UL 489

Underwriters Laboratories Inc.

Standard for Safety

Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures

UL Standard for Safety for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489

Eleventh Edition, Dated September 1, 2009

SUMMARY OF TOPICS

This new Eleventh Edition of ANSI/UL 489 includes the following:

1. Revision to Ampacity Requirements to Align with NEC Section 110.14(C)(1)

2. Revision to Clarify that Steel is an Acceptable Metal for Use as a Current-Carrying Part

3. Reconciling Type B Test Conditions

4. Revision of the Ignition-Protected Devices Test Requirements to Refer to UL 1500, the Standard for Ignition-Protection Test for Marine Products

5. Revision to the Voltage Ratings of Circuit Breakers and Circuit Breaker Accessories

6. Revision to Requirements for Single-Pole 1200-A Circuit Breakers

7. Clarification of the 135-Percent Calibration Test

8. Revision to the Requirements for Naval-Use Circuit Breakers to Allow a 50 °C Marked Rating

9. Inclusion of Requirements for Lock-On Devices

10. Revision of Requirements for Non-Time Delay Circuit Breakers

11. Clarification of Flammability Test Requirements to No Longer Reference Outdated CSA Standard

12. Revision to Specify Minimum and Maximum Ampere Ratings for Classified Circuit Breakers

13. Clarification of Frame Size in Table 7.1.3.1

14. Corrections

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 12, 2008, April 24, 2009, and May 1, 2009.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the preface. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

Association of Standardization and Certification
NMX-J-266-ANCE-2010
Third Edition

Canadian Standards Association
CSA C22.2 No. 5-09
Second Edition

Underwriters Laboratories Inc.
UL 489
Eleventh Edition

Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

September 1, 2009

ANSI/UL 489-2009

Commitment for Amendments

These procedures are issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the procedures may be submitted to ANCE, CSA, or UL at any time. Revisions to these procedures will be made only after review and approval by ANCE, CSA, and UL. Revisions of these procedures will be made by issuing revised or additional pages bearing their date of issue.

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This ANSI/UL Standard for Safety consists of the Eleventh Edition

The most recent designation of ANSI/UL 489 as an American National Standard (ANSI) occurred on September 1, 2009. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

The Department of Defense (DoD) has adopted UL 489 on January 18, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

NEMA (National Electrical Manufacturers Association) has adopted UL 489 (US Requirements) on August 11, 1999 as NEMA Standard AB1. The publication of revised pages or a new edition of this Standard will not invalidate the NEMA adoption.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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CONTENTS

MOLDED CASE SWITCHES

ACCESSORIES

ENCLOSURES

CONSTRUCTION

PERFORMANCE

MARKINGS

SUPPLEMENT SB – MOLDED-CASE CIRCUIT BREAKERS AND CIRCUIT-BREAKER ENCLOSURES (NAVAL USE)

INTRODUCTION

PERFORMANCE

MARKINGS

SUPPLEMENT SC – MOLDED-CASE CIRCUIT BREAKERS AND CIRCUIT-BREAKER ENCLOSURES FOR USE WITH UNINTERRUPTIBLE POWER SUPPLIES

INTRODUCTION

PERFORMANCE

Preface

This is the harmonized ANCE, CSA, and UL standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures. It is the third edition of NMX-J-266-ANCE, the second edition of CSA C22.2 No. 5, and the eleventh edition of UL 489. This edition of NMX-J-266-ANCE cancels the previous edition published in 1999. This edition of CSA C22.2 No. 5 supersedes the previous edition published in 2002. This edition of UL 489 supersedes the previous edition published in 2002.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). The efforts and support of the CANENA Technical Harmonization Committee are gratefully acknowledged.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

The present Mexican Standard was developed by the CT CDI Control y Distribución Industrial from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the circuit breaker manufacturers and users.

This standard was reviewed by the CSA Subcommittee on Molded Case Circuit Breakers under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

> **Note:** *Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.*

Level of harmonization

This standard uses the IEC format but is not based on, nor is it considered equivalent to, an IEC standard. This standard is published as an equivalent standard for ANCE, CSA, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

This standard provides requirements for molded-case circuit breakers, molded-case switches, and circuit-breaker enclosures for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for these products for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

ANCE effective date

The effective date for ANCE will be announced through the Diario Oficial de la Federación (Official Gazette) and is indicated on the cover page.

CSA effective date

The effective date for CSA International will be announced through CSA Informs or a CSA certification notice.

UL effective date

UL 489 is effective immediately.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

INTRODUCTION

1 Scope

1.1 The requirements of this standard cover molded-case circuit breakers, circuit breaker and ground-fault circuit-interrupters, fused circuit breakers, and accessory high-fault protectors. These circuit breakers are specifically intended to provide service entrance, feeder, and branch circuit protection in accordance with the National Installation Codes in Annex B, Ref. No.1. This standard also covers instantaneous-trip circuit breakers (circuit interrupters) specifically intended for use as part of a combination motor controller in accordance with the National Installation Codes in Annex B, Ref. No. 1.

1.2 This standard covers molded-case switches and fused molded-case switches.

1.3 This standard covers devices rated at 600 volts or less and 6000 amperes or less.

1.4 The devices referenced in 1.1 and 1.2 are intended for installation in an overall enclosure or as parts of other devices such as panelboards. The acceptability of the combination will be determined when the complete product is investigated.

1.5 This standard covers circuit-breaker enclosures and accessory devices intended for use with the devices described in 1.1 and 1.2.

1.6 This standard does not cover low-voltage power circuit breakers covered in Annex B, Ref. No. 3 and Ref. No. 4 or supplementary protectors covered in Annex B, Ref. No. 5.

1.7 This standard contains supplements covering the requirements for molded-case circuit breakers for:

a) Marine Use;

b) Naval Use;

c) Uninterruptible Power Supply Use;

d) Classified Circuit Breakers; and

e) Software in Programmable Components.

2 Definitions

2.1 For the purposes of this standard, the following definitions apply.

2.2 ACCESSORIES – a device or devices that perform a secondary or minor duty as an adjunct or refinement to the primary or major duty of a molded case product.

2.3 ACCESSORY HIGH-FAULT PROTECTOR – a self-contained unit housing fuses or high-fault protectors constructed for use with specific molded case products and with provision for connecting directly to the load terminals of the molded case product.

2.4 ADJUSTABLE CIRCUIT BREAKER – a circuit breaker that has adjustable time/current tripping characteristics. These may include:

a) Inverse-time (such as continuous current, long time, and/or short time);

b) Instantaneous; and

c) Ground-fault.

2.5 ADJUSTABLE INSTANTANEOUS RELEASE (TRIP) – that part of an overcurrent trip element that can be adjusted to trip a circuit breaker instantaneously at various values of current within a predetermined range of currents.

2.6 ALARM SWITCH – a switch that operates to open or close a circuit upon the automatic opening of the molded case product with which it is associated.

2.7 AMBIENT-COMPENSATED CIRCUIT BREAKER – a circuit breaker in which means are provided for partially or completely neutralizing the effect of ambient temperature upon the tripping characteristics.

2.8 AMBIENT TEMPERATURE – the temperature of the surrounding medium that comes in contact with the circuit breaker or switch. For an enclosed device, it is the temperature of the medium outside the enclosure.

2.9 AUXILIARY SWITCH – a switch that is mechanically operated by the main device.

2.10 CALIBRATION – the factory adjustment of the release mechanism of a circuit breaker to make the circuit breaker perform in accordance with its prescribed characteristics.

2.11 CALIBRATION TEST – verifies the tripping characteristics of a circuit breaker.

2.12 CIRCUIT BREAKER – a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent, without damage to itself when properly applied within its rating.

2.13 CIRCUIT BREAKER AND GROUND-FAULT CIRCUIT-INTERRUPTER – a device that performs all normal circuit breaker functions and provides personnel protection against risk of electric shock as required by the National Installation Codes in Annex B, Ref. No. 1.

2.14 CIRCUIT BREAKER AND SECONDARY SURGE ARRESTER – a device that performs all normal circuit breaker functions and provides protection against power-distribution system surge related damage to connected circuits and load-connected equipment.

2.15 CIRCUIT BREAKER AND TRANSIENT VOLTAGE SURGE SUPPRESSOR – a device that performs all normal circuit breaker functions and that is intended to limit the maximum amplitude of transient voltage surges on power lines to specified values. It is not intended to function as a surge arrester.

2.16 CIRCUIT BREAKER WITH EQUIPMENT GROUND-FAULT PROTECTION – a device that performs all normal circuit breaker functions and provides leakage current protection intended to reduce the likelihood of fire. It is not intended to function as a ground-fault circuit-interrupter.

2.17 CIRCUIT BREAKER ENCLOSURE – an enclosure intended to house a single, multipole, or two single-pole molded-case products.

2.18 CIRCUIT BREAKERS WITH GROUND-FAULT PROTECTION FOR EQUIPMENT – circuit breakers that perform all normal circuit breaker functions and also trip when a fault current to ground exceeds a predetermined value.

2.19 CLASS I GROUND-FAULT SENSING AND RELAYING EQUIPMENT – equipment that does not incorporate means to prevent opening of the disconnecting means at high levels of fault current.

2.20 CLASS II GROUND-FAULT SENSING AND RELAYING EQUIPMENT – equipment that incorporates means to prevent initiation of opening of the disconnecting device if the fault current exceeds the contact-interrupting capability of the disconnecting device.

2.21 CLASS CTL CIRCUIT BREAKER – one that, because of its size or configuration, in conjunction with a Class CTL panelboard, prevents more circuit breaker poles from being installed than the number for which the assembly is intended and rated.

2.22 CLOSE-OPEN OPERATION – a close operation followed immediately by an open operation without purposely delayed action. The letters ″CO″ signify this operation.

2.23 COMMON TRIP CIRCUIT BREAKER – a multipole circuit breaker constructed so that all poles will open when any one or more poles open automatically.

2.24 CROSS-OVER CURRENT – the current of a fused circuit breaker at which the function of the fuse coincides with the operation of the trip mechanism of the circuit breaker, i.e., where the fuse clearing time curve crosses the circuit breaker trip characteristic curve.

2.25 CURRENT-LIMITING CIRCUIT BREAKER – one that does not employ a fusible element and, when operating within its current-limiting range, limits the let-through I^2t to a value less than the I^2t of a 1/2-cycle wave of the symmetrical prospective current.

2.26 CURRENT-LIMITING RANGE – the rms symmetrical prospective currents between the threshold current and the maximum interrupting rating current.

2.27 CURRENT SETTING (I_r) – the rms current an adjustable circuit breaker is set to carry continuously without tripping. It is normally expressed as a percentage of the rated current and is adjustable.

2.28 DIELECTRIC VOLTAGE-WITHSTAND TEST – determines the ability of the insulating materials and spacings used to withstand overvoltages without breakdown under specified conditions.

2.29 DRAWOUT-MOUNTED CIRCUIT BREAKER – an assembly of a circuit breaker together with a supporting structure constructed so that the circuit breaker is supported and can be moved to either the main circuit connected or disconnected position without the necessity of removing connections or mounting supports. The structure includes both self-supporting circuit terminals and an interlocking means that permits movement of the circuit breaker between the main circuit connected and disconnected positions only when the circuit breaker contacts are in the open position.

2.30 ELECTRICAL OPERATOR – an electrical controlling device which is used to operate the mechanism of a circuit breaker in order to open, close, and if applicable, reset the circuit breaker or switch.

2.31 ENDURANCE TEST – determines compliance with a specified number of mechanical and electrical operations.

2.32 EXTERNAL OPERATING MECHANISM – a mechanism that engages the handle of a circuit breaker and provides a manual means for operating the circuit breaker.

2.33 FIXED INSTANTANEOUS RELEASE (TRIP) – that part of an overcurrent release element which contains a nonadjustable means that is set to trip a circuit breaker instantaneously above a predetermined value of current.

2.34 FRAME – an assembly consisting of all parts of a circuit breaker except an interchangeable trip unit.

2.35 FRAME SIZE – a term applied to a group of circuit breakers of similar physical configuration. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group. The same frame size designation may be applied to more than one group of circuit breakers.

2.36 FUSED CIRCUIT BREAKER – a circuit breaker that contains replaceable fuses or high-fault protectors assembled as an integral unit in a supportive environment and enclosed housing of insulating material.

2.37 FUSED MOLDED-CASE SWITCH – a switch with integral replaceable fuses or high fault protectors assembled as an integral unit in a supportive and enclosed housing of insulating material.

2.38 GROUND-FAULT DELAY – an intentional time delay in the tripping function of a circuit breaker when a ground-fault occurs.

2.39 GROUND-FAULT PICKUP SETTING – the nominal value of the ground-fault current at which the ground-fault delay function is initiated.

2.40 HEATING, AIR CONDITIONING, AND REFRIGERATION (HACR) CIRCUIT BREAKER – one intended for use with multi-motor and combination loads such as are found in heating, air conditioning, and refrigeration equipment.

2.41 INDEPENDENT TRIP CIRCUIT BREAKER – a multipole circuit breaker constructed such that all poles are not intended to open when one or more poles open automatically.

2.42 INSTANTANEOUS OVERRIDE – a fixed current level at which an adjustable circuit breaker will override all settings and will trip instantaneously.

2.43 INSTANTANEOUS PICKUP SETTING – the nominal value of current that an adjustable circuit breaker is set to trip instantaneously.

2.44 INSTANTANEOUS TRIP – a qualifying term indicating that no delay is purposely introduced in the automatic tripping of the circuit breaker.

2.45 INSTANTANEOUS TRIP CIRCUIT BREAKER (MOTOR CIRCUIT PROTECTOR OR CIRCUIT INTERRUPTER) – is one intended to provide short circuit protection only. Although acting instantaneously under short circuit conditions, these circuit breakers may include a transient dampening action to ride through initial motor transients.

2.46 INTERCHANGEABLE TRIP UNIT – one which can be interchanged by a user among circuit breaker frames of the same design. See also Rating Plug.

2.47 INTERNAL MECHANISM – the means by which the main contacts of a circuit breaker are actuated.

2.48 INTERRUPTING RATING – the highest current at rated voltage that a device is intended to interrupt under standard test conditions.

2.49 INVERSE TIME – a qualifying term indicating that there is a purposely introduced delayed tripping in which the delay decreases as the magnitude of the current increases.

2.50 I^2t (AMPERES SQUARED SECONDS) – an expression related to the circuit energy as a result of current flow. With respect to circuit breakers, the I^2t is expressed for the current flow between the initiation of the fault current and the clearing of the circuit.

2.51 LOCK-OFF DEVICE – a device that permits the circuit breaker to be locked in the OFF position.

2.52 LOCK-ON DEVICE – a device that permits the circuit breaker to be locked in the ON position.

2.53 LONG-TIME DELAY – an intentional time delay in the overload tripping of an adjustable circuit breaker's inverse time characteristics. The position of the long time portion of the trip curve is normally referenced in seconds at 600 percent of the current setting (I_r).

2.54 LONG-TIME PICKUP – the current at which the long-time delay function is initiated.

2.55 MECHANICAL INTERLOCK – a device or system that mechanically connects two or more circuit breakers or switches so that only selected ones can be closed at the same time.

2.56 MOLDED-CASE CIRCUIT BREAKER – a circuit breaker which is assembled as an integral unit in a supportive and enclosed housing of insulating material.

2.57 MOLDED-CASE SWITCH – a device designed to open and close a circuit by nonautomatic means, assembled as an integral unit in a supportive and enclosed housing of insulating material.

2.58 MULTIPOLE CIRCUIT BREAKER – a circuit breaker with two or more poles which provide two or more separate conducting paths.

2.59 NEUTRAL (or SOLID NEUTRAL) – an assembly consisting of an appropriate number of terminals providing for the connection of the neutral conductors. When used as a component of service equipment, the neutral also includes:

a) A means for making the required bonding connection between the neutral and the enclosure and

b) A terminal for the grounding electrode conductor.

2.60 OPEN OPERATION – the movement of the contacts from the closed to the open position. The letter ″O″ signifies this operation.

2.61 OVERVOLTAGE-TRIP RELEASE DEVICE – a trip mechanism that causes a circuit breaker to open automatically if the voltage across the terminals of the trip coil rises above a predetermined value.

2.62 PEAK CURRENT – the maximum instantaneous current that flows in a circuit.

2.63 PILOT DUTY – the rating assigned to a relay or switch that controls the coil of another relay or switch.

2.64 POLE – that portion of a circuit breaker or switch associated exclusively with one electrically separated conducting path of its main circuit.

2.65 PROSPECTIVE CURRENT (AVAILABLE CURRENT) – the current that would flow in a circuit if a short circuit of negligible impedance were to occur at a given point.

2.66 RATED CONTROL VOLTAGE – the designated voltage that is to be applied to the closing or tripping devices to open or close a circuit breaker or switch.

2.67 RATED CURRENT (I_n) – the marked current rating and the maximum RMS current a circuit breaker can carry continuously without tripping and the maximum current the circuit breaker will carry without changing, deleting, or adding a part or parts such as trip units and rating plugs. See also current setting (I_r).

2.68 RATED FREQUENCY – the service frequency of the circuit for which the circuit breaker is designed and tested.

2.69 RATED VOLTAGE – the rated voltage is the nominal rms voltage for which the circuit breaker is designed to operate.

2.70 RATING – the designated limit or limits of the rated operating characteristic(s) of a device.

2.71 RATING PLUG – a self-contained portion of a circuit breaker that is interchangeable and replaceable in a circuit breaker trip unit by the user. It sets the Rated Current (I_n) of the circuit breaker.

2.72 RECOVERY VOLTAGE – the voltage that appears across the terminals of a pole of a circuit breaker upon interruption of the circuit.

2.73 REMOTELY OPERATED CIRCUIT BREAKER – a circuit breaker that contains an integral means to remotely open and close the circuit.

2.74 SERIES RATED (SERIES CONNECTED) – a group of overcurrent devices, connected in cascade, comprised of a circuit breaker or main fuse and one or more downstream circuit breakers that have been tested together to permit the branch or downstream circuit breakers to be applied on circuits where the available short circuit current exceeds the marked interrupting rating on the branch circuit breaker.

2.75 SHORT CIRCUIT CURRENT RATING – the maximum RMS prospective (available) current to which a device can be connected when protected by the specified overcurrent protective devices. The rating is expressed in amperes and volts.

2.76 SHORT-TIME DELAY – an intentional time delay in the tripping of a circuit breaker between the overload and the instantaneous pickup settings.

2.77 SHORT-TIME PICKUP – the current at which the short-time delay function is initiated.

2.78 SHUNT-TRIP RELEASE DATA – a release mechanism energized by a source of voltage which may be derived either from the main circuit or from an independent source.

2.79 SUPERVISORY CIRCUIT – a feature included in a circuit breaker and ground-fault circuit-interrupter that provides a manual method for testing the device by simulating a ground fault.

2.80 SWITCHING DUTY (SWD) CIRCUIT BREAKER – a circuit breaker intended to switch fluorescent lighting loads on a regular basis.

2.81 THRESHOLD CURRENT – the RMS symmetrical prospective current at the threshold of the current limiting range, where:

a) The peak current let-through in each phase is less than the peak of that symmetrical prospective current, and

b) The I^2t in each phase is less than the I^2t of a 1/2 cycle wave of the symmetrical prospective current.

2.82 TRIP-FREE CIRCUIT BREAKER – a circuit breaker designed so that the contacts cannot be held in the closed position by the operating means during trip command conditions.

2.83 TRIPPING – the opening of a circuit breaker by actuation of the release mechanism.

2.84 TRIP UNIT – a self-contained portion of a circuit breaker that is interchangeable and replaceable in a circuit breaker frame by the user. It actuates the circuit breaker release mechanism and it sets the Rated Current (I_n) of the circuit breaker unless a rating plug is used. See also Rating Plug.

2.85 UNDERVOLTAGE TRIP RELEASE – a release mechanism that causes a circuit breaker to open automatically if the control voltage falls below a predetermined value.

2.86 UNFUSED MOLDED-CASE SWITCH – See Molded-Case Switch.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this Standard shall comply with the requirements for that component. See Annex A for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the ANCE, or the Canadian Standards Association, or the Underwriters Laboratories Inc. Standards as appropriate for the country where the product is to be used. When a product is intended for use in more than one country, a component shall comply with the appropriate component standards for all the countries in which it is intended to be used.

3.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

4 Units of Measurement

4.1 The values given in SI (metric) units shall be normative, except for AWG/kcmil conductor sizes. Any other values are for information only.

5 Reference Publications

5.1 Where undated reference is made to ANCE, CSA or UL Standards, such reference shall be considered to refer to the latest edition and all amendments published to that edition up to the time when this standard was approved. See Annex B.

5.2 A product shall comply with the installation codes and standards as appropriate for the country where the product is used. When the product is intended for use in more than one country, the product shall comply with the installation codes and standards for all the countries in which it is intended to be used.

MOLDED CASE CIRCUIT BREAKERS

6 Construction

6.1 All types

6.1.1 General

6.1.1.1 A circuit breaker intended particularly for use in panelboards and the like shall be evaluated with respect to its intended application as well as under the requirements of this standard.

6.1.1.2 A circuit breaker shall be provided with means for mounting.

6.1.1.3 A circuit breaker shall have an integral housing for all the mechanism and live parts except the operating handle and the wiring terminals, and shall be manually operable without opening this housing.

6.1.1.4 There shall be no direct opening in the front of a circuit breaker, except that a circuit breaker need not comply if a cotton indicator, as described in 7.1.7.10, does not ignite during the interrupting test described in Interrupting test, 7.1.7.

6.1.1.5 If a circuit breaker requires a specific receiving device, the combination of the circuit breaker and receiving device shall comply with all of the applicable requirements in this standard.

6.1.1.6 A circuit breaker shall have the strength and rigidity necessary for its intended use and to meet the test requirements of this standard.

6.1.1.7 A circuit breaker may be manufactured as a circuit breaker frame and an interchangeable trip unit and each shall be plainly marked in accordance with 9.1.1.2 and 9.14.1.

6.1.1.8 A Class CTL circuit breaker shall have a size or configuration that, in conjunction with the physical means provided in a Class CTL panelboard, prevents the installation of more circuit breaker poles than that number for which the assembly is designed and rated. See 9.1.4.2.

6.1.2 Corrosion Protection

6.1.2.1 Iron and steel parts, except for thermal elements; magnet-pole faces; and hardened and polished parts such as latching surfaces and the like, where such protection is impractical, shall be protected against corrosion by enamelling, galvanizing, plating, or other equivalent means.

6.1.2.2 Phosphate treatment with an oil or wax coating is acceptable as corrosion protection for magnets and armatures; oil treatment is acceptable as corrosion protection for steel springs; and stainless steel is acceptable without additional protection if polished or treated when necessary.

6.1.2.3 Copper and brass are not acceptable for the plating of steel wire-binding screws, nuts, and stud terminals.

6.1.3 Cases – Insulating Material

6.1.3.1 A case for mounting uninsulated live parts shall be strong, not easily ignited, moisture-resistant, and insulating. The case shall be of such material that it will withstand the most severe conditions likely to be met in service.

6.1.3.2 Ordinary fiber, rubber, and hot-molded shellac and tar compositions are not acceptable for the mounting of uninsulated live parts.

6.1.3.3 Insulating material, including barriers, shall have properties acceptable for the particular application.

6.1.3.4 An insulating barrier, which is required for the proper performance or installation of a circuit breaker, shall be an integral part of, or reliably attached to, the circuit breaker, or a marking shall be provided in accordance with 9.1.1.11.

6.1.3.5 Removable lug and terminal covers shall be permitted if specific marking on the circuit breaker housing is provided to indicate the need for replacement. See 9.1.1.12.

6.1.4 Current-Carrying Parts

6.1.4.1 General

6.1.4.1.1 Current-carrying parts shall be of silver, a silver alloy, copper, a copper alloy, or other metal acceptable for the application. The acceptability of metals shall be judged on the basis of their ability to carry current while the products in which they are used satisfy the performance requirements of this standard. The acceptability of other metals to resist corrosion shall be in accordance with 6.1.2

6.1.4.1.2 Screws, nuts, or wire binding screws made of iron or steel shall be permitted to be used to secure live parts, but shall not be depended upon to carry current.

6.1.4.1.3 Uninsulated live parts, other than soldering lugs or pressure wire-connectors meeting the requirements of 6.1.6.1.4 shall be so secured to the case or mounting surface that they will be prevented from turning. Friction between surfaces is not acceptable as a means of preventing the turning of live parts.

6.1.4.1.4 If parts are held together by screws, a threaded part shall have no fewer than two full, clean-cut threads engaged. If a screw does not extend all the way through a threaded part, the taper or lead and the first full thread are to be disregarded in a determination of the number of threads engaged.

6.1.4.2 Terminals

6.1.4.2.1 Except as described in 6.1.4.2.4, each field wiring terminal of a circuit breaker shall have a wire connector that has a capacity acceptable for the number, wire size, and type associated with the circuit breaker. See Table 6.1.4.2.1 and Terminations, Section 21.4. A wiring terminal shall be acceptable for the temperatures encountered. See also 6.1.4.2.9, 6.1.4.2.16, and 9.1.2.14.

6.1.4.2.2 A wire connector provided with or specified for use with a circuit breaker shall comply with the appropriate requirements of UL, CSA, or Mexico specified in one of the following:

a) Annex B, Ref. No. 6; or

b) Annex B, Ref. No. 7. When these connectors are used, an interrupting test for the circuit breaker shall be performed if the interrupting rating of the circuit breaker is greater than 10 kA.

6.1.4.2.3 The tightening torque for a field wiring terminal shall be as specified by the circuit breaker manufacturer, and the circuit breaker shall be marked as required by 9.1.2.5. The specified tightening torque shall not be less than 90 percent and not more than 100 percent of the value used in the static heating test as specified in Annex B, Ref. No. 6 for the wire size corresponding to the ampere rating of the circuit breaker. See Mechanical tests, 7.1.10.1. Torque values shall be permitted to be less than 90 percent if the connector is investigated in accordance with the lesser assigned torque value in Annex B, Ref. No. 6.

6.1.4.2.4 Wire connectors or wire-binding terminals for the line or the load, or both, may be omitted if:

a) Provision is made for a bus-bar connection;

b) Provision is made for a plug-in connection;

c) Field-installable kits are available from the manufacturer and the conditions in 6.1.4.2.5 are met; or

d) The circuit breakers have a special form of construction, such as those providing a switching neutral pole or an isolated pole for water heater use, and the like; such devices shall be permitted to have means of connection considered acceptable for the intended purpose in place of a pressure terminal connector.

Table 6.1.4.2.1
Terminal current and conductor size

Terminal current in Amperes[a]	Copper conductor			Aluminum or copper-clad aluminum conductor		
	Number of conductors	Size AWG or kcmil		Number of conductors	Size AWG or kcmil	
		60°C	75°C		60°C	75°C
15 or less	1	14	14	1	12	12
20	1	12	12	1	10	10
25	1	10	10	1	10	10
30	1	10	10	1	8	8
40	1	8	8	1	6	8
50	1	6	8	1	4	6
60	1	4	6	1	3	4
70	1	4	4	1	2	3
80	1	3	4	1	1	2
90	1	2	3	1		2
100	1	1	3	1		1
110	1		2	1		1/0
125	1		1	1		2/0
150	1		1/0	1		3/0
175	1		2/0	1		4/0
200	1		3/0	1		250
225	1		4/0	1		300
250	1		250	1		350
275	1		300	1		500
300	1		350	1		500
325	1		400	2		4/0
350	1		500	2		4/0
400	2		3/0	2		250
	1		500	1		750
450	2		4/0	2		300
500	2		250	2		350
550	2		300	2		500
600	2		350	2		500
700	2		500	3		350
800	3		300	3		400
1000	3		400	4		350
				3		600
1200	4		350	4		500
	3		600			
1400	4		500	5		500

Table 6.1.4.2.1 Continued on Next Page

Table 6.1.4.2.1 Continued

Terminal current in Amperes[a]	Copper conductor			Aluminum or copper-clad aluminum conductor		
	Number of conductors	Size AWG or kcmil		Number of conductors	Size AWG or kcmil	
		60°C	75°C		60°C	75°C
1600	5		400	5		600
	4		600			
2000	6		400	6		600
	5		600			
2500	8		400	8		600
	7		500	7		750
	6		600	9		500
3000	9		400	10		500
	8		500	9		600
	7		600	8		750
4000	12		400	13		500
	11		500	12		600
	10		600	11		750
5000[b]	15		400	16		500
	13		500	15		600
	12		600	13		750
6000[b]	18		400	19		500
	16		500	18		600
	15		600	16		750

[a] For terminal current other than indicated, the next higher rating is to be used – for example, if rated 35 A, enter at 40 A.

[b] Circuit breakers rated at more than 4000 A are to be considered as being bus- or cable-connected unless indicated otherwise in marking.

mm^2	2.1	3.3	5.3	8.4	13.3	21.1	26.7	33.6	42.4	53.5
AWG	14	12	10	8	6	4	3	2	1	1/0
mm^2	67.4	85.0	107.2	127	152	177	203	253	304	380
AWG or kcmil	2/0	3/0	4/0	250	300	350	400	500	600	750

6.1.4.2.5 Field-installable connectors shall meet the following conditions:

a) Component terminal kits shall be available from the circuit breaker manufacturer, or one or more wire connectors shall be specified for field installation on the equipment;

b) Fastening devices, such as studs, nuts, bolts, springs, and flat washers, or the like, as required for an effective installation, shall either be provided as part of the component terminal kit or mounted on, or separately packaged with, the circuit breaker;

c) The installation of the terminal kit shall not involve the loosening or disassembly of parts other than those normally disassembled for installation and wiring;

d) If the wire connector provided in a component terminal kit requires the use of a special tool for securing the conductor, any necessary instructions shall be included in the component terminal kit package or with the circuit breaker;

e) Installation of the wire connectors in the intended manner shall result in a product that meets the requirements of this standard; and

f) The circuit breaker or circuit breaker frame, and component terminal kit shall be marked in accordance with 9.1.2.11.

6.1.4.2.6 A wire-binding screw shall be permitted to be used at a field wiring terminal intended for the connection of a 10 AWG (5.3 mm^2) or smaller wire if upturned lugs or the equivalent are provided to retain the wire under the head of the screw should the screw become loosened.

6.1.4.2.7 A plug-in circuit breaker shall not have a screw or wire connector that can be used simultaneously for the connection of a conductor on the same side as the plug-in connection. A conversion kit with instructions may be provided to accomplish a change in the type of plug-in connection.

6.1.4.2.8 The plug-in connection members on a circuit breaker and on a receiving means shall have the strength necessary for the forces applied during inserting and removing the circuit breaker.

6.1.4.2.9 A plug-in circuit breaker shall be retained on the stabs without depending on the trim or cover of the enclosure.

6.1.4.2.10 If a screw-and-washer construction is used at a field wiring terminal, the screw shall not be smaller than No. 10 (4.8 mm) with no more than 32 threads per inch (per 25.4 mm).

6.1.4.2.11 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick and shall have not less than two full threads in the metal; except that a special alloy plate less than 1.27 mm (0.050 inch) but not less than 0.76 mm (0.030 inch) thick shall be permitted if the tapped threads have the necessary mechanical strength.

6.1.4.2.12 A terminal plate shall be permitted to have the metal extruded at the tapped hole so as to give the thickness necessary for at least two full threads provided that the thickness for the unextruded metal is not less than the pitch of the thread.

6.1.4.2.13 If conductors of the next larger size than that described in Table 6.1.4.2.1 can be inserted into main terminals of a circuit breaker, the terminals shall be capable of securing such larger conductors, unless marked in accordance with 9.1.2.7.

6.1.4.2.14 Pressure terminal connectors capable of holding the next larger size wire as described in 6.1.4.2.13 additionally shall be capable of withstanding the secureness and pullout tests described in Annex B, Ref. No. 6 with the size conductors described in 6.1.4.2.13 and Table 6.1.4.2.1.

6.1.4.2.15 A terminal for the connection of conductors other than those specified in Table 6.1.4.2.1 shall be acceptable only if found appropriate for the particular application.

6.1.4.2.16 Using normally available tools such as screwdrivers, pliers or wrenches, it shall be possible to retighten the conductor securing means of a wire connector without removal of the connector from the terminal plate or bus or without removal of any conductor from the connector.

6.1.4.2.17 For an interchangeable trip circuit breaker frame rated 100 A or less, a single pressure terminal connector shall be made available by the circuit breaker manufacturer that properly accommodates all sizes of wire for which the frame is intended.

6.1.4.3 Field wiring conductors

6.1.4.3.1 Conductors shall not differ by more than two wire sizes from the size referred to in Table 6.1.4.2.1. The wire size shall not be smaller than 14 AWG (2.1 mm^2).

6.1.4.3.2 Conductors shall consist of wire suitable for the particular application, when considered with respect to the temperature and voltage and conditions of service to which the wiring is likely to be subjected.

6.1.4.3.3 A conductor shall be constructed so as to withstand the stress of normal handling without damage to itself or to the unit. See 7.1.10.1.2.

6.1.4.3.4 Green coloring, with or without one or more yellow stripes, and white or gray coloring shall not be used for the covering of a conductor unless intended for connection to grounding and grounded circuit conductors, respectively.

6.1.4.3.5 The free length of a wiring conductor shall be at least 152 mm (6 inches).

6.1.5 Operating Mechanism

6.1.5.1 A multipole circuit breaker shall be constructed so that all poles will make and break simultaneously when operated manually or automatically in the intended manner; except that in a 2- or 3-pole circuit breaker rated at 125/250 V or less and having two operating poles intended for use on the outside (ungrounded) wires of a 3-wire, dc or single-phase ac system, the automatic tripping of either pole shall be permitted to be independent of the other if the independent tripping is indicated. See 9.1.4.6.

6.1.5.2 The handle of a circuit breaker shall not be capable of being readily left at or near the OFF position when the contacts are closed.

6.1.5.3 Single-pole circuit breakers rated at 120/240 V ac or 125/250 V dc shall have provision for the use of handle ties. Handle ties, when installed, shall:

a) Operate both circuit breakers when either circuit breaker handle is manually operated;

b) Not be readily removable; and

c) Not obscure the ampere marking on either circuit breaker.

6.1.5.4 Screws and nuts serving to attach operating parts to movable members shall be staked, upset, or otherwise locked in position to prevent loosening.

6.1.5.5 An operating handle of conducting material extending into the housing shall have provision for connection to an equipment grounding conductor. If the intended enclosure is of metal, this shall be permitted to be accomplished by having such operating handle of conducting material in electrical connection with the enclosure. The adequacy of such connection shall be determined by the electrical continuity test described in 7.12.1.

6.1.5.6 The means for operation of a circuit breaker shall be such that the contacts cannot be held in the closed position under overcurrent conditions - that is, the circuit breaker shall be trip-free from the operating handle. The construction shall be such that when the operating handle is held in the ON position and the circuit breaker is tripped automatically, the contacts will not automatically return to the closed position.

6.1.5.7 A circuit breaker shall be permitted to have an adjustable instantaneous release. A circuit breaker of frame size 200 A or more and with a current rating (minimum of adjustment range where applicable) of 100 A or more or a circuit breaker rated more than 250 V shall be permitted to have an adjustable inverse time (overload) response. See the requirements for adjustable circuit breakers described in Section 6.7 and Section 7.7. Circuit breakers of other ratings shall not have an adjustable inverse time (overload) response.

6.1.5.8 Except as permitted by 6.1.5.9, access to the trip mechanism of a circuit breaker or trip unit and tampering, changing, or interfering with the calibration of the trip mechanism or of a trip unit, except as noted in 6.1.5.7, shall require dismantling of the circuit breaker, or dismantling or removal of the trip unit, or the breaking of a seal.

6.1.5.9 A hole for a rod or wire shall be permitted in the housing of a circuit breaker or trip unit to permit tripping of the circuit breaker. Such holes shall not permit passage of a rod larger than 3.2 mm (1/8 inch) diameter. A button, lever, or similar member shall be permitted to be added for the same purpose. Any such hole or feature added shall not contribute to the interference with or change in calibration of the circuit breaker, permit blocking of the release mechanism, or permit contact with a live part involving a potential more than 42.4 V peak.

6.1.5.10 A circuit breaker rated at 100 A or less in conjunction with a voltage rating of not more than 240 V ac or 125/250 V dc shall be considered to comply with the interference aspect of 6.1.5.8 and 6.1.5.9, if interference with the automatic operation of the circuit breaker cannot be accomplished by:

a) Insertion of a 0.8 mm (1/32 inch) diameter straight rod through any opening in the case above a plane 12.7 mm (1/2 inch) below the plane of the trim when the circuit breaker is mounted in the intended manner, and

b) Insertion of a 2.8 mm (7/64 inch) diameter straight rod through any opening elsewhere in the case.

6.1.5.11 Any means for sealing shall be such that breaking or removing it will be plainly evident. Paper or cloth shall be permitted to be used as a seal indicator, but shall not be used as a means for holding parts together.

6.1.5.12 There shall not be any access, as defined in 6.1.5.13, to a part involving risk of electric shock within an area as indicated in 6.1.5.15:

a) While changing a trip unit in an interchangeable trip unit circuit breaker,

b) While replacing fuses or high-fault protectors in a fused circuit breaker, or

c) While modifying the response of an adjustable circuit breaker.

6.1.5.13 With regard to access to live parts through openings in surfaces, a part is considered to be accessible if it can be contacted by a 51 mm (2 inch) long, 9.5 mm (3/8 inch) diameter rod having a hemispherical end, inserted through openings in the surface.

6.1.5.14 A risk of electric shock is considered to exist if the open circuit voltage between the part in question and earth ground or any other accessible part is more than 42.4 V peak, and the continuous current flow through a 500 ohm resistor connected between the points exceeds 5 mA rms.

6.1.5.15 The areas referred to in 6.1.5.12 are:

a) The complete area of any opening created by the removal of interchangeable trip units,

b) The complete area of any opening created by the removal of the limiters, and so forth, and

c) Points within 51 mm (2 inches) of the periphery of any adjustment knob involved in modifying the response of a circuit breaker.

6.1.5.16 A reliability study for electronic circuit components shall be made in accordance with applicable requirements in Annex B, Ref. No. 8.

6.1.6 Spacings

6.1.6.1 General

6.1.6.1.1 The spacings of a circuit breaker shall not be less than those indicated in Table 6.1.6.1.1. ″Grounded Metal″ includes circuit breaker mounting screws and fittings for the connection of a wiring system. A ″Terminal″ includes the terminal proper and associated metal having the same degree of exposure or accessibility. Spacings shall be measured between the bare portions of insulated conductors. The insulation shall be brought up to the wire connector when space for the wire insulation exists.

6.1.6.1.2 The external spacing through air and over surface shall not be less than 3.2 mm (1/8 inch) between uninsulated line and load live parts of the same polarity.

6.1.6.1.3 In the determination of spacings, the overall wire diameters of Table 6.1.6.1.2 shall be used.

6.1.6.1.4 Except as indicated in 6.1.6.1.5, a pressure terminal connector shall be provided with a positive restraint, such as a shoulder or boss, to restrict turning that would reduce spacings to values less than those required. A lock washer alone is not acceptable for this purpose.

6.1.6.1.5 Means to prevent turning as indicated in 6.1.6.1.4 need not be provided if spacings are not less than the minimum acceptable values:

a) When the connector and any connector of opposite polarity have each been turned 30 degrees toward the other, and

b) When the connector has been turned 30 degrees toward other opposite polarity live parts or toward grounded dead metal parts.

Table 6.1.6.1.1
Minimum spacings in millimeters[e,f,g]

	At terminals				Other than at terminals					
	Between terminals of opposite polarity		Between terminals and any grounded metal[a]		Between uninsulated live parts of opposite polarity[b]		Between uninsulated live parts and any ground metal[a]			
	A		B		C		D[c]		E[d]	
Voltage between parts	Through air	Over surface	Through air	Over surface	Through air	Over surface	Through air	Over surface	Through air	Over surface
0 – 130	12.7	19.1	12.7	12.7	6.4	9.5	12.7	12.7	6.4	9.5
131 – 300	19.1	31.8	12.7	12.7	6.4	9.5	12.7	12.7	6.4	9.5
301 – 600	25.4	50.8	12.7	25.4	9.5	12.7	12.7	25.4	9.5	12.7

[a] The spacing to the enclosure or mounting means shall be permitted to be reduced if an acceptable liner of insulating material, not less than 0.8 mm (1/32 inch) thick, is used to provide the required spacing through air.

[b] Not applicable for spacings between parts of opposite polarity on a control circuit printed wiring board with conformal coating. See Table 6.1.6.2.1 and Printed Circuit and Wiring Board Assembly, 6.1.6.2.

[c] If indentation or deformation of the overall enclosure or circuit breaker mounting means could reduce spacings to less than those indicated in Column E.

[d] If indentation or deformation of the overall enclosure or circuit breaker mounting means would not affect spacings.

[e] An isolated dead metal part (such as a screw head or a washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and a grounded dead metal part is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

[f] In measuring an over surface spacing, any slot, groove, or the like, 0.33 mm (0.013 inch) wide or less in the contour of insulating material shall be disregarded.

[g] In measuring spacings, an air spacing of 0.33 mm (0.013 inch) or less between a live part and an insulating surface shall be disregarded, and the live part considered in contact with the insulating material.

mm	0.8	6.4	9.5	12.7	19.1	25.4	31.8	50.8
inches	1/32	1/4	3/8	1/2	3/4	1	1-1/4	2

Table 6.1.6.1.2
Wire diameters (over insulation)

	(mm^2)	inches	(mm)
AWG			
14	(2.1)	0.131	(3.33)
12	(3.3)	0.148	(3.76)
10	(5.3)	0.168	(4.27)
8	(8.4)	0.245	(6.22)
6	(13.3)	0.323	(8.20)
4	(21.2)	0.372	(9.45)
3	(26.7)	0.401	(10.19)
2	(33.6)	0.433	(11.00)
1	(42.4)	0.508	(12.90)
1/0	(53.5)	0.549	(13.49)
2/0	(67.4)	0.595	(15.11)
3/0	(85.0)	0.647	(16.43)
4/0	(107.2)	0.705	(17.91)
kcmil			
250	(127)	0.788	(20.12)
300	(152)	0.843	(21.41)
350	(177)	0.895	(22.73)
400	(203)	0.942	(23.93)
500	(253)	1.029	(26.14)
600	(304)	1.143	(29.03)
750	(380)	1.249	(31.72)
800	(405)	1.282	(32.56)
900	(456)	1.345	(34.16)
1000	(507)	1.404	(35.66)
1250	(633)	1.577	(40.06)
1500	(760)	1.702	(43.23)
1750	(887)	1.817	(46.15)
2000	(1010)	1.922	(48.82)

6.1.6.1.6 The spacings of a circuit breaker shall be measured with the circuit breaker wired with conductors of the size shown in Table 6.1.4.2.1, as appropriate for temperature rating(s) of the wires (see 9.1.2.9). Type TW wire is to be used for sizes 8 AWG (8.4 mm^2) and smaller; Type THW, TW75 or TW for sizes larger than 8 AWG (8.4 mm^2). Solid conductors are to be used for wire sizes 10 AWG (5.3 mm^2) and smaller. For circuit breakers acceptable for use with both copper and aluminum conductors, both types of wire of the proper size for the ampere rating are to be evaluated.

6.1.6.1.7 Except as noted in 6.1.6.1.8 and 6.1.6.1.12, an insulating barrier or liner used as the sole separation between uninsulated live parts and grounded dead metal parts (including the enclosure) or between uninsulated live parts of opposite polarity, shall be of a material which is acceptable for the mounting of uninsulated live parts and not less than 0.71 mm (0.028 inch) thick.

6.1.6.1.8 Fiber not less than 0.71 mm (0.028 inch) thick shall be permitted to be used as the sole separation between the enclosure and an uninsulated metal part electrically connected to a grounded circuit conductor.

6.1.6.1.9 A barrier or liner used in conjunction with an air space shall not be less than 0.71 mm (0.028 inch) thick except as noted in 6.1.6.1.11 and 6.1.6.1.12.

6.1.6.1.10 If the barrier indicated in 6.1.6.1.9 is of fiber, the air space shall not be less than 0.8 mm (1/32 inch).

6.1.6.1.11 A barrier or liner used in conjunction with an air space of one-half or more of the required through-air spacing shall be permitted to have a thickness of not less than 0.33 mm (0.013 inch), see also 6.1.6.1.12, if it is:

a) Of material acceptable for supporting uninsulated live parts;

b) Of adequate strength if exposed or otherwise likely to be subjected to damage;

c) Securely held in place; and

d) Located so that it shall not be adversely affected by operation of the equipment in service.

6.1.6.1.12 Insulating material having a thickness less than that indicated in 6.1.6.1.7, 6.1.6.1.9 and 6.1.6.1.11 shall be permitted to be used if tested and found acceptable as indicated in 7.1.10.2 and the mechanical strength and flammability is acceptable for the particular application.

6.1.6.1.13 Clamped joints between insulating-material members shall provide tightly-mated surfaces. Adhesives, cements, or the like, if used to effect a seal in place of a tightly-mated joint, shall be acceptable for the purpose.

6.1.6.1.14 The spacing between uninsulated live parts of different circuits (such as between shunt trip release and primary circuits) shall not be less than that required for the circuit of the higher voltage.

6.1.6.1.15 Live screw-heads or nuts on the underside of a case intended for surface mounting shall be suitably insulated or isolated from the enclosure or from a grounded metal mounting-plate in one of the following ways:

a) Spaced according to Table 6.1.6.1.1 and reliably prevented from turning or loosening by staking, upsetting, or other equivalent means;

b) Countersunk not less than 3.2 mm (0.125 inch) below the surface of the case; prevented, as in Item (a) above, from turning or loosening; and having under the case a barrier of moisture-absorption-resistant, insulating material fastened to the enclosure or to the metal mounting-plate; the barrier shall have such an area that Table 6.1.6.1.2 spacing will be maintained, or

c) Countersunk not less than 3.2 mm (0.125 inch) in the clear, and then covered with a waterproof, insulating, sealing compound which will not soften at a temperature 15°C (27°F) higher than the temperature attained in the circuit breaker at the point where it is used, but not lower than 90°C (194°F) in any case. Determination of the softening point of a sealing compound shall be made in accordance with applicable requirements in Annex B, Ref. No. 9.

6.1.6.2 Printed circuit and wiring board assembly

6.1.6.2.1 The spacings on a printed wiring board assembly shall be permitted to be less than indicated in Table 6.1.6.1.1 if a conformal coating and spacings are utilized in compliance with the requirements described in Table 6.1.6.2.1. The coated printed wiring assembly shall comply with the requirements for conformal coatings described in 7.1.10.3. A coating shall not be required if the voltage is 50 V or less and the board is located so that it is not readily subject to contamination by dust.

Table 6.1.6.2.1
Minimum opposite polarity spacings on printed-wiring assemblies with conformal coatings[a]

Voltage between parts	Power available	Minimum spacings	
		mm	Inch
0 – 600	Unlimited	0.8	(1/32)
0 – 30	Limited[b]	0.4	(1/64)

[a] Minimum spacing between live parts of opposite polarity. Spacing between live parts and dead metal shall comply with Table 6.1.6.1.1.

[b] See 6.1.6.3.1 and 6.1.6.3.2.

6.1.6.2.2 As an alternative to the measurement method specified in 6.1.6.2.1, the minimum acceptable clearances (through air spacings) and creepage distances (over surface spacings) for a printed wiring board assembly may be evaluated as specified in 6.1.6.2.3 – 6.1.6.2.5 using the applicable requirements in Annex B, Ref. No. 10.

6.1.6.2.3 When applying the requirements in Annex B, Ref. No. 10, the environment for a printed wiring board assembly within a circuit breaker is considered to be:

a) Pollution degree 3 for an assembly without a conformal coating,

b) Pollution degree 2 for an assembly with a conformal coating, or

c) Pollution degree 1 for an assembly with a conformal coating complying with the requirements in Annex B, Ref. No. 10.

6.1.6.2.4 For Clearance B (controlled overvoltage) requirements in Annex B, Ref. No. 10, the applicable overvoltage category for line-voltage circuits is Category III. Category I is applicable to low-voltage circuits if short circuit between the parts involved may result in operation of the controlled equipment that increases the risk of fire or electric shock. Any overvoltage protection device needed to achieve these categories shall be provided as an integral part of the circuit breaker.

6.1.6.2.5 Where measurement of clearances and creepage distances is involved to establish the minimum spacings, the methods specified in Measurement of Clearance and Creepage Distances, in Annex B, Ref. No. 10, shall be used.

6.1.6.3 Class 2 circuits

6.1.6.3.1 Minimum electrical spacings are not specified for Class 2 circuits that comply with 6.1.6.3.2.

6.1.6.3.2 A low-voltage, limited energy Class 2 circuit is a circuit supplied from an isolated secondary winding of a transformer where the open circuit secondary voltage does not exceed 30 V rms or 42.4 V peak. The transformer shall comply with one of the following:

a) The transformer complies with the construction and test requirements in Annex B, Ref. No. 11,

b) The transformer has an inherent winding impedance which will limit the secondary short circuit current to 8 A at one minute, or

c) The VA output capacity of the secondary winding is 250 VA or less, and an overcurrent protective device is connected in the secondary circuit rated at: 5 A or less for voltages up to and including 20 V rms; or 100/Vmax for voltages over 20 V rms, up to and including 30 V rms. Vmax is the maximum output voltage regardless of load with rated input applied.

6.1.6.3.3 With regard to the requirement in 6.1.6.3.2, a fixed series impedance in the secondary circuit shall be permitted to be used to limit the output of the transformer and, in such case, the secondary winding of the transformer and the fixed series impedance shall be investigated as part of the line-voltage circuit. The maximum output capacity of the secondary circuit shall be determined as described in the power level determination test of 7.1.10.4.

6.1.6.3.4 An overcurrent-protective device as indicated in 6.1.6.3.2(c) shall:

a) Not be of an automatically reset type;

b) Be trip-free from the reclosing mechanism if of the manually reset type; and

c) Not be interchangeable with one of a larger current rating if it is a renewable device.

6.2 Current-limiting circuit breakers

6.2.1 Current-limiting circuit breakers shall comply with the construction requirements in All Types, Section 6.1.

6.3 Instantaneous-trip circuit breakers

6.3.1 This section covers additional requirements for instantaneous-trip circuit breakers.

6.3.2 An instantaneous-trip circuit breaker shall have an adjustable instantaneous release.

6.3.3 An adjustable setting means of an instantaneous-trip circuit breaker that is accessible without opening a door or removing a cover shall be constructed so that a stop to limit the maximum setting may be installed.

6.4 Circuit breaker and ground-fault circuit-interrupters

6.4.1 General

6.4.1.1 This section covers additional requirements for circuit breakers and ground-fault circuit-interrupters that provide overcurrent protection and personnel protection against risk of electric shock as required by the National Installation Codes in Annex B, Ref. No. 1. These devices are rated Class A, single-pole, 120 V ac and/or 127 V ac, 60 Hz and 2-pole, 120/240 V ac, 60 Hz.

6.4.1.2 The ground-fault circuit-interrupter portion shall comply with the construction requirements in Annex B, Ref. No. 12 and Section 6.4 of this standard, except that printed wiring board spacings may be evaluated in accordance with 6.1.6.2.2 – 6.1.6.2.5.

6.4.2 Supervisory Circuit

6.4.2.1 If a 120/240 V circuit breaker mechanism is a common-trip type, the supervisory circuit need only be provided from one ungrounded pole. If a 2-pole circuit breaker mechanism is not a common-trip type, the need for more than one supervisory circuit shall be evaluated.

6.5 Circuit breakers with equipment ground-fault protection

6.5.1 This section covers additional requirements for circuit breakers with equipment ground-fault protection that provide overcurrent protection and ground-fault protection of equipment.

6.5.2 A multipole device that receives operating power from the circuit to which it is connected shall provide ground-fault protection with one or more ungrounded line terminals of the circuit breaker energized.

6.6 Integrally fused circuit breakers and high fault protectors

6.6.1 This section covers additional requirements for fused circuit breakers and accessory high-fault protectors.

6.6.2 An integrally fused circuit breaker shall automatically trip when the cover over the high-fault protectors or fuses, or their container, if separate, is removed if the cover can be removed with the circuit breaker ON.

6.6.3 An integrally fused circuit breaker shall automatically trip by signal, other than main current let-through, from fuses or high-fault protectors upon the clearing of one or more fuses or protectors, unless the circuit breaker is marked in accordance with 9.6.4.

6.6.4 Spacings at the load terminals of an accessory high-fault protector shall comply with Table 6.1.6.1.1, Columns A and B.

6.6.5 Spacings at other than the load terminals of an accessory high-fault protector shall comply with Table 6.1.6.1.1, Columns C, D, and E.

6.6.6 If two or more high-fault protectors having different let-through characteristics are provided for different ranges of ratings within a frame size, the construction shall be investigated in accordance with 7.6.4, unless a rejection means is provided to prevent the installation of a protector in any lower rated circuit breaker where it is not intended.

6.6.7 If two or more accessory high-fault protectors are provided for different ranges of ratings within a frame size, the combination shall be investigated in accordance with 7.6.4, unless a rejection means is provided to prevent the installation of a protector to any lower rated circuit breaker where it is not intended.

6.6.8 Except as indicated in 6.6.9, a high-fault protector or accessory high-fault protector casing shall be of ceramic, melamine impregnated glass fiber, or the equivalent.

6.6.9 Materials other than those specified in 6.6.8 shall be permitted if they are determined to be acceptable for the application.

6.6.10 Among the factors taken into consideration during an investigation, as indicated in 6.6.9, are the following properties of a material:

a) Physical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Combustibility; and

e) Resistance to distortion at temperatures to which the casing may be subjected under conditions of normal or abnormal use.

All of these factors shall be considered with regard to thermal aging.

6.6.11 Connections between the link and the terminals of a protector or accessory protector shall be such that a permanent electrical connection is provided. The connection shall be soldered, brazed, or welded, or shall otherwise be made permanently and adequately secure.

6.6.12 An adhesive used in a protector or accessory protector shall adequately and reliably secure together the parts that it is intended to secure.

6.6.13 To determine whether the adhesive complies with the requirement in 6.6.12, samples of the protector or accessory protector shall be subjected to appropriate interrupting tests, in combination with the circuit breaker after conditioning. Conditioning tests on the adhesive shall not be required if the device performs acceptably during the interrupting tests with the adhesive omitted.

6.7 Adjustable circuit breakers

6.7.1 This section covers additional requirements for adjustable circuit breakers.

6.7.2 As concerns the current setting, these circuit breakers are classed as either Type A or Type B. See 6.7.3 and 6.7.4.

6.7.3 The current setting (I_r) of a Type A circuit breaker shall not be adjustable to a value greater than the rated current (I_n) of the circuit breaker.

6.7.4 A Type B circuit breaker shall be restricted so that the current setting (I_r), once fixed at a particular value, cannot be changed to one higher, except by the addition or substitution of a part requiring use of a tool.

6.7.5 For a Type A circuit breaker, the current setting (I_r) shall be that which can be inferred from the device's settings, markings, or instruction literature. For a Type B circuit breaker, the current setting shall be that of the marking.

6.8 Heating, air conditioning, and refrigeration (HACR) circuit breakers

6.8.1 Heating, air conditioning, and refrigeration (HACR) circuit breakers shall comply with the construction requirements in All Types, Section 6.1.

6.9 Remotely-operated circuit breakers

6.9.1 This section covers additional requirements for remotely-operated circuit breakers.

6.9.2 A remotely-operated circuit breaker shall be trip free and the operating handle and mechanism shall be independent of the remotely-controlled operation.

6.9.3 In a 2-pole remotely-operated circuit breaker, the remotely controlled operation shall be permitted to operate only one pole.

6.10 Switching duty (SWD) rated circuit breakers

6.10.1 Switching duty (SWD) rated circuit breakers shall comply with the construction requirements in All Types, Section 6.1.

6.11 400 Hz rated circuit breakers

6.11.1 Circuit breakers rated 400 Hz shall comply with the construction requirements in All Types, Section 6.1.

6.12 Draw-out circuit breakers

6.12.1 This section covers additional requirements for draw-out circuit breakers.

6.12.2 The configuration of the grounding means between a metal part of a draw-out type circuit breaker intended to be grounded and any permanently grounded part shall be such that grounding continuity is established 3.2 mm (1/8 inch) before either primary or secondary disconnects of the draw-out unit are energized; and also be maintained until both primary and secondary disconnects have been de-energized by at least 3.2 mm (1/8 inch). See the electrical continuity test described in 7.12.1.

6.12.3 Draw-out circuit breakers shall be equipped with self-coupling disconnecting devices.

6.12.4 Interlocks shall be provided:

a) To prevent moving the circuit breaker to or from the connected position when the circuit breaker is in the closed position, and

b) To prevent closing the circuit breaker unless the primary disconnecting devices are in full contact or are separated by a distance that will withstand a minimum voltage described in 7.12.2.

6.13 Series-connected circuit breakers

6.13.1 Series-connected circuit breakers shall comply with the construction requirements in All Types, Section 6.1.

6.14 Interchangeable-trip circuit breakers

6.14.1 This section covers additional requirements for interchangeable-trip circuit breakers.

6.14.2 A circuit breaker having a frame size of 100 A or less in conjunction with a voltage rating of not more than 240 V ac or 125/250 V dc, shall not have an interchangeable trip unit.

6.14.3 A circuit breaker having a frame size of more than 100 A in conjunction with a voltage rating of not more than 240 V ac or 125/250 V dc, and any circuit breaker having a voltage rating greater than 240 V ac or 125/250 V dc, shall be permitted to have interchangeable trip units; except that an interchangeable trip unit for use in a circuit breaker having a voltage rating of not more than 240 V ac or 125/250 V dc shall not have a rating of less than 50 A. In any case, an interchangeable trip unit rated at 50 A or less shall be clearly marked in accordance with 9.14.4.

6.14.4 An interchangeable trip unit shall not be capable of being installed in any frame having a current rating less than that of the trip unit.

6.14.5 An interchangeable trip unit shall not be adjustable beyond the limitations imposed by 6.1.5.7 without breaking a seal or a permanent fastening.

6.14.6 An interchangeable trip unit circuit breaker shall not have any parts that will fall out of the circuit breaker housing when its cover is removed with the circuit breaker mounted in any position on a vertical surface.

6.14.7 An interchangeable-trip circuit breaker that employs a rating plug shall either be nonfunctional (circuit open) or function at its lowest ampere rating when its rating plug is not in place.

6.15 High-intensity-discharge (HID) type circuit breakers

6.15.1 High-intensity-discharge (HID) type circuit breakers shall comply with the construction requirements in All Types, Section 6.1.

6.16 Circuit breakers for use with 16 or 18 AWG wire

6.16.1 Circuit breakers for use with 16 or 18 AWG wire shall comply with the construction requirements in All Types, Section 6.1.

6.17 4-pole circuit breakers

6.17.1 4-pole constructions shall be permitted to be used for 3-phase circuits where a switched neutral is required. The fourth pole shall be provided either without overcurrent protection or with overcurrent protection of 50 or 100 percent of the other poles. See 7.1.1.11, 7.17.1 – 7.17.3, and 9.18.1.

7 Tests

7.1 Standard circuit breakers

7.1.1 General

7.1.1.1 The performance of a circuit breaker construction shall be investigated by subjecting representative sets to the test program indicated in Table 7.1.1.2. At the option of the manufacturer, Test Sequences X, Y, and Z may be combined for all frame sizes. When combining X-Y-Z Sequences or Y-Z Sequences, the Interrupting Test in the Y Sequence may be omitted.

7.1.1.2 Samples shall be selected based on Table 7.1.1.1.

Table 7.1.1.1
Sets of samples

Ampere rating of frame	Interchangeable trip unit	Samples per set[a]	
		Test sequence[b]	
		X or X-Y-Z	Y or Z or Y-Z
0 – 225	No	3 or 4[c]	3 or 4[c]
0 – 225	Yes	3 frames, 3 trip units	3 frames, 3 trip units
226 – 400	No	3[d]	2
226 – 400	Yes	2 frames, 3 trip units	2 frames, 2 trip units
401 – 1600	No	3[e]	1
401 – 1600	Yes	1 frame, 3 trip units	1 frame, 1 trip unit
1601 and higher	No	1	1
1601 and higher	Yes	1 frame, 1 trip unit	1 frame, 1 trip unit

[a] If a circuit breaker is not marked ″line″ and ″load″, one sample shall be tested with reversed line and load connections or an additional sample of each test set shall be provided. When only one sample constitutes a test set for operating tests, a second sample is required for reversed line-load connection tests. For reversed line-load connections, see 7.1.1.18.

[b] One set per test sequence or combination of test sequences.

[c] See 7.1.1.4 and 7.1.1.12.

[d] See 7.1.1.5 and 7.1.2.1.2.

[e] See 7.1.1.5 and 7.1.2.1.3.

Table 7.1.1.2
Test sequences[a]

Circuit-breaker type			Fully magnetic and solid-state trip[b] and uncompensated thermal breakers[c] rated 25°C or 40°C[d,e]			Compensated thermal breakers[f]		
			Sequence			Sequence		
	Test	Clause	X	Y	Z	X	Y	Z
1.	200 percent calibration at 25°C (77°F)	7.1.2.2	X	X	X	X	X	X
2.	135 percent calibration at 25°C (77°F)	7.1.2.3	X			X	X	
3.	200 percent calibration at 40°C (104°F)	7.1.2.2				X		
4.	135 percent calibration at 40°C (104°F)	7.1.2.3				X		
5.	Calibration of adjustable instantaneous trip	7.1.2.5		X			X	
6.	Overload	7.1.3	X			X		
7.	100 percent calibration at 40°C (104°F)[g,h,i]	7.1.2.4, 7.1.4	X			X		
8.	Temperature and 100 percent calibration at 25°C (77°F)	7.1.2.4, 7.1.4	X			X		
9.	Endurance	7.1.5		X			X	
10.	200 percent calibration at 25°C (77°F)	7.1.6		X			X	
11.	135 percent calibration at 25°C (77°F)	7.1.6		X			X	
12.	135 percent calibration at 40°C (104°F)[j]	7.1.6					X	
13.	Interrupting	7.1.7		X[k]	X[l]		X[k]	X[l]
14.	200 percent trip-out at 25°C (77°F)	7.1.8		X	X		X	X
15.	Dielectric voltage-withstand	7.1.9	X	X	X	X	X	X

X-indicates test required.

[a] For circuit breakers rated ac/dc, see 7.1.1.6.

[b] Circuit breakers whose automatic operation does not depend on the heating effect of current.

[c] Circuit breakers whose automatic operation depends on the heating effect of current and are affected by changes in ambient temperature.

[d] If the degree of compensation used in a circuit breaker is such that it will not carry rated current at 40°C (104°), it may, at the option of the manufacturer, be tested as a 25° (77°F) circuit breaker.

[e] If a circuit breaker includes any thermal compensation in its tripping mechanism, and if the manufacturer desires to have the circuit breaker marked ″40°C″, it shall be subjected to the tests for a compensated thermal breaker.

[f] Circuit breakers whose automatic operation depends on the heating effect of current, and which incorporate means for counteracting the effect of change in ambient temperature.

[g] This test may be performed after the temperature and 100 percent calibration tests at 25°C (77°F).

Table 7.1.1.2 Continued on Next Page

Table 7.1.1.2 Continued

Circuit-breaker type		Fully magnetic and solid-state trip[b] and uncompensated thermal breakers[c] rated 25°C or 40°C[d,e]			Compensated thermal breakers[f]		
		Sequence			Sequence		
Test	Clause	X	Y	Z	X	Y	Z

[h] Applies only to circuit breakers rated 40°C (104°F).

[i] For an uncompensated thermal circuit breaker rated 40°C (104°F), the test may be combined with the temperature test if the ambient temperature is 40°C during the temperature test.

[j] May be omitted if the tripping time at 135 percent of rated current in a 25°C (77°F) ambient after the endurance test is no more than it was before the endurance test.

[k] Test current shall be in accordance with Table 7.1.7.3 and operations shall be O-t-CO, where t is minimum of 2 minutes, maximum of 1 hour.

[l] Test current shall be in accordance with Table 7.1.7.2 and operations shall be in accordance with Table 7.1.7.1.

7.1.1.3 No conditioning of the circuit breaker shall take place during or between tests. During the test program, a circuit breaker shall be mounted with the front of the circuit breaker on a vertical plane in a position which would normally cause the line terminals to be at the top; except that for the 135- and 200-percent calibration test and dielectric voltage-withstand test, a circuit breaker may be mounted in any position in which it can be properly used.

7.1.1.4 The investigation of a circuit breaker of a frame size of 225 A or less of a specific pole construction shall include the testing of sets of samples of the maximum and minimum ratings. Sets of samples of one or more intermediate ratings may be additionally required to be subjected to the complete test program or a partial test program depending on construction differences.

7.1.1.5 The investigation of a circuit breaker of frame size more than 225 A usually requires complete testing of sets of the maximum rating only, unless basic construction differences are present. A set of the minimum rating shall be subjected to 200, 135, and 100 percent calibration and, where applicable to the instantaneous trip calibration, whenever such tests are not required on this rating as part of a more extensive test program. If the frame size includes ampere ratings of 125 A or less, but more than 30 A, that are to be marked for use with 75°C (167°F) wire, ratings shall be selected for the overload and temperature tests based on the use of 75°C (167°F) wire. In selecting the rating(s) for test, consideration shall be given to the relative heat dissipating effect of the 60°C (140°F) versus 75°C (167°F) wire size for the particular ampere rating.

7.1.1.6 If the marked rating of a circuit breaker includes both alternating and direct current, or if the marked rating does not exclude one or the other, the acceptability of the circuit breaker for both ratings shall be determined. The ac rating shall be verified by the test program described in Table 7.1.1.2. To verify the dc rating it will ordinarily be necessary only to additionally subject a previously untested sample set that has the maximum ampere rating of the frame size, to:

a) All calibration and trip-out tests with either ac or dc, whichever is more convenient;

b) Overload, endurance, and interrupting tests with dc; and

c) Dielectric voltage withstand tests with ac.

7.1.1.7 A circuit breaker having an instantaneous response as indicated in 6.1.5.7 shall be capable of passing the 100-percent calibration test with the instantaneous response set at its minimum setting, and the other tests with the instantaneous response set at its maximum setting, except as noted in Adjustable instantaneous trip calibration test, 7.1.2.5, note c of Table 7.1.3.1 and note a of Table 7.1.7.2.

7.1.1.8 For tests made with ac, a circuit having the rated frequency of the circuit breaker shall be used. If the specified frequency is in the range of 50 to 60 Hz, or if no frequency is indicated, a 48 – 62 Hz circuit shall be used. If the specified frequency is 400 Hz, a 380 – 420 Hz circuit shall be used. See 400 Hz Rated Circuit Breakers, Section 7.11 for testing 400 Hz rated circuit breakers.

7.1.1.9 Separately-operable circuit breakers in a common base shall not be considered as multipole circuit breakers but shall be treated throughout as individual circuit breakers. When a 2-pole circuit breaker consists of poles constructed so as to trip independently, not common trip, each pole shall be treated as a single pole circuit breaker during the calibration tests.

7.1.1.10 Separately-operable single-pole circuit breakers shall be treated as individual circuit breakers even though they may have a common housing.

7.1.1.11 While normally 1-, 2-, 3-, and 4-pole constructions will require individual representative sets of samples, it may be possible in certain instances, where constructions are basically identical, to represent other than the pole construction being tested.

7.1.1.12 If a single-pole circuit breaker is rated at 120/240 V ac or 125/250 V dc, see 6.1.5.3, two such circuit breakers shall be tested together in the intended manner as a 2-pole independent-trip circuit breaker in the overload, endurance, interrupting, and dielectric voltage-withstand test described below. Two such ″pairs″ of circuit breakers constitute a set.

7.1.1.13 In determining if a circuit breaker complies with the test requirements, the device shall be mounted or supported as in service and tested under conditions approximating those of intended operation, except as otherwise noted.

7.1.1.14 If a circuit breaker is marked for use with aluminum conductors only, all tests shall be conducted using aluminum conductors.

7.1.1.15 At the conclusion of any test sequence, there shall be no malfunction of functional parts of the circuit breaker, such as broken welds, and no more than 50 percent breaking of pigtails per pole.

7.1.1.16 When wires are used to connect a circuit breaker for test, the tightening torque applied to the circuit breaker terminals shall not exceed the value marked on the circuit breaker.

7.1.1.17 A 2-pole common trip circuit breaker that has an additional marking to indicate acceptability on a 3-phase, corner-grounded, delta circuit shall be caused to control 3-phase test circuits during the overload and endurance tests and both single and 3-phase circuits during the interrupting test. See 9.1.1.20.

7.1.1.18 Except for single-pole circuit breakers tested singly, if a circuit breaker is not marked ″line″ and ″load″, one sample of each set tested, or one additional sample, shall be connected with the line and load connections reversed during the overload, endurance, and interrupting tests. When an additional sample is used, it shall be subjected to the initial 200-percent calibration, the trip-out, and the dielectric voltage-withstand tests.

7.1.1.19 In the overload, endurance, and interrupting tests, a circuit breaker shall be mounted within the smallest metal enclosure that will be used in actual service; except that for the endurance test, an enclosure shall not be required if the vertical surface on which it is mounted is metal, unless there are features which would affect the performance of the circuit breaker if not mounted within an enclosure. The door or cover and any other openings including used and unused openings shall be closed on the outside of the enclosure by means of tape. However, any ventilating openings specified and permitted by this standard for circuit breakers rated 400 A or more, see 9.1.1.19, need not be closed. If the inside of the enclosure is painted, the paint shall be scraped off on the inside surface of the metal enclosure in areas of the vents of the circuit breaker and where an arc is likely to strike. A nonconducting enclosure shall be used if the circuit breakers are marked as precluding use in a metal enclosure as required by 9.1.1.18.

7.1.1.20 In the overload, endurance, and interrupting tests, a fuse acceptable for branch circuit protection shall be connected between the enclosure or mounting surface, see 7.1.1.19, and one line to indicate arc over as indicated in 7.1.11.3.1.14 and Figures 7.1.3.1, 7.1.5.1 and 7.1.7.1, respectively. The fuse shall be a 30 A nonrenewable type, having a voltage rating not less than the rating of the device being tested. The connection of the fuse shall be made to the load side of the limiting impedance by means of a 10 AWG (5.3 mm^2) wire not more than 1.829 m (6 feet) in length. The enclosure or mounting surface shall not be otherwise electrically connected.

7.1.2 Calibration Tests

7.1.2.1 General

7.1.2.1.1 To determine if a multipole circuit breaker complies with the requirements of 7.1.2.2 for operation on 200 percent of rated current, each pole shall be tested separately. To determine if a multipole circuit breaker complies with the requirements of 7.1.2.3 and 7.1.2.4, all poles shall be loaded equally, except as indicated in 7.1.1.10.

7.1.2.1.2 To determine if a circuit breaker rated 226 – 400 A complies with the requirements of 7.1.2.2 and 7.1.2.3, the procedure shall be as follows. For the X Sequence, if interchangeable trip units are involved, two samples of the frame and three samples of the trip unit shall constitute a set for the 200- and 135-percent initial calibration tests at 25°C (77°F). The two trip units having the shortest tripping time during the 135-percent calibration test at 25°C (77°F) and two frames shall be used for the remainder of the test sequence. For the Y and Z Sequences, two samples of the frame and two samples of the trip unit shall constitute a set. For the X Sequence, if noninterchangeable trip units are involved, three samples shall constitute a set for the 200- and 135-percent tests. The two samples having the shortest tripping time during the 135-percent calibration test at 25°C (77°F) shall be used for the remainder of the test sequence. For the Y and Z Sequences, two samples shall constitute a set. If X-Y-Z Sequences are combined, the procedure described for the X Sequence shall be followed.

7.1.2.1.3 To determine if a circuit breaker rated 401 – 1600 A complies with the requirements of 7.1.2.2 and 7.1.2.3, the procedure shall be as follows. For the X Sequence, if interchangeable trip units are involved, one sample of the frame and three samples of the trip unit shall constitute a set for the 200- and 135-percent initial calibration tests at 25°C (77°F). The trip unit having the shortest tripping time during the 135-percent calibration test at 25°C (77°F) and one frame shall be used for the remainder of the test sequence. For the Y and Z Sequences, one frame and one trip unit shall constitute a set. For the X Sequence, if noninterchangeable trip units are involved, three samples shall constitute a set for the 200- and 135-percent tests. The sample having the shortest tripping time during the 135-percent calibration test at 25°C (77°F) shall be used for the remainder of the test sequence. For the Y and Z Sequences, if noninterchangeable trip units are involved, one sample shall constitute a set. If the X-Y-Z Sequences are combined, the procedure described for the X Sequence shall be followed.

7.1.2.1.4 Calibration tests of a circuit breaker may be made at any voltage, using either ac or dc, taking into consideration the characteristics of the circuit breaker and the possible conditions of use. A device not specifically marked for either dc or ac shall be subjected to the 100-percent test with ac and may be subjected to the 135- and 200-percent test with dc. A circuit breaker rated only for a specific frequency other than in the range of 50/60 Hz, or dc, shall be tested at the rated frequency, or dc, or both, as appropriate.

7.1.2.1.5 Except as specified in 7.1.1.14, the conductors used in making the connections to a circuit breaker for the calibration tests of 7.1.2.2 shall be of copper of the size indicated in Table 6.1.4.2.1 and no less than 1.219 m (4 feet) in length, except that an accommodating fixture may be used for circuit breakers rated 100 A or less. For a circuit breaker or a circuit breaker frame with an interchangeable trip unit rated more than 30 A but not more than 125 A, the wire size shall be based on the temperature rating of the wire as indicated by the marking on the circuit breaker or trip unit. Where a dual wire temperature rating is marked, 60/75°C (140/167°F), the test shall be conducted with both size wires or the most adverse one, if it can be clearly determined.

7.1.2.1.6 Calibration tests of a circuit breaker shall be conducted with the temperature of the ambient air at 25 ±3°C (77 ±5°F), except that the 100-percent calibration test required at 40°C (104°F) shall be conducted with the temperature of the ambient air at 40 ±3°C (104 ±5°F). In addition, a compensated thermal circuit breaker shall be subjected to 200- and 135-percent calibration tests with the temperature of the ambient air at 40 ±3°C (104 ±5°F), the 135-percent test being conducted immediately after the circuit breaker has carried its rated current until constant temperatures have been reached.

7.1.2.1.7 In conducting calibration tests at 40 ±3°C (104 ±5°F), as indicated in 7.1.2.1.6, the circuit breaker, with leads attached shall be terminated in its intended manner and shall be mounted throughout the tests on a vertical surface in an oven, compartment, or room. The ambient temperature shall be measured as indicated in 7.1.4.1.7. The 200-percent calibration test shall be made when the temperature at the points shown in Figures 7.1.4.1.1 – 7.1.4.1.4 becomes constant. After the 200-percent calibration test has been completed, rated current shall be passed through the circuit breaker until the temperature on the circuit breaker becomes constant, at which time the 135-percent calibration test shall be made.

7.1.2.2 200 percent calibration test

7.1.2.2.1 Starting with the test sample at the ambient temperature indicated in Table 7.1.1.2, a circuit breaker carrying 200 percent of its rated current shall trip within the time limits given in Table 7.1.2.2.1. See 7.1.2.1.6.

Table 7.1.2.2.1
Automatic tripping time – 200 percent rated

Current rating (I_n) in Amperes	Maximum tripping time in minutes
0 – 30[a]	2
31 – 50	4
51 – 100	6
101 – 150	8
151 – 225	10
226 – 400	12
401 – 600	14
601 – 800	18
801 – 1000	20
1001 – 1200	24
1201 – 1600	26
1601 – 2000	28
Over 2000	30

[a] For circuit breaker frames rated more than 250 V, the maximum tripping time may be 3 minutes.

7.1.2.3 135 percent calibration test

7.1.2.3.1 A circuit breaker carrying 135 percent of its rated current in accordance with Table 7.1.1.2 shall trip within 1 hour for a device rated at 50 A or less, and within 2 hours for a device rated at more than 50 A. Unless otherwise directed, the test sample shall be at the ambient temperature indicated in Table 7.1.1.2 at the start of the test. See 7.1.2.1.6.

7.1.2.4 100 percent calibration test

7.1.2.4.1 A circuit breaker shall be capable of carrying 100 percent of its rated current without tripping until temperatures become constant. This test may be conducted concurrently with the temperature test. See 7.1.4.1.4 and 7.1.4.1.11.

7.1.2.5 Adjustable instantaneous trip calibration test

7.1.2.5.1 In a circuit breaker that has an adjustable instantaneous release as indicated in 6.1.5.7, the automatic tripping at the maximum setting shall be within the range of 80 – 130 percent of the marked tripping current. At the minimum setting, tripping shall be within the range of 80 – 130 percent of the marked tripping current.

7.1.2.5.2 To determine if a circuit breaker complies with the requirement of 7.1.2.5.1, tests shall be made using one of the following techniques. This test shall be performed at both the maximum and minimum settings of the instantaneous response. Each pole shall be tested separately three times at both the maximum and minimum settings. The average of the three tests on any pole shall be considered to be the tripping current of that pole.

a) Ramp Method – The test current at the beginning of the test shall be 70 percent of the setting, and the current is then to be increased rapidly until the circuit breaker trips by means of the instantaneous response.

b) Pulse Method – The test current shall be set at 80 percent of the marked trip setting and closed so that there is minimum asymmetry. The duration of the pulse shall be at least 6 cycles. The test current shall be increased in 5 percent increments. If the circuit breaker trips at 80 percent the test current shall be reduced by 5 percent to demonstrate that the circuit breaker does not trip within 6 cycles.

c) Other Methods – Another method that is found to give an accurate indication of the trip point shall be permitted.

7.1.3 Overload Test

7.1.3.1 A circuit breaker shall be capable of performing successfully when operated under the overload conditions indicated in 7.1.3.2 – 7.1.3.14. There shall be no electrical or mechanical breakdown of the device and the fuse indicated in 7.1.1.20 connected to indicate arc-over to the enclosure or grounded metal shall not have cleared.

7.1.3.2 A circuit breaker shall be operated as shown for circuit breakers in Table 7.1.3.1 making and breaking 600 percent of its rated current, but no less than 150 A, unless the inherent impedance of the circuit breaker will not provide the 150 A at rated voltage. In this case, the maximum current passed at rated voltage shall be used. If the circuit breaker does not latch at the specified rate of operation, the rate may be reduced sufficiently so that the circuit breaker will just remain latched.

Table 7.1.3.1
Overload test operations[a]

Frame size, Amperes	Number of operations			Number of cycles of operation per minute
	Circuit breakers		Switches	
	Close and open manually[b,c,d]	Close manually, open automatically		
100 or less	35	15	50	6
101 – 150	50[e]	–[e]	50	5
151 – 225	50	–	50	5
226 – 1600	50	–	50	1[f]
1601 – 2500	25	–	25	1[f]
2501 – 6000	28[g]	–	28[g]	1[g]

[a] The operations may be performed by a machine simulating manual operation.

[b] If the test sample trips during manual operation, it is still considered as a manual operation.

[c] At the option of the manufacturer, the adjustable instantaneous response of a circuit breaker rated 400 A or more may be adjusted to less than the maximum position.

[d] The minimum closed time shall be one cycle, unless the sample trips.

[e] In the case of a multipole breaker without a common trip, and rated at more than 100 A, 35 cycles of operation shall be made manually and 15 automatically as specified in 7.1.3.14.

[f] Operation may be conducted in groups of 5, with 15 minutes maximum between groups.

[g] Three operations at 600 percent of rating at the rate of 1 cycle per minute, followed by 25 operations at 200 percent of rating at the rate of 1 cycle per minute (may be conducted in groups of 5 with 15 minutes maximum between groups).

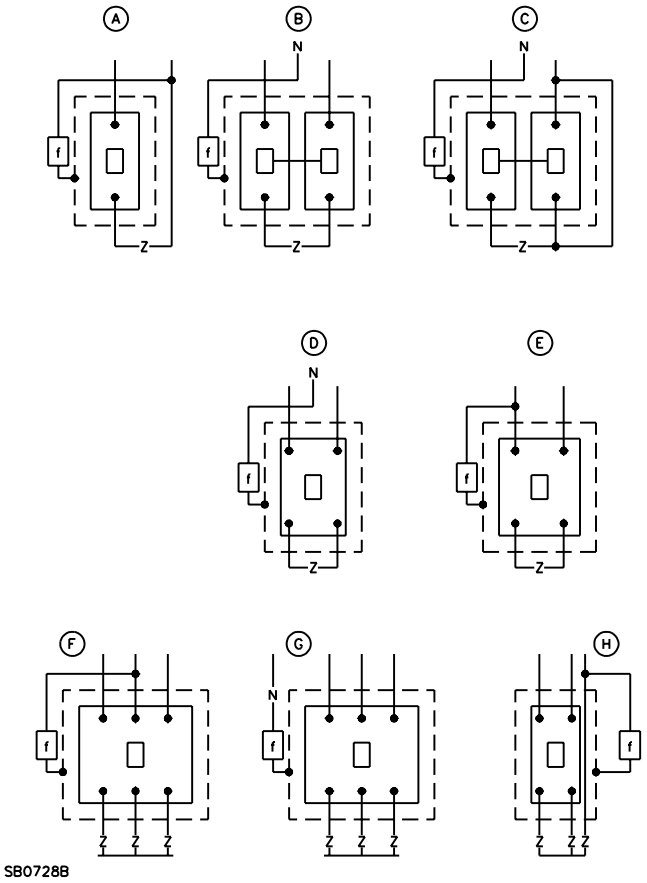
7.1.3.3 The line terminals shall be connected to a supply circuit as indicated below, and the load terminals shall be connected to the necessary impedance. The open circuit voltage of the supply circuit shall be not less than 100 percent nor more than 105 percent of the rated voltage of the circuit breaker, except that a higher voltage may be used if agreeable to the submitter and the testing agency. Except as permitted by 7.1.3.4, the current capacity of the supply circuit shall be such that the closed-circuit voltage across the circuit breaker and load with 600 percent of the rated current of the circuit breaker flowing is within 15 percent of the rated voltage of the circuit breaker.

7.1.3.4 The closed circuit voltage across the circuit breaker shall be permitted to deviate by more than 15 percent from the rated voltage of the circuit breaker if the supply circuit complies with the requirements for recovery voltage, as indicated for interrupting tests, using a load equal to the overload or if the supply circuit is considered to be acceptable for the interrupting test.

7.1.3.5 Wiring diagrams illustrating the test of circuit breakers under overload conditions are indicated in Figure 7.1.3.1. Refer to explanation of test methods and circuit characteristics given in this clause and 7.1.3.8 – 7.1.3.14. All conductors of an ac circuit shall pass through the same knockout, or all line conductors through one knockout and all load conductors through another knockout. Where parallel conductors are used, more than one knockout shall be permitted to be used if an equal number of conductors from each phase and from the same line or load side are routed through each knockout.

7.1.3.6 A circuit breaker intended for use on a system having one conductor grounded shall be tested with the enclosure, if of metal, connected to the grounded conductor through a fuse described in 7.1.1.20. If a circuit breaker is intended for use on other types of systems, the enclosure shall be connected through a similar fuse to the live pole least likely to strike to ground.

Figure 7.1.3.1
Overload test connection diagrams



A – 1–Pole

B, C – 1-Pole ″Tested in Pairs″ (also represents 2-Pole independent-trip type circuit breaker)

D – 2-Pole Common-Trip ″slant″ (120/240, 125/250 V) Rating

E – 2-Pole Common-Trip Rating other than D

F – 3-Pole

G – 3-Pole 208Y/120 V, 480Y/277 V or 600Y/347 V Rating

H – 2-Pole Common-Trip for 3-Phase Rating

N – Neutral

Z – Load Impedance

f – 30 A ″ground″ Fuse – Enclosure

7.1.3.7 A circuit breaker intended for use on a dc system, see 7.1.1.6, shall be tested with dc and with the device connected so that the enclosure will be positive in potential with regard to the nearest arcing point. The dc circuit shall have a time constant not less than 0.003 second.

7.1.3.8 Except as permitted by 7.1.3.9, a circuit breaker intended for use on an ac system shall be tested with ac with an air core inductive load. The power factor of the load shall be from 0.45 to 0.50 lagging except as noted in 7.1.3.14. Reactive components of the load shall be permitted to be paralleled but no reactances shall be connected in parallel with resistances, except that an air-core reactor in any phase shall be permitted to be shunted by resistance, the loss of which is approximately 1 percent of the total power consumption in that phase.

7.1.3.9 An iron-core reactor shall be permitted to be used if the maximum test current is not more than 225 A and the current wave shape at maximum current is such that the ratio of peak-to-rms values is equal to 1.414 ±5 percent (essentially sinusoidal). If referee tests are necessary, they shall be conducted using air-core reactors in accordance with 7.1.3.8.

7.1.3.10 For the overload test and for the endurance test, see 7.1.5.3, the resistance per phase in which the power loss is approximately 1 percent of the total power consumption in that phase will be as indicated in Table 7.1.3.2.

Table 7.1.3.2
Shunting resistance per phase

	Shunting resistance per phase in Ohms	
	Power factor 0.45 – 0.50	Power factor 0.75 – 0.80
Single phase	$\frac{163\ E}{I}$	$\frac{52\ E}{I}$
Three phase	$\frac{94\ E}{I}$	$\frac{30\ E}{I}$
E = Closed circuit line potential in Volts. I = Line current in Amperes.		

S4365

7.1.3.11 Circuit characteristics are normally determined using laboratory type meters. Where required because of high current conditions, the circuit shall be determined by oscillographic or equivalent means as described in Interrupting Test, 7.1.7. It is not necessary that a circuit breaker be in the circuit when making the circuit determination, so long as during the test it is shown that the circuit breaker is interrupting the correct value of current. The test current required shall be the rms symmetrical current value.

7.1.3.12 Except as noted in 7.1.3.14, a 2-pole circuit breaker intended for use on a dc or a single-phase ac, 3-wire system with a grounded neutral shall be tested on a 3-wire supply circuit having the neutral grounded. The circuit breaker shall be connected as shown in diagram D of Figure 7.1.3.1 with the poles connected to the ungrounded conductors of the circuit, with no connection to the midpoint of the load, and with the enclosure connected to the neutral through a fuse as indicated in 7.1.1.20.

7.1.3.13 A 3-pole circuit breaker intended for use in an ac circuit shall be tested in a 3-phase circuit with a 3-phase balanced load, except for a circuit breaker rated only 120/240 V, single phase. See 9.1.1.21.

7.1.3.14 Following the 35 cycles of manual operation, a 2-pole circuit breaker constructed so that either pole may trip independently of the other and a single-pole circuit breaker as indicated in 7.1.1.12 shall be tested by operating each pole separately for 15 cycles of automatic operation. The circuit breaker shall be connected as shown in diagram C of Figure 7.1.3.1 with both the line and load terminals of the other pole connected to the line wire of opposite polarity to that of the pole under test. If the circuit breaker is intended for use with ac, it shall be tested at a power factor of 0.75 – 0.80 for these automatic operations only. At the option of the manufacturer, a 2-pole common-trip circuit breaker as described in 7.1.3.12 may be tested in the same manner.

7.1.4 Temperature Test

7.1.4.1 General

7.1.4.1.1 A circuit breaker shall be subjected to the temperature test described in 7.1.4.2 or 7.1.4.3 as part of the X sequence. See 7.1.4.1.2 and 7.1.4.1.3.

7.1.4.1.2 A non 100 percent circuit breaker shall be tested in accordance with 7.1.4.2 without an enclosure, at 100 percent of its rated current. At the conclusion of this test, as an option in accordance with 7.1.4.2.4, a circuit breaker is permitted to be tested at 80 percent of its rated current while installed in an enclosure.

7.1.4.1.3 A 100 percent rated circuit breaker marked for use at 100 percent of its rated current shall be tested as described in 7.1.4.3 using one of the following options:

a) In the smallest enclosure with which it is intended to be used, or

b) In open air as part of the X sequence followed by a second test in the smallest enclosure with which it is intended to be used. If this option is used a new sample is allowed for the second test.

7.1.4.1.4 When tested without an enclosure under the conditions described in 7.1.4.1.5 – 7.1.4.1.24, or in an enclosure as described in 7.1.4.2.4, a circuit breaker shall operate without tripping until constant temperatures are attained, and materials used in the construction of a circuit breaker shall not be affected adversely by the temperatures to which they are exposed during the test.

7.1.4.1.5 The materials shall be considered as being affected adversely if temperature rises greater than those indicated in Tables 7.1.4.1.1 and 7.1.4.1.2 are attained.

Table 7.1.4.1.1
Maximum acceptable temperature rise

Material and components	°C	°F
Wire insulation or insulating tubing[a]	35	63
Electrical tape[a]	55	99
Varnish-cloth insulation[a]	60	108
Fiber employed as electrical insulation[a]	65	117
Phenolic composition or melamine[b]	110	198
Urea composition[b]	60	108
Other insulating materials[b]	–	–
Sealing compound[c]	50	90

[a] The limitations on insulating materials in 7.1.4.1.5 do not apply to a material or compound that has been investigated and has special heat-resistant properties.

[b] The acceptability of insulating materials shall be determined with respect to properties – such as flammability, arc resistance, relative or generic temperature indices, and the like – based on the temperature rise plus 40°C (104°F).

[c] The softening point shall be at least 40°C (104°F) higher than the temperature rise, but not less than 90°C (194°F) in any case.

Table 7.1.4.1.2
Maximum temperature rise on coils

	°C	°F
Wire-wound coils[a]		
Class 105 insulation		
Thermocouple method	65	117
Resistance method	85	153
Class 130 insulation		
Thermocouple method	85	153
Resistance method	105	189
Class 155 insulation		
Resistance method	115	207
Class 180 insulation		
Resistance method	135	243
Class 200 insulation		
Resistance method	150	270
Class 220 insulation		
Resistance method	165	297

Table 7.1.4.1.2 Continued on Next Page

Table 7.1.4.1.2 Continued

	°C	°F
Single-layer series coils with exposed surfaces uninsulated or film-coated wire		
Class 105 insulation		
Thermocouple method	90	162

[a]Some types of coil constructions may have a smaller difference between the hot spot temperature and the temperature measured by the change of resistance method than conventional types of coil winding as the result of the current winding bus through the center of the coil. In such cases, the limiting values shown may be exceeded if an investigation shows that the hottest-spot temperature rise plus the ambient temperature does not exceed the insulating system rating.

7.1.4.1.6 The maximum temperature on handles, knobs, and other surfaces subject to user contact during normal operation shall not exceed 60°C (140°F) on metallic and 85°C (185°F) on nonmetallic surfaces.

7.1.4.1.7 The circuit breaker shall be mounted in a closed room substantially free from air currents. The temperature of the ambient air shall be as indicated in 7.1.2.1.6 as determined by one thermometer or thermocouple placed 305 mm (12 inches) from the circuit breaker at one side in a plane horizontal to the center of the circuit breaker. The thermocouple or thermometer shall be shielded from any heat source, such as power sources, connecting wires, or bus bars.

7.1.4.1.8 Except for the temperature test outlined in 7.1.4.2.4, a circuit breaker shall be connected to a test source so that all poles carry 100 percent of rated current.

7.1.4.1.9 The temperature test shall be conducted using ac at any convenient voltage except that a circuit breaker marked for use on dc only shall be tested using dc. Polyphase circuit breakers shall be permitted to be tested using either single-phase or polyphase current. The frequency of the test voltage shall be 50 – 60 Hz unless the rating is outside this range, in which case, it shall be the rated frequency. The circuit breaker shall be permitted to be switched up to ten times with no load prior to the test.

7.1.4.1.10 A coil, such as used in a tripping mechanism, that is intended to be energized continuously, shall be energized at rated voltage or current and frequency (or dc). See 7.1.4.4 for method of temperature rise determination.

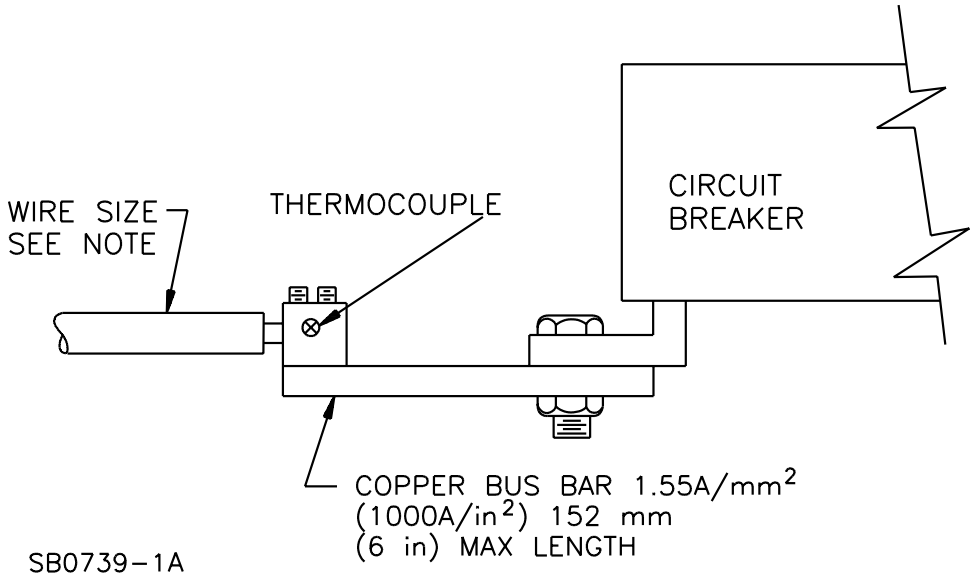
7.1.4.1.11 Temperature measurements on parts other than coils shall be obtained by means of thermocouples and a potentiometer-type of (or other suitable) indicating instrument. A temperature shall be considered to be constant when three successive readings, taken at intervals of 10 percent of the previous elapsed duration of the test but not less than 10 minutes nor more than 20 minute intervals, indicate that stable conditions have been reached.

7.1.4.1.12 The thermocouples indicated in 7.1.4.1.11 shall consist of wires not larger than 24 AWG (0.21 mm^2).

7.1.4.1.13 When thermocouples are used in the determination of temperatures in connection with the heating of electrical devices, thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer type of (or other suitable) indicating instrument shall be used whenever referee temperature measurements are necessary.

7.1.4.1.14 Thermocouples shall be attached at line and load wiring terminals at the point most likely to contact wiring insulation. When wiring terminals are not provided on the circuit breaker, thermocouples shall be attached at the points shown in Figures 7.1.4.1.1 – 7.1.4.1.4. Thermocouples shall be attached at other points as necessary to determine temperatures of materials in accordance with 7.1.4.2.1.

Figure 7.1.4.1.1
Connection for bolt-on circuit breaker rated less than 1600 A



Note: Wire size in accordance with Table 6.1.4.2.1

Figure 7.1.4.1.2
Connection for plug-in circuit breakers

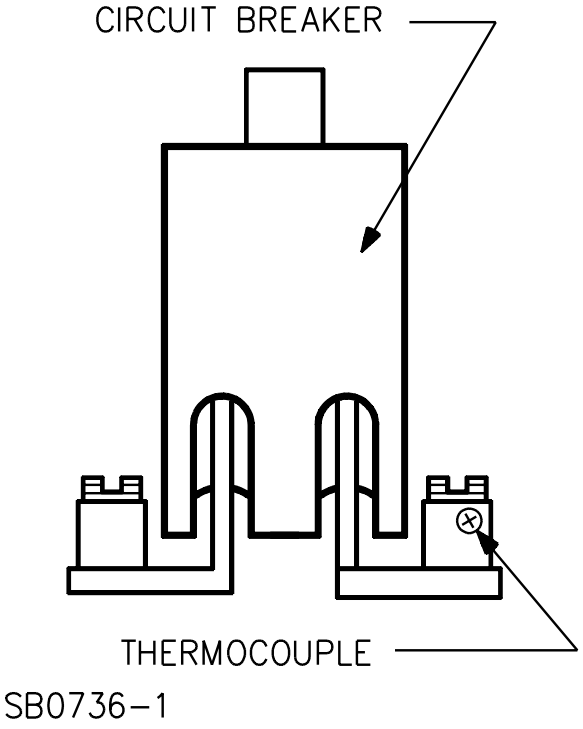


Figure 7.1.4.1.3
Connection for circuit breaker with extension member

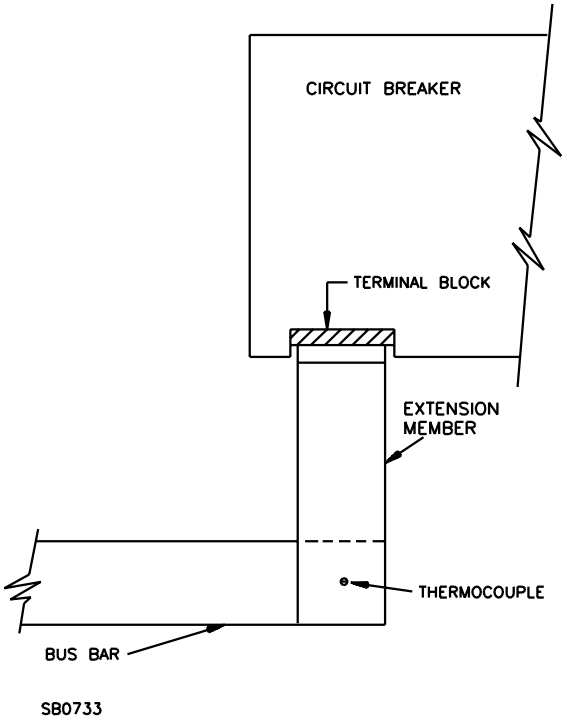
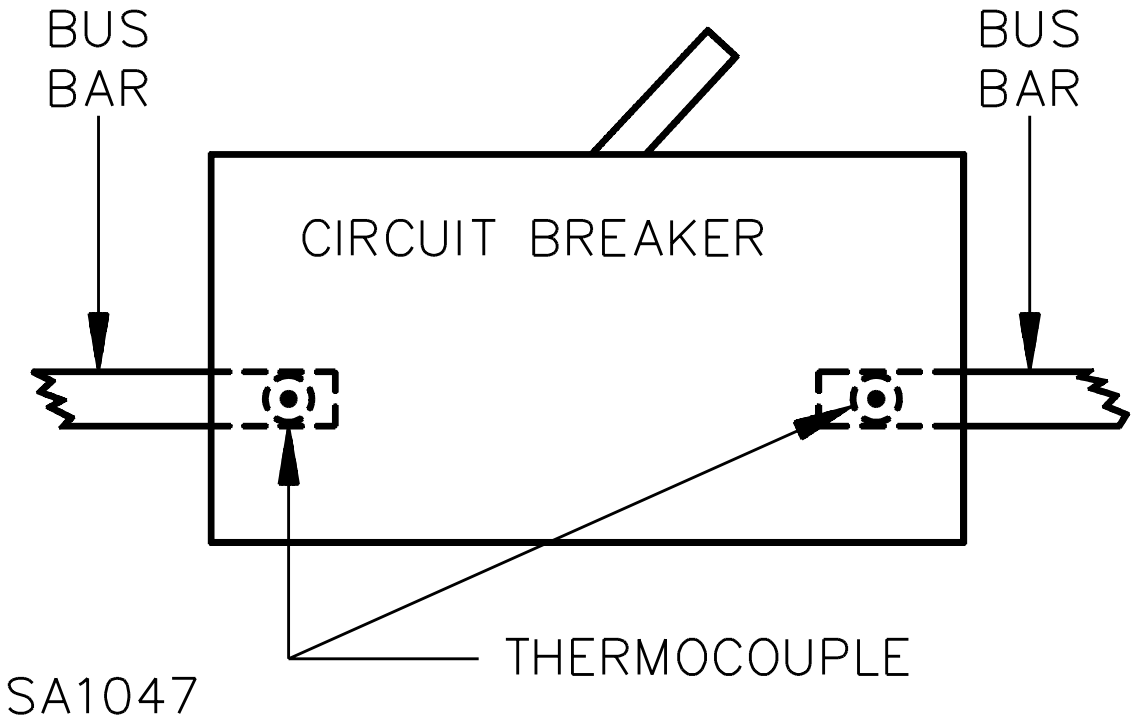


Figure 7.1.4.1.4
Connection of circuit breaker with bus bars



7.1.4.1.15 Except as noted in 7.1.4.1.18, a circuit breaker that has wiring terminals shall be connected for the temperature test with not less than 1.219 m (4 feet) of black Type RH, TW, TW75, RW75, THW, THHN, or THWN copper wire per terminal. The wire size shall correspond to the rating of the circuit breaker as given in Table 6.1.4.2.1. For a circuit breaker or a circuit breaker frame with an interchangeable trip unit rated 100 A or less or that is not marked for use with wire sizes of 1/0 or larger, the wire size shall also be based on the temperature rating of the wire as indicated by marking on the circuit breaker or trip unit. Where a dual temperature rating is marked, 60/75°C (140/167°F) wire, the test shall be conducted with 75°C (167°F) wire. If agreeable to the submitter and the testing agency, insulation of a color other than black shall be permitted.

7.1.4.1.16 To facilitate test connections, wires of any convenient size and number as required for the test current shall be permitted to connect the bus bars described in 7.1.4.1.18 to the source of supply.

7.1.4.1.17 If a circuit breaker rated less than 1600 A has terminals that have no provision for wire (bolt-on circuit breakers), the connections to those terminals during the temperature test shall be made with copper bus bars. The size of the bus bar used for the temperature test shall be 1.55 A/mm^2 (1000 A/in^2) of copper, based on the circuit breaker frame size, except that when the circuit breaker is intended for use with a smaller bus bar, such smaller bus bars shall be used. The bus bars shall be mounted as in actual service. Except as noted in 7.1.4.1.19, the length of the bus bar shall not exceed 152 mm (6 inches) and the bus bars shall terminate in one or more wire connectors. The wire connectors shall be wired in accordance with 7.1.4.1.15, and the combined length of bus bar and wire shall not be less than 1.219 m (4 feet). See Figure 7.1.4.1.1.

7.1.4.1.18 A circuit breaker of a frame size rated 1600 A or more may be tested with copper bus bars instead of with wire if agreeable to the submitter and the testing agency. A circuit breaker rated more than 4000 A shall be tested with copper bus bars unless it is marked for cable connection only (see 9.1.2.12). Unless marked to indicate otherwise (see 9.1.2.13), the bus bars shall be of the size shown in Table 7.1.4.1.3 and at least 1.219 m (4 feet) in length. The spacing between multiple bus bars shall be 6.4 mm (1/4 inch), with no intentional greater spacing except as necessary at the individual terminals of the circuit breaker.

Table 7.1.4.1.3
Size of copper bus bar connections for temperature test

Circuit breaker frame size in Amperes	Bus bar per terminal		
		Size in	
	Number	mm	(inches)
1600	2	6.4 x 76.2	(1/4 x 3)
2000	2	6.4 x 102	(1/4 x 4)
2500	2	6.4 x 127	(1/4 x 5)
	or 4	6.4 x 63.5	(1/4 x 2-1/2)
3000	4	6.4 x 102	(1/4 x 4)
4000	4	6.4 x 127	(1/4 x 5)
5000	6	6.4 x 127	(1/4 x 5)
6000	6	6.4 x 152	(1/4 x 6)

7.1.4.1.19 For the 100 percent rated test, a circuit breaker shall be connected with copper bus bars if the circuit breaker is intended for use with both bus bars and wiring terminals. Unless the circuit breaker is marked to indicate otherwise, the bus bars shall have a cross section of 1.55 A/mm^2 (1000 A/in^2) for ratings less than 1600 A. For ratings of 1600 A and higher, the bus bar shall be in accordance with Table 7.1.4.1.3. If the circuit breaker is intended only for use with wiring terminals, the test shall be conducted with insulated conductors, as specified in 7.1.4.1.15. The bus bars or cable shall be at least 1.219 m (4 feet) long. The test shall be permitted to be repeated using insulated cable for a circuit breaker intended for use with both bus bars and wiring terminals.

7.1.4.1.20 A circuit breaker that has specially formed terminals intended only for connection to mating parts (plug-in type), shall be tested with mating parts of the most adverse (smallest) size and configuration with which it is intended to be used. The receiving device mating parts mounted as in actual service shall terminate in one or more pressure terminal connectors which shall be connected for the test by the type and length of wire indicated in 7.1.4.1.15. See Figure 7.1.4.1.2.

7.1.4.1.21 For a circuit breaker constructed so that the points where wires or bus bars are intended to be attached are located on integral or separable parts that extend from the circuit breaker housing, the test procedure indicated in 7.1.4.1.22 and 7.1.4.2.4 shall be followed.

7.1.4.1.22 Connections for the temperature test shall be made to the intended points on the extension members using wire or bus bars as specified in 7.1.4.1.15, 7.1.4.1.17, 7.1.4.1.18 and Figure 7.1.4.1.3.

7.1.4.1.23 A circuit breaker that has specifically formed terminals intended only for connection to mating parts (draw-out type), shall be tested with mating parts of the most adverse (smallest) size and configuration with which it is intended to be used. The receiving device mating parts mounted as in actual service shall be tested with the receiving device connected to the source with bus sized in accordance with 7.1.4.1.19, unless the circuit breaker is marked for cable connection only.

7.1.4.1.24 A circuit breaker constructed so that the points where wires or bus bars are intended to be attached are located on integral or separable parts that extend from the circuit breaker housing shall be tested with bus connections to the source, unless the circuit breaker is marked for cable connection only. The bus shall be sized in accordance with 7.1.4.1.19.

7.1.4.2 Non 100 percent rated

7.1.4.2.1 Temperature rises at specific points shall not exceed the values indicated in 7.1.4.1.5 – 7.1.4.1.7, and Tables 7.1.4.1.1 and 7.1.4.1.2.

7.1.4.2.2 The temperature rise on a wiring terminal at a point to which the insulation of a wire is brought up as in actual service shall not exceed 50°C (90°F).

7.1.4.2.3 The temperature rise on a part of a circuit breaker, or an extension member, see 7.1.4.1.20, where a bus bar is to be connected shall not exceed 50°C (90°F).

7.1.4.2.4 If the temperature rise at the points where the connection specified in 7.1.4.1.22 are made exceeds 50°C (90°F) but is not more than 65°C (117°F) with the circuit breaker carrying 100 percent of rated current, the temperature test shall be permitted to be repeated using an untested circuit breaker installed in an enclosure that is representative of the smallest enclosure with which the circuit breaker is likely to be used. Under these conditions, with the circuit breaker carrying 80 percent of its maximum rated current, the temperature rise at the points where the connection to external wires or bus bars are made shall not exceed 50°C. Ventilated enclosures as specified in Ventilation, Section 18.4 shall be permitted.

7.1.4.3 100 percent rated

7.1.4.3.1 A circuit breaker shall be permitted to be rated for continuous operation at 100 percent of its ampere rating if it:

a) Is of a frame size rated 250 A or more or a multi-pole type of any ampere rating and rated higher than 250 V;

b) Is marked in accordance with 9.1.4.4; and

c) Complies with the requirements of 7.1.4.3.2 – 7.1.4.4.4.

7.1.4.3.2 A 100 percent rated circuit breaker shall be tested in the smallest enclosure or cubicle with which it is intended to be used.

7.1.4.3.3 The temperature rises where connections are made to external bus bars, when bus bars are used; or on a wiring terminal at a point to which the insulation of a wire is brought up as in actual service when tested with insulated wire shall not exceed 60°C (108°F), if marked in accordance with 9.1.2.14. The marking shall be permitted to indicate only specific current ratings (I_n) if a rating less than the frame rating does not exceed the 50°C (90°F) temperature rise.

7.1.4.4 Coils

7.1.4.4.1 The maximum temperature rise of a coil, when operating at its rated voltage or current, shall be not greater than that indicated in Table 7.1.4.1.2.

7.1.4.4.2 The preferred method of measuring the temperature of a coil shall be the resistance method; but the temperature measurements by either the thermocouple or resistance method are acceptable, except that the thermocouple method shall not be used for a temperature measurement at any point at which the winding is not accessible for the placement of a thermocouple.

7.1.4.4.3 The resistance method consists of the determination of the temperature of a copper or aluminum winding by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature, according to the formula:

$$T = \frac{R}{r}(234.5 + t) - 234.5 \ (copper)$$

$$T = \frac{R}{r}(225 + t) - 225 \ (aluminum)$$

in which:

r is the resistance in ohms at the known temperature;

R is the resistance in ohms at the temperature to be determined;

t is the known temperature in degrees C; and

T is the temperature in degrees C to be determined.

7.1.4.4.4 As it is generally necessary to de-energize the winding before measuring R, the value of R at shutdown shall be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time shall be plotted and extrapolated to give the value of R at shutdown.

7.1.5 Endurance Test

7.1.5.1 A circuit breaker shall be capable of performing successfully when operated manually or by means of a machine constructed to simulate manual operation for the number of cycles and at the rate indicated in Table 7.1.5.1. When an electrical load is involved, the circuit breaker shall be caused to make and break its rated current at rated voltage. There shall be no electrical or mechanical breakdown of the device. The fuse specified in 7.1.1.20, connected to indicate arc-over to the enclosure or grounded metal, shall not have cleared.

7.1.5.2 The rate of operation may be increased at the option of the submitter but shall not exceed 20 operations per minute.

7.1.5.3 To determine if a circuit breaker complies with the requirements of 7.1.5.1 and Table 7.1.5.1, the device shall be mounted, connected, and operated as indicated in 7.1.1.19, 7.1.1.20, and 7.1.3.3 – 7.1.3.14 under ″Overload,″ except that the power factor for an alternating current test shall be 0.75 – 0.80 lagging. A two-pole circuit breaker that has independent trip operation of each pole shall be tested with both poles operating simultaneously. In each cycle of operation of the endurance test with load, the circuit breaker shall be closed and then opened immediately unless a longer ″on″ period is agreeable to the submitter and the testing agency.

7.1.5.4 The current capacity of the supply circuit may be determined with rated current flowing (instead of 600 percent of rated current, as required in 7.1.3.3), in which case the voltage across the circuit breaker and load shall be not less than 97-1/2 percent of rated voltage of the circuit breaker except that the capacity of the supply circuit need not be greater than that of a circuit that is considered to be acceptable for the interrupting test.

7.1.5.5 Five wiring diagrams illustrating the test of circuit breakers under endurance conditions are indicated in Figure 7.1.5.1. See the explanation of test methods and circuit characteristics given in 7.1.5.1 – 7.1.5.4.

Table 7.1.5.1
Endurance test operations

Maximum frame size in amperes	Number of cycles of operation			
	Per minute[a]	With current	Without current	Total
100	6	6,000	4,000	10,000
150	5	4,000[b]	4,000	8,000[b]
225	5	4,000	4,000	8,000
600	4	1,000	5,000	6,000
800	1	500	3,000	3,500
1200	1	500	2,000	2,500
2500	1	500	2,000	2,500
6000	1[c]	400	1,100	1,500

[a] For circuit breakers rated more than 800 A, the endurance test may, at the option of the manufacturer, be conducted in groups of 100 load operations. No-load operations may be conducted between groups of load operations at the option of the manufacturer.

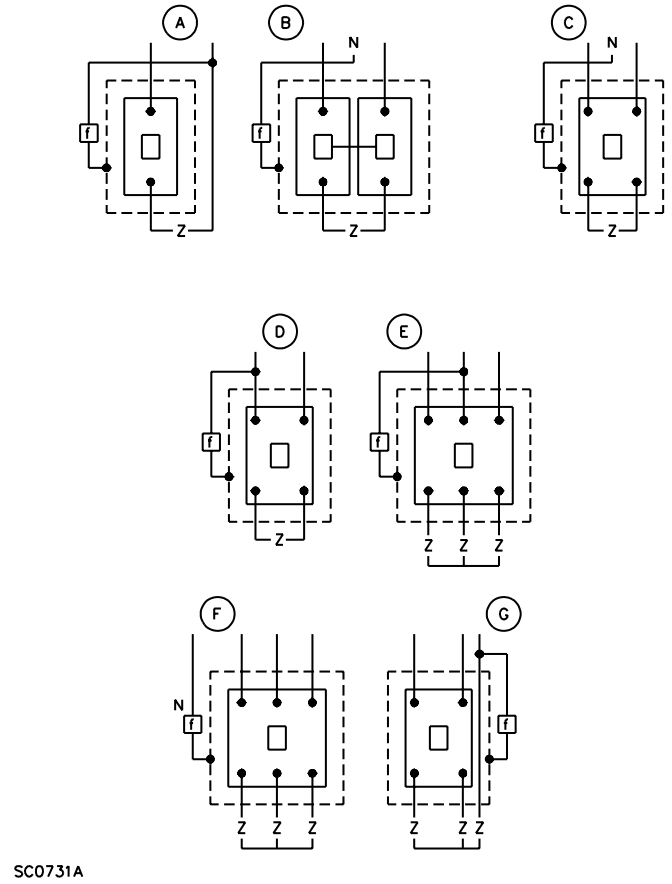
[b] Where tests are required on samples having ratings of 100 A or less, 250 V or less, the number of operations is to be the same as for the 100 A frame.

Table 7.1.5.1 Continued on Next Page

Table 7.1.5.1 Continued

Maximum frame size in amperes	Number of cycles of operation			
	Per minute[a]	With current	Without current	Total
[c] Rate of operation: 1 cycle per minute for first 10 operations; thereafter in groups of 5, at 1 cycle per minute, with an interval between groups that is agreeable to the submitter and the testing agency.				

Figure 7.1.5.1
Endurance test connection diagrams



A – 1–Pole

B – 1-Pole ″Tested in Pairs″ (also represents 2-Pole independent-trip type circuit breaker)

C – 2-Pole Common-Trip ″slant″ (120/240, 125/250 V) Rating

D – 2-Pole Common-Trip Rating other than C

E – 3-Pole

F – 3-Pole 208Y/120 V, 480Y/277 V or 600Y/347 V Rating

G – 2-Pole Common-Trip for 3-Phase Rating

N – Neutral

Z – Load Impedance

f – 30 A ″ground″ Fuse – Enclosure

7.1.6 Calibration Test

7.1.6.1 The 200-percent and the 135-percent calibration tests at 25°C (77°F) in 7.1.2.2 and 7.1.2.3 shall be conducted following the endurance test.

7.1.6.2 The 135-percent calibration test at 40°C (104°F) in 7.1.2.3 shall be conducted following the endurance test on a compensated thermal circuit breaker with the circuit breaker at ambient temperature, without pre-heating by carrying rated current. This test shall be permitted to be omitted if the compensation of the circuit breaker is not considered to be affected by the overload and endurance tests.

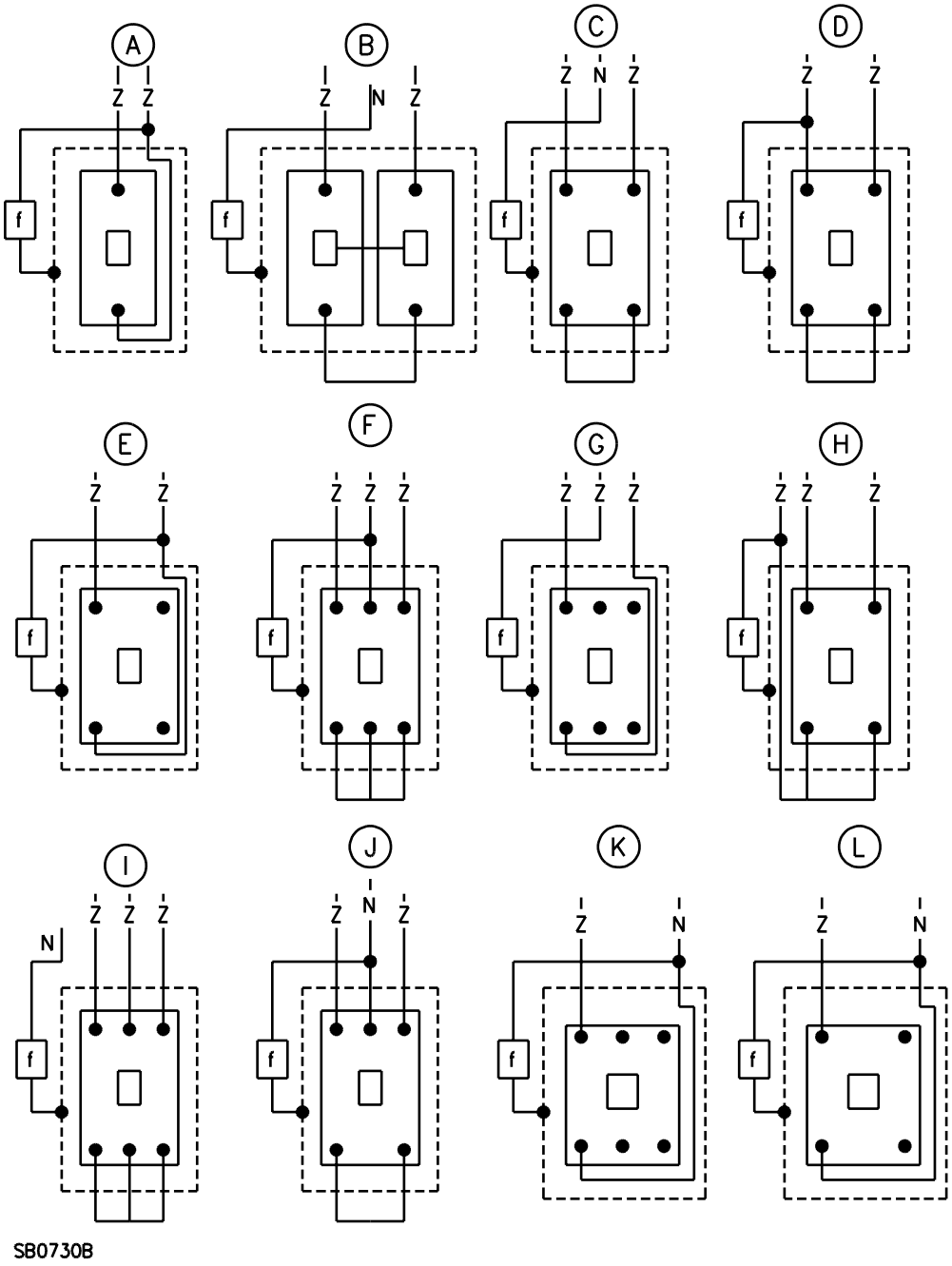
7.1.7 Interrupting Test

7.1.7.1 A circuit breaker shall perform successfully when operated under conditions indicated in 7.1.7.3 – 7.1.7.9. There shall be no electrical or mechanical breakdown of the device, and the fuse specified in 7.1.1.20 shall not have opened. Cotton indicators as indicated in 7.1.7.10 and 7.1.7.11 shall not be ignited. There shall be no damage to the insulation on conductors used to wire the device. After the final operation, the circuit breaker shall have continuity in the closed position at rated voltage.

7.1.7.2 The cotton indicator mentioned in 7.1.7.10 shall be permitted to be omitted, if, with the handle in any position, there is no opening around the handle through which a music wire 0.25 mm (0.010 inch) in diameter can be inserted in a straight line to where it intersects any straight line connecting the separating contacts.

7.1.7.3 Except as permitted by 7.1.7.4, a circuit breaker shall be subjected to the number and type of operations indicated in Table 7.1.7.1 when connected as shown in Figure 7.1.7.1 and shall interrupt the current indicated in Table 7.1.7.2. Successive operations shall be conducted by alternately closing the circuit on the circuit breaker (″O″ operation) by means of any appropriate switching device, using random closing, and closing the circuit breaker on the circuit (″CO″ operation). At the option of the manufacturer, the common or 3-phase operation may be conducted first if ″O″ – ″CO″ – ″O″ alternate operations are maintained.

Figure 7.1.7.1
Interrupting test connection diagrams



N – Neutral

Z – Limiting Impedance

F – 30 A “ground” Fuse – Enclosure

Table 7.1.7.1
Interrupting test operations[a]

Poles	Frame rating	Circuit breaker AC voltage rating	Letters indicate diagram in Figure 7.1.7.1						Total number of operations
			Operations on each pole			Common operations			
			O	CO	O	O	CO	O	
1	All	120, 127, 208, 240, 277, 347, 480, or 600	A	A	A	–	–	–	3
1	All	120/240 (tested in pairs)	–	–	–	B	B	B	3
2	All	240, 480, or 600	E	E	–	D	–	–	5
2	All	120/240	–	–	–	C	C	C	3
2	0 – 1200 A	208Y/120, 480Y/277, or 600Y/347	L	L	–	C	–	–	5
2	All	1ø – 3ø	E	E	–	H	–	–	5
3	0 – 1200 A	240, 480, 600	G	G	–	F	–	–	7
3	1200 – Up	240, 480, 600	G	G	–	F	–	–	7
3	All	120/240	–	–	–	J	J	J	3
3	0 – 1200 A	208Y/120, 480Y/277, 600Y/347	K	K	–	I	–	–	7
3	1201 – Up	208Y/120, 480Y/277, 600Y/347	K	K	–	I	–	–	7

[a] For the 125/250 V dc rating, the number of operations is the same as for the 120/240 V ac rating. For the 250 V dc rating, the number of operations is the same as for the 240 V ac rating.

7.1.7.4 For the Y Test Sequence, the number and type of operations, and the test current shall be as indicated in Table 7.1.7.3.

7.1.7.5 A circuit breaker with a short-time delay element shall additionally be evaluated by the tests in 7.1.7.6. The tests shall be conducted at both the maximum short-time pickup setting and maximum short-time delay setting. For these tests, the instantaneous element shall not operate to trip the circuit breaker. If the maximum short-time pickup setting and maximum short-time delay setting do not occur together, so that it is necessary to conduct separate tests for each setting, separate samples shall be permitted to be used for each test.

7.1.7.6 The test shall be a 3-phase, ″O″ and ″CO″ test conducted at rated voltage and a current between 100 and 120 percent of the current for the short-time pickup setting. The circuit breaker shall trip within the manufacturer's time band for the pickup setting.

7.1.7.7 When a circuit breaker is tested in accordance with note a of Table 7.1.7.2, the same sample – or at the option of the manufacturer an additional sample – shall be subjected to an additional test at any convenient voltage. The circuit breaker's delayed tripping element shall be set to the maximum delay position. The circuit breaker shall carry, and trip, a current equal to that required for the single-pole short circuit test. The test shall be performed once as a type ″O″ operation and repeated as a type ″CO″ operation.

7.1.7.8 With regard to Figure 7.1.7.1, during the common operation when using alternating current, the location of the fuse connection referred to in 7.1.1.20 shall be to that side of the supply least likely to arc to grounded metal and not necessarily as shown.

7.1.7.9 The time interval between the interrupting operations of a circuit breaker shall be 2 minutes, except that the time interval may be extended to whatever is necessary to allow the circuit breaker to be reset, but not more than 1 hour.

Table 7.1.7.2
Available current in test circuits

	RMS symmetrical or DC amperes				
	1 pole	2 pole		3 pole	
Frame rating		Individual[a]	Common	Individual[a]	Common
100 A maximum 250 V maximum	5,000	5,000	5,000	4,330[b,c]	5,000
100 A maximum 251 – 600 V	10,000	10,000	10,000	8,660[b,c,d]	10,000
101 – 800 A	10,000	10,000	10,000	8,660[b,c,d]	10,000
801 – 1200 A	14,000	14,000	14,000	12,120[b,d]	14,000
1201 – 1600 A	–	14,000	20,000	14,000	20,000
1601 – 2000 A	–	14,000	25,000	14,000	25,000
2001 – 2500 A	–	20,000	30,000	20,000	30,000
2501 – 3000 A	–	25,000	35,000	25,000	35,000
3001 – 4000 A	–	30,000	45,000	30,000	45,000
4001 – 5000 A	–	40,000	60,000	40,000	60,000
5001 – 6000 A	–	50,000	70,000	50,000	70,000

[a] At the option of the manufacturer, the adjustable response of a circuit breaker that incorporates a delayed-tripping element may be adjusted to less than the maximum position for the individual pole tests.

[b] This value is the current available when using two legs of the 3-phase circuit indicated under ″Common.″

[c] For dc ratings, the current indicated under ″Common″ is to be used for individual pole operation.

Table 7.1.7.2 Continued on Next Page

Table 7.1.7.2 Continued

Frame rating	RMS symmetrical or DC amperes				
	1 pole	2 pole		3 pole	
		Individual[a]	Common	Individual[a]	Common
[d] For the 208Y/120 V, 480Y/277 V or 600Y/347 V rating, the current indicated for 2-pole under ″Individual″ shall be used.					

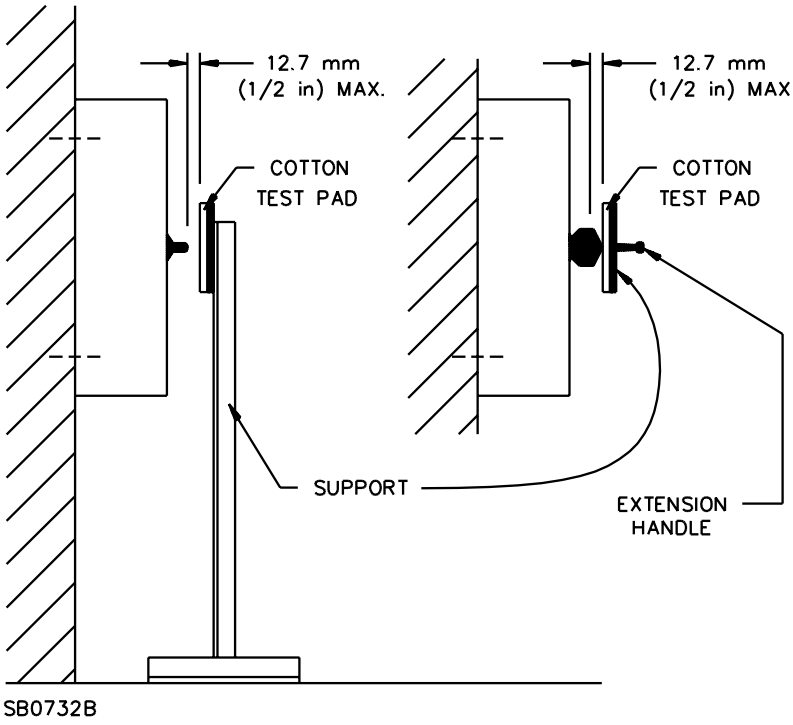
Table 7.1.7.3
Available current in test circuit[a]

Frame rating	RMS symmetrical or DC amperes	
	1-pole	2- and 3-pole
		Common
100 A maximum, 250 V maximum	1500	1500
100 A maximum, 251 – 600 V maximum	3000	3000
101 – 225 A	3000	3000
226 – 400 A	5000	5000
401 – 600 A	6000	6000
601 – 800 A	10,000	10,000
801 – 1200 A	14,000	14,000
1201 – 1600 A	–	20,000
1601 – 2000 A	–	25,000
2001 – 2500 A	–	30,000
2501 – 3000 A	–	35,000
3001 – 4000 A	–	45,000
4001 – 5000 A	–	60,000
5001 – 6000 A	–	70,000
[a] Sequence of operations shall be O-t-CO, where t is a minimum of 2 minutes and a maximum of 1 hour.		

7.1.7.10 A cotton pad at least 12.7 mm (1/2 inch) thick, and having a length and width 4 times the handle opening but not less than 76.2 mm (3 inches) in either dimension shall be centered and secured not more than 12.7 mm (1/2 inch) from the end of the circuit breaker handle (see 7.1.7.2). If a handle extension longer than 25.4 mm (1 inch) is used, the cotton pad shall be firmly supported and anchored to the extension as shown in Figure 7.1.7.2. The cotton pad may be supported on either a solid surface or on 12.7 mm (1/2 inch) mesh hardware cloth. A small opening shall be permitted in a cotton pad to pass a plunger to operate a push-type circuit breaker.

7.1.7.11 A circuit breaker intended for use in a ventilated enclosure shall be tested in that enclosure. A cotton pad indicator at least 12.7 mm (1/2 inch) thick shall be attached to the outside of and shall completely cover any louvers or other openings to determine compliance with 18.4.2.

Figure 7.1.7.2
Location of cotton pad for interrupting ability test



7.1.7.12 The line terminals shall be connected to a supply circuit as indicated in 7.1.7.19 – 7.1.7.23, and the leads for both line and load connections shall be as indicated in 7.1.7.14. Any impedance that may need to be added to limit the current shall be connected in the circuit on the line side of the circuit breaker. The open-circuit voltage of the supply circuit shall be not less than 100 percent nor more than 105 percent of the rated voltage of the circuit breaker, except that a higher voltage may be used if agreeable to the submitter and the testing agency.

7.1.7.13 With regard to the requirement in 7.1.7.12, the limiting impedance added in the test circuit may be divided appropriately between the supply lines. The grounding connection for the frame, enclosure, or both, of the circuit breaker shall be made on the load side of the added impedance.

7.1.7.14 Each circuit breaker shall be subjected to all the operations of the interrupting test, without replacement of any lead during the test. All leads shall consist of Type TW, TW75, RW75, THW, or THWN copper wires of the size indicated in Table 6.1.4.2.1 corresponding to the current rating (In) and markings of the circuit breaker, except as noted in 7.1.7.15, the leads for tests on 277 V, 347 V, 480 V, and 600 V circuit breakers rated 15 A or less shall be permitted to be 12 AWG (3.3 mm^2). For a circuit breaker rated 125 A or less, the 60°C (140°F) wire shall be used except as required by 7.1.7.15. A circuit breaker rated 1600 A or more shall be permitted to be tested with copper bus bars having a cross-section not less than indicated in Table 7.1.4.1.3. Line terminal leads shall be not more than 1.219 m (4 feet) in length. Load terminal leads shall be not more than 254 mm (10 inches) in length per terminal for multipole operation, and not more than 1.219 m (4 feet) in length for single-pole operations. However, for 600 A frame size and larger, leads of any AWG size not more than 1.219 m (4 feet) in length and that were included in the calibration circuit shall be permitted as load leads for multipole operation and as extension leads for single-pole operation. Leads shall be routed as described in 7.1.3.5.

7.1.7.15 For a circuit breaker rated 100 A or less that is not marked for use with wire sizes of 1/0 or larger, and marked for use with 75°C (167°F) wire only, 75°C wire shall be used. See note a of Table 7.1.11.3.1.1.

7.1.7.16 If a circuit breaker rated less than 1600 A has terminals that have no provision for wire the connections to those terminals for the interrupting test shall be as indicated in 7.1.4.1.19 with the combined length of the bus bars and the wires as indicated in 7.1.7.14.

7.1.7.17 A circuit breaker that has specially formed terminals intended only for connection to mating parts (plug-in type) shall be connected for the test as indicated in 7.1.4.1.20 or 7.1.4.1.23 with the length of the test leads as indicated in 7.1.7.14.

7.1.7.18 If a circuit breaker is constructed so that the points where wires or bus bars are attached are located on integral or separable parts that extend from the circuit breaker housing, the connections for the interrupting test shall be made to the intended points on these extension members with leads or bus bars as indicated in 7.1.7.14.

7.1.7.19 A circuit breaker intended for use on a dc system, see 7.1.1.6, shall be tested with dc and with the circuit breaker connected so that the frame and enclosure will be positive in potential with regard to the nearest arcing point.

7.1.7.20 The time constant of the test circuit shall not be less than 0.003 seconds for currents of 10,000 A or less and 0.008 seconds for currents greater than 10,000 A.

7.1.7.21 The DC open circuit voltage of the circuit shall not be less than 100% nor more than 105% of the rated voltage of the unit under test, except that a higher voltage may be used if agreeable to the submitter and the testing agency.

7.1.7.22 A circuit breaker intended for use on an ac system only shall be tested with essentially sinusoidal ac at rated frequency (as specified in 7.1.1.8). The power factor of the test circuit with required current flowing shall be as tabulated in Table 7.1.7.4, except that a lower power factor may be used if agreeable to the submitter and the testing agency. Reactive components of the impedance in the line shall be of the air core type and may be paralleled. No reactance shall be connected in parallel with resistances, except that an air-core reactor(s) in any phase shall be permitted to be shunted by resistance, the volt-ampere loss of which is approximately 0.6 percent of the reactive volt-amperes in the air-core reactor(s) in that phase. The shunting resistance (R) used with an air-core reactor having negligible resistance shall be calculated from the formula:

$$R = 167\frac{E}{I}$$

in which:

E is the voltage across the air-core reactor with current; and

I is the current flowing as determined by oscillographic measurement during the short-circuit calibration, or, by proportion, from meter measurements at some lower current.

7.1.7.23 Oscillograph recordings, or an equivalent method, shall be used to determine circuit characteristics. See Annex C.

Table 7.1.7.4
Power factor of test circuits

Test circuit in amperes	Power factor
10,000 or less	0.45 – 0.50
10,001 – 20,000	0.25 – 0.30
Over 20,000	0.15 – 0.20

7.1.8 Trip-out at 200 Percent Current Test

7.1.8.1 Following the interrupting ability test, a circuit breaker shall be capable of operating automatically, when carrying 200 percent of its rated current, within the time limits given in Table 7.1.2.2.1 when tested as indicated in 7.1.2.2. No minimum tripping time is specified for circuit breakers of the time-delay type.

7.1.9 Dielectric Voltage-Withstand Test

7.1.9.1 A circuit breaker shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential of 1000 V plus twice the voltage that is to be applied between the parts in question, when the breaker is connected in accordance with its maximum voltage rating:

a) Between line and load terminals with the breaker open – with the breaker in the tripped and off positions. The test voltages shall be based on the voltage rating of the circuit breaker. The test voltage for a circuit breaker rated 208Y/120, 120/240, 480Y/277, or 600Y/347 shall be based on 208, 240, 480, or 600 V as appropriate;

b) Between terminals of opposite polarity with the breaker closed. The test voltages shall be based on the voltage rating of the circuit breaker. The test voltage for a circuit breaker rated 208Y/120, 120/240, 480Y/277, or 600Y/347 shall be based on 208, 240, 480, or 600 V as appropriate; and

c) Between live parts and the overall enclosure, as described in 7.1.1.19, with the breaker both open and closed. The test voltage for a circuit breaker rated 208Y/120, 120/240, 480Y/277, or 600Y/347 shall be based on 120, 127, 277, or 347 V, as appropriate.

7.1.9.2 The test potential shall be 1000 V plus twice the voltage rating that is to be applied between the parts in question, when the circuit breaker is connected in accordance with its maximum voltage rating.

7.1.9.3 To determine if a circuit breaker complies with the requirement of 7.1.9.1, the test shall be made using a 500 VA or larger transformer, the output voltage of which can be varied. Starting at zero, the applied potential shall be increased to the required test value and held at that value for 1 minute. The increase in the applied potential shall be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter. The transformer shall be permitted to be less than 500 VA if the output voltage is measured directly.

7.1.10 Miscellaneous Tests

7.1.10.1 Mechanical tests

7.1.10.1.1 There shall be no breakage or damage of any part of the circuit breaker when 110 percent of the marked terminal tightening torque is applied to the wire securing means of the wire connector, securing the specified size of conductor. The value of the tightening torque shall be based on the wire size required for the ampere rating of the circuit breaker. If a circuit breaker frame uses different wire connectors; that is, one type connector for 15 – 40 A ratings and another type connector for 41 – 100 A ratings, the construction for each wire connector shall be investigated.

7.1.10.1.2 In order to determine compliance with the provisions of 6.1.4.3.3, each terminal lead shall withstand a tensile force increased gradually to 89 N (20 lb), and maintained at that value for 5 minutes.

7.1.10.2 Barrier and liner test

7.1.10.2.1 A barrier or liner less than 0.71 mm (0.028 inch) thick used in accordance with 6.1.6.1.12 shall be subjected to the application of a 5000 V, 60 Hz potential. A barrier or liner less than 0.33 mm (0.013 inch) thick used in accordance with 6.1.6.1.12 shall be subjected to the application of a 2500 V, 60 Hz potential. The test potentials shall be applied as indicated in 7.1.10.2.2.

7.1.10.2.2 The barrier or liner material shall be placed between two flat metal electrodes, and the test potential shall be increased to the test value. The maximum test potential shall be maintained for 1 second. The results are acceptable if there is no electrical breakdown.

7.1.10.3 Conformal coating

7.1.10.3.1 The acceptability of a conformal coating used on a printed wiring board having electrical spacings as specified in Table 6.1.6.2.1 shall be determined in accordance with the requirements for conformal coating in Annex B, Ref. No. 13.

7.1.10.4 Power level determination test

7.1.10.4.1 The maximum VA output capacity of the secondary winding of a transformer, as referred to in 6.1.6.3.2 and 6.1.6.3.3, shall be determined as follows. The primary winding of the transformer, at room temperature, shall be connected as intended in the device and the secondary winding in question shall be connected to a variable-resistance load with other loads disconnected. If a fixed series impedance is relied upon to limit the output, that impedance shall be included in the circuit during the test. A multiple-winding transformer shall have one secondary winding tested with all the other secondary windings open-circuited, and shall be allowed to cool to room temperature again before another winding is tested. The primary winding shall be connected to a source of rated voltage. The load on the secondary shall be varied in approximately ten increments from open-circuit to short-circuit conditions in 2-1/2 minutes. For each step of increment in the resistance, the product of the output voltage and current shall be recorded, plotted, and drawn as a smooth curve. The peak value obtained from this graph shall not exceed 250 VA and, if two or more secondary windings supply interconnected circuits, the sum of the outputs of the windings in question shall not exceed 250 VA.

7.1.11 High Available Fault Current Test Sequence

7.1.11.1 General

7.1.11.1.1 These requirements specify the additional performance requirements with which circuit breakers shall comply if they are to be acceptable with an interrupting rating greater than indicated in Table 7.1.7.2 for the rating of the circuit breaker (common columns for 2- or 3-pole). For current-limiting circuit breakers see Current-Limiting Circuit Breakers, Section 7.2.

7.1.11.1.2 Samples as described in Table 7.1.11.1.1 shall be of a type that complies with the performance requirements for use on limited available fault current circuits. Each sample shall be subjected to the calibration, interrupting, trip-out, and dielectric voltage-withstand tests in the order named unless otherwise specified.

7.1.11.1.3 If 2- and 3-pole circuit breakers are of identical construction and have identical current-interrupting ratings, only the 3-pole circuit breakers shall be tested.

7.1.11.1.4 Where the interrupting rating at a given voltage is the same for all current ratings (I_n) of a frame, samples shall be selected as indicated in Table 7.1.11.1.1. In frames where the interrupting rating is not the same for all current ratings (I_n), consideration shall be given to determine whether both minimum and maximum ratings of each group of interrupting ratings are to be tested.

7.1.11.1.5 If the marked rating of a circuit breaker includes both alternating and direct current, or if the marked rating does not exclude one or the other, the acceptability of the circuit breaker for both ratings shall be determined.

7.1.11.1.6 When wires are used to connect a circuit breaker for test, the tightening torque applied to the circuit breaker terminals shall not exceed the value marked on the circuit breaker.

7.1.11.1.7 For a circuit breaker with adjustable settings, the test shall be conducted with the adjustments at the maximum setting.

7.1.11.2 Calibration test

7.1.11.2.1 The calibration test at 200 percent of rated current shall be made as described in 7.1.2.2.

7.1.11.3 Interrupting test

7.1.11.3.1 General

7.1.11.3.1.1 A circuit breaker shall perform acceptably under the conditions indicated in 7.1.11.3.1.2 – 7.1.11.3.1.16.

7.1.11.3.1.2 The standard interrupting rating currents are limited to those shown in Table 8.1.

7.1.11.3.1.3 Three-pole circuit breakers shall be tested on a 3-phase circuit with all load terminals short circuited.

7.1.11.3.1.4 Two-pole circuit breakers shall be tested on a single-phase circuit with the load terminals short circuited. An additional two-pole sample shall be tested on a 3-phase circuit if the circuit breaker is marked “1ø - 3ø″.

7.1.11.3.1.5 All impedance shall be connected on the line side of the circuit breaker test terminals, except that low impedance metering shunts shall be permitted to be connected to the load terminals. If coaxial shunts are used and one is connected on the load side, the outer shell of a single (coaxial) shunt, or the common connection of the outer shells, if more than one shunt is used, shall be permitted to be grounded if there is no other ground on the circuit.

7.1.11.3.1.6 The connection of any limiting impedance and the value of any shunting resistance shall be in accordance with the requirements of 7.1.7.22.

Table 7.1.11.1.1
Samples required

Sample	Total number of samples required[a]	Interrupting current (IC)	Number of samples
Max. current rating of frame	3	Max IC rating[b]	1[c]
–	–	IC at max. voltage rating	1[c]
–	–	IC at max. kVA ratings[d]	1
Intermediate current rating of frame	e,f	e	
Min. current rating of frame	1[f,c]	Max. IC rating	1[c]

[a] The same sample may be used for more than one test if agreeable to the submitter and the testing agency.

[b] If maximum IC rating applies at maximum voltage rating, only one sample is required.

[c] One extra sample is required for the interrupting test under ″Bus Bar Conditions″ when the maximum rating of the frame or group tested is 100 amperes or less.

[d] May be omitted if maximum kilovolt-amperes occurs at the maximum voltage. If the maximum kilovolt-amperes occurs at more than one voltage, neither of which is the maximum voltage, the test shall be conducted at the highest voltage for the kilovolt-ampere rating.

[e] Intermediate current ratings (I_n) of interchangeable trip unit frames are not required for testing with leads. Intermediate current ratings (I_n) of noninterchangeable trip unit frames may be subjected to test if differences in construction are considered to appreciably affect the test performance. For 100 amperes and less frame sizes, where changes are made to braids, or contacts samples representing the maximum rating of each construction shall be selected for testing under bus bar conditions.

[f] Not required for dc tests if the circuit breaker already has an ac rating, and the dc rating does not exceed the corresponding ac rating.

7.1.11.3.1.7 A circuit breaker shall be tested in the smallest enclosure (box and cover) in which it is intended to be used. Openings shall be permitted in the enclosure if the combined area of all openings does not exceed 10 percent of the total external enclosure area and if no opening is directly opposite a vent in the circuit breaker case. A nonconducting enclosure shall be used if the circuit breaker is marked as precluding use in a metallic enclosure.

7.1.11.3.1.8 The test leads shall be sized as indicated in Table 7.1.11.3.1.1. The line terminal connections shall be not more than 1.219 m (4 feet) in length except that a greater length shall be permitted if the excess over 1.219 m (4 feet) per terminal is in the circuit during the test circuit calibration.

Table 7.1.11.3.1.1
Test leads

Manner tested	Ampacity	Ampere rating relative to frame or group within frame	Size of copper test leads[a,b]	
			Line	Load[c]
Tested with leads	100 A and above	Maximum Minimum	Rated Wire Rated Wire	Rated Wire Rated Wire
	Less than 100 A	Maximum Minimum	Rated Wire Rated Wire[e]	Rated Wire[d] Rated Wire[e]
Tested under "Bus bar Conditions"	100 A and less	Maximum Minimum	1 AWG[f] (42.4 mm^2)	Rated Wire (2 and 3 pole) 1 AWG (42.4 mm^2) (1 pole)[f]

[a] "Rated Wire" refers to size as specified in Table 6.1.4.2.1. For a circuit breaker rated 100 A or less or that is not marked for use with wire sizes of 1/0 or larger, the 60°C (140°F) wire shall be used, except that if the circuit breaker is marked "75°C", 75°C (167°F) wire shall be used.

[b] Circuit breakers of frame sizes rated 1600 A or more may be tested with bus bars of a size shown in Table 7.1.4.1.3.

[c] A copper bus bar may be substituted for the load leads if the ampacity is equal to or greater than the required lead ampacity.

[d] See 7.1.11.3.1.9 and 7.1.11.3.1.10.

[e] For circuit breakers rated 15 A at 277, 347, 480, or 600 V: 12 AWG (3.3 mm^2) wire shall be permitted to be used instead of 14 AWG (2.1 mm^2) wire.

[f] See 7.1.11.3.1.11 and 7.1.11.3.1.12.

7.1.11.3.1.9 For multipole circuit breakers and for pairs of single-pole circuit breakers, the load terminals of the circuit breaker shall be connected together with 254 mm (10 inch) test leads (per pole) brought to a common point, or brought to a shorting bar of adequate current-carrying capacity.

7.1.11.3.1.10 When testing a single-pole circuit breaker, the load side test lead shall be not more than 1.219 m (4 feet) long except that if the circuit breaker rating is less than 100 A and is the maximum of the frame or test group within the frame, the rated size wire shall be 254 mm (10 inches) long and shall be connected to the load supply terminal by 1.219 m (4 feet) of 1 AWG (42.4 mm^2) copper wire.

7.1.11.3.1.11 Except as permitted by 7.1.11.3.1.12, a circuit breaker that is rated 100 A and less shall be tested additionally under "bus bar conditions." See Table 7.1.11.3.1.1 for ratings to be tested. The line terminals of single and multipole circuit breakers, and the load terminals of single pole circuit breakers shall be connected with a 254 mm (10 inch) long lead of rated wire size. To the ends of each of these leads, 1 AWG (42.4 mm^2) leads, each 1.219 m (4 feet) long, shall be joined for connection to the test terminals.

7.1.11.3.1.12 If agreeable to the submitter and the testing agency, the 254 mm (10 inch) long lead of rated wire size may be omitted if the circuit breaker is connected to a copper bus bar that is directly connected to the 1 AWG (42.4 mm^2) leads. The bus bar shall have a cross-section greater than or equal to the rated wire and shall be not longer than 254 mm (10 inches).

7.1.11.3.1.13 The leads shall enter the test enclosure through a bushed hole, and shall be lashed together outside of the enclosure to the extent necessary to prevent appreciable motion during the interrupting test. Where parallel conductors are used, more than one bushed opening may be used if an equal number of conductors from each phase are run through each opening or equivalent methods, such as the use of conduit, shall be permitted.

7.1.11.3.1.14 The test enclosure shall be connected through a fuse as indicated in 7.1.1.20 to the line lead least likely to arc to the enclosure, or the neutral, if the circuit breakers are rated 208Y/120, 120/240 or 480Y/277 or 600Y/347 V ac. The connection shall be made to the load side of the limiting impedance by means of 10 AWG (5.3 mm^2) copper wire not more than 1.829 m (6 feet) in length.

7.1.11.3.1.15 For tests with leads, the circuit shall be closed on the circuit breaker by means of a switching device, using random closing. After a 2-minute interval, or the time necessary to allow the circuit breaker to reset, but no more than 1 hour, the circuit breaker shall be closed on the circuit.

7.1.11.3.1.16 For tests under ″bus bar conditions″ the test circuit shall be closed on the circuit breaker using random closing. No other operation is required. See also 7.1.11.3.1.11.

7.1.11.3.2 Circuit characteristics

7.1.11.3.2.1 The prospective current shall be determined as described in Annex C with the test-circuit terminals connected together by a conductor of negligible impedance.

7.1.11.3.2.2 The currents determined as in 7.1.11.3.2.1 shall be not less than the intended interrupting rating involved.

7.1.11.3.2.3 The open circuit voltage shall be not less than 100 percent nor more than 105 percent of the rated voltage for the test being conducted, except that a higher voltage may be used if agreeable to the submitter and the testing agency.

7.1.11.3.2.4 The power factor of the test circuit with the required current flowing shall be in accordance with 7.1.7.22 and Table 7.1.7.4.

7.1.11.3.2.5 The characteristics of ac circuits and dc circuits recovery voltage and ac decrement shall be as described in Annex C.

7.1.11.3.2.6 A circuit breaker intended for use on a dc system, see 7.1.1.6, shall be tested with dc and with the circuit breaker connected so that the frame and enclosure will be positive in potential with regard to the nearest arcing point.

7.1.11.3.2.7 The time constant of the test circuit shall not be less than 0.003 seconds for currents of 10,000 A or less and 0.008 seconds for currents greater than 10,000 A.

7.1.11.3.2.8 The DC open circuit voltage of the circuit shall not be less than 100% nor more than 105% of the rated voltage of the unit under test, except that a higher voltage may be used if agreeable to the submitter and the testing agency.

7.1.11.3.2.9 Oscillograph recordings, or an equivalent method, shall be used to determine circuit characteristics. See Annex C.

7.1.11.4 Trip-out test

7.1.11.4.1 The trip-out test following the interrupting test shall be made as described in 7.1.8 except that the test current shall be 250 percent of rated current.

7.1.11.4.2 If the pole under test does not trip within the time indicated in Table 7.1.2.2.1, the current shall be immediately increased to 400 percent of rated current under which condition the pole under test shall trip within 2 additional minutes. This additional 400 percent test shall be made on only one pole of a multipole circuit breaker.

7.1.11.4.3 The trip-out test shall not be required for those circuit breaker samples tested under the ″bus bar conditions″ of Table 7.1.11.3.1.1 that are not capable of reestablishing continuity.

7.1.11.5 Dielectric voltage-withstand test

7.1.11.5.1 A circuit breaker shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential:

a) Between line and load terminals with the circuit breaker open – that is, with the circuit breaker in the tripped and off positions;

b) Between terminals of opposite polarity with the circuit breaker closed; and

c) Between live parts and the overall enclosure with the circuit breaker both open and closed.

7.1.11.5.2 The test potential shall be twice the voltage rating at which the interrupting test was conducted but not less than 900 V.

7.1.11.5.3 For samples that have been subjected to the interrupting test under bus bar conditions it may not be possible to relatch and close the sample as required for the test of 7.1.11.5.1 and 7.1.11.5.2. In such cases, tests shall be made only under those conditions possible. An opposite polarity test between line terminals shall be made in any case.

7.1.11.5.4 To determine if a circuit breaker complies with the requirements in 7.1.11.5.1, the test shall be conducted in accordance with 7.1.9.3.

7.1.11.6 Interpretation of results

7.1.11.6.1 During performance testing for interrupting ratings, 7.1.11.1 – 7.1.11.5, test results may include the conditions described in 7.1.11.6.2 and 7.1.11.6.3.

7.1.11.6.2 ″Type A″ performance results include the following:

a) Inability of the circuit breaker under test to clear the test circuit;

b) Inability of a multipole common-trip circuit breaker to open all poles during the interrupting test;

c) Breakage of or holes in the circuit breaker case. See 7.1.11.6.4;

d) Welding of contacts;

e) Ejection of wire from the wire connector or burn off of leads during the interrupting test;

f) Inability of more than one pole of a multipole circuit breaker to trip during the trip-out test;

g) Ground fuse clearing;

h) Dielectric voltage-withstand test breakdown;

i) Inability of a multi-pole circuit breaker that includes a common - trip element to open all poles upon the tripping of any pole being tested during the trip-out test; and

j) Other types of similar results.

7.1.11.6.3 ″Type B″ performance results include the following:

a) Burned out shunts;

b) Burned out bimetals or heaters;

c) Conditions that do not permit relatching or reclosing of the circuit breaker;

d) Inability of one pole of a 2-, 3-, or 4-pole circuit breaker to trip during the trip out test;

e) Damage to conductor insulation; and

f) Other types of similar results.

7.1.11.6.4 The inability to relatch, reclose, or otherwise reestablish continuity – such as due to solid state components or braid – shall be considered acceptable for circuit breakers which are tested under ″bus bar conditions.″

7.1.11.6.5 Hairline cracks shall be considered acceptable but cracks where a portion of the case is deflected outward or inward are not acceptable. Any hole or opening in the case caused by the interrupting test operation is not acceptable. A crack that would permit separation of two sections of the case is acceptable only if the two sections are caused to maintain their proper relative positions because of securing means, such as mounting bolts, cover screws, or the like.

7.1.11.6.6 If no test result is classified as Type A or Type B, the construction shall be considered as meeting the test program for the rating.

7.1.11.6.7 If any test result is classified as Type A, or if more than one test result in any one interruption is classified as Type B, the construction shall be considered not to meet the requirements of the test program for the rating.

7.1.11.6.8 In the event of a single test result classified as Type B, a second sample of the same rating shall be subjected to the test program. If the second sample performs in the same manner as the original, the construction shall not be considered as meeting the test program for the rating. If the performance of the second sample is classified as Type B, but in a manner different than the original sample, a third sample shall be tested. If the performance of the third sample is classified as Type B, but in a manner different than the first or second sample, a fourth sample shall be tested. If the performance of the fourth sample is classified as Type A or B, the construction shall not be considered as meeting the test program.

7.2 Current-limiting circuit breakers

7.2.1 General

7.2.1.1 These requirements specify the additional performance criteria that circuit breakers shall comply with if they are to be identified as current-limiting. A circuit breaker's compliance with these requirements will, if the interruption and let-through measurements are higher than the prescribed ″limited available fault current″ levels, be acceptable at a higher interrupting rating than indicated in Table 7.1.7.2, that is, one of the values given in Table 8.1, without the testing described in 7.1.11. See 8.7.

7.2.1.2 Samples for test shall be as described in Table 7.2.1.1. Each sample shall be subjected to the calibration, interrupting and let-through measurement, trip-out and dielectric-voltage withstand tests, in the order presented. This table assumes that the let-through I^2t rating for all circuit breakers of a frame size is the same. When this is not the case, or when supplementary let-through ratings are assigned at less than the maximum voltage rating of the circuit breaker, additional samples and testing are required to verify the other let-through ratings.

7.2.1.3 For a circuit breaker with adjustable settings, the test shall be conducted with the adjustments at the maximum setting.

Table 7.2.1.1
Samples required[a,b,c]

Sample	Test currents		
Maximum current rating (I_n) of frame	Maximum IC rating[d]	Intermediate	Threshold
Maximum current rating (I_n) of frame	IC at maximum[d,e] voltage rating	Intermediate[e]	Threshold[e]
Maximum current rating ($I_{n)}$ of frame	IC at maximum[f] kVA rating	Intermediate[f]	Threshold[f]
Minimum current rating ($I_{n)}$ of frame	Maximum IC rating[d]	–	–
Intermediate current rating of frame	g	g	g

[a] One sample of each interrupting current (IC) test value, except that a sample may be used for more than one test if agreeable to the submitter and the testing agency.

[b] Additional samples are required for tests at a crossover point between two elements. See 7.2.3.3.

[c] Additional samples are required for a 2-pole breaker rated single-phase and 3-phase. See 7.2.3.4.

[d] An additional sample is required for ″bus bar″ conditions, per 7.2.3.7 when the maximum rating of the frame or group tested is 100 A or less.

[e] If maximum IC rating applies at maximum voltage rating, only three samples are required.

[f] May be omitted if maximum kVA occurs at the maximum voltage. If the maximum kVA occurs at more than one voltage, neither of which is at the maximum voltage, the test shall be conducted at the highest voltage for the kVA rating.

[g] Intermediate current ratings (I_n) of interchangeable trip unit frames shall not be required for testing with leads. Intermediate current ratings (I_n) of noninterchangeable trip unit frames may be subjected to test if differences in construction are considered to appreciably affect the test performance. For 100 A and less frame sizes, where changes are made to, braids, or contacts, samples representing the maximum rating of each construction shall be selected for testing under bus bar conditions.

7.2.2 Calibration test

7.2.2.1 The calibration test at 200 percent of rated current shall be made as described in 7.1.2.2.

7.2.3 Interrupting and Let-Through Measurement Test

7.2.3.1 Samples of each circuit breaker type shall interrupt the following prospective currents:

a) The threshold current minus 20 plus 0 percent, see 8.7;

b) One intermediate current level ±10 percent, from Table 7.2.3.1; and

c) The interrupting rating minus 0 plus 10 percent.

7.2.3.2 The intermediate current level shall be the value in Table 7.2.3.1 closest to the average of the threshold and interrupting rating currents.

Table 7.2.3.1
Intermediate test currents – Amperes

1,500	14,000	50,000
3,000	18,000	65,000
5,000	22,000	100,000
7,500	30,000	125,000
10,000	42,000	150,000

7.2.3.3 Testing at additional points, if not coincident with any of the levels described in 7.2.3.1, may be necessary as dictated by the construction of the circuit breaker. For example, if the circuit breaker incorporates two elements with a ″crossover″ point, testing at the crossover point – which may be below the threshold current – shall be conducted so the results are obtained with each element functioning.

7.2.3.4 For the interruption test, 3-pole circuit breakers shall be tested on a 3-phase circuit and 2-pole circuit breakers on a single-phase circuit, both with the load terminals short-circuited. Single-pole circuit breakers shall be tested on a single-phase circuit. A 2-pole circuit breaker shall also be tested on a 3-phase circuit if the circuit breaker is marked 1ø - 3ø. In the latter case, only the maximum current rating (I_n) of the frame size need be tested.

7.2.3.5 Each circuit breaker shall be tested at its rated frequency, or if rated with a range of frequencies, at the highest frequency in the range.

7.2.3.6 Each circuit breaker shall be tested with leads and shall be caused to interrupt the circuit twice. The first interruption shall be an ″O″ operation and the second shall be a ″CO″ operation. There shall be a two-minute interval, or the time necessary to allow the circuit breaker to be reset, but not more than one hour between the operations. For a 3-pole circuit breaker, or a 2-pole circuit breaker tested on a 3-phase circuit, circuit closing on the ″O″ operation shall be at random. For a single-pole circuit breaker, or a 2-pole circuit breaker tested on a single-phase circuit, controlled closing shall be used so as to close at the closing or contact separation angle (on the voltage wave) that results in greatest I^2t let-through.

7.2.3.7 Each circuit breaker type where the maximum rating of the frame or the group tested is 100 A or less shall be tested under ″bus bar″ conditions and shall be caused to interrupt the circuit once, under ″O″ operation. Circuit closing shall be at random.

7.2.3.8 All impedance shall be connected on the line side of the circuit breaker test terminals, except that low-impedance metering shunts shall be permitted to be connected to the load terminals. If coaxial shunts are used and one is connected on the load side, the outer shell of a single (coaxial) shunt, or the common connection of the outer shells, if more than one shunt is used, shall be permitted to be grounded if there is no other ground on the circuit.

7.2.3.9 The prospective current shall be determined as described in Annex C with the test-circuit terminals connected together by a conductor of negligible impedance.

7.2.3.10 The open-circuit voltage shall be not less than 100 nor more than 105 percent of the rated voltage of the circuit breaker for the test being conducted, except that a higher voltage shall be permitted if agreeable to the submitter and the testing agency.

7.2.3.11 The power factor of the test circuit with the required current flowing shall be as indicated in Table 7.1.7.4, except that a lower power factor shall be permitted if agreeable to the submitter and the testing agency. Reactive components of the impedance in the line shall be permitted to be paralleled if of the air core type, but no reactance shall be connected in parallel with the resistances, except that an air core reactor in any phase shall be permitted to be shunted by resistance, the volt-ampere loss of which is approximately 0.6 percent of the reactive volt-amperes in the air-core reactor in that phase.

7.2.3.12 Each circuit breaker shall be mounted in the smallest metallic enclosure (box and cover) in which it is intended to be used. Openings shall be permitted in the enclosure if the combined area of all openings does not exceed 10 percent of the total external enclosure area and if no opening is directly opposite a vent in the circuit breaker case. A nonconducting enclosure shall be used if the circuit breaker is marked as precluding use in a metallic enclosure. See 9.1.1.18.

7.2.3.13 The test leads shall be as indicated in Table 7.2.3.2. The line terminal connections shall be not more than 1.219 m (4 feet) in length, except that a greater length shall be permitted if the excess over 1.219 m (4 feet) per terminal is in the circuit during the test-circuit calibration.

Table 7.2.3.2
Test leads

Manner tested	Ampacity	Ampere rating relative to frame or group within frame	Size of copper test leads[a,b]	
			Line	Load[c]
Tested with leads	100 A and above	Maximum Minimum	Rated wire Rated wire	Rated wire Rated wire
	Less than 100 A	Maximum Minimum	Rated wire Rated wire[e]	Rated wire[d] Rated wire[e]
Tested under ″bus bar condition″	100 A and less	Maximum Minimum	1 AWG[f] (42.4 mm^2)	Rated wire (2 and 3 pole) 1 AWG (42.4 mm^2) (1 pole)[f]

[a] ″Rated wire″ refers to size as specified in Table 6.1.4.2.1. For a circuit breaker rated 100 A or less or that is not marked for use with wire sizes of 1/0 or larger, the 60°C (140°F) wire shall be used.

[b] Circuit breakers of frame size rated 1600 A or more shall be permitted to be tested with bus bars of a size shown in Table 7.1.4.1.3.

Table 7.2.3.2 Continued on Next Page

Table 7.2.3.2 Continued

Manner tested	Ampacity	Ampere rating relative to frame or group within frame	Size of copper test leads[a,b]	
			Line	Load[c]
[c] A copper bus bar may be substituted for the load leads if the ampacity is equal to or greater than the required lead ampacity.				
[d] See 7.2.3.14 and 7.2.3.15.				
[e] For circuit breakers rated 15 A at 277, 347, 480, or 600 V: 12 AWG (3.3 mm^2) wire shall be permitted instead of 14 AWG (2.1 mm^2) wire.				
[f] See 7.2.3.16.				

7.2.3.14 In both the single-phase (multipole, including single-pole circuit breakers tested in pairs) and 3-phase tests, the load terminals of the circuit breaker shall be connected together with 254 mm (10-inch) test leads (per pole) brought to a common point, or brought to a shorting bar of rated current-carrying capacity.

7.2.3.15 When testing a single-pole circuit breaker, the load-side test lead shall be not more than 1.219 m (4 feet) long, except that if the circuit breaker rating is less than 100 A and is the maximum of the frame or test group within the frame, the rated size wire shall be 254 mm (10 inches) long and shall be connected to the load supply terminal by 1.219 m (4 feet) of 1 AWG (42.4 mm^2) copper wire.

7.2.3.16 A circuit breaker that is rated 100 A or less shall be tested under ″bus bar″ conditions. See Table 7.2.3.2 for ratings to be tested. The line terminals of single-pole and multipole circuit breakers, and the load terminals of single-pole circuit breakers shall be connected with a 254 mm (10 inch) long lead of rated wire size. To the ends of each of these leads, 1 AWG (42.4 mm^2) leads, each 1.219 m (4 feet) long, shall be joined for connection to the test terminals.

7.2.3.17 The leads shall enter the test enclosure through a bushed hole and shall be lashed together outside of the enclosure to the extent necessary to prevent appreciable motion during the interrupting and let-through measurement tests. Where parallel conductors are used, more than one bushed opening shall be permitted to be used if an equal number of conductors from each phase are run through each opening. Equivalent methods, such as the use of conduit, shall be permitted.

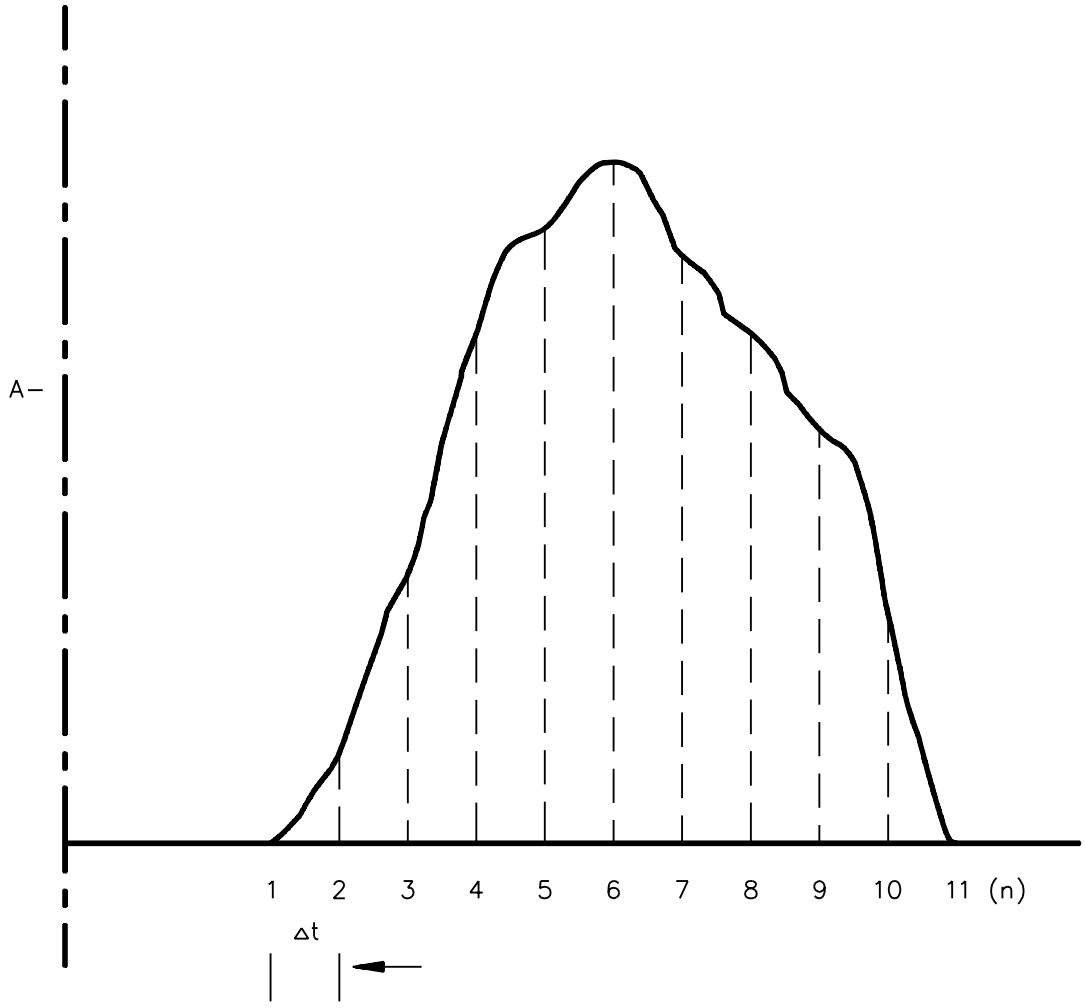
7.2.3.18 The tightening torque applied to any circuit breaker lead terminal shall be as marked on the circuit breaker.

7.2.3.19 A metallic test enclosure shall be connected through a 30-A fuse to the line lead least likely to arc to the enclosure, or the neutral, if the circuit breakers are rated 208Y/120, 480Y/277, or 600Y/347 V ac. The connection shall be made to the load side of the limiting impedance by means of 10 AWG (5.3 mm^2) copper wire no more than 1.829 m (6 feet) in length. The fuse shall be acceptable for branch-circuit protection and have a voltage rating not less than the circuit breaker being tested.

7.2.3.20 The peak current and I^2t let-through – in each phase for a multipole circuit breaker tested on a 3-phase circuit – shall not exceed the value specified by the manufacturer (see 8.7) at that particular prospective current and voltage level. In addition, the I^2t let-through at test points at prospective currents from the threshold current to the interrupting rating current shall not exceed the I^2t of a 1/2 cycle wave of the symmetrical prospective current (for example where the symmetrical prospective current is 100,000 A, the I^2t would be 83.3×10^6). The peak current and I^2t let-through limits shall not be applicable for circuit breakers tested under ″bus bar″ conditions.

7.2.3.21 The let-through I^2t shall be determined from an oscillogram showing a current trace during the interruption of the circuit by the circuit breaker. The determination shall be made by the application of Simpson's rule (Figure 7.2.3.1), the use of an integrating planimeter, or equivalent method. The use of approximation equations that use the peak let-through of the current and the time from initiation of the current to current zero shall not be used.

Figure 7.2.3.1
Application of Simpson's rule to current oscillogram to obtain let-through I^2t



1. Odd numbers of ordinates (n) are to be chosen evenly spaced (Δt). The more uneven the curve, the more ordinates.
2. Each ordinate is to be measured, multiplied by ampere scale (indicated by A in this figure), and squared.
3. I^2t is calculated as follows:

$$I^2t = \frac{\Delta t}{3}\left[(I_1^2 + I_n^2) + 4(I_2^2 + I_4^2 + I_6^2 \ldots I_{(n-1)}^2) + 2(I_3^2 + I_7^2 \ldots I_{(n-1)}^2)\right]$$

SB0662A

7.2.3.22 The time base (in degrees per unit linear measure) shall be determined by averaging the distance between zero-line crossover points of the voltage wave or a timing wave in which the current trace is most nearly centered.

7.2.3.23 The peak line to neutral arc voltage in any phase during the interruption operation shall not exceed two times the voltage rating, plus 1000 V for any voltage rating.

7.2.4 Trip-Out Test

7.2.4.1 A circuit breaker shall be tested in accordance with requirements of Trip-out test, 7.1.11.4.

7.2.5 Dielectric Voltage-Withstand test

7.2.5.1 A circuit breaker shall be tested in accordance with the requirements of Dielectric voltage-withstand test, 7.1.11.5.

7.2.6 Interpretation of Results

7.2.6.1 The results shall be evaluated, including additional testing, in accordance with interpretation of results described in 7.1.11.6.

7.3 Instantaneous-trip circuit breakers

7.3.1 General

7.3.1.1 This section covers performance requirements for instantaneous-trip circuit breakers.

7.3.1.2 The tests described in 7.3.1.5 – 7.3.1.12 cover the performance features of the instantaneous-trip circuit breaker and shall be conducted in the enclosure of the combination motor controller or in an enclosure that is considered to represent the application in the combination motor controller.

7.3.1.3 The maximum and minimum current ratings (I_n) of each circuit breaker frame size shall be subjected to the tests described in 7.3.1.5 – 7.3.1.12 in the order presented. Intermediate ratings in each frame size may be selected to represent variations in trip coil and tripping mechanism. Samples selected with the intermediate ratings shall be subjected to the calibration test only.

7.3.1.4 For each representative rating selected, the number of samples to be tested shall be as indicated in Table 7.3.1.

Table 7.3.1
Number of samples

Circuit breaker current rating, amperes	Number of samples
0 – 225	3
226 – 400	2
401 and higher	1

7.3.1.5 The maximum, minimum, and one intermediate trip setting for each sample shall be calibrated. The test current shall be increased, from zero or some value below the trip setting, until the circuit breaker trips. The rate of increase shall be such that an accurate indication of the trip point can be established. Each pole shall be calibrated separately three times at each setting. The tripping current shall be within the range of 80 – 130 percent of the marked tripping current for the trip setting tested.

7.3.1.6 The test method used for the calibration test shall be impulse testing with synchronous closing, or another method that has been found to give an accurate indication of the trip point.

7.3.1.7 The overload, temperature, and endurance tests shall be conducted on the circuit breaker mechanism in accordance with the requirements in 7.1.3 – 7.1.5, using the test sequences shown in Table 7.1.1.2. These tests need not be conducted if the circuit breaker is known to comply with all of the test requirements. The temperature test in 7.1.4 shall be conducted at the maximum continuous current rating (I_n).

7.3.1.8 The calibration test described in 7.3.1.5 shall be repeated on samples subjected to overload or endurance tests or both following these tests.

7.3.1.9 An interrupting test shall be conducted in accordance with the requirements in Interrupting test, 7.1.7. During the interrupting test, burnout of the magnetic-trip coil may occur. Such performance in testing the circuit breaker alone shall be acceptable if no trip coil burnout occurs when subjecting a separate sample of the circuit breaker under the same conditions to the interrupting test with the intended overload relays, or an equivalent impedance, in series with each pole.

7.3.1.10 Following the interrupting test, an instantaneous-trip circuit breaker tested alone or in series with an overload relay or equivalent shall trip when a current equal to 130 percent of the marked trip setting is passed through each pole separately.

7.3.1.11 The trip-out test is intended to show whether the circuit breaker operating mechanism has been damaged during the interrupting tests. Trip-out shall be determined in accordance with 7.3.1.5 except that the current shall be permitted to be brought quickly to the 130 percent value.

7.3.1.12 An instantaneous-trip circuit breaker shall be subjected to a dielectric voltage-withstand test in accordance with the requirements in 7.1.9.

7.4 Circuit breaker and ground-fault circuit-interrupters

7.4.1 General

7.4.1.1 This section covers circuit breaker and ground-fault circuit-interrupters that provide overcurrent protection and personnel protection against risk of electric shock as required by the National Installation Codes in Annex B, Ref. No. 1. These devices are rated Class A, single-pole, 120 V ac and/or 127 V ac, 60 Hz and 2-pole, 120/240 V ac, 60 Hz.

7.4.2 Circuit Breaker Test Sequences

7.4.2.1 General

7.4.2.1.1 The selection of samples for circuit breaker tests shall be in accordance with 7.1.1.2, except as otherwise noted.

7.4.2.1.2 The tests indicated in Table 7.4.2.1 shall be conducted in the sequence shown, except that at the option of the manufacturer, Test Sequence X, Y, and Z may be combined for all frame sizes. When combining X-Y-Z Sequences or Y-Z Sequences, the Interrupting Test, 7.1.7, in the Y Sequence shall be omitted.

7.4.2.1.3 The tests in Table 7.4.2.1 shall be performed in accordance with Standard Circuit Breakers, Section 7.1 except as modified by the requirements in 7.4.2.2.1 – 7.4.4.14.

7.4.2.2 Ground-fault calibration test

7.4.2.2.1 The ground-fault calibration shall be performed on each pole, one at a time, with the pole under test connected as shown in Figure 7.4.2.1. With the line terminals connected to a 60 Hz supply and with the supply adjusted to rated voltage, the resistance (R) shall be reduced gradually until tripping occurs. The ground-fault trip level is the current, measured in milliamperes, at the time of tripping. The ground-fault trip level shall be in the range from 4.0 to 6.0 mA.

Table 7.4.2.1
Test sequences

Circuit-breaker type		Fully magnetic and solid-state trip[a] and uncompensated thermal breakers[b] rated 25°C or 40°C[c,d]			Compensated thermal breakers[e]		
		Sequence			Sequence		
Test	Clause	X	Y	Z	X	Y	Z
1. 200 percent Calibration at 25°C (77°F)	7.1.2.2	X	X	X	X	X	X
2. 135 percent Calibration at 25°C (77°F)	7.1.2.3	X			X	X	
3. 200 percent Calibration at 40°C (104°F)	7.1.2.2				X		
4. 135 percent Calibration at 40°C (104°F)	7.1.2.3				X		
5. Ground-fault calibration	7.4.2.2	X	X	X	X	X	X

Table 7.4.2.1 Continued on Next Page

Table 7.4.2.1 Continued

Circuit-breaker type			Fully magnetic and solid-state trip[a] and uncompensated thermal breakers[b] rated 25°C or 40°C[c,d]			Compensated thermal breakers[e]		
			Sequence			Sequence		
Test		Clause	X	Y	Z	X	Y	Z
6.	Overload	7.1.3	X			X		
7.	100 percent Calibration at 40°C (104°F)[f,g,h]	7.1.2.4, 7.1.4	X			X		
8.	Temperature and 100 percent Calibration at 25°C (77°F)[i]	7.1.2.4, 7.1.4	X			X		
9.	Endurance	7.4.2.3		X			X	
10.	200 percent Calibration at 25°C (77°F)	7.1.6		X			X	
11.	135 Percent Calibration at 25°C (77°F)	7.1.6		X			X	
12.	135 Percent Calibration at 40°C (104°F)[j]	7.1.6					X	
13.	Interrupting	7.4.2.4		X[k]	X[l]		X[k]	X[l]
14.	200 Percent Trip-out at 25°C (77°F)	7.1.8		X	X		X	X
15.	Ground-fault calibration	7.4.2.5	X	X	X	X	X	X
16.	Dielectric voltage-withstand	7.4.2.6	X	X	X	X	X	X

X – indicates test required.

[a] Circuit breakers whose automatic operation does not depend on the heating effect of current.

[b] Circuit breakers whose automatic operation depends on the heating effect of current and are affected by changes in ambient temperature.

[c] If the degree of compensation used in a circuit breaker is such that it will not carry rated current at 40°C(104°), it may, at the option of the manufacturer, be tested as a 25°(77°F) circuit breaker.

[d] If a circuit breaker includes any thermal compensation in its tripping mechanism, and if the manufacturer desires to have the circuit breaker marked ″40°C″, it shall be subjected to the tests for a compensated thermal circuit breaker.

[e] Circuit breakers whose automatic operation depends on the heating effect of current, and which incorporate means for counteracting the effect of change in ambient temperature.

[f] This test may be performed after the temperature and 100 percent calibration tests at 25°C (77°F).

[g] Applies only to circuit breakers rated 40°C (104°F).

[h] For uncompensated thermal circuit breakers rated 40°C(104°F), the test may be combined with the temperature test if the ambient temperature is 40°C (104°F) during the temperature test.

[i] Temperature and 100 percent calibration shall be conducted at rated voltage.

[j] May be omitted if the tripping time at 135 percent of rated current in a 25°C (77°F) ambient after the endurance test is no more than it was before the endurance test.

[k] Test current shall be in accordance with Table 7.1.7.3 and operations shall be O-t-CO, where t is minimum of 2 minutes, maximum of 1 hour.

[l] Test current shall be in accordance with Table 7.1.7.2 and operations shall be in accordance with Table 7.4.2.2.

7.4.2.3 Endurance test

7.4.2.3.1 One-half of the ″with current″ operations of the endurance test shall be performed as follows:

a) Turn the circuit breaker on,

b) Depress the supervisory (test) switch to cause tripping, and

c) Relatch the circuit breaker.

7.4.2.4 Interrupting tests

7.4.2.4.1 For the interrupting test, the number of operations shall be performed in accordance with Table 7.4.2.2 and the connecting diagrams shown in Figure 7.4.2.2 shall be used. The length of integral leads shall be reduced to 152 mm (6 inches).

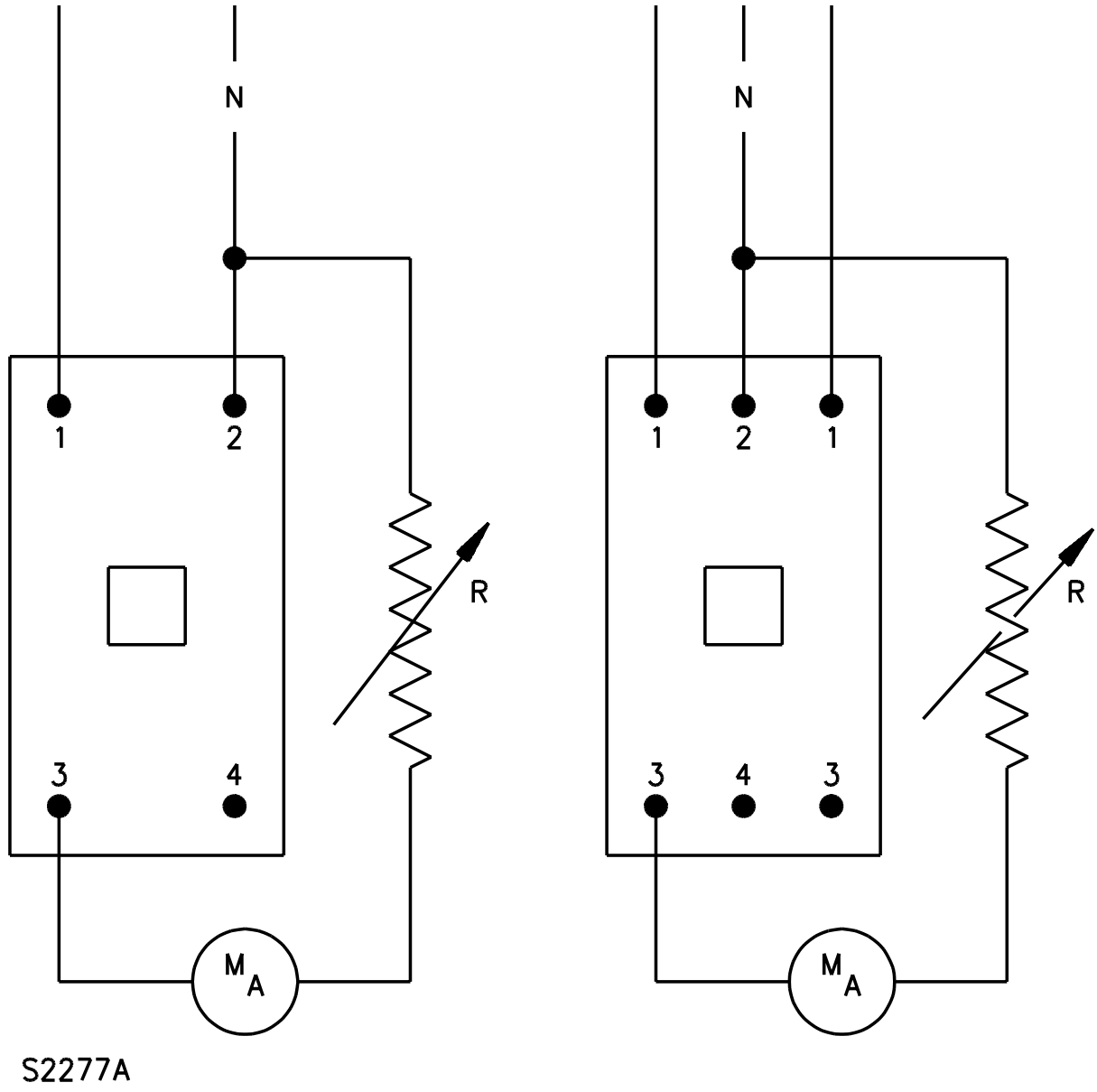
7.4.2.4.2 For the interrupting test during the Y test sequence, the test current shall be as indicated in Table 7.1.7.3 and the connections shall be per Figure 7.4.2.2, items A or C, as appropriate. The test shall consist of one ″O″ and one ″CO″ operation.

Table 7.4.2.2
Z Sequence
Interrupting test operations

Poles	Frame ratings	Circuit breaker AC voltage ratings	Operations on each pole[a]		Common operations[a]	Total number of operations
			″O″	″CO″	″O″	
1	All	120 or 127	B	B	A	3
2	All	120/240	D	D	C	5

[a] Letters indicate diagram in Figure 7.4.2.2.

Figure 7.4.2.1
Ground-fault calibration



N – Neutral

Terminal Designations

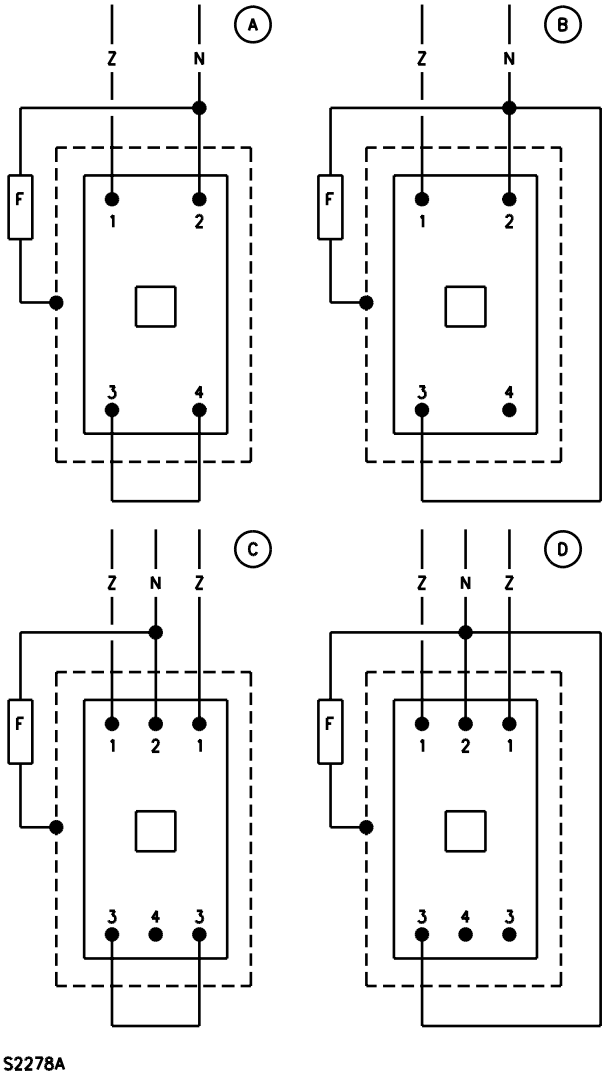
1 – Line

2 – Line Neutral or Panel Neutral

3 – Load or Load Power

4 – Load Neutral

Figure 7.4.2.2
Interrupting test connections



N – Neutral

Z – Limiting Impedance

F – 30 A ″ground″ Fuse, Enclosure

Terminal Designation

1 – Line

2 – Line Neutral or Panel Neutral

3 – Load or Load Power

4 – Load Neutral

7.4.2.5 Ground-fault calibration test

7.4.2.5.1 The ground-fault calibration test in 7.4.2.2 shall be conducted following the interrupting tests. The ground-fault trip level shall not be greater than 6.0 mA and not less than 3.5 mA.

7.4.2.6 Dielectric voltage-withstand test

7.4.2.6.1 Following the interrupting test, a circuit breaker and ground-fault circuit-interrupter shall be tested in accordance with 7.1.9 except as modified by 7.4.2.6.2.

7.4.2.6.2 No opposite polarity dielectric voltage-withstand tests shall be performed on single-pole devices. The opposite polarity dielectric voltage-withstand test shall be performed between the line terminals with the contacts open on 2-pole devices. During dielectric withstand tests the neutral terminals and/or lead shall be connected into the test circuit only during the test between live parts and the overall enclosure. The neutral terminals shall be considered to be live parts.

7.4.3 High Available Fault-Current Circuits

7.4.3.1 These requirements specify the additional performance requirements with which a circuit breaker and ground-fault circuit-interrupter shall comply if it is to be acceptable with an interrupting rating greater than 5 kA.

7.4.3.2 The selection of samples and the test methods shall be in accordance with 7.1.11 except as otherwise noted in 7.4.3.3 and 7.4.3.4.

7.4.3.3 The tests indicated in Table 7.4.3.1 shall be conducted in the sequence shown.

Table 7.4.3.1
Test sequence

1.	200-percent current calibration
2.	Ground-fault calibration
3.	Interrupting test
4.	Trip out
5.	Ground-fault calibration (see 7.4.2.5.1)
6.	Dielectric voltage-withstand (see 7.1.11.5)

7.4.3.4 For the short-circuit tests, the method of operation shall be as indicated in Table 7.4.3.2 and the connection diagrams shown in Figure 7.4.2.2 shall be used.

Table 7.4.3.2
Interrupting operations

Circuit breaker		Test with bus bar[a]	Test with leads[a]	
Frame ratings	AC voltage rating	″O″	″O″	″CO″
All	120 or 127	A	A	B
All	120/240	C	C	D[b]

[a] Letters indicate diagram in Figure 7.4.2.2.

[b] Only one pole is required to be tested when the circuit breaker design has been previously evaluated for the interrupting rating.

7.4.4 Ground-Fault Circuit-Interrupter Tests

7.4.4.1 The tests from Annex B, Ref. No. 12 that are referenced in this section, shall be performed in accordance with the requirements of those standards, except as modified by the requirements in this section.

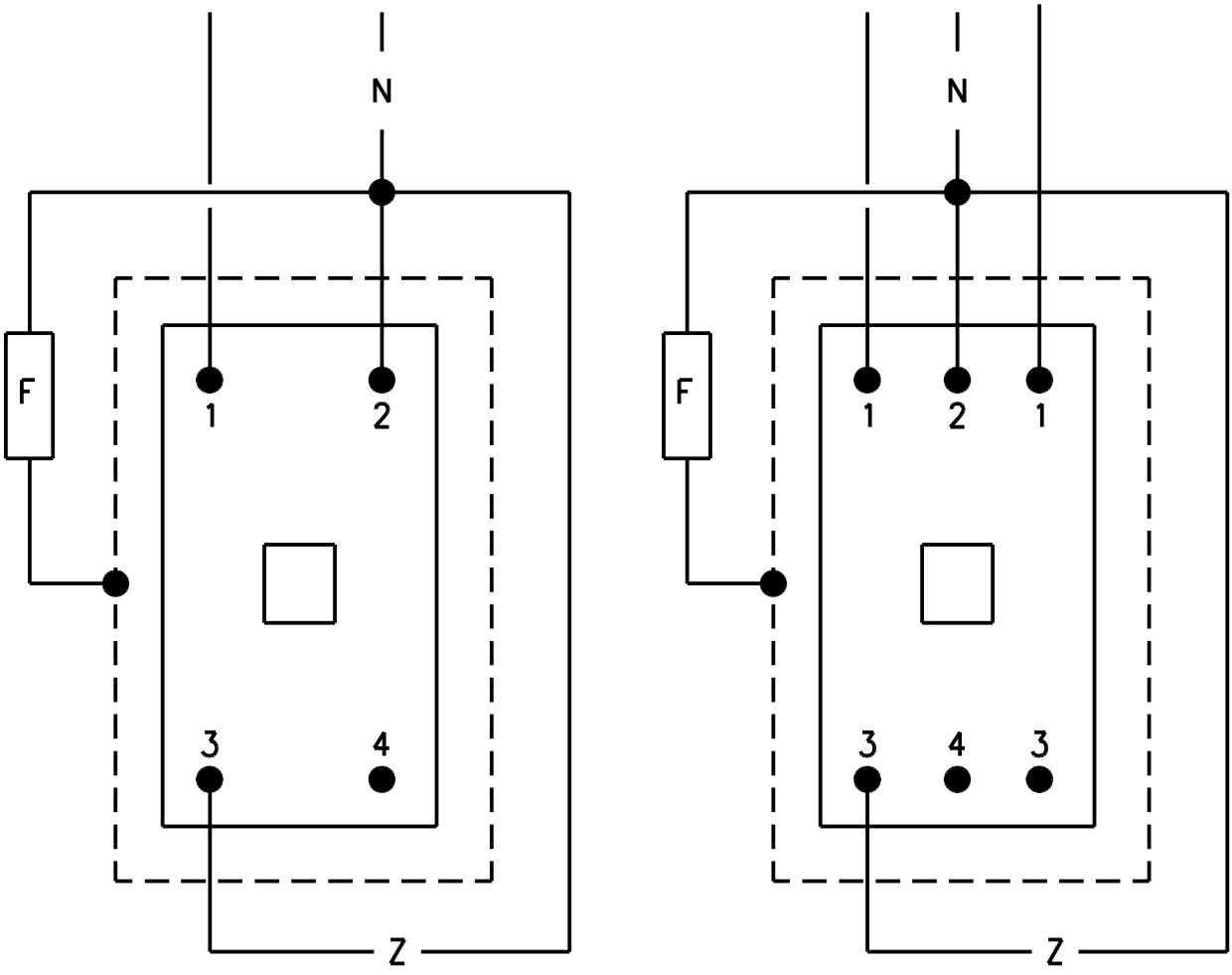
7.4.4.2 For the low resistance ground-fault test a sample, which shall be permitted to be previously untested, shall be connected to a supply adjusted to the rated voltage, plus 10 percent, minus 15 percent, under both open and closed circuit conditions. A resistance shall be adjusted to obtain six times the rated current. The resistance shall be connected between each ungrounded conductor load terminal, in turn, and the grounded conductor of the supply as indicated in Figure 7.4.4.1. The current shall be initiated by turning the circuit breaker on. The circuit breaker shall operate to open the circuit within the time specified by the equation, with a plus tolerance of 25 percent if the average of ten operations with each pole does not exceed the time specified by the equation. The allowable operating time ″T″ in seconds shall be calculated from the equation:

$$T = \left[\frac{10}{V}\right]^{1.43}$$

in which:

V is the closed circuit voltage at the line terminals of the circuit breaker.

Figure 7.4.4.1
Low resistance fault circuit connections



S2279A

N – Neutral

Z – Load Impedance

F – 30 A ″ground″ Fuse, Enclosure

Terminal Designation

1 – Line

2 – Line Neutral or Panel Neutral

3 – Load or Load Power

4 – Load Neutral

7.4.4.3 For the normal temperature test, a previously untested sample shall be tested unenclosed. The temperature limits of this standard shall be applied, except for parts of the ground-fault circuit-interrupter where the temperature limits in Annex B, Ref. No. 12 shall be applied. The circuit breaker shall be connected to a supply – 120 V or 127 V supply for a single-pole device and 120/240 V or two phases of a 208Y/120 V supply for a 2-pole device – adjusted to rated voltage. Loads shall be connected to the load terminals that cause the load conductors, including the neutral conductor, to carry rated current. A resistance adjusted to draw 3.9 mA shall be connected between one ungrounded load terminal and the grounded supply terminal.

7.4.4.4 For the operation test, a sample, which may, at the option of the submitter, be previously untested, shall be connected to a supply adjusted to rated voltage. The circuit breaker shall be switched on and immediately caused to operate by means of the supervisory (test) circuit. This cycle shall be repeated 24 times without intentional delay. The circuit breaker shall operate properly each time. Performance is acceptable if, when subjected to the ground-fault calibration test at the conclusion of the test, the ground-fault trip level is between 4.0 and 6.0 mA.

7.4.4.5 For the resistance to environmental noise test, a sample shall be subjected to the tests described in Annex B, Ref. No. 12.

7.4.4.6 For the ground-fault test sequence, a previously untested sample shall be subjected to humidity conditioning, leakage-current measurement, voltage-surge testing, high-resistance ground fault, resistance to false tripping, and dielectric voltage-withstand tests (see the requirements specified in Annex B, Ref. No. 12 which are modified for all ratings by 7.4.4.7 and 7.4.4.8 and for 120/240 V rated devices by 7.4.4.9 – 7.4.4.14).

7.4.4.7 The duration of the humidity conditioning shall be 168 hours (see the requirements specified in Annex B, Ref. No. 12).

7.4.4.8 The leakage current shall be measured between metal foil in contact with that portion of the circuit breaker and ground-fault circuit-interrupter which would protrude through the dead front of the enclosure and the grounded supply conductor (see Leakage Current Test specified in Annex B, Ref. No. 12).

7.4.4.9 For the voltage surge test, the surge shall be applied to each ungrounded conductor, in turn (see Voltage Surge Test specified in Annex B, Ref. No. 12).

7.4.4.10 For the high resistance ground-fault test, the test shall be performed with the resistance R_b or R_2 connected to one ungrounded conductor and repeated with the resistance connected to the other ungrounded conductor for a 120/240 V circuit breaker. If it can be determined from tests at 25°C (77°F) that performance is the same when the resistance is connected to either ungrounded conductor of a 120/240 V circuit breaker, the remainder of the test sequence may, at the option of the submitter, be performed with the resistance connected to only one conductor (see Annex B, Ref. No. 12).

7.4.4.11 In addition to the 85 – 110 percent of line voltage consideration, the absence of power from each ungrounded conductor of a 120/240 V circuit breaker, in turn, shall be considered to determine the most adverse operation (see Annex B, Ref. No. 12).

7.4.4.12 Loads connected between each ungrounded conductor of a 120/240 V circuit breaker and the grounded conductor shall be considered, in turn, as well as loads connected between the ungrounded conductors (see Annex B, Ref. No. 12).

7.4.4.13 The grounded neutral test shall be conducted with resistance R_b or R_2 connected to one ungrounded conductor and repeated with the resistance connected to the other ungrounded conductor of a 120/240 V circuit breaker. The test shall also be performed with the value of R_b (or R_2) set to 500 ohms (see Annex B, Ref. No. 12).

7.4.4.14 For the resistance to false tripping test, in addition to the 85 – 110 percent of line voltage consideration, the absence of power on each ungrounded conductor of a 120/240 V circuit breaker, in turn, shall be considered. Loads connected between each ungrounded conductor to the grounded conductor, in turn, shall be considered as well as loads connected between the ungrounded conductors of a 120/240 V circuit breaker (see Annex B, Ref. No. 12).

7.5 Circuit breakers with equipment ground-fault protection

7.5.1 General

7.5.1.1 This section covers additional requirements for circuit breakers with equipment ground-fault protection that provide overcurrent protection and ground-fault protection of equipment.

7.5.2 Circuit Breaker Test Sequences

7.5.2.1 General

7.5.2.1.1 Representative circuit breakers with equipment ground-fault protection shall be subjected to the tests in Table 7.5.1 in the sequence shown. At the option of the manufacturer, Test Sequences X, Y, and Z may be combined. When combining X-Y-Z or Y-Z Sequences, the Interrupting test, 7.1.7, in the Y Sequence may be omitted.

7.5.2.1.2 Representative circuit breakers with equipment ground-fault protection shall be selected in accordance with Table 7.1.1.1.

7.5.2.1.3 The tests in Table 7.5.1 shall be performed in accordance with Standard Circuit Breakers, Section 7.1, except as modified by the requirements in this section.

Table 7.5.1
Test sequences[a]

Circuit-breaker type			Fully magnetic and solid-state trip[a] and uncompensated thermal breakers[b] rated 25°C or 40°C[c, d]			Compensated thermal breakers[e]		
Test		Clause	Sequence			Sequence		
			X	Y	Z	X	Y	Z
1.	200 percent Calibration at 25°C (77°F)	7.1.2.2	X	X	X	X	X	X
2.	135 percent Calibration at 25°C (77°F)	7.1.2.3	X			X	X	
3.	200 percent Calibration at 40°C (104°F)	7.1.2.2				X		
4.	135 percent Calibration at 40°C (104°F)	7.1.2.3				X		
5.	Ground-fault calibration	7.5.2.2	X	X	X	X	X	X
6.	Overload	7.1.3	X			X		
7.	100 percent Calibration at 40°C (104°F)[f,g,h]	7.1.2.4, 7.1.4	X			X		
8.	Temperature and 100 percent calibration at 25°C (77°F)[i]	7.1.2.4, 7.1.4	X			X		
9.	Endurance	7.5.2.3.1		X			X	
10.	200 percent Calibration at 25°C (77°F)	7.1.6		X			X	
11.	135 percent Calibration at 25°C (77°F)	7.1.6		X			X	
12.	135 percent Calibration at 40°C (104°F)[j]	7.1.6					X	
13.	Interrupting	7.5.2.4.1, 7.5.2.4.2		X[k]	X[l]		X[k]	X[l]
14.	200 percent Trip-out at 25°C (77°F)	7.1.8		X	X		X	X
15.	Ground-fault calibration	7.5.2.5.1	X	X	X	X	X	X
16.	Dielectric voltage-withstand	7.5.2.6.1, 7.5.2.6.2	X	X	X	X	X	X

X – Indicates test required.

Table 7.5.1 Continued on Next Page

Table 7.5.1 Continued

Circuit-breaker type		Fully magnetic and solid-state trip[a] and uncompensated thermal breakers[b] rated 25°C or 40°C[c, d]			Compensated thermal breakers[e]		
Test	Clause	Sequence			Sequence		
		X	Y	Z	X	Y	Z

[a] Circuit breakers whose automatic operation does not depend on the heating effect of current.

[b] Circuit breakers whose automatic operation depends on the heating effect of current and are affected by changes in ambient temperature.

[c] If the degree of compensation used in a circuit breaker is such that it will not carry rated current at 40°C (104°F), it may, at the option of the manufacturer, be tested as a 25°C (77°F) circuit breaker.

[d] If a circuit breaker includes any thermal compensation in its tripping mechanism, and if the manufacturer desires to have the circuit breaker marked ″40°C″, it shall be subjected to the tests for a compensated thermal circuit breaker.

[e] Circuit breakers whose automatic operation depends on the heating effect of current, and which incorporate means for counteracting the effect of change in ambient temperature.

[f] This test may be performed after the temperature and 100 percent calibration tests at 25°C (77°F).

[g] Applies only to circuit breakers rated 40°C (104°F).

[h] For uncompensated thermal circuit breakers rated 40°C (104°F), the test may be combined with the temperature test if the ambient temperature is 40°C (104°F) during the temperature test.

[i] Temperature and 100 percent calibration shall be conducted at rated voltage if a voltage supply is required for operation.

[j] May be omitted if the tripping time at 135 percent of rated current in a 25°C (77°F) ambient after the endurance test is no more than it was before the endurance test.

[k] Test current shall be per Table 7.1.7.3 and operations shall be O-t-CO, where t is minimum of 2 minutes, maximum of 1 hour.

[l] Test current shall be per Table 7.1.7.2 and operations shall be per Table 7.1.7.1 or Table 7.5.2.

Table 7.5.2
Z sequence
Interrupting test operations[a]

Circuit breaker type	Frame ratings	Operations on each pole		Common operations[a]	Total number of operations
		″O″	″CO″	″O″	
1-pole	All	B	B	A	3
Multipole rated 120/240	All	D	D	C	5

[a] Letters indicate diagram in Figure 7.5.2.

7.5.2.2 Ground-fault calibration test

7.5.2.2.1 The ground-fault trip current shall be within ± 15 percent of the marked tripping current. The ground-fault calibration test shall be performed on each pole, one at a time, with the pole under test connected as shown in Figure 7.5.1. If a voltage supply is required, the representative circuit breaker shall be connected to a 60 Hz supply and the supply adjusted to rated voltage. The resistance (R) shall be reduced until tripping occurs. The ground-fault trip current measured at the time of tripping shall be recorded.

7.5.2.3 Endurance test

7.5.2.3.1 If the device includes an integral test circuit, 10 percent of the ″with current″ operations of the Endurance test, 7.1.5, is to be performed as follows:

a) Turn the circuit breaker on.

b) Depress the test switch to cause tripping.

c) Relatch the circuit breaker.

7.5.2.4 Interrupting test

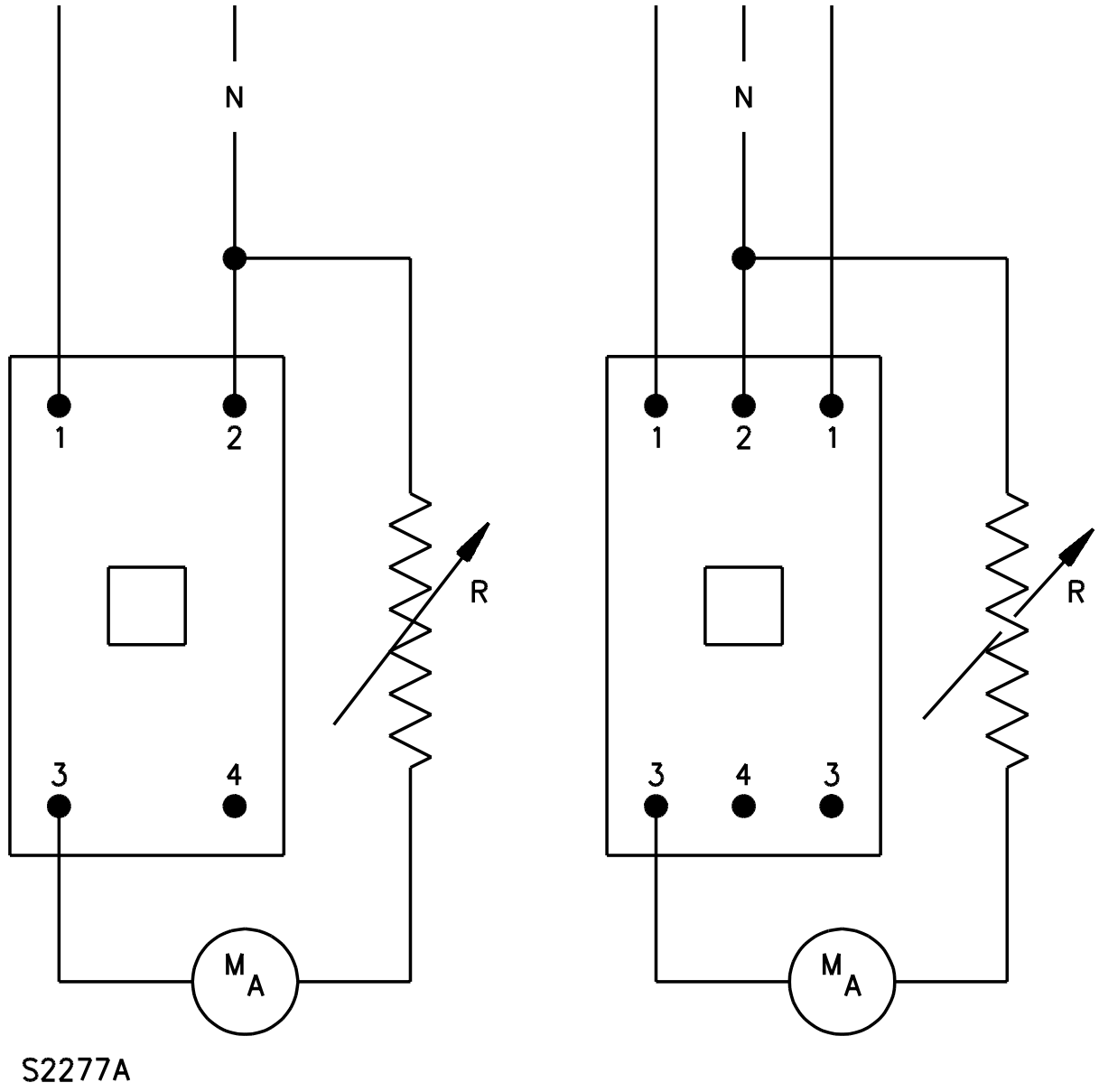
7.5.2.4.1 For the interrupting test, representative circuit breakers with equipment ground fault protection shall be connected and tested in accordance with the Interrupting test, 7.1.7, except that a multi-pole design rated 120/240 volts or a single-pole design shall be connected in accordance with Figure 7.5.2 and the operations shall be in accordance with Table 7.5.2.

7.5.2.4.2 For the Y-Sequence Interrupting test, 7.1.7, the devices are to be connected as described for the common operation in 7.5.2.4.1.

7.5.2.5 Ground-fault calibration test

7.5.2.5.1 The ground-fault calibration test in 7.5.2.2.1 shall be conducted following the interrupting test. The ground-fault trip level shall be within ±15 percent of the marked tripping current.

Figure 7.5.1
Ground-fault trip level



N – Neutral

Terminal Designation

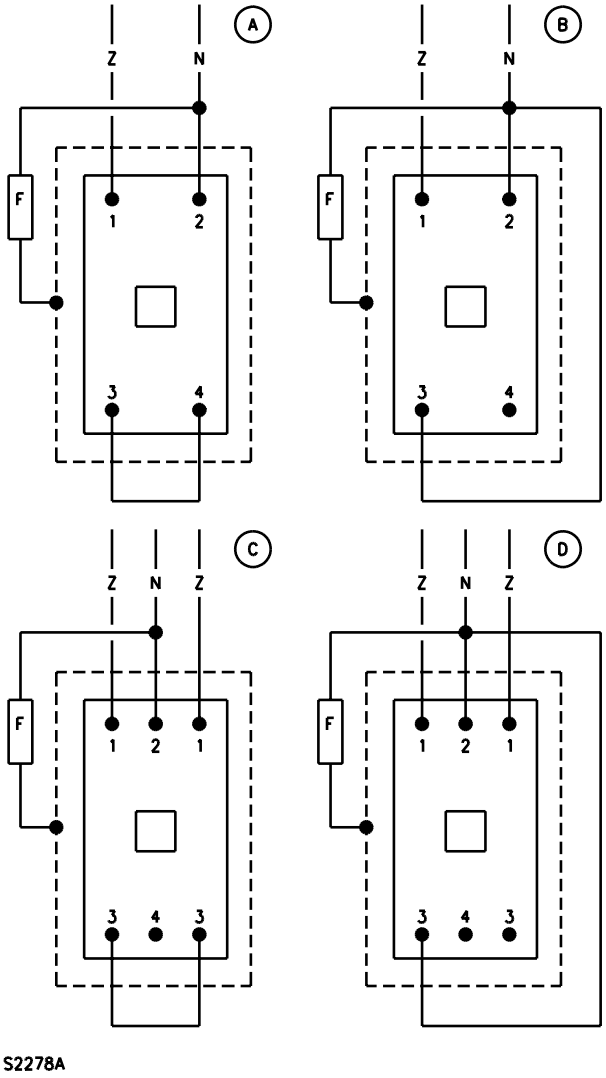
1 – Line

2 – Line Neutral or Panel Neutral

3 – Load or Load Power

4 – Load Neutral

Figure 7.5.2
Interrupting test connections



N – Neutral

Z – Limiting Impedance

F – 30 A ″ground″ Fuse, Enclosure

Terminal Designation

1 – Line

2 – Line Neutral or Panel Neutral

3 – Load or Load Power

4 – Load Neutral

7.5.2.6 Dielectric voltage-withstand test

7.5.2.6.1 A circuit breaker with equipment ground-fault protection shall be tested in accordance with 7.1.9, except as modified by 7.5.2.6.2.

7.5.2.6.2 Opposite polarity dielectric voltage-withstand tests are not required between terminals to which electronics assemblies are connected.

7.5.3 High Available Fault Current Circuits Tests

7.5.3.1 These requirements specify the additional performance requirements for devices that are intended to be marked with an interrupting rating greater than the value for which the device was tested in the Z Sequence Interrupting test, 7.1.7.

7.5.3.2 The selection of representative circuit breakers and the test methods is to be in accordance with High available fault current test sequence, Section 7.1.11, except as noted in 7.5.3.3 – 7.5.3.5.

7.5.3.3 The tests indicated in Table 7.5.3 are to be performed in the sequence shown.

Table 7.5.3
Test sequence

1. 200-percent current calibration (see 7.1.2.2)
2. Ground-fault calibration (see 7.5.2.2.1)
3. Interrupting test (see 7.5.3.4)
4. Trip out (see 7.1.11.4)
5. Ground-fault calibration (see 7.5.2.5.1)
6. Dielectric voltage-withstand (see 7.5.3.5)

7.5.3.4 For the Interrupting test, 7.1.11.3, the representative devices are to be connected as shown in Figure 7.1.7.1 except that the line neutral terminal is to be connected to the system neutral for any cases where such a connection is required to provide power to an electronics assembly.

7.5.3.5 The dielectric voltage-withstand test shall be conducted in accordance with 7.1.11.5, except that opposite polarity tests are not required between terminals to which electronic assemblies are connected.

7.5.4 Ground Fault Protection Tests

7.5.4.1 A representative circuit breaker or circuit breakers shall be subjected to the temperature test and calibration test requirements in Annex B, Ref. No. 14. The circuit breaker to be tested shall be representative of the group of devices being considered. If one device cannot be considered as representative of the group, then sufficient circuit breakers are to be selected to represent the group.

7.6 Integrally fused circuit breakers and high fault protectors

7.6.1 This section covers additional requirements for fused circuit breakers and the requirements for accessory high-fault protectors.

7.6.2 The selection of samples and test methods shall be in accordance with Standard Circuit Breakers, Section 7.1, except as otherwise noted.

7.6.3 Tests indicated in Tables 7.1.1.2 and 7.6.1 shall be conducted in the sequence shown. If the circuit breaker construction has previously been found to comply with the test sequence specified in Table 7.1.1.2, only the ″Z″ test sequence is required for the minimum ampere rating and only the ″X″ and ″Z″ test sequences are required for the maximum ampere rating.

Table 7.6.1
Test sequence

Test		Clause	Circuit breaker rating, amperes	
			Minimum	Maximum
1.	200 percent calibration	7.1.2.2	X	X
2.	Interrupting tests			
	A. Crossover (protectors and fuses)[a]	7.6.10	–	X
	B. Crossover (dummy fuses or protectors)[b]	7.6.10	–	X
	C. Maximum IC	7.6.13	X	X
	D. Maximum energy	7.6.15	–	X
	E. 25 x ampere rating (no less than 1000 A)[c]	Note [c]	–	X
3.	250 percent calibration	7.1.11.4	X	X
4.	Dielectric voltage-withstand (two times voltage rating, 900 V minimum)	7.1.11.5	X	X

Note

X – Indicates test required.

[a] ″O″ operation conducted slightly above crossover to provide for operation of protectors or fuses. Cotton indicators shall be used when crossover current is less than interrupting test current. See 7.1.7.2.

[b] With dummy fuses, ″O″ and ″CO″ operation, no cotton indicators used.

[c] Applicable only if crossover point is less than ″common″ interrupting rating current in Table 7.1.7.2. Fusible elements shall not open during tests. ″O″ and ″CO″ operation required. No cotton indicators used.

7.6.4 The tests indicated in Table 7.6.1 are based on the use of one protector or accessory protector having specific let-through characteristics for all ratings in a frame size. If two or more protectors or accessory protectors having different let-through characteristics are used, all of the above tests shall be conducted on the maximum and minimum ratings of the circuit breaker associated with each protector.

7.6.5 For the temperature test, temperatures shall not exceed the limits specified in 7.1.4. In addition, temperature rises on the protector or fuse terminals and casings shall not exceed 85°C (153°F) unless the insulating materials are rated for the temperature attained, based on use in 40°C (104°F) ambient.

7.6.6 The power factors for the tests shall be based on the prescribed current as tabulated in Table 7.1.7.4.

7.6.7 The peak line to neutral arc voltage in any phase during any test from crossover to maximum interrupting current shall not exceed 3000 V.

7.6.8 During the interruption tests, the fuses, protectors, or accessory protectors shall remain intact, not ignite cotton, or emit molten metal.

7.6.9 Each group of the following series shall be permitted to be conducted on new untested combination product samples: Tests (see Table 7.6.1) 2A, 2B, and 4; Tests 2E and 4; Tests 2D and 4; Tests 2C, 3, and 4. During Test Sequences X, Y, and Z the protectors or fuses shall not open, except that they shall open during the Z sequence interrupting test for a combination if the cross-over point current is less than the ″common″ interrupting rating current shown in Table 7.1.7.2.

7.6.10 The combination of devices shall be caused to interrupt a circuit, 3-phase for a 3-phase rated device, of available current not less than the value determined from the intersection of the circuit breaker and fuse, protector, or accessory protector, clearing time versus current curves, under ″O″ operation. Except as permitted by 7.6.11, the circuit breaker with any fuse or protector locations bridged by a solid bus shall then be caused to interrupt this circuit once under ″CO″ and once under ″O″ operation. Random closing shall be used for all operations. See Table 7.6.1, Tests 2A and 2B.

7.6.11 The ″CO″ and ″O″ operations with the fuse or protector locations bridged need not be conducted if the circuit breaker construction has been successfully evaluated for an interrupting rating at least equal to the crossover current.

7.6.12 During the test of 7.6.10 with live fuses, protectors, or accessory protectors, the fuses, protectors, or accessory protectors shall clear (for a three phase circuit at least two of three; for a single phase circuit at least one of two). If this is not the case, the current shall be increased slightly and the test repeated to cause the fuses, protectors, or accessory protectors to clear.

7.6.13 For Test 2C of Table 7.6.1, the tests on the overall combination shall be conducted on samples using protectors, accessory protectors, or fuses that are in the ″as received″ condition and also on sample protectors, accessory protectors or fuses that have been exposed to temperature conditioning, 90°C (194°F) for 24 hours. The samples shall be tested not later than 1 hour after removal from the conditioning environment. New circuit breakers shall be permitted to be used for the test of conditioned fuse samples. Oven conditioning shall not be required on high-fault protectors or fuses with tubing material of ceramic, polyester, glass melamine, or equivalent nonhygroscopic material when the fuse or protector uses a sand filler or no filler.

7.6.14 The combination of devices shall be caused to interrupt a circuit, 3-phase for a 3-phase rated device, of rated interrupting capacity – Test 2C – once under ″O″ operation and once under ″CO″ operation. During the ″O″ operation, start of arcing in any one phase shall be in the range of 60 – 90 degrees on the voltage wave. If start of arcing is after 90 degrees, with closing at zero, the test shall be considered satisfactory if additionally conducted:

a) With closing at 90 degrees on the voltage wave, and

b) With closing at 45 degrees on the voltage wave.

Only one pole of a multipole device shall be subjected to each such operation.

7.6.15 For Test 2D of Table 7.6.1, the tests on the overall combination shall be conducted on samples using protectors, accessory protectors, or fuses that are in the ″as received″ condition and also on sample protectors, accessory protectors, or fuses that have been humidity conditioned, 95 ±5 percent relative humidity at 20 – 25°C (68 – 77°F) for 5 days. The samples shall be tested not later than 1 hour after removal from the conditioning environment. New circuit breakers shall be permitted to be used for the test of conditioned fuse samples.

7.6.16 The combination of devices shall be caused to interrupt a circuit such that the peak current let-through of the combination is in the range of 70 – 100 percent of the peak value of the symmetrical component of the alternating current of the circuit under the ″O″ operation. The closing shall be at zero degrees on the voltage wave. This operation may be on either a 3-phase circuit with any 1-phase meeting these conditions, or on a single-phase circuit. This operation shall not be required for a fuse, protector, or accessory protector that is satisfactorily evaluated separately. If the circuit breaker impedance or operation interferes with the performance of this test, the operation shall not be conducted.

7.6.17 The conditions mentioned in 6.6.13 for investigating an adhesive used in a high-fault protector or an accessory high fault protector are:

a) Oven conditioning as described in 7.6.18: and

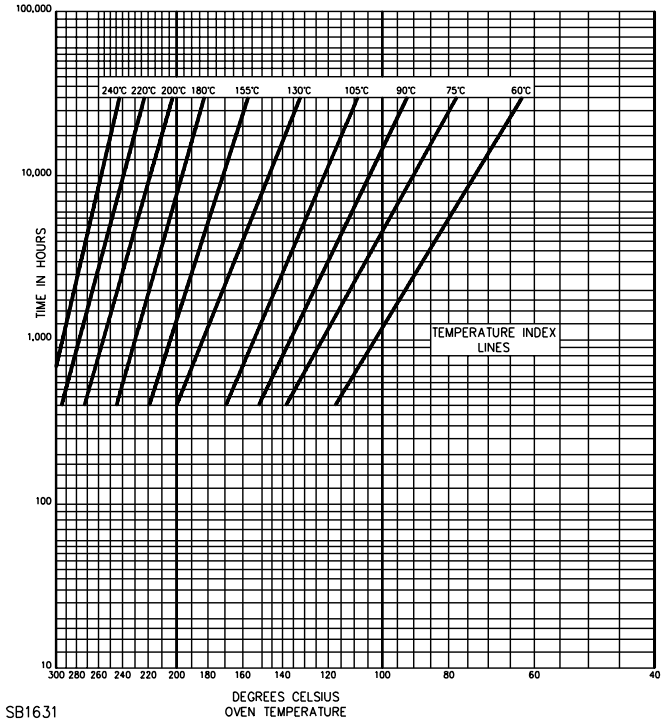
b) Humidity conditioning as described in 7.6.19.

7.6.18 The oven conditioning in 7.6.17 shall be conducted for 1000 hours. The oven temperature shall be taken from the intersection of a selected temperature-index line in Figure 7.5.1 with the 1000-hour line, where the temperature index T is the maximum observed operating temperature of the adhesive. Intermediate temperature indices shall be interpolated. The maximum observed operating temperature is that attained when the protector is carrying 100 percent of rated current in combination with any circuit breaker in or with which it is to be used and while in an ambient of 25 or 40°C (77 or 104°F) as appropriate. On the same selected temperature-index line in Figure 7.6.1, a shorter or longer time at the corresponding higher or lower temperature, respectively, shall be permitted if agreeable to the submitter and the testing agency, if the time is not less than 300 hours. See also 7.6.17 – 7.6.20.

7.6.19 The humidity conditioning referred to in 7.6.17 shall be 5 days in a relative humidity of 93 ±2 percent at 32.0 ±2.0°C (89.6 ±3.6°F).

7.6.20 After the conditioning, the protectors shall be brought to, and tested, at room temperature and humidity to determine their performance.

Figure 7.6.1
Aging time vs. aging temperature for adhesive



7.7 Adjustable circuit breakers

7.7.1 General

7.7.1.1 This section covers additional requirements for adjustable circuit breakers.

7.7.1.2 The number of samples shall be selected according to the requirements of Table 7.1.1.1.

7.7.2 Adjustable Current Setting (I_r)

7.7.2.1 A circuit breaker with an adjustable current setting (I_r) shall comply with the 200 percent, 135 percent, and 100 percent calibration test requirements described in 7.1.2.2 – 7.1.2.4.

7.7.2.2 The trip times, based upon the current setting (I_r), shall be in accordance with 7.1.2.2 and 7.1.2.3 and Table 7.1.2.2.1 for the 135 percent and 200 percent tests.

7.7.2.3 Tests shall be conducted at both the minimum and maximum current ratings for the frame and at the minimum and maximum current settings (I_r). Intermediate current ratings shall be tested if there is a change in the construction such as different current sensors.

7.7.2.4 If the long-time delay setting is adjustable, it shall be set at the minimum delay setting for the 100 percent test, and at the maximum delay setting for the 135 percent and 200 percent tests.

7.7.3 Short-Time Delay

7.7.3.1 A circuit breaker with a short-time delay shall comply with the calibration test requirements in 7.7.3.2 – 7.7.3.6.

7.7.3.2 The calibration test shall involve testing at two current levels. The first shall be at a current equal to 90 percent of the short-time pickup setting or the minimum of the band, whichever is less. The second test shall be at a current equal to 100 to 120 percent of the short-time pickup setting or the maximum of the band, whichever is greater.

7.7.3.3 The tests shall be conducted on both the maximum and minimum current ratings (I_n) for the frame and at both the maximum and minimum short-time pickup setting or band for each sample.

7.7.3.4 If the short-time delay setting is adjustable, it shall be set at the minimum delay setting for the test at 90 percent and at the maximum delay setting for the test at 100 to 120 percent.

7.7.3.5 For the test at 90 percent, the trip time shall be not less than the minimum time indicated on the manufacturer's trip curve for the short-time pickup and short-time delay setting under test. For the 100 to 120 percent test, the trip time shall be within the time indicated on the manufacturer's trip curve for the short-time pickup and short-time delay setting under test.

7.7.3.6 Terminal conductors shall be selected from Table 6.1.4.2.1 based upon the current setting (I_r) for the calibration tests in this section.

7.7.4 Instantaneous Pick-Up Setting

7.7.4.1 A circuit breaker that has an instantaneous pick-up setting shall comply with the calibration test requirements in 7.1.2.5.

7.7.5 Ground-Fault Trip Response

7.7.5.1 A circuit breaker that includes a ground-fault element shall comply with the calibration requirements in Annex B, Ref. No. 14.

7.8 Heating, air conditioning, and refrigeration (HACR) circuit breakers

7.8.1 A circuit breaker for group installation applications shall comply with Tables 7.1.1.1 and 7.1.1.2.

7.9 Remotely-operated circuit breakers

7.9.1 A remotely-operated circuit breaker shall comply with Tables 7.1.1.1 and 7.1.1.2. See 7.9.2.

7.9.2 Tests shall be additionally conducted on new sample sets with the following variations:

a) The remotely-operated circuit breaker shall be used for all ON-OFF and “CO” operations instead of the operating handle.

b) The first 25 endurance operations shall be conducted at 85 percent of the circuit breaker operator’s voltage rating, the next 25 operations shall be conducted at 110 percent of the operator’s voltage rating, and the balance of the operations shall be conducted at the operator’s rated voltage.

c) For the dielectric voltage-withstand tests with the circuit breaker in the OFF position, the circuit breaker handle mechanism shall be in the ON position and the remotely-operated circuit breaker in the OFF position. It is acceptable for the handle to move to the OFF position when the remotely-operated circuit breaker is moved to the OFF position.

7.10 Switching duty (SWD) rated circuit breakers

7.10.1 A circuit breaker rated 15 or 20 A, 347 V or less and intended to switch fluorescent lighting loads on a regular basis, see 9.10.1, shall in addition to other requirements in this standard be subject to the endurance and temperature test described in 7.10.2.

7.10.2 Additional circuit breakers shall be subjected to a temperature test, 7.1.4, after 999, 1000, 1001, 2999, 3000, and 3001 operations of endurance, 7.1.5. Three single-pole circuit breakers, or one pole of each of three multi-pole circuit breakers shall be tested. The voltage for the endurance test shall be 120, 127, 277, or 347 volts, as appropriate. After the 999th and 2999th operation, each circuit breaker shall be operated only to close the contacts for the temperature test. At the option of the submitter, the 1000, 1001, 3000, and 3001 cycles of operation may be performed with supply (full voltage or low-voltage) or without any supply connected. Except as noted in 7.10.3 – 7.10.5, the temperature rises on the line and load terminals shall be in accordance with 7.1.4.2.2 and Figures 7.1.4.1.1 and 7.1.4.1.2, and the temperature limit of the insulating material shall not be exceeded. To determine the temperature of the insulating material, a thermocouple shall be attached externally on the circuit breaker housing directly opposite the stationary contact.

7.10.3 If one temperature reading exceeds permitted limits (during the 999, 1000, 1001, 2999, 3000, or 3001 cycles), the circuit breaker shall be operated for three additional cycles (in addition to those performed), each cycle followed by measurement of constant temperatures. To be considered acceptable, all three additional temperature measurements shall be in compliance with the temperature limits.

7.10.4 If two temperature measurements on a single sample or one or more readings on each of the three samples exceed the limits specified, the results shall be considered not acceptable.

7.10.5 If two readings, one on each of two samples exceed the limits specified, three additional temperature measurements on each of the two circuit breakers on which excessive temperatures were recorded shall be obtained. To be considered acceptable, all six additional temperature measurements shall be in compliance with the temperature limits.

7.11 400 Hz rated circuit breakers

7.11.1 Except as permitted by 7.11.2, a circuit breaker, rated for use at 400 Hz, shall be subjected to the tests applicable to the type of circuit breaker as indicated in Table 7.1.1.2 and shall be tested on a 400 ±20 Hz supply. Samples shall be selected in accordance with 7.1.1.1 and 7.1.1.2.

7.11.2 A 400 Hz rated circuit breaker that is the same as a 60 Hz construction, except for possible calibration adjustment, shall only be subjected to the calibration test at 400 Hz ±20Hz, the overload test at 60 Hz, the temperature test at 400 Hz ±20 Hz, and the dielectric voltage-withstand test at 60 Hz if all of the following conditions are met:

a) Maximum ampere rating is 250 amperes or less;

b) Maximum voltage rating is 240 volts or less; and

c) Short-circuit interrupting rating is not more than one-half of the 60 Hz interrupting rating, but in no case more than 5 kA.

7.12 Draw-out circuit breakers

7.12.1 Electrical Continuity Test

7.12.1.1 The electrical continuity between the handle of conductive material, as described in 6.1.5.5, and the intended enclosure, and between any metal part of a draw-out unit intended to be grounded, as indicated in Draw-Out Circuit Breakers, Section 6.12, and the member of the stationary part that is intended to provide the grounding path, shall meet the requirements of 7.12.1.2 and 7.12.1.3.

7.12.1.2 The electrical continuity shall be such that the resistance does not exceed 0.06 ohm when tested as specified in 7.12.1.3.

7.12.1.3 Compliance with 7.12.1.2 shall be determined by measuring the voltage when a current of 30 A is passed between the parts in question. The current shall be derived from a 48 – 62 Hz or dc source, having an open circuit voltage, preferably not exceeding 30 V. A draw-out unit shall be in any position providing less than 3.2 mm (1/8 inch) clearance between the disconnect (primary and secondary) and the associated live part of the stationary unit. The voltage drop shall be measured between the two parts – within 150 mm (6 inches) of the stationary member to the farthest point on the draw-out unit – and the resistance shall be computed therefrom.

7.12.2 Dielectric Voltage-Withstand Test

7.12.2.1 The air gap between the circuit breaker terminals and the stationary terminals of a draw-out circuit breaker shall be capable of withstanding for one minute without breakdown, the application of a 48 – 62 Hz essentially sinusoidal potential of 1000 V plus twice the rated voltage.

7.13 Series-connected circuit breakers

7.13.1 General

7.13.1.1 This section covers additional requirements for circuit breakers intended to be used on a circuit having an available fault current higher than its marked interrupting rating by being connected on the load side of an acceptable overcurrent protective device.

7.13.2 Selection of Test Samples

7.13.2.1 The line-side overcurrent protective device shall be the maximum ampere rating for the combination connected in series in the application in which it is to be used. The load-side circuit breaker in each group or subgroup tested shall be as specified in 7.1.11.

7.13.2.2 Overcurrent protective devices in the as-received condition shall be used for the interrupting and the intermediate interrupting tests. If agreeable to the submitter and the testing agency, previously tested samples may be used.

7.13.2.3 A fuse used as the line-side overcurrent protective device shall be a Class CC, G, J, L, R, or T fuse or test limiter. Each fuse shall have such characteristics that, when tested on a single-phase circuit in accordance with the requirements for the class of fuse, the peak let-through current I_p and clearing I^2t would be not less than the corresponding values specified in Table 7.13.2.1, for the ampere rating of the largest fuse that can be installed in the intended fuseholder. To obtain the required values, it may be necessary to use a device of a different class or having a higher current rating (I_n). The values of I^2t and I_p shall be determined at the voltage rating of the fuse. If agreeable to the submitter and the testing agency, the determination may be made at the voltage rating of the series combination.

Table 7.13.2.1
Peak-let-through currents and clearing I^2t for fuses

Fuse rating, Amperes	Between threshold and 50 kA		100 kA		200 kA	
	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
			Class CC Fuses			
30	6	7	7.5	7	12	7
			Class G Fuses			
15	–	–	4	3.8	–	–
20	–	–	5	5	–	–
30	–	–	7	7	–	–
60	–	–	10.5	25	–	–
			300-Volt Class T Fuses			

Table 7.13.2.1 Continued on Next Page

Table 7.13.2.1 Continued

Fuse rating, Amperes	Between threshold and 50 kA		100 kA		200 kA	
	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
30	5	3.5	7	3.5	9	3.5
60	7	15	9	15	12	15
100	9	40	12	40	15	40
200	13	150	16	150	20	150
400	22	550	28	550	35	550
600	29	1000	37	1000	46	1000
800	37	1500	50	1500	65	1500
1200	50	3500	65	3500	80	4000
Class J and 600-Volt Class T Fuses						
30	6	7	7.5	7	12	7
60	8	30	10	30	16	30
100	12	60	14	80	20	80
200	16	200	20	300	30	300
400	25	1000	30	1100	45	1100
600	35	2500	45	2500	70	2500
800	50	4000	55	4000	75	4000
Class L Fuses						
800	80	10000	80	10000	80	10000
1200	80	12000	80	12000	120	15000
1600	100	22000	100	22000	150	30000
2000	110	35000	120	35000	165	40000
2500	–	–	165	75000	180	75000
3000	–	–	175	100000	200	100000
4000	–	–	220	150000	250	150000
5000	–	–	–	350000	300	350000
6000	–	–	–	350000	350	500000
Class RK5 Fuses[a,b]						
30	11	50	11	50	14	50
60	20	200	21	200	26	200
100	22	500	25	500	32	500
200	32	1600	40	1600	50	2000
400	50	5000	60	5000	75	6000
600	65	10000	80	10000	100	12000

[a] The value for a Class RK5 fuse is to be used when a Class RK1 fuse is specified for overcurrent protection.

[b] In Canada, Class RK5 fuses are designated as Class R.

7.13.2.4 A 300 V fuse may only be specified for series combinations with voltage ratings of 120, 127, 120/240, 240, or 277 V.

7.13.2.5 Fuses used for tests shall be selected from a lot from which samples have been selected and calibrated to determine that their I^2t and I_p characteristics comply with the prescribed values called for in 7.13.2.3. Two samples from the lot shall be calibrated if the fuses are of Class CC, G, J, R, or Class T rated 600 amperes or less, and one sample if the fuses are Class L or Class T rated greater than 600 amperes.

7.13.2.6 If, due to the current versus trip time characteristics of the overcurrent devices involved, devices used as line-side overcurrent protection do not clear during a test, the devices shall be permitted to be reused in later tests under either of the following conditions:

a) The devices when retested, do not clear. If the results are acceptable but the devices clear, the test shall be considered inconclusive and must be repeated.

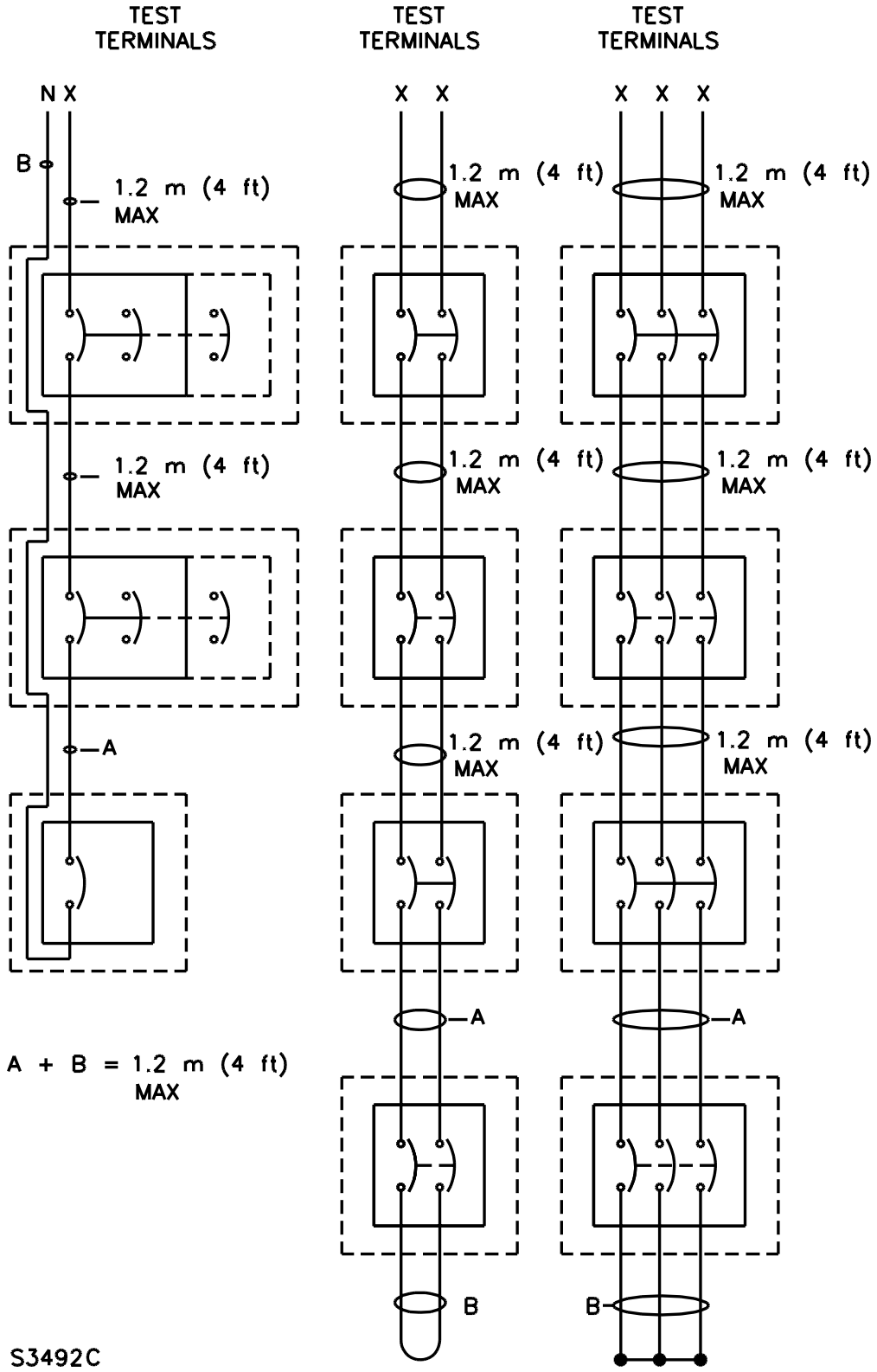
b) The internal resistance of each device that is to be reused was measured and recorded prior to the first test and is measured again prior to each subsequent test and does not show an increase. (It may be necessary to allow the devices to cool to room temperature prior to subsequent resistance measurements.)

7.13.3 Test Procedure

7.13.3.1 The ampacity of leads shall be as specified in Table 6.1.4.2.1. Determination of test-circuit characteristics shall be as specified in Annex C.

7.13.3.2 Except as permitted by 7.13.3.3 – 7.13.3.6, each overcurrent protective device shall be mounted in the smallest enclosure with which it is intended to be used, taking into account the required wire bending space. Openings shall be permitted in any enclosure if the combined area of all the openings does not exceed 10 percent of the total external enclosure area and if no opening is directly opposite a vent in a circuit breaker case. The enclosures shall be permitted to be connected by length(s) of conduit of any convenient trade size. Each lead, from test terminals to the line-side overcurrent protective devices, shall be not longer than 1.219 m (4 feet) per pole and shall be connected in accordance with Figure 7.13.3.1.

Figure 7.13.3.1
Connections for tests



7.13.3.3 The series overcurrent protective devices shall be permitted to be mounted within the end-use equipment that is intended to contain them and that is marked for use with the series combination. The line and load leads shall each be not longer than 1.219 m (4 feet). The load-side circuit breaker shall be positioned as closely as possible to the line-side overcurrent protective device.

7.13.3.4 Conduit need not be provided between test enclosures, but the enclosures shall be connected by a 10 AWG (5.3 mm^2) solid copper conductor. If conduit is not provided, the conductors outside the enclosure shall be restrained to prevent whipping during the test.

7.13.3.5 Fuses used as main devices need not be mounted in an enclosure.

7.13.3.6 Leads greater than 1.219 m (4 feet) in length shall be permitted if they were included in the circuit as part of the calibration.

7.13.3.7 When more than two circuit breakers in series are being considered, each intermediate and load-side circuit breaker that is being evaluated shall be subjected to a single type ″O″ and ″CO″ operation, followed by a trip-out test, 7.13.7 and a dielectric voltage-withstand test, 7.13.8. This may require several circuit breakers of the same rating to be used during the tests, but only the one specified for evaluation shall be subjected to trip-out and dielectric voltage-withstand tests.

For example, if four circuit breakers (A, B, C, and D) with the following ratings are being tested in series:

Circuit Breaker	IC Rating	Position
A	100 kA	Line-Side
B	65 kA	Intermediate
C	42 kA	Intermediate
D	22 kA	Load-Side

To evaluate the A-B-C-D combination for the 100 kA rating, each subgroup shall be evaluated with only the circuit breakers in that subgroup in the circuit for both type ″O″ and ″CO″ operations for the rating as follows:

Group	Evaluation Rating	Circuit Breaker Closed in ″CO″ Test
A–B	100 kA	B
A–B–C	100 kA	C
A–B–C–D	100 kA	D

Following the subgroup evaluation, for groups A–B, A–B–C, and A–B–C–D, circuit breakers B, C, and D respectively, shall be subjected to a trip-out test, 7.13.7, and a dielectric voltage-withstand test, 7.13.8.

During each evaluation (A–B, A–B–C, and so forth), the load-side sample shall be selected in accordance with 7.1.11.1.1 – 7.1.11.1.4.

7.13.3.8 A fuse shall be connected between the enclosure or enclosures and the line terminal of the pole least likely to arc to the enclosure, or the neutral, if the circuit breaker is rated 208Y/120 V, 120/240 V, 480Y/277 V, or 600Y/347 V ac. The connection shall be made to the load side of the limiting impedance by means of 10 AWG (5.3 mm^2) copper wire, not more than 1.829 m (6 feet) in length. The fuse shall be a 30 A nonrenewable type acceptable for branch circuit protection having a voltage rating not less than the rating of the device and an interrupting rating not less than the available current.

7.13.4 Closing Test

7.13.4.1 Random closing shall be used in all 3-phase tests. In tests in which the circuit is closed on the combination, controlled closing shall be used in single-phase tests so that closing occurs within 10 electrical degrees of the zero point of the supply-voltage wave.

7.13.5 Interrupting Test

7.13.5.1 The interrupting test shall be conducted in accordance with 7.1.11.3, except that the length of leads and the test enclosure shall be as specified in 7.13.3.2 and the tests under ″bus bar″ conditions need not be conducted.

7.13.5.2 For Type ″O″ tests, all overcurrent protective devices shall be fully closed and the test circuit shall be closed on the series combination.

7.13.5.3 For Type ″CO″ tests, all of the line-side overcurrent protective devices in the combination being tested shall be fully closed and the load side (ultimate) circuit breaker shall be closed on the circuit.

7.13.6 Intermediate Interrupting Test

7.13.6.1 Except as permitted by 7.13.6.2, a series combination having line-side fuses shall be tested at an available current as specified in Table 7.13.6.1 at maximum voltage. A dummy fuse shall be used in the fuseholder.

Table 7.13.6.1
Test current

Class of fuse in main	Fuse rating, Amperes	Test current, Amperes, minimum
RK5[a]	200	9,750
RK5[a]	400	19,500
RK5[a]	600	29,250
J or T	400	9,000
J or T	600	13,500
L or T	800	18,000
L or T	1200	27,000
L	1600	42,000
L	2000	52,500
L	2500	75,000
L	3000	90,000
L	4000	120,000
L	5000	150,000
L	6000	180,000

[a] In Canada, Class RK5 fuses are designated Class R.

7.13.6.2 The tests shall not be required if the required test current is equal to or less than the short-circuit interrupting rating of the load-side circuit breaker or circuit breakers either individually or in series.

7.13.6.3 With regard to 7.13.6.1, the series combination shall be subjected to the same operations as described in 7.13.5.2 and 7.13.5.3.

7.13.6.4 If the line-side overcurrent protective device is a circuit breaker, the series combination – if only two circuit breakers are being evaluated, or any subgroup of a larger group – shall be subjected to the same operations as described in 7.13.5.2 and 7.13.5.3 at the maximum current level that causes the load-side circuit breaker to open without also causing the line-side circuit breaker to open, except that if it can be shown that the current level is lower than the interrupting rating of the load-side circuit breaker being evaluated, this test shall not be required. See 7.13.6.6.

7.13.6.5 If the line-side overcurrent protective device is a current-limiting circuit breaker, the series combination shall be evaluated in the region below the current-limiting threshold of the line-side device, except that if it can be shown that the current level is lower than the interrupting rating of the load-side circuit breaker, this test shall not be required.

7.13.6.6 With regard to 7.13.6.4, the maximum current levels shall be in accordance with Table 8.1. To determine that the maximum current level used is correct, it will also be necessary to conduct the test at the next higher value of current to determine that the line-side circuit breaker opens.

7.13.7 Trip-Out Test

7.13.7.1 Following the interrupting and intermediate interrupting tests, the load-side circuit breaker being evaluated shall be subjected to a trip-out test as described in 7.1.11.4.

7.13.8 Dielectric Voltage-Withstand Test

7.13.8.1 Following the interrupting and intermediate interrupting tests, the load-side circuit breaker being evaluated shall be subjected to a dielectric voltage-withstand test as described in 7.1.11.5.

7.13.9 Interpretation of Test Results

7.13.9.1 The results shall be evaluated in accordance with 7.1.11.6.

7.14 Interchangeable-trip circuit breakers

7.14.1 An interchangeable trip circuit breaker shall comply with Tables 7.1.1.1 and 7.1.1.2.

7.15 High-intensity-discharge (HID) type circuit breakers

7.15.1 A circuit breaker rated 50 A maximum, 480 V or less and intended to switch high-intensity-discharge (HID) lighting loads on a regular basis, shall in addition to other requirements in this standard be subject to the Endurance Test, 7.1.5 and the Temperature Test, 7.1.4. See also 9.15.1.

7.15.2 Representative circuit breakers shall consist of three single pole, or one pole of each of three multipole circuit breakers of the maximum and minimum ampere ratings of the group to be covered. If there is a change in contacts in the group of ratings to be covered, additional representative circuit breakers will need to be tested.

7.15.3 Additional circuit breakers are to be subjected to the Temperature Test, 7.1.4, after 999, 1000, 1001, 2999, 3000 and 3001 operations of endurance. The endurance test shall be in accordance with Endurance Test, 7.1.5, except that the load shall have a power factor in the range of 45 – 50%. After the 999th and 2999th operation, each circuit breaker is to be operated only to close the contacts for the temperature test. The 1000, 1001, 3000 and 3001 cycles of operation may be performed with supply (full voltage or low voltage) or without any supply connected. Except as noted in 7.15.4 – 7.15.6, the temperature rises on the line and load terminals shall be in accordance with 7.1.4.2.2 and Figures 7.1.4.1.1 and 7.1.4.1.2, and the temperature limit of the insulating material shall not be exceeded. To determine the temperature of the insulating material, a thermocouple is to be attached externally on the circuit breaker housing directly opposite the stationary contact.

7.15.4 If one temperature reading exceeds permitted limits (during the 999, 1000, 1001, 2999, 3000, or 3001 cycles), the circuit breaker is to be operated for three additional cycles (in addition to those performed), each cycle followed by measurement of constant temperatures. To be considered acceptable, all three additional temperature measurements shall comply with the temperature limits.

7.15.5 If two temperature measurements on a single circuit breaker or one or more readings on each of the three circuit breakers exceed the limits specified, the results are not acceptable.

7.15.6 If two readings, one on each of two circuit breakers, exceed the limits specified, three additional temperature measurements are to be obtained on each of the two circuit breakers on which excessive temperatures were recorded. To be considered acceptable, all six additional temperature measurements shall comply with the temperature limits.

7.16 Circuit breakers for use with 16 or 18 AWG wire

7.16.1 General

7.16.1.1 This section covers additional requirements for circuit breakers intended for use with 16 or 18 AWG wire. Circuit breakers intended for use with 16 AWG wire shall be rated 10 A. Circuit breakers intended for use with 18 AWG wire shall be rated 7 A or less. See also Circuit Breakers for Use with 16 or 18 AWG Wire, Section 9.17.

7.16.2 Circuit Breaker Test Sequences

7.16.2.1 General

7.16.2.1.1 The selection of samples for circuit breaker tests shall be in accordance with 7.1.1.2, except as otherwise noted. Wire used in the tests shall be Type MTW and have thermoplastic insulation with a jacket rated no greater than 90° C.

7.16.2.2 Temperature test

7.16.2.2.1 A temperature test shall be conducted in accordance with Section 7.1.4, except as modified by 7.16.2.2.2.

7.16.2.2.2 The line terminals of the circuit breaker shall be connected to the test circuit terminals using 1.219 m (4 ft) of Type MTW copper wire of the size for which the circuit breaker is intended to be used (16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers).

7.16.2.3 Endurance test

7.16.2.3.1 If the circuit breaker has not met the requirements pursuant to Section 7.1.5, an endurance test shall be conducted in accordance with Section 7.1.5 except as modified in 7.16.2.3.2.

7.16.2.3.2 The line terminal leads shall be Type MTW copper wire and shall be 16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers.

7.16.2.4 Interrupting test

7.16.2.4.1 An interrupting test shall be conducted in accordance with Section 7.1.7 except as modified in 7.16.2.4.2.

7.16.2.4.2 The line terminals of the circuit breaker shall be connected to the test circuit terminals using 610 mm (2 ft) of Type MTW copper wire of the size for which the circuit breaker is intended to be used (16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers).

7.16.3 High Available Fault Current Test Sequence

7.16.3.1 Tests shall be conducted in accordance with Section 7.1.11 except as modified in 7.16.3.2.

7.16.3.2 The line terminals of the circuit breaker shall be connected to the test circuit terminals using 610 mm (2 ft) of Type MTW copper wire of the size for which the circuit breaker is intended to be used (16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers).

7.16.4 Thermal Withstand Sequence

7.16.4.1 A thermal withstand test shall be conducted as described in 7.16.4.2 – 7.16.4.4.

7.16.4.2 The lowest current level at which the circuit breaker will trip instantaneously shall be found.

7.16.4.3 Current at 5 percent below the instantaneous trip level found in 7.16.4.2 shall be conducted through the circuit breaker. The current shall flow until the circuit breaker thermally trips. The wire shall not be damaged.

7.16.4.4 The wire used shall be Type MTW of the size for which the circuit breaker is intended (16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers).

7.17 4-pole circuit breakers

7.17.1 4-pole constructions of the same design as 3-pole constructions shall be permitted to be represented by 3-pole constructions, except that the 4-pole construction shall be substituted for the 3-pole construction in Test Sequence Y of Table 7.1.1.2.

7.17.2 4-pole constructions with protected neutrals shall include the neutral pole in the required calibration and trip-out tests in accordance with Table 7.1.1.2, based on its rating.

7.17.3 The requirements of 7.1.1.20 and 7.1.11.3.1.14 shall apply, except that the neutral pole of 4-pole constructions shall be connected to the enclosure or mounting surface.

8 Ratings

8.1 A circuit breaker shall be rated in amperes, volts, and frequency. A circuit breaker shall be permitted to be rated for ac, dc, or both.

8.2 A circuit breaker shall have one or more of the following voltage ratings: 24, 48, 60, 65, 80, 125, 125/250, 160, 250, 500, and 600 V for dc; and 120, 127, 120/240, 208, 208Y/120, 240, 277, 347, 480Y/277, 480, 600Y/347, and 600 V for ac.

8.3 The interrupting rating of a circuit breaker, or a circuit breaker frame with an interchangeable trip unit shall be the value as prescribed in Table 7.1.7.2, ″common″ for 2- and 3-pole, or one or more of the values shown in Table 8.1 that are higher.

Table 8.1
Current-interrupting ratings rms symmetrical or dc amperes

7,500	25,000	65,000
10,000	30,000	85,000
14,000	35,000	100,000
18,000	42,000	125,000
20,000	50,000	150,000
22,000		200,000

8.4 The interrupting rating of a circuit breaker frame with an interchangeable trip unit shall be permitted to be less than that of the frame in which it is to be used.

8.5 If the interrupting ratings of all ampere ratings of a frame size of a non-interchangeable trip circuit breaker are not the same, all such interrupting ratings shall be permitted to be incorporated in an appropriate marking if each interrupting rating is clearly associated with the circuit breaker ampere rating or ratings to which it applies.

8.6 A current-limiting circuit breaker shall be rated additionally in terms of peak current and I^2t let-through, together with the frequency related to the let-through values. The rating for peak current and I^2t let-through shall be provided in terms of let-through versus prospective current curve, or in tabulated form. Such information shall be made available by the manufacturer and shall correlate with the particular circuit breaker. The let-through for at least the threshold current, interrupting rating current, and one intermediate point shall be indicated.

8.7 A current-limiting circuit breaker shall have a threshold current rating not more than the lesser of either:

a) The value indicated in Table 8.2 corresponding to its interrupting-current rating, or

b) 65 times the maximum current of the circuit breaker frame size.

8.8 A circuit breaker with equipment ground-fault protection shall have a ground-fault trip level rating.

Table 8.2
Maximum threshold current for interrupting rating

Interrupting rating	Maximum threshold current Amperes-rms, symm. or DC
5,000	1,500
7,500	3,000
10,000	5,000
14,000	7,500
18,000	10,000
20,000	12,000
22,000	14,000
25,000	15,000
30,000	18,000
35,000	20,000
42,000	25,000
45,000	27,000
50,000	30,000
60,000	36,000
65,000	42,000
70,000	45,000
85,000	55,000
100,000	65,000
125,000	85,000
150,000	100,000
200,000	130,000

9 Markings

9.1 General

9.1.1 Details

9.1.1.1 Location of required markings shall be in accordance with the ″Location Categories″ given in Table 9.1. See Table 21.1.1 for location of markings on circuit breaker enclosures.

Advisory Note: For products intended for use in Canada, markings shall be in English or in French and English; caution and warning markings shall be in French and English. For products intended for use in Mexico, all markings shall be at least in Spanish. For products intended for use in the United States, all markings shall be at least in English. See Annex D for suitable translations of caution and warning markings.

9.1.1.2 A circuit breaker and a circuit breaker frame shall be marked with the manufacturer's name or trademark, or with other means for identifying the manufacturer, the electrical rating, and with the type designation or the equivalent. Location Category B. The symbols ∿ for AC, ⎓ for DC, or both, as applicable, shall be used. Additional wording may be provided.

9.1.1.3 The marking of a circuit breaker shall be durable and legible.

9.1.1.4 The determination of the durability of the marking shall take into consideration the material used, the security with which the marking is attached, and the degree of abuse expected because of the marking location.

9.1.1.5 Ink stamped marking shall not be easily obliterated.

9.1.1.6 Paper stickers are not acceptable for the marking of a circuit breaker. A paper label with an adhesive that has been investigated and found to be acceptable and is not subject to delamination by moisture or heat shall not be considered a ″paper sticker.″

9.1.1.7 The ampere rating of a circuit breaker rated higher than 100 A shall be visible after removal of a trim or cover. Location Category B.

9.1.1.8 The ampere rating of a circuit breaker rated 100 amperes or less shall be molded, stamped, or etched into; ink-stamped onto; or similarly marked on the handle or the escutcheon area of the circuit breaker so as to be visible without removing the trim or cover of the enclosure. Location Category A. For handle marking of switches, see 13.4.

9.1.1.9 If the ampere rating marking is placed on the handle of the circuit breaker, the numerical value alone shall be considered to be adequate.

9.1.1.10 If a circuit breaker has characteristics which may affect adversely its operation under certain conditions of use, such as that of polarity or position, such characteristics shall be clearly indicated by a marking on the device. Location Category C.

Table 9.1
Location of markings circuit breaker

Clause numbers	Subject	Location categories[a] (See notes)
	General	
9.1.1.1	Location	–
9.1.1.2	Type designation	B
9.1.1.2	Manufacturer's name	B
9.1.1.2	Voltage rating	B
9.1.1.2	Frequency	B
9.1.1.3	Durability & legibility	–
9.1.1.7	Ampere rating – more than 100 A	B
9.1.1.8, 9.1.1.9	Ampere rating – 100 A or less	A
9.1.1.10 – 9.1.1.12	Special characteristics	C, F
9.1.1.13	Line and load	B
9.1.1.14	Factory identification	I
	Position Indication	
9.1.1.15	Open and Closed (On and Off)	A
9.1.1.16	Trip and Reset	B, D
9.1.1.17	Electrical operation (On and Off)	B, E
9.1.1.17	Electrical operation (Trip and Reset)	B, E

Table 9.1 Continued on Next Page

Table 9.1 Continued

Clause numbers	Subject	Location categories[a] (See notes)
	Terminations	
9.1.2.1 – 9.1.2.4	CU–AL	B
9.1.2.5, 9.1.2.6	Tightening torque	B, C
9.1.2.7	Maximum wire size	C, G
9.1.2.8	Multiple-conductor connectors	C
9.1.2.9, 9.1.2.10	60° C/75° C (140° F/167° F) – 100 A max or circuit breakers not marked for use with wire sizes of 1/0 or larger	B, C
9.1.2.11	Separately shipped connectors	C
9.1.2.12	Cable connection only	B
9.1.2.13	Bus bar sizes	B
9.1.2.14	90° C/Aluminum or copper-clad aluminum wire	B
	Interrupting Ratings	
9.1.3.1 – 9.1.3.3	Ratings	B, C
	Special Markings	
9.1.1.18	Nonconducting enclosures	C
9.1.1.19	Ventilated enclosures	B
9.1.1.20	2-pole – 3-phase rated	B
9.1.1.21	Multi-wire circuit	C
9.1.1.22	DC rated 3-pole	B
9.1.4.1	40° C	C
9.1.4.2	Class CTL	C
9.1.4.3	″Delta″–Replacement use only	C
9.1.4.4 – 9.1.4.5	100 percent continuous rated	B, C
9.1.4.6	Independent trip	B
9.2.1	Current limiting	C
9.3.1	Instantaneous trip	D
9.8.1	″HACR Type″	B
9.10.1	″SWD″	B
9.11.1	400 Hz	B
9.12.1	Draw-out circuit breaker	C
9.15.1	″HID″	B
9.17.1	16 or 18 AWG	C
9.18.1	4-pole with neutral	B
	CB/GFCI	
9.4.1	″Test″ function	A
9.4.2	″Class A″ marking	C
9.4.3, 9.4.4 – 9.4.6	Instructions	J
9.4.7, 9.4.8	Terminal identification	C, G

Table 9.1 Continued on Next Page

Table 9.1 Continued

Clause numbers	Subject	Location categories[a] (See notes)
	CB/Equipment ground-fault protection	
9.5.1	Ground-fault trip level/″Equipment Protection Only″	B
9.5.2 – 9.5.3	Terminal identification	C,G
	Fused circuit breakers	
9.6.1	Line and load	B
9.6.2	Identification	H
9.6.4	No open fuse tripping	B
	Adjustable	
9.7.1	Instantaneous trip	K
9.7.2 – 9.7.4	Type A and Type B	B
	Remotely-operated	
9.9.1	″Remotely Operated″	B
9.9.2	Equipment label	K
	Interchangeable Trip Units	
9.14.1	Manufacturer's name	K
9.14.2	Ampere rating	B
9.14.3	Frame designation & magnetic setting	K
9.14.4	50 A or less	C
	Rating plugs	
9.16.2	Current rating	B
9.16.3	Frame designation, manufacturer's name, and trip setting	K
9.16.4	50 A or less	C
	Accessories	
17.1, 17.2	Ratings	C
17.3	Shunt trip	C
17.4	Separately shipped	–
17.5	Separately shipped	C
17.6	External dropping resistor	C

NOTES

A Marking shall be visible without removing the trim or cover of enclosure.

Table 9.1 Continued on Next Page

Table 9.1 Continued

Clause numbers	Subject	Location categories[a] (See notes)
B Marking shall be visible without disassembling or removing device and shall be visible when the trim or cover of enclosure is removed, and may be visible with the trim or cover in place.		
C Marking may be on any convenient location, except on the rear.		
D Marking of ″TRIPPED″ and ″RESET″ need not be provided if on intended receiving device.		
E ″ON″ and ″OFF″ marking need not be visible on circuit breaker if on electrical operator.		
F Part replacement marking need not be visible when removable part is installed.		
G Marking shall be visible when wire connector is in place.		
H Fuse or protector identification shall be visible when cover over fuse or protector compartment is removed.		
I Marking may be anywhere on the circuit breaker.		
J Shipped with circuit breaker.		
K Marking need only be visible after removal of circuit breaker frame cover or equivalent.		
[a] At the option of the manufacturer, a higher order of location category may be used. The order of location category is A – K, with A being the highest.		

9.1.1.11 If the proper operation or installation of a circuit breaker is dependent upon an insulating barrier, liner, shield, or similar member being mounted on the circuit breaker or elsewhere, a marking on the circuit breaker shall be provided indicating the need for the barrier and giving all pertinent information, including its size and location. Location Category C.

9.1.1.12 Where the proper operation or installation of a circuit breaker is dependent upon a barrier or similar member that is part of the circuit breaker, such as a terminal cover, a marking shall be provided to indicate the need for the replacement of this part. Location Category F. The marking shall not be on the removable part.

9.1.1.13 Circuit breakers shall be marked ″line″ and ″load″ unless the construction and the test results are acceptable with the line and load connections reversed. A frame with interchangeable trip units that complies with 6.1.5.12 is not required to be marked ″line″ and ″load″. Location Category B.

9.1.1.14 If a manufacturer produces or assembles circuit breakers at more than one factory, each finished circuit breaker shall have a distinctive marking, which shall be permitted to be in code, by which it may be identified as the product of a particular factory. Location Category I.

9.1.1.15 A circuit breaker shall indicate clearly whether it is open or closed and such marking shall be visible with a trim or cover in place except that when enclosed it may require the opening of a hinged cover or door. Location Category A. For switches see 13.5.

9.1.1.16 If a circuit breaker handle has an additional or intermediate position which it takes upon automatic tripping, that position shall be marked to indicate that the circuit breaker has tripped. If the circuit breaker has two operating poles, either of which may trip independently of the other as described in 6.1.5.1, the tripping of each pole shall be separately indicated. Instructions for resetting the circuit breaker shall be included. See 9.1.1.17. Location Categories B and E. For switches see 13.5. Marking indicating the tripped position and the resetting instructions need not be provided on the circuit breaker if they are provided on the intended receiving device.

9.1.1.17 If the marking required in 9.1.1.15 to indicate whether a circuit breaker is in the open or closed position is not readily visible when an electrical operator is installed, the electrical operator shall clearly indicate whether the circuit breaker is in the ON or OFF position and may also indicate if the circuit breaker is in the tripped position. Location Categories B and E.

9.1.1.18 A circuit breaker not intended for use in a metal enclosure, see 7.1.1.19, shall be marked ″Suitable for use in a nonconducting enclosure only″. Equivalent wording shall be permitted. Location Category C.

9.1.1.19 A circuit breaker intended for use only in a ventilated enclosure shall either be marked with the type number, or equivalent, of the enclosure with which it is to be used or indicate the proper size of the enclosure and location and size of the ventilating openings. This marking shall be located where it will be readily visible after installation. See 7.1.4.2.4 and 18.4.1. Location Category B.

9.1.1.20 A 2-pole circuit breaker that has been investigated and found acceptable for controlling a 3-phase circuit shall be permitted to be marked ″1ø – 3ø″. Location Category B.

9.1.1.21 A multipole circuit breaker that is intended for use in only a multiwire circuit shall be marked with only a combination voltage rating, such as 480Y/277 V ac, provided that a 3-pole circuit breaker that is intended for use in only a single phase multiwire circuit includes in its marked voltage rating the term 1-phase or equivalent. Location Category C.

9.1.1.22 A 3-pole circuit breaker that is acceptable for 250 V direct current use shall be permitted to be marked ″250 V DC″ if it is clearly indicated that the rating applies to the use of at least two poles to control the circuit. Location Category B.

9.1.2 Terminations

9.1.2.1 The abbreviation ″CU″ for the word ″copper″ and ″AL″ for the word ″aluminum″ shall be permitted in any required marking.

9.1.2.2 A circuit breaker with wiring terminals intended and found acceptable for use with copper and aluminum conductors shall be marked ″Use copper or aluminum wire″ or with the abbreviations ″CU″, and ″AL″, ″CU/AL″, or the equivalent. Location Category B.

9.1.2.3 A circuit breaker with terminals intended and found acceptable for copper wire only shall be marked ″USE COPPER WIRE ONLY″ or with the abbreviation ″CU ONLY″. If the terminals are intended and found acceptable for aluminum wire only, the marking shall be ″USE ALUMINUM WIRE ONLY″ or ″AL ONLY″. Location Category B.

9.1.2.4 A circuit breaker with wiring terminals having a wire range of 14 – 10 AWG (2.1 – 5.3 mm^2) solid wire only shall be marked ″14 – 10 AWG SOLID″, ″14 – 10 AWG SOL.″, or with equivalent wording. The marking shall be located adjacent to the terminal and shall be visible after the circuit breaker has been installed in the intended manner. Location Category B.

9.1.2.5 With regard to the requirements in 6.1.4.2.3, a circuit breaker shall be marked to show a range of values or a nominal value of tightening torque to be applied to the clamping screws of all terminal connectors for field wiring. This marking shall be visible when a front or trim is removed. Location Category B.

9.1.2.6 Notwithstanding 9.1.2.5, a circuit breaker that is 38.1 mm (1-1/2 inch) wide per pole or less shall be permitted to have the marking at any convenient location on the circuit breaker except on the rear. Location Category C.

9.1.2.7 If the terminals of a circuit breaker will not acceptably hold the next larger size conductor than that required, the circuit breaker or the terminal shall be marked to indicate the maximum wire size. This marking shall be visible when the connector is in place. See 6.1.4.2.13. Location Categories C and G.

9.1.2.8 If a terminal is acceptable for the connection of more than one conductor in the same opening and is intended for such use, the marking shall indicate the proper connection. Location Category C.

9.1.2.9 A circuit breaker, circuit breaker frame, or interchangeable trip unit rated 100 A or less or that is not marked for use with wire sizes of 1/0 or larger, shall be marked as being suitable for 60°C (140°F), 75°C (167°F) only, or 60/75°C (140/167°F) wire, except that if the circuit breaker frame is so marked, the interchangeable trip unit need not be marked. Location Category B.

9.1.2.10 A circuit breaker that is 38.1 mm (1-1/2 inch) wide per pole or less shall be permitted to have the markings specified in 9.1.2.9 at any convenient location on the circuit breaker except on the rear. Location Category C.

9.1.2.11 If pressure terminal connectors are not provided on a circuit breaker or circuit breaker frame as shipped, the circuit breaker or circuit breaker frame shall be marked stating which pressure terminal connectors or component terminal kits are acceptable for use with the circuit breaker or circuit breaker frame. A wire connector of the type mentioned in the marking may be installed on the circuit breaker or circuit breaker frame at the factory with instructions, if necessary, to effect proper connection of the conductor. A terminal kit shall carry a marking identifying the wire size and manufacturer's name or trademark. Location Category C.

9.1.2.12 A circuit breaker rated more than 4000 A intended for cable only connections as mentioned in 7.1.4.1.18 and 7.1.4.1.19 shall be marked for cable connection only. Location Category B.

9.1.2.13 When a circuit breaker has been tested using bus bars larger or smaller than those specified in Table 7.1.4.1.3, it shall be marked to show the minimum size bus bar with which it can be used. Location Category B.

9.1.2.14 A circuit breaker that is intended to be operated continuously at 100 percent of its rating and that has a temperature rise on a wiring terminal exceeding 50°C (90°F), see 7.1.4.3.1 and 7.1.4.3.2, shall be marked, Location Category B:

a) For use with 90°C (194°F) wire and the wire size. The wire size shall be based on the ampacity of 75°C rated conductors as indicated in Table 6.1.4.2.1.

b) To indicate that wire connectors used shall be identified AL9, CU9AL, or AL9CU, if for use with aluminum or copper-clad aluminum conductors, unless connectors are provided on the circuit breaker.

9.1.3 Interrupting Ratings

9.1.3.1 A circuit breaker having an interrupting rating other than 5 kA shall be marked with the interrupting rating or ratings for which it has been found acceptable, in accordance with 8.3. The marking shall include the words ″Interrupting Rating(s)″ or ″Current Interrupting Rating(s)″, and may include the words ″Maximum RMS Symmetrical″, abbreviation thereof, or any portion thereof. An asymmetrical rating shall not be indicated. Where more than one value of voltage is associated with the interrupting ratings, all values of voltage shall be shown with the associated values of current.

9.1.3.2 Except as permitted by 9.1.3.3 the current-interrupting rating of a circuit breaker shall be located where it will be visible when a front or trim is removed. If there is more than one interrupting rating marked on the circuit breaker, all such ratings shall appear together. Location Category B.

9.1.3.3 A circuit breaker that is 38.1 mm (1-1/2 inch) wide per pole or less shall be permitted to have the marking at any convenient location on the circuit breaker except on the rear. Location Category C.

9.1.4 Special Markings

9.1.4.1 A circuit breaker meeting calibration requirements at 40°C (104°F) shall be permitted to be marked ″40 C″. A circuit breaker frame and interchangeable trip unit meeting calibration requirements at 40°C shall be permitted to have the trip unit only marked ″40 C″. An electronic trip circuit breaker is not affected by ambient temperatures and therefore meets calibration requirements at 40 °C. The marking is not required for electronic trip breakers but it is optional. Location Category C.

9.1.4.2 A circuit breaker that is required to be or is optionally marked to show intended use in Class CTL assemblies shall be marked ″Class CTL″ or ″CTL″. See 6.1.1.8. This marking is not required to be visible after installation. Location Category C. A ″half-size″ circuit breaker intended for use in a lighting or appliance branch circuit panelboard shall be marked ″Class CTL.″ A ″full-size″ circuit breaker intended for use in a lighting or appliance branch circuit panelboard shall be permitted to be marked ″Class CTL.″

9.1.4.3 A delta circuit breaker (a 3-phase, 3-pole circuit breaker having provision for two poles connected to a bus structure and a third isolated pole) shall be marked ″For Replacement Use Only″. Location Category C.

9.1.4.4 A circuit breaker, having a frame size of 250 A or greater, or a multi-pole type of any ampere rating rated over 250 V; and intended for continuous operation at 100 percent of rating, shall be marked: ″Suitable for continuous operation at 100 percent of rating only if used in a circuit breaker enclosure Type (Cat. No.) ____ or in a cubicle space ___ by ___ by ___ mm (inches)″. Equivalent wording shall be permitted. Location Category C. The blanks are to be filled in with the minimum dimensions.

9.1.4.5 Except as indicated in 9.1.4.4, a circuit breaker shall not be marked for continuous operation at 100 percent of rating.

9.1.4.6 A 2-pole independent trip circuit breaker shall be marked ″Independent Trip″, ″No Common Trip″, or the equivalent. See 6.1.5.1 and 8.3. Location Category B.

9.2 Current-limiting circuit breakers

9.2.1 If intended for such use, a circuit breaker that has been investigated and found to comply with the requirements for current-limiting circuit breakers shall be marked ″Current-Limiting″. In addition, the circuit breaker shall be marked with the rating mentioned in 8.6 or it shall be marked to indicate the source of the information. This marking shall not be required to be visible after installation. Location Category C.

9.3 Instantaneous-trip circuit breakers

9.3.1 Instantaneous-trip settings on an instantaneous trip circuit breaker shall be marked on the circuit breaker, and designations in code shall be permitted. Location Category D.

9.3.2 An instantaneous-trip circuit breaker shall not be marked with an interrupting rating in accordance with 9.1.3.1.

9.4 Circuit breaker and ground-fault circuit-interrupters

9.4.1 The supervisory (test) switch of a circuit breaker and ground-fault circuit-interrupter (CB/GFCI) shall be marked ″Test″ to identify its function. Location Category A.

9.4.2 A CB/GFCI shall be marked Class A. Location Category C.

9.4.3 CB/GFCI instructions shall be provided for correct operation of the supervisory (test) circuit, and the need to test monthly. Location Category J.

9.4.4 There shall be packaged with each CB/GFCI instructions to guide the installer. Location Category J.

9.4.5 Users of a CB/GFCI shall be informed that they are not protected in the event that they should contact more than one conductor of a circuit. This information need only be in the literature packaged with the device. Location Category J.

9.4.6 Information provided with a device intended to control a 120/240 V single-phase, 3-wire circuit or a 120/208 V circuit derived from a 3-phase, 4-wire supply shall include the following notice or the equivalent – Location Category J: ″To obtain maximum protection against electric shock, electric ranges and clothes dryers whose frames are grounded by connection to the grounded circuit conductor should not be connected to the load circuit of this device″.

9.4.7 At least three of the four terminals of a single-pole CB/GFCI and all but one of the terminals of a multipole CB/GFCI shall be identified. This marking shall be permitted to be on the side of the circuit breaker. Location Categories C and G.

9.4.8 Terminals of a CB/GFCI intended to be connected to the grounded circuit conductor shall be identified by the color white. The identification of other terminals shall be a readily distinguishable different color. The color green shall not be used. Location Categories C and G.

9.5 Circuit breakers with equipment ground-fault protection

9.5.1 A circuit breaker with equipment ground-fault protection shall be marked as follows:

a) With its ground-fault trip level in mA where visible after installation. Location Category B.

b) With the following wording or an equivalent abbreviation thereof on the front of the circuit breaker: ″Equipment Protection Only.″ Location Category B.

9.5.2 At least three of the four terminals of a 120 V or 127 V rated circuit breaker with equipment ground-fault protection and all but one of the terminals of a 120/240 V rated circuit breaker with equipment ground-fault protection shall be identified. This marking shall be permitted to be on the side of the circuit breaker. Location Categories C and G.

9.5.3 Terminals of a circuit breaker with equipment ground-fault protection intended to be connected to the grounded circuit conductor shall be identified by the color white. The identification of other terminals shall be a readily distinguishable different color. The color green shall not be used. Location Categories C and G.

9.6 Integrally fused circuit breakers and high fault protectors

9.6.1 A fused circuit breaker shall be marked ″line″ and ″load″, with the ″load″ marking on the same side of the contacts as the fuses or high-fault protectors. Location Category B.

9.6.2 A fused circuit breaker shall be marked to indicate, by specific catalogue numbers or the equivalent, the fuses or high-fault protectors that have been found by investigation to be acceptable for use therein. The marking shall be visible when the cover over the fuse or protector compartment is removed. Location Category H.

9.6.3 An accessory high-fault protector shall be marked to indicate the specific type number or equivalent of the circuit breakers with which it is intended to be used.

9.6.4 An integrally fused circuit breaker that does not automatically trip by signal, other than main current let-through, from fuses or high-fault protectors upon the clearing of one or more fuses or protectors shall be marked ″OPEN FUSE TRIPPING NOT PROVIDED″ or an equivalent wording. See 6.6.3. Location Category B.

9.7 Adjustable circuit breakers

9.7.1 A circuit breaker that has an adjustable instantaneous means for tripping shall be marked to indicate at least the rating of the minimum and maximum settings. This marking shall either be in amperes or as a percentage of the ampacity. Where an interchangeable trip unit is provided, this marking shall be permitted to be on the trip unit. Location Category K.

9.7.2 A Type A adjustable circuit breaker shall be marked with a single ampere rating, and with percentage (or other similar) markings, or with distinct current markings for each continuous current adjustment setting. See 6.7.5. Location Category B.

9.7.3 A Type B adjustable circuit breaker shall have provision for being marked with the ampere rating to which it is set, and shall show this as the rating when so set. See 6.7.4. Location Category B.

9.7.4 Each control of an adjustable circuit breaker shall be plainly marked as to its effect, with clearly defined setting points. Location Category B.

9.8 Heating, air conditioning, and refrigeration (HACR) circuit breakers

9.8.1 A circuit breaker intended for group installation shall be marked ″HACR Type″. Location Category B.

9.9 Remotely-operated circuit breakers

9.9.1 A remotely-operated circuit breaker shall be marked, ″Remotely Operated″. Location Category B.

9.9.2 A remotely-operated circuit breaker shall be furnished with a separate label marked ″Remotely-operated circuit breakers installed in this equipment″ and instructions for attaching the label to the equipment. The instructions shall indicate that the separate label shall be visible after attachment without removing the equipment trim or cover. Location Category K.

9.9.3 Installation instructions shall be provided with the circuit breaker identifying any Class 2 remotely-operated circuit and indicating the necessity to separate the Class 2 circuits from electric light, power and Class 1 circuits.

9.10 Switching duty (SWD) rated circuit breakers

9.10.1 A circuit breaker intended to switch fluorescent lighting loads on a regular basis and complying with Switching Duty (SWD) Rated Circuit Breakers, Section 7.10 shall be marked ″SWD″. Location Category B.

9.11 400 Hz rated circuit breakers

9.11.1 A circuit breaker rated 400 Hz shall be marked ″400 Hz″. Location Category B.

9.12 Draw-out circuit breakers

9.12.1 A draw-out circuit breaker shall be marked with the catalog number of the receiving device. Location Category C.

9.13 Series-connected circuit breakers

9.13.1 The interrupting rating of a series combination shall not exceed the marked interrupting rating of the line-side overcurrent protective device.

9.13.2 The interrupting rating of a series combination shall not be marked on any circuit breaker, but a circuit breaker shall be permitted to be marked to refer to a drawing or the like that contains the interrupting rating.

9.14 Interchangeable-trip circuit breakers

9.14.1 An interchangeable-trip unit shall be marked with the manufacturer's name or trademark, the rating in amperes and the frame for which it is intended, and if not provided as part of the circuit breaker marking, with the minimum and maximum settings of the adjustable magnetic means for tripping, except that the marking indicating the frame for which it is intended need not be provided if the instructions provided with the trip unit instruct the user on the proper use of the trip unit – frame designation or designations and the like.

9.14.2 The current rating (I_n) shall be visible when a trim or cover is removed. The numerical value alone shall be considered acceptable if the word amperes, or abbreviation thereof appears on the cover adjacent to the trip unit numerical value of rating. Location Category B.

9.14.3 The marking of the frame designation, the manufacturer's name, and the adjustable magnetic trip setting need only be visible after removing the frame cover. Location Category K.

9.14.4 An interchangeable trip unit rated at 50 A or less shall be clearly marked ″NOT FOR USE IN DWELLING UNITS″. Location Category C.

9.14.5 The interrupting ratings of all the circuit breaker frames with interchangeable trip units shall be marked on the circuit breaker frame. Each interrupting rating shall be clearly associated with the current rating (I_n) of the trip unit. Interrupting ratings shall not be marked on interchangeable trip units.

9.15 High-intensity-discharge (HID) type circuit breakers

9.15.1 A circuit breaker intended to switch HID lighting loads on a regular basis and complying with Performance – HID Type Circuit Breakers, Section 7.15 may be marked ″HID″. Location Category B.

9.16 Rating plugs

9.16.1 A rating plug shall be marked with the manufacturer's name or trademark, the rating in amperes and the frame for which it is intended. The minimum and maximum settings of the adjustable magnetic means for tripping need not be provided if they are provided on the circuit breaker.

9.16.2 The current rating (I_n) shall be visible when a trim or cover is removed. The numerical value alone shall be considered acceptable if the word amperes, or abbreviation thereof appears on the cover adjacent to the trip unit numerical value of rating. Location Category B.

9.16.3 The marking of the frame designation, the manufacturer's name, and the adjustable magnetic trip setting need only be visible after removing the rating plug. Location Category K.

9.16.4 A circuit breaker or an interchangeable trip unit that may accept a rating plug rated at 50 A or less shall be clearly marked ″NOT FOR USE IN DWELLING UNITS″. Location Category C.

9.16.5 The interrupting ratings of all the circuit breaker frames with rating plugs shall be marked on the circuit breaker frame. Each interrupting rating shall be clearly associated with the current rating (I_n) of the rating plug. Interrupting ratings shall not be marked on rating plugs.

9.17 Circuit breakers for use with 16 or 18 AWG wire

9.17.1 A circuit breaker having a rating less than 15 A that has been found to comply with the requirements of Section 7.15 shall be marked as intended for use with 16 or 18 AWG wire as appropriate (16 AWG for 10 A circuit breakers and 18 AWG for 7 A circuit breakers). Location Category C.

9.18 4-pole circuit breakers

9.18.1 A 4-pole circuit breaker shall have the fourth (neutral) pole marked "Protection – _% I_n". The percentage indicated shall be 0, 50 or 100. Location Category B.

MOLDED CASE SWITCHES

10 Construction

10.1 All types

10.1.1 General

10.1.1.1 The general details of a switch shall comply with 6.1.1.1 – 6.1.1.6.

10.1.2 Corrosion Protection

10.1.2.1 The corrosion protection of a switch shall comply with Corrosion Protection, 6.1.2.

10.1.3 Cases – Insulating Material

10.1.3.1 Insulating material of a switch shall comply with Cases – Insulating Material, 6.1.3.

10.1.4 Current-Carrying Parts

10.1.4.1 General

10.1.4.1.1 The general details of a switch shall comply with General, 6.1.4.1.

10.1.4.2 Terminals

10.1.4.2.1 The terminals of a switch shall comply with Terminals, 6.1.4.2.

10.1.4.3 Wiring leads

10.1.4.3.1 The wiring leads of a switch shall comply with Field Wiring Conductors, 6.1.4.3.

10.1.5 Operating Mechanism

10.1.5.1 The operating mechanism of a switch shall comply with 6.1.5.1 – 6.1.5.5.

10.1.5.2 If an instantaneous response release mechanism is provided, it shall be preset and sealed. Access to an internal mechanism with an instantaneous response release and tampering, changing or interfering with the mechanism shall require dismantling of the switch or the breaking of a seal, except if the switch is intended to have field installed accessories, the seal shall be permitted to be on the release mechanism only.

10.1.5.3 Any means for sealing a switch with an instantaneous release mechanism shall be such that breaking or removing it shall be plainly evident. Paper or cloth shall be permitted to be used as a seal indicator, but shall not be used as a means for holding parts together.

10.1.5.4 An enclosed fused molded case switch shall include an interlock that will prevent access to the fuses unless the switch is in the OFF position.

10.1.5.5 The blade or ferrule of a fuse shall not be used as a switch contact.

10.1.6 Spacings

10.1.6.1 The spacings of a switch shall comply with Spacings, 6.1.6.

10.2 Draw-out switches

10.2.1 Draw-out switches shall comply with Draw-Out Circuit Breakers, Section 6.12.

11 Performance

11.1 General

11.1.1 Details

11.1.1.1 Switches shall comply with the general performance requirements of 7.1.1.8 – 7.1.1.17 and the additional general requirements of Section 11.1.

11.1.1.2 Except as permitted by 11.1.1.3, the performance of a switch shall be investigated by subjecting representative sets of samples in commercial form to the applicable tests indicated in Table 11.1.1.1. The test sequence for Tests 1 – 4 shall be as specified in Table 11.1.1.1. No conditioning of the switch shall take place during or between tests. During the test program a switch shall be mounted in a vertical position that would normally cause the line terminals to be at the top. Sets of samples shall be constituted as indicated in Table 11.1.1.2. Separate samples shall be permitted for the remaining tests as indicated in the description of the tests.

Table 11.1.1.1
Tests[a]

Test	Section
1. Temperature	11.1.2
2. Overload	11.1.3
3. Endurance	11.1.4
4. Dielectric voltage-withstand	11.1.5
5. Short circuit current withstand	11.1.7.2
6. Mechanical	11.1.6.1
7. Electrical continuity	11.2.2
8. Power level determination	11.1.6.4
9. Contact opening[b]	11.1.7.6

[a] Only 1 – 4 are to be conducted in sequence and in the order given on the same set of samples.

Table 11.1.1.1 Continued on Next Page

Table 11.1.1.1 Continued

Test	Section
[b] See 11.1.1.10 and 11.1.1.11.	

Table 11.1.1.2
Sets of samples

Ampere rating	Samples per set[a]
0 – 225	3 or 4; see 7.1.1.12
226 – 400	2
401 and higher	1
[a] If a switch is not marked ″line″ and ″load″, one sample is to be tested with reversed line and load connections or an additional sample of each test set shall be provided. When only one sample constitutes a test set for operating tests, a second sample is required for reversed line-load connection tests. For reversed line-load connections see 11.1.1.9.	

11.1.1.3 A switch that is identical to a molded-case circuit breaker that complies with the requirements for circuit breakers in this standard, and that the release element is either omitted or made inactive, except for an instantaneous release mechanism, shall only be tested as indicated in Withstand Test, 11.1.7.

11.1.1.4 The investigation of a switch shall require complete testing of sets of the maximum rating only, unless basic design differences are present. If the frame size includes ampere ratings of 125 A or less, but more than 30 A, that are to be marked for use with 75°C (167°F) wire, ratings shall be selected for the Overload and Temperature Tests based on the use of 75°C wire (167°F). In selecting the rating(s) for test, consideration should be given to the relative heat dissipating effect of the 60°C (140°F) versus 75°C (167°F) wire size for the particular ampere rating.

11.1.1.5 If the marked rating of a switch includes both alternating and direct current, or if the marked rating does not exclude one or the other, the acceptability of the use of both ratings shall be determined. The ac rating shall be verified by the test program described in 11.1.1.2. To verify the dc rating it will ordinarily be necessary only to additionally subject a previously untested sample set that has the maximum ampere rating of the frame size, to:

a) Overload and endurance tests with dc; and

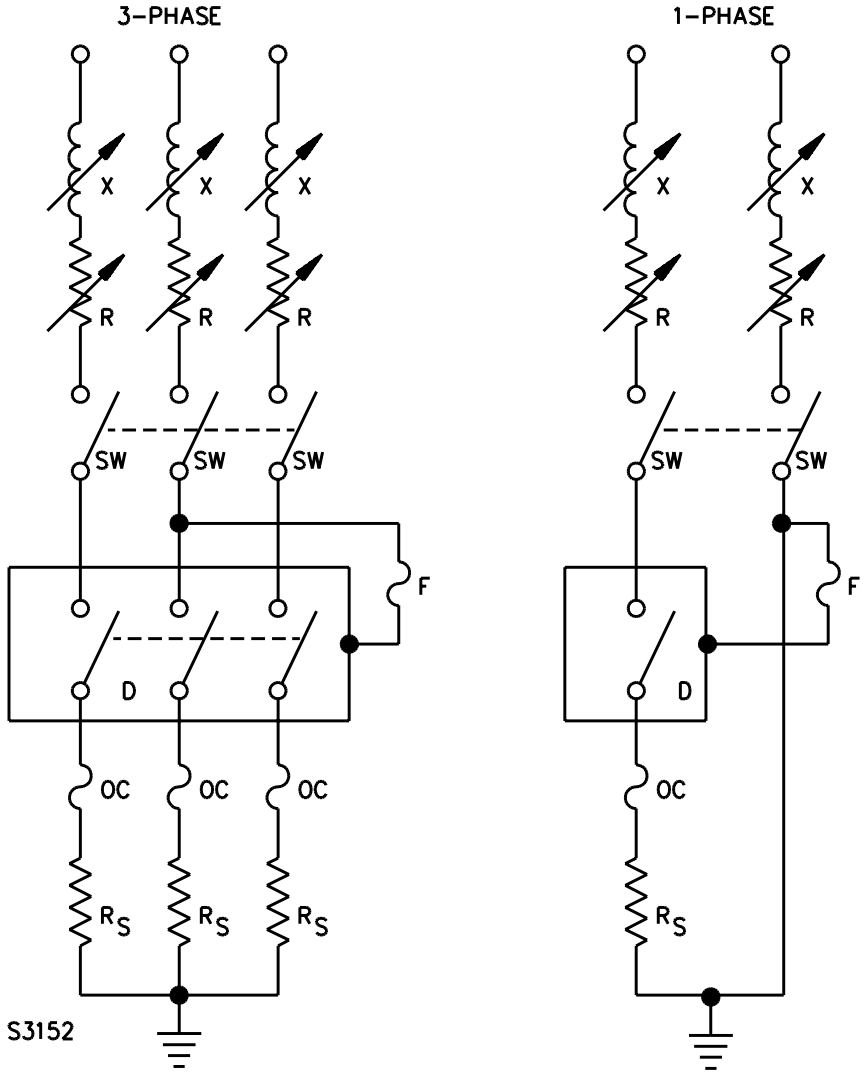
b) Dielectric voltage-withstand tests with ac.

11.1.1.6 A 2-pole switch that has an additional marking to indicate that it may be used on a 3-phase corner-grounded, delta circuit shall be caused to control 3-phase test circuits during the overload and endurance tests. See 9.1.1.20.

11.1.1.7 In the overload, endurance, and short-circuit withstand tests, a switch shall be mounted in an enclosure in accordance with the requirements of 7.1.1.19.

11.1.1.8 In the overload, endurance, and short-circuit withstand tests, a fuse, as specified in 7.1.1.20, shall be connected as shown in Figures 7.1.5.1 and 11.1.1.1 to indicate arc over.

Figure 11.1.1.1
Circuit for withstand and closing tests



X – Variable tap air-core reactor

R – Variable resistor

SW – Closing switch – may be located as shown or ahead of limiting impedance

F – Enclosure fuse

D – Device under test

R_S – Coaxial shunts for metering current

OC – Current-limiting fuses or circuit breakers used during test

11.1.1.9 If a switch is not marked ″line″ and ″load″, one sample of each set tested, or one additional sample, shall be connected with the line and load connections reversed during the overload and endurance tests. When an additional sample is used, it shall also be subjected to the dielectric voltage-withstand test.

11.1.1.10 An electrically tripped switch intended and marked for use as a disconnecting device in conjunction with Class 1 ground-fault sensing and relaying equipment shall have means to prevent automatic opening (lockout) if the current in any phase exceeds 850 percent of the switch ampere rating unless tested in accordance with Item 4 of Table 11.1.1.3.

Table 11.1.1.3
Circuit-opening – current multiplier

Item	Type of switch	Test current
1	Electrically tripped	10 times rated
2	Electrically tripped – for use with Class II ground-fault sensing and relaying equipment	10 times rated
3	Electrically tripped – with integral lockout (see 11.1.1.10) – for use with Class I ground-fault sensing and relaying equipment	10 times rated
4	Electrically tripped – without integral lockout (see 11.1.1.10) – for use with Class I ground-fault sensing and relaying equipment	10 times rated

11.1.1.11 A switch which includes a shunt release (electrically tripped) shall be tested in accordance with 11.1.7.6.

11.1.2 Temperature Test

11.1.2.1 The temperature test requirements of 7.1.4.1.4 – 7.1.4.2.3, 7.1.4.4 and the additional requirements of 11.1.2.2 – 11.1.2.3 shall apply to switches.

11.1.2.2 A switch shall be installed and operated in the smallest enclosure in which it is intended to be used until constant temperatures are obtained. Ventilation openings shall be permitted in enclosures for switches rated 400 A or more.

11.1.2.3 For the test, the temperature of the ambient air shall be within a range of 10 – 40°C (50 – 104°F).

11.1.2.4 Except as noted in 11.1.2.5, a fused molded-case switch shall be tested using dummy fuses in place of regular fuses.

11.1.2.5 A fused molded-case switch employing Class T or L fuses or 400 or 600 A Class J fuses shall be tested with fuses in place and while carrying 80 percent of its rated current.

11.1.3 Overload Test

11.1.3.1 A switch shall be capable of performing successfully when operated under the overload conditions of Overload test, 7.1.3.

11.1.3.2 A fused molded case switch shall be tested using dummy fuses in place of regular fuses.

11.1.4 Endurance Test

11.1.4.1 A switch shall be capable of performing successfully when operated under the conditions of Endurance test, 7.1.5.

11.1.5 Dielectric Voltage-Withstand Test

11.1.5.1 A switch shall be capable of performing successfully when tested under the conditions of Dielectric voltage-withstand test, 7.1.9.

11.1.6 Miscellaneous Tests

11.1.6.1 Mechanical test

11.1.6.1.1 Switches shall comply with the mechanical test requirements of 7.1.10.1.

11.1.6.2 Barrier and liner test

11.1.6.2.1 A barrier or liner less than 0.71 mm (0.028 inch) thick used in accordance with 6.1.6.1.12 shall comply with the requirements of 7.1.10.2.

11.1.6.3 Conformal coating test

11.1.6.3.1 Conformal coatings shall be judged in accordance with the requirements of 7.1.10.3.

11.1.6.4 Power level determination test

11.1.6.4.1 The power level of the secondary winding of a transformer shall be determined and limited as specified in 7.1.10.4.

11.1.7 Withstand Test

11.1.7.1 General

11.1.7.1.1 To determine if a switch complies with the requirements for short-circuit current withstand, low-level dielectric voltage-withstand, and closing, a representative sample of each ampere rating shall be subjected to the applicable tests indicated in Table 11.1.7.2.1. A switch marked with two or more short-circuit ratings shall be tested at each rating, unless a test at any one rating is representative of the performance at the other ratings. See 12.2 and 13.7 – 13.11. Oscillograph recordings, or an equivalent method, shall be used to determine circuit characteristics. See Annex C.

Table 11.1.7.2.1
Short-circuit current withstand tests

Short circuit rating	Maximum specified overcurrent protection ampere rating	Instantaneous release mechanism in switch	Notes
10 kA or less	Not more than switch	With	a
10 kA or less	Not more than switch	Without	–
10 kA or less	More than switch	With	a
10 kA or less	More than switch	Without	–
Over 10 kA	Not more than switch	With	a
Over 10 kA	Not more than switch	Without	–
Over 10 kA	More than switch	With	b
Over 10 kA	More than switch	Without	–

[a] A switch that is identical in construction and ratings to a molded-case circuit breaker that complies with the requirements in this Standard and in which the release element is either omitted or made inactive, except for an instantaneous release mechanism, need not be tested.

[b] Tests described in Withstand Test, 11.1.7 are to be conducted with the available current adjusted to a value just below the pick-up current of the instantaneous trip of the switch.

11.1.7.1.2 A switch shall be tested in the smallest enclosure (box and cover) in which it is intended to be used. Openings shall be permitted in the enclosure, if the combined area of all openings does not exceed 10 percent of the total external enclosure area, and if no opening is directly opposite a vent in the case of the switch. If the enclosure includes a door, it shall be closed and secured by its latch during the short-circuit withstand test. No bolt or lock shall be used unless it is the only securing means.

11.1.7.2 Short-circuit current withstand test

11.1.7.2.1 A circuit capable of providing the maximum short-circuit current for which the switch is rated shall be closed on a previously untested sample. The switch shall withstand the designated current until the overcurrent protective devices open. For a switch not marked as requiring a specific circuit breaker or fuse, the test current shall be maintained for 3 cycles or the time required for an instantaneous release mechanism to respond. After the circuit is opened:

a) The fuse connected to the enclosure shall not have cleared.

b) There shall not be any breakage to the extent that the integrity of the mounting of live parts is impaired.

c) A door shall not have opened. Deformation of the enclosure shall be considered to be acceptable unless live parts are accessible to the articulated probe shown in Figure 11.1.7.2.1.

d) The switch shall be capable of being opened manually with its operating handle, and the switch contacts shall be capable of being reclosed.

e) The contacts shall be permitted to weld provided that the operating handle stays in the ON position. The weld shall be broken by operating the handle, and the switch contacts shall be capable of being reclosed.

11.1.7.2.2 For the test specified in 11.1.7.2.1:

a) The open-circuit voltage of the power-supply circuit shall not be less than the maximum rated voltage of the switch.

b) The available short-circuit rms symmetrical current in amperes shall not be less than the marked short-circuit current rating of the switch.

c) The test enclosure shall be connected through a 30-A nonrenewable cartridge fuse rated for branch-circuit use. The fuse shall have a voltage rating not less than the rating of the switch being tested. It shall be connected to the pole of the switch considered least likely to arc to the enclosure. This connection shall be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire having a length of 1.22 – 1.83 m (4 – 6 ft), except that the fuse shall be permitted to be connected to the grounded conductor, if the switch is intended for use on a grounded system.

d) For Withstand Test of 10 kA or less:

1) The circuit shall be as indicated in Figure 11.1.1.1. External overcurrent protective devices shall be connected where the ″OC″ symbols are indicated, see 11.1.7.2.3.

2) The power factor of the circuit shall be 0.45 – 0.50, lagging.

e) For Withstand Test Greater than 10 kA:

1) The circuit shall be as indicated in Figure 11.1.1.1 and shall include the necessary measuring equipment and the fuse-mounting means. A circuit breaker shall be used if specified for use with the switch.

2) The power factor of the circuit shall be as specified in Table 7.1.7.4.

11.1.7.2.3 The overcurrent protective devices specified in 11.1.7.2.2(d) shall be externally-connected Class H fuses of the maximum rating for the case size of the rating specified or circuit breakers of the type and rating indicated by the marking.

11.1.7.2.4 The overcurrent protective devices specified in 11.1.7.2.2(e) shall be externally-connected fuses as described in 11.1.7.2.7 – 11.1.7.2.9 or circuit breakers as marked on the switch.

11.1.7.2.5 The tests specified in 11.1.7.2.1 shall be permitted to be performed without overcurrent protection devices, if it can be shown that the test-circuit current was maintained for a period of time at least equal to the opening time of the specified overcurrent protective devices at the level of current involved.

11.1.7.2.6 For the performance of the test, the line and load terminals of the switch shall be connected to the corresponding test-circuit terminals by copper-wire leads, not longer than 1.22 m (4 ft) per terminal, each of which has an ampacity not less than the current rating (I_n) of the switch.

11.1.7.2.7 Fuses used for ratings greater than 10 kA shall have characteristics representing the peak let-through current (I_p) and clearing I^2t values associated with the maximum rated fuses by which the switch is intended to be externally protected. It is assumed that protection will be provided by the maximum fuse in the case size of the indicated fuse. The fuses shall be installed on the load side of the device as shown in Figure 11.1.1.1. Each of these fuses shall be of such characteristics that, when tested on a single-phase circuit, they will permit a peak let-through current (I_p) and a clearing I^2t of not less than the corresponding values specified in the requirements for the class and the current and voltage ratings of the fuse intended for use with the switch being tested. Special test fuses having the required characteristics shall be permitted to be used. To obtain the required values of these characteristics, it may be necessary to employ a fuse having a current rating (I_n) larger than that of the fuse specified and of a different class.

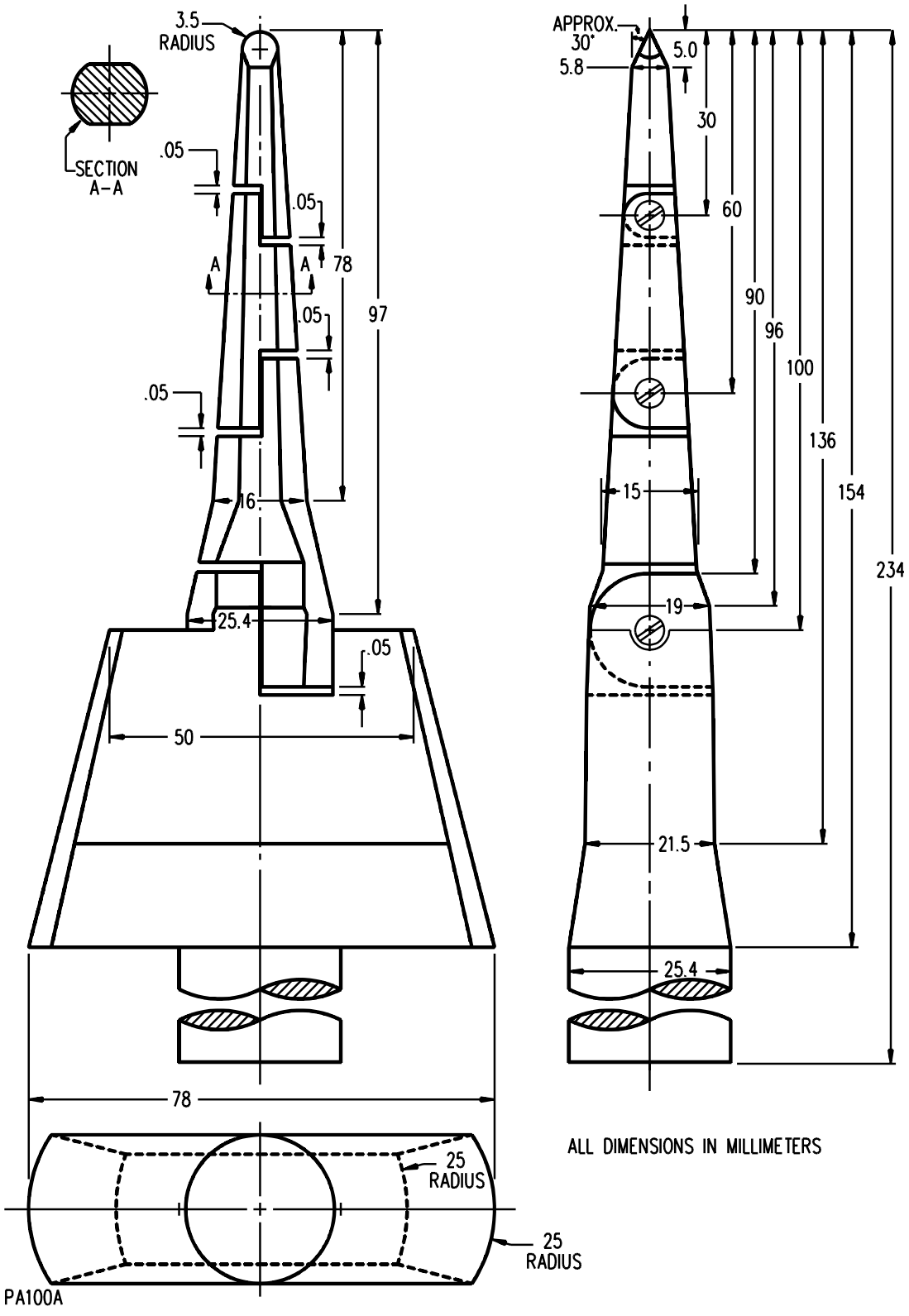
11.1.7.2.8 The fuse referred to in 11.1.7.2.7 shall be permitted to be any Class G, J, L, T, or R fuse, without regard to its peak let-through current and clearing I^2t, if the test current is below the point (threshold value of the fuse) at which the fuse is considered to be current-limiting.

11.1.7.2.9 Fuses used for tests shall be selected from a lot from which two samples have been selected if the fuses are of Class G, J, RK5, or T and one sample if the fuse is Class L and that have been calibrated to determine that their I^2t and I_p characteristics comply with the prescribed values called for in 11.1.7.2.7.

11.1.7.2.10 The characteristics of recovery voltage and ac decrement shall be as required by Annex C.

11.1.7.2.11 With the device in the full-closed position, the test circuit shall be closed on the device. For devices tested on a single-phase circuit, controlled closing shall be employed so that maximum current flow (I_p) is obtained. The closing angle shall be essentially at the zero of the voltage wave (maximum offset) or later, to produce the start of arcing within 30 electrical degrees prior to system peak voltage.

Figure 11.1.7.2.1
Articulated probe



11.1.7.3 Dielectric voltage-withstand test

11.1.7.3.1 Unless the same sample is to be subjected to the closing test, a switch that has been subjected to the short-circuit withstand test shall comply with the requirements in 7.1.11.5.1, 7.1.11.5.2 and 7.1.11.5.4.

11.1.7.4 Closing test

11.1.7.4.1 A sample of the switch shall be closed on a circuit capable of providing the maximum short circuit withstand current. After the circuit has cleared, the switch shall comply with the requirements in 11.1.7.2.1(a), (b), and (d).

11.1.7.4.2 The sample for this test shall be that used for the short-circuit withstand test, or at the option of the submitter a previously untested sample. The conditions of the closing test shall be the same as for the short-circuit withstand test, except that random closing shall be employed. Complete physical closure of the switch contacts need not be established.

11.1.7.5 Dielectric voltage-withstand test

11.1.7.5.1 The dielectric voltage-withstand test described in 7.1.11.5.1, 7.1.11.5.2, and 7.1.11.5.4 shall be conducted following the closing test.

11.1.7.6 Contact opening test

11.1.7.6.1 An electrically tripped switch shall be capable of being operated by the electrical tripping mechanism to break levels of current as indicated in Table 11.1.1.3. The number of operations shall be three except that a switch intended for use on single-phase circuits only, shall be tested for five operations. The circuit on which the test is conducted shall have a normal frequency recovery voltage equal to the rated voltage of the device, except that the recovery voltage need not be determined if the closed-circuit voltage is not less than 90 percent of the rated voltage of the device. The open-circuit voltage shall not be more than 110 percent of the rated voltage except that a higher open-circuit voltage may be used if agreeable to the submitter and the testing agency. See 11.1.1.11.

11.1.7.6.2 The test circuit power factor shall be:

a) 0.45 – 0.50 lagging for a switch rated 1200 A or less,

b) 0.25 – 0.30 lagging for a switch rated 1201 – 2500 A,

c) 0.15 – 0.20 lagging for a switch rated 2501 – 6000 A.

A lower power factor shall be permitted if agreeable to the submitter and the testing agency.

11.1.7.6.3 At the conclusion of the test, the device shall be in operable condition. The fuse connected to indicate arc-over to the enclosure or grounded metal shall not have opened.

11.1.7.7 Dielectric voltage-withstand test

11.1.7.7.1 The dielectric voltage-withstand test described in 7.1.11.5.1, 7.1.11.5.2 and 7.1.11.5.4 shall be repeated following the contact opening test.

11.2 Draw-out switches

11.2.1 General

11.2.1.1 A draw-out switch shall additionally comply with the requirements in Section 11.2.2.

11.2.2 Electrical Continuity Test

11.2.2.1 Switches shall comply with the electrical continuity test requirements of 7.12.1.

12 Ratings

12.1 A switch shall be rated in accordance with the requirements of 8.1 and 8.2 and with the additional requirements of 12.2.

12.2 The short-circuit rating of a switch shall be one or more of the values shown in Table 12.1. The rating shall not be greater than that of the specified overcurrent protective device or integral fuses. The rating shall be 10,000 A for plug, Class H, and Class K fuses. The rating shall not be less than 25,000 A for Class G, J, L, R, and T fuses.

12.3 A 300 V rated fuse may be specified for switches rated 120, 127, 120/240, 240, or 277 V. See also 13.12.

12.4 A 300 V rated fuse may be specified for a switch rated 480Y/277 V if the switch is marked in accordance with 13.13.

Table 12.1
Short circuit current rating, rms

Symmetrical amperes		
5,000	25,000	65,000
7,500	30,000	70,000
10,000	35,000	85,000
14,000	42,000	100,000
18,000	45,000	125,000
20,000	50,000	150,000
22,000	60,000	200,000

13 Markings

13.1 Switches shall be marked in accordance with the requirements of General, Section 9.1 and Markings, Section 17, and the additional requirements of this Section. Location of required markings shall be in accordance with the ″Location Categories″ given in Table 13.1.

Advisory Note: For products intended for use in Canada, markings shall be in English or in French and English; caution and warning markings shall be in French and English. For products intended for use in Mexico, all markings shall be at least in Spanish. For products intended for use in the United States, all markings shall be at least in English. See Annex D for suitable translations of caution and warning markings.

Table 13.1
Location of markings – switches

Clause numbers	Subject	Location categories (See notes)
	General	
13.1	Location	–
9.1.1.2	Type designation	B
9.1.1.2	Manufacturer's name	B
9.1.1.2	Voltage rating	B
9.1.1.3	Durability and legibility	–
13.4	Ampere rating	B
13.5	Ampere rating – 100 A or less	B
9.1.1.10 – 9.1.1.12	Special characteristics	C, F
9.1.1.13	Line and load	B
9.1.1.14	Factory identification	H
13.2, 13.3	Switch identifier/Caution statement	A, B
	Position indication	
13.6	Open or close (on or off)	A
13.6	Intermediate position – reset	B, D
9.1.1.17	Electrical operator (on or off)	B, E
	Short circuit ratings	
13.7 – 13.17	Ratings	B, C
	Terminations	
9.1.2.1 – 9.1.2.4	CU-AL	B
9.1.2.5, 9.1.2.6	Tightening torque	B, C
9.1.2.7	Maximum wire size	C, G
9.1.2.8	Multiple-conductor connectors	C
9.1.2.9, 9.1.2.10	60°C/75°C – 125 A Max.	B, C
9.1.2.11	Separately shipped connectors	C
	Accessories	
17.1, 17.2	Ratings	C
17.3	Shunt release	C
17.4, 17.5	Separately shipped	–

Table 13.1 Continued on Next Page

Table 13.1 Continued

Clause numbers	Subject	Location categories (See notes)
17.6	External dropping resistor	C
	Special markings	
13.14	Automatic opening	B
9.1.1.18	Non-conducting enclosures	C
9.1.1.19	Ventilated enclosures	B
9.1.1.20	2-pole, 3-phase rated	B
9.1.1.21	Multi-wire circuit	C
9.1.1.22	DC rated 3-pole	B

A Marking shall be visible without removing the trim or cover of enclosure.

B Marking shall be visible without disassembling or removing device and shall be visible when the trim or cover of enclosure is removed, and may be visible with the trim or cover in place.

C Marking may be on any convenient location except on the rear.

D Marking of intermediate position and ″RESET″ need not be provided if on intended receiving device.

E ″ON″ and ″OFF″ marking need not be visible on switch if on electrical operator.

F Part replacement marking need not be visible on switch if on electrical operator.

G Marking shall be visible when wire connector is in place.

H Marking need only be visible after removal of switch from panel of enclosure.

13.2 An unfused switch shall be marked in accordance with either of the following:

a) With the switch symbol: ⎯⁄⎯ , or

b) ″Caution″ and with the following or equivalent statement ″Does not provide over-current protection.″

Location Category A.

13.3 An unfused switch shall be marked ″Caution″ and with the following or equivalent statement ″Does not provide over-current protection″, Location Category B, unless the device is marked in accordance with 13.2(b).

13.4 The ampere rating of a switch shall be distinct so that it may be clearly understood what is the ampere rating on the switch. Location Category B.

13.5 The ampere rating of a switch rated 100 A or less shall be permitted to be stamped, etched, or similarly marked into the handle or the escutcheon area of the switch so as to be visible without removing the trim or cover of the enclosure with which it may be properly used. Location Category B.

13.6 A switch shall indicate clearly whether it is open or closed and such marking shall be visible with a trim or cover in place except that when enclosed it may require the opening of a hinged cover or door. If a switch handle has an additional or intermediate position which it takes upon automatic opening, that position shall be marked to indicate that the switch has automatically opened. Instructions for resetting the switch shall be included. The word ″tripped″ shall be permitted to be used on the handle but shall not be used in the instructions. Location Categories B and D. Marking indicating the intermediate open position and the resetting instructions shall not be required on the switch if they are provided on the intended receiving device. Location Category D.

13.7 Except as permitted by 13.8 – 13.11, an unfused switch shall be marked, ″This switch is suitable for use on a circuit capable of delivering not more than ____ ampere, rms symmetrical, ____ volts maximum when protected by Class ____ fuses (type ____ circuit breaker) rated ____ amperes maximum″, or with an equivalent marking. See 12.2.

13.8 If the short-circuit rating is 10,000 A, the class of fuse shall not be required but the current rating (I_n) shall be provided.

13.9 If the short-circuit rating is 5,000, 7,500, or 10,000 A, and the continuous-current rating (I_n) of the specified circuit breaker or fuse does not exceed that of the switch, the type designation and manufacturer of the circuit breaker shall not be required.

13.10 The type designation and manufacturer of the circuit breaker or Class of fuse shall not be required if:

a) The short-circuit rating is 5,000, 7,500, or 10,000 A;

b) The continuous-current rating (I_n) of the specified circuit breaker or fuse exceeds that of the switch; and

c) The combination was tested for three cycles as indicated in 11.1.7.2.1.

13.11 If the short-circuit rating is greater than 10,000 A and the combination was tested for three cycles as indicated in 11.1.7.2.1, the type designation and manufacturer of the circuit breaker and Class of fuse shall not be required.

13.12 When the overcurrent protective device is a 300 V rated fuse, the marking mentioned in 13.7 shall include ″300 volts maximum″ after the ″rated ____ amperes maximum.″

13.13 A switch rated 480Y/277 V that is specified for use with a 300 V fuse shall be marked with the following or equivalent wording: ″For use with line-to-neutral loads only.″

13.14 A switch having an instantaneous release shall additionally be marked as part of its short circuit rating ″May open circuit above _____ A″ or equivalent wording or ″May open automatically″. When the latter marking is provided, the likely tripping current shall be published in other literature which is made available to system designers, and the like. Location Category B.

13.15 The marking in 13.7 – 13.11 shall be permitted to be repeated for several different types of protection.

13.16 The short circuit rating of a switch shall be located where it will be visible when a front or trim is removed. If there is more than one rating marked on the switch, all such ratings shall appear together. Location Category B.

13.17 Notwithstanding 13.16, a switch that is 38.1 mm (1-1/2 inch) wide per pole or less may have the marking at any convenient location on the switch except on the rear. Location Category C.

13.18 A fused molded-case switch constructed to accept only Class CC, G, J, R or T fuses shall be marked with the following statement ″Suitable for use on a circuit capable of delivering not more than _____ amperes, RMS symmetrical, _____ volts maximum: Use Class _____ fuses.″

13.19 A fused molded-case switch shall be marked, ″Continuous load current not to exceed 80 percent of the marked rating of fuses″.

ACCESSORIES

14 Construction

14.1 General

14.1.1 General Details

14.1.1.1 A component part of an accessory shall comply with the requirements for that accessory.

14.1.2 Installation

14.1.2.1 A circuit breaker or switch may have provision for field-installed accessories provided the following conditions are met:

a) The circuit breaker or switch is acceptable for use with or without the accessory.

b) Each accessory is acceptable for the intended use.

c) Each accessory may be installed without the breaking of a seal and without the disassembly of factory-installed circuit breaker parts except for:

1) Those parts necessary to install or replace a circuit breaker trip unit;

2) A circuit breaker or switch operating handle; or

3) Other parts that if omitted are considered not to affect the intended performance of the circuit breaker or switch.

d) Instructions for the installation, operation, and necessary adjustments are provided with each accessory.

e) The installation of an accessory does not require the use of other than normally available tools, such as screwdrivers, pliers and wrenches, unless such a tool and instructions for its use are furnished with each accessory.

f) A barrier that is necessary because spacing would otherwise be less than required, or for any other reason, is securely attached at the factory to either the circuit breaker or switch, or to the accessory to be installed.

g) The accessory is an essentially complete unit and does not require detailed assembly in the field. Except as permitted in (h), the installation of the accessory does not expose live or mechanical functional parts that would not be exposed during the replacement of an interchangeable trip unit. An arrangement that requires cutting, splicing of existing wires, or resoldering of connections within the circuit breaker housing is not acceptable.

h) Except as noted in (i) and (j) means for mounting the accessory require no drilling, cutting, or filing of holes. Openings to provide for the accessory actuator to operate the trip mechanism may be provided in the trip unit housing. If breakouts are provided for this purpose they shall be removable in one piece.

i) Drilling, cutting, or filing is acceptable in the circuit breaker or switch housing only to provide an opening for the accessory leads and the location of such openings is indicated by drill points or breakouts.

j) It is possible to accomplish the operation described in (i) in a manner so that debris inside the circuit breaker or switch housing does not accumulate.

k) Strain or pushback relief, if required to meet the requirements of 14.1.5.1 and 14.1.5.2, is provided as an integral part of the accessory or is furnished as part of the kit along with any instructions or tools necessary to comply with the requirements of this standard.

l) The accessory complies with the marking requirements of 17.4.

m) The installation of the accessory does not affect the performance of the circuit breaker or switch.

14.1.2.2 So that instructions are always available should it become necessary to replace a circuit breaker or trip unit, a circuit breaker or interchangeable trip unit intended to accept field-installed accessories shall be provided with information for the proper reinstallation of the accessory.

a) If interchangeable trip units are involved, this information may be:

1) Part of the trip unit installation instruction;

2) Marked on the trip unit; or

3) Provided on a separate tag attached to the trip unit.

b) If noninterchangeable trip units are involved, this information may be:

1) Marked on the circuit breaker; or

2) Provided on a separate sheet packaged with the circuit breaker.

c) The information shall comply with one of the following:

1) Be complete as required by 14.1.2.1 (d).

2) Provide a condensed version of the instructions specified in 14.1.2.1 (d); or

3) Refer to where installation instructions for each accessory may be obtained; in this case, the information shall include a statement of the need to determine that the accessory performs its intended function after it has been reinstalled.

14.1.3 Mounting

14.1.3.1 An accessory shall be securely mounted in position and prevented from loosening or turning if such motion may affect adversely the intended performance of the circuit breaker or switch or reduce the minimum spacing to less than that indicated in 14.1.6.1.

14.1.4 Field Wiring

14.1.4.1 An accessory shall be provided with means for the connection of wires having ampacity corresponding to the rating of the accessory. See Tables 6.1.4.2.1 and 14.1.4.1.

14.1.4.2 Terminal leads of a circuit breaker accessory shall consist of wire suitable for the particular application, when considered with respect to the temperature and voltage and conditions of service to which the wiring is likely to be subjected.

14.1.4.3 Terminal leads shall be 22 AWG (0.32 mm^2) minimum. The free length of a terminal lead shall be at least 150 mm (6 inches).

Table 14.1.4.1
Ampacities of insulated conductors

Wire size		60°C (140°F)	
AWG	(mm^2)	Copper	Aluminum
22	(0.32)	3	–
20	(0.52	5	–
18	(0.82)	7	–
16	(1.3)	10	–

14.1.4.4 A pressure connector provided for use with an accessory shall comply with 6.1.4.2.2.

14.1.5 Strain Relief

14.1.5.1 Strain relief shall be provided to prevent a mechanical stress on the accessory supply leads to which field connections are made from being transmitted to terminals, splices, or interior wiring. See 15.1.3.

14.1.5.2 Means shall be provided to prevent the accessory supply leads to which field connections are made from being pushed into the housing of a circuit breaker or switch through the lead entry holes, if such displacement is likely to subject the lead to mechanical injury, or if it is likely to reduce spacings – such as to a metal strain-relief clamp – below the minimum acceptable values, or if the mechanical operation of the circuit breaker or switch, or accessory is impaired.

14.1.5.3 Any surface with which the leads may come in contact shall be free from any projections, sharp edges, burrs, fins, or the like that may cause abrasion of the insulation on the conductors.

14.1.6 Spacings

14.1.6.1 With any combination of accessories installed, the circuit breaker or switch spacings shall not be less than those required in General, 6.1.6.1.

14.1.6.2 The requirements in 14.1.6.1 do not apply:

a) Between uninsulated live parts of opposite polarity within a component, such as an auxiliary switch;

b) Between uninsulated live parts of the component and dead metal that is part of the component; or

c) Between uninsulated live parts of the component and that part of the dead metal surface of the circuit breaker or switch on which the component is mounted in the intended manner.

14.1.6.3 The requirements in 14.1.6.1 do apply:

a) Between live parts in different components; and

b) Between an uninsulated live part of a component and a live part or the dead metal of the circuit breaker or switch, other than the dead metal surface on which the component is mounted.

14.1.6.4 The spacings at an accessory and its field-wiring terminals shall be in accordance with Table 14.1.6.1.

Table 14.1.6.1
Minimum acceptable spacings in millimeters (inches)[a,b,c]

Location		Potential involved in volts		
		0 – 130	131 – 300	301 – 600
Between any uninsulated live part and uninsulated live parts of opposite polarity, uninsulated grounded parts other than the enclosure, or exposed metal parts	Through air	3.2 (1/8)	6.4 (1/4)	9.5 (3/8)
	Over surface	6.4 (1/4)	9.5 (3/8)	12.7 (1/2)

[a] An isolated dead metal part (such as a screw head or a washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and a grounded dead metal part is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

[b] In measuring an over surface spacing, any slot, groove, or the like, 0.33 mm (0.013 inch) wide or less in the contour of insulating material shall be disregarded.

[c] In measuring spacings, an air spacing of 0.33 mm (0.013 inch) or less between a live part and an insulating surface shall be disregarded, and the live part considered in contact with the insulating material.

14.2 Shunt trip release devices

14.2.1 A shunt trip release device shall have a normally open auxiliary switch contact (″a″ type) connected in series with its coil, except that the auxiliary switch may be omitted under any one of the following conditions:

a) The shunt trip coil is rated for continuous duty,

b) The operating voltage for the coil is taken from the load side of the circuit breaker, or

c) The supply voltage to the coil is reduced, such as with electronic circuits. In this instance it shall be necessary to conduct the temperature test on the coil at the voltage to which the operating voltage has been reduced.

14.3 Undervoltage-trip release devices

14.3.1 An undervoltage-trip release device shall normally have its coil connected to the line side of the circuit breaker or switch without an auxiliary switch.

14.3.2 An attempt to close the circuit breaker or switch during an undervoltage condition shall not result in maintaining contacts in a closed position for more than ten cycles.

14.4 Overvoltage-trip release devices

14.4.1 An overvoltage-trip release device shall be so designed that the armature will be released for tripping under an overvoltage condition when the circuit breaker is in the ON position and also during the closing stroke of the circuit breaker or switch.

14.5 Electrical operators

14.5.1 An electrical operator shall be compatible for the particular application, and shall be capable of handling its maximum normal load without introducing any adverse condition.

14.5.2 A winding shall be such as to resist the absorption of moisture and shall be formed and assembled in a workmanlike manner.

14.5.3 With regard to the requirement in 14.5.2, film-coated magnet wire is not required to be additionally treated to prevent absorption of moisture, but fiber slot liners, cloth coil wrap, and similar moisture-absorptive materials should be provided with impregnation or otherwise treated to prevent moisture absorption.

14.5.4 An electrical operator intended to be mounted externally to the circuit breaker or switch may be factory- or field-installed. Instructions shall be provided with the electrical operator when it is intended to be field-installed.

14.5.5 Provision shall be made for manual operation of a circuit breaker or switch that is equipped with an electrical operator and shall be so located that when in use, the wiring space and live parts are not exposed. Means shall be provided to prevent the electrical operator from functioning during manual operation if electrical operation can result in a risk of electric shock or injury to operating personnel.

14.5.6 An electrical operator shall be provided with acceptable means for grounding all exposed accessible metal parts.

14.5.7 An electrical operator shall not require manual reset of the circuit breaker or switch.

14.6 Alarm and auxiliary switches

14.6.1 Auxiliary switch contacts shall be permitted to be designated as ″a″ or ″b″ as indicated below, but other contact arrangements shall be permitted to be used:

a) ″a″ contacts are opened when the molded-case product contacts are opened, and are closed when the molded-case product contacts are closed.

b) ″b″ contacts are closed when the molded-case product contacts are opened, and are opened when the molded-case product contacts are closed.

14.7 Mechanical interlock

14.7.1 A mechanical interlock supplied as a kit for field installation shall comply with 14.1.2.1.

14.7.2. A mechanical interlock shall have the necessary mechanical strength to ensure reliable and positive mechanical performance.

14.8 Lock-off device

14.8.1 A lock-off device supplied as a kit for field installation shall comply with all of the following:

a) Accommodate a padlock that will prevent the operation of the circuit breaker or switch with the padlock in place;

b) Require the use of a tool for removal;

c) Have the necessary mechanical strength to ensure reliable and positive mechanical performance;

d) Not depend on the panel enclosure cover to retain the device in place;

e) Not interfere with the normal intended operation of the circuit breaker or switch;

f) Ensure that the ON-OFF marking for the circuit breaker or switch is clearly visible with the padlocking attachment in place; and

g) Be marked in accordance with 17.9.

14.8.2 The ON-OFF marking mentioned in 14.8.1(f) may appear on the lock-off device.

14.9 Lock-on device

14.9.1 A lock-on device supplied as a kit for field installation shall comply with all of the following:

a) Accommodate a padlock that will prevent the operation of the circuit breaker or switch with the padlock in place;

b) Require the use of a tool for removal;

c) Have the necessary mechanical strength to ensure reliable and positive mechanical performance;

d) Not depend on the panel enclosure cover to retain the device in place;

e) Not interfere with the normal intended operation of the circuit breaker or switch;

f) Ensure that the ON-OFF marking for the circuit breaker or switch is clearly visible with the padlocking attachment in place; and

g) Be marked in accordance with 17.9.

14.9.2 The ON-OFF marking mentioned in 14.9.1 (f) may appear on the lock-on device.

15 Performance

15.1 General

15.1.1 One sample of each accessory is to be installed in the intended manner to determine compliance with the construction requirements of this standard. It shall also be determined that with the accessory(ies) installed in the intended manner, the combination complies with the performance requirements of this Standard. More than one type of accessory shall be permitted to be installed.

15.1.2 To determine compliance with the performance requirement section the following factors shall be considered with regard to the test program to be performed:

a) Whether the circuit breaker or switch has been found to comply with the performance section.

b) Whether the accessories have been found to comply with the requirements covering the accessory classification.

c) Whether the installed accessory(ies) affect(s) the operating characteristics, mechanical, arcing, calibration, and the like, of the circuit breaker or switch.

15.1.3 The strain-relief means provided on the accessory leads to which field connections are made, when tested in accordance with 15.1.4 shall be capable of withstanding for 1 min, without displacement, a pull of 89 N (20 lbf) applied to the leads with the connections within the circuit breaker or switch disconnected.

15.1.4 The specified force shall be applied to the individual leads and so supported by the circuit breaker or switch that the strain-relief means will be stressed from any angle that the construction of the circuit breaker or switch permits. The strain relief is not acceptable if, at the point of disconnection of the conductors, there is enough movement of the leads to indicate that stress on the connections would have resulted.

15.1.5 Except as specified in 15.1.8 and 15.1.9 if an accessory affects parts involving mechanical or arcing characteristics, because of its proximity to such parts, the device with the accessory installed shall be subjected to the interruption type tests specified in 15.1.6. If an accessory affects the calibration of a circuit breaker, the calibration tests shall also be performed.

15.1.6 The interruption type tests to be performed in accordance with 15.1.5 are as follows:

a) For circuit breakers – overload, endurance and interrupting as well as high available fault current if the circuit breaker has such a rating.

b) For switches – overload, endurance, and withstand, if applicable.

15.1.7 During tests on the circuit breaker or switch, the accessory and the circuit breaker or switch shall, except where otherwise noted, carry rated current at rated voltage. The voltage shall be applied to cause the most severe opposite polarity possible, including reverse line and load connection, unless the circuit breaker or switch is marked to indicate line-load connections.

15.1.8 For circuit breaker or switch frame sizes rated over 150 A, interrupting type tests shall not be required on the combination if a solid barrier with no holes is located between the accessory and the arcing contacts.

15.1.9 Interrupting type tests shall not be required on circuit breaker or switch frame sizes rated over 150 A with the accessory installed, if the accessory is located more than 50.8 mm (2 inches) from the nearest point of the open end of the arc plate, measured as a straight line between the arc plate and uninsulated live parts or the uninsulated dead metal parts of the accessory itself.

15.1.10 Should there be any questions regarding the acceptability of the barrier mentioned in 15.1.8, such as material size and the like, or should the accessory be mounted less than 50.8 mm (2 inches) from the nearest point of the open end of an arc plate in circuit breaker or switch frame sizes rated greater than 150 A, then the combination shall be subjected to the maximum voltage interrupting test or withstand test to determine whether additional interrupting type tests are necessary. The accessory shall be energized as intended during the test.

15.1.11 No additional interrupting type tests shall be necessary if the combination of circuit breakers or switches rated greater than 150 A and installed accessories satisfactorily completes the maximum voltage interrupting test followed by the recalibration and dielectric voltage-withstand tests.

15.1.12 Interruption type tests shall be required on circuit breaker or switch frame sizes rated 150 A or less with the accessories installed within the circuit breaker or switch housing, except when there are no uninsulated live or exposed dead metal parts on the accessory and the accessory does not interfere with the intended operation – mechanical, calibration, or arcing characteristics – of the circuit breaker.

15.1.13 More than one type of accessory, shunt trip, alarm switch, and the like may be installed in the circuit breaker or switch when it is subjected to any one of the interrupting type tests.

15.1.14 Tests need not be performed on the accessory or component parts of the accessory if component parts have been previously tested and found acceptable for the application. Should tests be necessary to determine the acceptability of the accessory for the application, the circuit breaker or switch need not be energized if the construction is such that the accessory is encapsulated or there are no uninsulated live or exposed dead metal parts on the accessory.

15.1.15 If it is required to conduct tests on a circuit breaker with the accessory installed, the number of circuit breaker samples required shall be in accordance with Table 7.1.1.2, except that only one sample shall be required if the circuit breaker without the accessory installed is found to comply with the performance requirements.

15.1.16 If it is required to conduct tests on a switch with the accessory installed, the number of switch samples required shall be in accordance with Table 11.1.1.2, except that only one sample shall be required if the switch without the accessory installed is found to comply with the performance requirements.

15.2 Shunt-trip release devices

15.2.1 Temperature

15.2.1.1 The maximum temperature rise of a coil intended for continuous duty, when operated at its rated voltage, shall not be higher than that permitted by Table 7.1.4.1.2.

15.2.2 Overvoltage Test

15.2.2.1 A coil of a shunt-trip device intended for continuous duty shall be capable of withstanding continuously 110 percent of its rated voltage without injury.

15.2.3 Operation Test

15.2.3.1 A shunt-trip device shall operate in the intended manner at 75 percent of its rated voltage to trip the circuit breaker or switch, except that a shunt-trip device for use in a ground-fault protection of equipment application shall operate at 55 percent of rated voltage for ac control power.

15.2.4 Endurance Test

15.2.4.1 A shunt-trip device, including a switch used to de-energize the coil as described in 14.2.1 shall be capable of performing successfully for 10 percent of the number of “With Current” operations and at the rate of operation shown in Table 7.1.5.1.

15.2.4.2 The tests may be performed in conjunction with the endurance test on the circuit breaker or switch.

15.2.4.3 A shunt-trip device shall be connected to a rated source of coil voltage. The test shall consist of repeating the following cycle for the required number of operations. The circuit breaker or switch shall trip on each cycle of operation:

a) Close circuit breaker or switch.

b) Energize shunt-trip with rated voltage.

15.2.5 Dielectric Voltage-Withstand Test

15.2.5.1 With the shunt-trip device installed in the circuit breaker or switch, the shunt-trip device shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential:

a) Between all live parts (including circuits) within the accessory,

b) Between all live parts tested in (a) and live parts of the circuit breaker or switch, and

c) Between the accessory coil winding and its frame.

15.2.5.2 The test potential for 15.2.5.1 (a), (b), and (c), respectively, shall be:

a) Twice the voltage rating of the accessory plus 1000V,

b) Twice the voltage rating of the circuit breaker plus 1000 V, and

c) Twice the voltage rating of the accessory plus 1000 V,

except that the test potential of a), b), and c) above shall be twice the voltage rating, but not less than 900 V, when tested after the high available fault current circuits interrupting capacity test for circuit breakers or the withstand test for switches. The test described in (b) is not required when the design of the circuit breaker isolates the accessory from energized parts in the circuit breaker, such as in a separate pole or in an accessory pocket.

15.2.5.3 The dielectric voltage-withstand test shall be performed after the interruption test(s), if the test(s) was performed to evaluate the acceptability of the combination. If no tests were performed, the dielectric voltage-withstand test shall be conducted with the combination in an as-received condition.

15.3 Undervoltage-trip release devices

15.3.1 Temperature

15.3.1.1 The maximum temperature rise of an undervoltage-trip release coil shall not be higher than that permitted by Table 7.1.4.1.2. See 15.1.7.

15.3.2 Overvoltage Test

15.3.2.1 The coil shall be capable of withstanding without injury 110 percent of its rated voltage continuously. See 15.1.7.

15.3.3 Operation Test

15.3.3.1 An undervoltage-trip release device shall operate to open the circuit breaker or switch at 35 percent or less of the marked voltage rating of the trip coil.

15.3.3.2 An undervoltage-trip release device shall not operate to open the circuit breaker or switch at 70 percent (or higher) of the marked voltage rating of the trip coil.

15.3.3.3 An undervoltage-trip release device may operate to open the circuit breaker or switch when the voltage across the trip coil is greater than 35 percent but less than 70 percent of the marked voltage rating of the trip coil.

15.3.3.4 An electrically reset undervoltage-trip release device shall pick up and a mechanically reset undervoltage-trip release device shall seal in at 85 percent of the rated voltage. Both devices may also pick up and seal in at lower voltage.

15.3.3.5 To determine compliance with 15.3.3.1 – 15.3.3.4, the test shall be conducted as follows starting with the circuit breaker in the tripped position or the switch in the off position:

a) Energize the undervoltage-trip release device at 85 percent of the marked rated voltage of the coil.

b) Close circuit breaker or switch.

c) Reduce voltage to 70 percent of the marked rated voltage of the coil. The circuit breaker or switch shall not operate at this voltage.

d) Reduce voltage to 35 percent of the marked rated voltage of the coil. The circuit breaker or switch shall operate at this voltage.

15.3.4 Endurance Test

15.3.4.1 An undervoltage-trip release device shall be capable of performing successfully for 10 percent of the number of “With Current” operations and at the rate of operation shown in Table 7.1.5.1.

15.3.4.2 The tests may be performed in conjunction with the endurance test on the circuit breaker or switch.

15.3.4.3 To determine compliance with 15.3.4.1, the test shall be conducted as follows starting with the circuit breaker in the tripped position or the switch in the off position, except that the last ten operations shall be performed in accordance with 15.3.3.5:

a) Energize the undervoltage-trip release device at 85 percent of the marked rated voltage of the coil.

b) Close the circuit breaker or switch.

c) Reduce coil voltage to zero. The circuit breaker or switch shall trip at zero coil voltage.

15.3.5 Dielectric Voltage-Withstand Test

15.3.5.1 With the undervoltage-trip release device installed in the circuit breaker or switch, the undervoltage-trip release device shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential:

a) Between all live parts (including circuits) within the accessory,

b) Between all live parts tested in (a) and live parts of the circuit breaker or switch, and

c) Between the accessory coil winding and its frame.

15.3.5.2 The dielectric voltage-withstand test shall be performed in accordance with 15.2.5.2 and 15.2.5.3.

15.3.6 Contact Closing Test

15.3.6.1 An attempt to close the circuit breaker or switch during an undervoltage condition shall not result in maintaining contacts in a closed position for more than 10 cycles.

15.4 Overvoltage-trip release devices

15.4.1 Temperature

15.4.1.1 The maximum temperature rise of an overvoltage-trip release coil, when operating at its nominal rated voltage, shall be less than or equal to that permitted by Table 7.1.4.1.2.

15.4.2 Overvoltage Test

15.4.2.1 An overvoltage-trip release coil that is intended to be connected to the load side of its circuit breaker or switch, or is intended for use in series with an “a” auxiliary contact, shall be capable of withstanding continuously without injury 98 percent of the voltage at which it causes the circuit breaker or switch to trip.

15.4.2.2 An overvoltage-trip release coil that is intended to be connected directly to the line side of a circuit breaker or switch, with no series auxiliary switch contact, shall be capable of withstanding continuously without injury its marked maximum voltage rating. See 17.4(a)

15.4.3 Operation Test

15.4.3.1 Both before and after the endurance test described in 15.4.4, an overvoltage-trip release device shall operate to cause the circuit breaker or switch to trip within ±5 percent of the rated trip voltage of the coil and shall not cause the circuit breaker or switch to trip when the nominal rated voltage is applied to the coil.

15.4.4 Endurance Test

15.4.4.1 An overvoltage-trip release device shall be capable of performing successfully for 10 percent of the number of “With Current” operations and at the rate of operation shown in Table 7.1.5.1.

15.4.4.2 The tests may be performed in conjunction with the endurance test on the circuit breaker or switch.

15.4.4.3 To determine compliance with 15.4.4.1, the test shall be conducted as follows starting with the circuit breaker in the tripped position or the switch in the off position:

a) With no voltage applied to the overvoltage-trip release device coil, close the circuit breaker or switch.

b) Apply a gradually increased voltage to the coil. The circuit breaker or switch shall trip when the applied voltage is within 5 percent of the rated value.

15.4.5 Dielectric Voltage-Withstand Test

15.4.5.1 With the overvoltage-trip release device installed in the circuit breaker or switch, the overvoltage-trip release device shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential:

a) Between all live parts (including circuits) within the accessory,

b) Between all live parts tested in (a) and live parts of the circuit breaker or switch, and

c) Between the accessory coil winding and its frame.

15.4.5.2 The dielectric voltage-withstand test shall be performed in accordance with 15.2.5.2 and 15.2.5.3.

15.5 Electrical operators

15.5.1 Endurance Test

15.5.1.1 An electrical operator shall perform acceptably when subjected to the endurance test described in 15.5.1.2 – 15.5.1.8.

15.5.1.2 An electrical operator shall be tested on the frame size circuit breaker or switch for which it is intended for the number of “Without Current” operations indicated in Table 7.1.5.1 for the given frame size.

15.5.1.3 An electrical operator intended for use with more than one frame size of circuit breaker or switch shall be tested on the maximum and minimum frame sizes for which it is intended. The total number of operations for each frame size shall be as indicated in Table 7.1.5.1, except that if the same operator is used for both tests, the number of operations required on the smallest frame size may be reduced by the number of operations required for the maximum frame size.

15.5.1.4 The first 25 operations shall be conducted at 85 percent of the electrical operator voltage rating at the rate required for the endurance test with the current as indicated in Table 7.1.5.1. During each of these operations, the circuit breaker or switch if appropriate shall be tripped so as to involve a resetting operation.

15.5.1.5 The next 25 operations shall be conducted as in 15.5.1.4 except at 110 percent of the electrical operator voltage rating.

15.5.1.6 The balance of the operations shall be completed with the electrical operator connected to a rated voltage supply and cycling ON and OFF without tripping the circuit breaker or switch at a rate agreeable to the submitter and the testing agency.

15.5.1.7 If overcurrent or overload protection is provided with the operator, it shall not function during the endurance test.

15.5.1.8 If the electrical operator, or any part of the operator, is installed within the circuit breaker or switch housing, or is installed so as to interfere with the intended venting of the circuit breaker or switch, consideration shall be given to the need for interrupting tests to be performed on the circuit breaker or switch with the electrical operator installed.

15.5.2 Dielectric Voltage-Withstand Test

15.5.2.1 An electrical operator intended to be installed externally to the circuit breaker or switch shall withstand, for a period of 1 min, without breakdown, the application of a 48 – 62 Hz essentially sinusoidal potential of 1000 V. The test voltage shall be applied between current-carrying parts of the electrical operator and accessible dead metal parts.

15.5.2.2 If the electrical operator or any part thereof is installed within the circuit breaker or switch housing, the dielectric voltage-withstand test specified in 7.1.9 is applicable.

15.6 Alarm and auxiliary switches

15.6.1 Temperature

15.6.1.1 The temperature attained on an alarm or auxiliary switch shall not exceed the values given in Tables 7.1.4.1.1 and 7.1.4.1.2, and the temperature rise at any connections intended for field wiring shall not exceed 50°C (90°F) when tested as outlined in 15.6.1.2 and 15.6.1.3.

15.6.1.2 The alarm and/or auxiliary switch or switches to be tested shall be installed in the intended circuit breaker or switch. If the circuit breaker or switch is constructed to accept more than one alarm and/or auxiliary switch, the maximum intended number of switches shall be installed.

15.6.1.3 Each alarm or auxiliary switch shall be caused to carry its rated current and the circuit breaker or switch shall carry its rated current while connected as for the temperature test specified in 7.1.4.1.4.

15.6.2 Overload Test

15.6.2.1 An alarm or auxiliary switch shall perform acceptably when subjected to an overload test. When rated in amperes, this test shall consist of 50 cycles of operation, making and breaking 150 percent of rated current at rated voltage. The rate of operation shall be in accordance with Table 7.1.3.1. The test shall be made on direct current with a noninductive resistance load if the switch is rated dc only, and shall be made with alternating current and an inductive load having a 75 – 80 percent power factor if ac rated. If both ac and dc ratings are involved, tests shall be conducted to represent both ratings, except that tests using a dc circuit may represent both ratings provided that ac current levels are equal to or less than the dc rating.

15.6.2.2 An alarm or auxiliary switch rated for pilot duty (electromagnetic loads) shall be capable of performing acceptably when subjected to 50 cycles of operation making and breaking a circuit consisting of a load as indicated in Table 15.6.2.1 when connected to a test voltage adjusted to 110 percent of the value indicated in Table 15.6.2.2.

Table 15.6.2.1
Standard electromagnetic loads for alarm or auxiliary switches

	Standard duty		Heavy duty	
Voltage, V rating	Normal current	Inrush current	Normal current	Inrush current
110 – 127 ac[a]	3.0	30	6.0	60
220 – 240 ac[a]	1.5	15	3.0	30
440 – 480 ac[a]	0.75	7.5	1.5	15
550 – 600 ac[a]	0.6	6	1.2	12
115 – 125 dc	1.1	–	2.2	–
230 – 250 dc	0.55	–	1.1	–
550 – 600 dc	0.2	–	0.4	–

[a] Power factor, 0.35 or less.

Table 15.6.2.2
Values of voltage for tests

Voltage rating of alarm or auxiliary switch	Test potential in Volts[a]
110 – 120	120
127	127
220 – 240	240
440 – 480	480
550 – 600	600

[a] If the rating of the switch does not fail within any of the indicated voltage ranges, it is to be tested at its rated voltage.

15.6.2.3 The load indicated in 15.6.2.2 shall be an electromagnet representative of the load that the device is intended to control. The load shall be adjusted to draw the normal and inrush currents indicated in Table 15.6.2.1 when connected to a test voltage as indicated in Table 15.6.2.2 before being connected for the test described in 15.6.2.2.

15.6.3 Endurance Test

15.6.3.1 An alarm switch shall be capable of performing acceptably when subjected to 10 percent of the number of “With Current” operations and at the rate of operation shown in Table 7.1.5.1.

15.6.3.2 An auxiliary switch shall be capable of performing acceptably when subjected to the number of “With Current” operations and at the rate of operation shown in Table 7.1.5.1.

15.6.3.3 The tests may be performed in conjunction with the endurance test on the circuit breaker or switch.

15.6.3.4 An ampere-rated switch shall be connected to a source of rated voltage. For dc only rated switches, the test shall be made on direct current with a noninductive resistance load of 100 percent rated current. For ac only rated switches, the test shall be made on alternating current with an inductive load having a 75 – 80 percent power factor and 100 percent of rated current. If both direct current and alternating current ratings (I_n) are the same, the test shall be conducted on direct current to represent both ratings. See also 15.1.10 and 15.1.12.

15.6.3.5 An alarm or auxiliary switch rated for pilot duty (electromagnetic loads) connected to a test voltage as indicated in Table 15.6.2.2 shall be capable of performing acceptably when making and breaking a load as indicated in Table 15.6.2.1. The load shall consist of an electromagnet representative of the load that the device is intended to control.

15.6.4 Dielectric Voltage-Withstand Test

15.6.4.1 With an alarm or auxiliary switch installed in the circuit breaker or switch, the accessory shall be capable of withstanding for 1 minute without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential between all live parts of the accessory including the associated wiring and live parts of the circuit breaker or switch.

15.6.4.2 The dielectric voltage-withstand test shall be performed in accordance with 15.2.5.2 and 15.2.5.3.

15.7 Mechanical interlock

15.7.1 A mechanical interlock provided with a pair or group of circuit breakers or switches shall demonstrate the ability to only allow the intended circuit breaker(s) or switch(es) to be turned “ON” as determined by the following:

a) Close one circuit breaker or switch and attempt to close the other circuit breaker(s) or switch(es) of the interlocked pair or group

b) Open the circuit breaker or switch

c) Move the interlock to the other position

d) Close the second circuit breaker or switch and attempt to close the first and any other circuit breakers or switches

e) Repeat steps (a) – (d) for each circuit breaker or switch that is controlled by the interlock.

15.8 Lock-off device

15.8.1 A lock-off device provided with a circuit breaker or switch shall prevent the circuit breaker or switch with which it is associated from being turned “ON”.

15.8.2 To demonstrate the correct operation of a lock-off device, it shall be installed, per the manufacturer’s instructions, and an attempt should be made to turn the circuit breaker “ON”.

15.9 Lock-on device

15.9.1 A lock-on device provided with a circuit breaker or switch shall prevent the circuit breaker or switch with which it is associated from being turned “OFF”.

15.9.2 To demonstrate the correct operation of a lock-on device, it shall be installed per the manufacturer’s instructions, and an attempt shall be made to turn the circuit breaker “OFF”.

16 Ratings

16.1 An accessory for a circuit breaker or switch shall have voltage, current, and frequency or dc ratings appropriate for the application.

17 Markings

17.1 A circuit breaker or switch provided with an accessory shall be marked to identify the installed accessory. The marking shall include type, proper connections (if not obvious), and the electrical rating of the accessory. Location Category C. See Table 9.1.

Advisory Note: For products intended for use in Canada, markings shall be in English or in French and English; caution and warning markings shall be in French and English. For products intended for use in Mexico, all markings shall be at least in Spanish. For products intended for use in the United States, all markings shall be at least in English. See Annex D for suitable translations of caution and warning markings.

17.2 The electrical rating for each type of accessory shall contain at least the following information.

Type of accessory	Volts	Amps	DC or Hertz	VA
Alarm switch	X	B	C	–
Auxiliary switch	X	B	C	–
Electrical operator	X	A	X	A
Over-voltage trip	X	A	X	A
Shunt trip	X	A	X	A
Under-voltage trip	X	A	X	A

X – Indicates this information required.

A – Indicates either amperes or VA information required.

B – Indicates either amperes or pilot duty rating required.

C – Indicates AC (or frequency in Hz), DC, or both.

17.3 A circuit breaker or switch provided with a shunt trip accessory, intended for use with ground-fault sensing and relaying equipment, shall be marked to indicate the specific equipment with which it is to be used, or shall bear the following marking, Location Category C:

a) Voltage and frequency, or dc, of tripping circuit;

b) Rated tripping current at 0.25 second if for dc or rated tripping current at 0.033 second and 0.25 second if for ac. Where the circuit provides for automatic disconnection of the shunt trip while the circuit breaker or switch contacts are open, the 0.25 second ac rating need not be provided; and

c) ″Suitable for Ground-Fault Protection when combined with Class I, or manufacturer and catalogue number, Ground-Fault Sensing Element″, or the equivalent.

17.4 If, in accordance with 14.1.2.1 and 14.1.2.2, an accessory is shipped from the factory separately from the circuit breaker or switch with which it is intended to be used:

a) The accessory shall be marked with its own catalogue number or the equivalent, with the name or trademark of the manufacturer, and with the electrical rating, except that when physical space does not permit permanent marking on the accessory and the accessory is marked with some identification that can be referenced, a removable tag or alternate marking means may be used. See 15.4.2.2.

b) Instructions shall be furnished with the accessory indicating the specific types of circuit breakers or switches with which the accessory is intended to be used.

c) A marking label that can be attached to the circuit breaker or switch to identify the field-installed accessory and its connections shall be furnished with the accessory, along with instructions for attaching the label to the circuit breaker or switch.

d) Installation and wiring instructions shall be furnished with the accessory unless the construction makes the installation obvious.

17.5 A circuit breaker or switch accessory shall be permitted to be marked with a type number indicating the external conditions as specified in Annex B, Ref. No. 15 for which it is acceptable. A circuit breaker or switch accessory that complies with the requirements for more than one type shall be permitted to have multiple designations. Location Category C.

17.6 If an external dropping resistor is intended to be connected between the line terminals of the circuit breaker or switch and the line terminals of an under-voltage trip device, the circuit breaker or switch shall be marked to identify this fact. The circuit breaker or switch shall also be marked to indicate the name of the manufacturer, the catalogue number, and the electrical rating of the resistor. Location Category C.

17.7 Each kit or package of a mechanical interlock shall be marked with:

a) Its identification, including the catalog or type number or numbers of the circuit breaker(s) or switch(es) with which it may be used;

b) The name, trademark, or trade name of the manufacturer; and

c) The method of installation.

17.8 Each kit shall contain a label to identify each circuit breaker or switch that is associated with the interlock as being interlocked and instructions that the installer should label the circuit breakers. As an example, a label may state: “Circuit breaker _____ is interlocked with circuit breaker _____”.

17.9 Each kit or package of a lock-off or lock-on device shall be marked with:

a) Its identification, including the catalogue or type number or numbers of the circuit breaker(s) or switch(es) with which it may be used;

b) The name, trade name, or trademark of the manufacturer; and

c) The method of installation unless the construction makes the installation plainly evident.

ENCLOSURES

18 Construction

18.1 General

18.1.1 An overall enclosure provided with a circuit breaker shall comply with Annex B, Ref. No. 16, except for modifications and additional requirements as specifically described in this standard.

18.1.2 When conducting the rain test, consideration shall be given to the effects of the operating-handle position on the integrity of the enclosure.

18.1.3 An external operating means, such as one for a disconnect, a pilot device, or a resetting operation, mounted on or through an enclosure shall withstand the environmental tests.

18.1.4 Gaskets employed on Type 12 or 12K enclosures shall be oil resistant.

18.1.5 A circuit breaker enclosure that includes a meter socket of the semi-flush type shall be marked as an enclosure Type 3R and shall additionally be marked concerning its use as specified in 21.5.4.

18.1.6 Except as noted in 18.1.7, a circuit breaker enclosure that includes a ringless meter socket and that is intended for outdoor use shall:

a) Have a permanent structural system to channel any accumulation of water to the outside of the enclosure,

b) Be constructed to prevent water from entering the circuit breaker compartment above the level of live parts, and

c) Be marked as an enclosure Type 3R.

18.1.7 A circuit breaker enclosure that completely encloses a meter socket so that an installed meter is not exposed to rain shall be permitted to be marked as an enclosure Type 3, 3S, 4, 4X, or combination of these types.

18.1.8 An enclosure intended for surface mounting and a box proper intended for flush mounting shall be permitted to be formed of sheet steel not less than 1.07 mm (0.042 inch) thick (base metal thickness not including a coating thickness) provided that:

a) The length does not exceed 457 mm (18 inches) and the width does not exceed 356 mm (14 inches),

b) The depth of the box proper is not more than 127 mm (5 inches), and

c) The thickness of a cover, front, door, trim, and the like provided as part of an enclosure intended for flush mounting is as specified in Annex B, Ref. No. 16.

18.1.9 An overall enclosure constructed to accommodate a circuit breaker shall use materials throughout that are acceptable for the purpose and shall be constructed so as to have the strength and rigidity necessary to resist the ordinary abuses to which it may be subjected, including any tests specified in this standard, so that:

a) It will retain its shape,

b) Doors will close tightly, and

c) Covers, fronts, and the like will fit properly.

18.1.10 The enclosure mentioned in 18.1.9 shall completely enclose all current-carrying parts whether dead or alive, regardless of the position, off or on, of the circuit breaker; and with the circuit breaker in position shall not have any open hole or slot to provide for the movement of an operating handle. The enclosure shall be reasonably tight and shall have means for mounting.

18.1.11 Where circuit breaker handles are operated vertically rather than rotationally or horizontally, the uppermost position shall be the on position.

18.1.12 A back-fed circuit breaker that uses a friction or plug-on bus bar connection shall not be used to terminate the field installed ungrounded supply conductors. A back-fed circuit breaker provided with an additional fastener that requires other than a pull to release the unit from its mounting position (such as a hold-down kit) shall be permitted to be used to terminate field installed ungrounded supply conductors. See 21.7.1.

18.2 Provision for locking

18.2.1 A door or cover that gives access to the interior of the enclosure shall be fastened by screws or shall have provision for locking.

18.2.2 Means shall be provided for the locking of a circuit breaker in the off position. This may be accomplished by any one of the following means:

a) A locking means that is part of the circuit breaker;

b) A locking means that is part of the enclosure;

c) A lockable door or cover over the circuit breaker handle; or

d) A separate locking means, with instructions for its installation, which is shipped with and can be easily installed on the circuit breaker or the enclosure.

18.3 Connections to wiring systems

18.3.1 If knockouts are provided in a circuit breaker enclosure, they may be of any size; but at least two of them, or more when multiple conduits are involved, shall be located so that the installation of bushings will not result in spacings between live parts and bushings of less than those specified in Table 6.1.6.1.1 when the knockouts are reamed to accommodate the size of conduit required for the maximum number and gauge of conductors necessitated by the maximum rating of the circuit breaker intended to be used in the enclosure.

18.3.2 If threads for the connection of conduit are tapped all the way through a hole in a circuit breaker enclosure, or if an equivalent construction is used, there shall not be less than 3-1/2 threads in the metal, and the construction of the device shall be such that a conduit bushing can be properly attached. If the threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than five full threads in the metal and there shall be a smooth well-rounded inlet hole for the conductors, which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and which shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

18.3.3 A separable conduit hub shall comply with the requirements in 18.3.2.

18.4 Ventilation

18.4.1 Ventilating openings shall be permitted in Type 1 and Type 2 enclosures housing a circuit breaker having a frame size of 400 A or larger.

18.4.2 A ventilating opening in an enclosure shall be constructed and located so that no flame or molten metal will be emitted during the interrupting test on the circuit breaker. See 7.1.7.11.

18.4.3 A ventilating opening in an enclosure shall have such size or shape or shall be so covered by screening or by an expanded, perforated, or louvered metal panel that a test rod having the diameter specified in 18.4.4 will be prevented from entering.

18.4.4 The test rod indicated in 18.4.3 shall be 13.1 mm (33/64 inch) in diameter if the plane of the opening is less than 102 mm (4 inches) from an uninsulated live part, or 19.4 mm (49/64 inch) in diameter if the plane of the opening is 102 mm (4 inches) or more from such a part.

18.4.5 A louver shall not be more than 305 mm (12 inches) in length.

18.4.6 The size, shape, and location of a ventilating opening shall be such as not to unduly weaken the overall enclosure.

18.4.7 The total area of enclosure material removed from a wall for ventilation, together with the total area of ventilating openings as a result of forming the parent material, shall not exceed 25 percent of the area of the entire surface of any wall in which such ventilating openings are located, except that the 25 percent limitation may be exceeded provided suitable means of reinforcement, such as stiffeners, are employed and the enclosure complies with 18.4.6.

18.4.8 The area of any ventilating opening, as defined by the opening in the parent metal, shall not exceed 1.29 m^2 (200 in^2) if the ventilated closing panel is formed from material that has a thickness less than that of the parent metal. A ventilated closing panel of 1.35 mm (0.053 inch) thick uncoated or 1.42 mm (0.056 inch) thick coated or lighter steel or 14 AWG (2.1 mm^2) or lighter wire mesh shall not be used to close an opening of more than 5.16 m^2 (80 in^2).

18.4.9 The wires of a screen of a ventilating opening shall not be smaller than 16 AWG (1.3 mm^2) if the screen openings are 323 mm^2 (1/2 in^2) or less in area, and not smaller than 12 AWG (3.3 mm^2) for larger screen openings. A supplementary screen of smaller openings may be additionally provided. The supplementary screen shall not be considered in the evaluation of the ventilating opening screen.

18.4.10 Except as permitted by 18.4.11, perforated sheet steel and sheet steel expanded mesh shall not be less than 1.07 mm (0.042 inch) thick (base metal thickness not including a coating thickness), if the mesh openings or perforations are 323 mm^2 (1/2 in^2) or less in area, and shall not be less than 2.03 mm (0.080 inch) thick (base metal thickness not including a coating thickness) for larger openings.

18.4.11 Where the indentation of a guard on an enclosure will not alter the clearance between uninsulated live parts and grounded metal, so as to affect performance adversely or reduce spacings below the minimum values given in General, 6.1.6.1, 0.51 mm (0.020 inch) minimum expanded metal mesh (base metal thickness not including a coating thickness) shall be permitted. See 18.4.8.

18.4.12 If a barrier is located behind a ventilating opening to comply with 18.4.2 the barrier shall comply with 18.4.13 – 18.4.17.

18.4.13 Except as permitted by 18.4.14 a sheet-metal barrier shall have a thickness of not less than 1.35 mm (0.053 inch) if uncoated and not less than 1.42 mm (0.056 inch) if galvanized.

18.4.14 A metal barrier shall be permitted to be of steel of thickness less than that indicated in 18.4.13 if it is formed or reinforced so that its strength and rigidity is not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness.

18.4.15 A nonmetallic barrier shall not be less than 6.4 mm (1/4 inch) thick and shall be supported so as to give adequate strength and rigidity.

18.4.16 The thickness of a nonmetallic barrier shall be permitted to be less than 6.4 mm (1/4 inch) if the barrier is located so that it will not be subjected to mechanical abuse during installation and is located and supported so that it will have adequate physical strength and rigidity.

18.4.17 A ventilating opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening to prevent the entry of foreign material.

18.5 External operating mechanism

18.5.1 It shall not be necessary to expose wiring or live parts in order to operate a circuit breaker installed in an enclosure.

18.5.2 An operating member that indicates the position of the circuit breaker contacts – closed or open – shall be constructed so that the door, front, or cover cannot be secured in place so that the member indicates off or tripped with the circuit breaker contacts in the closed position.

18.5.3 The construction of the operating mechanism shall be such as to provide ample strength and rigidity. Screws and nuts serving to attach operating parts to crossbars or other movable members shall be staked, upset, or otherwise locked in position to prevent loosening. Means shall be provided so that there is not undue strain of circuit breaker parts.

18.5.4 An external operating handle of conducting material shall be in electrical connection with the enclosure.

18.5.5 A metal rod using the wall of the box as a bearing is considered to be in electrical connection with the enclosure.

18.5.6 If the position of a circuit breaker is indicated by the position of the operating handle, the construction of the operating mechanism shall be such that the handle cannot be left readily at or near the off position when the circuit breaker is on.

18.5.7 The external member shall clearly indicate whether the circuit breaker is in the on or off position. See also 21.2.1.

18.5.8 All metal parts, unless of corrosion resistant material, shall be protected against corrosion.

18.5.9 Metal parts that are galvanized, plated, painted, or enameled are considered to be acceptably protected against corrosion.

18.5.10 An external operating mechanism that is provided as part of a circuit breaker enclosure shall be subjected to an endurance test. The number of operations shall be as indicated in Column 5 of Table 7.1.5.1, based on the frame size of the circuit breaker used therein. The test shall be permitted to be conducted in conjunction with the endurance test on the circuit breaker. There shall not be any mechanical malfunction of the operating mechanism or breakage of the circuit breaker handle.

18.6 Cases – insulating material

18.6.1 A case for mounting an uninsulated live part in a circuit breaker enclosure shall comply with the requirements in Cases – Insulating Materials, 6.1.3.

18.7 Current-carrying parts

18.7.1 A circuit breaker enclosure that incorporates current carrying parts other than a neutral shall comply with the temperature test described in 7.1.4, when tested with its maximum current rated circuit breaker installed and carrying 80 percent of rated current of the circuit breaker.

18.7.2 Any terminals provided as part of a circuit breaker enclosure, including the neutral, shall be acceptable for the wire size and type associated with the circuit breakers designated to be installed and shall comply with the requirements of 6.1.4.2.2 and 6.1.4.2.3. See Table 6.1.4.2.1. If the circuit breaker enclosure is marked as being acceptable for use as service equipment, all terminals provided shall be acceptable for a wire size of at least 8 AWG (8.4 mm^2).

18.7.3 In a circuit breaker enclosure having line terminals or constructed to be used with a circuit breaker having line terminals acceptable for copper and aluminum conductors, any neutral line terminals shall also be acceptable for copper or aluminum conductors unless the enclosure is marked “Use Copper Wire Only”. See 21.4.2.

18.7.4 A soldering lug or other connection which depends upon solder shall not be provided for the connection of the service conductors to a circuit breaker or circuit breaker enclosure marked acceptable for use as service equipment.

18.7.5 Unless the terminal parts intended for the connection of the grounded conductor are clearly evident, a terminal for the connection of a grounded conductor shall be identified by means of a metallic plating substantially white in color, or the terminal may be of a metal substantially white in color, and shall be readily distinguishable from the other terminals.

18.7.6 A neutral assembly in or for use in a circuit breaker enclosure shall have an ampacity equal to the highest ampere rating of the circuit breaker with which it is intended to be used except that when limited to use on a 3-wire dc or 3-wire, single-phase or 4-wire, 3-phase circuit, the capacity shall be permitted to be reduced to not less than 200 A plus 70 percent of the highest circuit breaker ampere rating with which it is intended to be used. See 21.1.2.

18.7.7 If a circuit breaker enclosure is acceptable for use both with and without a neutral assembly, such assembly need not be mounted in place in the circuit breaker enclosure when it is shipped from the factory if the neutral assembly is shipped completely assembled with the necessary barriers and other accessories which would be required for its use. The neutral assembly is acceptable for field installation if it is complete, needs no field assembly of parts other than terminals, and has appropriate markings. See 21.6.1 and 21.6.2.

18.8 Spacings

18.8.1 General

18.8.1.1 The spacings provided in a circuit breaker enclosure shall not be less than the applicable spacings of 6.1.6.1.1 – 6.1.6.1.14.

18.8.1.2 Except as indicated in 18.10.3.1 and 18.10.3.2, a terminal that is intended to accommodate the grounded conductor shall comply with the requirements in 18.8.1.1. The voltage between the terminal intended to accommodate the grounded conductor and grounded metal is considered to be equal to the line to neutral voltage of the supply.

18.8.2 Wiring Space

18.8.2.1 There shall be adequate space within an enclosure for the installation and termination of all wires intended to be employed.

18.8.2.2 In the consideration of wiring space, it is assumed that conductors larger than 750 kcmil (380 mm^2) will not be used. For example, a 600 A connection will usually involve two 350 kcmil (177 mm^2) cables, rather than one 1500 kcmil (760 mm^2) conductor. If terminals are provided for the connection of conductors larger than 750 kcmil (380 mm^2), the wiring space provided shall be adequate for the larger conductors unless the enclosure is marked to indicate the size of conductors for which it is intended and also to indicate that the use of larger conductors will necessitate their being brought into the enclosure directly opposite the wiring terminals to which they are to be connected.

18.8.2.3 A circuit breaker enclosure having terminals identified as being acceptable with copper or aluminum conductors and an enclosure intended to be used with circuit breakers having terminals identified as being acceptable with copper or aluminum conductors shall provide wiring space for the proper size aluminum conductors.

18.8.2.4 With regard to the requirement of 18.8.2.1, the number of wires for which wiring space is to be provided is twice the number of circuit breaker poles – the maximum number of wires involved when the wires enter the enclosure at the end opposite to the end at which the terminals to which they will be connected are located. If a solid neutral terminal is supplied, wiring space for such wires will also be required. The provision of barriers to prevent the running of wires end-to-end is acceptable in place of the wiring space otherwise required if the barriers are riveted, welded, or otherwise secured in place as to make their removal difficult.

18.8.2.5 If knockouts are provided in a side wiring space, the width of such a space shall be such as to accommodate – with regard to bending – the maximum size of wire for the particular application, except that side wiring spaces of less width shall be permitted if knockouts of appropriate size are properly located elsewhere, and if they can be used conveniently in the normal wiring of the device. The minimum wiring space for conductor sizes of 8 AWG (8.4 mm^2) and larger are given in Tables 18.8.2.1 and 18.8.2.2.

Table 18.8.2.1
Minimum wire-bending space at terminals in mm

Wire size		Wires per terminal (pole)[a]			
AWG or kcmil	(mm^2)	1	2	3	4 or more
14 – 10	(2.1 – 5.3)	Not specified	–	–	–
8	(8.4)	38.1	–	–	–
6	(13.3)	50.8	–	–	–
4	(21.2)	76.2	–	–	–
3	(26.7)	76.2	–	–	–
2	(33.6)	88.9	–	–	–
1	(42.4)	114.3	–	–	–
1/0	(53.5)	127	127	177.8	–
2/0	(67.4)	152.4	152.4	190.5	–
3/0	(85.0)	165.1 (12.7)	165.1 (12.7)	203.2	–
4/0	(107)	177.8 (25.4)	190.5 (38.1)	215.9 (12.7)	–
250	(127)	215.9 (50.8)	215.9 (50.8)	228.6 (25.4)	254
300	(152)	254 (76.2)	254 (50.8)	279.4 (25.4)	304.8
350	(177)	304.8 (76.2)	304.8 (76.2)	330.2 (76.2)	355.6 (50.8)
400	(203)	330.2 (76.2)	330.2 (76.2)	355.6 (76.2)	381.0 (76.2)
500	(253)	355.6 (76.2)	355.6 (76.2)	381.0 (76.2)	406.4 (76.2)
600	(304)	381.0 (76.2)	406.4 (76.2)	457.2 (76.2)	482.6 (76.2)
700	(355)	406.4 (76.2)	457.2 (76.2)	508.0 (76.2)	558.8 (76.2)
750	(380)	431.8 (76.2)	482.6 (76.2)	558.8 (76.2)	609.6 (76.2)
800	(405)	457.2	508.0	558.8	609.6
900	(456)	482.6	558.8	609.6	609.6
1000	(507)	508.0	–	–	–
1250	(633)	558.8	–	–	–
1500	(760)	609.6	–	–	–
1750	(887)	609.6	–	–	–
2000	(1013)	609.6	–	–	–

[a] Wire bending space may be reduced by the number of millimeters shown in parentheses under the following conditions:

1. Only removable wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal).

2. The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

mm	12.7	25.4	38.1	50.8	76.2	88.9	114.3	127	152.4	165.1	177.8
inch	1/2	1	1-1/2	2	3	3-1/2	4-1/2	5-1/2	6	6-1/2	7
mm	190.5	203.2	215.9	228.6	254	279.4	304.8	330.2	355.6	381.0	406.4
inch	7-1/2	8	8-1/2	9	10	11	12	13	14	15	16
mm	431.8	457.2	482.6	508.0	558.8	609.6					
inch	17	18	19	20	22	24					

Table 18.8.2.2
Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in mm (inches)[a,b]

Size of wire		Wires per terminal (pole) mm (inches)									
AWG or kcmil	(mm^2)	1		2		3		4		5	
14 – 10	(2.1 – 5.3)	Not specified		–		–		–		–	
8 – 6	(8.4 – 13.3)	38.1	(1-1/2)	–		–		–		–	
4 – 3	(21.1 – 26.7)	50.8	(2)	–		–		–		–	
2	(33.6)	63.5	(2-1/2)	–		–		–		–	
1	(42.4)	76.2	(3)	–		–		–		–	
1/0 – 2/0	(53.5 – 67.4)	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	(85.0 – 107)	102	(4)	152	(6)	203	(8)	–		–	
250	(127)	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	(152 – 177)	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	(203 – 253)	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	(304 – 355)	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	(380 – 456)	203	(8)	305	(12)	356	(14)	406	(16)	457	(18)
1000 – 1250	(507 – 633)	254	(10)	–		–		–		–	
1500 – 2000	(760 – 1010)	305	(12)	–		–		–		–	

[a] The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

[b] For circuit breakers rated 125 A or less, and marked to indicate use of both 60°C and 75°C wire, the wire bending space is based on the use of 60°C (140°F) insulated wire.

18.8.2.6 The clear wiring space at any point, independent of all projections, obstructions, or interference from moving parts of the operating mechanism, shall not be less in width nor in depth than the values given in Table 18.8.2.3.

Table 18.8.2.3
Wiring space

Maximum size of wire or cable involved AWG or kcmil (mm^2)	Minimum width and depth of wiring space		Minimum areas in mm^2 (in^2) required for multiple wires based on factor of 2.5											
			Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
	mm	(inch)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)
12 AWG	9.5	(3/8)	90	(0.14)	135	(0.21)	181	(0.28)	226	(0.35)	271	(0.42)	316	(0.49)
10	9.5	(3/8)	148	(0.23)	219	(0.34)	297	(0.46)	368	(0.57)	439	(0.68)	516	(0.80)
8	12.7	(1/2)	277	(0.43)	413	(0.64)	548	(0.85)	690	(1.07)	826	(1.28)	968	(1.50)
6	15.9	(5/8)	400	(0.62)	600	(0.93)	800	(1.24)	1000	(1.55)	1200	(1.86)	1400	(2.17)
4	19.1	(3/4)	516	(0.80)	774	(1.20)	1032	(1.60)	1290	(2.00)	1548	(2.40)	1806	(2.80)
3	19.1	(3/4)	587	(0.91)	877	(1.36)	1174	(1.82)	1465	(2.27)	1755	(2.72)	2052	(3.18)
2	22.2	(7/8)	665	(1.03)	1000	(1.55)	1329	(2.06)	1665	(2.58)	2000	(3.10)	2329	(3.61)
1	25.4	(1)	877	(1.36)	1316	(2.04)	1755	(2.72)	2194	(3.40)	2632	(4.08)	3071	(4.76)
1/0	25.4	(1)	1000	(1.55)	1503	(2.33)	2000	(3.10)	2503	(3.88)	3006	(4.66)	3503	(5.43)
2/0	25.4	(1)	1155	(1.79)	1729	(2.68)	2310	(3.58)	2884	(4.47)	3458	(5.36)	4039	(6.26)
3/0	28.6	(1–1/8)	1342	(2.08)	2006	(3.11)	2684	(4.16)	3348	(5.19)	4013	(6.22)	4690	(7.27)
4/0	31.8	(1-1/4)	1561	(2.42)	2342	(3.63)	3123	(4.84)	3903	(6.05)	4684	(7.26)	5465	(8.47)
250 kcmil	34.9	(1-3/8)	1910	(2.96)	2865	(4.44)	3819	(5.92)	4774	(7.40)	5729	(8.88)	6684	(10.36)
300	38.1	(1-1/2)	2206	(3.42)	3310	(5.13)	4413	(6.84)	5516	(8.55)	6619	(10.26)	7716	(11.96)
350	38.1	(1-1/2)	2458	(3.81)	3690	(5.72)	4916	(7.62)	6148	(9.53)	7381	(11.44)	8606	(13.34)
400	41.3	(1-5/8)	2697	(4.18)	4045	(6.27)	5394	(8.36)	6742	(10.45)	8090	(12.54)	9439	(14.63)
500	44.5	(1-3/4)	3174	(4.92)	4761	(7.38)	6348	(9.84)	7935	(12.30)	9523	(14.76)	11110	(17.22)
600	47.6	(1-7/8)	3852	(5.97)	5781	(8.96)	7703	(11.94)	9632	(14.93)	11561	(17.92)	13484	(20.90)
700	50.8	(2)	4310	(6.68)	6465	(10.02)	8619	(13.36)	10774	(16.70)	12929	(20.04)	15084	(23.38)
750	50.8	(2)	4542	(7.04)	6813	(10.56)	9084	(14.08)	11355	(17.60)	13626	(21.12)	15897	(24.64)
800	54.0	(2-1/8)	4768	(7.39)	7155	(11.09)	9535	(14.78)	11923	(18.48)	14310	(22.18)	16690	(25.87)
900	57.2	(2-1/4)	5219	(8.09)	7826	(12.13)	10439	(16.18)	13045	(20.22)	15652	(24.26)	18264	(28.31)
1000	57.2	(2-1/4)	5658	(8.77)	8484	(13.15)	11316	(17.54)	14142	(21.92)	16968	(26.30)	19800	(30.69)
1250	63.5	(2-1/2)	7116	(11.03)	10677	(16.55)	14232	(22.06)	17794	(27.58)	21355	(33.10)	24910	(38.61)
1500	69.9	(2-3/4)	8219	(12.74)	12329	(19.11)	16439	(25.48)	20548	(31.85)	24658	(38.22)	28768	(44.59)
1750	73.0	(2-7/8)	9323	(14.45)	13981	(21.67)	18123	(28.09)	23303	(36.12)	27961	(43.34)	32626	(50.57)

Table 18.8.2.3 Continued on Next Page

Table 18.8.2.3 Continued

Maximum size of wire or cable involved AWG or kcmil (mm^2)	Minimum width and depth of wiring space		Minimum areas in mm^2 (in^2) required for multiple wires based on factor of 2.5											
			Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
	mm	(inch)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)	mm^2	($inch^2$)
2000	79.4	(3-1/8)	10348	(16.04)	15523	(24.06)	20697	(32.08)	25871	(40.10)	31045	(48.12)	36219	(56.14)

18.8.2.7 The clear wiring space, independent of all projections, obstructions, or interference from moving parts of the operating mechanism, shall be fully adequate for the wiring of the device, and shall not be less in total area than 250 percent of the total cross-sectional area of the maximum number of wires that may be used in such space.

18.8.2.8 Minimum values for some of the more common multiple-wire conditions are given in Table 18.8.2.3.

18.8.2.9 To determine if a wiring space complies with the requirements of 18.8.2.7, consideration shall be given to the actual size of wires that will be used in that space, but it is to be assumed that wires smaller than 12 AWG (3.3 mm^2) will not be used. In computing the actual area of a wiring space, consideration shall be given to all the available space that is permitted for the placement of wires.

18.8.2.10 For a circuit breaker, the wire-bending space at the line and load terminals shall be as specified in Table 18.8.2.1 for the conductor size that corresponds with the maximum ampere rating of the circuit breaker enclosure.

18.8.2.11 The wire-bending space from a connector to any barrier or other obstruction that is part of a circuit breaker enclosure shall be as specified in Table 18.8.2.2.

18.8.2.12 If a wire is restricted by barriers or other means from being bent in a 90-degree or S bend from the terminal to any usable location in the wall of the enclosure, the distance shall be measured from the end of the barrier or other obstruction.

18.8.2.13 The distance indicated in 18.8.2.10 and 18.8.2.11 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any reliable means provided to prevent its turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like shall be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure. Side wire bending space, such as at a neutral in side gutter, shall be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal.

18.8.2.14 The construction and arrangement of the operating mechanism and its relation to the wiring space shall be such that it will not cause injury to wires.

18.8.2.15 If a circuit breaker enclosure is divided by barriers into separate sections for the purpose of isolating watt-hour meters so that field wiring is not installed from one section to another, and is provided with a separate cover for the meter socket compartment that may be individually sealed, the wiring space, wiring gutters, and wire bending space required in each section shall be based only on the field installed conductors to be located in that section. Further, the wiring space, wiring gutters, and wire bending space in the meter socket compartment shall be permitted to be in accordance with the requirements in Annex B, Ref. No. 17.

18.9 Equipment grounding terminals

18.9.1 Provision shall be made in circuit breaker enclosures for the termination of grounding conductors.

18.9.2 The grounding means shall be permitted to be in the form of a kit. See 21.4.10.

18.10 Enclosures suitable for use as service equipment (not for use in Canada)

18.10.1 General

18.10.1.1 The requirements in 18.10 do not apply to enclosures suitable for use as service equipment that are intended for use in Canada. Such enclosures shall instead comply with the requirements in Enclosures suitable for use as service equipment (for use in Canada), Section 18.11.

18.10.1.2 The grounding and bonding terms used in Section 18.10 are in accordance with the UL column in Figure 18.10.1. The corresponding CEC and ANCE terms are also provided for information.

18.10.2 Disconnecting Means

18.10.2.1 A circuit breaker enclosure which has provision for the connection of a grounded service conductor, shall, if marked to indicate that it is acceptable for use as service equipment, be provided with means for disconnecting the grounded service conductor from the grounded load conductor.

18.10.2.2 The required disconnecting means shall be permitted to be a link, screw, or similar conducting piece intended to make connection between two terminals; it shall be permitted to be a terminal plate provided with a terminal or terminals.

18.10.2.3 If a disconnecting means as described in 18.10.2.1 is provided, there shall be provision for the separate connection of the grounded line and load conductors.

18.10.3 Provision for Grounding

18.10.3.1 A circuit breaker enclosure marked as being acceptable for use as service equipment shall have provision for connection of the grounding electrode conductor to the grounded service conductor. The size of the grounding electrode conductor terminal shall be in accordance with Table 18.10.3.1. A soldering lug or other connection means that depends upon solder is not acceptable.

18.10.3.2 There shall be provision for connection of the grounding-electrode conductor, indicated in 18.10.3.1, to the grounded conductor, if a grounded conductor is provided. The provision shall be permitted to be on the equipment-grounding terminal assembly, bus, or the like if the main-bonding jumper is a bus bar or wire and is connected directly from the grounded conductor to the equipment-grounding terminal assembly. See Figure 18.10.1.

Table 18.10.3.1
Size of grounding electrode conductors and main bonding jumper

Ampere rating not exceeding	Minimum size of main bonding jumper terminal[a,b,c] AWG or kcmil (mm^2)				Minimum cross section of main bonding jumper in square mm ($inch^2$)[a,b]				Minimum size of grounding electrode conductor terminal AWG or kcmil (mm^2)			
	Copper		Aluminum[i]		Copper		Aluminum[i]		Copper		Aluminum[i]	
90	8	(8.4)	6	(13.3)	8.4[d]	(0.013[d])	13.5[d]	(0.021[d])	8	(8.4)	6	(13.3)
100	6	(13.3)	4	(21.2)	13.5[d]	(0.021[d])	21.3[d]	(0.033[d)]	6	(13.3)	4	(21.2)
125	6	(13.3)	4	(21.2)	13.5[d]	(0.021[d])	21.3[d]	(0.033[d])	6	(13.3)	4	(21.2)
150	6	(13.3)	4	(21.2)	13.5[e]	(0.021[e])	21.3[e]	(0.033[e])	4	(21.2)	4	(21.2)
200	4	(21.2)	2	(33.6)	21.3[e]	(0.033[e])	33.5[e]	(0.052[e])	3	(26.7)	3	(33.6)
225	2	(33.6)	1/0	(53.5)	33.5[f,g]	(0.052[f,g])	53.5[f,g]	(0.083[f,g])	2	(33.6)	1/0	(53.5)
400	1/0[h]	(53.5)	3/0[h]	(85.0)	53.5[g,h]	(0.083[g,h])	85.2[g,h]	(0.132[g,h])	2/0	(67.4)	3/0[h]	(85.0)
500	1/0	(53.5)	3/0	(85.0)	53.5	(0.083)	85.2	(0.132)	3/0	(85.0)	3/0	(85.0)
600	2/0	(67.4)	4/0	(107.2)	67.7	(0.105)	107	(0.166)	3/0	(85.0)	4/0	(107.2)
800	2/0	(67.4)	4/0	(107.2)	67.7	(0.105)	107	(0.166)	3/0	(85.0)	4/0	(107.2)
1000	3/0	(85.0)	250	(127)	85.2	(0.132)	126	(0.196)	3/0	(85.0)	250	(127)
1200	250	(127)	250	(127)	114	(0.177)	126	(0.196)	3/0	(85.0)	250	(127)
1600	300	(152)	400	(203)	152	(0.236)	190	(0.294)	3/0	(85.0)	250	(127)
2000	400	(203)	500	(253)	190	(0.294)	228	(0.353)	3/0	(85.0)	250	(127)
2500	500	(253)	700	(355)	228	(0.353)	332	(0.515)	3/0	(85.0)	250	(127)
3000	600	(304)	750	(380)	266	(0.412)	380	(0.589)	3/0	(85.0)	250	(127)
4000	750	(380)	1000	(507)	380	(0.589)	523	(0.810)	3/0	(85.0)	250	(127)

[a] The cross section shall be permitted to be reduced to 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase on equipment rated 1200 A and above. This applies when the cross section of the service conductors is limited by the wire terminal connectors provided.

[b] For equipment rated 1200 A or more and that has wiring terminals intended to connect service conductor wires sized larger than 600 kcmil (304 mm^2) copper or 750 kcmil (380 mm^2) aluminum, the cross section of the main bonding jumper shall be at least 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase

[c] These are also sizes for the grounded service conductor of 18.10.3.3.

[d] A No. 8 (4.17 mm) or larger brass or No. 10 (4.83 mm) or larger steel screw shall be permitted.

[e] A No. 10 (4.83 mm) or larger brass or steel screw shall be permitted.

[f] A No. 10 (4.83 mm) or larger brass or steel screw shall be permitted.

[g] A 6.4 mm (1/4 inch) diameter or larger brass or steel screw shall be permitted.

Table 18.10.3.1 Continued on Next Page

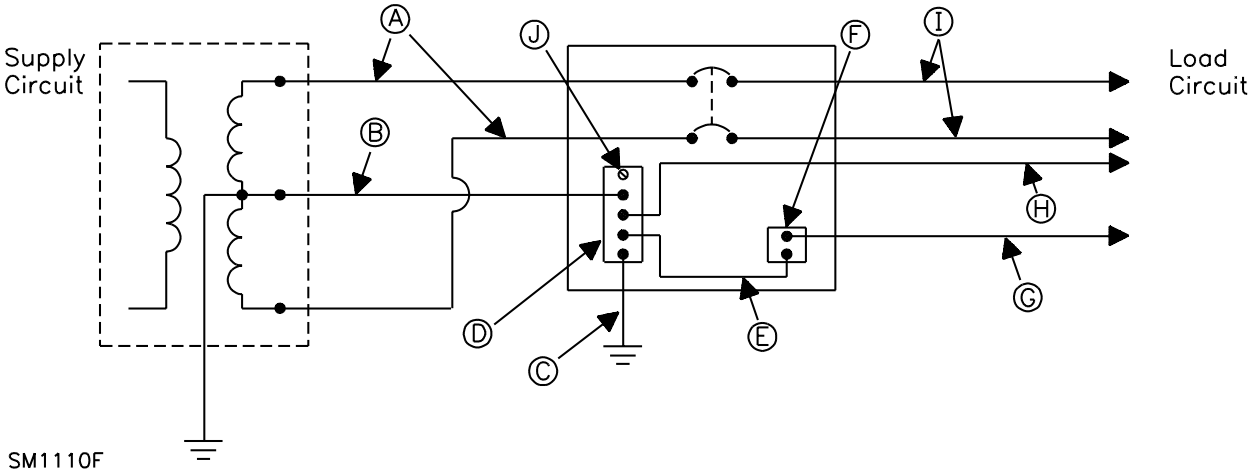
Table 18.10.3.1 Continued

Ampere rating not exceeding	Minimum size of main bonding jumper terminal[a,b,c] AWG or kcmil (mm^2)		Minimum cross section of main bonding jumper in square mm (inch^2)[a,b]		Minimum size of grounding electrode conductor terminal AWG or kcmil (mm^2)	
	Copper	Aluminum[i]	Copper	Aluminum[i]	Copper	Aluminum[i]

[h] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are acceptable for two 3/0 AWG (85.0 mm^2) copper or two 250 kcmil (127 mm^2) aluminum conductors but will not accept a 600 kcmil (304 mm^2) copper conductor, these values shall be permitted to be reduced to 2 AWG (0.052 in^2) (33.6 mm^2) copper or 0 AWG (53.5 mm^2) (0.083 in^2) aluminum.

[i] The Canadian Electrical Code CSA C22.1 requires copper conductor to be used as a grounding electrode conductor.

Figure 18.10.1
Typical grounding system for single-phase service



Note: This figure is only intended to show the use of terminology it is not intended to represent construction practices.

UL TERMS	CEC TERMS	ANCE TERMS
A– Ungrounded service conductor	Ungrounded service conductor	Conductores de fase de la acometida
B– Grounded service conductor	Grounded service conductor	Conductor de acometida puesto a tierra
C– Grounding electrode conductor	Grounding conductor	Conductor de electrodo de puesta a tierra
D– Insulated neutral bus	Neutral bus	Barra para neutro
E– Bonding jumper	Bonding jumper	Puente de union

Table Continued on Next Page

Table Continued

UL TERMS	CEC TERMS	ANCE TERMS
F– Ground bus	Bonding bus/bonding connector	Barra para puesta a tierra
G– Equipment grounding conductor	Bonding conductor	Conductor de puesta a tierra del equipo
H– Grounded circuit conductor	Identified circuit conductor	Conductor del circuito puesto a tierra
I– Ungrounded circuit conductor	Ungrounded circuit conductor	Conductores de fase del circuito
J– Screw serving as bonding jumper	Bonding screw	Tornillo que sirve como puente de union

18.10.3.3 A circuit breaker enclosure that is marked for service equipment use shall have a terminal for a grounded service conductor even though it has no provision for a load conductor to be connected to the grounded service conductor. If there is no provision for such as load conductor, the grounded service conductor terminal shall:

a) Accommodate a conductor of the same size as the grounding electrode conductor specified in Table 18.10.3.1,

b) Be bonded to the enclosure, and

c) Be directly connected to the grounding electrode conductor terminal.

The terminals need not be supplied if the circuit breaker enclosure is marked as covered in 21.8.1.

18.10.3.4 A single wire connector shall be permitted for both the disconnecting means for the grounded service conductors and the connection of the grounding electrode conductor if the connector is capable of separately securing one, two, or three conductors.

18.10.4 Provision for Bonding

18.10.4.1 The terminal indicated in 18.8.1.2 may be in electrical connection with the enclosure. See 21.8.4.

18.10.4.2 If the connection indicated in 18.10.4.1 is solely by means of a screw, strap, or other bonding device that can be readily removed and is not depended upon to perform a mechanical function, the circuit breaker enclosure shall:

a) Comply with the requirement in 18.8.1.1 when the bonding device is removed, or

b) Be marked as described in 21.8.7.

18.10.4.3 If the bonding device described in 18.10.4.2 is provided with but not installed in the circuit breaker enclosure and is such that the circuit breaker enclosure complies with the requirements in 18.8.1.1, the marking described in 21.8.8 shall be permitted.

18.10.4.4 Except for steel or brass screws as specified in Table 18.10.3.1, a main bonding jumper shall be of copper or aluminum and shall have a cross-sectional area as indicated in Table 18.10.3.1.

18.10.4.5 Except when the intended use and method of installation are obvious, instructional markings shall accompany the bonding device indicated in 18.10.4.3.

18.10.4.6 With reference to 18.10.4.2, if the main bonding jumper is a screw, the screw shall have a green-colored head. The screw shall be visible without disassembly or removal of devices inside the circuit breaker enclosure.

18.10.5 Provisions for Ground-Fault Protection

18.10.5.1 Ground-fault protection shall be provided with enclosures rated for solidly grounded wye-connected services in excess of 150 V to ground, but not exceeding 600 V phase-to-phase that are intended for use with a minimum 1000 A rated circuit breaker and all enclosures rated 2000 A or more and are marked for service equipment use only in accordance with 21.8.4. The ground-fault sensing and relaying equipment provided shall operate to cause the service disconnecting means to open all ungrounded conductors of the faulted circuit. The maximum setting of the ground-fault protection shall be 1200 A. The system is assumed to be solidly grounded unless marked as indicated in 21.10.2. It is also assumed that a 3-phase, 3-wire enclosure shall be permitted to be connected to a solidly grounded 3-phase, 4-wire, wye-connected service unless the enclosure is marked as specified in 21.10.2. See also 21.12.1. The following conditions shall also be permitted:

a) The ground-fault protection shall be permitted to be integral to the circuit breaker.

b) Ground-fault protection need not be provided for an enclosure marked in accordance with 21.10.2.

c) If marked in accordance with 21.10.3, ground-fault protection need not be provided for a source intended to supply power to a fire pump, or an alternate source for an emergency system or required standby system as defined in Annex B, Ref. No. 2.

18.10.5.2 Where ground-fault protection is provided, it shall comply with the requirements for the installation of ground-fault protection equipment in this standard, except that, if marked in accordance with 21.10.4, the ground-fault protection shall be permitted to initiate an audible or visual signal rather than open a source intended for emergency or required standby systems in accordance with the requirements in Annex B, Ref. No. 2.

18.10.5.3 A ground-fault protection system that uses a sensing element that encircles the neutral conductor (if any) and all ungrounded conductors of the protected circuit (zero sequence type) shall be installed in such a manner that the sending element is located on the load side of any grounding or bonding connections to the neutral. It shall be permitted to be on the line or load side of the disconnecting device for the protected circuit.

18.10.5.4 A ground-fault protection system that combines the outputs of separate sensing elements for the neutral (if any) and each ungrounded conductor (residual type) shall be installed in such a manner that the neutral sensing element is located on the load side of any grounding or bonding connection to the neutral. The ungrounded conductor sensors shall be permitted to be on the line or load side of the disconnecting device for the protected circuit.

18.10.5.5 A ground-fault protection system that uses a single sensing element to detect the actual fault current (ground return type) shall be installed in such a manner that the sensing element detects any current that flows in the grounding electrode conductor, the main bonding jumper, and any other grounding connections within the enclosure that may be made to the neutral. This will require the neutral to be insulated from noncurrent-carrying metal.

18.10.5.6 If the enclosure or ground bus is factory bonded to the neutral, any conductive part connected to the neutral that would interfere with the operation of a ground-fault protection system, if in contact with the enclosure, shall be insulated and provided with at least 3.2 mm (1/8 inch) spacings through air or over surface to the enclosure. For zero sequence type ground-fault protection, or the residual type ground-fault protection, parts that would interfere with its operation if grounded include all neutral parts on the load side of the neutral current sensing means. For the ground return type, parts that would interfere with its operation if grounded include all conductive parts connected to the neutral except those on the ground side of the sensing means.

18.10.5.7 In an enclosure incorporating ground-fault protection of the ground return type as described in 18.10.5.5, the main bonding jumper shall be factory connected to the neutral bus and to the ground bus (or the enclosure frame if a ground bus is not provided) and the enclosure shall be marked in accordance with 21.8.4.

18.10.5.8 A ground-fault protection sensor shall be securely mounted to reduce the risk of damage to it or its leads during shipment.

18.10.5.9 If the construction of ground-fault sensing and relaying equipment is such that a reset operation is required to restore the equipment to functional status following operation due to a ground fault or test:

a) The construction shall be such as to prevent closing and maintaining contact of the disconnecting device to be controlled by the ground-fault sensing and relaying equipment until the reset operation is performed, or

b) Such means shall be incorporated in the disconnect device.

18.10.5.10 A ground-fault protection control circuit transformer with a primary rating of 12 A or less shall be operated from a circuit protected by either a circuit breaker or branch circuit type fuses rated at not more than 15 A. A transformer having a primary rating greater than 12 A shall be protected by an individual overcurrent device in the primary connection, rated or set at not more than 125 percent of the rated primary current of the transformer, except that:

a) A fuse rated 2 A or less may be a miscellaneous fuse.

b) Overcurrent protection shall not be required for the shunt trip coil of a circuit breaker used with ground-fault protection if the coil is connected to the load side of the controlled circuit breaker as covered in 18.10.5.11.

18.10.5.11 The primary of a ground-fault protection control circuit transformer shall be permitted to be connected on the line or load side of the main disconnect or to an external source. The primary of such a transformer shall be connected to two line voltage parts (not line and neutral). If connected to the line side of the main, or an external source, a fused disconnect switch or circuit breaker rated for use as service equipment and providing overcurrent protection as covered in 18.10.5.10 shall be installed ahead of the transformer or control circuit. Overcurrent protection is not required for the control circuit if wired to the load side of the main disconnect unless the control circuit contains a snap switch. Markings as indicated in 21.10.1 or 21.10.5 shall be provided if the transformer is not connected to the load side of the main disconnect.

18.10.5.12 The control circuit of a ground-fault protection system shall be connected on the line side of the main disconnect if a test or monitor panel is provided and if such connection is required for intended functioning of the panel.

18.11 Enclosures suitable for use as service equipment (for use in Canada)

18.11.1 General

18.11.1.1 The requirements in 18.11 apply only to enclosures suitable for use as service equipment intended for use in Canada.

18.11.1.2 Molded case circuit breaker enclosures intended for use as service equipment shall comply with 18.11.1.3 – 18.11.2.1 and 21.9.1 – 21.9.4.

18.11.1.3 If an enclosure is marked for service use as described in 21.9.2, the circuit breaker shall be manually operable.

18.11.1.4 Associated equipment that must, by its operation, be connected to the line side of the circuit breaker, such as phase-failure or phase-reversal relays, shall be permitted to be installed in the enclosure. Such equipment shall comply with the requirements in 4.17.4 of Annex B, Ref. No. 18.

18.11.1.5 The enclosure shall have provision such that incoming service conductors are capable of being connected to the line side of the circuit breaker while maintaining separation from conductors connected to the load side of the circuit breaker i.e. without crossing over each other.

18.11.1.6 There shall be provision for locking and sealing the enclosure to prevent access by unauthorized persons.

18.11.1.7 The handle of the service-disconnecting circuit breaker shall be lockable in the OFF position.

18.11.1.8 Where a service requires a neutral conductor, enclosures marked as suitable for service equipment in accordance with 21.9.2 shall be provided with a neutral assembly. The neutral assembly shall be provided with an adequate number of suitable pressure-terminal connectors, clamps, or other approved means for connecting the following:

a) Incoming grounded circuit or grounded service conductor;

b) Corresponding outgoing identified conductor if any;

c) Grounding conductor;

d) Bonding jumper conductor to the enclosure; and

e) Bonding jumper conductor to the service raceway (or equivalent).

The grounding conductor terminal size shall be determined in accordance with Table 18.11.1. The terminal size for bonding jumper conductors shall be determined in accordance with Tables 18.11.2 and 18.11.3.

18.11.1.9 The bonding jumper connection described in 18.11.1.8(d) shall be permitted to be omitted if a nonferrous or corrosion resistant steel screw is provided for bonding the service equipment enclosure to the neutral bar (convertible neutral). The screw shall not be less than:

a) No. 10 for equipment rated at 100 A or less;

b) 6.3 mm diameter for equipment rated over 100 A and up to and including 225 A; and

c) 7.9 mm diameter for equipment rated over 225 A and up to and including 400 A.

18.11.1.10 The neutral assembly described in 18.11.1.8 shall be:

a) Constructed such that it is insulated from the enclosure,

b) Bonded to the enclosure if installed within the enclosure before shipment, and

c) Marked in accordance with 21.9.4.

18.11.1.11 Equipment intended for service use shall be provided with wiring leads not smaller than 8 AWG (8.4 mm^2) or with terminals acceptable for connection of 10 AWG (5.3 mm^2) or larger conductors.

18.11.2 Ground Fault Protection

18.11.2.1 Ground fault protection equipment shall comply with the requirements of Rule 14-102 in Annex B, Ref. No. 1 under the Canada column. See Annex E for additional information.

Table 18.11.1
Minimum size of grounding conductor for AC systems or common grounding conductor

Ampacity of largest service conductor or equivalent for multiple conductors	Size of copper grounding conductor	
	AWG	(mm^2)
100 or less	8	(8.4)
101 to 125	6	(13.3)
126 to 165	4	(21.1)
166 to 200	3	(26.7)
201 to 260	2	(33.6)
261 to 355	1/0	(53.5)
356 to 475	2/0	(67.4)
Over 475	3/0	(85.0)

Table 18.11.2
Minimum size of bonding jumper conductor to service enclosure

Rating or setting of overcurrent device in circuit ahead of equipment, conduit, etc. not exceeding – Amperes	Size of bonding Conductor			
	Copper wire		Aluminum wire	
	AWG	(mm^2)	AWG	(mm^2)
20	14	(2.1)	12	(3.3)
30	12	(3.3)	10	(5.3)
40	10	(5.3)	8	(8.4)
60	10	(5.3)	8	(8.4)
100	8	(8.4)	6	(13.3)
200	6	(13.3)	4	(21.1)
300	4	(21.1)	2	(33.6)
400	3	(26.7)	1	(42.4)
500	2	(33.6)	1/0	(53.5)
600	1	(42.4)	2/0	(67.4)
800	1/0	(53.5)	3/0	(85.0)
1000	2/0	(67.4)	4/0	(107.2)
1200	3/0	(85.0)	250 kcmil	(127)
1600	4/0	(107.2)	350 kcmil	(177)
2000	250 kcmil	(127)	400 kcmil	(203)
2500	350 kcmil	(177)	500 kcmil	(253)
3000	400 kcmil	(203)	600 kcmil	(304)
4000	500 kcmil	(253)	800 kcmil	(405)
5000	700 kcmil	(355)	1000 kcmil	(507)
6000	800 kcmil	(405)	1250 kcmil	(633)

Table 18.11.3
Minimum size of bonding jumper for service raceways

Ampacity of largest service conductor or equivalent for multiple conductors	Size of bonding jumper			
	Copper wire		Aluminum wire	
	AWG	(mm^2)	AWG	(mm^2)
100 or less	8	(8.4)	6	(13.3)
200	6	(13.3)	4	(21.1)
400	4	(21.1)	2	(33.6)
600	2	(33.6)	1/0	(53.5)
800	1/0	(53.5)	2/0	(67.4)
1000	2/0	(67.4)	3/0	(85.0)
1200	3/0	(85.0)	4/0	(107.2)

19 Performance (Short-Circuit Current Ratings)

19.1 General

19.1.1 These requirements cover circuit breaker enclosures intended for use with their identified circuit breakers on circuits having available short circuit currents of not more than 200,000 A, rms symmetrical.

19.1.2 Except as permitted by 19.1.3 – 19.1.5, a circuit breaker enclosure with short-circuit current ratings shall be subjected to short-circuit current tests, and dielectric voltage-withstand tests with representative circuit breakers installed.

19.1.3 A circuit breaker enclosure shall be acceptable without short-circuit testing for the short-circuit current rating equal to the minimum interrupting rating of 5000, 7500, or 10,000 A of the circuit breaker(s) identified for use in the enclosure.

19.1.4 Unless further restricted as noted in 19.1.3, a circuit breaker enclosure using meter-mounting equipment shall be acceptable without any short-circuit testing for 10,000 A or less as the short-circuit current rating.

19.1.5 A circuit breaker enclosure whose construction is represented by the enclosure used in the current-interrupting tests on the identified circuit breakers need not be retested. This does not apply to circuit breaker enclosures provided with a door, if the door is not provided, or if provided, not in the closed position, during the current-interrupting test on the circuit breaker. See 19.9.1(e).

19.2 Sample selection

19.2.1 A representative number of sizes and ratings of the circuit breaker enclosure of each construction, representing indoor and outdoor constructions, shall be tested to determine acceptability. If it can be shown that the test on the outdoor construction is more severe and is representative of the indoor enclosure, testing of the indoor construction shall be permitted to be waived.

19.3 Sample preparation

19.3.1 The enclosure shall be mounted and supplied as in a normal installation.

19.3.2 The enclosure shall be connected through a 30-A, nonrenewable cartridge fuse to the line lead of the pole least likely to arc to the enclosure. The fuse shall have a voltage rating not less than the test voltage. The connection shall be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire 1.2 – 1.8 m (4 – 6 feet) long. The fuse may be connected to the grounded conductor if the circuit breaker is intended for use on a grounded system.

19.3.3 The circuit breaker enclosure shall be complete with any intended dead-front shield and filler plates installed. If the enclosure is to be provided with a door, the door shall be installed and closed during the maximum short circuit current test.

19.3.4 A circuit breaker of the intended type having the maximum ampere rating shall be used for each test. Separate circuit breaker samples shall be permitted to be used for the maximum short circuit current and maximum voltage tests.

19.3.5 A circuit breaker having adjustable trip features shall have all adjustments set at maximum current or time settings.

19.4 Line connections

19.4.1 The circuit breaker enclosure or circuit breaker line terminals shall be connected by means of copper cables having an ampacity, based on Table 6.1.4.2.1, nearest to but not less than the rating of the circuit breaker enclosure or the installed circuit breaker. The cables shall enter the gutter through approximately 305 mm (12 inches) of conduit at the line end of the enclosure, at a point that provides the maximum length of unsupported cables within the enclosure. The line terminals shall be wired and tightened to the torque marked on the circuit breaker. The cables shall not be braced inside the enclosure unless the construction includes provision for such bracing. A cable shall be permitted to be braced as it leaves the conduit on the supply side.

19.4.2 The value of tightening torque marked on a circuit breaker enclosure with meter-mounting equipment shall be used if such marking appears on the enclosure.

19.4.3 Each line circuit breaker enclosure terminal or circuit breaker terminal shall be supplied through a cable having a length of 1.2 m (4 feet). Cable length as described in 19.5.2 shall be permitted.

19.5 Load connections

19.5.1 The circuit breaker enclosure load terminals or circuit breaker load terminals shall be short-circuited by a cable to each terminal having a length of 1.2 m (4 feet) and an ampacity not less than the rating of the circuit breaker. The cables shall be lashed outside the cabinet to keep them from whipping during the test. The cables to the load terminals or the instrument shunts shall be short-circuited by a copper bus bar having a cross-sectional area not less than that of the cables. Cable length as described in 19.5.2 shall be permitted.

19.5.2 If the physical arrangement of the test facilities requires leads longer than specified in 19.4.3 and 19.5.1, or lengths of bus bars necessary to extend the terminals, the additional length of leads or bus bars shall be included in the circuit calibration.

19.6 Meter-mounting equipment

19.6.1 If a circuit breaker enclosure uses meter-mounting equipment, a watthour meter shall be in place during any required short-circuit tests. Copper bus bars shall be permitted to be used in the jaws of meter-mounting equipment when such equipment is used in conjunction with current transformers. The cross-sectional dimensions of such bars shall be 2.4 by 19.1 mm (3/32 by 3/4 inch).

19.7 Short-circuit procedure

19.7.1 A 3-phase circuit breaker enclosure shall be tested on a 3-phase circuit using a 3-phase circuit breaker. These tests shall be permitted to qualify a single-phase circuit breaker enclosure.

19.7.2 A single-phase circuit breaker enclosure using adjacent bus bars of the 3-phase construction shall be tested on a single-phase circuit controlled as indicated in 19.7.7.

19.7.3 A circuit breaker enclosure rated 208Y/120 V, 480Y/277 V, or 600Y/347 V and intended to accommodate only single-pole circuit breakers shall be tested on a 208Y/120 V, 480Y/277 V, or 600Y/347 V, 3-phase, 4-wire supply with a short circuit from one line to neutral and line potential applied to the adjacent circuit breaker with that circuit breaker in the on position.

19.7.4 A circuit breaker enclosure having a higher short-circuit current rating for line-to-neutral faults than for line-to-line faults shall be tested with line-to-neutral faults as well as line-to-line faults.

19.7.5 The open-circuit voltage at the supply connection shall be 100 – 105 percent of rated voltage for the test being conducted, except that, a voltage higher than 105 percent shall be permitted to be used if agreeable to the submitter and the testing agency. The supply frequency shall be in the range of 48 – 60 Hz.

19.7.6 Random closing shall be used for the 3-phase maximum current withstand test.

19.7.7 Controlled closing shall be used for the single-phase maximum current withstand test. Closing of the test circuit shall occur within 10 electrical degrees of the zero point of the supply-voltage wave.

19.7.8 The available rms symmetrical current shall be determined at the test-station terminals unless cable lengths, as described in 19.5.2, are used.

19.7.9 The magnitude of the test current and the power factor shall be determined by the applicable method described in C1 – C5 of Annex C. The power factor shall be in accordance with Table 7.1.7.4.

19.7.10 The available short-circuit current in rms symmetrical amperes shall not be less than the short-circuit current specified for the test. The circuits used for the tests described in 19.7.3 and 19.7.4 shall be calibrated line-to-neutral.

19.7.11 The maximum peak let-through current shall be measured during the short-circuit testing of circuit breaker enclosures with meter-mounting equipment. The short-circuit rating of the circuit breaker enclosure shall be such that the measured value does not exceed 30,000 A. Short-circuit fault currents can adversely affect the accuracy and operation of a watthour meter. This measurement need not be made if:

a) The I_p value of the overcurrent protective device is known to be 30,000 A or less, or

b) The meter-mounting equipment is on the secondary side of current transformers.

19.8 Short-circuit tests

19.8.1 A test shall be conducted at rated voltage corresponding to the maximum short-circuit current rating of the circuit breaker enclosure.

19.8.2 With the circuit breaker in the fully closed position, the test circuit shall be closed on the circuit breaker enclosure. If the enclosure is provided with a door, it shall be closed during this test.

19.8.3 A test shall be conducted at rated short-circuit current corresponding to the maximum rated voltage of the circuit breaker enclosure.

19.8.4 The test circuit breaker shall be closed on the circuit. If the enclosure is provided with a door and the circuit breaker can be operated with the door closed, the door shall be closed during this test.

19.9 Interpretation of results

19.9.1 After being tested under any of the short-circuit conditions described in Short Circuit Tests, Section 19.8, the mechanical condition of a circuit breaker enclosure shall be substantially the same as its condition prior to the test and each of the following shall be complied with:

a) Bus bars or straps shall not have been permanently distorted or displaced to an extent that affects normal functioning of the enclosure or reduces an electrical spacing to less than 85 percent of the value specified in Table 6.1.6.1.1.

b) An insulator or support shall not have been broken or cracked to such an extent that the integrity of the mounting of live parts is impaired.

c) The fuse indicated in 19.3.2 shall not have opened.

d) The enclosure or parts of the enclosure – such as filler plates, doors, or the like – shall not have been damaged or displaced to the extent that live parts are accessible.

e) A closed door of the enclosure shall not have blown open more than 60 degrees from the closed position.

f) There shall not be evidence of arcing between live parts of opposite polarity.

g) There shall not be Type A or Type B results during the testing as determined by 7.1.11.6, except that no trip-out test is required.

h) The circuit breaker enclosure shall comply with the Dielectric Voltage-Withstand Test, Section 19.10 with the circuit breaker or circuit breakers still installed.

19.10 Dielectric voltage-withstand test

19.10.1 With all circuit breakers closed, a circuit breaker enclosure that has been subjected to the short-circuit tests shall withstand for 1 minute without breakdown the application of a 60 Hz sinusoidal potential of twice the maximum rated voltage, but not less than 900 V between:

a) Wiring terminals of opposite polarity, and

b) Uninsulated live parts and the enclosure.

19.10.2 To determine whether a circuit breaker enclosure complies with the requirement in 19.10.1, the test shall be conducted using a 500 VA or larger-capacity transformer, the output voltage of which is essentially sinusoidal and can be varied. The applied potential shall be increased from zero until the required test value is reached, and shall be held at that level for 1 minute. The applied potential shall be increased at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter. The transformer shall be permitted to be less than 500 VA if the output voltage is measured directly.

20 Ratings

20.1 The short-circuit rating of a circuit breaker enclosure shall be one or more of the values specified in Table 8.1.

21 Markings

21.1 General

21.1.1 Markings shall be located as indicated in Table 21.1.1. See Table 9.1 for location of marking on circuit breakers.

Advisory Note: For products intended for use in Canada, markings shall be in English or in French and English; caution and warning markings shall be in French and English. For products intended for use in Mexico, all markings shall be at least in Spanish. For products intended for use in the United States, all markings shall be at least in English. See Annex D for suitable translations of caution and warning markings.

Table 21.1.1
Location of markings circuit-breaker enclosures

Clause numbers	Subject (see also Table 9.1)	Location categories[a] (see notes)
	General	
21.1.2, 21.1.3	General marking	B
21.1.4	Durability and legibility	–
21.1.5	Multiple factory identification	C
	Position Indication	
21.2	On, Off, Tripped	A
	Short-Circuit Current Rating	
21.3	Rating	B
	Termination Markings	
21.4.1, 21.4.7	CU-AL	B
21.4.8	Conductor temperature rating	B
21.4.9	Tightening torque	B
	Enclosure types	
21.5.1 – 21.5.3	Environmental types	B
21.5.4	Semi-flush meter sockets	A
	Neutral Assemblies	
21.6.1, 21.6.2	Identification	B
21.6.3	Ground-fault protection, load/size	B
	Back-Fed Hold-Down Kit	
21.7.1	Required hold-down kit	B
	Service Equipment Use	
21.8.2	Grounded service conductor	B
21.8.3, 21.8.4	Permanently-bonded enclosure	B
21.8.5, 21.8.6	Service disconnect	A
21.8.7	Removable bonding means	B
21.8.8	Suitable for use as service equipment	B
21.8.9	Separate service disconnect marking	K
21.8.10	Use with post or pedestal	B
21.8.11	Meter socket	B
21.8.12, 21.8.13	Meter socket	L
21.8.14	Meter socket	M
	Service Equipment Use	
21.10.1 – 21.10.4	Ground-fault protection	B
21.10.5	Ground-fault protection	A

A Marking shall be visible without removing the trim or cover, or opening the door of the enclosure.

B Marking shall be visible when trim or cover of enclosure is removed, or a door opened, if trim or cover may be removed or door opened regardless of the position of the circuit breaker.

C Marking need not be visible after installation.

K Shipped separately with circuit-breaker enclosure.

Table 21.1.1 Continued on Next Page

Table 21.1.1 Continued

Clause numbers	Subject (see also Table 9.1)	Location categories[a] (see notes)
L Marking shall be visible with the meter removed.		
M Shipped separately with kit.		
[a] At the option of the manufacturer, a higher order of location category may be used. The order of location category is A – M, with A being the highest.		

21.1.2 A circuit breaker enclosure shall be marked with the manufacturer's name or trademark or other means of identification, its type number or the equivalent, and the maximum electrical rating and type of circuit breaker(s) for which the enclosure is intended. In addition, appropriate neutral marking shall be provided when necessary. See 18.7.6, 18.7.7, 21.6.1 and 21.6.2.

21.1.3 The required markings of a circuit breaker enclosure shall be on the outside of the enclosure, but will be acceptable if located on the inside of a door or cover if the door may be opened or the cover removed regardless of the position of the circuit breaker. Location Category B.

21.1.4 The marking on a circuit breaker enclosure shall be durable and legible. See 21.11.1.

21.1.5 If a manufacturer produces or assembles circuit breaker enclosures at more than one factory, each finished enclosure shall have a distinctive marking, which shall be permitted to be in code, by which it may be identified as the product of a particular factory. Location Category C.

21.2 Position indication

21.2.1 If a supplementary external operating handle is provided as part of the circuit breaker enclosure, the on and off positions shall be appropriately marked externally. Location Category A.

21.2.2 Except as noted in 21.2.3, if a circuit breaker handle, or a simple extension of that handle, has an additional or intermediate position that it takes upon automatic tripping, that position and the resetting instructions for the circuit breaker shall be described in a marking located where visible while operating the handle. Location Category A.

21.2.3 Marking to indicate the tripped position is not required in the case of a separate, external operating handle, other than a simple handle extension, that is not part of the circuit breaker. Such a handle shall be permitted to remain in the on position.

21.3 Short-circuit current rating

21.3.1 A circuit breaker enclosure shall be marked with the following or equivalent information:

a) The phrase ″Short-Circuit-Current Rating″ and the short-circuit current rating in rms symmetrical amperes and, if a meter socket is used, the phrase ″Watthour meter not included in short-circuit-current rating″. If the meter socket is rated 30 A or less (intended for use with current transformers), it need not be so marked.

b) The maximum voltage rating for each short-circuit current rating.

c) A phrase indicating that additional or replacement devices shall be of the same manufacture, type designation, and interrupting rating. This may be accomplished by specific reference to the device.

d) The ampere rating of the identified circuit breaker, if all ratings of a particular type designation of an identified circuit breaker are not acceptable for use in the circuit breaker enclosure.

21.3.2 If the circuit breaker enclosure short-circuit current rating or ratings are the same as the interrupting rating or ratings of the indicated circuit breaker(s), reference to those rating(s) are considered as providing equivalent information.

21.3.3 The short-circuit current rating of a circuit breaker enclosure shall be located where it will be visible if a front or trim is removed. This marking shall be:

a) An integral part of the marking containing the manufacturer's name, or

b) An integral part of the other required marking. If there is more than one short-circuit rating, all such ratings shall appear together. Location Category B.

21.4 Terminations

21.4.1 If any enclosure terminal, see 21.4.8, is marked to indicate that aluminum conductor may be used at that terminal, such as by being marked with the symbol ″Al″, and if such marking is visible under the conditions described in 21.4.6, the enclosure shall be marked in accordance with 21.4.2, 21.4.3, or 21.4.4, whichever applies. This marking shall be visible when the cover, front, or trim of the enclosure is removed. Location Category B.

21.4.2 If, because of wiring space or other factors, no enclosure terminal is acceptable for use with aluminum conductors, the enclosure shall be marked ″USE COPPER WIRE ONLY″ or with equivalent wording. See 18.7.3. Location Category B.

21.4.3 If the wiring space and other factors are such that all enclosure terminals are acceptable for use with aluminum conductors as well as with copper conductors, the enclosure shall be marked ″USE COPPER OR ALUMINUM WIRE″ or with equivalent wording. Location Category B.

21.4.4 If the wiring space and other factors are such that some enclosure terminals are acceptable for use with aluminum conductors as well as with copper conductors, while the remainder of the terminals are acceptable for use with copper conductors only, the enclosure shall be marked ″USE COPPER WIRE ONLY EXCEPT AT TERMINALS _____″, or the equivalent. The marking shall positively identify the terminals that are acceptable for use with aluminum conductor. Location Category B.

21.4.5 The word terminal as used in 21.4.1 – 21.4.4 signifies any enclosure terminal as well as any terminal of any circuit breaker or neutral assembly that is installed or intended to be installed in the enclosure.

21.4.6 A marking on a separately supplied connector or on a connector or part thereof that is likely to be removed or displaced during the wiring operation is considered to be visible. Location Category B.

21.4.7 The characters in the markings described in 21.4.2 – 21.4.4 shall be legible and not less than 1.6 mm (1/16 inch) high.

21.4.8 A circuit breaker enclosure with terminals mounted therein shall be marked in a readily visible location to indicate the required temperature rating for all field-installed conductors. Location Category B.

21.4.9 With regard to the requirements in 6.1.4.2.3, a circuit breaker enclosure shall be marked to show a range of values or a nominal value of tightening torque to be applied to the clamping screws of all terminal connectors for field wiring. This marking shall be visible when a front or trim is removed. Location Category B.

21.4.10 If equipment grounding terminals are not provided on the equipment as shipped, the equipment shall be marked stating which pressure wire connector or component terminal kits are acceptable for use with the equipment. A wire connector of the type mentioned in the marking shall be permitted to be installed in the equipment at the factory with instructions, if necessary, to effect proper connection of the conductor. A terminal kit shall carry an identifying marking, wire size, and manufacturer’s name or trademark. Location Category B.

21.4.11 An enclosure that is not provided with means for terminating equipment grounding conductors nor has means for the field installation of an equipment grounding assembly shall be marked to indicate that the enclosure is to be used in an installation in which the equipment is grounded by connection to metal raceway or metallic cable sheaths.

21.5 Environmental-type designations

21.5.1 A circuit breaker enclosure shall be marked with a type number indicating the external conditions as specified in Annex B, Ref. No. 15 for which it is acceptable. A circuit breaker enclosure that complies with the requirements for more than one type of enclosure shall be permitted to have multiple designations. The marking shall be permitted to be on the inside or outside surface but shall be visible after installation. Location Category B.

21.5.2 A circuit breaker enclosure marked with an enclosure designation of Type 3, 3S, 4, 4X, 6, or 6P shall be permitted to additionally be marked ″Raintight″ or ″Rainproof″. A circuit breaker enclosure marked with an enclosure designation of Type 3R shall be permitted to additionally be marked ″Rainproof″. Location Category B.

21.5.3 A circuit breaker enclosure having an opening for accommodating a watt-hour meter shall not be marked with an enclosure designation of Type 6 or 6P.

21.5.4 With regard to 18.1.5, a circuit breaker enclosure with a meter socket of the semi-flush type shall be provided with markings to specify that when the enclosure is mounted as intended, the flange shall be covered by building paper or flashing. The marking shall be located on the front of the flange. Location Category A.

21.5.5 An external operating mechanism shall be permitted to be marked with a type number indicating the external conditions as specified in Annex B, Ref. No. 15 for which it is acceptable. An external operating mechanism that complies with the requirements for more than one type shall be permitted to have multiple designations. Location Category C.

21.6 Neutral assemblies

21.6.1 Except as indicated in 21.6.2, a neutral assembly that is found to be acceptable for separate shipment shall comply with the following:

a) The neutral assembly shall be marked with

1) Its own ampere rating,

2) Its own catalog number or the equivalent, and

3) The manufacturer’s name or trademark;

b) The circuit breaker enclosure shall be marked with the catalog number of the neutral assembly and with an indication of the voltage ratings for which the neutral bus bar must be used.

Location Category B.

21.6.2 A neutral assembly as described in 21.6.1 need not be marked with its ampere rating if all enclosures in which it is to be used are marked with the neutral catalog number or the equivalent and the neutral ampere rating.

21.6.3 In an enclosure with ground-fault protection, that part of the neutral bus for load terminations shall be marked with the word ″WARNING″ and with the following or the equivalent: ″Do not connect grounding conductors to these or any other neutral terminals; to do so will defeat ground-fault protection″. The marking shall be located on or adjacent to the neutral. Location Category B.

21.7 Back-fed hold-down kit

21.7.1 A circuit breaker enclosure intended for use with a back-fed unit hold-down kit as permitted by 18.1.12, shall be marked ″Back-fed circuit breaker requires hold-down kit Cat. No. _____″ or the equivalent.

21.8 Service equipment use (not for use in Canada)

21.8.1 The marking requirements in 21.8 do not apply to enclosures intended for use as service equipment that are intended for use in Canada. Such enclosures shall instead comply with the marking requirements in Service equipment use (for use in Canada), Section 21.9.

21.8.2 If the terminals for grounded service conductors described in 18.10.3.3 are required but are not supplied with the circuit breaker enclosure, the enclosure shall be marked with a catalog number of a kit including the terminals, or information stating the wire size of terminals required, and instructions for assembly in the enclosure. Location Category B.

21.8.3 The marking required by 21.8.2 or 21.8.8 shall be located where it will be visible if a front or trim is removed. This marking shall be:

a) An integral part of the marking containing the manufacturer's name, or

b) An integral part of the other required marking.

21.8.4 If the construction is as described in 18.10.4.1 and the circuit breaker enclosure is otherwise found acceptable, the circuit breaker enclosure shall be marked "Suitable only for use as service equipment". Location Category B.

21.8.5 If a circuit breaker enclosure is marked "Suitable only for use as service equipment", the service disconnecting means for ungrounded conductors shall be marked "Service disconnect". Location Category B.

21.8.6 The marking "Service disconnect" identifying the service disconnecting circuit breakers required by 21.8.4 shall appear on or adjacent to the circuit breaker handle. Location Category A.

21.8.7 If the construction is as described in 18.10.4.2 and the spacings would not comply with the requirements in 18.8.1.1 when the bonding device is removed, the circuit breaker enclosure shall be marked "Bonded Neutral - Remove bonding device for test purposes only" or equivalent. Location Category B.

21.8.8 If the construction is as described in 18.10.4.3 and the circuit breaker enclosure is otherwise found acceptable, the circuit breaker enclosure shall be marked "Suitable for use as service equipment", if intended for such use. Location Category B.

21.8.9 If marked “Suitable for use as service equipment”, the marking “Service Disconnect” shall be provided in the form of pressure-sensitive labels in an envelope, or on a card, with instructions to apply near the service disconnect means if the equipment is used as service equipment.

21.8.10 A circuit breaker enclosure intended to be field installed on a mounting post or pedestal for distribution equipment shall be marked to indicate the post or pedestal with which it is to be used. Either the post or pedestal or the circuit breaker enclosure shall bear the name or trademark of the manufacturer and identification number of the unit or units with which it may be used. The other unit or units shall bear the complete identification of the unit or units with which it may be used or the words “Use only with the (posts, pedestals, or circuit breaker enclosures) marked for use with this type or catalog number product”, or the equivalent. Location Category B.

21.8.11 If the socket jaws of meter mounting equipment are mounted on terminals or extensions to which terminals are mounted and these terminals are intended for field-installed wires, service equipment shall be marked to indicate the maximum torque to be applied to these terminals to prevent the rotation of the jaws and terminals as specified in the rotation prevention test for socket jaws and wire connectors in Annex B, Ref. No. 17. Location Category B.

21.8.12 If a meter socket is provided along with service equipment that will automatically render load circuit parts live when the meter is not in place, the enclosure shall be marked in a location next to the exposed live parts with the word “WARNING” and the following or the equivalent: “Risk of electric shock. Removal of meter does not de-energize circuit”. Location Category L.

21.8.13 If a meter socket is provided with a manually operated device that will render load circuit parts live when the meter is not in place, the enclosure shall be marked in a location next to the exposed live parts to indicate that the circuit may be live with the meter removed. Location Category L.

21.8.14 If an automatic or manual closer for a meter socket is furnished in the form of a kit for field installation, the marking specified in 21.8.12 and 21.8.13 shall be furnished with the kit with instructions for applying the marking. Location Category M.

21.9 Service equipment use (for use in Canada)

21.9.1 The marking requirements in 21.9.2 – 21.9.4 apply only to service equipment intended for use in Canada.

21.9.2 Equipment intended for service use shall be marked with the following or equivalent wording: SUITABLE FOR USE AS SERVICE EQUIPMENT.

21.9.3 The equipment marking required by 21.9.2 shall be plainly visible on or within the service compartment.

21.9.4 Equipment intended for service use and constructed in accordance with 18.11.1.8 shall be provided with a temporary tag, instruction sheet, or the equivalent indicating how the bond is to be installed or removed when required by the Electrical Inspection Authorities (for example, “Where Electrical Inspection Authorities require the neutral assembly to be disconnected from the enclosure...”). Each manufacturer shall add specific instructions applicable to the particular construction.

21.10 Ground-fault protection

21.10.1 With regard to 18.10.5.11, when intended to be connected to an external source, the control circuit for ground-fault protection shall be identified by a permanent marking, “External source connection for control circuit of ground-fault sensing and relaying equipment _____ volts (ac or dc)”. Terminals for an external source for other types of control circuits shall be similarly marked. Location Category B.

21.10.2 An enclosure intended for use with a minimum 1000 A rated circuit breaker that is intended only for use as service equipment and not provided with ground-fault protection as covered in 18.10.5.1(b) shall be marked, Location Category B, for the use specified as follows:

a) For an enclosure rated 208Y/120 V, 480Y/277 V, or 600Y/347 V, 3-phase, 4-wire:

1) “Suitable only for use as service equipment when supplying a continuous industrial process” or

2) “Suitable for use as service equipment only if supplying a continuous industrial process”.

b) For an enclosure rated 480 or 600 V, 3-phase, 3-wire, marked as specified in (a) (1) or (a) (2) with the following addition: “or for systems where the neutral is not solidly grounded”.

21.10.3 An enclosure intended for use with a minimum 1000 A rated circuit breaker marked “Suitable only for use as service equipment” and not provided with ground-fault protection as covered in 18.10.5.1(c) shall be marked, Location Category B:

a) For an alternate source for emergency service,

b) For supplying a fire pump, or

c) For an alternate source for required standby service as defined in Article 701 in Annex B, Ref. No. 2.

21.10.4 An enclosure that has ground-fault protection with only an audible or visual signal as covered in 18.10.5.2 shall be marked for an alternate source for emergency service as covered in 21.10.3. Location Category B.

21.10.5 If a transformer providing control voltage for ground-fault protection as covered in 18.10.5.11 is connected to the line side of the main disconnect or to a separate source, this disconnect shall be permitted to be identified as the “Main” but the enclosure shall be marked adjacent to the main disconnect, with the word “WARNING” and with the following or the equivalent: “Risk of electric shock. This main does not disconnect control and instrument circuits”. Location Category A.

21.11 Permanence of marking

21.11.1 A marking shall be molded, die-stamped, paint-stenciled, stamped or etched metal that is permanently secured, or indelibly applied lettering on a label secured by adhesive that, upon investigation, is found to be acceptable for the application. Ordinary usage, including likely exposure to weather and other ambient conditions, handling, storage, and the like of the equipment is considered in the determination of the acceptability of the application.

21.12 Installation instructions for the testing of ground-fault protection of equipment

21.12.1 Each ground-fault relay or apparatus incorporating a ground-fault relay or its functions shall be provided with information sheets describing system testing instructions, and with a test form. The form shall include a space for the date the test was performed and the results, and shall state that the form should be retained by those in charge of the building's electrical installation in order to be available to the authority having jurisdiction. The instructions shall include the following items and shall basically prescribe only that information necessary to perform the tests. The instructions shall be separate and apart from any more elaborate test detail that the manufacturer may wish to provide. The instructions shall specify that:

a) The interconnected system shall be investigated in accordance with the manufacturer's detailed instructions, and that this investigation is to be undertaken by qualified personnel.

b) The location of the sensors around the bus of the circuit to be protected shall be determined. This can be done visually, with knowledge of which bus is involved.

c) The grounding points of the system shall be verified to determine that ground paths do not exist that would bypass the sensors. The use of high-voltage testers and resistance bridges may be suggested.

d) The installed system is to be tested for correct response by the application of full scale current into the equipment to duplicate a ground-fault condition, or by equivalent means such as by a simulated fault current generated by,

1) A coil around the sensors, or

2) A separate test winding in the sensors.

e) The results of the test are to be recorded on the test form provided with the instructions.

Annex A (Informative)

Standards for Components

A1 Component Standards

The ANCE, CSA, and UL Standards listed below are used for evaluation of components and features of products covered by this standard. These standards shall be considered to refer to the latest edition and all amendments published to that edition.

COMPONENT TYPE	UL	CSA	ANCE
Enclosures for Electrical Equipment	UL 50	CAN/CSA—C22.2 No. 94–M91(R2006)	NMX-J-235/1-ANCE and NMX-J-235/2-ANCE
Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors	UL 486E	CAN/CSA—C22.2 No. 65–03	No equivalent
Ground-Fault Circuit-Interrupters	UL 943	CAN/CSA—C22.2 No. 144–06	NMX-J-520-ANCE
Ground-Fault Sensing and Relaying Equipment	UL 1053	CSA C22.2 No. 144–M91	No equivalent
Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment	UL 840	CSA C22.2 No. 0.2–93	NMX-J-150/1-ANCE
Meter Sockets	UL 414	CSA C22.2 No. 115–M1981(R2005)	No equivalent
Polymeric Materials – Use in Electrical Equipment Evaluations	UL 746C	No equivalent	No equivalent
Panelboards	UL 67	CSA C22.2 No. 29–M1989(R2004)	NMX-J-118/1-ANCE
Supplementary Protectors for Use in Electrical Equipment	UL 1077	CSA C22.2 No. 235–04	No equivalent
Tests for Safety-Related Controls Employing Solid-State Devices	UL 991	CSA C22.2 No. 0.8–M1986(R2008)	No equivalent
Transformers, Class 2 and 3	UL 5085-1 and UL 5085-3	CSA C22.2 No. 66.3–06	No equivalent
Wire Connectors	UL 486A-486B	CSA C22.2 No. 65–03	NMX-J-543-ANCE

Annex B (Normative)

Referenced Standards

B1 Referenced Standards

When reference is made to other organization's Standards, such reference shall be considered to refer to the latest edition and all amendments published to that edition up to the time when this standard was approved.

REFERENCED STANDARDS			
Ref. No.	**United States**	**Canada**	**Mexico**
1	ANSI/NFPA 70, National Electrical Code	CSA C22.1, Canadian Electrical Code-06	NOM-001–SEDE, Electrical installations (utility)
2	ANSI/NFPA 70, National Electrical Code	No equivalent	NOM-001–SEDE, Electrical installations (utility)
3	ANSI/IEEE C37.13-1993, Low Voltage AC Power Circuit Breakers Used in Enclosures	Same as U.S.	No equivalent
4	ANSI/IEEE C37.14-1999, Low Voltage DC Power Circuit Breakers Used in Enclosures	Same as U.S.	No equivalent
5	UL 1077 Standard for Supplementary Protectors for Use in Electrical Equipment	CSA C22.2 No. 235–04, Supplementary Protectors	No equivalent
6	UL 486A-486B Standard for Wire Connectors	CAN/CSA—C22.2 No. 65–03, Wire Connectors	NMX-J-543-ANCE
7	UL 486E Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors	CAN/CSA—C22.2 No. 65–03, Wire Connectors[a]	No equivalent
8	UL 991 Standard for Tests for Safety-Related Controls Employing Solid-State Devices	CSA C22.2 No. 0.8–04, Safety Functions Incorporating Electronic Technology	No equivalent
9	ASTM E28, Test Method for Softening Point by Ring-and-Ball Apparatus	Same as U.S.	NMX-J-412-ANCE
10	UL 840 Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment	CSA C22.2 No. 0.2–93, Insulation Coordination	NMX-J-150/1-ANCE

Table Continued on Next Page

Table Continued

REFERENCED STANDARDS			
Ref. No.	**United States**	**Canada**	**Mexico**
11	UL 5085-1 Standard for Low Voltage Transformers – Part 1: General Requirements and UL 5085-3 Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers	CSA C22.2 No. 66.3–06, Low-Voltage Transformers – Part 3: Class 2 and Class 3 Transformers	No equivalent
12	UL 943 Standard for Ground-Fault Circuit-Interrupters	CAN/CSA—C22.2 No. 144–M1991(R2006), Ground-Fault Circuit Interrupters	NMX-J-520-ANCE
13	UL 746C Standard for Polymeric Materials – Use in Electrical Equipment Evaluations	No equivalent	No equivalent
14	UL 1053 Standard for Ground-Fault Sensing and Relaying Equipment	No equivalent	No equivalent
15	UL 50 Standard for Enclosures for Electrical Equipment	CAN/CSA—C22.2 No. 94–M1991(R2006), Special Purpose Enclosures	NMX-J-235/1-ANCE and NMX-J-235/2-ANCE
16	UL 50 Standard for Enclosures for Electrical Equipment	CAN/CSA—C22.2 No. 94–M1991(R2006), Special-Purpose Enclosures and CAN/CSA—C22.2 No. 4–04,Enclosed and Dead-Front Switches	NMX-J-235/1-ANCE and NMX-J-235/2-ANCE
17	UL 414 Standard for Meter Sockets	CSA C22.2 No. 115–M1989(R2005), Meter-Mounting Devices	No equivalent
18	N/A	CAN/CSA—C22.2 No. 14–05, Industrial Control Equipment	N/A
19	Standard for Motor Craft, (Pleasure and Commercial), National Fire Protection Association (NFPA) 302	No equivalent	No equivalent
20	UL 67 Standard for Panelboards	CSA C22.2 No. 29–M1989(R2004), Panelboards and Enclosed Panelboards	NMX-J-118/1-ANCE
21	ANSI/IEEE C37.09-1979(R1989), Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis	Same as U.S.	No equivalent
22	UL 1500 Standard for Ignition-Protection Test for Marine Products	No equivalent	No equivalent

[a] The use of the pull-out torque values of Table 14.1 of the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, are permitted to be used for the evaluation of equipment wiring terminals as described in 6.1.4.2.2(b).

Annex C (Normative)

Circuit Calibration and Instrumentation Test Circuits

C1 Instrumentation

C1.1 The galvanometers in a magnetic oscillograph used for recording voltage and current during circuit calibration and while testing shall be of a type have a flat (±5 percent) frequency response from 50 to 1200 cycles per second, except that for tests involving fused circuit breakers and current-limiting circuit breakers, the galvanometers shall have a flat (±5 percent) frequency response from 50 to 3000 cycles per second.

C2 Calibration of Galvanometers

C2.1 When a shunt is used to determine the circuit characteristics, a dc calibrating voltage is generally used. The voltage applied to the oscillograph galvanometer circuit shall result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the intended short-circuit current is flowing. The voltage shall be applied so as to cause the galvanometer to deflect in both directions. Additional calibrations shall be made using approximately 50 percent and approximately 150 percent of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as in the case of a symmetrically closed single-phase circuit, any other appropriate calibration point is to be chosen. The sensitivity of the galvanometer circuit in volts per mm (or inch) shall be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per mm (or inch) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is used for the determination of the rms current as described in C4.1.

C2.2 A 50- or 60-Hz sinusoidal potential may be used for calibrating the galvanometer circuit using the same general method described in C2.1. The resulting factor must be multiplied by 1.414.

C2.3 When a current transformer is used to determine the circuit characteristics, an ac current shall be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit shall result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short-circuit current is flowing in the primary. Additional calibrations shall be made at approximately 50 percent and approximately 150 percent of the current used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as in the case of a symmetrically closed single-phase circuit, any other appropriate calibration point is to be chosen. The sensitivity of the galvanometer circuit in rms amperes per mm (or inch) shall be determined in each case and the results averaged. The average sensitivity is multiplied by the current transformer ratio and by 1.414 to obtain peak amperes per inch (or mm). This constant is used for the determination of the rms current as described in C4.1.

C2.4 All the galvanometer elements used shall line-up properly in the oscillograph, or the displacement differences shall be noted and used as needed.

C2.5 The sensitivity of the galvanometers and the recording speed shall be sufficient to provide a record from which values of voltage, current, and power factor can be measured accurately. The recording speed shall not be less than 1.52 m (60 inches) per second and higher speeds are recommended.

C2.6 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests indicated in C2.7 and C2.8 shall be conducted to verify the accuracy of the manufacturer's instrumentation.

C2.7 With the secondary open-circuited, the transformer shall be energized and the voltage at the test terminals observed to see if rectification is taking place. If rectification is occurring, the circuit is not acceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings shall be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check can be omitted if testing is not commenced before the transformer has been energized for approximately 2 seconds, or longer if an investigation of the test equipment shows that a longer time is necessary.

C2.8 With the circuit short-circuited by connecting the test terminals together by means of a copper bar, a single-phase circuit shall be closed as nearly as possible at the angle that will produce a current wave with maximum offset. The short-circuit current and voltage shall be recorded. The primary voltage shall be recorded if primary closing is used. The current measured by the reference shunt shall be within 5 percent of that measured using the manufacturer's instrumentation and there shall not be any measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

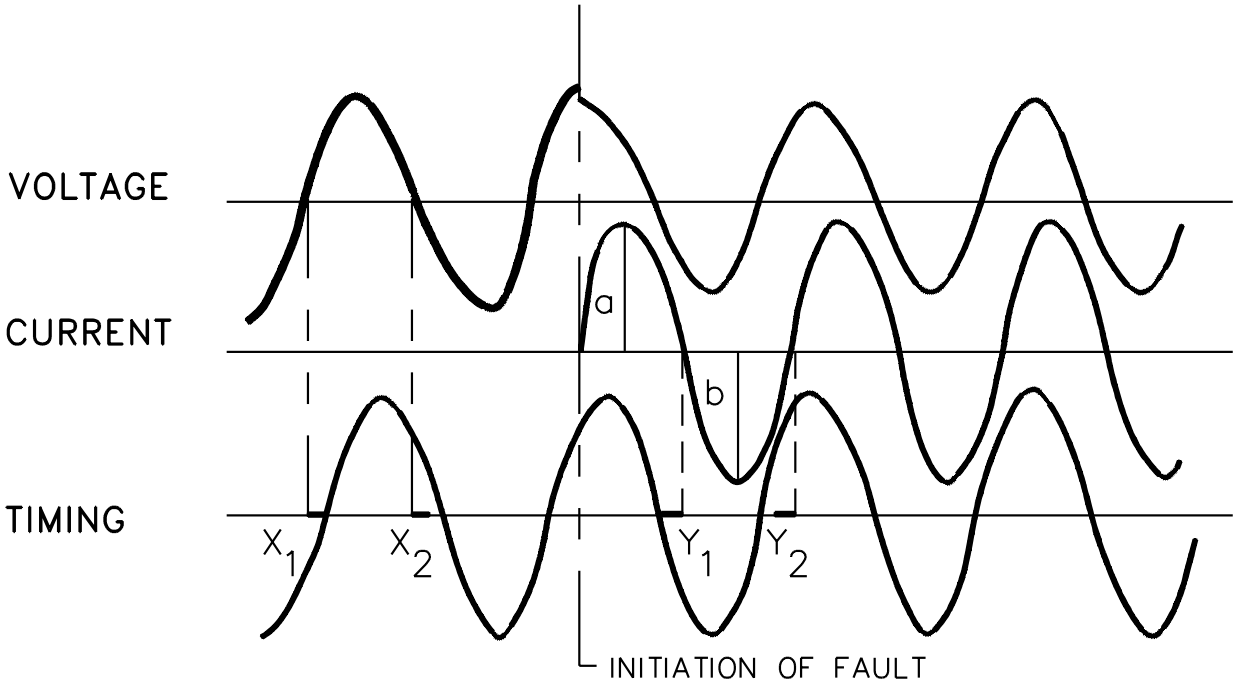
C2.9 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt shall be removed from the circuit – it is not to be used during the final calibration of the test circuit nor during the testing of circuit breakers.

C3 Alternating Current Circuits 10,000 A and Less

C3.1 For an ac circuit intended to deliver 10,000 A or less, the determination of the current and power factor shall be in accordance with C3.2.

C3.2 The current in a 3-phase test circuit shall be determined by averaging the rms values of the first complete cycle of current in each of the three phases. The current in a single-phase test circuit shall be the rms value of the first complete cycle (see Figure C3.1), when the circuit is closed to produce an essentially symmetrical current waveform. The ″dc component″ shall not be additionally added to the value obtained when measured as shown. In order to obtain the desired symmetrical waveform of a single-phase test circuit, random or controlled closing shall be permitted. A waveform shall be considered to be essentially symmetrical if the difference between the deflection below and above the zero trace in the first full cycle is no greater than 7 percent of the smaller deflection. The power factor shall be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through an appropriate timing wave – the power factor to be computed as an average of the values obtained by using these two current zero points and the voltage to neutral to be used in the case of a 3-phase circuit.

Figure C3.1
Determination of current and power factor for circuits of 10,000 A and less



$$Current = \frac{a+b}{2} \text{ rms calibration of instrument element}$$

$$Power\ Factor = \frac{Cos\left[(Y_1 + X_1) \times 180°\right]}{2} + \frac{Cos\left[(Y_2 + X_2) \times 180°\right]}{2}$$

in which:

X and Y values are fractions of the 1/2 cycle distance in which they occur

SB0740C

C4 Alternating Current Circuits Greater than 10,000 A

C4.1 The rms symmetrical current shall be determined, with the supply terminals short-circuited by measuring the ac component of the wave at an instant 1/2 cycle (on the basis of a power frequency timing wave) after the initiation of the short circuit. The current shall be calculated in accordance with Figure 7 of Annex B, Ref. No. 21.

C4.2 For a 3-phase test circuit, the rms symmetrical current is the average of the currents in the three phases. However, the rms symmetrical current in any one phase shall not be less than 90 percent of the value of the required test current.

C4.3 For a single-phase circuit, closing to produce minimum asymmetry may be selected but one test shall be made at the closing angle that will produce maximum asymmetry because this is required for power factor determination.

C4.4 The test circuit and its transients shall be such that:

a) Three cycles after initiation of the short circuit, the symmetrical alternating component of current will be no less than 90 percent of the symmetrical alternating component of current at the end of the first half-cycle, or

b) The symmetrical alternating component of current at the time at which the circuit breaker will interrupt the test circuit is at least 100 percent of the rating for which the circuit breaker is being tested.

In 3-phase circuits the symmetrical alternating component of current of all three phases shall be averaged. In the case of the delayed-tripping test, the symmetrical alternating component of current at 1/2 second shall not be less than 80 percent of the value measured at one-half cycle after initiation of the current.

C4.5 The power factor shall be determined at an instant 1/2 cycle (on the basis of a power frequency timing wave) after the short circuit occurs. The total symmetrical rms amperes shall be measured in accordance with C4.1 and the ratio M_A or M_M calculated as follows:

$$\text{Ratio } M_A \text{ (for 3 } \phi \text{ tests)} = \frac{\text{Total 3 phases Asymmetrical rms Amperes}}{\text{Total 3 phases Symmetrical rms Amperes}}$$

$$\text{Ratio } M_M \text{ (for 1 } \phi \text{ tests)} = \frac{\text{Asymmetrical rms Amperes}}{\text{Symmetrical rms Amperes}}$$

Using ratio M_A or M_M the power factor is determined from Table C4.1.

Table C4.1
Short-circuit power factor

Short-circuit power factor, percent	Ratio M_M	Ratio M_A	Short-circuit power factor, percent	Ratio M_M	Ratio M_A
0	1.732	1.394	30	1.130	1.064
1	1.697	1.374	31	1.122	1.062
2	1.662	1.354	32	1.113	1.057
3	1.630	1.336	33	1.106	1.053
4	1.599	1.318	34	1.098	1.050
5	1.569	1.302	35	1.091	1.046
6	1.540	1.286	36	1.085	1.043
7	1.512	1.271	37	1.079	1.040
8	1.486	1.256	38	1.073	1.037
9	1.461	1.242	39	1.068	1.034
10	1.437	1.229	40	1.062	1.031
11	1.413	1.216	41	1.058	1.029
12	1.391	1.204	42	1.053	1.027
13	1.370	1.193	43	1.049	1.025
14	1.350	1.182	44	1.045	1.023
15	1.331	1.172	45	1.041	1.021
16	1.312	1.162	46	1.038	1.019
17	1.295	1.152	47	1.035	1.017
18	1.278	1.144	48	1.032	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.016	1.008
22	1.219	1.112	60	1.009	1.004
23	1.205	1.105	65	1.005	1.002
24	1.193	1.099	70	1.002	1.001
25	1.181	1.092	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.00001
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.076	100	1.00000	1.00000
29	1.139	1.071			

C4.6 The power factor of a 3-phase circuit may be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. Each phase would then have the power factor determined using the method described for single-phase circuits in C4.5. The power factor in any one phase shall not be greater than that required for the test.

C5 Recovery Voltage – AC

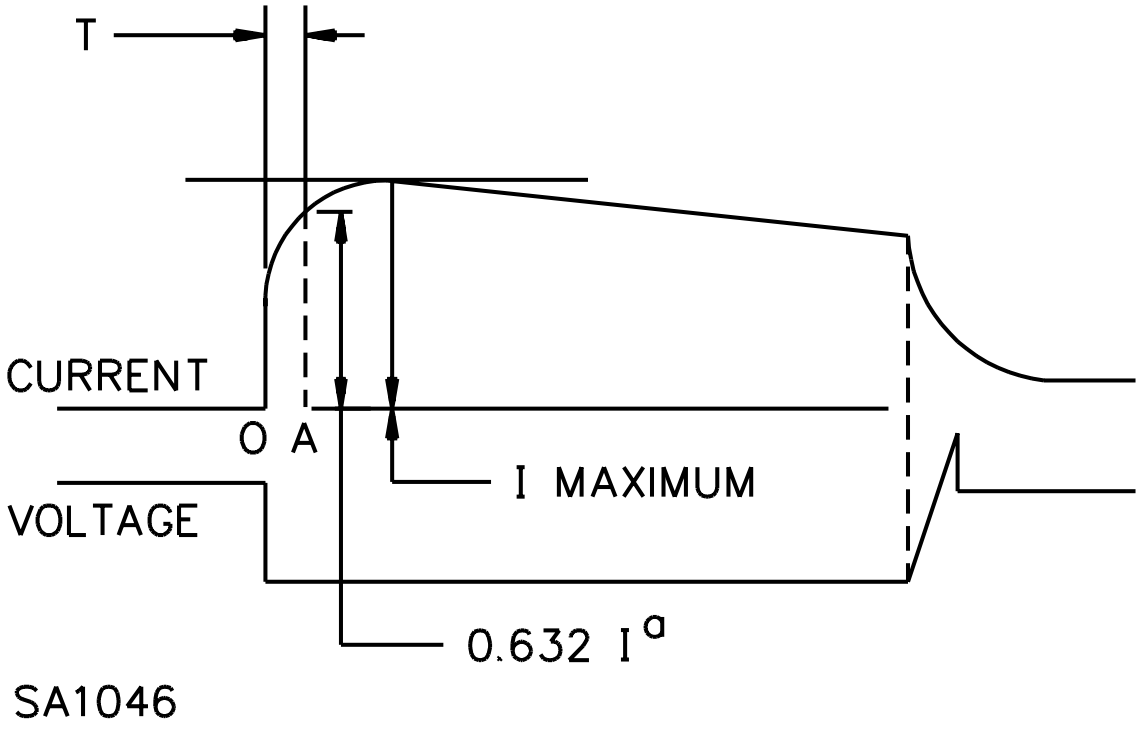
C5.1 The recovery voltage shall be at least equal to the rated voltage of the circuit breaker. The peak value of the recovery voltage within the first full half cycle after clearing and for the next five successive peaks shall be at least equal to 1.414 times the rms value of the rated voltage of the device under test. Each of the peaks shall be displaced by no more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage; that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage of each of the first six half cycles measured at the 45- and 135-degree points on the wave shall not be less than 85 percent of the rms value of the rated voltage of the device under test. The instantaneous value of recovery voltage measured at the 45- and 135-degree points of each of the first six half cycles shall in no case be less than 75 percent of the rms value of the rated voltage of the device under test.

C5.2 If, in a circuit which uses secondary closing, there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open circuit secondary voltage wave before current flow, the detailed measurement of recovery voltage characteristics as indicated above shall not be required.

C6 Direct Current Circuits

C6.1 For a dc source, the requirements of C6.1 – C6.4 shall be applied. The time constant of the test circuit shall be determined by the method shown in Figure C6.1 and shall not be less than 0.003 seconds for currents of 10,000 A or less or not less than 0.008 seconds for currents greater than 10,000 A.

Figure C6.1
Determination of the short-circuit time constant (oscillographic method) of direct-current circuits



C6.2 The dc open circuit voltage of the circuit shall not be less than 100 percent nor more than 105 percent of the rated voltage of the unit under test, except that a higher voltage may be used if agreeable to the submitter and the testing agency. This measurement shall be made with a voltmeter. In addition, the open circuit voltage, as determined by the arithmetic average of the maximum and minimum values of the voltage wave read from an oscillogram, shall be within 99 percent and 105 percent of the rated voltage of the circuit breaker, except that a higher voltage may be used if agreeable to the submitter and the testing agency.

C6.3 The minimum point on the dc voltage wave shall not be less than 90 percent of the rated voltage of the device under test.

C6.4 The available dc capacity of the circuit shall not be less than the value required for the rating of the device under test as indicated in Table 7.1.7.2. The prospective current shall be determined with the supply terminals short circuited by measuring the maximum displacement on an oscillogram at a time, after the start of current, of no less than 4 times the required time constant. Any overshoot above time-current curve (exponential curve) shall not be considered. If the current source has a ripple, measurements shall be made from the midpoint of the ripple.

C6.5 The DC recovery voltage 8 ms after opening shall not be less than 95% of the rated voltage of the circuit and shall be maintained for not less than 50 ms.

Annex D (Informative)

French and Spanish Translations and Markings

D1 General

Clause	English	French	Spanish
13.2	CAUTION Does not provide overcurrent protection	ATTENTION N'assure pas la protection contre les surintensités	PRECAUCION No suministra protección de sobrecorriente
21.6.3	WARNING Do not connect grounding conductors to these or any other neutral terminals; to do so will defeat ground-fault protection	AVERTISSEMENT Ne pas raccorder le conducteur de mise á la terre á ces bornes ni á aucune autre borne neutre; cela annulera la protection contre les fuites á la terre.	ADVERTENCIA No conecte los conductores de puesta a tierra a esta terminal del neutro ni a ninguna otra; si lo hace se invalida la protección de falla a tierra
21.8.11	WARNING Risk of electric shock. Removal of meter does not de-energize circuit	AVERTISSEMENT Risque de choc électrique. Le retrait du compteur ne met pas le circuit hors tension.	ADVERTENCIA Riesgo de choque eléctrico. Al quitar el dispositivo de medicion no se desenergiza el circuito
21.10.5	WARNING Risk of electric shock. This main does not disconnect control and instrument circuits	AVERTISSEMENT Risque de choc électrique. Cet interrupteur principal ne met pas hors tension les circuits de commande et des instruments.	ADVERTENCIA Riesgo de choque eléctrico. Este principal no desconecta los circuitos de control e instrumentos

Annex E (For Canada Only — Informative)

Note: This Annex is not a mandatory part of this Standard but is written in mandatory language to accommodate its adoption by anyone wishing to do so.

Guidelines for Ground Fault Protection Equipment

E1 General

E1.1 This Annex is provided for information only.

E1.2 A ground-fault protection system that uses a sensing element that encircles the neutral conductor (if any) and all ungrounded conductors of the protected circuit (zero sequence type) shall be installed in such a manner that the sending element is located on the load side of any grounding or bonding connections to the neutral. It shall be permitted to be on the line or load side of the disconnecting device for the protected circuit.

E1.3 A ground-fault protection system that combines the outputs of separate sensing elements for the neutral (if any) and each ungrounded conductor (residual type) shall be installed in such a manner that the neutral sensing element is located on the load side of any grounding or bonding connection to the neutral. The ungrounded conductor sensors shall be permitted to be on the line or load side of the disconnecting device for the protected circuit.

E1.4 A ground-fault protection system that uses a single sensing element to detect the actual fault current (ground return type) shall be installed in such a manner that the sensing element detects any current that flows in the grounding electrode conductor, the main bonding jumper, and any other grounding connections within the enclosure that may be made to the neutral. This will require the neutral to be insulated from non-current-carrying metal.

E1.5 If the enclosure or ground bus is factory bonded to the neutral, any conductive part connected to the neutral that would interfere with the operation of a ground-fault protection system, if in contact with the enclosure, shall be insulated and provided with at least 3.2 mm (1/8 inch) spacings through air or over the surface to the enclosure. For zero sequence type ground-fault protection, or the residual type ground-fault protection, parts that would interfere with its operation if grounded include all neutral parts on the load side of the neutral current sensing means. For the ground return type, parts that would interfere with its operation if grounded include all conductive parts connected to the neutral except those on the ground side of the sensing means.

E1.6 A ground-fault protection sensor shall be securely mounted to reduce the risk of damage to it or its leads during shipment.

E1.7 If the construction of ground-fault-sensing and relaying equipment is such that a reset operation is required to restore the equipment to functional status following operation due to a ground fault or test:

a) The construction shall be such as to prevent closing and maintaining contact of the disconnecting device to be controlled by the ground-fault sensing and relaying equipment until the reset operation is performed, or

b) Such means shall be incorporated in the disconnect device.

E1.8 A ground-fault protection control circuit transformer with a primary rating of 12 A or less shall be operated from a circuit protected by either a circuit breaker or branch circuit type fuses rated at not more than 15 A. A transformer having a primary rating greater than 12 A shall be protected by an individual overcurrent device in the primary connection, rated or set at not more than 125 percent of the rated primary current of the transformer, except that:

a) For a 120 V circuit, a fuse rated 2 A or less may be a miscellaneous fuse.

b) Overcurrent protection shall not be required for the shunt trip coil of a circuit breaker used with ground-fault protection if the coil is connected to the load side of the controlled circuit breaker as covered in E1.9.

E1.9 The primary of a ground-fault protection control circuit transformer shall be permitted to be connected on the line or load side of the main disconnect or to an external source. The primary of such a transformer shall be connected to two line voltage parts (not line and neutral). If connected to the line side of the main, or an external source, a dead front fuse assembly, a fused disconnect switch or circuit breaker rated for use as service equipment and providing overcurrent protection as covered in E1.8 shall be installed ahead of the transformer or control circuit. Over current protection is not required for the control circuit if wired to the load side of the main disconnect unless the control circuit contains a snap switch. Markings as indicated in 21.10.1 or 21.10.5 shall be provided if the transformer is not connected to the load side of the main disconnect.

E1.10 The control circuit of a ground-fault protection system shall be connected on the line side of the main disconnect if a test or monitor panel is provided and if such connection is required for intended functioning of the panel.

SUPPLEMENT SA – MOLDED-CASE CIRCUIT BREAKERS AND CIRCUIT-BREAKER ENCLOSURES (MARINE USE) FOR USE UNDER USCG ELECTRICAL SYSTEMS REGULATIONS SUBCHAPTER S (33 CFR, PART 183) AND USCG ELECTRICAL ENGINEERING REGULATIONS SUBCHAPTER J (46 CFR, PARTS 110 – 113)

INTRODUCTION

SA1 Scope

SA1.1 These requirements cover marine circuit breakers intended to be installed and used aboard a boat or vessel in accordance with Annex B, Ref. No. 19; the applicable publications of the American Boat and Yacht Council Inc.; and the regulations of the United States Coast Guard. These circuit breakers shall comply with the applicable requirements of the preceding sections of this standard, except as modified or added to by the requirements in this supplement.

SA1.2 These requirements apply to all types of circuit breakers covered by this standard intended for marine use and, in addition, apply to low-voltage direct-current (dc) circuit breakers rated 50 V or less intended to be powered from onboard batteries.

SA2 Glossary

SA2.1 Ignition-Protected – A device or component constructed in such a manner that it will not ignite an explosive mixture of propane and air surrounding the device under normal operating conditions. An ignition-protected device is not necessarily ″explosion-proof″ as that term is applied to devices used on commercial vessels.

SA2.2 Marine Circuit Breaker – one designed and constructed to meet special requirements for marine use.

CONSTRUCTION

SA3 General

SA3.1 Circuit breakers to be used in marine service shall be rated for an ambient temperature of 40°C (104°F).

SA3.2 A terminal intended for connection of field-installed wiring shall be acceptable for stranded copper wire.

SA3.3 A pigtail lead intended for external connections shall be a stranded copper conductor, Type TW, THW, TW75, or equivalent (moisture and flame retardant properties), having the minimum stranding indicated in Table SA3.1.

SA3.4 The requirements of 6.1.2 for corrosion protection apply to marine circuit breakers, except that aluminum or aluminum alloys shall not be used for terminal connections or parts in direct contact with copper conductors, even if the aluminum parts are plated.

Table SA3.1
Conductor stranding

Conductor size		Minimum number of strands
AWG	(mm^2)	
18 – 8	(0.82 – 8.4)	19
6	(13.3)	37
4	(21.1)	61
2 – 2/0	(33.6 – 67.4)	127
3/0	(85.0)	259
4/0	(107)	418

PERFORMANCE

SA4 General

SA4.1 Marine circuit breakers intended for use on vessels over 19.8 m (65 feet) in length shall comply with the requirements of this standard; and the additional testing requirements of SA7.1, if applicable.

SA4.2 Marine circuit breakers intended for use on vessels 19.8 m (65 feet) or less in length shall comply with the requirements of this standard, with all requirements in this supplement, and shall be subjected to all of the tests in Sections SA5 – SA8.

SA5 Vibration Test

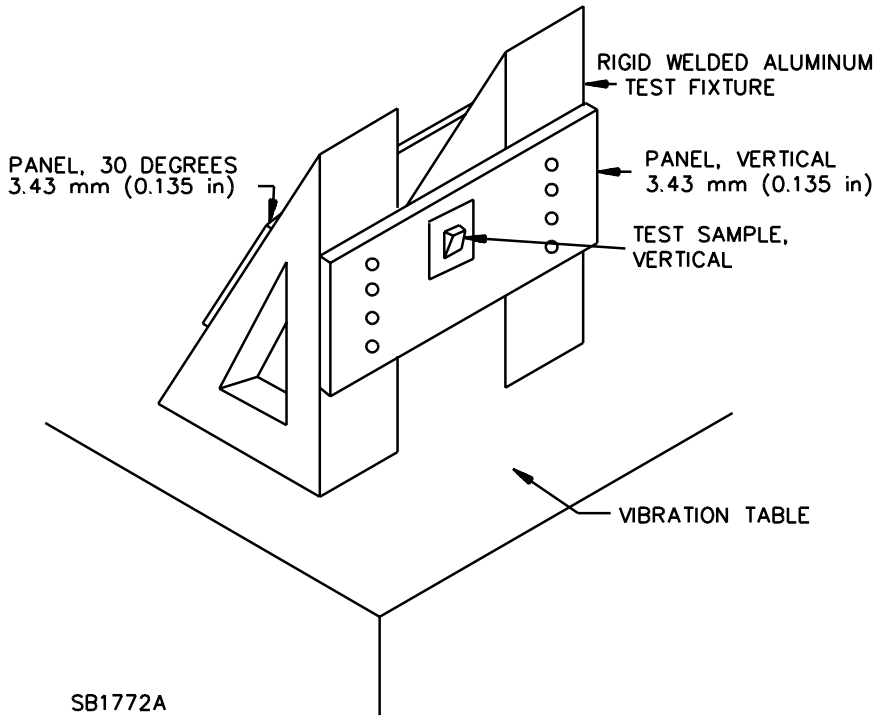
SA5.1 Marine circuit breakers shall be capable of withstanding sinusoidal vibration in accordance with Table SA5.1 without failure of the device, change in calibration, or failure of the mounting means. Permanent opening of the contacts while carrying 100 percent of rated current, permanent closing of the contacts when open, or the presence of any transient switching action having a duration longer than 5 milliseconds, will constitute a failure of the device, see SA5.3. The supply, load wiring, or both, shall not come loose from the terminals during this test.

Table SA5.1
Vibration-test requirements

Type	Test duration	Peak-to-peak amplitude in mm	Peak-to-peak amplitude in (inch)	Period frequency
Circuit breaker marked "Ignition Protected"	12 hours (4 hours in x, y, and z planes)	0.51 ±0.03	(0.020 ±0.001)	10 – 60 – 10 Hz (every 4 minutes)
Circuit breaker not marked "Ignition Protected"	12 hours (4 hours in x, y, and z planes)	0.38 ±0.03	(0.015 ±0.001)	10 – 60 – 10 Hz (every 4 minutes)

SA5.2 Two circuit breakers shall be mounted in separate 3.43 mm (0.135 inch) steel or aluminum panels, which shall in turn be secured to two rigid, welded test fixtures secured to the vibration table, see Figure SA5.1. One circuit breaker and panel is to be secured in the intended manner to the vertical surface of the test fixture and the other to a surface inclined 30 degrees from the vertical. If the circuit breakers are provided with their own enclosure, two enclosures, with the circuit breakers installed, shall be mounted directly to the test fixtures in the manner and positions described for the individual circuit breaker panels. Unsupported panel surfaces shall be kept to a minimum to avoid resonance of the panels within the test frequency range. Each circuit breaker shall be wired with stranded copper conductors of the appropriate size for the rating and properly torqued. The wires shall be connected to a power supply and instrumentation located off the platform of the vibration-test machine. The wiring shall be installed to simulate a normal installation and shall be secured within 178 mm (7 inches) of the terminals. As installed, the wiring shall not be resonant.

Figure SA5.1
Typical vibration-table test setup



SA5.3 To determine whether the contacts open when closed or close when opened, an oscilloscope shall be connected across the circuit breaker contacts.

SA5.4 While mounted as described in SA5.2, each circuit breaker shall be connected to a supply capable of delivering rated voltage and current. The circuit breakers shall be turned off during the first 2 hours of testing in each plane of vibration and turned on with 100 percent of rated current load during the final 2 hours in each plane. The test shall be conducted at room ambient.

SA5.5 Each circuit breaker shall be subjected to a variable frequency test in each of the three rectilinear axes, horizontal, vertical, and lateral, for 4 hours in each plane, total 12 hours, at the amplitude specified in Table SA5.1. The vibration frequency shall be automatically cycled at a constant rate from 10 to 60 to 10 Hz every 4 minutes.

SA5.6 For these tests, peak-to-peak amplitude is defined as the total displacement of sinusoidal motion of the test table.

SA6 Shock Test

SA6.1 The circuit breakers used in the vibration test shall withstand 5000 impacts of 10 g (322 ft/s^2 or 98 m/s^2) peak with a duration of 20 – 25 milliseconds – measured at the base of the approximate half-sine shock wave envelope – without failure of the device, change in calibration, or failure of the mounting means. Permanent opening of the contacts while carrying 100 percent of rated current, permanent closing of the contacts when open, or the presence of any transient switching action having a duration longer than 5 milliseconds shall constitute a failure of the device, see SA5.3. The supply or load wiring shall not come loose from the terminals during this test.

SA6.2 The circuit breakers and mounting fixture used in the vibration test shall be mounted on the shock table and subjected to the impacts indicated in SA6.1. The devices shall be installed and wired as described in SA5.2. The circuit breakers shall carry 100 percent of their rated current during the first 2500 impacts and shall be in the OFF position for the final 2500 shock impulses.

SA6.3 Following the shock test, a calibration test at 200 percent of rated current shall be made as described in 7.1.2.1.1. The test shall be conducted at either 25 or 40°C (77 or 104°F).

SA7 Short-Circuit Test

SA7.1 A short-circuit test shall be conducted on all circuit breakers rated at 50 V or less with a source of dc current capable of delivering 3000 A. The current shall be measured 0.05 seconds after initiation of the short through a 1.2 m (4 foot) length of 1 AWG (42.4 mm^2) stranded copper wire. The test method, sample selection, and acceptance criteria shall be in accordance with Interrupting test, 7.1.7.

SA8 Ignition-Protected Devices Test

SA8.1 Marine circuit breakers or circuit breakers in combination with their enclosures intended to be used in machinery spaces or other areas requiring ignition-protected equipment shall be subjected to the tests described in Annex B, Ref. No. 22.

MARKINGS

SA9 General

SA9.1 In addition to the requirements of SA9.2 and SA9.3, the circuit breakers shall be provided with all of the applicable required markings listed in the marking sections of this standard.

SA9.2 Circuit breakers marked ″Ignition-Protected″ shall comply with the Ignition-Protected Devices Test, SA8.

SA9.3 Marine circuit breakers not subjected to the vibration and impact tests shall be marked, ″For Use On Vessels Over 19.8 m (65 Feet) In Length″.

SUPPLEMENT SB – MOLDED-CASE CIRCUIT BREAKERS AND CIRCUIT-BREAKER ENCLOSURES (NAVAL USE)

INTRODUCTION

SB1 Scope

SB1.1 These requirements cover molded-case circuit breakers and circuit breaker enclosures intended for use aboard non-combatant and auxiliary naval ships. A naval circuit breaker shall comply with the applicable requirements of the preceding sections of this standard, except as modified or added to by the requirements in this supplement.

PERFORMANCE

SB2 Vibration Test

SB2.1 General

SB2.1.1 During and after the vibration tests specified in SB2.2.1– SB2.3.3, a naval circuit breaker:

a) Shall not open the contacts when they are in the closed position;

b) Shall not close the contacts when they are in the open position;

c) Shall continue to perform its intended function with no adjustments or repairs;

d) Shall fall within the limits of the specified time bands for calibration;

e) Shall have an insulation resistance of 10 megohms after vibration test; and

f) Shall not exceed ±5 percent of the calibration limits specified in 7.1.2.2 or 7.1.11.2, as applicable.

SB2.1.2 During and after the vibration tests specified in SB2.2.1– SB2.3.3, fuse units shall not open the circuit, change protective characteristics, lose filler material, or show signs of deformation.

SB2.1.3 To determine whether the contacts open when closed or close when open, an oscillograph is to be connected across the circuit breaker contacts.

SB2.1.4 For these tests, peak-to-peak amplitude is defined as the maximum displacement of sinusoidal motion (total table displacement).

SB2.2 Resonance frequency test

SB2.2.1 A search shall be made to determine the presence of resonance. A circuit breaker shall be vibrated at a peak-to-peak amplitude of 0.51 ±0.05 mm (0.020 ±0.002 inch) in three rectilinear axes, horizontal, vertical, and lateral at frequencies starting at 4 Hz (or the lowest attainable frequency) to 33 Hz. A change in frequency shall be made in discrete intervals of 1 Hz and maintained at each frequency for 15 seconds. The frequency and orientation at which resonances occur shall be noted.

SB2.2.2 If a resonance has been determined in accordance with SB2.2.1, the circuit breaker shall be subjected to that resonant frequency, displacement, and orientation in accordance with SB2.2.1 for 2 hours. If no resonance is observed in accordance with SB2.2.1, the test shall be conducted at 33 Hz at an amplitude of 0.51 ±0.05 mm (0.020 ±0.002 inch) for 2 hours in any plane.

SB2.3 Variable frequency test

SB2.3.1 A variable frequency test shall be conducted separately in each of the three rectilinear axes, horizontal, vertical, and lateral. All tests in one direction shall be completed before proceeding to the tests in another direction. The circuit breaker shall be energized as intended in actual service during the test. The test shall be conducted at room temperature.

SB2.3.2 Two circuit breakers shall be mounted as specified in SB2.3.3 and subjected to the vibration displacement ranges and amplitude specified in Table SB2.3.1. The vibration equipment shall be varied in discrete frequency intervals of 1 Hz and shall be maintained at each interval for 5 minutes.

Table SB2.3.1
Displacement of vibration

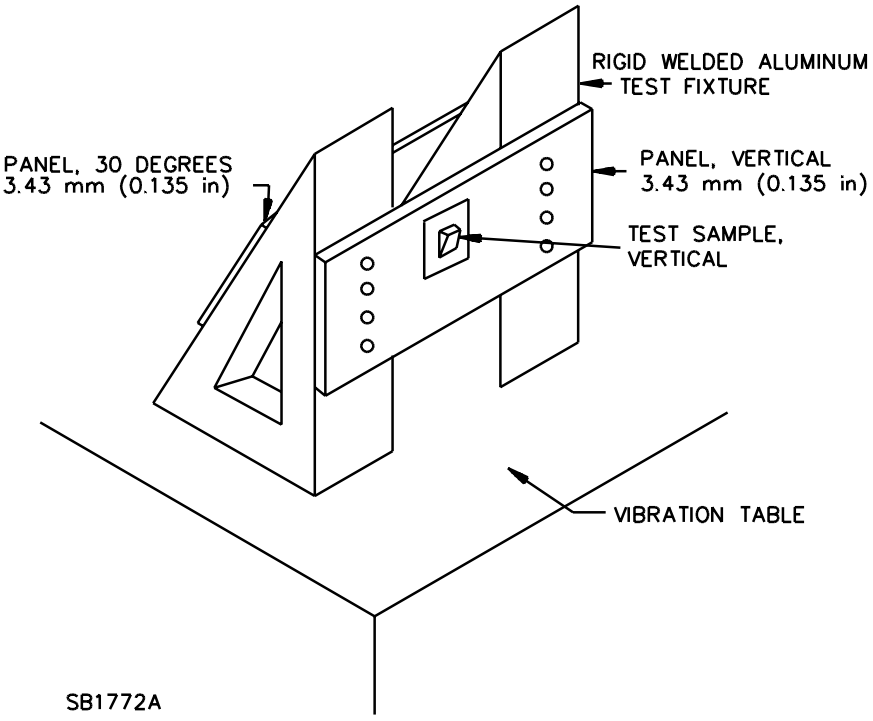
Frequency range Hz	Table amplitude mm	(inch)
4 to 15	1.52 ±0.15	(0.060 ±0.006)
16 to 25	1.02 ±0.10	(0.040 ±0.004)
26 to 33	0.51 ±0.05	(0.020 ±0.002)

SB2.3.3 Two circuit breakers shall be mounted in separate 3.43 mm (0.135 inch) steel or aluminum panels, which shall in turn be secured to two rigid, welded test fixtures secured to the vibration table, see Figure SB2.3.1. One circuit breaker and panel shall be secured in the intended manner to the vertical surface of the test fixture and the other to a surface inclined 30 degrees from the vertical. If the circuit breakers are provided with their own enclosure, two enclosures, with the circuit breakers installed, shall be mounted directly to the test fixtures in the manner and positions described for the individual circuit breaker panels. Unsupported panel surfaces shall be kept to a minimum to avoid resonance of the panels within the test frequency range. Each circuit breaker shall be wired with stranded copper conductors of the appropriate size for the rating and properly torqued. The wires shall be connected to a power supply and instrumentation located off the platform of the vibration-test machine. The wiring shall be installed to simulate a normal installation and shall be secured within 178 mm (7 inches) of the terminals. As installed, the wiring shall not be resonant.

SB3 Calibration Test

SB3.1 A calibration test at 200 percent of rated current shall be made as described in 7.1.2. The calibration shall not exceed ±5 percent of the limits. The test shall be conducted at 50°C (122°F).

Figure SB2.3.1
Typical vibration-table test setup



MARKINGS

SB4 General

SB4.1 In addition to the requirement in SB4.2, a circuit breaker shall be provided with all the applicable required markings specified in the marking sections of this standard.

SB4.2 A circuit breaker that complies with the requirements in SB1 – SB3, in addition to the requirements in this standard, shall be marked ″Naval″, or the equivalent.

SB4.3 A circuit breaker that complies with the requirements in SB1 – SB3, in addition to the requirements in this standard, shall be permitted to be marked “50 °C”.

SUPPLEMENT SC – MOLDED-CASE CIRCUIT BREAKERS AND CIRCUIT-BREAKER ENCLOSURES FOR USE WITH UNINTERRUPTIBLE POWER SUPPLIES

INTRODUCTION

SC1 Scope

SC1.1 These requirements cover molded-case circuit breakers and circuit breaker enclosures rated greater than 250 V dc intended for use with uninterruptible power supplies (UPS) wired with 2 or 3 poles in series.

SC1.2 A circuit breaker intended for use with uninterruptible power supplies shall comply with the applicable requirements of the preceding sections of this standard, except as modified or supplemented by the following requirements.

SC1.3 These circuit breakers shall have the same construction and comply with the requirements for ac rated circuit breakers.

SC1.4 These requirements do not cover circuit breakers rated 250 V dc or less.

SC2 Glossary

SC2.1 UPS Circuit Breaker – a circuit breaker intended to have two or more poles connected in series in order to operate at voltages of certain UPS systems.

PERFORMANCE

SC3 General

SC3.1 The sample selection and performance test sequences shall be conducted as specified in Standard Circuit Breakers, Section 7.1.

SC4 Calibration Test

SC4.1 The UPS circuit breaker shall be subjected to all of the applicable calibration and recalibration tests, including the adjustable instantaneous response calibration test specified in 7.1.2.5.1.

SC5 Overload Test

SC5.1 The UPS circuit breaker shall be subjected to the overload test specified in 7.1.3 at the maximum rated voltage specified in Table SC7.1. The number of operations and the test current of the overload test shall be in accordance with Table SC5.1.

Table SC5.1
Overload test

Circuit breaker rating, amperes	No. of cycles	Percent of rated current
249 and less	50	200
250 – 6000	25	200

SC6 Endurance Test

SC6.1 The UPS circuit breaker shall be subjected to the endurance test specified in 7.1.5 at the maximum rated voltage specified in Table SC7.1. The number of operations of the endurance test shall be in accordance with Table SC6.1.

Table SC6.1
Endurance test

Circuit breaker rating, amperes	Cycles of operation	
	With load	Without load
249 and less	1000	1000
250 to 6000	400	400

SC7 Interrupting Test

SC7.1 The UPS circuit breaker shall be subjected to the interrupting tests specified in 7.1.7 at the nominal rated voltage specified in Table SC7.1. The test currents are to be selected from the “Common” column in Table 7.1.7.2. The sequence for these tests shall be “O – CO – O”.

Table SC7.1
Voltage rating, volts DC

Level	Nominal	Maximum
1	384	500
2	500	600

SC8 Dielectric Voltage-Withstand Test

SC8.1 The UPS circuit breaker shall be subjected to the dielectric voltage-withstand test specified in 7.1.9.

SC9 High-Available-Fault-Current Testing

SC9.1 The UPS circuit breaker may be subjected to the high-available-fault-current tests specified in 7.1.11. The interrupting capacity test specified in 7.1.11.3.1 shall be conducted at the nominal voltage rating specified in Table SC7.1.

RATINGS

SC10 General

SC10.1 UPS circuit breakers shall be rated for one of the nominal and maximum dc voltages indicated in Table SC7.1.

MARKINGS

SC11 General

SC11.1 In addition to the following requirements, a circuit breaker shall be provided with all the applicable required markings specified in the marking sections of this standard.

SC11.2 A circuit breaker shall be marked with the nominal and maximum dc voltage rating. Location Category B.

SC11.3 A circuit breaker shall be marked with a wiring diagram indicating the proper connections of the poles in series. Location Category B.

SC11.4 A circuit breaker shall be marked to indicate it is intended for use on ungrounded systems only. Location Category B.

SC11.5 A circuit breaker shall be marked ″For _____ V dc nominal _____ V dc maximum rating the circuit breaker is suitable only for use with uninterruptible power supplies″. The blank lines shall be filled in with the appropriate ratings from Table SC7.1. The words ″uninterruptible power supplies″ shall be permitted to be abbreviated ″UPS″. Location Category B.

SUPPLEMENT SD – CLASSIFIED CIRCUIT BREAKERS FOR USE WITH SPECIFIED PANELBOARDS AS AN ALTERNATE FOR SPECIFIED CIRCUIT BREAKERS

INTRODUCTION

SD1 Scope

SD1.1 These requirements cover classified circuit breakers intended for use as alternates for specified circuit breakers for use with specified panelboards rated 225 amperes, 120/240 V maximum where the available short-circuit current is 10 kA, 120/240 V ac maximum. These circuit breakers are rated 15–60 amperes, 120/240 V maximum.

SD1.2 These requirements are intended for use in conjunction with the requirements in Supplement SB for Classified Circuit Breakers for Use with Specified Panelboards as an Alternate for Specified Circuit Breakers specified in Annex B, Ref. No. 20.

SD2 Glossary

SD2.1 Classified Circuit Breaker – A circuit breaker identified by the manufacturer of the circuit breaker as suitable for use in a specified panelboard as an alternate for a specified circuit breaker.

SD2.2 Specified Circuit Breaker – A circuit breaker identified by the panelboard manufacturer by a catalog number or the equivalent for use with that manufacturer's panelboard.

SD2.3 Specified Panelboard – A panelboard identified by the classified circuit breaker manufacturer by a catalog number or the equivalent provided on or with a classified circuit breaker. A panelboard identified by the classified circuit breaker manufacturer by a catalog number or the equivalent provided on or with a classified circuit breaker.

CONSTRUCTION

SD3 General

SD3.1 A classified circuit breaker shall comply with the requirements in this standard and also with the applicable requirements in Annex B, Ref. No. 20.

PERFORMANCE

SD4 General

SD4.1 A classified circuit breaker shall comply with the requirements in this standard, and be investigated and marked for at least the same ratings and features (such as SWD, HACR, and the like) as the specified circuit breaker.

SD5 Interrupting Test

SD5.1 A single-pole classified circuit breaker rated 120/240 V ac shall additionally be subjected to testing in pairs. The second circuit breaker of the pair shall be the specified circuit breaker, and in addition, any other previously classified circuit breaker intended as an alternate for the specified circuit breaker.

SD5.2 The testing shall be in accordance with:

a) Table 7.1.1.2, Test Sequences;

b) 7.1.1.11 and 7.1.11.5; and

c) For high-available fault-current testing, 7.1.11.1 – 7.1.11.5.

SD5.3 During the testing specified in SD5.2, each circuit breaker pair shall be handle-tied.

SD5.4 The results for each test shall comply with the requirements for each test as specified elsewhere in this standard. In addition, the handle tie shall continue to function as intended.

MARKINGS

SD6 Details

SD6.1 A classified circuit breaker shall be marked in accordance with the requirements in this standard and also in accordance with the supplement to Annex B, Ref. No. 20 Supplement SB for Classified Circuit Breakers for Use with Specified Panelboards as an Alternate for Specified Circuit Breakers.

SUPPLEMENT SE – MOLDED-CASE CIRCUIT BREAKERS AND MOLDED-CASE SWITCHES WITH SOFTWARE IN PROGRAMMABLE COMPONENTS

SE1 Scope

SE1.1 These requirements apply to molded case circuit breakers and molded case switches with embedded microprocessor software. These circuit breakers and switches shall also comply with the applicable requirements of the preceding sections of this standard.

SE1.2 These requirements address the risks unique to software in programmable components.

SE1.3 These requirements address the risks that occur as a result of the process used to develop and maintain the software, such as the following:

a) Requirements conversion faults that cause differences between the specification for the programmable component and the software design;

b) Design faults such as incorrect software algorithms or interfaces;

c) Coding faults, including syntax, incorrect signs, endless loops, and other coding faults; and

d) Latent, user, input/output, range, and other faults that are only detectable when a given state occurs.

SE2 Glossary

SE2.1 For the purpose of this supplement, the following definitions apply.

SE2.2 Built-In Test – A design method that allows a product to test itself by adding logic for test signal generation and analysis of test results.

SE2.3 Critical Section – A segment of the software that is intended to perform the functions that address or control risks.

SE2.4 Data – A representation of facts, concepts, or instructions in a manner suitable for storage, communication, interpretation, or processing.

SE2.5 Design – The process of defining the software architecture, components, modules, interfaces, test approach, and data for a software system to satisfy specified requirements.

SE2.6 Embedded Software – Software that is physically part of a product and whose primary purpose is to maintain some property or relationship between other components of the product in order to achieve the overall system objective.

SE2.7 Error – A discrepancy between a computed, observed, or measured value or condition and the true, specified, or theoretically correct value or condition.

SE2.8 Fail-Operational Procedure – A procedure executed in the event that a failure has occurred which continues product operation but provides degraded performance or reduced functional capabilities.

SE2.9 Failure – The inability of a product or component to perform its specified function.

SE2.10 Fault – A deficiency in a product or component that is capable of, under some operational conditions, contributing to a failure.

SE2.11 Fault-Tolerant – The capability of software to provide continued correct execution in the presence of a defined set of microelectronic hardware and software faults.

SE2.12 Hazard – A potential source of physical injury to persons.

SE2.13 Instruction – A statement that specifies an operation to be performed and that is capable of identifying data involved in the operation.

SE2.14 Integrity – The degree to which a system or component prevents unauthorized access to, or modification of, computer programs or data.

SE2.15 Non-Volatile Memory – A storage device not alterable by the interruption of the power to the memory; for example, ROM, FLASH, PROM, EPROM, and EEPROM.

SE2.16 Off-The-Shelf (OTS) Software – Software which is made available on the market and intended for broad distribution, generally without the need for additional tailoring, including, but not limited to, operating system software, runtime libraries, real-time executives, kernel primitives, shareable reentrant library-type routines.

SE2.17 Parameter Settings – A finite collection of values assigned to variables to select, enable, or disable known pre-existing function or functions or features of the software.

SE2.18 Post-Release Testing – All testing for changes implemented after the final production software is released.

SE2.19 Procedure – A course of action taken to perform a task.

SE2.20 Process – A sequence of steps performed to produce a given result.

SE2.21 Product – An instrument, apparatus, implement, or machine intended for personal, household, industrial, laboratory, office, or transportation use.

SE2.22 Product Hardware – Any hardware that is part of a product and that provides electrical, mechanical, or any combination of electromechanical functions.

SE2.23 Programmable Component – Any microelectronic hardware that can be programmed in the design center, in the factory, or in the field. Here the term ″programmable″ is taken to be ″any manner in which one can alter the software wherein the behavior of the component can be altered.″

SE2.24 Risk – The potential for fire, electric shock, or injury to persons associated with the intended use of the product as specified by the product safety requirements.

SE2.25 Risks Addressed (RA) State – A state, as defined by the manufacturer, that is characterized by all reasonably foreseeable risks associated with the intended use of the product being addressed such that there is no longer a likelihood of the risk.

SE2.26 Safety-Related Functions – Control, protection, and monitoring functions that are intended to reduce the risk of fire, electric shock, or injury to persons.

SE2.27 Software – Computer programs, procedures, and data pertaining to the operation of a programmable component that provides safety-related functions as follows:

a) Exercises direct control over the state of microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data are capable of resulting in a risk.

b) Monitors the state of microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data provide data that is capable of resulting in a risk.

c) Exercises direct control over the state of the microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data are capable of, in conjunction with other human actions, product hardware or environmental failure, resulting in a risk.

SE2.28 Software Design – The process of defining the software architecture, components, modules, interfaces, test approach, and data for a software implementation to satisfy specified requirements.

SE2.29 State – The values assumed, at a given instant in time, by a collection of variables that define certain specified characteristics of the product or its components.

SE2.30 Stress Testing – Testing conducted to evaluate a product or component at or beyond the limits of its specified requirements.

SE2.31 Supervisory Section – The main section of software that controls the execution of the critical and non-critical sections of the software (for example, the operating system of a microprocessor).

SE2.32 Tool – Any equipment (such as logic analyzers, oscilloscopes, multimeters, digital and analog computers), devices, or software programs [such as simulators, computer-aided software/systems engineering (CASE) tools, compilers, type checkers, static analyzers, automated testing scripts, debuggers, linkers, loaders, assemblers, code generators, code librarians, editors, and software analyzers] used to automate or partially automate software development activities, including design, implementation, and testing.

SE2.33 Tool Qualification – The acceptance of analysis, testing, and resulting evidence for which confidence is obtained regarding the correctness of a tool's outputs.

SE2.34 Tool Vendor – The organization responsible for providing the tool.

SE2.35 Unique Identifier – An encoded value that distinctively characterizes each individual version or revision of a manufacturer's software.

SE2.36 User – A qualified service person or an operator of the programmable component.

SE2.37 Validation – The test and evaluation of the integrated computer system (hardware and software) and its specification to determine whether it carries out its intended purpose.

SE2.38 Verification – The process of determining whether the products of a given development phase are correct and consistent with the products and standards provided as input to that phase.

SE3 Risk Analysis

SE3.1 A risk analysis shall be conducted to determine the risks associated with, and addressed by, the software. Examples of identified risks include but are not limited to the following:

a) Unable to perform primary protective function or functions.

b) Invalid protective function setting.

c) Invalid protective function setting enacted via remote communications.

SE3.2 The risk analysis shall be based on the safety requirements unique to the programmable component.

SE3.3 An analysis shall be conducted to identify the critical, non-critical, and supervisory sections of the software.

SE3.4 An analysis shall be conducted to identify software states or transitions that are capable of resulting in a risk.

SE4 Process Definition

SE4.1 All software development process activities shall be described (see Documentation, Section SE11).

SE4.2 The software development process activities shall be identified with distinct entry points, exit points, and criteria for transitioning among activities.

SE4.3 The software development process shall begin with a risk analysis in accordance with the requirements of Risk Analysis, Section SE3.

SE4.4 Criteria for transitioning among activities shall include consideration of the safety-related requirements for the programmable component.

SE4.5 Work products (such as meeting minutes, analysis and test results, formal documentation) shall be identified and associated with software development process activities.

SE4.6 All software development process activities shall support the communication of issues that could impact the safety-related functioning of the programmable component.

SE4.7 Safety-related requirements for the programmable component shall be traceable throughout the software development process activities.

SE4.8 The verification, validation, and testing activities in the software development process shall address errors at their source.

SE5 Qualification of Software Tools

SE5.1 Evidence of tool qualification shall be provided for all tools used in the implementation of software in the programmable component using at least one of the following forms:

a) Documentation attesting to tool verification, and validation activities.

b) Evidence that the tool or tools have met formally defined requirements by a recognized third-party tool certification program.

c) When validated tools are unavailable, self-certification is acceptable using such techniques as object code inspection.

SE5.2 For any identified error in the tool, the feature that leads to an error shall not be used by the manufacturer in the development of safety-related software.

SE6 Software Design

SE6.1 The software shall employ means to identify and respond to software states that are capable of resulting in a risk. Examples of such means include initialization, fail-safe and fault-tolerant concepts, run-time checks, and built-in tests.

SE6.2 The software shall maintain a Risks Addressed (RA) state upon detection of a condition that is capable of resulting in a risk as identified in Risk Analysis, Section SE3.

SE6.3 Detection of a failure in the software during the intended operation of the product shall be handled in a manner that is in accordance with the Risk Analysis described in Section SE3.

SE6.4 In allocating resources to tasks, consideration shall be given to the scheduling frequency of the task, the criticality of the task, and the resources utilized by the task, as well as the impact that each of these factors has on the ability to address the identified risks.

SE6.5 Means shall be employed for the prevention, detection, and resolution of non-terminating and non-deterministic states and error states such as division by zero and under/overflow that are capable of affecting the intended operation of the software.

SE7 Critical and Supervisory Sections of Software

SE7.1 The software shall be initialized to a documented RA state.

SE7.2 Critical and supervisory sections of the software shall be partitioned from non-critical sections.

SE7.3 When it is not possible to partition the critical and supervisory sections from the non-critical sections of the software as in SE7.2, all of the software shall be considered critical or supervisory.

SE7.4 Means shall be employed to avoid, or detect and recover from, memory usage and addressing conflicts.

SE7.5 The supervisory section shall maintain control of the execution of the software during the operation of the programmable component.

SE7.6 Software shall enter a RA state in the event that a failure in a critical or supervisory section is detected.

SE7.7 There shall be provisions to control the accessibility of instructions and data dedicated to critical and supervisory section functions.

SE7.8 There shall be provisions to protect instructions and data for critical and supervisory sections of software from being affected by any function except critical and supervisory section functions.

SE7.9 Supervisory and critical sections of software shall be stored in non-volatile memory.

SE7.10 Means shall be employed to preserve the integrity of data used by critical and supervisory sections of software.

SE7.11 Fixed or one-time changing data used for critical and supervisory sections of software shall reside in non-volatile memory.

SE8 Product Interface

SE8.1 For power interruptions of any duration, the software shall maintain a documented RA state.

SE8.2 When initialization is allocated as a software function, the software shall initialize the product to a documented RA state.

SE8.3 Upon any situation in which the software terminates, the product shall maintain a documented RA state.

SE8.4 A procedure or instruction intended to halt the programmable component shall maintain an RA state of the product.

SE9 User Interfaces

SE9.1 The requirements in this section only apply to software that accepts user input.

SE9.2 The time limits and other parameters of the software shall not be changeable by a user such that the intended execution of critical and supervisory sections of software is adversely affected.

SE9.3 The time limits and other parameters of the software that are intended to be configured by qualified personnel shall be prevented from being changed to the extent that the intended operation of the critical or supervisory sections of software is adversely affected.

SE9.4 Input commands that can affect the software in a manner capable of resulting in unintended action when executed shall not be enacted by the software.

SE9.5 Incorrect input shall not adversely affect execution of critical sections of software.

SE10 Software Analysis and Testing

SE10.1 Software analysis

SE10.1.1 Software design and code analysis shall be conducted to evaluate that the critical and supervisory sections of software only perform those functions that they are intended to perform and do not result in a risk.

SE10.1.2 Examples of software design and code analysis to be conducted include the following:

a) Correctness and completeness with respect to the safety requirements for the programmable component;

b) Coverage of each decision and function that is capable of involving a risk;

c) That fail-safe and fail-operational procedures bring the product to an RA state. See SE6.1, SE6.3, and SE7.6;

d) That the scheduling requirements are met and safety-related functions meet the timing constraints specified by the safety requirements for the programmable component. See SE6.4;

e) The integrity of the partitions between supervisory, critical, and non-critical sections of software. See SE7.2;

f) That partition violations caused by such occurrences as data handling errors, control errors, timing errors, and misuse of resources do not occur; and

g) Consistency in the data and control flows across interfaces.

SE10.2 Software testing

SE10.2.1 Software testing shall include development and post-release testing.

SE10.2.2 Tests of the software shall be conducted and test results documented to evaluate that the software only performs those functions for which it is intended and does not result in a risk.

SE10.2.3 Test cases shall be developed based on the risk analysis, the documented descriptions of the software operation and safety features (see SE11.7.2), and the software analysis. See SE10.1.

SE10.2.4 Examples of tests to be conducted include the following:

a) Correctness and completeness with respect to the safety requirements for the programmable component;

b) Coverage of each decision and function that is capable of involving a risk;

c) That fail-safe and fail-operational procedures bring the product to an RA state. See SE6.1, SE6.3, and SE7.6;

d) That the scheduling requirements are met and safety-related functions meet the timing constraints specified by the safety requirements for the programmable component. See SE6.4;

e) The integrity of the partitions between supervisory, critical, and non-critical sections of software. See SE7.2;

f) That partition violations caused by such occurrences as data handling errors, control errors, timing errors, and misuse of resources do not occur; and

g) Consistency in the data and control flows across interfaces.

SE10.2.5 The outputs that the software generates to control product hardware shall be tested to determine their effects on the product hardware, based on the expected output.

SE10.2.6 In addition to testing under normal usage, software stress tests shall be conducted.

SE10.2.7 Examples of software stress testing include the following:

a) Operator errors that are capable of adversely affecting the intended operation or the control of the programmable component;

b) Errors in data received from external sensors or other software processes; and

c) Failures associated with the entry into, and execution of, critical and supervisory sections of software.

SE10.2.8 Test cases shall include the following, as determined in accordance with SE10.1.2 (b):

a) Out-of-range, and

b) Boundary condition.

SE11 Documentation

SE11.1 User documentation

SE11.1.1 Except for embedded software that has no direct user interaction, user documentation (such as manual, guide, or other documents) shall be prepared.

SE11.1.2 The user documentation shall describe the required data and control inputs, input sequences, options, program limitations, and other activities or items necessary for intended execution of the software.

SE11.1.3 All error messages shall be identified and corrective actions described in the user documentation.

SE11.2 Software plan

SE11.2.1 A software plan shall be documented, which describes the software development activities.

SE11.2.2 The software plan shall include a description of the software design methodology, development rationale, any metrics to be collected, applicable standards and the engineering methods/techniques employed, and an itemized list of all documents produced throughout the software process.

SE11.3 Risk analysis approach and results

SE11.3.1 The risk analysis approach and results (see Risk Analysis, Section SE3) shall be documented.

SE11.3.2 The risk analysis shall illustrate how a failure in the software is capable of leading to an identified hazard.

SE11.3.3 The risk analysis shall list all identified risks as a result of software failure associated with the product.

SE11.4 Configuration management plan

SE11.4.1 A configuration management plan, which applies to the off-the-shelf software, software tools, and the manufacturer-provided software, shall be documented.

SE11.4.2 The configuration management plan shall describe:

a) How changes to the software and hardware are managed;

b) The initiation, transmittal, review, disposition, implementation and tracking of discrepancy reports, and change requests; and

c) The methods and activities employed to formally control receipt, storage and backup, handling, and release of software and all documentation identified in this section.

SE11.5 Programmable system architecture

SE11.5.1 The programmable system architecture shall be documented.

SE11.5.2 The programmable system architecture shall describe the programmable component, including interfaces to users, sensors, actuators, displays, microelectronic hardware architecture, top-level software architecture, the mapping of the software to the hardware, and block diagrams of the programmable system showing a high-level view of the product architecture.

SE11.5.3 The programmable system architecture shall describe the software-to-software interfaces and the hardware-to-software interfaces.

SE11.5.4 The configuration or configurations of the programmable component or components that the software is intended to be operated with shall be identified. See SE2.23.

SE11.6 Programmable component and software requirements specification

SE11.6.1 A programmable component and software requirements specification shall be documented.

SE11.6.2 The programmable component and software requirements specification shall describe functional, performance, and interface requirements of the programmable system and the software.

SE11.6.3 The specification shall include a description of all modes of operation, identification of failure behavior, and required responses.

SE11.6.4 The programmable system and software requirements specification shall be traceable to the risk analysis results documented in SE11.3.

SE11.7 Software design documentation

SE11.7.1 Software design documentation shall be prepared.

SE11.7.2 The software design documentation shall include a description of the operation and safety features of the software, with respect to the intended function.

SE11.7.3 The software design documentation shall include the inputs and outputs, functions, data descriptions and relationships, control and data flow, fault handling, and algorithms.

SE11.7.4 The software design documentation shall describe details of how the design of the software meets the system and software requirements specification.

SE11.8 Analysis and test documentation

SE11.8.1 All analysis and test methods and results shall be documented.

SE11.8.2 A test plan shall be documented which covers all software that is used in the programmable component, including off-the-shelf and third party supplied software (See Off-the-Shelf Software, Section SE12).

SE11.8.3 The test plan shall include or reference the documented test procedures that are used to verify the correct implementation of the software in the programmable component.

SE11.8.4 Test procedures shall include a description of the test parameters, test criteria, test configuration, and any special provisions or assumptions regarding the set-up, execution, and interpretation of the test cases (See SE10.2.3, SE10.2.4, and SE10.2.7).

SE11.8.5 Test cases shall be documented and traceable to the software implementation.

SE11.8.6 Test results shall be documented and traceable to the test case or cases that produced them.

SE12 Off-the-Shelf (OTS) Software

SE12.1 For all OTS software that interfaces with the manufacturer-supplied software, the following information shall be provided in the software plan, see SE11.2:

a) The name and version/revision identifier of the OTS software;

b) The name of the OTS software provider;

c) A description of the purpose for which the software is being used;

d) A clear description of the function provided by the software;

e) An interface specification showing all control and data flows in and out of the OTS software; and

f) References to the OTS software documentation for each callable routine that interfaces with the manufacturer's software.

SE12.2 At least one of the following forms of evidence shall be provided for OTS software:

a) Documentation attesting to verification and testing activities of the OTS software to the extent that risks involving the OTS software are addressed.

b) Evidence that the OTS software has met formally defined requirements by an independent OTS software certification program.

SE12.3 When available from the OTS software developer or other sources (such as the user community), the manufacturer shall provide a list of known bugs for the precise revision/version of the OTS software that the manufacturer intends to use in the embedded software. For each identified error in the known bug report for the OTS software, the following evidence shall be provided when implementing SE12.2 (a):

a) The feature that leads to an error has been fixed, tested, and approved for distribution by the OTS software developer in a new release that has been incorporated into the manufacturer's version of the software, or

b) The feature that leads to an error has not been used by the manufacturer in the development of safety-related software and does not lead to a risk.

SE12.4 For OTS software that performs supervisory or critical section functions or is used by the supervisory or critical section of software, the requirements contained in SE6.4, SE10.1.2 (d), SE10.1.2 (e), SE10.1.2 (f), and Critical and Supervisory Sections of Software, Section SE7, of this supplement apply.

SE13 Software Changes and Document Control

SE13.1 Changes to parameter settings and data shall not create a risk or impact a risk that has previously been identified other than to reduce or eliminate it.

SE13.2 Changes or patches to the software shall not create a risk or impact a risk that has previously been identified other than to reduce or eliminate it.

SE13.3 To determine compliance, all changes are to be evaluated in accordance with this supplement.

SE13.4 Documentation shall be reviewed to determine that it correctly reflects safety-related changes that have been made in the software.

SE13.5 There shall be procedures to maintain and control software changes to the configuration of the programmable components and critical and supervisory sections of software to facilitate traceability.

SE14 Identification

SE14.1 Software shall contain a unique identifier stored in non-volatile memory.

SE14.2 The unique identifier shall be computed as a function of the critical and supervisory sections of the software.

SE14.3 Each time a change or patch is incorporated in the software, a new unique identifier shall be assigned.

SE14.4 Documentation shall include sufficient information to identify each item that is investigated with the software. For example, identification of software elements shall include the version number, release number, and date. Programmable microelectronic hardware elements shall include the part number and revision level.