstand Voltage Requirements

8.1 Circuit Breakers

Circuit breakers, when tested in accordance with Section 9, shall be capable of withstanding without damage the following power frequency test voltages (dry test) for a period of 60 s. The test voltages shall be essentially sinusoidal with a crest value equal to 1.414 times the specified values. The frequency of the test voltage shall be within ± 20% of rated frequency of the circuit breaker being tested.

1) Primary circuit of a new, completely assembled circuit breaker, 2200 V.
2) Secondary control wiring (except items 3, 4, and 5), 1500 V.
3) Motors shall be tested at their specified dielectric withstand voltage but not less than 1000 V.
4) Control devices and circuitry operating at 80 Vac rms (110 Vdc) or less and not connected directly to primary or external secondary control circuits, 500 V.
5) For undervoltage trip devices operating at a voltage above 250 Vac, twice rated voltage plus 1000 V.
6) After interruption of a short-circuit current duty cycle and before servicing, the withstand test voltage shall be 60% of the values in (1)–(5) above.
7) After storage or installation in the field, a circuit breaker that has not been subjected to a short-circuit current interruption or has been serviced after interruption shall withstand 75% of the values listed in (1)–(5) above.

8.2 Dielectric Test Procedures

The dielectric test procedures and the method of voltage measurement shall be in accordance with IEEE Std 4-1978 [7].

9. Test Procedures

See ANSI C37.50-1989 [3].

10. Application Guide

This guide covers the application of circuit breakers on low-voltage ac systems and applies to circuit breakers rated in accordance with Section 5.

10.1 General

Circuit breakers should be applied within their assigned voltage(s), frequency, continuous current, short-time current, and short-circuit ratings as defined in this standard with proper consideration given to the service conditions stated in Section 2.. They should be selected to provide the protection required by the other components of the circuit. For other applications not covered by this standard, the manufacturer should be consulted.

10.1.1 Voltage

The voltage of the system to which circuit breakers are applied, including any possible variations, should not exceed the rated maximum voltages listed in 5.2. For application voltages between those listed, a circuit breaker should be selected on the basis of the next higher rated maximum voltage. See Tables 1 and 2 of ANSI C37.16-1988 [1].

10.1.2 Frequency

The normal applicable frequency for circuit breakers is 60 Hz (see 5.3). Application at 50 Hz may require recalibration of solid-state trip devices and consideration must be given to the operation of all electromechanical devices. Application at nominal frequencies other than 50 Hz or 60 Hz may require that consideration be given to the performance of the circuit breaker element itself.

10.1.3 Continuous Current

The circuit breaker should be applied to a circuit having a maximum continuous-load current no greater than the continuous current rating of the circuit breaker. Direct-acting trip devices should be selected so as to provide the trip settings required, and should have a continuous current rating equal to, or greater than, the maximum current rating of the circuit to which they are to be applied.

Pickup settings of the electromechanical long-time-delay elements are provided above the continuous current ratings of these trip devices for the purpose of maintaining circuit continuity during momentary overload. However, the trip device and the circuit-breaker frame combination cannot be expected to carry continuously more current than the assigned continuous current.

Pickup settings of the solid-state long-time-delay elements may be provided above the continuous current ratings of these trip devices for application purposes. Although this type of trip device may be able to carry current continuously at such settings, the circuit-breaker frame size continuous current must never be exceeded.

10.1.3.1 Forced-Air Cooling

It is recognized that a circuit breaker may continuously carry current in excess of its continuous current rating if the circuit breaker is forced-air cooled by means such as a blower or a fan. The manufacturer of the assembly in which the circuit breaker and forced-air cooling means are to be installed should be contacted to obtain information about the increased capability. Suitable protection schemes should be utilized to assure that excessive temperatures do not result from necessary air filters becoming clogged or from failure of the forced-air cooling means to provide sufficient cooling. Settings of direct-acting trip devices should also be reevaluated in this circumstance.

10.1.3.2 Lower Than 40 °C Ambient Temperature

If the ambient temperature outside the circuit-breaker enclosure is maintained at less than 40 °C, the circuit breaker may be capable of carrying current in excess of its continuous current rating. However, since the long-time performance and useful life of the circuit breaker may be affected by such an increase in continuous current, the circuit-breaker manufacturer should be consulted concerning any increased capability. Settings of direct-acting trip devices should be reevaluated in this circumstance.

10.1.4 Short-Circuit Current

Circuit breakers may be applied on a system when the calculated maximum available short-circuit current on the source side of the circuit breaker, modified by the power factor considerations in 10.1.4.3, is not more than the short-circuit current rating of the circuit breaker.

For three-phase ac circuits, the available current calculated is the maximum rms symmetrical value of the three phases at an instant 1/2 cycle after the short circuit occurs. This value is the total available current from all sources, including synchronous and induction motors.

For single-phase ac circuits, the current should be calculated using the same considerations as used for three-phase circuits. When a circuit breaker is applied in such a way on a single-phase circuit that the system voltage impressed across a single pole is no greater than 58% of any one of the rated maximum voltages, the maximum available short-circuit current may be equal to 100% of the corresponding three-phase short-circuit current rating.

When a circuit breaker is applied in such a manner on a three-phase system that the voltage impressed across a single pole exceeds 58% of the rated maximum voltage, the maximum available short-circuit current shall be limited to 87% of the corresponding three-phase short-circuit rating as listed in Tables 1 and 2 of ANSI C37.16-1988 [1].

In determining the suitability of a circuit breaker for the short-circuit current conditions of a system, consideration should be given to the following:

1) Source contribution
2) Motor contribution
3) Effects of power factor
4) Types of operating mechanism
5) Duty cycle
6) Direct-acting trip devices
7) Effect of remote protective devices

Recommended guidance in calculating short-circuit currents is given in IEEE Std 141-1986 [8], IEEE Std 241-1990 [9], and IEEE Std 242-1986 [10].

10.1.4.1 Source Contribution

The symmetrical short-circuit current, consisting of the sum of all sources, should be calculated by taking into account all impedances up to the source side of the circuit breaker but not including any of the circuit-breaker impedance. Small impedances, such as cable impedances, should be taken into account, since they may greatly affect the result.

10.1.4.2 Motor Contribution

The part of the symmetrical short-circuit current due to motor contributions should be calculated as follows: Induction and synchronous motors, connected to the bus, act as generators, and at 1/2 cycle after the short circuit occurs, contribute current that may be calculated from the subtransient reactance of the motor plus the impedance of the interconnecting cable. Where the impedances for the installation are not known, it should be assumed that the induction motors contribute 3.6 times their full-load current and that synchronous motors contribute 4.8 times their full-load current.

When the motor load of the installation is not known, the following assumptions should be made:

1) For nominal system voltages of 120 V and 208Y/120 V, it should be assumed that the connected load is 50% lighting and 50% motor load. This corresponds to an equivalent symmetrical contribution of approximately twice the full-load current.
2) For nominal system voltages of 240 V to 600 V, it should be assumed that the load is 100% motor load and, in the absence of exact information, that 25% of the motors are synchronous and 75% induction. This corresponds to an equivalent symmetrical contribution of approximately four times the full-load current.

10.1.4.3 Power Factor Considerations

Normally the short-circuit power factor (*X/R*) of a system need not be considered in applying circuit breakers. This is based on the fact that the power factors on which the ratings of the circuit breakers in this standard have been established amply cover most applications. For unfused circuit breakers this power factor is 15% (*X/R* ratio of 6.6). For fused circuit breakers the power factor is 20% (*X/R* ratio of 4.9), which is consistent with the standards established for fuses. The high short-circuit current rating of fused circuit breakers makes the need to consider power factor even more unlikely. There are, however, some specific applications when the available short-circuit current approaches 80% of the circuit breaker short-circuit current rating, which may require additional consideration because of lower short-circuit power factors. These considerations are as follows:

- Local generation at circuit-breaker voltage in unit sizes greater than 500 kVA
- Gas-filled and dry-type transformers in sizes 1000 kVA and above; all types 2500 kVA and above
- Network systems
- Transformers with impedances higher than those specified in the ANSI C57 series of standards
- Current-limiting reactors at circuit-breaker voltage in source circuits
- Current-limiting busway at circuit-breaker voltage in source circuits

To determine the short-circuit current rating of the circuit breaker required for these applications, two approaches are possible:

1) If the short-circuit X/R ratio of the power system is known, the appropriate multiplying factor can be selected from Table 3 and multiplied by the calculated value of rms symmetrical current.
2) If the short-circuit X/R ratio of the power system has not been determined, a ratio of 20 should be assumed and the calculated value of rms symmetrical current should be multiplied by the appropriate multiplying factor selected from Table 3.
3) The multiplying factors for unfused circuit breakers are based on the highest peak current calculated in accordance with Eq 1:

$$MF = \frac{\sqrt{2}[1 + e^{-\pi/(X/R)}]}{2.29} \tag{1}$$

4) The multiplying factors for fused circuit breakers are based on total rms current (asymmetrical) calculated in accordance with Eq 2:

$$MF = \frac{\sqrt{1 + 2e^{-2\pi/(X/R)}}}{1.25} \tag{2}$$

Table 3— Selection of Multiplying Factor

System Short-Circuit Power Factor %	System *X/R* Ratio	Multiplying Factor for Calculated Short-Circuit Current	
		*	†
20	4.9	1.00	1.00
15	6.6	1.00	1.07
12	8.27	1.04	1.12
10	9.95	1.07	1.15
8.5	11.72	1.09	1.18
7	14.25	1.11	1.21
5	20.0	1.14	1.26

* Factors for unfused circuit breakers
† Factors for fused circuit breakers

10.1.4.4 Short-Circuit Duty Cycle Application

The applicable short-circuit current duty cycle for circuit breakers consists of an opening operation followed by a close-open operation. For unfused circuit breakers, the time between the open and the close-open operations is 15 s (0-15 s-CO). For fused circuit breakers, the time between these operations is the time necessary to replace the fuses and to reset the open-fuse trip device.

As soon as possible after performance at or near its rated short-circuit current, a circuit breaker should be removed from service and inspected, cleaned and, if necessary, otherwise maintained before being returned to service. Where insulation resistance levels have been lowered to 60% by surface deposits of interruption products, removal by cleaning will permit the 75% field dielectric test values of 8.1 (7) to be met.

10.1.4.5 Direct-Acting Trip Devices

See ANSI C37.17-1979 [2].

10.1.4.5.1

Circuit breakers with instantaneous phase trip elements should be applied in accordance with the short-circuit current ratings. The settings of the instantaneous phase trip elements should not exceed 12 times the continuous current rating. Preferred values are listed in Table 1 of ANSI C37.16-1988 [1].

10.1.4.5.2

Circuit breakers with long-time-delay and short-time-delay phase trip elements, but without instantaneous phase trip elements, should be applied in accordance with the short-circuit current ratings. Preferred values are listed in Table 2 of ANSI C37.16-1988 [1].

10.1.4.5.3

Circuit breakers with phase trip elements may use instantaneous or short-time-delay ground trip elements in coordination with the normal phase trip element combination as required.

10.1.4.5.4

Circuit breakers without phase trip elements may use instantaneous or short-time-delay ground trip elements, in coordination with the remote protective devices as required.

10.1.4.5.5

Circuit breakers are generally not applied with long-time-delay phase trip or ground trip elements only. Such applications are considered unusual, and the manufacturer should be consulted.

10.1.4.6 Effect of Remote Protective Devices

Circuit breakers not equipped with direct phase trip elements should be applied in accordance with the assigned short-circuit current ratings. The preferred values are listed in Table 2 of ANSI C37.16-1988 [1]. They should not be subjected to a time delay in tripping of more than 1/2 s duration at their assigned ratings. Protection afforded under these conditions should be equivalent to that provided for the circuit breaker by a direct-acting phase trip device.

10.1.4.7 Protection of Connected Equipment When Fused Circuit Breakers Are Applied

When applied on high short-circuit current capacity systems, the effects of the let-through characteristics of the fused circuit breakers on the connected equipment must be considered. The presence of the current-limiting fuse as part of the fused circuit breaker does not necessarily imply that the connected equipment can adequately withstand these effects.

It should be noted that the fused circuit breaker does not have any current-limiting effect until the current associated with the fault exceeds the threshold current of the fuse. When fuses of relatively low continuous current rating and relatively low peak let-through current rating are selected to give protection to downstream equipment, there is increased likelihood that they will open at currents much below the circuit-breaker element short-circuit current rating. If the full coordination study for the protection of connected equipment is made known to the manufacturer, then the best combination of direct-acting trip devices and fuses may be selected. Nonoptimum combinations can lead to needless fuse opening. In no case should combinations of trip devices and fuses that are not approved by the manufacturer be installed.

Where fuses of different manufacture are being considered for the same system, the characteristics of all the fuses and circuit breakers in the system should be evaluated, since both the melting time current characteristic and peak let-through current of a given fuse rating may vary substantially between manufacturers.

10.2 Short-Time Current

10.2.1 Unfused Circuit Breakers

1) Unfused circuit breakers without direct-acting phase trip devices should not be applied to a circuit having a maximum symmetrical current available at the point of application that is greater than the short-time current rating of the circuit breaker. The preferred ratings are listed in Table 2 of ANSI C37.16-1988 [1].
2) *Short-Time Current Duty Cycle Application*. The applicable short-time current duty cycle for unfused circuit breakers consists of two periods of 1/2 s current flow, separated by a 15 s interval of zero current.

10.2.2 Fused Circuit Breakers

Fused circuit breakers do not have a rated short-time current, and the short-time duty cycle of unfused circuit breakers does not apply. However, because the circuit breaker element has a rated short-time current, the preferred values of which are given in Table 2 of ANSI C37.16-1988 [1], fused circuit breakers may be applied with remote relays instead of with direct-acting phase trip elements. The tripping delay for currents that do not cause fuse operation is to be no longer than it could be when using long-and short-time-delay direct-acting phase trip elements. The maximum fuse element rating for this delayed tripping condition may be less than that allowable with instantaneous trip elements, or the same maximum fuse element rating may result in a lesser short-circuit current rating. The manufacturer should be consulted regarding the maximum fuse element rating. For currents that cause fuse operation, tripping will occur by means of the open-fuse trip device.

10.3 Application of Circuit Breakers for Selective Tripping

Where continuity of service is desired, selective tripping arrangements should be used. A selective tripping arrangement is the application of circuit breakers in series so that, of the circuit breakers carrying overcurrent, only the one electrically nearest the cause of the overcurrent should open to isolate this circuit condition.

10.3.1

When circuit breakers are applied to low-voltage circuits in phase-selective tripping arrangements, the following requirements should be observed:

10.3.1.1

Each circuit breaker should have an assigned short-circuit current rating equal to, or greater than, the available short-circuit current at the point of its application.

10.3.1.2

The time-current characteristics of each circuit breaker, at all values of available phase overcurrent, should be sufficient to ensure that the circuit breaker nearest the cause of the overcurrent should open to isolate this circuit condition. Those nearest the source of power should remain closed and continue to carry the remaining load current.

It should be noted that continuity of service requires coordination of the low-voltage circuit breakers with the rest of the system. For example, circuit breakers on the load side of a transformer bank should properly coordinate with relays or fuses on the high-voltage side.

10.3.1.3

Each circuit breaker, except the one farthest from the source of power, should be equipped with short-time-delay phase trip elements. The circuit breaker farthest from the source of power should normally be equipped with instantaneous phase trip elements.

10.3.2

When circuit breakers are applied to low-voltage circuits in ground-selective tripping arrangements, the following should be observed:

10.3.2.1

For 3-wire or 4-wire grounded single-source systems or 3-wire grounded multiple-source systems, the application and coordination methods closely parallel those used for phase coordination.

10.3.2.2

For 4-wire grounded multiple-source systems, ground coordination is complicated and varies with the method and location of grounding. Application information should be obtained from the manufacturer.

10.3.3

To permit the circuit breaker in any selective arrangement function to meet these requirements, the time-current characteristics of associated circuit breakers should not overlap. To accomplish this, the pickup settings and time-delay adjustments of all trip elements should be properly selected.

10.3.4

For fused circuit breakers, the following requirements should be observed to ensure selective overcurrent tripping.

10.3.4.1

Each fused circuit breaker should have a short-circuit current rating greater than the available fault current at the point of application. When applied without instantaneous phase trip elements, note the possible modification in 10.2.2.

10.3.4.2

The time-current characteristics of each fused circuit breaker and all values of available overcurrent should be such that the fused circuit breaker electrically nearest the fault will function to remove the overcurrent. The fused circuit breakers electrically nearer the source of power should remain closed and continue to carry the remaining load current.

10.3.4.3

To assure that each circuit breaker and fuse combination will function to meet these requirements, the time-current characteristics of associated fused circuit breakers should not overlap for values of current up to the maximum available fault current at the fused circuit-breaker element nearest the fault. The fuse time-current characteristics and direct-acting trip device pickup settings and time-delay bands of both the longtime- and short-time-delay elements, and the pickup settings of the instantaneous devices, should be properly selected. The manufacturer should be consulted for coordination information if the available fault current is enough to cause fuse operation at times less than 0.01 s.

10.4 Application of Circuit Breakers to Full-Voltage Motor-Starting and Running Duty of Three-Phase 60 Hz Motors

10.4.1

Table 6 of ANSI C37.16-1988 [1] applies to circuit breakers used for motor-starting duty equipped with direct-acting trip devices with long-time-delay and instantaneous phase trip elements. The long-time-delay phase trip element settings are covered by Note 1 of Table 6 of ANSI C37.16-1988. Table 18 of ANSI C37.16-1988 applies to fused circuit breakers whose direct-acting trip-device long-time-delay elements are calibrated at either approximately 80% to 160% or 80% to 125% of their continuous current rating. (See ANSI C37.17-1979 [2].)

The power ratings in horsepower apply to all motors having full-load current ratings between the minimum and maximum currents shown in Table 18 of ANSI C37.16-1988. The fused circuit-breaker continuous current rating should be at least 115% of the maximum full-load current of the motor. Hence an 80% trip setting is equal to not more than 125% of the minimum full-load motor current shown in Table 18 of ANSI C37.16-1988.

10.4.2

Instantaneous phase trip elements should be set between 10 and 12 times the full-load current rating of the motor, since it is usual to assume that the locked rotor current is six to eight times full-load rating and that the motor inrush current approaches twice the locked rotor current. This setting should generally prove satisfactory, since it includes allowances for transient asymmetry, possible motor overvoltages, and the pickup tolerance of the instantaneous phase trip element.

10.4.3

Short-time or instantaneous ground trip elements may be applied as required by the application and, if used, should have the greatest sensitivity and shortest time delay to provide the best motor protection.

10.5 Application of Circuit Breakers for Capacitance Switching

The continuous current rating of the circuit breaker should be at least 135% of the capacitor bank-rated current. (See NEMA CP1-1988 [11].)

Short-circuit current contributions and inrush currents during switching of isolated capacitor banks do not generally influence the selection of the circuit breakers, except that they should be considered for proper fuse selection for fused circuit breakers. When parallel capacitor banks are involved, circuit breaker as well as fuse selection may be influenced.

If desired, the following steps may be taken to reduce the effect of the inrush currents:

1) Space the parallel banks far enough apart, or insert reactors to obtain sufficient impedance between the banks, or
2) Reduce the size (kvar) of the banks, or
3) Select a circuit breaker of increased short-circuit current rating.

The circuit breaker should be equipped with a direct-acting trip device for short-circuit protection. Instantaneous phase trip elements should be set sufficiently high to prevent tripping on inrush currents.

Capacitance switching ratings are under consideration and the manufacturer should be consulted for specific applications.

10.6 Service Conditions Affecting Circuit-Breaker Applications

10.6.1 Altitude Correction

Circuit breakers, when applied at altitudes greater than 6600 ft (2000 m), should have their dielectric withstand, continuous current, and rated maximum voltage ratings multiplied by the correction factors shown in Table 4 to obtain values at which the application is made. The short-time and short-circuit current ratings are not affected by altitude. However, the short-circuit current should not exceed that of the voltage rating prior to derating in accordance with Tables 1 and 2 of ANSI C37.16-1988 [1].

Table 4— Altitude Correction Factors

Altitude (ft)	Altitude (m)	Rated Continuous Current	Rated Voltage
6600 and below	2000 and below	1.00	1.00
8500	2600	0.99	0.95
13,000	3900	0.96	0.80

NOTE — Values for intermediate altitudes may be derived by linear interpolation.

10.6.2 Other Service Conditions

Certain service conditions may require unusual construction or operation, and these should be brought to the attention of those responsible for the application, manufacture, and operation of the circuit breaker. Wherever possible, steps such as inclusion of heaters, placement in controlled atmosphere areas, or others, should be taken at the site of the installation to nullify the deleterious effect of the following:

1) Exposure to damaging fumes or vapors, excessive or abrasive dust, explosive mixture of dust or gases, steam, salt spray, excessive moisture, dripping water, radiation, and other similar conditions
2) Exposure to abnormal vibration, shocks, seismic occurrences, or tilting
3) Exposure to excessively high or low temperature
4) Exposure to unusual transportation or storage conditions
5) Exposure to extreme solar temperatures
6) Unusual operating duty, frequency of operation, and difficulty of maintenance
7) Load currents of nonsinusoidal wave forms
8) Temperature of circuit-breaker parts that falls below the dew point of the surrounding air, causing moisture condensation on the parts.

10.7 Repetitive Duty Operations and Normal Maintenance

Power-operated circuit breakers, when operating under service conditions listed in Section 2., can be expected to operate the number of times specified in Tables 5 and 19, as applicable, of ANSI C37.16-1988 [1].

These numbers of operation apply to all parts of a circuit breaker that function during normal operation. They do not apply to other parts, such as direct-acting trip devices, open fuse trip devices, or fuses that function only during infrequent abnormal circuit conditions.

10.7.1 Operating Conditions-Unfused Circuit Breakers

The following paragraphs referenced in the column headings of Table 5 of ANSI C37.16-1988 [1] are applicable to the number of operations listed.

1) Servicing consists of adjusting, cleaning, lubricating, tightening, etc., as recommended by the manufacturer. When current is interrupted, dressing of contacts may be required as well. The operations listed are on the basis of servicing at intervals of six months or less.
2) When closing and opening no-load.
3) With rated control voltage applied.
4) Frequency of operation not to exceed 20 operations in 10 min or 30 operations in 1 h. Rectifiers or other auxiliary devices may further limit the frequency of operation.
5) Servicing at no greater intervals than shown in Column 2 (Table 5, ANSI C37.16-1988).

6) No functional parts should have been replaced during the listed operations.
7) The unfused circuit breaker should be in a condition to carry its rated continuous current at rated maximum voltage and perform at least one opening operation at rated short-circuit current. After completion of this series of operations,functional part replacement and general servicing may be necessary.
8) When closing and opening current up to the continuous current rating of the circuit breaker at voltages up to the rated maximum voltage and at 85% power factor or higher.
9) When closing current up to 600% and opening currents up to 100% (80% power factor or higher) of the continuous current rating of the circuit breaker at voltages up to the rated maximum voltage.
   When closing currents up to 600% and opening currents up to 600% (50% power factor or less) of the continuous current rating of the circuit breaker at voltages up to rated maximum voltage, the number of operations shown shall be reduced to 10% of the number listed.
10) If a fault operation occurs before the completion of the listed operations, servicing is recommended and possible functional part replacements may be necessary, depending on previous accumulated duty, fault magnitude, and expected future operations.

10.7.2 Operating Conditions—Fused Circuit Breakers

The following paragraphs referenced in the column headings of Table 19 of ANSI C37.16-1988 [1] are applicable to the number of operations listed.

Paragraphs (1) through (6) are as specified in 10.7.1.

Paragraph (7). The fused circuit breaker should be in a condition to carry its rated continuous current at rated maximum voltage and perform at least one opening operation at any current not exceeding rated short-circuit current. The ability of the fuses to limit fault current should be unimpaired. After completion of this series of operations, functional part replacement and general servicing may be necessary.

Paragraphs (8) and (9) are as specified in 10.7.1.

Paragraph (10). If a fault operation occurs before the completion of the listed operations, servicing is recommended and possible functional part replacement may be necessary, depending on previous accumulated duty, fault magnitude, and expected future operations. Replacement of unblown fuses should be considered when continuity of service is critical because the time-current characteristic of the fuse could be affected.

10.8 Application of Circuit Breakers in Cascade

Application of circuit breakers above their short-circuit ratings in cascade is not recommended.

10.9 Application of Circuit Breakers Without Enclosures

Application of circuit breakers without enclosures is not recommended.

10.10 Application of Circuit Breakers With Dependent Manual Closing Mechanisms

Application of circuit breakers with dependent manual mechanisms is not recommended.