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(Revision of ANSI/IEEE C37.010-1972)

An American National Standard
IEEE Application Guide for
AC High-Voltage Circuit Breakers
Rated on a Symmetrical Current Basis

Sponsor
Switchgear Committee of the
IEEE Power Engineering Society

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Foreword

(This Foreword is not a part of ANSI/IEEE C37.010-1979, American National Standard Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.)

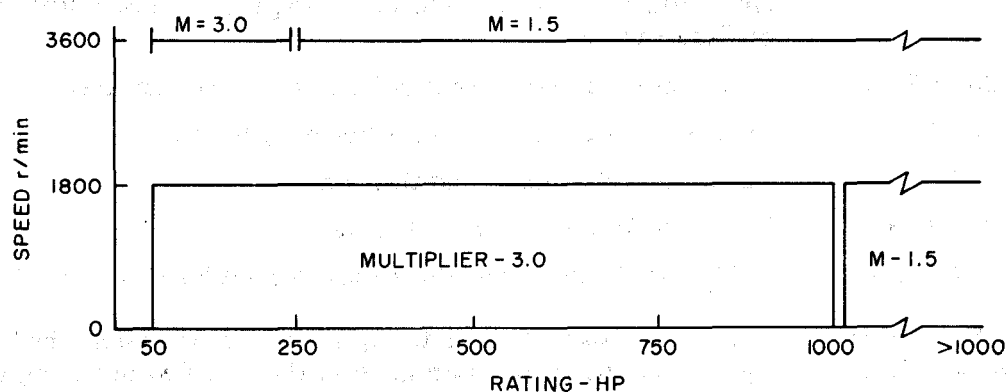
This standard is a guide to aid in the selection and application of AC high-voltage circuit breakers on electrical power systems. Described in the guide are the general application conditions, application considerations, and short-circuit considerations necessary to apply alternating current circuit breakers.

This standard is a revision of ANSI/IEEE C37.010-1972. This revision contains substantive revisions due to the efforts of a working group on revisions to C37.010-1972, and editorial changes as a result of general power circuit breaker consolidation efforts.

Three substantive revisions are included. The first involves deletion of a *Procedure Chart*, from Section 5.3, page 26, of the previous standard. This simplified procedure for calculating short-circuit current was useful in only a few cases, and was somewhat confusing for anyone attempting to use it.

The second substantive revision is an expansion of the statements in 5.3.2 involving the general terms "one transformation" and "two or more transformations" to recognize large external impedances such as long lines or station service transformers. Previously, "one transformation" in the form of a station service transformer dictate the use of factors from Figs 7 and 8. However, because this relatively large impedance limits the ac component decay, the wording on page 34 specifies the use of factors from Fig 9 for both three-phase and line-to-ground faults.

The third substantive revision involves the rotating machine reactance table of multipliers on page 40. The multipliers under the heading "Closing and Latching Duty" were previously specified in a section of Note 4 which is deleted. The substantive change involves the placing of all motors above 1000 hp with speeds 1800r/min and below into the 1.5 multiplier category. See chart below.



Based on the ac short-circuit time constants of these larger, slower-speed machines and the fact that circuit breakers are available with rated interrupting times of 5 cycles or less, the 1.5 multiplier will give conservative results, whereas the previously shown 3.0 multiplier would not.

The remainder of the changes are editorial. They involve updating the examples and clarification of the material in the guide. In addition, a number of changes were made as part of the general consolidation of power circuit breaker standards.

The development of standards for the rating, testing, and manufacture of high-voltage circuit breakers began almost simultaneously with the application of the first circuit breakers in early power supply systems.

A number of engineering and manufacturers trade organizations were interested in standards for high-voltage circuit breakers as well as other types of electrical equipment and worked to develop standard requirements for capabilities, sizes, and testing procedures. Among these groups were the AIEE¹, the National Electric Light Association (NELA), the Electric Power Club (a predecessor of NEMA — the National Electrical Manufacturers Association), the Association of Edison Illuminating Companies (AEIC), and the Edison Electric Institute (EEI).

During the years up to 1940, these organizations adopted and published a number of standardization proposals concerning rating, testing, and other requirements for high-voltage circuit breakers.

In 1941, a unified series of standards for circuit breakers, based on those of AIEE, AEIC, and NEMA, were published for trial use by the American Standards Association (ASA). This comprised the first American Standard for high-voltage circuit breakers. In 1945, this series was issued as an approved American Standard with the familiar C37 number identification. This series included sections on rating, preferred sizes, testing, and application of circuit breakers. In 1952 and 1953, this series of standards was revised and supplemented by additional sections, forming the complete, basic group of American Standards for high-voltage circuit breakers. At the time of publication this group of standards included:

ANSI C37.4-1953	AC Power Circuit Breakers (included definitions, rating basis, and some test requirements)
ANSI C37.5-1953	Methods for Determining the RMS Value of a Sinusoidal Current Wave and Normal-Frequency Recovery Voltage, and for Simplified Calculation of Fault Currents
ANSI C37.6-1953	Schedules of Preferred Ratings for Power Circuit Breakers
ANSI C37.7-1952	Interrupting Rating Factors for Reclosing Service
ANSI C37.8-1952	Rated Control Voltages and their Ranges
ANSI C37.9-1953	Test Code for Power Circuit Breakers
ANSI C37.12-1952	Guide Specifications for Alternating Current Power Circuit Breakers

Under these original standards, the basis of the interrupting rating was established by 6.11 of ANSI C37.4-1953 as the highest current to be interrupted at the specified operating voltage and was the "... rms value including the dc component at the instant of contact separation as determined from the envelope of the current wave." Since this standard based the interrupting rating on the total current including dc component at the instant of contact separation, it has become known as the "Total Current Basis of Rating."

For circuit breaker application, a simplified method was available in ANSI C37.5-1953, which listed multiplying factors for use with the system symmetrical fault current to derive a maximum possible total rms current which could be present at contact separation. This current was used to choose the required circuit breaker rating from those listed in ANSI C37.6-1953, or subsequent revisions. The factors recognized typical system characteristics and circuit breaker operating times.

¹AIEE (American Institute of Electrical Engineers) merged with IRE (Institute of Radio Engineers) January 1, 1963 to form the joint organization IEEE (Institute of Electrical and Electronics Engineers).

In 1951, the AIEE Switchgear Committee began to give consideration to the development of a circuit breaker rating method based on symmetrical interrupting currents. This work was initiated with the goal of:

- (1) Simplifying application where high-speed relaying and fast clearing circuit breakers are used
- (2) Bringing American standards into closer agreement with accepted international standards (IEC-International Electrotechnical Commission) to avoid confusion on rating differences
- (3) Requiring that circuit breakers are proven to demonstrate a definite relationship between asymmetrical interrupting capability and symmetrical ratings

During the course of this work, principally in a working group of the AIEE Power Circuit Breaker Subcommittee, numerous reports of the proposals on the new rating, testing, and application methods were made to the industry as a whole through committee sponsored papers at AIEE meetings in 1954, 1959, and 1960. Suggestions made in discussions were considered by the working group and incorporated where practicable. The principal change from the 1953 "Total Current" standard was in the basis of rating. 4.5.1 of ANSI C37.04 established the Rated Short Circuit Current as "the highest value of the symmetrical component of the... short-circuit current in rms amperes, measured from the envelope of the current wave at contact separation, which the circuit breaker is required to interrupt at rated maximum voltage...". Certain related capabilities were also required, including operation under specified conditions of asymmetry based on typical circuit characteristics and circuit breaker timing. This rating structure became known as the *Symmetrical Current Basis of Rating* as compared to the previous *Total Current Basis of Rating*. However, as the new ratings were developed, it became apparent that changes from the older to the newer standard could not occur overnight due to requirements for rerating and retesting of many PCBs. It was, therefore, decided to retain both rating structures, with the understanding that all new circuit breaker developments would be directed toward the *symmetrical* standards. The circuit breakers based on the *total current* standards would be transferred to the new standards as work progressed in rerating programs. This transfer is being carried out and ANSI C37.6 and ANSI C37.06 have been revised accordingly a number of times.

The *symmetrical current* group of standard sections was published in 1964 and was given ANSI C37.04, C37.05, C37.06, etc, designations. These sections and the corresponding 1953 sections were:

Total Current Standard	Symmetrical Current Standard	Subject
ANSI C37.4	ANSI C37.03 ANSI C37.04 ANSI C37.04a	Definitions Rating Structure
ANSI C37.5	ANSI C37.05	Measurement of Voltage and Current Waves
ANSI C37.6	ANSI C37.06 ANSI C37.06a	Preferred Ratings
ANSI C37.7	ANSI C37.07	Reclosing Factors
ANSI C37.8	(included in ANSI C37.06)	Control Voltages
ANSI C37.9	ANSI C37.09 ANSI C37.09a	Test Code
ANSI C37.5 (Section 3)	ANSI C37.010	Application Guide (expansion of material previously in C37.5)

Sections .04a, .06a, and .09a, also issued in 1964, were addenda concerned with supplemental dielectric capability requirements.

In ANSI C37.06-1964 and subsequent revisions prior to 1971, circuit breaker symmetrical current interrupting ratings were derived from ratings in ANSI C37.6-1961 by a relationship following a middle ground position between the total (asymmetrical) current of the former rating method and the full range of related requirements of the new rating method. For a given breaker this derivation was expressed by the formula:

$$\text{rated short circuit current} = I_{1961} \left(\frac{\text{nominal voltage}}{\text{rated maximum voltage}} \right) F$$

where

I_{1961} = interrupting rating in amperes appearing in ANSI C37.6-1961

F = 0.915 for 3 cycle breakers

0.955 for 5 cycle breakers

1.0 for 8 cycle breakers

Rated short circuit current was tabulated for rated maximum voltage rather than for nominal voltage as had been the case under the total current basis of rating.

It was stressed that this derivation was for the numerical conversion only and that a given circuit breaker, designed and tested under the total current basis of rating, could not be assumed to have these capabilities under the symmetrical current basis of rating without approval of the manufacturer.

In the revision of ANSI C37.06 published in 1971, several simplifications were introduced, including the use of a new method for selection of interrupting current ratings for outdoor circuit breakers 121 kV and above. Values for rated short circuit current were chosen from the R-10 preferred number series, and the use of a reference nominal 3-phase MVA identification was discontinued. Also the rated voltage range factor K was changed to unity, 1.0, to simplify rating and testing procedures.

In the intervening years since the official publication of the primary sections of the symmetrical basis of rating standard for high-voltage circuit breakers, a number of revisions, additions, and improvements have been developed and published. Many of these additions were in subject areas of major importance in the rating, testing, and application of circuit breakers and were published as complete standards containing appropriate definitions, rating performance criteria, rating numbers, test procedures, and application considerations. This was done to avoid delay in publication and the necessity of reprinting other existing standards as each of these was completed. The result has been the publication of a substantial number of individual supplementary standards. The basic subject areas considered in these supplementary standards, and their initial publication dates, are shown below:

ANSI C37.071-1969	Requirements for Line Closing Switching Surge Control
ANSI C37.072-1971	Requirements for Transient Recovery Voltage
ANSI C37.0721-1971	Application Guide for Transient Recovery Voltage
ANSI C37.0722-1971	Transient Recovery Voltage Ratings
ANSI C37.073-1972	Requirements for Capacitance Current Switching
ANSI C37.0731-1973	Application Guide for Capacitance Current Switching
ANSI C37.0732-1972	Preferred Ratings for Capacitance Current Switching
ANSI C37.074-1972	Requirements for Switching Impulse Voltage Insulation Strength
ANSI C37.076-1972	Requirements for Pressurized Components
ANSI C37.078-1972	Requirements for External Insulating

ANSI C37.0781-1972	Test Values for External Insulation
ANSI C37.079-1973	Method of Testing Circuit Breakers When Rated for Out-of-Phase Switching

A goal of work recently completed, and represented by the 1979 publication of these standards, has been the editorial incorporation of all the supplementary standards listed above into the proper primary standards documents. For circuit breakers rated on a symmetrical current basis, the consolidated standards sections are:

ANSI/IEEE C37.04-1979	Rating Structure
ANSI C37.06-1979	Preferred Ratings and Related Required Capabilities
ANSI/IEEE C37.09-1979	Test Procedure
ANSI/IEEE C37.010-1979	Application Guide — General
ANSI/IEEE C37.011-1979	Application Guide — Transient Recovery Voltage
ANSI/IEEE C37.012-1979	Application Guide — Capacitance Current Switching

The present ANSI C37.05, Measurement of Current and Voltage Waves, is incorporated into ANSI/IEEE C37.09; ANSI C37.07, Interrupting Capability Factors for Reclosing Service, is incorporated into ANSI/IEEE C37.04, ANSI C37.06, and ANSI/IEEE C37.09. Definitions which have been in C37.03-1964 are now in ANSI C37.100-1972.

Standards are presently being developed in a number of additional subject areas, which will be initially published as supplementary standards and incorporated into the primary subject document at some future date. Included among these subjects are requirements for current transformers, a guide for synthetic testing, sound level measurements, and seismic capability requirements.

For circuit breakers still rated on a total current basis, as listed in ANSI C37.6, the existing standards ANSI C37.4, ANSI C37.6, ANSI C37.7, and ANSI C37.9 will continue to be applicable.

Documents pertaining to guide specification and control schemes, which apply to both groups of ratings, are included in the ANSI C37 series as shown below:

ANSI C37.11-1972	Requirements for Electrical Control on AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis
ANSI C37.12-1969	Guide Specifications for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis and a Total Current Basis

Periodic review of all these standards takes place through the normal ANSI procedure that standards are reaffirmed, revised, or withdrawn within no more than five year intervals from the original publication date.

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the

American National Standards Institute
1430 Broadway
New York, NY 10018

The basic data included in this consolidated document is the result of contributions made by many individuals over many years. At the time of approval, however, the American National

Standards Committee on Power Switchgear, C37, which reviewed and approved this standard, had the following personnel:

C. L. Wagner, *Chairman*

J. P. Lucas, *Secretary*

J. E. Beehler, *Executive Vice-Chairman of High-Voltage Switchgear Standards*

W. E. Laubach, *Executive Vice-Chairman of Low-Voltage Switchgear Standards*

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Tennessee Valley Authority.	R. C. St. Clair
U.S. Department of the Army	R. H. Bruck
U.S. Department of the Interior, Bureau of Reclamation.	E. M. Tomsic
U.S. Department of the Navy, Naval Facilities Engineering Command	D. M. Hannemann

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D. O. Craghead
M. A. Durso
C. J. Dvorak
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D. R. Kanitz
W. E. Laubach
G. N. Lester
F. W. Smith
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When the IEEE Standards Board approved this standard on September 4, 1975, it had the following membership:

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4	4.0000	4.0000	4.0000	4.0000	4.0000
5	5.0000	5.0000	5.0000	5.0000	5.0000
6	6.0000	6.0000	6.0000	6.0000	6.0000
7	7.0000	7.0000	7.0000	7.0000	7.0000
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4	4.0000	4.0000	4.0000	4.0000	4.0000
5	5.0000	5.0000	5.0000	5.0000	5.0000
6	6.0000	6.0000	6.0000	6.0000	6.0000
7	7.0000	7.0000	7.0000	7.0000	7.0000
8	8.0000	8.0000	8.0000	8.0000	8.0000
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An American National Standard

IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

Supplement C37.010d-1984 is indicated by a revision bar in the margin.

1. Scope

This application guide applies to the ac high-voltage circuit breakers rated in accordance with the methods given in ANSI/IEEE C37.04-1979, Schedules of Rating Structure for AC High-Voltage Circuit Breakers, and listed in ANSI C37.06-1979, Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis. Circuit breakers rated and manufactured to meet other standards, or used in switchgear assemblies, should be applied in accordance with application procedures adapted to their specific ratings or applications.

1.1 Related Standards

When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, Incorporated, the revision shall apply.

ANSI/IEEE C37.04-1979, Rating Structure for AC High-Voltage Circuit Breakers.

ANSI C37.06-1979, Schedules of Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

ANSI/IEEE C37.09-1979, Test Procedure for AC High-Voltage Circuit Breakers.

ANSI/IEEE C37.5-1979, Guide for Calculation of Fault Currents for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis.

ANSI/IEEE C37.24-1971, Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Clad Switchgear.

ANSI/IEEE Std 21-1977, Requirements and Test Code for Outdoor Apparatus Bushings.

ANSI C37.100-1972, American National Standard Definitions for Power Switchgear.

2. Purpose

This guide is intended for general use in the application of circuit breakers. Familiarity with other American National Standards applying to circuit breakers is assumed, and provisions of those standards are indicated herein only when necessary for clarity in describing application requirements.

3. General Application Conditions

3.1 Usual Service Conditions. Service conditions for circuit breakers are defined in ANSI/IEEE C37.04-1979 (see 4.1). These conditions specify limits in altitude and in ambient temperature.

3.1.1 Provision for System Growth. Power system facilities must be increased from time to time to serve larger loads. This usually results in higher values of short-circuit current. Therefore, liberal allowance for expected future increase in short-circuit current is advisable.

3.1.2 System Design. Methods of limiting the magnitude of short-circuit currents or reducing the probability of high-current faults by system design are outside the scope of this guide. Such methods should be considered where short-circuit currents approach the maximum capability of the circuit breakers. Many station design features may depend on available circuit breaker ratings. System design should take into account the necessity for circuit breaker inspection and maintenance.

3.2 Unusual Service Conditions. Unusual service conditions are listed in 4.2 of ANSI/IEEE C37.04-1979 and include those conditions listed below. Special installation, operation, and

maintenance provisions should be considered where these conditions are encountered.

3.2.1 Applications at Altitudes Above 3300 ft (1000 m). Rating corrections for altitudes above 3300 ft (1000 m) are listed in Table 1 of ANSI/IEEE C37.04-1979.

EXAMPLE: Consider an outdoor oil circuit breaker having a rated maximum voltage of 38 kV, a continuous current rating of 1200 A, a rated short-circuit current of 22 000 A at 38 kV, a maximum symmetrical interrupting capability of 36 000 A, and a rated interrupting time of 5 cycles. Assume that this breaker is to be operated at an altitude of 7000 ft (2100 m). The operating voltage and the normal-frequency recovery voltage should be [interpolating between the values given for 5000 and 10 000 ft (1500 and 3000 m)]:

$$38 \text{ kV} \left[0.95 - (0.95 - 0.80) \left(\frac{7000 - 5000}{10000 - 5000} \right) \right] = 33.8 \text{ kV.}$$

Rated withstand voltages should be multiplied by the same factor. The continuous current must be similarly interpolated:

$$1200 \text{ A} \left[0.99 - (0.99 - 0.96) \left(\frac{7000 - 5000}{10000 - 5000} \right) \right] = 1174 \text{ A.}$$

The rated short-circuit current, related required capabilities, and the rated interrupting time are not affected by altitude.

3.2.2 Exposure to Damaging Fumes, Vapor, Steam, Oil Vapors, Salt Air, Hot and Humid Climate

(1) Provision may be necessary to avoid condensation on all electrical insulation and current-carrying parts

(2) Bushings with extra creep distance may be required

(3) In cases where particular exposure represents a hazard to insulation security, special maintenance including insulator washing may be necessary

(4) Materials resistant to fungus growth may be required.

3.2.3 Exposure to Excessive Dust or Abrasive, Magnetic, or Metallic Dust

(1) Totally enclosed nonventilated equipment or compartments may be necessary

(2) Where current-carrying equipment designed for ventilated operation is enclosed in a nonventilated compartment, derating may be necessary.

3.2.4 Exposure to Explosive Mixtures of Dust or Gases. Standard circuit breakers are

not designed for use in explosive atmospheres. For this type of service, special consideration should be given in conjunction with applicable regulatory bodies so that acceptable equipment is selected.

3.2.5 Exposure to Abnormal Vibration, Shock, or Tilting. Standard circuit breakers are designed for mounting on substantially level structures free from excessive vibration, shock, or tilting. Where any of these abnormal conditions exist, recommendations for the particular application should be obtained from the manufacturer.

3.2.6 Seasonal or Infrequent Use. Equipment stored or deenergized for long periods should be protected against accelerated deterioration. Before energizing for service, operating performance and insulation security should be checked.

4. Application Consideration

In the application of circuit breakers to electrical systems, careful attention must be given to many items of technical importance to assure that a misapplication does not occur. In the usual application, the principal function of the circuit breaker is to carry load current and provide a means for the interruption of short-circuit current. However, it may be used for frequent load, exciting current, or capacitive-current switching. In some cases, switching requirements may be the determining factor in selection rather than the requirements of short-circuit current interruption. Special attention must also be given to applications where frequent operations are essential.

In the selection of a circuit breaker, consideration must be given to the future as well as to the present needs for interrupting capacity and for current-carrying capability. These considerations include the possibility of connected circuit changes, such as additions of supplemental cooling means for transformers or connection of multiple cable or overhead lines to the breaker, or possible future transfer of the circuit breaker from its initial position to some other location.

In the United States, two types of circuit breakers are available for use at most voltage ratings. These types come under the general classification of oil and oilless power circuit

breakers, and the preferred ratings available are listed in ANSI C37.06-1979. The choice of breaker type may be influenced by such considerations as attended versus nonattended operation, contaminated atmosphere, location, maintenance, ease of handling the interrupting medium, and cost of the installation.

4.1 Maximum Voltage for Application. The operating voltage and the normal-frequency recovery voltage should not exceed the rated maximum voltage, since this is the upper limit for operation.

4.2 Voltage Range Factor. The voltage range factor, K , is published in ANSI C37.06-1979. In most cases, the voltage range is within the range commonly used. (See 4.10.)

4.3 Frequency. Rated frequency for circuit breakers is 60 Hz.

At slightly lower frequencies, such as 50 Hz, the main current-carrying parts will be adequate, but ac control devices may not be suitable for the application.

At 25 Hz, the continuous current ratings in amperes are higher and are listed in ANSI C37.06-1979.

Interruption of fault currents on systems operating at frequencies other than rated frequency may require modification of mechanisms to change speed of opening or may require a change in interrupting ratings of the circuit breakers.

In any case, special consideration should be given to applications at frequencies differing from 60 Hz.

4.4 Continuous Current. Circuit breakers are designed for normal application where the sustained load current does not exceed the rated continuous current, the altitude above sea level is 3300 ft (1000 m) or less, and the ambient temperature does not exceed 40°C. Rated continuous current of a circuit breaker should not be exceeded except for short periods such as in starting of motors or synchronous condensers or energizing cold loads or for conditions covered by 4.4.3.

4.4.1 Normal Operation. The conditions to be followed when making an application are:

(1) Breakers designed for installation in enclosures may be so used without any further derating

(2) Breakers designed for use in open rooms and outdoors cannot be used in enclosures

without derating so that none of their temperature limits is exceeded

(3) As far as temperature limits are concerned, any high-voltage circuit breaker may be used with cables having an 85°C or lower temperature limit, provided that the temperature limit of the cable insulation is not exceeded. Among the methods of accomplishing this are:

(a) Operate the breaker at a continuous current sufficiently below its rating

(b) Use a section of oversize conductors or a special terminal connector ahead of the cable to reduce the temperature at the cable terminal (See IEEE Std 55-1953, Guide for Temperature Correlation in the Connection of Insulated Wire and Cables to Electric Equipment.)

(4) The possible adverse effect on or by closely associated equipment operating at a higher or a lower temperature than the breaker should be examined

(5) It is recognized that when a circuit breaker is properly selected for continuous current operation, it may also be used for starting such equipment as motors, synchronous condensers, and cold loads on an infrequent basis; under this condition, the continuous current rating may be exceeded without causing damage to the circuit breaker.

4.4.2 Rated Continuous Current for Capacitor Banks. When a high-voltage circuit breaker is used in a circuit supplying static capacitors, the continuous current rating should be selected to include the effects of:

(1) Operation at voltages below and up to 10 percent above the capacitor rated voltage

(2) The positive tolerance in capacitance of static capacitors (-0+15 percent)

(3) The additional heating caused by harmonic currents

(4) The effect of grounded or nongrounded neutral connection of the capacitor.

In the absence of specific information, it will usually be conservative to use 1.25 times the nominal capacitor current at rated capacitor voltage for nongrounded neutral operation or 1.35 times the nominal current for grounded neutral operation.

4.4.3 Load Current Carrying Capability Under Various Conditions of Ambient Temperature and Load

4.4.3.1 General. Circuit breakers are designed for normal application in accordance