UL 845

STANDARD FOR SAFETY

Motor Control Centers

UL Standard for Safety for Motor Control Centers, UL 845

Sixth Edition, Dated June 28, 2021

SUMMARY OF TOPICS

This revision of ANSI/UL 845 dated February 28, 2025 includes the following changes in requirements:

– Addition of Class CF; 9.3.6, 9.15.4.2, Annex C, and Annex D

– Calibration Performance; 8.3.2

– Contactor Overload Protection; 8.3.8

– Trip-out Performance of Circuit Breakers; 8.3.17.1.1, 8.3.17.1.2, and 8.3.17.1.3

– Correction in Conversion of HP to kW; Table 15, Table 16

– Short-time and Short-circuit Current Ratings of Motor Control Center Units; 5.4.1 (title), 5.4.1.4, 5.4.4.1, 5.4.4.2, Table 3, Table 45, 6.3.11A, 6.3.11B, 8.3.10A, 8.3.15A, 8.3.16A, Clause 9.10A, Clause 9.11A, Clause 9.15A, and Clause 9.16A

– Short Circuit Test Performance; 8.3.12 – 8.3.17, 8.3.22, 8.3.23, 9.12, 9.12.1.2, 9.12.3.8, Clauses 9.13 – 9.17, 9.16.1, Clauses 9.23 and 9.24

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated August 9, 2024 and December 6, 2024.

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NMX-J-353-ANCE-2021
Third Edition

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Second Edition

ULSE Inc.
UL 845
Sixth Edition

Motor Control Centers

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ANSI/UL 845-2025

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as “CSA Group”), and ULSE Inc. (ULSE). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or ULSE at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and ULSE. CSA Group and ULSE will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and ULSE pages.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through February 28, 2025. The most recent designation of ANSI/UL 845 as an American National Standard (ANSI) occurred on February 28, 2025. 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 845 on April 20, 1993. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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Preface

This is the harmonized ANCE, CSA Group, and ULSE standard for Motor Control Centers. It is the third edition of NMX-J-353-ANCE, the second edition of CSA C22.2 No. 254, and the sixth edition of UL 845. This edition of NMX-J-353-ANCE/CSA C22.2 No. 254/UL 845 supersedes the previous edition published on August 31, 2005. This harmonized standard has been jointly revised on February 28, 2025. For this purpose, CSA Group and ULSE are issuing revision pages dated February 28, 2025, and ANCE is issuing a new edition dated February 28, 2025.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), the CSA Group, and ULSE. The efforts and support of the Technical Harmonization Subcommittee 17D – Motor Control Centers on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA) 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 Distribucion Industrial from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the motor control centers manufactures and users.

This standard was reviewed by the CSA Integrated Committee on Industrial Control, 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 developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of 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 is published as an identical standard for ANCE, CSA Group, and ULSE.

An identical standard is a standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

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.

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Motor Control Centers

1 Scope

1.1 Products covered

1.1.1 This standard applies to motor control centers to be used in accordance with the U.S. *National Electrical Code*, ANSI/NFPA 70, CSA C22.1, *Canadian Electrical Code, Part 1*, and the Mexican *Electrical Installations (Utility)*, NOM-001-SEDE.

1.1.2 These requirements cover motor control centers for use on circuits having available short-circuit currents not more than 200 000 A rms symmetrical or 200 000 A dc.

1.1.3 This standard applies to single- and three-phase 50 and 60 Hz and dc motor control centers rated not more than 1000 V ac or dc.

1.1.4 Requirements for fire pump controllers are as provided in Annex C, item 11.

1.2 Products not covered

These requirements do not cover switchboards or panelboards intended for the control of electric light and power circuits, nor do they cover an individual unit for this purpose. Such units, however, that consist of manually or automatically operated switches, branch-circuit or service-circuit circuit-breakers, overcurrent-protective devices, or the like may be used within a motor control center.

1.3 Equipment

1.3.1 A motor control center can contain, but is not limited to, any combination of equipment such as the following:

a) full-voltage reversing or non-reversing combination motor control units;

b) full-voltage multispeed combination motor control units;

c) reduced-voltage part-winding, wye-delta or auto-transformer combination motor control units;

d) solid-state industrial controllers, such as adjustable-speed drives, programmable controllers, protective relays, and the like;

e) lighting or distribution panelboards;

f) feeder-tap units;

g) incoming-line equipment, such as main lugs, fusible switch, isolation switch, or circuit-breaker;

h) control or lighting transformers;

i) special equipment assemblies;

j) combination contactor units.

1.3.2 The foregoing equipment can contain, but is not limited to, such items as pushbuttons, selector switches, indicating lights, control transformers, control circuit fuses, and auxiliary devices incorporated as an integral part of the units.

1.4 Units of measurement

The first values given are SI (metric) units. Alternate measurements shown in parentheses are US customary units, which sometimes are not strict conversions.

2 Normative references

The normative references listed in Annex C contain provisions which, through reference in this text, constitute provisions of this standard. Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the edition of that code or standard and all published changes up to the time when this standard was approved.

In Canada, general requirements are as indicated in Annex C, item 16.

3 Definitions

3.1 For the purposes of this standard, the following apply.

3.2 **auxiliary devices** – types of devices such as indicating meters (instruments), current transformers, control devices, control relays, timers, protective relays or protective devices, communications devices, etc.

3.3 **available short-circuit current** – the short-circuit current available at the equipment line terminals plus any motor contribution. The available ac short-circuit current is expressed in rms symmetrical A.

3.4 bus, horizontal – a bus that extends through a motor control center section.

3.5 **bus, vertical** – a bus that serves the units in a section and that originates from the horizontal bus. This bus may be replaced by insulated wiring.

3.6 **Class I motor control centers** – mechanical groupings of combination motor control units, feeder-tap units, other units, and electrical devices arranged in an assembly. (See Annex H).

3.7 **Class II motor control centers** – a Class I motor control center provided with manufacturer-furnished electrical interlocking and wiring between units, as specifically described in overall control system diagrams supplied by the user. (See Annex H).

3.8 **combination controller unit** – a control unit containing a magnetic or solid-state controller and an externally operable disconnecting means and overcurrent protection. The controller may or may not contain motor overload protection.

3.9 **combination motor control unit** – a control unit that contains components that perform the following functions: externally operable circuit-disconnecting means, motor branch-circuit overcurrent protection, motor overload protection, and motor control.

NOTE Two sets of externally operable circuit-disconnecting means, each with branch-circuit overcurrent protection and motor controller, may be mounted in a single compartment to form a dual unit.

3.10 **dummy fuse** – a current-carrying part made of copper and having such dimensions that it will fit its fuse mounting means with the same conditions of pressure, contact, and cross-sectional areas as are obtained on terminals of the fuse that it is intended to replace.

3.11 **feeder-tap unit** – a unit that includes an externally operable circuit-disconnecting means and branch-circuit overcurrent protection, principally used for non-motor loads.

NOTE Two sets of externally operable circuit means, each with branch-circuit overcurrent protection, may be mounted in a single compartment to form a dual unit.

3.12 **incoming supply conductor** – a conductor installed to provide power to the equipment.

3.13 **main bonding jumper** – the connection between the grounded circuit conductor and the equipment grounding conductor at the service.

3.14 **motor control center** – a floor-mounted assembly of one or more enclosed vertical sections typically having a horizontal common power bus and principally containing combination motor control units.

NOTE Usually, units are mounted one above the other in the vertical sections. The sections normally incorporate vertical buses connected to the common power bus, thus extending the common power supply to the individual units. Power may be supplied to the individual units by bus bar connections, by stab connections, or by suitable wiring.

3.15 **motor control center section** – the vertical enclosure and assembly that is prevented by the structural framework from being physically separated into smaller parts and is intended to receive individual combination motor control units. The function of the vertical section is to support the horizontal and vertical buses, units, covers, and doors when the doors are not mounted directly to the unit.

3.16 **service equipment** – the necessary equipment, usually consisting of a circuit-breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cut-off of the supply.

3.17 **system bonding jumper** – the connection between the grounded circuit conductor and the equipment grounding conductor at a separately derived system.

3.18 **Type A wiring** – user (field) load and control wiring connected directly to device terminals internal to the unit (See Annex H.)

3.19 **Type B wiring** – user (field) control wiring connected to unit terminal blocks; the field load wiring is connected either to power terminal blocks or directly to the device terminals. Terminal blocks are internal or adjacent to the unit. (See Annex H.)

3.20 **Type C wiring** – user (field) control wiring connected to master terminal blocks; the field load wiring is connected either to master power terminal blocks or directly to the device terminals. Master terminal blocks are mounted at the top or bottom of the vertical sections that contain combination motor-control units or control assemblies. (See Annex H.)

4 Application information and components

4.1 Recommended classifications and application information are given in Annex H.

4.2 Components

4.2.1 A component of a product covered by this standard shall comply with the requirements for that component. See Annex D for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the ANCE, CSA, or UL standards as appropriate for the country where the product is to be used.

4.2.2 A component shall be used in accordance with its rating established for the intended conditions of use except as otherwise permitted in this standard.

5 Characteristics

5.1 General

5.1.1 A motor control center section shall be rated as follows:

a) voltage (Volt, V, Vac, Vdc);

b) phase (Ø, phase);

c) frequency (Hz, hertz);

d) horizontal and vertical power bus ampacity (A, ampere), including neutral bus when supplied;

e) bus short-circuit current ratings (A rms sym, or A dc V max).

5.1.2 A motor control center unit shall be rated as follows:

a) voltage (Volt, V, Vac, Vdc);

b) phase (Ø, phase);

c) frequency (Hz, hertz);

d) load (hp, A, ampere, kW, kVA, kvar). In Mexico, kW is required for motor loads;

e) unit short-circuit current ratings (A rms sym or A dc – V max).

5.2 Voltage ratings

The voltage rating of a motor control center shall not be more than 1000 V ac or dc. Common ratings are shown in Table 1.

5.3 Current

5.3.1 Incoming rating

5.3.1.1 A motor control center shall be assigned an incoming rating for current that shall not exceed the ampacity of the horizontal bus.

5.3.1.2 In Mexico and the United States, the supply rating of equipment that is marked to indicate it is suitable for use as service equipment, has provision for 2 watt-hour meters without provision for current transformers, and is provided with two main disconnects shall not be less than 50 % of the sum of the continuous ampere range of the assembled meter positions. (See Annex G.)

In Canada, this is not permitted.

5.3.2 Horizontal bus rating

The horizontal common power bus shall have a continuous-current rating of 600 A or higher. Preferred ratings are 800, 1 000, 1 200, 1 600, or 2 000 A.

5.3.3 Vertical bus

A vertical bus shall have a minimum continuous-current rating of 300 A.

5.4 Short-circuit

5.4.1 Short-circuit and short-time current withstand ratings of motor control center units

5.4.1.1 Each unit of a motor control center containing a short-circuit protective device shall be assigned a short-circuit current rating. Except for units containing only control-circuit components, the rating shall be the applicable rating from Table 2.

5.4.1.2 Each unit of a motor control center containing only control-circuit components shall be assigned a short-circuit current rating not greater than the interrupting rating of the short-circuit protective device, but not exceeding 100 kA.

5.4.1.3 A unit not containing any short-circuit protective device shall not be connected directly to the power bus (with the exception of lightning and surge arresters) and shall not be assigned a short-circuit current rating, which shall be indicated as "NA." Absence of a short-circuit current rating on such a unit does not affect the short-circuit current rating of the motor control center.

5.4.1.4 A main or feeder unit containing a low-voltage power circuit breaker, or a main lug only unit may be assigned a short-time current rating if tested in accordance with 9.15A. The rating shall be the applicable rating from Table 3 and the duration shall be one of the values from Table 45. The rating shall not be greater than the short time current rating or duration of the low-voltage power circuit breaker.

5.4.2 Combination motor control units

A combination motor control unit, for other than variable speed drives, may have a short-circuit current rating greater than the short-circuit current rating of any individual component if evaluated by design tests.

For combination motor control units containing variable speed drives the short circuit current rating shall not be greater than the interrupting rating of the short-circuit protective device. When the short-circuit protective device is an instantaneous-trip circuit breaker, it shall be evaluated by design tests.

5.4.3 Separately derived systems

Motor control center short-circuit current ratings are not affected by units connected to a separately derived system in a motor control center. The short-circuit current rating for such a unit shall be equal to or greater than the short-circuit current capacity of the separately derived system.

5.4.4 Rating of bus structure

5.4.4.1 The bus structure (horizontal and vertical bus) of a motor control center shall have a short-circuit current rating. The rating shall be the applicable rating from Table 3.

5.4.4.2 The bus structure (horizontal and vertical bus) of a motor control center may additionally have a short-time current rating if tested in accordance with 8.3.10A. The current shall be the applicable rating from Table 3 and the duration shall be one of the values from Table 45.

6 Markings and product information

6.1 Identification

The following information shall be given by the manufacturer for both sections and units, where applicable:

a) manufacturer's name or trademark. If a manufacturer produces or assembles motor control centers at more than one factory, the factory location shall be identified. Factory identification may be in coded form; and

b) type designation, serial number, or equivalent.

6.2 Product information

6.2.1 The following information shall be given by the manufacturer for sections:

a) electrical ratings (see Clause 5.1);

b) enclosure type;

c) termination and wiring information, as follows:

1) tightening torque for field-installed conductors (pound-inches, lb-in, or N-m). In Mexico, N-m is required as a minimum;

2) required temperature rating for field installed power conductors (°C);

3) material requirements for conductors (Cu, Al, Cu-Al, Al-Cu).

6.2.2 The following information shall be given by the manufacturer for units:

a) electrical ratings (see Clause 5.1.2);

b) technical information, as follows:

1) wiring diagrams or tables;

2) current element tables for overload relays, where applicable;

3) instantaneous-trip circuit-breaker setting information, where applicable.

c) service disconnect (see Annex G);

d) if applicable, suitability for use as service entrance equipment (see Annex G);

e) termination and wiring information, as follows:

1) tightening torque for field-installed power conductors (pound-inches, lb-in, or N-m). In Mexico, N-m is required as a minimum;

2) required temperature rating for field-installed conductors (°C);

3) material requirements for conductors (Cu, Al, Cu-Al, Al-Cu).

6.3 Marking

6.3.1 All markings shall be in the appropriate language (or symbols as noted in this standard), as necessary, for the country in which the motor control center will be installed (Spanish for Mexico, and English for Canada and the United States.). A manufacturer may choose to utilize multiple languages on a motor control center. See Annex B for translations of some markings that are also required to be in French if installed in Canada.

6.3.2 Markings shall be located as specified in Table 7, Table 8, and Table 9.

6.3.3 A required marking shall comply with the permanence of marking requirements of Annex C, item 3.

6.3.4 The manufacturer's name or trademark and the type designation, serial number, or equivalent, as described in Clause 6.1, shall be marked on the equipment.

6.3.5 Applicable characteristics as described in Clause 6.2 shall be marked on the equipment and shall be easily legible and plainly visible after installation. The characteristic marking may be omitted under the following conditions:

a) If the tightening torque for a field-wiring terminal is provided on a component in a visible location, the motor control center unit need not be marked.

b) Technical information (see Clause 6.2.2) provided in a pocket need not be marked on the equipment.

6.3.6 Motor control center sections not containing bus shall have the electrical ratings marked “N/A”.

6.3.7 Motor control center units not containing short-circuit protective devices shall be marked with a short-circuit current rating “N/A”, in accordance with Clause 5.4.1.

6.3.8 The short-circuit current rating of a motor control center section shall be an integral part of a marking containing the manufacturer's name or other required marking.

6.3.9 A motor control center section shall be marked

“Short-circuit current rating ___A rms symmetrical, ____ V maximum. Do not install on circuits with available short-circuit currents higher than the lowest short-circuit current rating of any installed unit" or the equivalent.

If the short-circuit current rating of a motor control center section is dependent upon the use of a specific overcurrent-protective device ahead of the center, the section shall be marked

“When used with ____ ampere maximum Class ____ fuses (type ____ circuit-breaker), this motor control center section is acceptable for use on a circuit capable of delivering not more than ____ A rms symmetrical, ____ V maximum.”

An individual section need not be marked with the short-circuit current rating provided that the section is part of a motor control center line-up having an unspliced, common main bus and that one of the sections is marked as required above.

*For dc rated assemblies, replace “rms symmetrical” with “DC”.

6.3.10 A motor control center unit shall be marked

"Unit short-circuit current rating_____ A rms symmetrical*, _____ V maximum, when equipped with___", or the equivalent.

The information that shall be provided in the third blank is the class and ampere rating of fuse or the manufacturer's name and type designation of the circuit-breaker, whichever is applicable.

If the short-circuit current rating of a motor control center unit is dependent upon the use of a specific protective device ahead of the unit, the motor control center unit shall be marked

"When used with ____ ampere maximum Class ____ fuses (type ____ circuit-breaker), this motor control center unit is acceptable for use on a circuit capable of delivering not more than ___ A rms symmetrical* _____ V maximum", or the equivalent.

* For dc rated assemblies, replace "rms symmetrical" with "DC".

6.3.11 Technical information [see Clause 6.2.2 b)] for individual units shall be

a) secured to each unit in a plainly visible location;

b) secured to the inside of the unit door; or

c) provided at a single location on or in the motor control center in a pocket expressly for this purpose and the individual units shall have a marking secured at a plainly visible location giving the proper diagram, current element table, and electrical rating information numbers, and referencing the location.

6.3.11A A motor control center section provided with a short-time current rating shall be marked:

"Short-time current rating ___A rms symmetrical, ____ V maximum, ____ seconds.

When protected by a circuit breaker with a short-time trip response, the short-time response of the circuit breaker shall be coordinated with the short-time current rating of the motor control section" or the equivalent. This marking shall be an integral part of a marking containing the manufacturer's name or other required marking.

An individual section need not be marked with the short-time current rating provided that the section is part of a motor control center line-up having an unspliced common main bus and that one of the sections is marked as required above.

NOTE For dc rated assemblies, replace "rms symmetrical" with "DC".

6.3.11B A motor control center main or feeder unit with a low-voltage power circuit breaker or a main lug only unit tested in accordance with 9.15A may be marked:

"Unit short-time current rating ____ A rms symmetrical*, ___ V maximum, ____ seconds ", or the equivalent.

NOTE For dc rated assemblies, replace "rms symmetrical" with "DC".

6.3.12 Marking for service equipment

6.3.12.1 In Canada, if a motor control center is intended for use as service equipment, it shall be marked as follows (see Annex G):

"Suitable for use as service equipment."

6.3.12.2 In Mexico and the United States, if a motor control center is intended for use as service equipment, the following applies (see Annex G):

a) In the case of an insulated neutral, it shall be marked with the following:

"Suitable for use as service equipment."

b) In the case of a factory-bonded neutral, it shall be marked with the following:

"Suitable only for use as service equipment."

6.3.13 With reference to Clause 8.2.9.4, vertical bus bars that are common for both rear-mounted units, and front-mounted units shall be marked to indicate the C, B, A phase arrangement for the rear-mounted units.

6.3.14 In Mexico and the United States, if a motor control center section or unit is marked "Suitable for use as service equipment", instructions for installing the bonding means specified in Clause 8.2.33.2 shall be provided if the installation method is not apparent. (See Annex G.) 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 them near the disconnect handles when the equipment is used as service equipment.

In Canada, this requirement is not permitted.

6.3.15 If a motor control center section or unit is marked "Suitable only for use as service equipment", a service-disconnecting device for ungrounded conductors shall be marked "Service disconnect" on or adjacent to the switch or circuit-breaker handle. (See Annex G.)

6.3.16 A motor control center section or unit not provided with ground-fault protection as covered in Clause 8.2.21.7 shall be marked for the use specified in Clauses 6.3.17 and 6.3.18.

6.3.17 In Mexico and the United States, a motor control section or unit rated 3-phase, 4-wire and having a solidly grounded neutral shall be marked as follows (see Annex G):

a) "Suitable only for use as service equipment when supplying a continuous industrial process"; or

b) "Suitable for use as service equipment only if supplying a continuous industrial process."

In Canada, this requirement is not permitted.

6.3.18 In Mexico and the United States, a motor control center section or unit that is marked "Suitable only for use as service equipment" or "Suitable for use as service equipment" and that is not provided with ground-fault protection, or that is marked as described in Clause 8.2.21.7 c), shall be marked for

a) supplying a fire pump;

b) an alternate source for legally required standby service;

c) a 3-phase, 4-wire system that is a wye-connected service and that is not solidly grounded but impedance grounded (see Annex G) ; or

d) use as the disconnecting means for a separate building or a structure on the property where ground-fault protection is provided at the service entrance.

In Canada, this requirement is not permitted.

6.3.19 Ground fault signalling for service entrance

6.3.20 In Mexico and the United States, a motor control center section or unit fed by an alternate source that has ground-fault protection with only an audible or visual signal as covered in Clause 8.2.21.11 shall be marked as specified in Clause 6.3.18 (see Annex G).

In Canada, this requirement is not permitted.

6.3.21 If a service equipment unit is supplied by a 3-phase, 4-wire system that is not solidly grounded (an impedance grounded wye-connected system) and has ground-fault protection with only an audible or visual signal, it shall be marked as specified in Clause 6.3.18 (see Annex G).

6.3.22 The markings specified in Clause 6.3.12 shall be plainly visible after installation without requiring the opening of a door or cover. Other markings shall not be located within 3.0 mm (0.12 in) of the above markings unless the above markings are in a contrasting colour or located in a distinctly separated area. Markings within 12.7 mm (0.5 in) of the markings required in Clause 6.3.16 shall be of less height.

6.3.23 A motor control center section or unit that has had the neutral bonded at the factory by means of a removable bonding means shall be marked, “Bonded neutral – must not be disconnected except for testing” (see Annex G).

6.3.24 If the motor control center section or unit is so equipped, the main bonding jumper, the grounding electrode conductor terminal, and the neutral disconnect link shall each be respectively identified as such by a marking or tag located on or adjacent to the part (see Annex G).

6.3.25 The current element table referenced in Clause 6.2.2 b) 2) shall include a current element rated for use at the maximum rating of the motor control unit.

6.3.26 The current element table referenced in Clause 6.2.2 b) 2) shall not include a current element or overload relay that is not intended to be used with the associated controller. A table may cover more than one size of starter or may cover the use of one, two, or three overload relays or heater elements, provided that the table is clearly marked to indicate the limits of its use. A resistance- or autotransformer-type controller, a combination-starter unit, or a similar device intended for limited horsepower rating may be provided with a table covering the elements furnished as if the limiting feature were not present.

6.3.27 In Canada, the following marking requirement for utility compartments shall apply. A motor control center compartment for electrical utility supply authority use shall be marked

“COMPARTMENT FOR ELECTRICAL SUPPLY AUTHORITY USE ONLY.”

In Mexico and the United States, this requirement does not apply (see Annex G).

6.3.28 The word “terminal” as used in Clauses 6.3.29 to 6.3.31, 6.3.41, and 6.3.42 signifies any terminal of the motor control center, as well as any terminal in any component unit, such as a circuit-breaker, switch, and the like, that is installed or intended to be installed in the motor control center and to which power conductors are connected in the field. The motor control center shall be marked in accordance with Clause 6.3.29, 6.3.30 or 6.3.31, whichever applies.

6.3.29 With regard to Clause 6.3.28, if, because of wiring space or other factors, no terminal of the motor control center is acceptable for use with aluminum conductors, the motor control center shall be marked “Use Copper/Cu Wire Only” or equivalent.

6.3.30 If the wiring space and other factors are such that all terminals of the motor control center are acceptable for use with aluminum conductors as well as with copper conductors the motor control center shall be marked

"USE COPPER OR ALUMINUM WIRE" or "CU – AL" or equivalent.

6.3.31 If the wiring space and other factors are such that some terminals of the motor control center are acceptable for use with aluminum as well as copper conductors, while the remainder or the terminals are acceptable for use with copper conductors only, the motor control center shall be marked

"USE COPPER WIRE ONLY EXCEPT AT TERMINALS _____" or equivalent.

The marking shall clearly identify the terminals that are acceptable for use with aluminum wire.

6.3.32 Marking provided in accordance with Clause 6.3.29, 6.3.30, or 6.3.31 shall be readily and clearly visible after the installation with the cover or trim removed.

6.3.33 Motor control centers shall be marked to indicate the temperature rating (60 °C only, 60/75 °C, or 75 °C only) of the field-installed conductors for which the equipment has been investigated unless the field wiring terminal is only intended for the connection of a control circuit conductor.

6.3.34 Where required by Clause 8.2.17.3, the motor control center incoming supply sections/units shall be permanently marked with the allowable ampacity of the field-installed incoming supply conductors, in a location readily visible prior to wiring, with the following or equivalent wording:

"Field installed incoming supply conductors may use 75/90 °C ampacity ratings." and "Les conducteurs d'alimentation entrants installés sur site peuvent utiliser une intensité nominale de 75/90 °C."

Note: See also Rule 4-006 of the Canadian Electrical Code, Part I, and Article 110.14(C) in the.

6.3.35 As required in Clauses 8.2.16.8 and 8.2.29.3.2, the maximum conductor sizes allowable shall be identified by a prominent marking, such as a wiring diagram, in the motor control center that will state the number and size of wires for which the construction is intended.

6.3.36 Equipment shall be marked to show the range of values or the nominal value of tightening torque to be applied to the clamping screws of all terminal connectors for field wiring.

When the line terminal torque value is above normal levels as permitted in Clause 9.10.8.3, the marking shall be located adjacent to the terminals and shall specify the minimum value of torque that shall be applied to the terminal screws.

6.3.37 Limited energy circuit field-wiring

6.3.38 As allowed by Clause 8.2.15.2 a), circuits that are intended to be supplied from a Class 1 extra-low-voltage, low-energy power source shall be identified "Input ____ V, ____ A Class 1 Only", or the equivalent. Class 1 supplies conforming to the requirements of Annex C, item 13, shall be permitted to be identified "Output ____ V, ____ A, Class 1."

6.3.39 As allowed by Clause 8.2.15.2 b), circuits that are intended to be supplied from a Class 2 extra-low-voltage, low-energy power source shall be identified "Input ____ V, ____ A Class 2," or the equivalent. Class 2 supplies conforming to the requirements of Annex C, item 14, shall be permitted to be identified "Output ____ V, ____ A, Class 2."

6.3.40 The identification noted in Clauses 6.3.38 and 6.3.39 shall be given in an instruction sheet, in drawings, or by marking the termination point as a Class 1 or Class 2 circuit.

6.3.41 Where leads, wire-binding screws, or pressure wire connectors 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 terminal kit shall carry an identifying marking, an identification of wire size, and the manufacturer's name or trademark.

6.3.42 Where special terminals such as crimped lugs are provided, they are sometimes included in the equipment at the factory. Instructions including reference to necessary tools to effect proper connection of the conductor shall be provided.

6.3.43 With reference to Clause 8.2.21.5 or 8.2.21.6, if ground-fault protection is provided in a motor control center section or unit, markings shall be provided to indicate which circuits (main, feeder, or branch) are so protected. If a marking on the ground fault sensing or relaying equipment is not visible from the front of the motor control center with the motor control center cover removed, a separate marking, on a wiring diagram or in another suitable location, shall be provided (see Annex G).

6.3.44 In a motor control center section or unit with ground-fault protection, that part of the neutral bus which is for load terminations shall be marked with the hazard signal word or symbol (e.g., "WARNING" or "DANGER") and with the following or equivalent wording:

"RISK OF FIRE AND ELECTRIC SHOCK – 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 (see Annex G).

In Canada, this marking is not permitted.

6.3.45 With respect to Clause 8.2.21.16, 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 ____ V (ac or dc)". Terminals for external sources for other types of control circuits shall be similarly marked (see Annex G).

6.3.46 The disconnecting means shall clearly indicate whether they are in the “OPEN-OFF” or “CLOSED-ON” position. In applications employing separate external operating mechanisms, the contacts shall be open when the position indicator shows “OPEN-OFF”, but the position indicator may show “CLOSED-ON” when the contacts are in either the trip or closed position.

NOTE International IEC symbols, “I” indicating on and “O” indicating off, also may be used.

6.3.47 If a transformer providing control voltage or an instrument or control circuit fuse is connected to the line side of the main disconnect or to a separate source, this disconnect may be identified as the "Main", but the motor control center shall be marked on the dead front adjacent to the main disconnect with the word "DANGER" and with the following or equivalent wording:

"RISK OF ELECTRIC SHOCK. THIS MAIN DOES NOT DISCONNECT CONTROL AND INSTRUMENT CIRCUITS."

6.3.48 A motor control center section that is designated for either top cable entry only or bottom cable entry only shall be marked

"TOP ENTRY ONLY" or "BOTTOM ENTRY ONLY" or equivalent.

The marking shall be located adjacent to the incoming terminals or as indicated on the wiring diagram.

6.3.49 A combination motor control unit in the motor control center shall be marked with a hazard signal word (e.g., “WARNING”, “DANGER”, “CAUTION”) and the following or equivalent:

"THE OPENING OF THE BRANCH-CIRCUIT PROTECTIVE DEVICE CAN BE AN INDICATION THAT A FAULT CURRENT HAS BEEN INTERRUPTED. TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CURRENT-CARRYING PARTS AND OTHER COMPONENTS OF THE COMBINATION CONTROLLER SHOULD BE EXAMINED AND REPLACED IF DAMAGED. WHEN A FAULT CURRENT HAS BEEN INTERRUPTED, THE COMPLETE OVERLOAD RELAY MUST BE REPLACED.”

The marking may be in the form of a single label mounted on the motor control center sections that can incorporate combination motor control units.

6.3.50 A motor control center unit intended to be used with a protective device in an accessory kit as permitted in Clause 8.2.14.3 shall be marked to identify the kit to be used in that unit.

6.3.51 An accessory intended for field installation shall be provided with installation and wiring instructions. An accessory shall be plainly marked with

a) the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified, hereinafter referred to as “the manufacturer's name”;

b) the electrical rating;

c) the catalogue number or equivalent.

6.3.52 Identification of the kits that can be installed in a motor control center shall be marked on the equipment, supplied separately, or included in the manufacturer’s catalogue.

6.3.53 A motor control center unit utilizing an instantaneous-trip circuit-breaker without additional protection for control circuit conductors as permitted in Clause 8.2.14.2 shall be marked with the maximum control-circuit protective-device rating corresponding to the size of the control-circuit wire used within the equipment, as specified in Table 4.

6.3.54 Where a supplementary fuse is provided there shall be a marking near the fuseholder specifying the voltage and current rating of the replacement fuse.

6.3.55 With reference to Clauses 8.2.14.1 to 8.2.14.5, where a branch-circuit type (other than supplementary) fuse is provided and the fuseholder will accept a fuse having a higher current rating than as specified in Table 12, a marking specifying the maximum fuse size shall be provided near the fuseholder.

6.3.56 Where the fuse used to determine compliance with the fuse-clip temperature-rise requirement (see Clause 8.2.8.3) is a Class G or K, there shall be a marking near the fuseholder specifying the class of the replacement fuse.

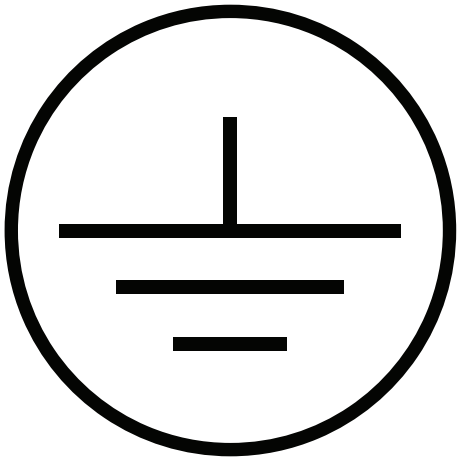
6.3.57 Unless its intended use is obvious the equipment-grounding terminal or assembly shall be

a) green, or the heads of the terminal screws shall be green; or

b) identified by one of the following adjacent to the terminal:

1) the marking “Equipment Grounding Terminal”, or an equivalent marking or abbreviation; or

2) the symbol



Grounding Symbol
See IEC 60417, Symbol 5019

6.3.58 With reference to Clause 8.2.34.5, if an equipment-grounding-terminal assembly is intended for field installation,

a) the section shall be marked to indicate the catalogue or type number of the terminal assembly intended to be used;

b) proper installation instructions shall be marked on the equipment in which the terminal assembly is intended to be used, or shall be provided on or in the individual shipping package or carton of the terminal assembly.

6.3.59 Cautionary markings required by this standard shall be located on a part that cannot be removed without impairing the operation or appearance of the equipment.

6.3.60 A cautionary marking shall be prefixed with the hazard signal word "CAUTION", "WARNING", or "DANGER", as applicable, in letters not less than 2.3 mm (0.09 in) high or 9 point. The remaining letters of the cautionary marking, unless specified otherwise in individual marking requirements, shall not be less than 1.5 mm (0.06 in) high or 6 point.

6.3.61 With respect to Clause 9.10.8.1, a marking specifying the type of bracing to be added to cables routed through the section between the point of entry and the incoming terminals shall be located adjacent to the incoming terminals or shall be supplied in separate instructions provided with the equipment. Bracing items not provided as a part of the center shall consist of components readily available to the installer.

6.3.62 A motor control center that does not preclude the installation of a unit with the operating handle higher than 2 m (6 ft, 7 in) shall be marked

"THE MOTOR CONTROL CENTRE UNIT INSTALLED IN THE UPPERMOST POSITION SHALL BE SELECTED SO THAT THE CENTRE OF THE GRIP OF THE HANDLE IS LOCATED NOT MORE THAN 2 METRES (6 FEET, 7 INCHES) FROM THE FLOOR OR A WORKING PLATFORM."

A motor control center unit requiring an additional accessory, such as an extension, chain, or similar operating means, to meet the operating handle height limits shall have the list of accessories provided in the unit, in the instructions, or in a separate catalogue.

6.3.63 When required by Clause 8.1.4, equipment shall be marked with the following or equivalent wording:

"WARNING: WHEN MOUNTING ON OR OVER A COMBUSTIBLE SURFACE, A FLOOR PLATE OF AT LEAST 1.43 mm (0.056 INCH) GALVANIZED OR 1.6 mm (0.063 INCH) UNCOATED STEEL EXTENDED TO THE OUTSIDE PERIMETER OF THE EQUIPMENT MUST BE INSTALLED."

This marking need not be permanent.

6.3.64 Equipment that is energized from more than one circuit and that does not have means for disconnecting all ungrounded conductors within a single enclosure or compartment shall be permanently marked on the outside with the following or equivalent wording:

"WARNING: MORE THAN ONE LIVE CIRCUIT. SEE DIAGRAM."

NOTE This clause does not apply to circuits of extra-low voltage as defined in Annex C, item 1.

6.3.65 Power conversion equipment incorporating capacitors shall be marked with the following or equivalent wording:

"WARNING: CAPACITIVE VOLTAGES ABOVE 50 V CAN REMAIN FOR _____ S AFTER POWER IS DISCONNECTED."

6.3.66 A unit incorporating an instantaneous-trip circuit-breaker shall be provided with complete instructions for the breaker adjustment and overload relay current element selection to provide protection in accordance with Annex C, item 1.

6.3.67 A unit employing an overload relay that can be selected for automatic reset and supplied with a wiring diagram indicating two-wire control shall be permanently marked to indicate that a motor connected to the circuit can start automatically when the relay is in the automatic reset position.

6.3.68 When two or more bonding conductors 13.3 mm^2 (6 AWG) or smaller are terminated in a single or multiple-conductor terminal that accepts a range of conductor sizes, the marking

"WARNING: TWIST WIRES TOGETHER BEFORE INSERTING IN TERMINAL"

shall appear adjacent to the grounding terminal. If the terminal is suitable for both copper and aluminum conductors, the following marking shall be added:

"COPPER WIRES MUST NOT BE MIXED WITH ALUMINUM WIRES IN THE SAME TERMINAL HOLE."

6.3.69 With respect to Clause 8.2.32.3, if a grounding electrode conductor is required, a motor control center section containing a power transformer feeding circuits that leave the section from a secondary winding not conductively connected to the primary shall be marked, or have indicated on the wiring diagram, the need for connecting the secondary neutral conductor to a grounding electrode, where applicable, in accordance with existing installation requirements pertaining to separately derived systems.

6.3.70 In Canada, motor control centers intended for service entrance use and constructed in accordance with Clause 8.2.20.13 shall be provided with a temporary tag, instruction sheet, or the equivalent, indicating how the bond shall be removed when required by electrical inspection authorities (e.g., "Where electrical inspection authorities require the neutral assembly to be disconnected from the enclosure followed by specific instructions applicable to the particular construction*.") (see Annex G).

6.3.71 When required by Clause 9.12.5.1 or 9.12.5.6, a combination motor control unit shall be marked with the type of protective device used and the maximum size of the protective device.

6.3.72 When disconnects or circuit breakers are reverse or back-fed, the unit shall be marked with the following words or the equivalent: DANGER: REVERSE FED DEVICE – LINE SIDE POWER CONNECTED TO LOAD SIDE TERMINALS OF DEVICE. DE-ENERGIZE POWER BEFORE SERVICING.

6.4 Installation instructions

The ground-fault protection equipment instructions and test form shall be provided with the equipment.

7 Normal service and transport conditions

7.1 General

Additional service and transportation conditions are given in Annex H or in individual application information.

7.2 Normal service conditions

Apparatus within the scope of this standard shall be capable of operation within its performance specifications under the following conditions:

a) The temperature of the air outside of the enclosure and the ambient temperature is above 0 °C but does not exceed 40 °C, and its average value, measured over a 24 h period, does not exceed 35 °C.

b) The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapors, or salt.

c) The average value of relative humidity, measured over a period of 24 h, does not exceed 95 % non-condensing.

d) The altitude does not exceed 2 000 m (6 600 ft), or 1 000 m (3 300 ft) if the equipment includes solid-state controllers.

NOTE: See Annex H for abnormal service conditions.

8 Construction and performance requirements

8.1 General assembly

8.1.1 A motor control center section shall have all enclosure panels and bus bars in place except for any necessary bus bar links or enclosure panels that are completed by the installation of an adjacent section. Motor control center units that plug into the bus bars need not be shipped with the section, but provision shall be made for the proper installation of such units. Motor control center units may be shipped without doors, but provision shall be made for the installation of such doors.

8.1.2 Enclosure – General

8.1.2.1 A motor control center enclosure shall comply with the requirements of Annex C, item 10, except for modifications and additional requirements as specifically described in this Standard. For environmental rating tests, see Annex C, item 2.

8.1.2.2 A nonmetallic plug or other closure assembled as part of the enclosure shall comply with the requirements of Annex C, item 10, as applicable.

8.1.3 No horizontal covering shall be required across the bottom of the surrounding enclosure if exposed live parts within the device are not less than 152 mm (6 in) above the plane of the mounting surface. Insulated parts located within 152 mm (6 in) of the lower edge of the enclosure shall be guarded. Equipment provided with longitudinal base channels shall have a vertical covering between the base channels at the ends of the equipment or have a bottom plate above the base channels.

8.1.4 Motor control centers shall be so constructed that molten or flaming particles cannot fall to the surface on which the equipment is mounted or shall be marked in accordance with Clause 6.3.63.

8.1.5 Openings for operating handles

8.1.5.1 Openings provided for an operating handle or other component projecting through a door shall be close-fitting. The clearance between the edge of the hole and the handle or component escutcheon shall not exceed 2.4 mm (0.093 in) on either side (one side only) and 3.2 mm (0.125 in) total (both sides).

8.1.5.2 Operating handle clearances shall be measured with the handle in the " ON", "OFF", and "TRIP" positions when a tripping mechanism is provided, with the handle and its supporting member assembled in any position that will result from ordinary factory assembly.

8.1.6 In a unit incorporating fused switches, the location of the fuses shall be such that

a) fuses will be accessible and the fuse terminals will be dead when the switch is open; and

b) fuses can be replaced without a person touching any live part.

8.1.7 Door interlock

8.1.7.1 The door of a motor control center unit having a disconnecting device shall be interlocked with the disconnecting device so that the door cannot be opened without first opening the disconnecting device and so that the door cannot be closed unless the disconnect handle is in the same position as the disconnect device. Where two sets of circuit-disconnecting means are mounted in a single compartment to form a dual unit, each disconnecting device shall be interlocked with its associated door. This requirement does not apply to a ground fault control circuit disconnect that does not have an external operating handle.

8.1.7.2 Provision for deactivating the interlock for inspection purposes while the disconnecting device is closed shall be permitted.

8.1.8 Securing doors and covers

8.1.8.1 A part of a motor control center enclosure, such as a door or a cover, shall be provided with means, such as latches, locks, interlocks, or screws, for firmly securing it in place.

8.1.8.2 If bare live parts are exposed by the opening of doors or covers, means requiring the use of a tool to open them or means that can be locked shall be provided to secure the doors or covers in the closed position.

NOTE Electrical components that are behind a barrier/dead front or that are not contacted by the IEC articulate probe as shown in Figure 10 are not considered to be bare live parts.

8.1.9 Doors required to be opened during normal operation may have hand-operated latches or screws, and

a) doors shall be hinged such that the door will not come off inadvertently;

b) barriers or finger-safe devices shall be used to prevent contact with bare live parts during normal operation, unless the door is provided with an interlock to a disconnecting means that de-energizes all hazardous voltages.

NOTE The replacement of fuses is not considered a normal operation with respect to industrial control equipment, but the resetting of overload devices, repeated adjustment of timers or switches, etc., are considered normal operations.

8.1.10 There shall be no openings in the surface of a unit enclosure, other than those allowed in Clauses 8.1.5.1 and 8.2, that will be exposed after the installation of the unit in the motor control center.

8.1.11 The number, arrangement, and ratings or settings of overcurrent protective devices used in motor control centers shall be in accordance with the requirements of Annex C, item 1.

8.1.12 Provision shall be made for securely mounting a device to a supporting surface. A bolt, screw, or other part used to mount a component of an assembly shall not also be used to mount the assembly to the supporting surface.

8.1.13 Devices that can be handled in normal operation, such as switches and rheostats, shall be staked or otherwise prevented from rotating. Such devices that rely solely on friction shall not be acceptable.

8.1.14 A single-throw knife switch shall be mounted so that gravity will not tend to close it.

8.1.15 A single-throw knife switch shall be connected so that the blade or blades will be dead when the switch is open unless the switch is designed so that all live parts are inaccessible when the switch is in the open position.

8.1.16 A separate disconnecting means shall be provided for each motor starter in a grouped control except where such a control assembly is a coordinated drive of a single machine and all motors forming part of the machine drive are disconnected by a single suitable switch.

8.1.17 When control power for a motor controller is obtained conductively from a grounded system, the control circuit shall be so arranged that an accidental ground in the wiring from the controller to any remote control or signal device will not

a) start the motor; or

b) prevent the stopping of the motor by the normal operation of any control or safety device in the control circuit.

8.2 Construction requirements

8.2.1 Ventilation

8.2.1.1 A ventilation opening for natural or forced ventilation in the motor control center enclosure shall be constructed or located or provided with a barrier to ensure that no flame or molten metal will be emitted due to arcing encountered during the operation of a disconnect switch or a circuit-breaker.

8.2.1.2 In order to conform to the requirements in Clause 8.2.1.1, a barrier of metal or of a material such as those mentioned in Clause 8.2.1.5 shall be interposed between a ventilating opening and a possible source of arcing such as a disconnect switch or a circuit-breaker, unless one of the following conditions applies:

a) the opening is at least 305 mm (12 in) from an arcing part;

b) during the short-circuit test, there is no emission of flame or molten material from the opening as determined by flame indicators (see Annex C, item 12); or

c) the equipment is solid-state power conversion equipment.

8.2.1.3 The barrier shall be of such dimensions and located so that straight lines drawn from any arcing part past the edge of the barrier define an area at the plane of the opening at least 6.4 mm (0.25 in) outside the edges of the opening.

8.2.1.4 A metal barrier shall have a thickness not less than

a) 1.35 mm (0.053 in) if uncoated steel;

b) 1.42 mm (0.056 in) if zinc-coated;

c) 1.91 mm (0.075 in) if aluminum

unless its strength and rigidity are not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness (see Clause 9.19).

8.2.1.5 A non-metal barrier shall not be less than 6.4 mm (0.25 in) thick unless it is located so that it is not subject to mechanical damage during installation, and it shall be supported to provide the necessary strength and rigidity.

8.2.2 Size, location, and covering or screening

8.2.2.1 An opening in an enclosure shall have such size or shape, or shall be covered in such a way by screening or by an expanded, perforated, or louvred metal panel that a test rod as specified in Clause 8.2.2.2 cannot enter.

8.2.2.2 The test rod mentioned in Clause 8.2.2.1 shall be 13.1 mm (33/64 in) in diameter, unless the plane of the opening is 102 mm (4 in) or more from the nearest uninsulated live part, in which case the test rod shall be 19.4 mm (49/64 in) maximum in diameter.

8.2.2.3 A louver shall not be more than 305 mm (12 in) long.

8.2.2.4 The area of all openings cut or formed from the enclosure metal shall not exceed 25 % of the area of the wall in which the openings are located unless reinforcing means, such as stiffeners, are employed and the enclosure complies with the comparative deflection test requirement in Clause 9.19. The area of an opening covered by a louvered, perforated, or expanded metal panel that is thinner than the enclosure shall not exceed 1290 cm^2 (200 in^2). The area of an opening covered by a 1.35 mm (0.053 in) thick or thinner steel panel or a screen of 2.1 mm^2 (14 AWG) or smaller steel wire shall not exceed 516 cm^2 (80 in^2).

8.2.2.5 The wires of a screen shall not be smaller than 1.3 mm^2 (16 AWG) for screen openings 3.2 cm^2 (0.5 in^2) or less in area, and not smaller than 3.3 mm^2 (12 AWG) for larger screen openings. A supplementary screen having smaller openings may be provided but shall not be considered in evaluating the primary screen.

8.2.2.6 Perforated sheet steel employed for expanded metal mesh shall not be less than 1.07 mm (0.042 in) thick, or 1.14 mm (0.045 in) thick if zinc-coated, for mesh openings or perforations 3.2 cm^2 (0.5 in^2) or less in area, and it shall not be less than 2.03 mm (0.080 in) thick, or 2.13 mm (0.084 in) thick if zinc-coated, for larger openings.

8.2.2.7 If the indentation of the guard or enclosure made from the perforated sheet steel or expanded metal mesh does not alter the clearance between uninsulated live parts and grounded metal so as to adversely affect the performance or reduce spacings below the minimum acceptable values specified in Table 19, perforated sheet metal or expanded metal mesh not less than 0.51 mm (0.020 in) thick, or 0.58 mm (0.023 in) thick, if zinc-coated, may be employed.

8.2.2.8 A grille construction that complies with the intent of the requirements in Clause 8.2.2.6 may be used if it has been investigated and found to be acceptable for the application.

8.2.2.9 A ventilating opening in the top of the enclosure shall be provided with a hood or protective shield located above the opening to reduce the likelihood of entry of foreign material.

8.2.3 Type 3R enclosures

8.2.3.1 In a Type 3R enclosure, a switch, a circuit-breaker, a receptacle (complete with its associated attachment plug), a fuseholder, or a similar device, including the opening provided for an operating handle, shall be protected from exposure to rain. If a live part is directly below a meter, water that can enter a rainproof enclosure through a ringless meter opening shall be channeled to the outside by a permanent structural system.

8.2.3.2 With reference to Clause 8.2.3.1, the diameter of a ringless meter opening shall not be less than 166 mm (6.55 in).

8.2.3.3 Live parts shall be located at least 102 mm (4 in) above the enclosure mounting surface of an enclosure intended for horizontal pad mounting.

8.2.4 Hinged doors and covers

8.2.4.1 Other than as noted in Clauses 8.2.4.3 and 8.2.4.4, an enclosure cover shall be hinged if it gives access to fuses or any other overload-protection devices, the intended functioning of which requires renewal, or if it is necessary to open the cover in connection with the intended operation of the device.

8.2.4.2 Hinged covers shall be independent of the units unless removal of the unit will not leave the bus so exposed that unintentional contact with it is likely.

8.2.4.3 A hinged cover shall not be required for a device that requires access only in the event of the burnout of heater elements or the like on short-circuit.

8.2.4.4 A hinged cover shall not be required for a device in which the only fuses enclosed are control-circuit fuses if the fuses and control-circuit loads (other than a fixed control-circuit load, such as a pilot lamp) are within the same enclosure.

8.2.4.5 A hinged door or cover shall open to not less than 90°.

8.2.5 Enclosure working space configurations

8.2.5.1 Motor control center sections supplied with and located in walk-in enclosures shall be configured as shown in Figure 1, Figure 2, and Figure 3.

8.2.5.2 A motor control center section or group of sections under a common top supplied in a non-walk-in motor control center enclosure shall be so constructed that there are no interferences to obtaining access to the motor control center section(s).

8.2.6 Protection against corrosion

Iron and steel parts shall be protected against corrosion by enamelling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts upon which proper mechanical operation can depend, with the following exceptions:

a) bearings, thermal elements, sliding surfaces of a hinge or shaft, and the like, where such protection is impracticable;

b) small parts of iron or steel (except terminal parts), such as washers, screws, bolts, and the like, that are not current-carrying if the corrosion of such parts is not likely to result in a risk of fire, electric shock, or injury to persons;

c) parts made of stainless steel of Type 304 or better.

8.2.7 Insulating materials

8.2.7.1 Material for the support of an uninsulated live part shall be acceptable for the support of such a part and shall be capable of withstanding the most severe conditions likely to be met in service.

A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 43. A material is in direct support of an uninsulated live part when:

a) it is in direct physical contact with the uninsulated live part; and

b) it serves to physically support or maintain the relative position of the uninsulated live part.

8.2.7.2 Other than as indicated in Clause 8.2.7.3, a live screwhead, rivet, or nut on the underside of a base designed for surface mounting shall be countersunk so that there will be at least a 3.2 mm (0.125 in) clearance between the screwhead, rivet, or nut and the mounting surface, and shall be covered to a depth of not less than 3.2 mm (0.125 in) with a waterproof, insulating sealing compound. The compound shall not soften at a temperature 15 °C higher than the temperature observed at the point where it is used, but the softening point shall not be lower than 65 °C, as determined in accordance with the test for softening point by means of ring and ball apparatus (i.e., ball pressure test) (see Annex C, item 9). The test shall not be required for a thermosetting material.

8.2.7.3 All screws and nuts, other than those mentioned in Clause 8.2.7.2, shall be staked, headed over, upset, or otherwise reliably prevented from loosening unless it can be shown that no reduction of spacings can result from the loosening or falling out of such threaded parts.

8.2.7.4 If the screw or nut mentioned in Clause 8.2.7.3 is prevented from loosening by being staked or upset by a lock washer or by other equivalent means, it shall be insulated from the mounting surface by an insulating barrier (see Clause 8.2.28.1) or by providing a spacing through air from the mounting surface no less than that specified in Table 19 and Table 20.

8.2.8 Current-carrying parts

8.2.8.1 A current-carrying part shall be of silver, a silver alloy, copper, a copper alloy, aluminum, or other metal acceptable for the application.

8.2.8.2 Plated steel screws, nuts, and studs may be used to secure pressure wire connectors and bus bars. No. 10 and larger plated steel wire-binding screws may be used at terminals, in connection with a nonferrous terminal plate. Bolts, washers, and nuts at the hinges of knife switches are considered to be

parts that are not depended upon to carry current. Copper and brass shall not be used for plating steel wire-binding screws, nuts, and stud terminals; plating shall be zinc, tin, or silver.

8.2.8.3 A current-carrying part shall be of such size that a temperature rise does not exceed the limits specified in Table 29.

8.2.8.4 An uninsulated live part, other than a pressure wire connector as mentioned in Clause 8.2.27.14, shall be secured to the base or mounting surface so that it is prevented from turning or shifting in position. Friction between surfaces shall not be used as a means to prevent turning of uninsulated live parts. Turning shall be prevented by the use of

a) two screws or rivets;

b) shoulders or mortises;

c) a dowel pin, lug, or offset;

d) a connecting strap or clip fitted into an adjacent part; or

e) some equivalent method.

8.2.8.5 A conical spring washer, or a construction other than a spring washer that has been investigated and found to be equivalent in performance, shall be used in a bolted joint involving aluminum conductors and in all riveted joints. The investigation of an equivalent construction shall consist of the heat cycling test described in Annex C, item 6.

8.2.9 Bus bars

8.2.9.1 A copper bus rated over 600 A and an aluminum bus shall be plated at every bolted or plug-in connection with tin or silver.

8.2.9.2 A bus bar shall be securely supported by bolting, riveting, or other means so that all spacings are maintained. The vertical or horizontal bus bar shall be supported independently of any switch, circuit-breaker, or the like that is connected to it.

8.2.9.3 In a 3-phase, 4-wire construction, the neutral shall not be smaller than the size required for the main bus bars unless its ampacity (based on a heating test) is at least 200 A and is clearly marked on the nameplate.

8.2.9.4 The phase arrangement of 3-phase horizontal common power and vertical bus bars shall be A, B, C from front to back, top to bottom, or left to right, as viewed from the front of a motor control center. However, rear-mounted units connected to a vertical bus that is common to front-mounted units may have a C, B, A phase arrangement if the bus bars are marked accordingly to identify the respective phases. See Clause 6.3.13.

8.2.10 Protection of service personnel

8.2.10.1 Where a bolted pressure contact switch or low-voltage air circuit-breaker that requires periodic inspection and maintenance is mounted above other equipment that remains energized with the switch or circuit-breaker open in the same enclosure, it shall be separated from the other equipment by a horizontal barrier to prevent any serviceable part from falling onto a live part of equipment located below. The barrier shall be securely fastened in place. The width and depth of the barrier shall either

a) extend beyond any live part below it; or

b) extend rearward from the front wall of the compartment to the vertical projection of the rear of the switch base, and, if space permits, laterally at least 152 mm (6 in) beyond the vertical projection of each side of the switch base. If space does not permit the 152 mm (6 in) extension, the barrier shall extend to the sidewall of the compartment. Any edge of the barrier not extending to the sidewall of the compartment shall have an upturned flange at least 19.1 mm (0.75 in) high.

8.2.10.2 With regard to Clause 8.2.10.1 or 8.2.19.8, as applicable, a metal barrier shall have a thickness not less than 0.81 mm (0.032 in) if uncoated steel and not less than 0.86 mm (0.034 in) if galvanized, and shall be supported independent of support provided by units that will be installed in the field. The barrier may be of expanded metal or screen if the openings are not larger than 1.6 cm^2 (0.25 in^2). A non-metallic barrier shall be at least 1.6 mm (0.0625 in) thick and shall be reinforced if necessary to provide mechanical strength.

8.2.10.3 The barrier specified in Clause 8.2.19.6 shall comply with the requirements in Clauses 8.2.10.1 and 8.2.10.2 if uninsulated live parts ahead of the service disconnect are located below any load terminal or the neutral disconnect link in such a way that a falling tool or other metal part can contact them.

In Canada, the requirement in 8.2.10.3 is not applicable.

8.2.11 Combination motor control unit

8.2.11.1 A combination motor control unit provides a disconnecting means and a load switching means within a device or assembly. In addition, provision for overload and short-circuit protection shall also be incorporated. The functions may be provided by individual discrete components or be combined in a single controller. Table 10 summarizes the applicable construction requirements for the various constructions of combination motor control units.

8.2.11.2 Typical constructions of combination motor control units are indicated in Table 11. This table is for reference only.

8.2.11.3 The disconnecting means of an enclosed combination motor controller shall be provided with a method of being locked in the off position.

8.2.11.4 The disconnecting means shall open all ungrounded supply conductors and shall be constructed so that no pole will be independently operated under normal service conditions. One pole of the disconnecting means may disconnect a grounded conductor, provided that the disconnecting means is constructed so that the pole of the grounded conductor cannot be opened without disconnecting all conductors of the circuit in the same operation.

8.2.11.5 A combination motor controller using fuses or inverse-time or instantaneous-trip circuit breakers as the motor branch-circuit protection shall be evaluated in accordance with the applicable requirements for the specific protective device employed.

8.2.11.6 A disconnecting means in a combination motor controller shall comply with the applicable standards listed in Annex C, items 7, 10, and 27. See also Table 11 and Clause 8.2.26.

8.2.11.7 An adjustable setting means of an instantaneous-trip circuit breaker or self-protected control device that is accessible without opening a door or removing a cover shall be constructed so that a stop to limit the maximum setting can be installed. Directions for the installation of the stop shall be included with the complete controller.

8.2.11.8 A unit containing a Type E combination motor controller shall have a means, which is visible with the device mounted as intended with the unit door opened, that indicates which function (overload or short-circuit) has operated.

8.2.11.9 If a unit is provided with a circuit-breaker having an adjustable trip unit, it shall be factory set to the minimum setting or its specific installation setting.

8.2.12 Unit mounting

Provision shall be made so that each combination motor control unit and feeder-tap unit can be readily removed as a unit for rearrangement, replacement, or repair. Exceptions shall be permitted where the size or weight of the unit makes its removal impracticable.

8.2.13 Internal wiring

8.2.13.1 The internal wiring of a motor control center shall consist of general-use wire or appliance wiring material acceptable for the application, when considered with respect to the temperature, voltage, and conditions of service to which the wiring is likely to be subjected. Conductors shall be not smaller than 0.20 mm^2 (24 AWG), and the temperature rating shall be not less than 90 °C unless investigation proves the suitability of other conductors.

NOTE 1 The requirements of Clause 8.2.13.1 apply only to the wiring furnished on or in motor control centers as a part of the equipment. They do not apply to the supply wiring run to control equipment, to motors, or to other apparatus.

NOTE 2 For motor and control-circuit applications, the use of Table 5, together with Table 6, as a guide in selecting the conductor sizes in motor control centers, can obviate the need to perform a temperature test on the wire. Conductor sizes for other applications, e.g., heating loads, are subject to investigation.

8.2.13.2 A bare conductor, including pigtails and coil leads, shall be supported so that the spacings required elsewhere in this Standard will be maintained unless protected by insulating sleeving or tubing.

8.2.13.3 All splices and connections shall be mechanically secure and shall be arranged so that there is no strain on the connections and terminals.

8.2.13.4 A splice shall be provided with insulation equivalent to that of the wires involved.

8.2.13.5 A wireway shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like that can cause abrasion of the insulation on conductors.

8.2.13.6 A hole through which insulated wires pass in a sheet metal wall within the enclosure of the equipment shall be provided with a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wires can bear to reduce the risk of abrasion of the insulation. See Clause 8.2.13.8.

8.2.13.7 A bushing employed at the opening mentioned in Clause 8.2.13.6 shall be glass, hard fibre, phenolic composition, cold-moulded composition, thermoplastic composition, or the equivalent. A bushing of neoprene having acceptable characteristics, including aging and resistance to mechanical damage, may be employed. A metal eyelet or grommet having a smooth, rounded surface on which the wire or cable can bear may be used in place of a bushing.

8.2.13.8 For other than control circuits, or constructions described in Clauses 8.2.13.9 and 8.2.13.10, if the conductors of an alternating-current circuit pass through a wall or partition of metal having magnetic properties, all of the conductors of the circuit, including the neutral, shall be run through the same opening. See Clause 8.2.13.6.

8.2.13.9 With reference to the requirement in Clause 8.2.13.8, the conductors may pass through individual openings in a wall or partition if the openings are connected by slots cut in the metal wall. The conductors may be run through individual openings in an insulating block used to cover an opening in the

metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like is placed across the insulating material between the conductors. See Figure 4.

8.2.13.10 If the neutral conductor of a circuit is separated from the phase conductors by a complete path of magnetic material, the construction shall be tested to determine whether adverse conditions result. A current equal to the current rating of the phase conductor, but not greater than 600 A, shall be passed through at least one of the phase conductors and the neutral conductor. Temperature rises measured on the interposed magnetic material shall not exceed 20 °C where the material is likely to be contacted by conductors.

8.2.13.11 Conductors may be run in parallel provided the arrangement is such as to provide equal division of total current among all conductors involved. All of the parallel conductors shall be of the same length, the same conductor material, cross-section area, and insulation type, and all shall terminate in the same manner. Where conductors are run in separate raceways or cables, the raceways or cables shall have the same physical characteristics.

8.2.13.12 Internal wiring shall not be in contact with bare live parts of opposite polarity or with bare live parts of other circuits.

8.2.13.13 Internal wiring shall not be in contact with heat-generating components such as power resistors, fuse bodies, heat sinks, etc., or moving parts where movement can cause an inadvertent insulation degradation.

8.2.13.14 Conductors in an assembly intended for use in a complete enclosure shall be insulated for the highest voltage normally occurring between such conductors unless

a) the wires are grouped so as to segregate the several voltages; or

b) the circuits involving the wires rated at the lower voltage(s) do not extend beyond the complete enclosure.

8.2.13.15 Except as specified in 8.2.13.16, other than for required interconnections and control wiring, only those conductors intended for termination in a vertical section shall be located in that section.

8.2.13.16 Conductors may transverse horizontally through vertical sections if such conductors are isolated from the busbars by a barrier. An insulating barrier shall comply with 8.2.28, Insulating Barriers.

8.2.14 Protection of internal primary and secondary control circuit conductors

8.2.14.1 Except as specified in Clauses 8.2.14.2 to 8.2.14.4, conductors of control circuits that are connected to the load side of the motor branch-circuit short-circuit protective device shall be protected against overcurrent in accordance with Table 12 by protective devices located within the controller unit. Overcurrent protective devices shall be provided in each ungrounded conductor.

8.2.14.2 Additional protection shall not be required if the rating, or the trip setting in the case of an instantaneous-trip circuit-breaker, of the intended motor branch-circuit short-circuit protective device is not more than the applicable value specified in Table 4 and the controller unit is marked in accordance with Clause 6.3.53.

8.2.14.3 The protective device need not be assembled as part of the controller if

a) the manufacturer makes available an accessory kit intended for installation in the controller enclosure;

b) the motor control center unit is marked in accordance with Clause 6.3.50.

8.2.14.4 Short direct leads approximately 305 mm (12 in) long or printed-wiring assemblies having no connection external to the center and having not more than casual contact with insulated or uninsulated parts of opposite polarity or with grounded parts need not be so protected.

8.2.14.5 A protective device specified in Clause 8.2.14.1 shall be either a supplementary or a branch-circuit overcurrent-protective device. A fuse shall be factory installed in a supplementary fuseholder, but may be omitted if a branch-circuit-type fuseholder is provided. The controller shall be marked in accordance with Clause 6.3.54.

8.2.14.6 Only overcurrent-protective devices acceptable for the available fault currents involved shall be used. If fuses are used, the fuseholder shall be appropriate for the fuse used.

8.2.15 Control-circuit transformer protection

8.2.15.1 Except as specified in Clause 8.2.15.2, the control-circuit transformer primary and secondary windings shall be protected by one or more of the following types of overcurrent protection:

a) an individual overcurrent device or devices located in the primary circuit that are rated or set as specified in Table 13. Overcurrent protective devices shall be provided in each ungrounded conductor;

b) secondary circuit protection rated or set at not more than 125 % of the rated secondary current of the transformer, with the primary feeder circuit having protection rated or set at not more than 250 % of the rated primary current of the transformer;

c) a coordinated thermal overload protection arranged to interrupt the primary circuit, provided the primary circuit overcurrent device is rated for or set to open at a current of not more than

1) for transformers having not more than 6 % impedance, 6 times the rated current of the transformer;

2) for transformers having more than 6 % but less than 10 % impedance, 4 times the rated current of the transformer.

8.2.15.2 Overcurrent protection need not be provided if

a) the transformer supplies a Class 1 power-limited, Class 2, or Class 3 remote-control circuit;

NOTE In Canada, Class 3 wiring is not applicable.

b) the transformer is rated less than 50 VA, is inherently protected, and is an integral part of the motor controller;

c) the primary feeder circuit overcurrent device provides the required protection; or

d) the protection is provided by other means that comply with the applicable requirements in item 1 of Annex C.

8.2.15.3 With respect to Clause 8.2.15.1 b), if the rated secondary current of a transformer is 2 A or more, the current rating of the secondary overcurrent device may be as indicated in Table 14.

If the rated primary current of the transformer is 9 A or more and 125 % of this current does not correspond to a standard rating of fuse or nonadjustable circuit-breaker, the next higher standard rating of protective device shall be used. For applications in Mexico and the US, standard ratings for fuses and inverse-time circuit-breakers are specified in Annex C, item 1.

8.2.15.4 A control transformer and its primary and secondary conductors may be protected by overcurrent devices located only in the primary circuit, provided

a) the transformer is single phase and has only a two-wire (single voltage) secondary;

b) the maximum value of an intended overcurrent device is determined in accordance with Clause 8.2.15.1;

c) the maximum value of an intended overcurrent device as determined in item b) does not exceed the value of the overcurrent device obtained from Table 12 for the secondary conductor multiplied by the secondary-to-primary voltage of the transformer.

8.2.15.5 The same overcurrent protective device may be used for both control-circuit transformer protection and primary-circuit conductor protection where its rating satisfies each requirement.

8.2.16 Field-wiring terminals

8.2.16.1 A terminal (i.e., a pressure wire connector or wire-binding screw) shall be provided for connection of each conductor intended to be installed in the motor control center in the field. A wire-binding screw shall be acceptable for securing a 5.3 mm (10 AWG) or smaller conductor only. This requirement does not apply to

a) the main connections of a section specifically constructed for the connection of bus bars;

NOTE A section having a rectangular opening in the enclosure adjacent to the ends of main bus bars is considered to be specifically designed for the connection of the bus bars.

b) connectors, as provided in Clause 8.2.16.4.

8.2.16.2 An incoming line (supply) terminal shall be capable of securing the smallest conductor, or group of conductors in parallel, of standard cross-section area having an ampacity, as specified in Table 18, acceptable for the rated current of the motor control center. Unless otherwise specified, the rated current of the motor control center shall be considered to be equal to the rating of the horizontal power bus.

8.2.16.3 Motor control center units shall be provided with wiring terminals for the connection of conductors having an ampacity, as specified in Table 18, not less than the larger of the following:

a) the ampere rating of the product;

b) 125 % of the full-load motor current specified in Table 15, Table 16 and Table 17 for the horsepower rating or 125 % of the motor current rating;

c) 125 % of the ampere rating of the devices intended to control a continuous fixed electric heating equipment load;

d) 135 % of the nominal capacitive current rating of the devices intended to switch capacitors for power factor correction.

8.2.16.4 A pressure terminal connector, including one that is compression-tool-applied, for field connection to line or load need not be provided for equipment with field wiring larger than 5.3 mm^2 (10 AWG) if the construction complies with the following conditions:

a) Component terminal connectors are available from the equipment manufacturer as a kit, and one or more are specified for field installation on the equipment.

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or the like, that is required for installation is provided as part of the component terminal assembly, or is mounted on or separately packaged with the equipment.

c) The installation of the terminal assembly does not involve the loosening or disassembly of a part other than a cover or other part giving access to the terminal location. The means for securing the terminal connectors shall be accessible for tightening before and after installation of the conductor.

d) If the pressure connector provided in a component terminal assembly requires the use of other than an ordinary tool for securing the conductor, instructions referencing use of the tool shall be included with the component assembly or with the equipment.

e) Installation of a pressure terminal connector in the intended manner shall result in a product that complies with the requirements in this standard.

f) The equipment is marked in accordance with Clause 6.3.41.

8.2.16.5 With reference to the requirements in Clauses 8.2.16.2 and 8.2.16.3, the sizes of field-installed conductors (see Table 18) shall be determined as follows:

a) wire rated 75 °C in the 53.5 mm^2 (1/0 AWG) and larger sizes;

b) wire rated 60 °C in the 42.4 mm^2 (1 AWG) and smaller sizes, except 75 °C wire if the equipment is marked for 75 °C in accordance with Clause 6.3.33 and has been found acceptable in the temperature test;

c) aluminum wire at any terminal identified on a wiring diagram or the like as being acceptable for use with such wire, whether or not that terminal is also identified as being acceptable for use with copper wire. See Clauses 6.3.28 to 6.3.42.

8.2.16.6 A wiring terminal shall be located so that

a) it is accessible for examination, and

b) connections can be tightened or wires removed without loosening any screws that secure bus bars, switches, circuit-breakers, fuseholders, or the like.

8.2.16.7 The requirements in Clauses 8.2.16.2 and 8.2.16.3 shall not preclude use of a connector that also accommodates a wire or wires of a size or sizes different from that specified in Clauses 8.2.16.2 and 8.2.16.3.

8.2.16.8 A wiring terminal of a device that is marked in accordance with 6.3.35 on either the wiring terminal or on the wiring diagram for wire of the next larger size than the size required by the current rating of the device shall be capable of securing both the smaller and the larger of the two wire sizes.

8.2.17 Optional field installed incoming supply connections for 90 °C ampacity conductors

8.2.17.1 Where field-installed incoming supply conductors connect to a suitable length of internal bus and not directly to devices, it is permissible to allow a 90 °C ampacity rated conductor to be connected to the motor control center, which would otherwise not be permitted by the allowable termination temperature rating of the devices themselves. Suitability for 90 °C ampacity shall be determined in accordance with Clause 8.2.17.2 and 8.2.17.3. The incoming supply connections shall additionally be suitable for 75 °C ampacity conductors as required elsewhere in this Standard.

NOTE: For example, a 1000 A circuit breaker is rated for a maximum of 75 °C ampacity conductors. Incoming supply conductors connected directly to the circuit breaker cannot exceed the allowable ampacity for 75 °C conductors. If those conductors instead connect to a length of bus and then the bus is connected to the circuit breaker, then provided that the bus is of a suitable length and

cross-section to dissipate sufficient heat, and if testing proves the termination temperature at the circuit breaker does not exceed the allowable values in Table 29, 90 °C ampacity conductors may be used to connect to the bus.

8.2.17.2 An additional temperature-rise test in accordance with Clause 9.3 shall be conducted, except that the incoming line conductors to be used for the test shall have a temperature rating no less than 90 °C.

8.2.17.3 An additional short-circuit test (bus structure) in accordance with Clause 9.10 shall be conducted, except that the incoming line conductors to be used for the test shall be sized for an ampacity based on 90 °C.

8.2.17.4 The motor control center shall be permanently marked in accordance with Clause 6.3.34.

8.2.17.5 Connectors for field-installed incoming supply conductors shall be suitable for a 90 °C termination temperature rating and shall be capable of securing conductors in accordance with Table 29 for an ampacity based on 90 °C.

8.2.18 Pressure wire connectors

8.2.18.1 A pressure wire connector provided with or specified for use with equipment as a field-wiring terminal shall comply with item 6 or 17 in Annex C.

8.2.18.2 The tightening torque for a field-wiring terminal shall be as specified by the equipment manufacturer, as required by Clause 6.3.36. The specified tightening torque shall not be less than 90 % of the value employed in the static heating test on the wire connector for the wire size required for the ampere rating of the motor control center. The tightening torques for wire connectors for use with copper conductors are specified in item 6 or 17 in Annex C.

8.2.19 Service equipment for use in Mexico and the United States (See Annex G)

8.2.19.1 A motor control center section or unit marked for service equipment use shall be provided with both overcurrent protection and disconnecting means for the service conductors. Where used as service equipment, each motor control center shall be provided with a single disconnecting means to disconnect all ungrounded service conductors. A second service disconnect shall be permitted to supply additional equipment in accordance with Clauses 8.2.19.7 and 8.2.19.8.

8.2.19.2 A motor control center section or unit marked for service equipment use shall comply with Clause 6.3.12.2.

8.2.19.3 A motor control center section or unit marked for service equipment use shall be provided with a grounding electrode conductor terminal, and if a neutral is provided, with means for disconnecting the neutral service conductors and with a main bonding jumper.

8.2.19.4 In a multi-section motor control center, only one section need contain a main bonding jumper and a grounding electrode conductor terminal. The main bonding jumper and the grounding electrode conductor terminal need not be located in a section marked for service equipment use.

8.2.19.5 In a multi-section motor control center, means for disconnecting the neutral from the service conductors may be located in only one section if it disconnects all the outgoing neutral conductors in all the sections from the service conductors. The neutral disconnecting means need not be located in a section marked for service equipment use.

8.2.19.6 In a motor control center marked as being acceptable for use as service equipment, uninsulated bus bars and terminals on the line side of a service disconnect shall be isolated by a barrier so that, with all

service disconnects in the off position, no uninsulated live part is exposed to contact while servicing any load terminal including a neutral-load terminal, a branch-circuit equipment-grounding terminal, or the neutral-disconnect link.

8.2.19.7 A motor control center provided with more than one service disconnect shall have each service disconnect in a separate motor control center section.

8.2.19.8 The two motor control center sections referenced in 8.2.19.7 shall be separated by a barrier. The barrier shall comply with the requirements in Clause 8.2.10.2.

8.2.20 Service equipment for use in Canada (See Annex G)

8.2.20.1 A motor control center intended for use as service equipment shall comply with Clauses 8.2.20.2 to 8.2.20.14 and Clause 6.3.12.

8.2.20.2 A motor control center intended for use as service equipment shall be provided with wiring leads not smaller than 8.4 mm^2 (8 AWG) or with terminals acceptable for the connection of 5.3 mm^2 (10 AWG) or larger conductors.

8.2.20.3 The electrical spacing on the supply side of the main overcurrent protection in a motor control center intended for use as service equipment shall comply with Table 19.

8.2.20.4 Equipment marked for service use as described in Clause 6.3.12 shall have a single, load-rated, manually operable service-disconnecting fused switch or circuit-breaker that opens all ungrounded conductors.

8.2.20.5 The service-disconnecting means and its associated overcurrent devices shall be located in a separate compartment.

8.2.20.6 Associated equipment that must, by its operation, be connected to the line side of the main switch or circuit-breaker, such as phase-failure/phase-reversal relays, shall be protected by overcurrent devices having an interrupting rating equal to or greater than the service entrance unit short-circuit current rating. There shall be a means for disconnecting the circuits ahead of these overcurrent devices. A circuit-breaker or dead-front fuse assembly is deemed to satisfy both requirements.

8.2.20.7 Incoming service conductors shall be capable of being connected to the line side of the main switch or circuit-breaker without passing through compartments or raceways containing conductors connected to the load side of the main switch or circuit-breaker.

8.2.20.8 There shall be provision for locking and sealing the service-disconnecting switch or circuit-breaker compartment to prevent access by unauthorized persons.

8.2.20.9 The handle of the service-disconnecting switch or circuit-breaker shall be lockable in the OFF position.

8.2.20.10 A compartment provided for supply authority use shall be lockable or have provision for sealing and shall be marked as specified in Clause 6.3.27.

8.2.20.11 Equipment intended to function as service equipment on ac services involving a neutral shall be provided with a neutral assembly located within the service-disconnecting compartment. 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) the incoming (grounded) neutral conductor;

b) the corresponding outgoing (load) connector, if any;

c) the service-grounding conductor;

d) the bonding conductor to the enclosure;

e) the bonding conductor to the service conduit (or equivalent).

The connection means shall be grouped together and shall utilize pressure-type wire connectors for all field-made terminations. Terminal sizes shall be determined in accordance with Table 19 and Table 20 of the *Canadian Electrical Code, Part I*.

8.2.20.12 With reference to item d) of Clause 8.2.20.11, the specified bonding connection may be omitted and a nonferrous screw provided for bonding the enclosure to the neutral bar (convertible neutral). The screw shall be not less than No. 10 for switches rated 100 A or less, 6.3 mm (0.25 in) diameter for switches rated over 100 A and up to and including 225 A, and 7.9 mm (0.31 in) diameter for switches rated over 225 A and up to and including 400 A.

8.2.20.13 The neutral assembly described in Clause 8.2.20.11 shall be insulated from the enclosure, bonded to the enclosure before shipment, and marked in accordance with Clause 6.3.70.

8.2.20.14 Ground-fault protection and ground fault indicating equipment shall comply with the requirements of Annex C, item 1. (See Section 14 of Annex C, item 1).

8.2.21 Ground-fault protection (See Annex G)

8.2.21.1 Means shall be provided to lock a control circuit disconnect for ground-fault protection in the energized position. A pilot light shall be provided to indicate that the ground-fault protection control circuit is energized. The pilot light shall be visible with all covers in place.

8.2.21.2 A locking means or pilot light shall not be required for a circuit breaker or switch in the power circuit that also serves as the control circuit disconnect.

8.2.21.3 If the ground fault protector is actuated by the fault current so that no separate control circuit is required, a pilot light or means to lock the control circuit disconnect in the on position shall not be required.

8.2.21.4 The pilot light need not be visible on the outer cover of a Type 3R enclosure.

8.2.21.5 Except as noted in Clause 8.2.21.7 c), a motor control center section or unit marked for use as service equipment for 3-phase, 4-wire, solidly grounded wye-connected services rated in excess of 150 V to ground, but not exceeding 1 000 V phase-to-phase, shall be provided with ground-fault protection for each service-disconnecting means rated 1 000 A or more. 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 1 200 A, and the maximum time delay shall be 1 s for ground fault currents equal to or greater than 3 000 A.

8.2.21.6 For motor control centers intended to be installed in Canada, ground-fault protection shall be provided in solidly grounded circuits rated 150 V or less to ground and 2 000 A or more (see Annex G).

8.2.21.7 Ground-fault protection need not be provided for a motor control center section or unit that is

a) identified for use only on a 3-phase, 3-wire supply;

b) identified for use on systems that are not solidly grounded;

c) in accordance with Clause 6.3.17 or 6.3.18; or

d) identified for use in a separate building or a structure on the property where ground-fault protection is provided at the service entrance.

8.2.21.8 If a service-disconnecting means rated 1 000 A or more is provided with a shunt trip that is intended for use with ground-fault protection, the ground fault sensor and relaying equipment may be in a separate section of the motor control center if several sections are intended for use in a group.

8.2.21.9 With regard to Clause 8.2.21.8, the rating of a service-disconnecting means shall be determined as specified in item a), b), or c) as follows:

a) For a fused switch, the rating of the disconnecting means shall be determined by the largest fuse that can be installed in the switch.

b) For a circuit-breaker frame with an interchangeable trip unit, the rating of the disconnecting means shall be determined by the rating of the factory-installed trip unit.

c) For a circuit-breaker with a non-interchangeable trip unit, the rating of the disconnecting means shall be determined by the rating of the circuit-breaker with the adjustable pickup, if provided, set at its maximum value.

8.2.21.10 If ground-fault protection is provided, though not required as specified in Clause 8.2.21.5, it shall comply with the requirements for the installation of ground-fault protection equipment in this standard (see Annex G).

8.2.21.11 If ground-fault protection is provided, though not required as specified in Clause 8.2.21.5, and if it is marked in accordance with Clause 6.3.19, then the ground-fault protection may initiate an audible or visual signal rather than open a source intended for a legally required standby system or a 3-phase, 4-wire service that is wye-connected and impedance grounded (see Annex G).

8.2.21.12 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 sensing element is located on the load side of any grounding or bonding connections to the neutral. It may be on the line or load side of the disconnecting device for the protected circuit (see Annex G).

8.2.21.13 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 may be on the line or load side of the disconnecting device for the protected circuit (see Annex G).

8.2.21.14 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 motor control center section that can be made to the neutral (see Annex G).

8.2.21.15 If the design 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, the design shall be such as to prevent reclosure of the tripped disconnect until the reset operation is performed, or such means shall be incorporated in the disconnect device (see Annex G).

8.2.21.16 The primary of a ground-fault protection control circuit transformer may be connected on the line or load side of the main overcurrent protective device or may be connected to an external source. The

primary of such a transformer shall be connected to two line-voltage points (not line and neutral). If connected to the line side of the main or to an external source, a fused disconnect switch or circuit-breaker rated for use as service equipment and providing overcurrent protection rated as specified in Clauses 8.2.14 and 8.2.15 shall be installed ahead of the transformer or control circuit. Overcurrent protection shall not be required for the control circuit if wired to the load side of the main overcurrent protective device unless the control circuit wiring (other than from a ground fault sensor) leaves the section or the control circuit contains a snap switch. Markings as specified in Clause 6.3.45 or 6.3.47 shall be provided if the transformer is not connected to the load side of the main disconnect (see Annex G).

8.2.21.17 In a motor control center section or unit not marked for use as service equipment, the fused disconnect switch specified in Clause 8.2.21.16 may be replaced with a fuseholder as specified in Clause 8.2.25.1.

In Canada, this requirement does not apply.

8.2.22 Neutral disconnecting means

8.2.22.1 In a motor control center section or unit that has a neutral and that is marked for service equipment use, means shall be provided for disconnecting the neutral service conductors. This shall be incorporated in the disconnecting means referred to in Clause 8.2.19.1 or shall be

a) a disconnect link;

b) removal of the conductor from its terminal; or

c) removal of the terminal.

(See Annex G.)

8.2.22.2 The disconnecting means shall be on the load side of the grounding electrode conductor terminal and of the main bonding jumper. (See Annex G.)

8.2.22.3 In a multi-section motor control center the neutral disconnecting means may be located in another section as specified by Clause 8.2.19.4. (See Annex G.)

8.2.22.4 The disconnect link mentioned in Clause 8.2.22.1 shall take the form of a link, or similar conducting piece, designed to make connection between two terminals. Simple removal of bolts from a single bus bar joint shall not satisfy this requirement. A splice bus may be used as a neutral disconnect link if there is no branch circuit leaving the first section in the group. (See Annex G.)

8.2.22.5 A disconnect link shall be located, guarded, recessed, or enclosed so that unintentional contact with any uninsulated, ungrounded part on the line side of the main switch or circuit-breaker does not occur while the link is being removed or replaced. The neutral disconnect link shall be accessible for removal without the need for loosening any screws or bolts that secure bus bars (other than those of the disconnect link). (See Annex G.)

8.2.22.6 The disconnect link shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by the serving agency (electric utility or power company). (See Annex G.)

8.2.23 Equipment on supply side of disconnect

8.2.23.1 The following equipment may be connected to the supply side of the service-disconnecting means

a) meters;

b) instrument transformers (current and potential), high-impedance shunts, surge-protective devices identified for use on the supply side of the service disconnect, load management devices, and surge arresters located in the motor control center;

c) control circuits of power-operable service-disconnecting means, including a ground-fault protection system, as specified in Clause 8.2.21;

d) in Mexico and the United States, connections for a fire pump controller.

(See Annex G.)

For Canadian fire pump controller requirements, see Annex E.

8.2.24 Multiple source motor control centers

8.2.24.1 Unless intended for parallel operation, the disconnect identified in Figure 5 and Figure 6 as the tie-breaker shall be provided with mechanical, keyed, or electrical interlocking with the service disconnects shown in the figures so that sources cannot be paralleled (see Annex G).

8.2.24.2 With the exception specified in Clause 8.2.24.3, a circuit-breaker marked "line and load" or a fused switch shall not be used as a tie-breaker or tie-disconnect.

8.2.24.3 A fused switch may be used as a tie-disconnect or source disconnect if both ends of each fuseholder are disconnected from either voltage source when the switch is in the OFF position.

8.2.25 Cartridge fuse disconnecting means

8.2.25.1 In Mexico and the United States, a disconnecting means shall be provided on the supply side of cartridge fuses unless

a) the motor control center section is not marked for use as service equipment;

b) the fuse(s) are provided in an instrument circuit or control circuit, and it can be demonstrated that the fuse is accessible only to qualified personnel (for example, by being located behind a screwed-on cover or a locked cover), and a marking as specified in Clause 6.3.47 is provided in the case of a motor control center with a main disconnect.

8.2.25.2 In Canada, a disconnecting means is required on the supply side of all cartridge fuses.

8.2.25.3 Extractable deadfront fuseholders shall be acceptable as the disconnecting means for control and instrumentation circuits.

8.2.26 Unit-disconnecting means

8.2.26.1 Unit disconnects of a combination motor controller or motor control unit shall have a minimum ampacity of 115 % of the full-load motor current and horsepower ratings for the ratings assigned to the unit. See Table 15, Table 16 or Table 17.

8.2.26.2 A switch or circuit-breaker shall be installed so that the center of the grip of the operating means (an external handle, extension, or chain) of the switch or circuit-breaker, when in its highest position, is not more than 2 m (6 ft, 7 in) above the floor or working platform. If the handle grip is not clearly defined, the center of the handle grip shall be considered to be a point 76 mm (3 in) in from the end of the handle.

8.2.26.3 A unit intended for installation in the field and requiring an extension, chain, or similar means shall be provided with such means or shall be marked as indicated in Clause 6.3.62.

8.2.26.4 If a circuit-breaker handle or switch, as installed in a motor control center, is operated vertically rather than rotationally or horizontally, the UP position of the handle shall be the ON position.

8.2.26.5 If a manual motor controller is used within a motor control center, it shall be provided with a separate disconnecting means.

8.2.26.6 Provision shall be made for locking the disconnecting device in the open position when the door is closed. The design shall be such that the disconnecting device is open and the handle position indicator shows “open” before locking can be accomplished.

8.2.27 Electrical spacings

8.2.27.1 Spacings in a motor control center shall be as specified in Clauses 8.2.27.2 to 8.2.27.14, Table 19, and Table 20.

8.2.27.2 Spacings at all horizontal and vertical buses, at incoming terminals or service-entrance compartments, at the plug-in portion of all units, and at feeder units consisting of fusible disconnect switches or circuit-breakers only, having other than horsepower ratings, shall be as specified in Table 19 (see Annex G).

8.2.27.3 In Mexico and the United States, if the enclosure or ground bus is factory bonded to the neutral as specified in Clauses 8.2.33.1 and 8.2.33.5, 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 (0.125 in) spacings through air or over surface to the enclosure. Parts that can interfere with operation of a ground-fault protection if grounded include

a) for zero sequence type ground-fault protection or residual type ground-fault protection, all neutral parts on the load side of the neutral current sensing means;

b) for the ground return type, all conductive parts connected to the neutral except those on the ground side of the sensing means.

See Annex G.

NOTE In Canada, this clause does not apply.

8.2.27.4 The values in Table 19 are based on the following assumptions:

a) The voltage from a live part, other than the neutral, to grounded dead metal equals the line-to-line voltage of the system.

b) The voltage from a neutral live part to grounded dead metal equals the line-to-neutral voltage of the system.

c) Spacings at a fuseholder are measured with a fuse of the maximum standard dimensions, including the maximum projections for assembly screws and rivets, in place. Dimensions of fuses and fuseholders are specified in the applicable requirements for fuses. See Annex C, item 8 and items 18 – 26.

8.2.27.5 Spacings shall be measured with all field-wiring terminals unwired and then wired with conductors determined in accordance with Clauses 8.2.16.3 and 8.2.16.5.

8.2.27.6 The spacing at a field-wiring power-circuit terminal shall be measured with wire of the appropriate size for the rating connected to the terminal as in actual service. The connected wire, if the terminals accommodate it properly or the device is not marked to restrict its use, shall be the next larger size than that normally required.

8.2.27.7 Terminals and other parts intended to be connected to the grounded conductor of a circuit shall be considered to be uninsulated live parts unless such parts are mounted directly on or in permanent electrical connection with grounded dead metal.

8.2.27.8 In measuring spacings between an uninsulated live part and a bushing installed at a knockout, it shall be assumed that a bushing having the dimensions specified in Table 21 but without a lock nut inside the enclosure is in place.

8.2.27.9 Except as specified in Clause 8.2.27.10, spacings of a component serving as the service disconnect shall comply with Table 19 (see Annex G).

8.2.27.10 Spacings within a circuit-breaker or a moulded case switch shall be in accordance with the requirements applicable to that component.

8.2.27.11 Spacings within all combination motor control units, including the load terminal boards, if provided, shall be as specified in Table 20. Other units shall be judged according to their respective standards.

8.2.27.12 Except as required by 8.2.27.2, spacings in a component, such as industrial control equipment, a clock-operated switch, and the like within a motor control center, and located on the load side of the service disconnect and overcurrent protection shall comply with the requirements applicable to that component, except that the spacings to the overall enclosure (other than inherent spacings) and spacings between individual components shall comply with Table 20.

8.2.27.13 A wire connector shall be prevented from turning in such a way that spacings become less than the minimum acceptable values. The means for turn prevention shall be reliable, such as a shoulder or boss; a lock washer alone shall not be used.

8.2.27.14 Means to prevent turning as mentioned in Clause 8.2.27.13 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° toward the other;

b) when the connector has been turned 30° toward other opposite-polarity live parts and toward grounded dead metal parts.

8.2.28 Insulating barriers

8.2.28.1 The liner or barrier referred to in Clauses 8.2.28.2 to 8.2.28.6 is insulating material that separates uninsulated live parts of opposite polarity or separates an uninsulated live part from a grounded dead metal part (including the enclosure), where the through-air spacing between the parts would otherwise be less than the minimum acceptable value.

8.2.28.2 A barrier that comprises the sole separation or that is used in conjunction with an air space less than 0.33 mm (0.013 in) shall comply with items a) – e). The barrier shall be:

a) of material as indicated below:

1) as covered in Clause 8.2.7.1; or

2) electrical grade (vulcanized) fiber if used as a barrier between the enclosure and an uninsulated live part electrically connected to a grounded circuit conductor (neutral); or

3) based on the end-product tests specified in Reference Item 9 in Annex C (Not for Canada).

b) of such strength to withstand the stress associated with normal handling, installation, and

use of the equipment;

c) secured in place;

d) located so that it will not be adversely affected by operation of the equipment in service; and

e) have a minimum thickness of 0.71 mm (0.028 in).

1) Material other than vulcanized fiber may have a thickness less than 0.71 mm (0.028 in) if it withstands a 60 hertz dielectric-withstand voltage of 5 000 V applied in accordance with the requirements in Clause 8.3.

8.2.28.3 A barrier used in conjunction with a minimum air space of 0.33 mm (0.013 in) shall comply with a) – e). The barrier shall be:

a) of a material as covered in Clause 8.2.7.1, or as follows:

1) vulcanized fiber with a minimum thickness of 0.71 mm (0.028 in) and used in conjunction with a minimum 0.8 mm (0.031 in) air space or

2) a barrier based on the end-product tests specified in Reference Item 9 in Annex C (not for Canada).

b) of such strength to withstand the stress associated with normal handling, installation, and

use of the equipment;

c) secured in place;

d) located so that it will not be adversely affected by operation of the equipment in service; and

e) of a minimum thickness of 0.71 mm (0.028 in):

1) Material other than vulcanized fiber may have a thickness less than 0.71 mm (0.028 in) if it withstands a 60 hertz dielectric-withstand voltage of 5 000 V applied in accordance with the requirements in Clause 8.3.21.

2) Material other than vulcanized fiber used in conjunction with an air space of 1/2 or more of the required through-air spacing may have a thickness:

i) no less than 0.33 mm (0.013 in); or

ii) less than 0.33 mm (0.013 in) if it withstands a 60 Hz dielectric-withstand voltage of 2 500 V applied in accordance with the requirements in Clause 8.3.21.

8.2.28.4 A wrap of two or more layers of thermoplastic tape, acceptable for use as sole insulation, may be employed if the tape is not subject to compression, is not wrapped over a sharp edge, and if

a) at a point where the spacing prior to the application of the tape is not less than 1/2 the required through-air spacing, the wrap is not less than 0.33 mm (0.013 in) thick;

b) at a point where the spacing prior to the application of the tape is less than 1/2 the required through-air spacing, the wrap is not less than 0.71 mm (0.028 in) thick.

8.2.28.5 If spacings would otherwise be less than the minimum acceptable values, thermoplastic tubing acceptable for the application may be employed if

a) it is not subjected to compression, repeated flexure, or sharp bends;

b) all edges of the conductor that are protected with the tubing are rounded and free from sharp edges;

c) for chemically dilated tubing, a solvent recommended by the tubing manufacturer is used;

d) its wall thickness after assembly is not less than 0.56 mm (0.022 in) for tubing 12.7 mm (0.5 in) or less in diameter and is not less than 0.71 mm (0.028 in) for larger tubing;

e) it is not used in a circuit with a voltage greater than its insulation rating.

8.2.28.6 In applications rated 600 V or less, no additional evaluation of the RTI shall be required when the generic material used complies with Table 44.

8.2.29 Wiring space

8.2.29.1 General requirements

In Canada, the requirements of Annex C, item 4, shall be permitted.

The space within the enclosure of a motor control center shall provide ample room for the installation and distribution of wires and cables required for the proper wiring of the device.

8.2.29.2 Wire deflection and bending

8.2.29.2.1 The wire-bending space from a field-wiring terminal to a wall of the enclosure and to any barrier or other obstruction that is part of the motor control center shall be as specified in Table 22, except that if a hole, knockout, or other provision for connection of a wiring system is provided in the wall opposite the terminal, it shall be considered to be obvious that a conductor will enter or exit the enclosure through that wall, and the wire-bending space shall be as specified in Table 23.

8.2.29.2.2 If a conductor is restricted by barriers, branch-circuit units, or other means from being bent in a 90° 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.

8.2.29.2.3 The distance mentioned in Clause 8.2.29.2.1 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the wall or barrier. The wire terminal shall be turned so that the axis of the wiring opening in the connector is as close to perpendicular to the wall of the enclosure as it can be 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. The main connection for a neutral shall be considered to be a terminal (that is, neutral branch terminals shall not be considered in this determination). 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. If the connectors for a circuit are fixed in position (for example, by the walls of a recess) so that they are turned toward each other, the distance shall be measured at the wire opening nearest to the wall in a direction perpendicular to the wall.

8.2.29.2.4 When using Table 22, bending space may be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal. The connector shall not be oriented so that the wire will be directed into a corner of the box to such extent that the transverse wall necessitates additional bending.

8.2.29.3 Clear wiring space

8.2.29.3.1 The clear wiring space, independent of all projections, obstructions, or interference from moving parts of a switching mechanism, shall be fully adequate for the wiring of the device, and shall not be

a) smaller in width or depth than the values specified in Table 24 and Table 25;

b) smaller in total area than 250 % of the total cross-sectional area of the maximum number of wires that may be used in such space as specified in Table 24 and Table 25.

8.2.29.3.2 The adequacy of wiring spaces shall be judged using

a) the size and conductor material of a wire used at a terminal in accordance with Clause 8.2.16.5, except where ampacities are 110 A or less, the size shall be based on 60 °C insulated conductors if the marking specifies 60 °C or 75 °C wire;

b) the full complement of branch-circuit devices installed in the motor control center necessitating the largest wiring space.

If a terminal is acceptable for use with two or more combinations of conductors in multiple, each of which is appropriate for that terminal in accordance with Clause 8.2.16.5, the combination necessitating the largest wiring space shall be used unless the motor control center is marked in accordance with Clause 6.3.35. If a terminal is provided for conductors in multiple, the size of each of the conductors shall be based on the use of multiple circuits. The area occupied by a terminal compartment, as well as the area above such a compartment, shall not be included when wiring space is determined; however, space above or around an individual terminal or neutral located in a gutter shall be considered to be available space.

8.2.29.3.3 An operating mechanism and its relation to the wiring space shall be such that it cannot cause damage to wires with which it can come in contact during its operation.

8.2.29.3.4 Wiring space and other compartments intended to enclose wires shall be smooth and free from sharp edges, burrs, fins, and the like that may damage the conductor insulation.

8.2.29.3.5 No uninsulated live part shall be located within a wiring space.

8.2.29.3.6 An uninsulated neutral strap with its line connections is a live part. It shall be considered as being in the wiring compartment unless covered or located so that circuit wires other than those connected thereto will not be brought into contact with it.

8.2.29.3.7 An individual terminal shall not be considered as being in a wiring compartment if it is recessed between closely fitting walls to such a depth that, when wired with a conductor of the size corresponding to the rating of the terminal, the top of the terminal is not in contact with a straight edge placed across the walls. More than one terminal shall not be located in the same recess unless additional protection is provided.

8.2.30 Grounding and bonding

8.2.30.1 The grounding and bonding terms used in Clauses 6.3.57 and 6.3.58 and Clauses 8.2.31 to 8.2.34 are in accordance with the UL column in Figure 7. The corresponding CEC and ANCE terms are also provided for information.

8.2.30.2 In Canada, the requirements of Annex C, item 5, shall apply, except that the test current for the impedance test shall be based on the ampere rating of the device.

8.2.30.3 The marking, when required, for an equipment grounding terminal shall comply with the requirements in Clauses 6.3.57 and 6.3.58.

8.2.30.4 There shall be provision for grounding a motor control center section frame or structure.

8.2.30.5 Where accessible, the following shall be grounded:

a) the case or a frame of an instrument transformer;

b) the case of an instrument, meter, relay, or similar device unless the device is mounted on a grounded metal surface and secured thereto by means of metal screws to provide an adequate ground;

c) the secondary circuit of a potential transformer;

d) the secondary circuit of a current transformer. However, the uninsulated case or frame of a current transformer that is used exclusively to supply current to a meter and that has a primary that is not over 150 V to ground need not be grounded.

8.2.30.6 In Mexico and the United States, all exposed dead metal parts, except as specified in Clause 8.2.30.8, and the grounding contact of a grounding receptacle shall be in reliable contact with the means for grounding. The resistance shall not exceed

a) 0.1 ohm between the ground bus and either an exposed dead metal part or the grounding contact of a grounding type receptacle rated 30 A or less;

b) 0.005 ohm between the ground bus and the grounding contact of a grounding receptacle rated more than 30 A.

In Canada, this test shall not be required. However, the grounding contact shall be hard-wired to the ground bus with a minimum 2.1 mm^2 (14 AWG) wire.

8.2.30.7 A switch-operating handle or operator-actuated pilot device of conducting material need not be grounded if it is effectively insulated.

8.2.30.8 The resistance of the connection between adjacent motor control center sections and between a busway, ground bus, wireway, or an auxiliary gutter and a motor control center section enclosure shall not exceed 0.005 ohm. The resistance between the motor control center section enclosure and a wire connector for a grounding or bonding conductor larger than 8.4 mm^2 (8 AWG) copper or 13.3 mm^2 (6 AWG) aluminum shall not exceed 0.005 ohm.

8.2.30.9 Paint shall be removed as necessary to maintain the resistance within the limits specified in Clauses 8.2.30.6 and 8.2.30.8.

8.2.30.10 All motor control center units shall have provision for grounding. Grounding may be accomplished by having the unit in electrical connection with the section by means of a threaded screw or equivalent contacting both members.

8.2.30.11 The grounding means between a metal part of a draw-out motor control center unit that is intended to be grounded, including a feeder-tap unit, and any permanently grounded part shall be such that grounding continuity is established at least 3.2 mm (0.125 in) before the disconnects of the draw-out unit are energized and is maintained until the disconnects have been de-energized by at least 3.2 mm (0.125 in).

8.2.31 Grounding electrode conductor terminal

8.2.31.1 In Mexico and the United States, the requirements of Clauses 8.2.31.2 and 8.2.31.3 shall apply. In Canada, these requirements do not apply. See Annex G.

8.2.31.2 A motor control center section marked for service equipment use and provided with a neutral shall have a terminal for the connection of the grounding electrode conductor to the neutral bus or to the ground bus in accordance with Table 26 or Table 27. The connections shall not depend on solder for securing the grounding electrode conductor. If located on the neutral bus, the terminal shall be on the supply side of a switching disconnect means or a disconnect link. The terminal may be located in another section.

8.2.31.3 The terminal for the grounding electrode conductor shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by the serving agency (electric utility or power company).

8.2.32 Transformer secondary grounding

8.2.32.1 A secondary circuit of a power or control power transformer shall be grounded under any of the following conditions if the circuit extends or can extend beyond the section in which the transformer is mounted:

a) if the secondary is less than 50 V and the transformer supply is over 150 V to ground or the transformer supply at any voltage is ungrounded (for Canada, see Rule 10-104 of Annex C, item 1);

b) if the secondary is 50 V or higher and the secondary circuit can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 V;

c) the system incorporates a neutral conductor (for Canada, see Rule 10-106-1b of Annex C, item 1);

8.2.32.2 In Canada, a secondary circuit of an instrument transformer shall be grounded where the primary is connected to circuits of 300 V or more to ground (see Rule 10-116 of Annex C, item 1).

In Mexico and the United States, this requirement does not apply.

8.2.32.3 If a transformer secondary is required to be grounded in accordance with Clause 8.2.32.1 or 8.2.32.2, a system bonding jumper shall be factory connected from the transformer secondary to either the

a) ground bus;

b) enclosure if a ground bus is not provided; or

c) draw-out unit.

8.2.32.4 Except as specified in Clause 8.2.32.5, the size of the system bonding jumper shall be as specified in Table 26 and Table 27, based on the transformer secondary current rating. A grounding-electrode-conductor terminal sized in accordance with Table 26 (Columns 4 and 5) shall be provided on the ground bus, if any, in the section containing the transformer or in an adjoining section, and a marking in accordance with Clause 6.3.69 shall be provided.

8.2.32.5 The size of the bonding jumper for a system that supplies a remote-control circuit and is derived from a transformer rated no more than 1 000 VA shall be no smaller than the phase conductors and shall be no smaller than 2.1 mm^2 (14 AWG) copper or 3.3 mm^2 (12 AWG) aluminum.

8.2.32.6 Notwithstanding Clause 8.2.32.3, a grounding conductor shall not be required for a system that supplies a remote-control circuit and that is derived from a transformer rated no more than 1 000 VA, provided the system grounded conductor is bonded to the transformer frame or enclosure by a system bonding jumper sized in accordance with Clause 8.2.32.5.

8.2.32.7 In Canada, if the transformer is larger than 1 000 VA, the system bonding jumper shall be connected to the ground bus.

In Mexico and the United States, this requirement does not apply.

8.2.32.8 If the control circuit must be grounded, the ground connection shall be made at a transformer secondary lead or terminal.

8.2.32.9 Where the secondary of a control transformer is ungrounded, provision for grounding shall be supplied.

8.2.33 Main bonding jumper

8.2.33.1 The enclosure shall not be bonded to the neutral when the unit is shipped unless the motor control center is marked for use only as service equipment. However, the enclosure may be bonded to the neutral as specified in Clause 8.2.32.3 (see Annex G).

8.2.33.2 For a motor control center section or unit marked for use as service equipment in accordance with Clause 6.3.12.2, a main bonding jumper shall be provided to bond the enclosure and the ground bus to the neutral of an alternating-current circuit. If several sections, each containing overcurrent protective and disconnection means, are intended to be used in a group, only one section need contain a main bonding jumper. The construction shall be such that when the bonding means is not used, the spacings given in Table 19 exist. See Clause 6.3.14 and Annex G.

8.2.33.3 A main bonding jumper shall be as specified in Table 26 and Table 27, based on the largest supply ampere rating of any section in the group of sections. The section neutral bus to which the main bonding jumper is connected shall not be smaller than the required size for the main bonding jumper. In determining the size of the main bonding jumper, no credit shall be given for another main bonding jumper in another section. The connection of the main bonding jumper to the neutral shall be on the supply side of a switching-type disconnect means as specified in Clause 8.2.22.2 or a disconnect link as specified in Clause 8.2.22.4. See Annex G.

8.2.33.4 The main bonding jumper shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by a utility. See Annex G.

8.2.33.5 For a motor control center section or unit incorporating ground-fault protection of the ground-return type as described in Clause 8.2.21.14, the main bonding jumper as specified in Clause 8.2.33.2 shall be factory connected to the neutral bus and to the ground bus (or to the motor control center frame if

a ground bus is not provided), and the section or unit shall be marked in accordance with Clause 6.3.12.2 b). See Annex G.

8.2.34 Ground bus

8.2.34.1 A multi-section center shall include a ground bus sized in accordance with Table 26 and Table 27. A section having through-bus bars extending beyond the section bus bars with provision for another section to be added at a later time shall be considered part of a multi-section motor control center.

8.2.34.2 If a ground bus is not provided in a single motor control center section, at least two terminals shall be provided on the frame or enclosure as follows:

a) for an equipment-grounding conductor of a size in accordance with Table 26, a terminal to ground the center frame; and

b) for an equipment-grounding conductor, a terminal to bond all outgoing conduits to the center frame. The second connection shall accommodate an equipment-grounding conductor sized in accordance with Table 26, corresponding to the largest branch circuit.

8.2.34.3 In Mexico and the United States, in reference to Clause 8.2.34.2, the terminal in item a) may be omitted if the enclosure is factory bonded to the neutral, a grounding electrode conductor terminal is located on the neutral, and the section or unit is marked in accordance with Clause 6.3.12.2 b). The terminal in item b) may be omitted if all conduits enter the enclosure through metal cover plates. See Annex G.

In Canada this requirement does not apply.

8.2.34.4 In addition to the terminals specified in Clause 8.2.34.2, a section without a ground bus shall have provision for attaching additional terminals or grounding-terminal assemblies to accommodate equipment-grounding wires used with outgoing non-metallic or under-floor raceway. If a branch circuit has provision for multiple conductors, the additional terminals shall have provision for multiple equipment-grounding conductors sized in accordance with Table 26. However, the terminals need not accommodate an equipment-grounding conductor larger than one of the current-carrying conductors.

8.2.34.5 If there is provision for a field-installed terminal assembly for an equipment-grounding conductor, the assembly shall be marked in accordance with the requirements in Clause 6.3.58. See Annex G.

8.2.34.6 In addition to the grounding means required by Clause 8.2.34.1, a motor control center not marked for service equipment use only may have a neutral bus bar or terminal strip sized as specified in Table 26 that is insulated from the enclosure.

8.3 Performance requirements

8.3.1 General

A combination motor control unit constructed as Type A, C, D, and E as specified in Table 11 and having individual replaceable components that comply with the appropriate requirements for those components or have been investigated in this application shall also be subjected to the applicable tests specified in Table 34. See Table 35 for test sequence. However, individual components of Type A, C, and D controllers shall not be required to be subjected to the tests in Table 35 if previously evaluated.

8.3.2 Calibration performance

These requirements shall apply to an overload relay or an industrial control equipment incorporating an overload relay. The overload relay shall operate within the time specified when tested in accordance with Clause 9.2.

In Canada and the US, the use of an overload relay that has been evaluated to Annex C, Item 10 need not be tested.

8.3.3 Temperature-rise performance

A motor control center, when tested under the conditions described in Clause 9.3, shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to adversely affect any materials employed in the device, or to exceed the temperature rises specified in Table 29. No automatic thermal control shall operate during the test.

8.3.4 Overvoltage and undervoltage performance

A unit using a control-circuit transformer and one or more electromagnetic switching components shall operate at the undervoltage specified in Clause 9.4.2 and shall withstand the overvoltage without damage to the operating coil when tested in accordance with Clause 9.4.3.

8.3.5 Dielectric voltage-withstand performance (after temperature-rise test or overvoltage/undervoltage test)

As soon as practicable following the temperature-rise test or the overvoltage/undervoltage test, the motor control center section or unit shall withstand the test potential for 1 min without breakdown when tested in accordance with Clause 9.5.

NOTE: The intention is to test while circuit components are as close to normal operating temperatures as practicable.

8.3.6 Current-withstand performance

When tested in accordance with Clause 9.6, a Type D combination motor controller having instantaneous-trip circuit-breakers shall withstand currents of 600 % and 1 000 % of full-load motor current without damage to any parts or connected wires that would impair their function. Softening of wire insulation shall be acceptable, but melting and dripping of wire insulation shall not be acceptable.

8.3.7 Dielectric voltage-withstand performance (after current-withstand test)

Immediately following the current-withstand test, the motor control center unit shall withstand the test potential for 1 min without breakdown when tested in accordance with Clause 9.7.

8.3.8 Contactor overload performance

A magnetic motor contactor that is intended for use in a Type D combination with an instantaneous-trip circuit-breaker shall exhibit no electrical or mechanical breakdown of the equipment, no undue burning or pitting of the contacts, and no welding of the contacts, when tested in accordance with Clause 9.8, and the fuse specified in Clause 9.8.9 shall not open.

In Canada and the US, the use of a magnetic motor contactor that has been evaluated as part of the Type D combination to Annex C, Item 10 need not be tested.

8.3.9 Dielectric voltage-withstand performance (after contactor overload test)

Following the contactor overload test, the motor control center unit shall withstand the test potential for 1 min without breakdown when tested in accordance with Clause 9.9.

8.3.10 Short-circuit test performance of bus structure

When a motor control center has been tested under any of the short-circuit conditions described in Clause 9.10 for a rating selected from Table 3, the results shall be acceptable if the motor control center is in substantially the same mechanical condition as prior to the test, and if

a) there is no permanent distortion or displacement of the bus bars or cable that can affect the normal functioning of the bus assembly or reduce spacings to less than 75 % of those specified in Table 19;

b) there is no distortion of a plug-in bus assembly that can impair normal insertion of a plug-in unit such as a motor control or feeder-tap unit;

c) a bus bar insulator, support, or cable restraint has not separated into two or more pieces. Also, there shall be no cracks appearing on opposite sides of a base and no cracks, including surface cracks, running the full length or width of the support. The cracks are considered acceptable if, after a repeated short-circuit test on the same sample, the MCC complies with the Dielectric Voltage-Withstand Test, Clause 9.11, and the electrical spacings are not reduced to less than 75 percent of the values specified in Table 19. Other cracks, chips, or the like, which are not considered to reduce the structural integrity of the support are acceptable if the resulting spacings are not reduced to less than 75 % of the values specified in Table 19.

d) the fuse described in Clause 9.10.10.6 has not opened;

e) the enclosure or a part of the enclosure has not been damaged or displaced to the extent that a live part is accessible to a test rod

1) 13.2 mm (0.51 in) in diameter for any opening less than 107 mm (4 in) from an uninsulated live part; or

2) 19.4 mm (0.76 in) in diameter for any opening 107 mm (4 in) or more from such a part;

f) there is no damage due to arcing;

g) there is no significant damage to a conductor or its insulation or to the terminal connector, and the conductor has not pulled out of the terminal connector;

h) the motor control center complies with the dielectric voltage-withstand test described in Clause 9.11.

8.3.10A Short-time current rating test (optional)

A motor control center marked with a short-time current rating shall be tested under the conditions described in 9.10A and shall withstand the short-time current for the specified duration. The results shall be considered acceptable if the motor control center is substantially in the same mechanical condition as prior to the test, and if the criteria in 8.3.10 are met.

8.3.11 Dielectric voltage-withstand performance (after short-circuit test of bus structure)

Following the bus structure short-circuit test, the motor control center assembly shall withstand the test potential for 1 min without breakdown when tested in accordance with Clause 9.11.

8.3.12 Short-circuit (standard level) performance requirements for motor control center units for other than main and feeder units

After a motor control center unit, other than a main or feeder unit, has been tested in accordance with Clause 9.12, the results shall be considered acceptable if the unit complies with the acceptance criteria shown in Table 32.

8.3.13 Dielectric voltage-withstand performance (after standard-level unit short-circuit test for other than main and feeder units)

The samples that have been subjected to the standard-level unit short-circuit test shall withstand the test potential without breakdown when tested in accordance with Clause 9.13.

8.3.14 Trip-out performance of circuit breakers (after standard-level unit short-circuit test for other than main and feeder units)

8.3.14.1 Magnetic trip-out (Type D and Type E controllers)

The tripping current of a controller provided with an adjustable instantaneous trip (release function) shall be no greater than 130 % of the marked tripping current when tested as described in Clause 9.14.1.

8.3.14.2 Inverse-time trip-out (Type C controllers)

Controllers tested at short-circuit current ratings greater than the circuit-breaker interrupting rating shall be tested in accordance with Clause 9.14.2. The tripping time shall be no greater than that shown in Table 33.

8.3.15 High available short-circuit performance – motor control center units other than main and feeder units

After a motor control center unit, other than a main or feeder unit, has been tested in accordance with Clause 9.15, the results shall be considered acceptable if the unit complies with the acceptance criteria shown in Table 32.

8.3.15A Short-time current performance (optional) – motor control center main and feeder units with low-voltage power circuit breakers and main lug only units

After a motor control center unit has been tested in accordance with Clause 9.15A, the results shall be considered acceptable if the unit complies with the acceptance criteria shown in Table 32.

8.3.16 Dielectric voltage-withstand performance (after high available unit short-circuit test – motor control center units other than main and feeder units)

The samples that have been subjected to the high-level unit short-circuit test shall withstand the test potential without breakdown when tested in accordance with Clause 9.16.

8.3.16A Dielectric voltage-withstand performance (after short-time current performance – motor control center units with low-voltage power circuit breaker)

The samples that have been subjected to the short-time current performance – motor control center units with low-voltage power circuit breaker shall withstand the test potential without breakdown when tested in accordance with Clause 9.16A.

8.3.17 Trip-out performance of circuit-breakers (after high available unit short-circuit test other than main and feeder units)

8.3.17.1 Magnetic trip-out (Type D and Type E controllers)

8.3.17.1.1 The tripping current of a Type E controller provided with an adjustable instantaneous trip (release function) shall be no greater than 130 % of the marked tripping current when tested as described in Clause 9.17.1.

8.3.17.1.2 The tripping current of a Type D controller with an adjustable instantaneous trip (release function) shall be tested in accordance with Clause 9.17.1 unless all the following criteria are met:

a) The instantaneous-trip circuit-breaker has an electronic trip unit;

b) The instantaneous-trip circuit-breaker has an interrupting rating equal to or greater than the short-circuit current rating of the Type D controller;

c) The instantaneous-trip circuit-breaker did not experience coil burnout during the short-circuit testing of the instantaneous-trip circuit-breaker when tested individually in accordance with Annex C, Item 7; and

d) The instantaneous-trip circuit-breaker is installed in a compartment having dimensions greater than or equal to the required enclosure size of the circuit breaker. Consideration shall also be given to the distance from the vents of the circuit breaker to the nearest wall or other obstruction, and reduction of the compartment volume by other components inside the combination motor unit.

8.3.17.1.3 The tripping current shall be no greater than 130 % of the marked tripping current.

8.3.17.2 Inverse-time trip-out (Type C controllers)

Controllers tested at short-circuit current ratings greater than the circuit-breaker interrupting rating shall be tested in accordance with Clause 9.17.2. The tripping time shall be no greater than that shown in Table 33. A single pole, when tested at the 400 % value as permitted in Clause 9.17.2, shall trip within 2 additional min.

8.3.18 Strength of insulating base and support performance

8.3.18.1 When tested in accordance with Clause 9.18, the insulating base of a field-wiring terminal shall not be damaged when a conductor of rated ampacity is connected to the terminal and the clamping screw is torqued to 110 % of the value marked on the equipment. However, the test shall not be required for terminations on components that have been previously evaluated for field wiring.

8.3.18.2 Damage shall be considered to have occurred if the base insulating material breaks or cracks; if bosses, recesses, or other means to prevent turning do not perform their intended function; if straps or bus bars bend or twist; or if members move at electrical joints so as to reduce spacings to an unacceptable degree or otherwise impair the electrical connection. Minor chipping or flaking of brittle insulating material or momentary flexing of metallic members without permanent deformation shall be acceptable.

8.3.19 Comparative deflection test

As required by Clauses 8.2.1.4 and 8.2.2.4, a barrier or enclosure shall be tested in accordance with Clause 9.19. The resulting deflection of the test piece shall be not less than that of a reference sheet-metal enclosure or barrier of the maximum length and width constructed of the minimum required sheet metal thickness.

8.3.20 Auto-transformer starter overload test

An autotransformer starter or a reactor starter shall show no resultant flame or molten particles from either transformer or reactor windings when tested in accordance with Clause 9.20. If the windings are oil immersed, the oil shall not overflow the containing case.

8.3.21 Insulating barrier dielectric test

As required by Clauses 8.2.28.2 and 8.2.28.3, a barrier or liner shall be tested in accordance with Clause 9.21. The barrier or liner shall show no signs of dielectric breakdown during the test.

8.3.22 Short-circuit performance – main and feeder units

After a main or feeder unit has been tested in accordance with Clause 9.23, the results shall be considered acceptable if the unit complies with the acceptance criteria shown in Table 32.

8.3.23 Dielectric voltage-withstand performance (after short-circuit test – main and feeder units)

The main and feeder unit samples that have been subjected to the short-circuit test shall withstand the test potential without breakdown when tested in accordance with Clause 9.24.

9 Motor control center tests

9.1 General

The performance of a motor control center shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Clause 9. See Table 34 for a summary of performance and tests. See Table 35 for test sequence.

9.2 Calibration tests

9.2.1 Individual combination motor control units shall be subjected to overload relay calibration tests.

9.2.2 When tested at an ambient temperature of 40 °C (104 °F), an overload relay shall operate

a) ultimately when carrying 100 % of the current element rated tripping current;

b) within 8 min when carrying 200 % of the current element rated tripping current; and

c) within

1) 20 s when carrying 600 % of the current element rated tripping current; or

2) 10 s for a Class 10 relay and 30 s for a Class 30 relay if the class of the relay is marked on the relay or on the controller with which the overload relay is used. (Class designations in excess of 30 s may be used, in which case the tripping time in seconds shall be equal to the numerical class marking.)

9.2.3 If an adjustable relay covers several tripping current ratings, the relay shall comply with the above requirements for each separate rating.

9.2.4 The test shall be conducted with the unit located at the bottom of the vertical section and without any units mounted above. A section of less than standard height, sufficient to house the unit under test, may be used instead of a complete section.

9.3 Temperature-rise tests

9.3.1 The equipment shall be tested so that each current-carrying component carries the maximum rated current. More than one temperature test can be required to test various configurations of current-carrying parts of sections and units at their maximum rating. See Clause 9.3.7.

9.3.2 During the test, the section or sections shall be mounted as in service, with a unit mounted in the top position. No other unit needs to be installed, but all doors and covers shall be in place, and unused openings shall be closed. See Table 29, item 1a.

9.3.3 As an alternate test, the section or sections shall be mounted as in service, with a test unit mounted in the top position. The remainder of the section shall be filled with feeder units sized and operated to fully load the vertical bus. All units shall be run at their ratings. All doors and covers shall be in place, and unused openings closed. See Table 29, item 1b.

9.3.4 The test assembly shall consist of a section or sections including a sufficient length of horizontal bus to determine the maximum temperature of the bus, including the splice bus between sections. Incoming line connections shall be made in the intended manner, and jumper connections shall be such as to minimize the heat loss from the bus.

9.3.5 A motor control center shall be tested with a minimum of 1.2 m (4 ft) of wire attached to each field-wiring terminal. Incoming supply conductors shall be of the smallest size having an ampacity of at least 100 % of the bus rating. The wire to be used at the units shall be of the smallest size having an ampacity, as specified in Table 18, of at least 125 % of the test current for motor loads and at least 100 % for other loads. If the terminal will not receive the size of wire required for testing in accordance with Clause 9.3.7, the maximum allowable wire size shall be used.

9.3.6 The test shall be conducted with actual fuses installed in fuseholders or with dummy fuses for

a) plug fuses;

b) Class CC, G, H, K, and R fuses, HRC Form II; or

c) 0 to 200 A Class CF and J fuses.

If actual fuses are used for testing of Class H fuseholders, dual element time-delay Class K5 or RK5 fuses shall be used. For combination motor control units, the fuse shall have a maximum ampere rating according to the manufacturer's recommendations, if provided. When not specified, the fuse shall be sized in accordance with the applicable country's electrical installation code.

9.3.7 For a combination motor control unit, and for a motor control unit rated over 600 V, the temperature test shall be conducted using the maximum full-load current specified in the manufacturer's table.

9.3.8 To determine whether the motor control center complies with the temperature test requirements, the device shall be operated under normal conditions and, except as noted in Clause 9.3.11, shall carry its rated current continuously until temperatures are constant. Other than as noted in Clause 9.3.7, the rated current for a horsepower-rated device shall be as specified in Table 15 and Table 16.

9.3.9 Jumpers connected to a bus in order to complete a test circuit shall have a cross-sectional area equal to or less than that of the bus.

9.3.10 A motor control center section containing a transformer or transformers with a total applied rating in excess of 10 kVA, or heating elements with a total applied rating exceeding 250 W, shall be tested in

accordance with Table 29. However, a heating element controlled by a thermostat set at 40 °C (104 °F) or less shall not require a temperature rise test.

9.3.11 A low-potential source of supply may be used for temperature tests on parts other than coils and electronic equipment. The tests on all parts shall be conducted simultaneously, as the heating of one part can affect the heating of another part. Some electronic equipment may be tested with low-potential sources after consideration of all heating effects.

9.3.12 Tests shall be conducted at an ambient temperature within the range of 10 °C to 40 °C.

9.3.13 The acceptability of insulating materials, other than those specified in Table 29, shall be determined with respect to properties such as flammability, arc resistance, and the like, based on an operating temperature equal to the measured temperature rise plus 40 °C.

9.3.14 Ambient temperature shall be determined by taking the average of the readings of three thermometers or thermocouples placed as follows:

a) level with the top of the motor control center;

b) 305 mm (12 in) above the bottom of the motor control center;

c) midway between the locations in items a) and b).

The thermometers or thermocouples shall be placed 914 mm (36 in) from the motor control center and in locations unaffected by drafts caused by the motor control center or appreciable radiation from the equipment. If the ambient temperature is subject to variations that can result in errors in measuring the temperature rise and if thermometers are used to determine the ambient temperatures, the thermometers shall be immersed in a liquid such as oil in a heavy metal cup.

9.3.15 The temperature of a coil shall be determined by the change-of-resistance method (see Clause 9.3.17). All other temperatures shall be measured by means of thermocouples in accordance with Clause 9.3.16.

9.3.16 Temperatures shall be measured by thermocouples consisting of wires not larger than 0.20 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG). When thermocouples are used in determining temperatures in electrical equipment, the common practice is to employ thermocouples consisting of 0.05 mm^2 (30 AWG) iron and constantan wire and a potentiometer-type instrument; such equipment shall be used whenever referee temperature measurements by thermocouples are necessary.

9.3.17 The change-of-resistance method for temperature measurement as specified in Clause 9.3.15 consists of the calculation of the temperature rise of a winding using the following equation:

$$\Delta t = \frac{r_2}{r_1}(k + t_1) - (k + t_2)$$

where

ΔT = the temperature rise of the winding in °C;

r_1 = is the resistance of the coil at the beginning of the test in ohms;

r_2 = the resistance of the coil at the end of the test in ohms (see Clause 9.3.18);

k = 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors shall be determined;

t_1 = the ambient temperature in °C at the beginning of the test;

t_2 = the ambient temperature in °C at the end of the test.

9.3.18 As it is generally necessary to de-energize the winding before measuring r_2, the value of r_2 may 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 can be plotted and extrapolated to give the value of r_2 at shutdown.

9.3.19 A temperature shall be considered to be constant when three successive readings, taken not less than 15 min apart, are constant within 1K .

9.3.20 A thermocouple junction and adjacent thermocouple lead wire shall be securely held in good thermal contact with the surface of the material the temperature of which is being measured. In most cases, adequate thermal contact will result from securely taping or cementing the thermocouple in place, but if a metal surface is involved, brazing or soldering the thermocouple to the metal can be necessary.

9.4 Overvoltage and undervoltage test

9.4.1 The voltage for conducting the test shall be applied on the primary side of the control-circuit transformer.

9.4.2 The electromagnet shall first be energized under the conditions of the temperature test until constant coil temperatures are observed. The control circuit voltage shall then be reduced to 90 % of the unit rated voltage. The control circuit shall then be opened and closed several times to determine if full closure of the armature results.

9.4.3 The control circuit voltage shall be increased to 110 % of the rated unit primary voltage, until constant temperatures are observed using the thermocouple method. The voltage shall then be rapidly reduced to rated unit voltage and the control circuit shall be immediately opened and closed several times to determine if full closure of the armature results.

9.4.4 An electromagnet intended for intermittent duty shall be tested to determine whether it complies with the requirements in Clauses 9.4.2 and 9.4.3 for the time rating specified. If resistance is inserted into the electromagnet circuit after closing of the contactor, this resistance shall be included in the circuit when the coil is energized under temperature test conditions.

9.5 Dielectric voltage-withstand tests (after temperature-rise test or overvoltage/undervoltage test)

9.5.1 The motor control center shall be subjected to a 50 or 60 Hz essentially sinusoidal potential as follows:

a) The applicable voltage shall be

1) 500 V for devices rated 50 V or less;

2) 1 000 V plus twice the maximum rated voltage for devices rated 51 to 750 V; or

3) 2 000 V plus 2.25 times the rated voltage for devices rated 751 to 1 000 V.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

b) The applicable voltage shall be applied for 1 min between

1) uninsulated live parts and the enclosure with the disconnecting means and contactor open;

2) uninsulated live parts and the enclosure with the disconnecting means and contactor closed;

3) terminals of opposite polarity with the disconnecting means and contactor closed;

4) uninsulated live parts of different circuits.

9.5.2 If a watt-hour meter socket base incorporates spacings less than those shown in Table 19, the test potential applied to it shall be 10 times the voltage rating of the motor control center section or unit, but not less than 5 000 V.

9.5.3 With reference to Clause 9.5.1, a transformer, a coil, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during the test in item b).

9.5.4 If a barrier or liner is employed to insulate an exposed metal part, the device shall withstand the potential specified in Clause 9.5.1 between current-carrying parts and the exposed dead metal parts. See Clause 8.2.28.2.

9.5.5 If a motor control center involves a meter or meters, such instruments shall be disconnected from the circuit and the complete device subjected to a dielectric voltage-withstand test as described in Clauses 9.5.1 to 9.5.4. The meter or meters shall then be tested separately for dielectric voltage withstand, with an applied potential of 1 000 V for an ammeter, and 1 000 V plus twice rated voltage for any other instrument having a potential circuit.

9.5.6 An ac test potential shall be supplied from a 500 VA or larger capacity testing transformer, the output voltage of which can be varied. The applied potential shall be increased from zero at an essentially uniform rate and as rapidly as is consistent with its value being correctly indicated by the voltmeter until the required test value is reached, and shall be held at that level for 1 min. The voltage shall then be reduced to zero at the same uniform rate. A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter to measure the applied output potential directly.

9.6 Current-withstand test

9.6.1 A Type D combination motor controller shall be tested at currents of 600 and 1 000 % of the full-load motor-running current.

9.6.2 A sufficient number of representative samples shall be selected to cover the possible combinations of overload relays, current elements, and instantaneous-circuit-breaker trip coils.

9.6.3 Each test sample shall be connected with wire sized in accordance with Table 18, based on the full-load, motor current ratings found in Table 15, Table 16 and Table 17. The instantaneous-trip circuit-breaker shall be set to its maximum value, or its trip mechanism shall be defeated, or jumpered if necessary, so that the test can be continued until operation of the overload relay opens the contactor. The test may be conducted using a low-voltage electrical supply source and with all poles connected in series. The test shall be conducted at normal room temperature. The 600 % test shall be followed by the 1 000 % test as quickly as the overload mechanism can be reset.

9.7 Dielectric voltage-withstand tests (after current-withstand test)

Dielectric voltage-withstand tests shall be performed as specified in Clause 9.5.

9.8 Contactor overload test

9.8.1 When required by Clause 8.3.8, a contactor shall be subjected to a test that shall consist of 3 breaking operations of a test current of 1 000 % of full-load motor current at rated voltage as follows:

a) 40 to 50 % power factor at rated voltage for ac contactors; and

b) non-inductive, resistive load for dc contactors.

9.8.2 The wire used for this test shall have an ampacity, as specified in Table 18, of at least 125 % of the maximum full-load motor current or at least 100 % for other loads.

9.8.3 The overload test or tests shall cover the conditions of maximum interrupting values of voltage, power, and current.

9.8.4 Tests on equipment having an alternating-current rating shall be conducted using a circuit having a frequency of 25 to 60 Hz.

9.8.5 Air core reactors or non-saturated iron core reactors shall be used to obtain the reactive power factor specified in Clause 9.8.1. Air core reactors may be connected in parallel. Iron core reactors shall be connected in series. A reactor shall not be connected in parallel with a resistor. However, an air core reactor in any phase may be connected in parallel with a resistor (RSH) if the resistor power consumption is approximately 1 % of the total power consumption in the phase calculated in accordance with the following formula:

$$R_{SH} = 100\left(\frac{1}{PF} - PF\right)\frac{E}{I}$$

where

PF = power factor;

E = closed-circuit phase voltage;

I = phase current.

9.8.6 Except as specified in Clause 9.8.7, the closed test circuit voltage shall be 100 to 110 % of the overload test voltage specified in Table 41.

9.8.7 For a motor controller rated more than 18.6 kW output (25 horsepower) or a magnetically operated switch rated more than 100 A, the open-circuit voltage shall be as much above the rated voltage as the closed-circuit voltage is below the rated voltage unless such adjustment results in the open-circuit voltage being more than 110 %. In that case, the test shall be conducted using whatever closed-circuit voltage is obtained when the open-circuit voltage is 110 % of the rated voltage. However, the capacity of the supply circuit need not be greater than that of a circuit that is considered to be acceptable for the short-circuit test.

9.8.8 The test cycle times shall be as follows

a) 1 s ON for a non-reversing controller;

b) 1 s FORWARD and 1 s REVERSE for a reversing controller;

NOTE If it is determined that, for a duration less than 1 s, the device conducts the test current without interrupting the circuit or being adversely affected by heat, and the device contacts are properly seated before the break is initiated, as confirmed by oscilloscopic or oscillographic measurements, the ON time may be reduced to that duration.

c) OFF time shall be 9 s for non-reversing controllers rated 499 A or less;

d) OFF time shall be 8 s for reversing controllers rated 499 A or less;

e) OFF time shall be 120 s maximum for controllers rated 500 to 1499 A;

f) OFF time shall be 240 s maximum for controllers rated 1 500 A or greater.

9.8.9 During the test, the enclosure shall be connected through a 30 A non-time-delay cartridge fuse to the electrical test circuit pole considered least likely to strike to ground.

9.8.10 Except where poles are marked for same polarity, all devices having two or more poles shall be tested with opposite polarity between two adjacent poles.

9.8.11 During tests on multi-pole devices for use in opposite-polarity applications, all unused poles shall be connected electrically to the enclosure.

9.8.12 Unless a device is provided with a wiring diagram or equivalent marking indicating the number of poles to be used to control the load, the device shall be tested using one pole to control single-phase or direct-current loads and using two poles to control polyphase loads.

9.9 Dielectric voltage-withstand test (after contactor overload test)

A dielectric voltage-withstand test shall be conducted as described in Clause 9.5, except that only the contactor shall be subjected to the test.

9.10 Short-circuit tests – bus structure

9.10.1 AC-rated motor control centers

Representative ac-rated motor control center samples, as selected according to Clause 9.10.3, shall be tested for the short-circuit current rating selected from Table 3. The test shall be conducted for not less than 3 electrical cycles unless the short-circuit current rating of the section is dependent upon a specific integral or separate overcurrent-protective device and the section is marked in accordance with Clause 6.3.9.

9.10.2 DC-rated motor control centers

Representative dc-rated motor control center samples, as selected according to Clause 9.10.3, shall be tested on a resistive dc circuit or tested in accordance with Clause 9.10.1. The test duration shall be not less than 0.05 s unless the short-circuit current rating of the section is dependent upon a specific integral or separate overcurrent-protective device and the section is marked in accordance with Clause 6.3.9.

9.10.3 Motor control center bus – sample selection and preparation

9.10.3.1 A motor control center assembly selected for bus-bar withstand tests shall represent the strongest and weakest bus bar and bracing structures for the rating and configuration being tested.

9.10.3.2 Representative samples shall be tested to determine the performance of each principal bus configuration or cable arrangement, or both.

9.10.3.3 In choosing representative samples, the following factors shall be considered

a) bracing structure, if different, for each rating;

b) material and cross-sectional configuration of each bus-bar structure;

c) weakest bus-bar structure that can most easily result in bus-bar distortion;

d) strongest bus-bar structure that can transmit the maximum forces to the bracing;

e) various incoming bus and terminal configurations provided;

f) covers, doors, and filler plates shall not be required to be in place during the test unless located within a distance of 51 mm (2 inches) to the bus.

9.10.4 Horizontal bus

9.10.4.1 The sample for each test shall include the horizontal bus and its associated splice bus.

9.10.4.2 The horizontal bus under test shall be short-circuited to cause short-circuit currents to pass through the splice bus and the complete horizontal bus. Short-circuit current shall not pass through the vertical bus unless it is necessary to feed the horizontal bus.

9.10.4.3 The horizontal bus shall be short-circuited directly by bus bars or flexible conductors of minimum length and of at least the ampacity of the horizontal bus bars.

9.10.5 Vertical bus

9.10.5.1 The sample for each test shall consist of a section with representative buses for the connection of motor control center units.

9.10.5.2 A unit shall be installed in the normal manner at the weakest point of the bus.

9.10.5.3 The vertical bus under test shall be short-circuited at the end farthest from the source to cause fault current to pass through the entire bus. The section bus shall be short-circuited directly by bus bars or by flexible conductors of minimum length and having an ampacity not less than that of the vertical bus bars.

9.10.6 Branch circuit connection

9.10.6.1 If the branch circuit device used in this test is a circuit breaker, the field wiring load terminals shall be short-circuited by cable having a length of 1.2 m (4 ft) per terminal and an ampacity, as specified in Table 18, no less than the rating of the circuit breaker. The cable may be lashed outside the enclosure to prevent whipping during the test. The load terminals cables or the instrument shunts may be short-circuited by bus.

9.10.6.2 If the branch circuit device used in the test is a fusible switch, cable having a length of 1.2 m (4 ft) per terminal and an ampacity, as specified in Table 18, no less than the rating of the switch shall be run from each field wiring load terminal to the test fuses located outside the motor control center. The load terminals of the test fuses or the instrument shunts shall be short-circuited by a bus bar. All load cables may be lashed together or braced outside the enclosure to prevent whipping during the test. A copper bus bar or tube (dummy fuse), as described in Clause 9.10.6.3, shall be installed in each fuseholder of the switch under test.

9.10.6.3 The copper bus bar or tube shall have a cross-section no less than that of the blade or ferrule of the fuse that the fuseholder is intended to accommodate. Each bar or tube may be individually reinforced to enable it to withstand the short-circuit forces. A bar or tube shall be secured in place in the same manner as a fuse is secured in intended service.

9.10.7 Test circuit calibrations

9.10.7.1 Except as permitted in Clause 9.10.7.3, the available rms symmetrical or dc current shall be determined at the line terminals of the separate main device (see Clauses 9.10.8.3 and 9.10.8.4) or, if no separate main device is used, at the line terminals of the motor control center.

9.10.7.2 When the physical arrangement requires the test leads between the separate main device or test station terminal and the motor control center line terminals to be longer than 2.4 m (8 ft), the additional length of leads shall be included in the circuit calibration.

9.10.7.3 As an alternative, when the test leads (from the load terminals of the separate main device or from the test station to the motor control center line terminals) are no longer than 2.4 m (8 ft), and if

a) the circuit is rated 25 000 A or less, the available current may be determined at the test-station terminals or the line terminals of the separate main device;

b) the circuit is rated between 25 001 and 50 000 A, the maximum available current for the test shall be not less than 5 % higher than the required test current, as determined at the test-station terminals or the line terminals of the separate main device; or

c) the circuit is rated between 50 001 and 200 000 A, the maximum available current for the test shall be not less than 10 % higher than the required test current, as determined at the test-station terminals or the line terminals of the separate main device.

9.10.7.4 The magnitude of the test current and the power factor, where applicable, shall be determined by the applicable requirements in Annex A. The power factor, where applicable, shall be in accordance with Table 36.

9.10.7.5 Short-circuit tests for calibrated circuits shall comply with the applicable recovery voltage requirements in Annex A. For calibrated circuits without overcurrent devices to be used in withstand tests only, the recovery voltage requirements of Annex A shall not apply.

9.10.7.6 The open-circuit voltage at the supply connections is not to be less than 100 % nor more than 105 % of the rated voltage of the motor control center being tested. The supply frequency for ac circuits shall be in the range of 48 to 60 Hz.

NOTE A higher voltage may be employed with the concurrence of those concerned.

9.10.7.7 The available short-circuit current in rms symmetrical A shall not be less than the short-circuit current specified for the test.

9.10.8 Line connections

9.10.8.1 Feeder bus terminals shall be supplied by means of copper cables having the ampacity, as specified in Table 18, based on 75 °C insulation, nearest to but not less than the rating of the horizontal bus. The cables shall enter the motor control center at the line end of the cabinet at a point that will provide the maximum length of unsupported cable within the center enclosure. Line terminals of the pressure wire connector type shall be wired and tightened to the torque specified in items 6 and 17 in Annex C. The cables shall not be braced inside the motor control center enclosure unless the design includes instructions for bracing the conductors as indicated in Clause 6.3.61. The provision for bracing shall not be required to be provided with the center. A cable may be braced as it leaves the enclosure on the supply side.

9.10.8.2 For a motor control center that does not have provision for wire connectors, bus bars of the same ampacity as the horizontal bus may be used for line connections.

9.10.8.3 Line terminals of the pressure wire connector type may be tightened to a torque greater than that specified in items 6 and 17 in Annex C provided the motor control center is marked as specified in Clause 6.3.36. The effect of the increased tightening torque shall be evaluated in accordance with the applicable requirements in items 6 and 17 in Annex C.

9.10.8.4 A motor control center that is designed for either top or bottom cable entry, but not both, and that is marked as indicated in Clause 6.3.48 with a restriction to one or the other type of entry depending on the location of the incoming terminals may be tested with the cables entering the center as instructed by the marking.

9.10.8.5 In a motor control center provided with an integral main protective device, the supply cable shall be connected to the terminals of the motor control center. For an integral main fusible switch, the test fuse mentioned in Clause 9.10.9.4 shall be installed in the main fusible switch. If the size of the test fuse is such that it cannot fit in the fuseholder, an external fuseholder shall be used. The external fuseholder shall be inserted

a) between the load side of the fusible switch and the main bus bar;

b) on the load side of the bus being tested; or

c) on the line side of the fusible switch.

If external fuses are used, a copper bus or tube (dummy fuse) shall be installed in each fuseholder of the main fusible switch. The combined length of supply cable and all other leads, other than the leads on the load side of a unit, shall be part of the calibrated circuit or shall be in accordance with Clause 9.10.8.7.

9.10.8.6 If a separate main device is used, the method of line connection shall be as illustrated in Figure 8. In the case of a separate fusible main, fuses shall be installed in an external fuseholder, as described in Clause 9.10.9.3 and as shown in Figure 9. The main device line terminals shall be connected to the test-station terminals by cable that is part of the calibrated circuit or of the length specified in Clause 9.10.8.7. The combined length of each cable (including the line, external fuseholder, and connections between separate main device and the motor control center) shall not exceed the length specified in Clause 9.10.8.7 by more than 2.4 m (8 ft) unless the excess is part of the calibrated circuit. See Clause 9.10.7.2.

9.10.8.7 The length of the supply conductors shall not exceed 2.4 m (8 ft) per terminal unless the excess length is included in the test circuit calibration as specified in Clause 9.10.7.2.

9.10.9 Protective devices

9.10.9.1 Protective devices are optional for the short-circuit test of the bus assembly. See Clauses 9.10.1, 9.10.2 and 9.10.10.1.

9.10.9.2 A circuit-breaker having adjustable-trip features shall have all adjustments set at the maximum current and time setting.

9.10.9.3 Each test fuse shall have such characteristics that, if tested on a single-phase circuit in accordance with the requirements for the class of fuse used in the motor control center, it permits a let-through current, I_P, and clearing, I^2t, not less than the corresponding values established for the class and for the ampere rating of the largest fuse intended for use in the fuseholder.

9.10.9.4 For a motor control center intended for use with a Class RK1 or RK5 fuse, the test fuse shall represent the Class RK5 fuse. To obtain the required values of these characteristics, it is sometimes necessary to employ a fuse of different class or having a current rating greater than that of the fuse the fuseholder accommodates.

9.10.9.5 With regard to Clause 9.10.9.4, the values of I_P and I^2t shall be determined at the voltage rating of the fuse.

9.10.9.6 With regard to Clause 9.10.9.4, with the concurrence of those concerned, the determination of I_P and I^2t may be made at the voltage rating of the motor control center.

9.10.10 Short-circuit withstand procedures – bus structure

9.10.10.1 When an integral or separate overcurrent-protective device limits the duration of the short circuit test, the test may be less than three cycles (0.05 s for dc); otherwise, the duration of the test shall be three cycles (0.05 s for dc).

9.10.10.2 Except as noted in Clause 9.10.10.3, controlled closing shall be used in all ac tests as specified in Table 37.

9.10.10.3 For a 3-phase short-circuit test involving an overcurrent device, random closing may be used.

9.10.10.4 The 3-phase tests shall be considered to cover single-phase ratings of the same ampacity.

9.10.10.5 The motor control center shall be mounted and supplied as in a normal installation. All unused openings, other than ventilation openings, within a distance of 51 mm (2 inches) to the bus, shall be closed.

9.10.10.6 For all horizontal bus and vertical bus withstand tests, the enclosure shall be connected through a 30 A, non-time-delay 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 rated voltage of the equipment being tested. This connection shall be made on the load side of the limiting impedance by a 5.3 mm^2 (10 AWG) copper wire that is 1.2 to 1.8 m (4 to 6 ft) long.

9.10.10.7 The test circuit shall be closed on the motor control center.

9.10A Short-time current tests – bus structure

9.10A.1 AC-rated motor control centers

Representative ac-rated motor control center samples, as selected according to Clause 9.10A.3, shall be tested for the short-time current rating selected from Table 3. The test shall be conducted for not less than the time specified.

9.10A.2 DC-rated motor control centers

Representative dc-rated motor control center samples, as selected according to Clause 9.10A.3, shall be tested on a resistive dc circuit or tested in accordance with Clause 9.10A.1. The test duration shall be not less the time specified.

9.10A.3 Motor control center bus – sample selection and preparation

9.10A.3.1 A motor control center assembly selected for short-time current rating tests shall represent the strongest and weakest bus bar and bracing structures for the rating and configuration being tested.

9.10A.3.2 Representative samples shall be tested to determine the performance of each principal bus configuration or cable arrangement, or both.

9.10A.3.3 In choosing representative samples, the following factors shall be considered:

a) bracing structure, if different, for each rating;

b) material and cross-sectional configuration of each bus-bar structure;

c) weakest bus-bar structure that can most easily result in bus-bar distortion;

d) strongest bus-bar structure that can transmit the maximum forces to the bracing;

e) various incoming bus and terminal configurations provided; and

f) covers, doors, and filler plates shall not be required to be in place during the test unless located within a distance of 51 mm (2 in) to the bus.

9.10A.4 Horizontal bus

9.10A.4.1 The sample for each test shall include the horizontal bus and its associated splice bus.

9.10A.4.2 The horizontal bus under test shall be short-circuited to cause short-circuit currents to pass through the splice bus and the complete horizontal bus. Short-circuit current shall not pass through the vertical bus unless it is necessary to feed the horizontal bus.

9.10A.4.3 The horizontal bus shall be short-circuited directly by bus bars or flexible conductors of minimum length and of at least the ampacity of the horizontal bus bars.

9.10A.5 Vertical bus

9.10A.5.1 The sample for each test shall consist of a section with representative buses for the connection of motor control center units.

9.10A.5.2 A unit shall be installed in the normal manner at the weakest point of the bus.

9.10A.5.3 The vertical bus under test shall be short-circuited at the end farthest from the source to cause fault current to pass through the entire bus. The section bus shall be short-circuited directly by bus bars or by flexible conductors of minimum length and having an ampacity not less than that of the vertical bus bars.

9.10A.6 Test circuit calibrations

9.10A.6.1 Except as permitted in Clause 9.10A.6.3, the available rms symmetrical or dc current shall be determined at the line terminals of the motor control center.

9.10A.6.2 When the physical arrangement requires the test leads between the test station terminal and the motor control center line terminals to be longer than 2.4 m (8 ft), the additional length of leads shall be included in the circuit calibration.

9.10A.6.3 As an alternative, when the test leads (from the test station to the motor control center line terminals) are no longer than 2.4 m (8 ft), and if

a) the circuit is rated 25 000 A or less, the available current may be determined at the test-station terminals;

b) the circuit is rated between 25 001 and 50 000 A, the maximum available current for the test shall be not less than 5 % higher than the required test current, as determined at the test-station terminals; or

c) the circuit is rated between 50 001 and 200 000 A, the maximum available current for the test shall be not less than 10 % higher than the required test current, as determined at the test-station terminals.

9.10A.6.4 The magnitude of the test current and the power factor, where applicable, shall be determined by the applicable requirements in Annex A. The power factor, where applicable, shall be in accordance with Table 36.

9.10A.6.5 The open-circuit voltage at the supply connections shall not be less than 100 % nor more than 105 % of the rated voltage of the motor control center being tested. The supply frequency for ac circuits shall be in the range of 48 to 60 Hz.

NOTE A higher voltage may be employed with the concurrence of those concerned.

9.10A.6.6 The available short-circuit current in rms symmetrical A shall not be less than the short-time current specified for the test.

9.10A.7 Line connections

9.10A.7.1 Incoming supply terminals shall be supplied by means of copper cables having the ampacity, as specified in Table 18, based on 75 °C insulation, nearest to but not less than the rating of the horizontal bus. The cables shall enter the motor control center at the line end of the cabinet at a point that will provide the maximum length of unsupported cable within the center enclosure. Line terminals of the pressure wire connector type shall be wired and tightened to the torque specified in items 6 and 17 in Annex C. The cables shall not be braced inside the motor control center enclosure unless the design includes instructions for bracing the conductors as indicated in Clause 6.3.61. The provision for bracing shall not be required to be provided with the center. A cable may be braced as it leaves the enclosure on the supply side.

9.10A.7.2 For a motor control center that does not have provision for wire connectors, bus bars of the same ampacity as the horizontal bus may be used for line connections.

9.10A.7.3 Line terminals of the pressure wire connector type may be tightened to a torque greater than that specified in items 6 and 17 in Annex C provided the motor control center is marked as specified in Clause 6.3.36. The effect of the increased tightening torque shall be evaluated in accordance with the applicable requirements in items 6 and 17 in Annex C.

9.10A.7.4 A motor control center that is designed for either top or bottom cable entry, but not both, and that is marked as indicated in Clause 6.3.48 with a restriction to one or the other type of entry depending on the location of the incoming terminals may be tested with the cables entering the center as instructed by the marking.

9.10A.7.5 In a motor control center provided with an integral low voltage power circuit breaker, the supply cable shall be connected to the terminals of the motor control center.

9.10A.7.6 The length of the supply conductors shall not exceed 2.4 m (8 ft) per terminal unless the excess length is included in the test circuit calibration as specified in Clause 9.10.7.2.

9.10A.8 Short-time current test procedures – bus structure

9.10A.8.1 The duration of the test shall be not less than the rated short-time current duration as specified in 5.4.4.

9.10A.8.2 Controlled closing shall be used in all ac tests as specified in Table 37.

9.10A.8.3 The 3-phase tests shall be considered to cover single-phase ratings of the same ampacity.

9.10A.8.4 The motor control center shall be mounted and supplied as in a normal installation. All unused openings, other than ventilation openings, within a distance of 51 mm (2 inches) to the bus, shall be closed.

9.10A.8.5 For all horizontal bus and vertical bus withstand tests, the enclosure shall be connected through a 30 A, non-time-delay 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 rated voltage of the equipment being tested. This connection shall be made on the load side of the limiting impedance by a 5.3 mm^2 (10 AWG) copper wire that is 1.2 to 1.8 m (4 to 6 ft) long.

9.10A.8.6 The test circuit shall be closed on the motor control center.

9.11 Dielectric voltage-withstand test (after short-circuit test – bus structure)

9.11.1 A motor control center bus assembly that has been subjected to the short-circuit withstand test shall withstand the application of 50 or 60 Hz essentially sinusoidal potential for 1 min without breakdown. The test potential shall be applied

a) between uninsulated live parts of opposite polarity;

b) between an uninsulated live part and the enclosure.

9.11.2 The test potential shall be twice the voltage at which the short-circuit test was conducted, but not less than 900 V.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.11.3 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.11.4 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

9.11A Dielectric voltage-withstand test (after short-time current test – bus structure)

9.11A.1 A motor control center bus assembly that has been subjected to the short-time withstand test shall withstand the application of 50 or 60 Hz essentially sinusoidal potential for 1 min without breakdown. The test potential shall be applied:

a) between uninsulated live parts of opposite polarity; and

b) between an uninsulated live part and the enclosure

9.11A.2 The test potential shall be twice the voltage at which the short-time current test was conducted, but not less than 900 V.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.11A.3 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.11A.4 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

9.12 Short-circuit (standard-level) tests for motor control center units other than main and feeder units

9.12.1 Testing requirements

9.12.1.1 Short-circuit tests shall be conducted on representative units mounted in their intended manner within motor control center vertical sections, except where the unit contains only control-circuit components protected by a short-circuit protective device.

9.12.1.2 A short-circuit test shall be conducted on a combination controller in accordance with Clause 9.12.6.2.

9.12.1.3 Testing with inverse-time circuit-breakers shall not be required when it is shown that the let-through energy, I^2t, and peak let-through current, I_p, of the inverse-time circuit-breakers is less than that of the fuse with which the product has been tested.

9.12.1.4 After each short-circuit operation, the contacts of the motor control devices or the entire motor control device may be replaced and new current elements may be installed in the overload relay. The same sample may be used provided that no additional impedance is introduced. If an overload relay employs non-interchangeable current elements, the entire overload relay may be replaced.

9.12.1.5 Alternating-current tests shall verify ac ratings only. Direct-current tests shall verify dc ratings only. See Annex A, Clause A2, for ac circuit calibration. See Annex A, Clause A3, for dc circuit calibration.

9.12.1.6 Incoming line circuit connections and calibrations shall be made according to Clause 9.10.7 and 9.10.8.

9.12.2 Sample selection and preparation

9.12.2.1 Units shall be installed in a location as close as practicable to the motor control center incoming terminals.

9.12.2.2 A unit having the smallest dimensions and the least provision for pressure relief shall be selected. Consideration shall also be given to the location of arcing components in relation to other components.

9.12.2.3 The unit door shall be held closed only by the intended latch mechanism and securement means.

9.12.3 Load terminal connections

9.12.3.1 The load terminal connections shall be made with conductors of insulated copper wire. For combination motor control units, each conductor shall have an ampacity, as specified in Table 18, of at least 125 % of the maximum full-load motor current rating of the current element.

9.12.3.2 Unless the unit is marked for 75 °C wire only, the wire shall be acceptable for a temperature of 60 °C for a full-load current rating of 100 A or less.

9.12.3.3 The wire shall be acceptable for 75 °C for a full-load current rating greater than 100 A.

9.12.3.4 For 60 °C rated wire, the insulation type shall be T or TW.

9.12.3.5 For 75 °C rated wire, the insulation type shall be THW, THWN, TWH-75, or RW-75.

9.12.3.6 The maximum allowable wire size shall be used where the terminal cannot receive the required size of wire or where the device is marked to limit the size of wire.

9.12.3.7 For a combination motor controller rated more than 150 kW (200 hp), the load connections may be made with bus bar equivalents, in amperes per square inch, for the wires specified in Clauses 9.12.3.1 to 9.12.3.6.

9.12.3.8 *Deleted*

9.12.3.9 *Deleted*

9.12.3.10 The section enclosure shall be connected to the phase of the source of supply that is connected to the pole judged as having the least risk of arcing to ground. For equipment marked 600Y/347 V or 480Y/277 V, or a wye voltage rating greater than 600Y/347 V, the section shall be connected to the center of the wye. The connection shall be made to the load side of the limiting impedance by a solid copper wire that is 1.2 to 1.8 m (4 to 6 ft) long. Continuity shall be verified between the section enclosure and the pole least at risk of arcing to ground, and

a) for circuits with load conductors, 5.3 mm^2 (10 AWG) and larger, this connection shall be made with 5.3 mm^2 (10 AWG) wire;

b) for circuits with load conductors less than 5.3 mm^2 (10 AWG) wire, this connection shall be made with 3.3 or 2.1 mm^2 (12 or 14 AWG) wire, whichever corresponds to the matching load conductor size.

9.12.4 Overload relay

9.12.4.1 Samples for the test shall be selected among motor control devices employing overload relays with the largest and smallest impedance values that can be used with the protective device specified for the motor control device.

9.12.4.2 The maximum number of current elements that can be accommodated by the device shall be in place during each test. Three-phase tests are considered to cover single-phase tests for a device of the same design.

9.12.4.3 A solid state overload relay with line terminals, load terminals, or both shall be selected and tested according to 9.12.4.1 and 9.12.4.2. A pass through overload relay having no main terminals, where power conductors pass through current transformers only, may be evaluated by a single representative sample specified for the motor controller.

9.12.5 Protective devices

9.12.5.1 The fuses used for the tests shall be a type specified by the manufacturer and sized at the maximum value in accordance with Table 28. If the tested fuses are less than the maximum value, a marking as specified in Clause 6.3.71 shall be required.

9.12.5.2 For non-time-delay fuses, if the calculated value of the fuse is between two standard ratings as listed in Clause 9.12.5.3, a fuse of the nearest standard rating shall be used. If the calculated value of the fuse is less than 1 A, a fuse rated 1 A shall be used, and no marking of fuse size is required on the product.

9.12.5.3 Standard ampere ratings for fuses are 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1 000, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000, 5 000, and 6 000.

9.12.5.4 Testing with Class RK5 fuses shall be considered representative of tests using Class H and K fuses.

9.12.5.5 A combination motor controller with specified protective device ratings above and below 600 A shall be tested with a 600 A one-time, non-renewable fuse at 10 000 A, and in addition shall be tested in accordance with Clause 9.23.5.2.

9.12.5.6 An inverse-time circuit-breaker used for the test described in Clause 9.12.5.8 shall be sized at no more than the value determined in accordance with Table 30. If the tested circuit-breaker rating is less than the maximum value, a marking as specified in Clause 6.3.71 shall be required.

9.12.5.7 A sufficient number of overload-relay current elements considered to be representative of the line shall be subjected to short-circuit tests in series with a motor protective device. Representative samples shall be selected on the basis of configuration, material, and resistance.

9.12.5.8 For a combination motor controller unit, short-circuit tests shall be conducted employing current elements of both the maximum and minimum resistances available for use with the overload relay.

9.12.5.9 An inverse-time circuit-breaker with an adjustable magnetic trip shall be adjusted to its maximum setting unless the product is marked to indicate a limit of protection.

9.12.5.10 An instantaneous-trip circuit-breaker mechanism shall be adjusted to 17 times the full-load current or its maximum setting unless the product is marked to indicate a limit of protection.

9.12.6 Test current levels and number of operations

9.12.6.1 Alternating-current rated combination motor controllers shall be subjected to short-circuit currents and power factors listed in Table 31 for given horsepower ratings. Direct-current rated controllers shall be subjected to short-circuit currents with a series resistive-inductive circuit with a time constant in accordance with Table 42.

9.12.6.2 Combination controllers not previously tested to the applicable standard level short-circuit current test requirements as referenced in Annex C, item 10, shall be subjected to the number and type of operations specified in Table 38 and shall meet the performance requirements of Clause 8.3.12. Successive operations shall be conducted by closing the circuit on the test unit (“O” operation) by means of any appropriate switching device, using random closing.

9.12.6.3 *Deleted*

9.12.6.4 If the short-circuit current rating of a fusible unit is higher than the short-circuit current rating of its disconnect switch, the unit shall be subjected to the number and type of operations required by the product standard covering the switch. See Annex C, items 7 and 27.

Clause 9.12.6.4 is not permitted in Canada.

9.12.6.5 Series-rated protective devices shall be acceptable if tested as motor control center units, marked in accordance with Clause 6.3.10, and installed in accordance with the applicable installation codes or standards. See Annex C, items 1 and 7.

9.13 Dielectric voltage-withstand test (after standard-level unit short-circuit test for motor control center units other than main and feeder units)

9.13.1 The motor control center unit shall be subjected to a 50 or 60 Hz essentially sinusoidal potential of twice the rated potential plus 1 000 V applied as follows:

a) between line and load terminals of the protective device assembly with the protective device open (that is, with the circuit-breaker in the tripped position with current limiters in their holders, or with the disconnecting means open and the fuses in their holders, as applicable);

b) between line and load terminals of the disconnecting means with the disconnecting means open (that is, between line terminals of the disconnecting means and the line side of the fuse or current limiter, as applicable);

c) between terminals of opposite polarity with the disconnect switch or circuit-breaker contacts closed;

d) between live parts and the overall enclosure with the disconnect switch or circuit-breaker contacts both open and closed.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.13.2 A motor control center unit may be removed from the motor control center section when conducting the dielectric test described in Clause 9.13.1.

9.13.3 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.13.4 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

9.14 Trip-out test for circuit-breakers (after standard-level unit short-circuit test for other than main and feeder units)

9.14.1 Magnetic trip-out test for circuit-breakers used with Type D and Type E controllers

9.14.1.1 Each pole shall be subjected to a magnetic trip-out test at the setting used during the standard-level unit short-circuit test and shall perform in accordance with the requirements of Clause 8.3.14. The initial test current shall be set at some value below the trip setting and adjusted upward until the breaker trips.

9.14.1.2 The test method may be impulse testing with synchronous closing or with another method that has been found to give accurate indication of the current at the tripping point.

9.14.2 Inverse-time trip-out test for circuit-breakers used with Type C controllers

9.14.2.1 When tested under the conditions specified in Clauses 9.14.2.2 to 9.14.2.8, breakers carrying 200 % of their rated current shall operate within the time limits given in Table 33.

9.14.2.2 Breakers may be mounted in any position unless there are features that can affect their test performance if not mounted in some particular position.

9.14.2.3 The tests may be made at any convenient voltage and with either ac or dc if the breaker is suitable for both. The tests shall be made with ac for a breaker marked for ac only or with dc for a breaker marked for dc only.

9.14.2.4 If breakers are marked specifically for a given frequency, tests shall be conducted at that frequency. If the frequency is not marked, a 48 to 62 Hz supply shall be used.

9.14.2.5 Except as specified in Clause 9.14.2.6, the conductors used in connecting a breaker for the calibration tests shall be of copper, or aluminum if the breaker is marked for use with aluminum conductors only, and not less than 1.2 m (4 ft) in length. The size of the conductor shall be chosen in accordance with Table 18 for 75 °C insulation.

9.14.2.6 For a breaker rated more than 30 A but not more than 125 A, the conductor size shall be based on the temperature rating of the wire as marked on the breaker. Where a dual (60/75 °C) temperature rating is shown, a test shall be conducted for each wire size or for the most adverse one if it can be determined.

9.14.2.7 Each pole of a multipole circuit breaker shall be tested separately.

9.14.2.8 Thermal trip-out tests shall be conducted at room temperature.

9.15 Short-circuit (high-level) test for motor control center units other than main and feeder units

9.15.1 Testing requirements

9.15.1.1 The tests described in Clause 9.15 are optional tests intended to evaluate combination motor control units rated at short-circuit current levels greater than the values given in Table 31.

9.15.1.2 Units containing only control-circuit components with a short-circuit protective device shall not be required to be tested in accordance with Clause 9.15. These units shall be assigned a short-circuit current rating not greater than the interrupting rating of the short-circuit protective device, but not exceeding 100 kA.

9.15.1.3 Units containing combination motor controllers not previously tested to the applicable high current requirements as referenced in Annex C, item 10, shall be tested as outlined in Clauses 9.15.1.6 to 9.15.5.

9.15.1.4 If the interrupting rating of a circuit-breaker in a combination starter is lower than the proposed marked short-circuit current rating of the combination starter in accordance with Clause 6.3.10, the combination shall be evaluated and subjected to the appropriate requirements as described in Annex C, item 7.

9.15.1.5 Units containing combination motor controllers that have been previously tested to the applicable high current requirements referenced in Annex C, item 10, shall be tested as outlined in Clauses 9.15.1.6 to 9.15.5.5 except as modified by Clause 9.15.6.

9.15.1.6 The test circuit shall have the characteristics specified in Table 39.

9.15.1.7 If multiple short-circuit tests are required in accordance with Clause 9.15.5.3, after each short-circuit operation, the contacts of the motor control devices or the entire motor control device may be replaced and new current elements may be installed in the overload relay. The same sample may be used provided that no additional impedance is introduced. If an overload relay employs non-interchangeable current elements, the entire overload relay may be replaced.

9.15.1.8 Alternating-current tests shall verify ac ratings only. Direct-current tests shall verify dc ratings only. See Annex A, Clause A2, for ac circuit calibration. See Annex A, Clause A3, for dc circuit calibration.

9.15.1.9 Incoming line circuit connections and calibrations shall be made in accordance with Clause 9.10.7 and 9.10.8.

9.15.2 Sample selection and preparation

9.15.2.1 A unit having the smallest dimensions and the least provision for pressure relief shall be selected.

9.15.2.2 During the test, the section or sections shall be mounted as in service, with the sample unit mounted in the section. The unit door shall be held closed only by the intended latch mechanism and securement means. No other units need to be installed, but all doors and covers shall be in place, and unused openings shall be closed.

9.15.2.3 The load-terminal connections for motor starter units shall be made with leads of insulated copper wire, each of which has an ampacity, as specified in Table 18, of at least 125 % of the maximum full-load motor-current rating of the current element. Unless the unit is marked for 75 °C wire only, the wire shall be acceptable for a temperature of 60 °C for a full-load current rating of 100 A or less and shall be acceptable for 75 °C for a full-load current rating greater than 100 A. The load-terminal leads shall be connected together. Each load lead shall not be longer than 1.2 m (4 ft).

9.15.2.4 The metal enclosure shall be connected to the phase of the source of supply that is connected to the pole judged as having the least risk of arcing to ground. The connection shall be made to the load side of the limiting impedance by a 5.3 mm^2 (10 AWG) solid copper wire that is 1.22 to 1.83 m (4 to 6 ft) long. Continuity shall be verified between the enclosure and the pole least at risk of arcing to ground.

9.15.2.5 For equipment marked 600Y/347 or 480Y/277 V, or a wye voltage rating greater than 600Y/347V, the enclosure shall be connected to the center of the wye.

9.15.3 Overload relay

9.15.3.1 Samples for the test shall be selected among motor control devices employing the largest and smallest current element that can be used with the protective device specified for the motor control device.

9.15.3.2 The maximum number of current elements that can be accommodated by the device shall be in place during each test. Three-phase tests shall be considered to cover single-phase tests for a device of the same design.

9.15.3.3 A solid state overload relay with line terminals, load terminals or both shall be selected and tested according to 9.15.3.1 and 9.15.3.2. A pass through overload relay having no main terminals, where power conductors pass through current transformers only, may be evaluated by a single representative sample specified for the motor controller.

9.15.4 Protective devices

9.15.4.1 For combination motor control units with circuit-breakers, the protective devices used for the test shall be the largest used in a manufacturer's selection process.

9.15.4.2 For a motor control device or overload relay intended to be used with fuses, the protective devices used for the test shall be sized in accordance with Table 28 and shall be selected as follows:

a) Fuses specified for branch-circuit protection for motor control devices rated over 10 000 A shall be limited to high-interrupting capacity, current-limiting types (e.g., Class CC, CF, G, J, L, R, and T), with the following exception: a motor control device rated 37 kW (50 hp) or less and tested at 10 000 A may specify Class H or K fuses for motor-branch-circuit protection.

b) A motor control device that is required to be used with RK1 or RK5 fuses shall be tested with fuses having I^2t and I_p characteristics for Class RK5 fuses. All references to Class R fuses are intended to mean fuses with energy let-through, I^2t, characteristics of Class RK5 fuses.

c) A Class CC, CF, G, J, L, R, or T fuse shall be selected such that, when tested on a single-phase circuit, the peak let-through current and clearing I^2t are not less than the maximum value established for the fuse that is intended to be used with the controller being tested (see Annex C, items 18 to 26). For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse shall be selected so as to have at least the maximum values of the current corresponding to the marked short-circuit current rating of the motor control device. The following conditions shall apply:

1) a test limiter may be used in place of the fuses;

2) combination motor controller self-protecting control devices shall be provided with integral short-circuit and ground-fault protection.

9.15.4.3 If a test shall be performed on series-connected circuit-breakers, the circuit-breakers shall be selected consistent with their coordination in accordance with the standards for moulded-case circuit-breakers and circuit-breaker enclosures (see of Annex C, item 7).

9.15.5 Procedure for combination controllers not previously tested at high current

9.15.5.1 A combination controller shall be tested according to the requirements in Clauses 9.15.5.2 to 9.15.5.5. The terminals of the test circuit described in Clause 9.10.7 shall be connected together by a copper bar, and the test circuit shall be calibrated as described in Clause 9.10.7 at the maximum available short-circuit current for which the motor control device is rated. The short-circuit current level and rating of the unit shall be one of the values shown in Table 2.

9.15.5.2 The test circuit shall have the characteristics specified in Table 39 for ac circuits and Table 42 for dc circuits.

9.15.5.3 For the short-circuit-closing test (“CO” shot), each switching device of the motor control device shall be closed on the test circuit. There shall be separate tests for each switching device, as specified in Table 40: one in which the disconnecting means, when provided, is closed on the circuit, and a second in which the contactor is closed on the circuit. Complete physical closure of the switching contacts shall not be required to be established. When complete physical closure of the switching contact is established, the closing test on the disconnecting means shall be able to cover the withstand test (“O” shot) on the motor control device, and the closing test on the motor control device shall be able to cover the withstand test on the disconnecting means. To determine whether complete physical closure of the contacts has occurred, the oscillogram of the short-circuit current and voltage traces between circuit initiation and current interruption by the protective device shall be reviewed. A smooth sinusoidal waveform in this area of the trace shall be an indication of complete physical closure.

9.15.5.4 The equipment shall be subjected to the number and type of operations specified in Table 40 and shall comply with Clause 8.3.15. Tests shall be conducted with random closing of the test circuit.

9.15.5.5 When closing the circuit on the equipment ("O" shot), the disconnecting means and the motor control device shall be in the fully closed position.

9.15.6 Procedure for combination motor controllers previously tested at high current

The procedure shall be the same as that outlined in Clause 9.15.5 except the combination motor control unit shall be subjected to a single "O" test with each switching device in the closed position prior to energizing the test circuit.

9.15A Short-time current tests for main, main lug only and feeder units (optional)

9.15A.1 Testing requirements

9.15A.1.1 Short-time current tests shall be conducted on representative units with low voltage power circuit breakers mounted in their intended manner within motor control center vertical sections.

9.15A.1.2 A short-time current test shall be conducted on:

a) main units with low-voltage power circuit breakers in accordance with Clause 9.15A.5.2;

b) feeder units with low-voltage power circuit breakers in accordance with Clause 9.15A.5.2; or

c) main lug only units marked in accordance with Clause 9.15A.5.2.

9.15A.1.3 Alternating-current tests shall verify ac ratings only. Direct-current tests shall verify dc ratings only. See Annex A, Clause A2, for ac circuit calibration. See Annex A, Clause A3, for dc circuit calibration.

9.15A.1.4 Incoming line circuit connections and calibrations shall be made according to Clause 9.10A.6 and 9.10A.7.

9.15A.2 Sample selection and preparation

9.15A.2.1 Feeder units shall be installed in a location as close as practicable to the motor control center incoming terminals.

9.15A.2.2 A unit having the smallest dimensions and the least provision for pressure relief shall be selected. Consideration shall also be given to the location of arcing components in relation to other components. In choosing representative samples, the following factors shall be considered:

a) bracing structure, if different, for each rating;

b) material and cross-sectional configuration of each bus-bar structure;

c) weakest bus-bar structure that can most easily result in bus-bar distortion;

d) strongest bus-bar structure that can transmit the maximum forces to the bracing;

e) various incoming bus and terminal configurations provided; and

f) covers, doors, and filler plates shall not be required to be in place during the test unless located within a distance of 51 mm (2 in) to the bus.

9.15A.2.3 The unit door shall be held closed only by the intended latch mechanism and securement means, if installed.

9.15A.3 Feeder load terminal connections

9.15A.3.1 The load terminal connections of feeder units shall be made with conductors of insulated copper wire.

9.15A.3.2 Unless the unit is marked for 75 °C wire only, the wire shall be acceptable for a temperature of 60 °C for a current rating of 100 A or less.

9.15A.3.3 The wire shall be acceptable for 75 °C for a current rating greater than 100 A.

9.15A.3.4 For 60 °C rated wire, the insulation type shall be T or TW.

9.15A.3.5 For 75 °C rated wire, the insulation type shall be THW, THWN, THW-75, or RW-75.

9.15A.3.6 The maximum allowable wire size shall be used where the terminal cannot receive the required size of wire or where the device is marked to limit the size of wire.

9.15A.3.7 The tests described in Clause 9.15A.5.2 for feeders shall be conducted using 1.2 m (4 ft) of cable, sized in accordance with the rating of the device, connected together at the load side of the unit.

9.15A.3.8 The tests described in Clauses 9.15A.5.2 for mains shall be conducted with the horizontal bus connected together either with shorting bus or with up to 1.2 m (4 ft) of cable sized to the main breaker rating. If shorting bus is used, the 1.2 m (4 ft) of cable may be on the line side. The 1.2 m (4 ft) of cable shall be in addition to the cable specified in Clause 9.10.8.7.

9.15A.3.9 The section enclosure shall be connected to the phase of the source of supply that is connected to the pole judged as having the least risk of arcing to ground. For equipment marked 600Y/347 V or 480Y/277 V, or a wye voltage rating greater than 600Y/347 V, the section shall be connected to the center of the wye. The connection shall be made to the load side of the limiting impedance by a solid copper wire that is 1.2 to 1.8 m (4 to 6 ft) long. Continuity shall be verified between the section enclosure and the pole least at risk of arcing to ground, and:

a) for circuits with load conductors, 5.3 mm^2 (10 AWG) and larger, this connection shall be made with 5.3 mm^2 (10 AWG) wire;

b) for circuits with load conductors less than 5.3 mm^2 (10 AWG) wire, this connection shall be made with 3.3 or 2.1 mm^2 (12 or 14 AWG) wire, whichever corresponds to the matching load conductor size.

9.15A.4 Protective devices

9.15A.4.1 The trip system of the low voltage power circuit breaker shall be disabled or removed, or the main breaker shall be replaced with a dummy.

9.15A.5 Test current levels and number of operations

9.15A.5.1 Alternating-current rated main and feeder units shall be subjected to short-time currents and power factors listed in Table 3 and Table 36. Direct-current rated main and feeder units shall be subjected to short-circuit currents with a series resistive-inductive circuit with a time constant in accordance with Table 3 and Table 42.

9.15A.5.2 The low-voltage power circuit-breaker main and feeder units, and main lug only units, shall be subjected to one withstand operation at the short-circuit current level as marked in accordance with Clause 6.3.14. In no case shall the rating of the unit be greater than the marked short-time rating of the

low-voltage power circuit breaker. Units shall be tested with the power factor in accordance with Table 39 and shall meet the performance requirements of Clause 8.3.12.

9.16 Dielectric voltage-withstand test (after high-level short-circuit test – motor control center units other than main and feeder units)

9.16.1 The combination motor controller unit tested in accordance with Clause 9.15 shall be subjected to the test voltage for 1 min at a 50 or 60 Hz essentially sinusoidal potential, as follows:

a) the unit may be located outside the motor control center;

b) a motor controller may be disconnected during the test;

c) the test potential shall be twice the voltage at which the short-circuit test was conducted, but not less than 900 V;

d) the test voltage shall be applied between a live part and the unit frame with the disconnect switch or circuit-breaker contacts both open and closed;

e) the test voltage shall be applied between the line and load side of the disconnect switch or circuit-breaker contacts with the contacts open.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.16.2 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.16.3 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

9.16A Dielectric voltage-withstand test

9.16A.1 The main and feeder unit shall be subjected to a 50 or 60 Hz essentially sinusoidal potential of twice the rated potential but not less than 900 V:

a) between line and load terminals of the low-voltage power circuit breaker;

b) between terminals of opposite polarity with the low-voltage power circuit breaker; and

c) between live parts and the overall enclosure with the low-voltage power circuit breaker both open and closed.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.16A.2 A withdrawable/plug-in main and feeder unit may be removed from the motor control center section when conducting the dielectric test described in Clause 9.16A.1.

9.16A.3 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.16A.4 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

9.17 Trip-out test for circuit-breakers (after high-level unit short-circuit test other than main and feeder units)

9.17.1 Magnetic trip-out test for circuit-breakers used with Type D and Type E controllers

9.17.1.1 Each pole shall be subjected to a magnetic trip-out test at the setting used during the high-level unit short-circuit test and shall perform in accordance with the requirements of Clause 8.3.17. The initial test current shall be set at some value below the trip setting and adjusted upward until the breaker trips.

9.17.1.2 The test method may be impulse testing with synchronous closing or with another method that has been found to give accurate indication of the current at the tripping point.

9.17.2 Inverse-time trip-out test for circuit-breakers used with Type C controllers

9.17.2.1 When tested under the conditions specified in Clauses 9.17.2.2 to 9.17.2.8, breakers carrying 250 % of their rated current shall operate within the time limits given in Table 33. If the pole under test does not trip within the time indicated in Table 33, the current shall be immediately increased to 400 % of rated current under which condition the pole under test shall trip within 2 additional minutes. This additional 400 % test shall be made on only one pole of a multipole circuit breaker.

9.17.2.2 Breakers may be mounted in any position unless there are features that can affect their test performance if not mounted in some particular position.

9.17.2.3 The tests may be made at any convenient voltage, and with either ac or dc if the breaker is suitable for both. The tests shall be made with ac for a breaker marked for ac only or with dc for a breaker marked for dc only.

9.17.2.4 If breakers are marked specifically for a given frequency, tests shall be conducted at that frequency. If the frequency is not marked, a 48 to 62 Hz supply shall be used.

9.17.2.5 Except as specified in Clause 9.17.2.6, the conductors used in connecting a breaker for the calibration tests shall be of copper, or aluminum if the breaker is marked for use with aluminum conductors only, not less than 1.2 m (4 ft) in length. The size of the conductor shall be chosen in accordance with Table 18 for 75 °C insulation.

9.17.2.6 For a breaker rated more than 30 A but not more than 125 A, the conductor size shall be based on the temperature rating of the wire as marked on the breaker. Where a dual (60/75 °C) temperature rating is shown, a test shall be conducted for each wire size or for the most adverse one, if it can be determined.

9.17.2.7 Each pole of a multipole circuit breaker shall be tested separately.

9.17.2.8 Thermal trip-out tests shall be conducted at room temperature.

9.18 Strength of insulating base and support tests

To determine that an insulating base complies with the requirement, the equipment shall be mounted as intended and may be fitted with a short length of rigid conduit. A short length of field-wiring conductor of rated ampacity shall be routed through the conduit, if fitted, and connected to the terminal. The wiring terminal clamping screw shall be tightened to 110 % of the value of torque specified on the equipment. For equipment marked for use with copper and aluminum conductors, the wire connectors shall be torqued to 110 % of the highest torque value marked for either conductor.

9.19 Comparative deflection test

A force shall be applied at any point on the surface of the enclosure or barrier except for a point on the door or cover, using a flat face of a steel bar 12.7 mm x 12.7 mm (0.5 in x 0.5 in). Force shall be applied to the end, side, and rear walls of each enclosure or barrier. The values of the force and the limit of deflection, both of which shall be measured and recorded, are not specified, but the force on each wall of both the test and reference enclosures shall be sufficient to result in a measurable deflection on the test enclosure.

9.20 Autotransformer starter test

An autotransformer starter or a reactor starter shall have full line voltage applied to the line terminals, and 300 % of the full-load motor-running current at 0.50 maximum power factor shall be drawn from the taps giving 45 to 70 % of normal line voltage. Unless marked to indicate different periods of load and rest, the operating test cycles shall be as follows:

a) for starters rated 200 hp or less, the test shall comprise a duty cycle of 15 s ON and 225 s OFF repeated for a total of 15 cycles in the case of automatically operated starters or for a total of 4 cycles in the case of manually operated starters; and

b) for automatically operated starters rated between 200 and 3 000 hp, the test shall comprise a duty cycle of 30 s ON and 30 s OFF for a total of 3 cycles.

This test may be terminated before the end of the specified period if the autotransformer is prevented from overheating by a reliably operating, nonadjustable thermostat or similar device.

After undergoing the test, the starter shall comply with Clause 8.3.20.

9.21 Insulating barrier dielectric

The barrier material shall be placed between two metal electrodes. The electrodes shall be cylindrical brass or stainless steel rods 6.4 mm (1/4 in) in diameter with edges rounded to a 0.8 mm (1/32 in) radius. The test potential shall be increased to the required test value and shall be maintained for 1 second.

9.22 Factory tests

See Annex F.

9.23 Short-circuit tests for main and feeder units

9.23.1 Testing requirements

9.23.1.1 Short-circuit tests shall be conducted on representative units mounted in their intended manner within motor control center vertical sections.

9.23.1.2 A short-circuit test shall be conducted on:

a) main units (fusible switches and circuit-breakers) in accordance with Clause 9.23.5.3; and

b) feeder units (fusible switches and circuit-breakers) in accordance with Clause 9.23.5.3.

9.23.1.3 Testing with inverse-time circuit-breakers shall not be required when it is shown that the let-through energy, I^2t, and peak let-through current, I_p, of the inverse-time circuit-breakers is less than that of the fuse with which the product has been tested.

9.23.1.4 Alternating-current tests shall verify ac ratings only. Direct-current tests shall verify dc ratings only. See Annex A, Clause A2, for ac circuit calibration. See Annex A, Clause A3, for dc circuit calibration.

9.23.1.5 Incoming line circuit connections and calibrations shall be made according to Clauses 9.10.7 and 9.10.8.

9.23.2 Sample selection and preparation

9.23.2.1 Units shall be installed in a location as close as practicable to the motor control center incoming terminals.

9.23.2.2 A unit having the smallest dimensions and the least provision for pressure relief shall be selected. Consideration shall also be given to the location of arcing components in relation to other components.

9.23.2.3 The unit door shall be held closed only by the intended latch mechanism and securement means.

9.23.3 Load terminal connections

9.23.3.1 The load terminal connections shall be made with conductors of insulated copper wire.

9.23.3.2 Unless the unit is marked for 75 °C wire only, the wire shall be acceptable for a temperature of 60 °C for a current rating of 100 A or less.

9.23.3.3 The wire shall be acceptable for 75 °C for a current rating greater than 100 A.

9.23.3.4 For 60 °C rated wire, the insulation type shall be T or TW.

9.23.3.5 For 75 °C rated wire, the insulation type shall be THW, THWN, TWH-75, or RW-75.

9.23.3.6 The maximum allowable wire size shall be used where the terminal cannot receive the required size of wire or where the device is marked to limit the size of wire.

9.23.3.7 The tests described in Clause 9.24. for feeders shall be conducted using 1.2 m (4 ft) of cable, sized in accordance with the rating of the device, connected together at the load side of the unit.

9.23.3.8 The tests described in Clauses 9.24 for mains shall be conducted with the horizontal bus connected together either with shorting bus or with up to 1.2 m (4 ft) of cable sized to the main breaker rating. If shorting bus is used, the 1.2 m (4 ft) of cable may be on the line side. The 1.2 m (4 ft) of cable shall be in addition to the cable specified in Clause 9.10.8.7.

9.23.3.9 The section enclosure shall be connected to the phase of the source of supply that is connected to the pole judged as having the least risk of arcing to ground. For equipment marked 600Y/347 V or 480Y/277 V, or a wye voltage rating greater than 600Y/347 V, the section shall be connected to the center of the wye. The connection shall be made to the load side of the limiting impedance by a solid copper wire that is 1.2 to 1.8 m (4 to 6 ft) long. Continuity shall be verified between the section enclosure and the pole least at risk of arcing to ground, and

a) for circuits with load conductors, 5.3 mm^2 (10 AWG) and larger, this connection shall be made with 5.3 mm^2 (10 AWG) wire;

b) for circuits with load conductors less than 5.3 mm^2 (10 AWG) wire, this connection shall be made with 3.3 or 2.1 mm^2 (12 or 14 AWG) wire, whichever corresponds to the matching load conductor size.

9.23.4 Protective devices

9.23.4.1 Testing with Class RK5 fuses shall be considered representative of tests using Class H and K fuses.

9.23.4.2 An inverse-time circuit-breaker with an adjustable magnetic trip shall be adjusted to its maximum setting unless the product is marked to indicate a limit of protection.

9.23.5 Test current levels and number of operations

9.23.5.1 Alternating-current rated main and feeder units shall be subjected to short-circuit currents and power factors listed in Table 31 for given horsepower ratings. Direct-current rated main and feeder units shall be subjected to short-circuit currents with a series resistive-inductive circuit with a time constant in accordance with Table 42.

9.23.5.2 Except as required by Clause 9.23.5.3, circuit-breaker and fusible switch main and feeder units shall be subjected to one "O" operation at the short-circuit current level as marked in accordance with Clause 6.3.10. In no case shall the rating of the unit be greater than the marked interrupting rating of the device (fuse or circuit-breaker) except for series-rated protective devices, as specified in Clause 9.23.5.4. Units shall be tested with the power factor in accordance with Table 39 and shall meet the performance requirements of Clause 8.3.12.

9.23.5.3 If the short-circuit current rating of a fusible unit is higher than the short-circuit current rating of its disconnect switch, the unit shall be subjected to the number and type of operations required by the product standard covering the switch. See Annex C, items 7 and 27.

NOTE Clause 9.23.5.3 is not permitted in Canada.

9.23.5.4 Series-rated protective devices shall be acceptable if tested as motor control center units, marked in accordance with Clause 6.3.10, and installed in accordance with the applicable installation codes or standards. See Annex C, items 1 and 7.

9.24 Dielectric voltage-withstand test (after short-circuit tests for main and feeder units)

9.24.1 The main and feeder unit shall be subjected to a 50 or 60 Hz essentially sinusoidal potential of twice the rated potential but not less than 900 V:

a) between line and load terminals of the protective device assembly with the protective device open (that is, with the circuit-breaker in the tripped position with current limiters in their holders, or with the disconnecting means open and the fuses in their holders, as applicable);

b) between line and load terminals of the disconnecting means with the disconnecting means open (that is, between line terminals of the disconnecting means and the line side of the fuse or current limiter, as applicable);

c) between terminals of opposite polarity with the disconnect switch or circuit-breaker contacts closed; and

d) between live parts and the overall enclosure with the disconnect switch or circuit-breaker contacts both open and closed.

NOTE Where it is more convenient to do so, the dielectric strength test may be made by applying a dc voltage instead of an ac voltage, provided that the voltage used is 1.4 times the values specified above.

9.24.2 A main and feeder unit may be removed from the motor control center section when conducting the dielectric test described in Clause 9.24.1.

9.24.3 The test potential shall be supplied from a transformer as detailed in Clause 9.5.6, following the described method of application.

9.24.4 See Clauses 9.5.2 to 9.5.5 for other test details, as applicable.

10 Application

See Annex H.

TABLES

Table 1
Common voltage ratings

(Clause 5.2)

System		Common voltage ratings
Number of phases	**Number of wires**	**Volts**
1	2	120, 240, or 277 ac
1	3	120/240 or 208Y/120 ac
3 (derived from 3-phase, 4-wire system)	3 or 4	208Y/120, 220Y/127,440Y/254, 480Y/277,400Y/217, 600Y/347, or 690Y/400 ac
3	3	120, 240, 480, 600, 690, or 1 000 ac
3	4-wire delta with the neutral at midpoint of one phase	240/120 ac
NA	2	125 dc
	3	125/250 dc
	2	250 dc
	2	500 dc
	2	600 dc
	2	750 dc
	2	800 dc
	2	850 dc

Table 2
Unit short-circuit current ratings

(Clauses 5.4.1 and 9.15.5.1)

RMS symmetrical or dc amperes	
5 000	42 000
7 500	50 000
10 000	65 000
14 000	85 000
18 000	100 000
22 000	125 000
25 000	150 000
30 000	200 000
35 000	

Table 3
Bus structure
Short-circuit and short-time current ratings

(Clauses 5.4.4, 8.3.10, 9.10.1, and 9.10A.1)

RMS symmetrical or dc amperes	
22 000	85 000
25 000	100 000
42 000	125 000
50 000	150 000
65 000	200 000

Table 4
Branch-circuit short-circuit protection – copper conductors

(Clauses 6.3.53 and 8.2.14.2)

Control-circuit wire size, mm^2 (AWG)	Maximum rating of branch-circuit-protective device, amperes	
	Conductors within center enclosure	Conductors outside center enclosure
0.32 (22)	12	3
0.52 (20)	20	5
0.82 (18)	25	7
1.3 (16)	40	10
2.1 (14)	100	45
3.3 (12)	120	60
5.3 (10)	160	90

Table 5
Allowable ampacities of insulated copper conductors inside motor control centers (based on a room ambient temperature of 40 °C)

(Clause 8.2.13.1)

Conductor size, mm^2 (AWG)	Conductors with 90 °C insulation		Conductors with 105 °C insulation	
	In small or nonventilated enclosure	Large ventilated enclosure	In small or nonventilated enclosure	Large ventilated enclosure
0.20 (24)	1	2	1	2
0.32 (22)	2	3	2	3
0.52 (20)	3	4	3	4
0.82 (18)	4	6	4	6
1.3 (16)	6	9	6	9
2.1 (14)	9	13	10	15
3.3 (12)	12	17	15	22
5.3 (10)	18	27	22	35
8.4 (8)	31	47	35	55
13.3 (6)	45	67	52	80
21.2 (4)	61	91	71	108
26.7 (3)	70	104	80	121
33.6 (2)	80	120	90	140
42.4 (1)	94	141	107	164
53.5 (1/0)	110	164	133	190
67.4 (2/0)	128	191	148	221
85 (3/0)	148	221	171	257
107 (4/0)	173	258	200	300

Table 6
Ampacity correction factors for multiple conductor groupings

(Clause 8.2.13.1)

Number of conductors	Correction factor
1 to 3	1.00
4 to 6	0.80
7 to 24	0.70
25 to 42	0.60
43 and more	0.50

Table 7
Marking locations for motor control centers

(Clause 6.3.2)

Clause reference	Required marking[a]	Location[b]
General		
6.2.2, 6.3.5	Tables, diagrams, and electrical rating information other than as specified in Clause 6.2.1	C
6.3.12	"Suitable for use as service equipment." or "Suitable for use as service equipment when not more than two main disconnecting devices are installed."	A (see Clause 6.3.22)
6.3.14	Instructions for installing the bonding means, in sections or units marked "Suitable for use as service equipment."	
6.3.15	"Service disconnect."	see Clause 6.3.15
6.3.17	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."	A
6.3.18	(1) For supplying a fire pump or (2) for an alternate source for legally required standby service or (3) for services where the neutral is not solidly grounded.	A
6.3.19	Similar marking as above except for a motor control center section or unit that has ground-fault protection with only audible or visual signal	A
6.3.23	"Bonded neutral – Must not be disconnected except for testing."	D
6.3.24	Identification of main bonding jumper, grounding electrode conductor terminal, and the neutral disconnect link	D
6.3.37	Identification of Class 1 power supplies and the circuits they supply	C or on or near the circuit terminals (Clause 6.3.37)
6.3.37	Identification of Class 2 power supplies and the circuits they supply	C or on or near the circuit terminals (Clause 6.3.37)
6.3.43	The circuits that are protected by ground-fault protection (main, feeder, or branch)	B or C
6.3.45	"External source connection for control circuit of ground fault sensing and relaying equipment ___ V (ac or dc)."	C
6.3.46	"OPEN-OFF" or "CLOSED-ON" position for disconnecting means	A
Wiring terminal markings		
6.3.28, 6.3.29	"Use Copper/Cu Wire Only."	B
6.3.28, 6.3.30	"Use Copper or Aluminum Wire or Cu-Al."	B
6.3.33	The required temperature rating of all field-installed conductors	C
6.3.35	The number and size of wires for which the terminal is acceptable	C
6.3.28, 6.3.31	"Use Copper/Cu Wire Only Except at Terminals ____."	B
6.3.36	The specific tightening torque for the terminals	C
6.3.41	Pressure terminal connectors or component terminal assemblies that are acceptable for use with the equipment	C
6.3.42	Same as above, except with instructions for special terminations	C
6.3.57 b)	The IEC Symbol No. 5019 for the equipment grounding terminal	Adjacent to the equipment grounding terminal
6.3.70	Instructions for disconnecting the bonding conductor that connects the neutral assembly to the enclosure.	Temporary tag or instruction sheet
Cautionary		

Table 7 Continued on Next Page

Table 7 Continued

Clause reference	Required marking[a]	Location[b]
6.3.44	"WARNING" and the following or equivalent: "RISK OF FIRE AND ELECTRICAL SHOCK – DO NOT CONNECT GROUNDING CONDUCTORS TO THESE OR ANY OTHER NEUTRAL TERMINALS; TO DO SO WILL DEFEAT GROUND-FAULT PROTECTION."	On or adjacent to the neutral.
6.3.47	"DANGER" and the following or equivalent "RISK OF ELECTRIC SHOCK. THIS MAIN DOES NOT DISCONNECT CONTROL AND INSTRUMENT CIRCUITS."	A and on the dead front adjacent to the main disconnect
6.3.59	All cautionary markings	A*
6.3.60	"CAUTION", "WARNING", or "DANGER"	On all cautionary markings.
6.3.64	"WARNING: MORE THAN ONE LIVE CIRCUIT. SEE DIAGRAM."	A
6.3.68	"WARNING: TWIST WIRES TOGETHER BEFORE INSERTING IN TERMINAL." and "COPPER WIRES MUST NOT BE MIXED WITH ALUMINUM WIRES IN THE SAME TERMINAL HOLE."	Adjacent to the grounding terminal

[a] These are brief summaries of the marking requirements. For complete details, see the specific clause reference.

[b] The marking locations for the corresponding letters are as follows:

A Marking shall be plainly visible after installation. Markings shall be visible without removing the trim or cover of the enclosure. Markings may be on the front of the enclosure or on the inside of a hinged door.

A * Same as A, except (see Clause 6.3.59) marking shall be located on a part

a) that would require tools for removal; or

b) that cannot be removed without impairing the operation of the product.

B Marking shall be visible

a) when the enclosure cover is removed or the door is open;

b) when other devices are mounted nearby as intended;

c) when devices are installed side by side.

C See Clause 6.3.11.

D Each part shall be identified by a marking (i.e., a label or a direct marking) or tag located on or adjacent to the part.

Table 8
Marking locations for motor control center sections

(Clause 6.3.2)

Clause reference	Required marking[a]	Location[b]
	General	
6.3.4	Manufacturer's name or trademark and type designation, serial number, or equivalent factory identification code	A
6.3.5	Electrical ratings and enclosure type	A
6.3.5	Termination and wiring information	B
6.3.6	Short-circuit current rating of N/A for sections not containing bus	A
6.3.8	Short-circuit-current rating of a section shall be part of a marking containing the manufacturer's name or other required marking.	A
6.3.9	"Short-circuit-current rating ___ A rms symmetrical ___ V maximum. Do not install on circuits with available short-circuit currents higher than the lowest short-circuit current rating of any installed unit" or the equivalent	A

Table 8 Continued on Next Page

Table 8 Continued

Clause reference	Required marking[a]	Location[b]
6.3.9	"When used with ___ ampere maximum Class ___ fuses (type ___ circuit-breaker), this motor control center section is acceptable for use on a circuit capable of delivering not more than ___A rms symmetrical, ___ V maximum."	A
6.3.34	"Field installed incoming supply conductors up to 90 °C ampacity rating are permitted."	Adjacent to the incoming terminals
6.3.36	The minimum value of torque that shall be applied to the terminal screws	Adjacent to the terminals
6.3.48	"TOP ENTRY ONLY" and "BOTTOM ENTRY ONLY."	Adjacent to the incoming terminals
6.3.58 a)	The catalogue or type no. of the terminal assembly intended to be used	B
6.3.58 b)	Proper installation instructions for terminal assembly	C
6.3.61	The type of bracing to be added to cables routed through the section between the point of entry and the incoming terminals	Adjacent to the incoming terminals
6.3.63	Flammable mounting surfaces	B
6.3.69	Connect the secondary neutral conductor to a grounding electrode in accordance with existing installation requirements pertaining to separately derived systems	See Clause 6.3.11

[a] These are brief summaries of the marking requirements. For complete details see the specific clause reference.

[b] The marking locations for the corresponding letters are as follows:

A Markings shall be plainly visible after installation. Markings shall be visible without removing the trim or cover of the enclosure.
Markings may be on the front of the enclosure or on the inside of a hinged door.

B The marking shall be provided on the section, on the device, or in the pocket.

C See Clause 6.3.58 b).

Table 9
Marking locations for motor control center units

(Clause 6.3.2)

Clause reference	Required marking[a]	Location[b]
	General	
6.3.4	Manufacturer's name or trademark and type designation, serial number, or equivalent factory identification code	A
6.3.5	Electrical ratings, enclosure type, and termination and wiring information	A
6.3.10	"Unit short-circuit-current rating ___A rms symmetrical, ___V maximum, when equipped with ___" or the equivalent	A
6.3.10	"When used with ___ ampere maximum Class ___ fuses (type ___ circuit-breaker), this motor control center unit is acceptable for use on a circuit capable of delivering not more than ___ rms symmetrical A, ___ V maximum." or the equivalent	A
6.3.34	"Field installed incoming supply conductors up to 90 °C ampacity rating are permitted."	Adjacent to the incoming terminals
6.3.50	The protective device accessory kit to be used with the controller units	Wiring diagram/installation instructions
6.3.50	The voltage and current rating together with the designation of the fuse or equivalent, or	B (near the fuseholder)

Table 9 Continued on Next Page

Table 9 Continued

Clause reference	Required marking[a]	Location[b]
	same as above, except the short-circuit current rating shall also be provided	B (near the fuseholder)
6.3.53	The maximum control-circuit protective device size of control-circuit wire used within the equipment	Wiring diagram/installation instructions
6.3.55	The maximum current rating of the fuse (i.e., other than a supplementary fuse) to be used	B (near the fuseholder)
6.3.56	Class of replacement fuse if Class G or Class K	B (near the fuseholder)
6.3.71	Instructions for instantaneous-trip breaker adjustment and overload-relay current-element selection	A (or see Clause 6.3.11)
6.3.71	Maximum size of protective device in a combination motor control unit	
Cautionary		
6.3.11	"CAUTION: SEE _____ FOR INSTRUCTIONS AND SETTING INFORMATION."	A*
6.3.49	"WARNING" and the following or the equivalent: "THE OPENING OF THE BRANCH-CIRCUIT PROTECTIVE DEVICE CAN BE AN INDICATION THAT A FAULT CURRENT HAS BEEN INTERRUPTED. TO REDUCE THE RISK OF FIRE OR ELECTRIC SHOCK, CURRENT-CARRYING PARTS AND OTHER COMPONENTS OF THE COMBINATION CONTROLLER SHOULD BE EXAMINED AND REPLACED IF DAMAGED. WHEN A FAULT CURRENT HAS BEEN INTERRUPTED, THE COMPLETE OVERLOAD RELAY MUST BE REPLACED."	A*
6.3.65	"WARNING: CAPACITIVE VOLTAGES ABOVE 50 V CAN REMAIN FOR _____ S AFTER POWER IS DISCONNECTED."	A*
6.3.67	Warning that a motor can start automatically when the relay is in the automatic reset position.	A*

[a] These are brief summaries of the marking requirements. For complete details, see the specific clause reference.

[b] The marking locations for the corresponding letters are as follows:

A Markings shall be plainly visible after installation. Markings shall be visible without removing the trim or cover of the enclosure. Markings may be on the front of the enclosure, on the unit, or on the inside of a hinged door.

A * Same as A, except (see Clause 6.3.59) marking shall be located on a part

a) that would require tools for removal; or

b) that cannot be removed without impairing the operation of the product.

B Marking shall be visible

a) when the enclosure cover is removed or the door is open;

b) when other devices are mounted nearby as intended;

c) when devices are installed side by side.

Table 10
Construction of combination motor control units

(Clause 8.2.11.1)

Construction type	Construction requirements (clause)	Component[a]	Disconnect	Component function		
				Branch circuit protection	Motor control	Motor overload
A	8.2.11.3 – 8.2.11.6	Manual disconnect	X			
		Fuse		X		
		Magnetic or solid state motor controller			X	
		Overload relay				X
C	8.2.11.3 – 8.2.11.6, and 8.2.11.9	Inverse-time circuit breaker	X	X		
		Magnetic or solid state motor controller			X	
		Overload relay				X
D	8.2.11.3 – 8.2.11.7, and 8.2.11.9	Instantaneous-trip circuit-breaker	X	X		
		Magnetic or solid-state motor controller			X	
		Overload relay				X
E	8.2.11.3 – 8.2.11.4 and 8.2.11.6 – 8.2.11.9	Self-protected control device	X	X	X	X

[a] Tests are conducted on the identical components according to the applicable requirements from the clauses listed.

Table 11
Various constructions of combination motor control units

(Clauses 8.2.11.2, 8.2.11.6, and 8.3.1 and Table 35)

Component parts	Construction type			
	A	C	D	E
Disconnecting means	Manual disconnect UL 98 CSA C22.2 No. 4 or CSA C22.2 No. 5 NMX-J-162-ANCE	Circuit-breaker UL 489 CSA C22.2 No. 5 NMX-J-266-ANCE	Circuit-breaker UL 489 CSA C22.2 No. 5 NMX-J-266-ANCE	Self-protected control device UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE
Short-circuit protective device	Fuse UL 248 series CSA C22.2 No. 248 NMX-J-009/248-ANCE	Inverse time trip circuit-breaker UL 489 CSA C22.2 No. 5 NMX-J-266-ANCE	Instantaneous-trip circuit-breaker UL 489 CSA C22.2 No. 5 NMX-J-266-ANCE	
Motor controller	Magnetic UL 508 CSA C22.2 No 14 NMX-J-515-ANCE	Magnetic UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE	Magnetic UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE	
Overload protection	Overload relay UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE	Overload relay UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE	Overload relay UL 508 CSA C22.2 No. 14 NMX-J-515-ANCE	

NOTE Tests are conducted on the individual components in accordance with the standards shown in the table following each component. See Annex D for a list of applicable standards.

Table 12
Overcurrent protection – copper conductors

(Clauses 6.3.55, 8.2.14.1, and 8.2.15.4)

Control-circuit wire size, mm^2 (AWG)	Maximum protective device rating, amperes
0.20 (24)	2
0.32 (22)	3
0.52 (20)	5
0.82 (18)	7
1.3 (16)	10
2.1 (14)	20
3.3 (12)	25
5.3 (10)	35

Table 13
Maximum acceptable rating of primary overcurrent device

(Clause 8.2.15.1)

Rating primary current, amperes	Maximum rating of overcurrent protective device expressed as a percentage of transformer primary current rating
Less than 2	500
2 to less than 9	167
9 or more	125[a]

[a] See Clause 8.2.15.3.

Table 14
Maximum acceptable rating of secondary overcurrent device

(Clause 8.2.15.3)

Rating secondary current, amperes	Maximum rating of overcurrent protective device expressed as a percentage of transformer secondary current rating
Less than 9	167
9 or more	125[a]

[a] See Clause 8.2.15.3.

Table 15
Full-load motor-running currents in amperes corresponding to various ac horsepower ratings (110 – 240 V)

(Clauses 8.2.16.3 b), 8.2.26.1, 9.3.8, and 9.6.3 and Table 31)

KW (Hp)	110 – 120 Volts		200 Volts		208 Volts		220 – 240 V[a]	
	Single-phase	Three-phase	Single-phase	Three-phase	Single-phase	Three-phase	Single-phase	Three-phase
0.08 (1/10)	3.0	–	–	–	–	–	1.5	–
0.09 (1/8)	3.8	–	–	–	–	–	1.9	–
0.13 (1/6)	4.4	–	2.5	–	2.4	–	2.2	–
0.19 (1/4)	5.8	–	3.3	–	3.2	–	2.9	–
0.25 (1/3)	7.2	–	4.1	–	4.0	–	3.6	–
0.37 (1/2)	9.8	4.4	5.6	2.5	5.4	2.4	4.9	2.2
0.56 (3/4)	13.8	6.4	7.9	3.7	7.6	3.5	6.9	3.2
0.75 (1)	16.0	8.4	9.2	4.8	8.8	4.6	8.0	4.2
1.1 (1-1/2)	20.0	12.0	11.5	6.9	11.0	6.6	10.0	6.0
1.5 (2)	24.0	13.6	13.8	7.8	13.2	7.5	12.0	6.8
2.2 (3)	34.0	19.2	19.6	11.0	18.7	10.6	17.0	9.6
3.7 (5)	56.0	30.4	32.2	17.5	30.8	16.7	28.0	15.2
5.6 (7-1/2)	80.0	44.0	46.0	25.3	44.0	24.2	40.0	22.0
7.5 (10)	100.0	56.0	57.5	32.2	55.0	30.8	50.0	28.0
11 (15)	135.0	84.0	–	48.3	–	46.2	68.0	42.0
15 (20)	–	108.0	–	62.1	–	59.4	88.0	54.0
19 (25)	–	136.0	–	78.2	–	74.8	110.0	68.0
22 (30)	–	160.0	–	92.0	–	88.0	136.0	80.0
30 (40)	–	208.0	–	120	–	114	176.0	104.0
37 (50)	–	260.0	–	150	–	143	216.0	130.0
45 (60)	–	–	–	177	–	169	–	154.0
56 (75)	–	–	–	221	–	211	–	192.0
75 (100)	–	–	–	285	–	273	–	248.0
93 (125)	–	–	–	359	–	343	–	312.0
112 (150)	–	–	–	414	–	396	–	360.0
149 (200)	–	–	–	552	–	528	–	480.0
186 (250)	–	–	–	–	–	–	–	604.0
224 (300)	–	–	–	–	–	–	–	722
261 (350)	–	–	–	–	–	–	–	828
298 (400)	–	–	–	–	–	–	–	954
336 (450)	–	–	–	–	–	–	–	1030
373 (500)	–	–	–	–	–	–	–	1180

[a] To obtain full-load currents for 265 and 277 volt motors, decrease 220 – 240 volt ratings by 13 and 17 %, respectively.

Table 16
Full-load motor-running currents in amperes corresponding to various ac horsepower ratings (380 – 600 V)

KW (Hp)	380 – 415 V		440 – 480 V		550 – 600 V	
	Single-phase	Three-phase	Single-phase	Three-phase	Single-phase	Three-phase
0.08 (1/10)	1.0	–	–	–	–	–
0.09 (1/8)	1.2	–	–	–	–	–
0.13 (1/6)	1.4	–	–	–	–	–
0.19 (1/4)	1.8	–	–	–	–	–
0.25 (1/3)	2.3	–	–	–	–	–
0.37 (1/2)	3.2	1.3	2.5	1.1	2.0	0.9
0.56 (3/4)	4.5	1.8	3.5	1.6	2.8	1.3
0.75 (1)	5.1	2.3	4.0	2.1	3.2	1.7
1.1 (1-1/2)	6.4	3.3	5.0	3.0	4.0	2.4
1.5 (2)	7.7	4.3	6.0	3.4	4.8	2.7
2.2 (3)	10.9	6.1	8.5	4.8	6.8	3.9
3.7 (5)	17.9	9.7	14.0	7.6	11.2	6.1
5.6 (7-1/2)	27.0	14.0	21.0	11.0	16.0	9.0
7.5 (10)	33.0	18.0	26.0	14.0	20.0	11.0
11 (15)	44.0	27.0	34.0	21.0	27.0	17.0
15 (20)	56.0	34.0	44.0	27.0	35.0	22.0
19 (25)	70.0	44.0	55.0	34.0	44.0	27.0
22 (30)	87.0	51.0	68.0	40.0	54.0	32.0
30 (40)	112.0	66.0	88.0	52.0	70.0	41.0
37 (50)	139.0	83.0	108.0	65.0	86.0	52.0
45 (60)	–	103.0	–	77.0	–	62.0
56 (75)	–	128.0	–	96.0	–	77.0
75 (100)	–	165.0	–	124.0	–	99.0
93 (125)	–	208.0	–	156.0	–	125.0
112 (150)	–	240.0	–	180.0	–	144.0
149 (200)	–	320.0	–	240.0	–	192.0
186 (250)	–	403.0	–	302.0	–	242.0
224 (300)	–	482.0	–	361.0	–	289.0
261 (350)	–	560.0	–	414.0	–	336.0
298 (400)	–	636.0	–	477.0	–	382.0
336 (450)	–	–	–	515	–	412
373 (500)	–	786.0	–	590.0	–	472.0

Table 17
Full-load motor-running currents in amperes corresponding to various dc horsepower ratings

(Clauses 8.2.16.3 b), 8.2.26.1, and 9.6.3 and Table 31)

kW (hp)	90 V	110 – 120 V	180 V	220 – 240 V	500 V	550 – 600 V
0.08 (1/10)	–	2.0	–	1.0	–	–
0.09 (1/8)	–	2.2	–	1.1	–	–
0.13 (1/6)	–	2.4	–	1.2	–	–
0.19 (1/4)	4.0	3.1	2.0	1.6	–	–
0.25 (1/3)	5.2	4.1	2.6	2.0	–	–
0.37 (1/2)	6.8	5.4	3.4	2.7	–	–
0.56 (3/4)	9.6	7.6	4.8	3.8	–	1.6
0.75 (1)	12.2	9.5	6.1	4.7	–	2.0
1.1 (1-1/2)	–	13.2	8.3	6.6	–	2.7
1.5 (2)	–	17.0	10.8	8.5	–	3.6
2.2 (3)	–	25.0	16.0	12.2	–	5.2
3.7 (5)	–	40.0	27.0	20.0	–	8.3
5.6 (7-1/2)	–	58.0	–	29.0	13.6	12.2
7.5 (10)	–	76.0	–	38.0	18.0	16.0
11 (15)	–	110.0	–	55.0	27.0	24.0
15 (20)	–	148.0	–	72.0	34.0	31.0
19 (25)	–	184.0	–	89.0	43.0	38.0
22 (30)	–	220.0	–	106.0	51.0	46.0
30 (40)	–	292.0	–	140.0	67.0	61.0
37 (50)	–	360.0	–	173.0	83.0	75.0
45 (60)	–	–	–	206.0	99.0	90.0
56 (75)	–	–	–	255.0	123.0	111.0
75 (100)	–	–	–	341.0	164.0	148.0
93 (125)	–	–	–	425.0	205.0	185.0
112 (150)	–	–	–	506.0	246.0	222.0
149 (200)	–	–	–	675.0	330.0	294.0

Table 18
Ampacity of insulated conductors for field wiring

(Clauses 8.2.16.3, 8.2.16.5, 8.2.17, 9.6.3, 9.14.2.5, and 9.17.2.5)

Wire size		60 °C		75 °C		90 °C	
mm^2	(AWG or kcmil)	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
0.20	(24)	2	–	–	–	–	–
0.32	(22)	3	–	–	–	–	–
0.52	(20)	5	–	–	–	–	–
0.82	(18)	7	–	–	–	14	–

Table 18 Continued on Next Page

Table 18 Continued

Wire size		60 °C		75 °C		90 °C	
mm^2	(AWG or kcmil)	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
1.3	(16)	10	–	–	–	18	–
2.1	(14)	15	–	15	–	25	–
3.3	(12)	20	15	20	15	30	25
5.3	(10)	30	25	30	25	40	35
8.4	(8)	40	30	50	40	55	45
13.3	(6)	55	40	65	50	75	60
21.2	(4)	70	55	85	65	95	75
26.7	(3)	80	65	100	75	110	85
33.6	(2)	95	75	115	90	130	100
42.4	(1)	110[a]	85[a]	130	100	150	115
53.5	(1/0)	–	–	150	120	170	135
67.4	(2/0)	–	–	175	135	195	150
85.0	(3/0)	–	–	200	155	225	175
107	(4/0)	–	–	230	180	260	205
127	(250)	–	–	255	205	290	230
152	(300)	–	–	285	230	320	260
177	(350)	–	–	310	250	350	280
203	(400)	–	–	335	270	380	305
253	(500)	–	–	380	310	430	350
304	(600)	–	–	420	340	475	385
355	(700)	–	–	460	375	520	425
380	(750)	–	–	475	385	535	435
405	(800)	–	–	490	395	555	445
456	(900)	–	–	520	425	585	480
506	(1 000)	–	–	545	445	615	500
633	(1 250)	–	–	590	485	665	545
760	(1 500)	–	–	625	520	705	585
887	(1 750)	–	–	650	545	735	615
1 010	(2 000)	–	–	665	560	750	630

NOTE For a multiple conductor connector at a terminal, the value shall be multiplied by the number of conductors 53.5 mm^2 (1/0 AWG) or larger that the terminal will accommodate.

[a] If the motor control center is marked to indicate that 75 °C (167 °F) wire shall be used at the terminal, the acceptable current is 130 A for a copper conductor and 100 A for an aluminum conductor.

[b] Applicable only to incoming supply conductors in accordance with 8.2.17.

Table 19
Electrical spacings[a]

(Clauses 8.2.2.7, 8.2.7.4, 8.2.20.3, 8.2.27.1, 8.2.27.2, 8.2.27.4, 8.2.27.9, 8.2.33.2, 8.3.10, and 9.5.2)

Voltage involved	Minimum spacing, mm (in)					
	Between live parts of opposite polarity				Between live parts and grounded metal parts, through air and over surface	
	Through air		Over surface			
0 – 150	12.7	(0.5)	19.1	(0.75)	12.7	(0.5)
151 – 300	19.1	(0.75)	31.8	(1.25)	12.7	(0.5)
301 – 600	25.4	(1)	50.8	(2)	25.4[b]	(1[b])
601 – 1000	38	(1-1/2)	63	(2-1/2)	c	c

[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 grounded dead metal, is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

[b] A through-air spacing of not less than 12.7 mm (0.5 in) is acceptable

a) at a circuit-breaker or fusible disconnecting means;

b) between grounded dead metal and the neutral of a 3-phase, 4-wire motor control center.

[c] Through-air spacing required is 38 mm (1-1/2 in); over-surface spacings required is 50 mm (2 in).

Table 20
Electrical spacings within motor control units

(Clauses 8.2.7.4, 8.2.27.1, 8.2.27.11, and 8.2.27.12)

Voltage involved	Minimum spacing, mm (in)		
	Between uninsulated live parts of opposite polarity and between an uninsulated live part and an exposed or uninsulated dead metal part other than the enclosure		Between uninsulated live parts and the walls of a metal enclosure[a], including fittings for conduit or armoured cable
	Through air	Over surface	Shortest distance
0 – 150	3.2 (0.125)[b]	6.4 (0.25)	12.7 (0.5)
151 – 300	6.4 (0.25)	9.5 (0.375)	12.7 (0.5)
301 – 600	9.5 (0.375)	12.7 (0.5)	12.7 (0.5)
601 – 1 000[d]	14.0 (0.55)	21.6 (0.85)	c

[a] The enclosure refers to the section enclosure.

[b] The spacing between wiring terminals of opposite polarity shall not be less than 6.4 mm (0.25 in) if the terminals are in the same plane. A metal piece attached to the enclosure shall be considered to be a part of the enclosure for the purpose of this note if deformation of the enclosure is likely to reduce the spacing between the metal piece and a live part.

[c] Through-air spacing required is 20.3 mm (0.8 in); over-surface spacings required is 25.4 mm (1 in).

[d] DC circuits derived from rectified ac circuits without increases to the peak nominal voltage may comply with the electrical spacings of the ac supply voltage.

Table 21
Dimensions of bushings

(Clause 8.2.27.8)

Trade size of conduit	IEC conduit designation	Overall diameter		Height	
		mm	(in)	mm	(in)
1/2	16	25.4	1.00	9.5	0.38
3/4	21	31.4	1.23	10.7	0.42
1	27	40.5	1.59	13.1	0.51
1-1/4	35	49.2	1.94	14.3	0.56
1-1/2	41	56.0	2.20	15.1	0.59
2	53	68.7	2.70	15.9	0.63
2-1/2	63	81.8	3.22	19.1	0.75
3	78	98.4	3.88	20.6	0.81
3-1/2	91	112.7	4.44	23.8	0.94
4	103	126.2	4.97	25.4	1.00
4-1/2	NA	140.9	5.55	27.0	1.06
5	129	158.0	6.22	30.2	1.19
6	155	183.4	7.22	31.8	1.25

Table 22
Minimum width of gutter and wire-bending space[a,c]

(Clauses 8.2.29.2.1 and 8.2.29.2.4)

Size of wire		Minimum bending space, terminal to wall, mm (in)					
		Wires per terminal[b]					
mm^2 or (AWG or kcmil)		1		2	3	4	5
2.1 – 5.3	(14 – 10)	Not specified		–	–	–	–
8.4 – 13.3	(8 – 6)	38.1	(1.5)	–	–	–	–
21.1 – 26.7	(4 – 3)	50.8	(2)	–	–	–	–
33.6	(2)	63.5	(2.5)	–	–	–	–
42.4	(1)	76.2	(3)	–	–	–	–
53.5 – 67.4	(1/0 – 2/0)	88.9	(3.5)	127 (5)	178 (7)	–	–
85.0 – 107	(3/0 – 4/0)	102	(4)	152 (6)	203 (8)	–	–
127	(250)	114	(4.5)	152 (6)	203 (8)	254 (10)	–
152 – 177	(300 – 350)	127	(5)	203 (8)	254 (10)	305 (12)	–
203 – 253	(400 – 500)	152	(6)	203 (8)	254 (10)	305 (12)	355 (14)
304 – 355	(600 – 700)	203	(8)	254 (10)	305 (12)	355 (14)	406 (14)
380 – 456	(750 – 900)	203	(8)	305 (12)	355 (14)	406 (16)	457 (18)
507 – 633	(1 000 – 1 250)	254	(10)	–	–	–	–
760 – 1 010	(1 500 – 2 000)	305	(12)	–	–	–	–

NOTE Products manufactured for use only in Canada may use the values in Annex C, item 4.

Table 22 Continued on Next Page

Table 22 Continued

Size of wire mm^2 or (AWG or kcmil)	Minimum bending space, terminal to wall, mm (in)				
	Wires per terminal[b]				
	1	2	3	4	5

[a] The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

[b] The main connection for a neutral shall be considered to be a terminal; that is, neutral branch terminals shall not be included when determining the number of wires per terminal.

[c] For ampacities of 110 A or less, and if the motor control center is marked to indicate the use of 60 °C or 75 °C wire, the wire-bending space shall be based on the use of 60 °C insulated wire.

Table 23
Wire-bending space at terminals

(Clause 8.2.29.2.1)

Wire size, mm^2 (AWG or kcmil)		Minimum bending space, mm (in)[a]							
		Wires per terminal							
		1		2		3		4 or more	
2.1 – 5.3	(14 – 10)	Not specified		–	–	–	–	–	–
8.4	(8)	38.1 (1.5)	–	–	–	–	–	–	–
13.3	(6)	50.8 (2)	–	–	–	–	–	–	–
21.2	(4)	76.2 (3)	–	–	–	–	–	–	–
26.7	(3)	76.2 (3)	–	–	–	–	–	–	–
33.6	(2)	88.9 (3.5)	–	–	–	–	–	–	–
42.4	(1)	114 (4.5)	–	–	–	–	–	–	–
53.5	(1/0)	140 (5.5)	–	140 (5.5)	–	178 (7)	–	–	–
67.4	(2/0)	152 (6)	–	152 (6)	–	191 (7.5)	–	–	–
85.0	(3/0)	165 (6.5)	[152 (6)]	165 (6.5)	[152 (6)]	203 (8)	–	–	–
107	(4/0)	178 (7)	[152 (6)]	191 (7.5)	[152 (6)]	216 (8.5)	[203 (8)]	–	–
127	(250)	216 (8.5)	[165 (6.5)]	216 (8.5)	[165 (6.5)]	229 (9)	[203 (8)]	254 (10)	–
152	(300)	254 (10)	[178 (7)]	254 (10)	[203 (8)]	279 (11)	[254 (10)]	305 (12)	–
177	(350)	305 (12)	[229 (9)]	305 (12)	[229 (9)]	330 (13)	[254 (10)]	356 (14)	[305 (12)]
203	(400)	330 (13)	[254 (10)]	330 (13)	[254 (10)]	356 (14)	[279 (11)]	381 (15)	[305 (12)]
253	(500)	356 (14)	[279 (11)]	356 (14)	[279 (11)]	381 (15)	[305 (12)]	406 (16)	[330 (13)]
304	(600)	381 (15)	[305 (12)]	406 (16)	[330 (13)]	457 (18)	[381 (15)]	483 (19)	[406 (16)]
355	(700)	406 (16)	[330 (13)]	457 (18)	[381 (15)]	508 (20)	[432 (17)]	559 (22)	[483 (19)]
380	(750)	432 (17)	[356 (14)]	483 (19)	[406 (16)]	559 (22)	[483 (19)]	610 (24)	[533 (21)]
405	(800)	457 (18)	–	508 (20)	–	559 (22)	–	610 (24)	–
456	(900)	483 (19)	–	559 (22)	–	610 (24)	–	610 (24)	–
507	(1000)	508 (20)	–	–	–	–	–	–	–
633	(1250)	559 (22)	–	–	–	–	–	–	–
760 – 1 010	(1 500 – 2 000)	610 (24)	–	–	–	–	–	–	–

Table 23 Continued on Next Page

Table 23 Continued

Wire size, mm^2 (AWG or kcmil)	Minimum bending space, mm (in)[a]			
	Wires per terminal			
	1	2	3	4 or more

NOTE Products manufactured for use only in Canada may use the values in Annex C, item 4.

[a] The values in brackets apply to removable and lay-in wiring terminals intended for only one wire. A removable wiring terminal is one that can be removed from its intended location without disturbing structural or electrical parts other than a cover and that can be reinstalled with the conductor in place.

Table 24
Wire space – Two wires, three wires, and four wires

(Clause 8.2.29.3.1)

Maximum size of wire or cable, mm^2 (AWG or kcmil)		Minimum width and depth of wiring space, mm (in)		Minimum area in square cm^2 (in^2) required for multiple wires based on factor of 2.5					
				Two wires		Three wires		Four wires	
3.3	(12)	9.5	(0.375)	0.9	(0.14)	1.4	(0.21)	1.8	(0.28)
5.3	(10)	9.5	(0.375)	1.5	(0.23)	2.2	(0.34)	3.0	(0.46)
8.4	(8)	12.7	(0.5)	2.8	(0.43)	4.1	(0.64)	5.5	(0.85)
13.3	(6)	15.9	(0.625)	4.0	(0.62)	6.0	(0.93)	8.0	(1.24)
21.2	(4)	19.1	(0.75)	5.2	(0.80)	7.7	(1.20)	10.3	(1.60)
26.7	(3)	19.1	(0.75)	5.9	(0.91)	8.8	(1.36)	11.7	(1.82)
33.6	(2)	22.2	(0.875)	6.6	(1.03)	10.0	(1.55)	13.3	(2.06)
42.4	(1)	25.4	(1)	8.8	(1.36)	13.2	(2.04)	17.5	(2.72)
53.5	(1/0)	25.4	(1)	10.0	(1.55)	15.0	(2.33)	20.0	(3.10)
67.4	(2/0)	25.4	(1)	11.5	(1.79)	17.3	(2.68)	23.1	(3.58)
85.0	(3/0)	28.6	(1.125)	13.4	(2.08)	20.1	(3.11)	26.8	(4.16)
107	(4/0)	31.8	(1.25)	15.6	(2.42)	23.4	(3.63)	31.2	(4.84)
127	(250)	34.9	(1.375)	19.1	(2.96)	28.6	(4.44)	38.2	(5.92)
152	(300)	38.1	(1.5)	22.1	(3.42)	33.1	(5.13)	44.1	(6.84)
177	(350)	38.1	(1.5)	24.6	(3.81)	36.9	(5.72)	49.2	(7.62)
203	(400)	41.3	(1.625)	27.0	(4.18)	40.5	(6.27)	53.9	(8.36)
253	(500)	44.5	(1.75)	31.7	(4.92)	47.6	(7.38)	63.5	(9.84)
304	(600)	47.6	(1.875)	38.5	(5.97)	57.8	(8.96)	77.0	(11.94)
355	(700)	50.8	(2)	43.1	(6.68)	64.6	(10.02)	86.2	(13.36)
380	(750)	50.8	(2)	45.4	(7.04)	68.1	(10.56)	90.8	(14.08)
405	(800)	54.0	(2.125)	47.7	(7.39)	71.5	(11.09)	95.4	(14.78)
456	(900)	57.2	(2.25)	52.2	(8.09)	78.3	(12.13)	104.4	(16.18)
507	(1 000)	57.2	(2.25)	56.6	(8.77)	84.8	(13.15)	113.2	(17.54)
633	(1 250)	63.5	(2.5)	71.2	(11.03)	106.8	(16.55)	142.3	(22.06)
760	(1 500)	69.8	(2.75)	82.2	(12.74)	123.3	(19.11)	164.4	(25.48)
887	(1 750)	73.0	(2.875)	93.2	(14.45)	139.8	(21.67)	186.5	(28.90)
1010	(2 000)	79.4	(3.125)	103.5	(16.04)	155.2	(24.06)	207.0	(32.08)

NOTE Products manufactured for use only in Canada may use the values in Annex C, item 4.

Table 25
Wire space – Five wires, six wires, and seven wires

(Clause 8.2.29.3.1)

Maximum size of wire or cable, mm² (AWG or kcmil)		Minimum width and depth of wiring space, mm (in)		Minimum area in square cm² (in²) required for multiple wires based on factor of 2.5					
				Five wires		Six wires		Seven wires	
3.3	(12)	9.5	(0.375)	2.3	(0.35)	2.7	(0.42)	3.2	(0.49)
5.3	(10)	9.5	(0.375)	3.7	(0.57)	4.4	(0.68)	5.2	(0.80)
8.4	(8)	12.7	(0.5)	6.9	(1.07)	8.3	(1.28)	9.7	(1.50)
13.3	(6)	15.9	(0.625)	10.0	(1.55)	12.0	(1.86)	14.0	(2.17)
21.2	(4)	19.1	(0.75)	12.9	(2.00)	15.5	(2.40)	18.1	(2.80)
26.7	(3)	19.1	(0.75)	14.6	(2.27)	17.5	(2.72)	20.5	(3.18)
33.6	(2)	22.2	(0.875)	16.6	(2.58)	20.0	(3.10)	23.3	(3.61)
42.4	(1)	25.4	(1)	21.9	(3.40)	26.3	(4.08)	30.7	(4.76)
53.5	(1/0)	25.4	(1)	25.0	(3.88)	30.1	(4.66)	35.0	(5.43)
67.4	(2/0)	25.4	(1)	28.8	(4.47)	34.6	(5.36)	40.4	(6.26)
85.0	(3/0)	28.6	(1.125)	33.5	(5.19)	40.1	(6.22)	46.9	(7.27)
107	(4/0)	31.8	(1.25)	39.0	(6.05)	46.8	(7.26)	54.6	(8.47)
127	(250)	34.9	(1.375)	47.7	(7.40)	57.3	(8.88)	66.8	(10.36)
152	(300)	38.1	(1.5)	55.2	(8.55)	66.2	(10.26)	77.2	(11.96)
177	(350)	38.1	(1.5)	61.5	(9.53)	73.8	(11.44)	86.1	(13.34)
203	(400)	41.3	(1.625)	67.4	(10.45)	80.9	(12.54)	94.4	(14.63)
253	(500)	44.5	(1.75)	79.4	(12.30)	95.2	(14.76)	111.1	(17.22)
304	(600)	47.6	(1.875)	96.3	(14.93)	115.6	(17.92)	134.8	(20.90)
355	(700)	50.8	(2)	107.7	(16.70)	129.3	(20.04)	150.8	(23.38)
380	(750)	50.8	(2)	113.5	(17.60)	136.3	(21.12)	159.0	(24.64)
405	(800)	54.0	(2.125)	119.2	(18.48)	143.1	(22.18)	166.9	(25.87)
456	(900)	57.2	(2.25)	130.5	(20.22)	156.5	(24.26)	182.6	(28.31)
507	(1 000)	57.2	(2.25)	141.4	(21.92)	169.7	(26.30)	198.0	(30.69)
633	(1 250)	63.5	(2.5)	177.9	(27.58)	213.5	(33.10)	249.1	(38.61)
760	(1 500)	69.8	(2.75)	205.5	(31.85)	246.6	(38.22)	287.7	(44.59)
887	(1 750)	73.0	(2.875)	233.0	(36.12)	279.6	(43.34)	326.3	(50.57)
1010	(2 000)	79.4	(3.125)	258.7	(40.10)	310.5	(48.12)	362.2	(56.14)

NOTE Products manufactured for use only in Canada may use the values in Annex C, item 4.

Table 26
Size of bonding, equipment grounding, grounding electrode conductors, and ground bus[a]

(Clauses 8.2.31.2, 8.2.32.4, 8.2.33.3, 8.2.34.1, 8.2.34.2, 8.2.34.4, and 8.2.34.6)

Maximum ampere rating[b]	Size of equipment grounding or bonding conductor, minimum mm² (AWG or kcmil)		Size of grounding electrode conductor, minimum mm² (AWG or kcmil)		Size of main bonding jumper or system bonding jumper, minimum mm² (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum[e]	Copper	Aluminum[e]
15	2.1 (14)	3.3 (12)	–	–	–	–
20	[2.1][f] 3.3 ([14][f] 12)	[3.3][f] 5.3 ([12][f] 10)	–	–	–	–
30	[3.3][f] 5.3 ([12][f] 10)	[5.3][f] 8.4 ([10][f] 8)	–	–	–	–
40	5.3 (10)	8.4 (8)	–	–	–	–
60	5.3 (10)	8.4 (8)	–	–	–	–
90	8.4 (8)	13.3 (6)	8.4 (8)	13.3 (6)	8.4 (8)	13.3 (6)
100	8.4 (8)	13.3 (6)	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)
150	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)
200	13.3 (6)	21.2 (4)	21.2 (4)	33.6 (2)	21.2 (4)	33.6 (2)
300	21.2 (4)	33.6 (2)	33.6 (2)	53.5 (1/0)	33.6 (2)	53.5 (1/0)
400	26.7 (3)	42.4 (1)	53.5[c] (1/0[c])	85[c] (3/0[c])	53.5[c] (1/0[c])	85[c] (3/0[c])
500	33.6 (2)	53.5 (1/0)	53.5 (1/0)	85 (3/0)	53.5 (1/0)	85 (3/0)
600	42.4 (1)	67.4 (2/0)	67.4 (2/0)	107 (4/0)	67.4 (2/0)	107 (4/0)
800	53.5 (1/0)	85 (3/0)	67.4 (2/0)	107 (4/0)	67.4 (2/0)	107 (4/0)
1 000	67.4 (2/0)	107 (4/0)	85 (3/0)	127 (250)	85 (3/0)	127 (250)
1 200	85 (3/0)	127 (250)	85 (3/0)	127 (250)	127[d] (250[d])	127 (250)
1 600	107 (4/0)	177 (350)	85 (3/0)	127 (250)	152[d] (300[d])	203[d] (400[d])
2 000	127 (250)	203 (400)	85 (3/0)	127 (250)	203[d] (400[d])	253[d] (500[d])
2 500	177 (350)	[253][f] 304 ([500][f] 600)	85 (3/0)	127 (250)	253[d] (500[d])	355[d] (700[d])
3 000	203 (400)	304 (600)	85 (3/0)	127 (250)	304[d] (600[d])	380[d] (750[d])
4 000	253 (500)	405 (800)	85 (3/0)	127 (250)	380[d] (750[d])	507[d] (1 000[d])
5 000	355 (700)	[507][f] 608 ([1 000][f] 1 200)	85 (3/0)	127 (250)	456 (900)	633 (1 250)
6 000	405 (800)	[633][f] 608 ([1 250][f] 1 200)	85 (3/0)	127 (250)	633 (1 250)	760 (1 500)

[a] See Table 27 for equivalent area of bus. Size of ground bus to be in accordance with Table 27 based on columns 1 – 3 of Table 26.

[b] Maximum ampere rating of center or circuit overcurrent device ahead of equipment-grounding means.

[c] If the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 85 mm² (3/0 AWG) copper conductors or two 127 mm² (250 kcmil) aluminum conductors but will not accept a 304 mm² (600 kcmil) conductor, these values may be reduced to 33.6 mm² (2 AWG) copper or 53.5 mm² (1/0 AWG) aluminum.

[d] The cross-section may be reduced to 12.5 % of the total cross-section of the largest main service conductor of the same material (copper or aluminum) for any phase on centers rated 1 200 A and over. This applies when the cross-section of the service conductors is limited by the wire terminal connectors provided.

[e] Aluminum is not permitted in Canada.

[f] In Canada, the values in brackets [xx] apply.

Table 27
Equivalent cross-sectional areas

(Clauses 8.2.31.2, 8.2.32.4, 8.2.33.3, and 8.2.34.1 and Table 26)

Wire size mm² (AWG or kcmil)	Minimum cross-section	
	mm²	(in²)
2.1 (14)	2.08	(0.003)
3.3 (12)	3.31	(0.005)
5.3 (10)	5.26	(0.008)
8.4 (8)	8.39	(0.013)
13.3 (6)	13.55	(0.021)
21.2 (4)	21.29	(0.033)
26.7 (3)	26.45	(0.041)
33.6 (2)	33.55	(0.052)
42.4 (1)	42.58	(0.066)
53.5 (1/0)	53.55	(0.083)
67.4 (2/0)	67.74	(0.105)
85 (3/0)	85.16	(0.132)
107 (4/0)	107.10	(0.166)
127 (250)	126.45	(0.196)
152 (300)	152.26	(0.236)
177 (350)	177.42	(0.275)
203 (400)	202.58	(0.314)
253 (500)	253.55	(0.393)
304 (600)	304.0	(0.471)
355 (700)	354.84	(0.550)
380 (750)	380.00	(0.589)
405 (800)	405.16	(0.628)
507 (1000)	506.45	(0.785)
608 (1200)	607.73	(0.942)
633 (1250)	632.90	(0.981)
760 (1500)	760.00	(1.178)
887 (1750)	887.00	(1.374)
1 010 (2000)	1 013.00	(3.100)

Table 28
Ratings of fuses used for tests

(Clauses 9.12.5.1 and 9.15.4.2)

Type of fuse[a]	Current, amperes	Maximum percent of rated motor full-load current[b]	Fuse size marking required
Non-time-delay	0 – 600	400[c,d]	No
Non-time-delay	0 – 600	< 400 but ≥ 300[e]	Yes
Non-time-delay	0 – 600	< 300 but > 225[f]	Yes
Time-delay	0 – 600	≤ 225[g]	Yes
Non-time-delay	601 – 6 000	300[h]	No
Non-time-delay	601 – 6 000	< 300[i]	Yes
Time-delay	601 – 6 000	225[g]	Yes

[a] Tests with 225 % full-load ampere time-delay fuses are not considered representative of tests with 400 % full-load ampere non-time-delay fuses.

[b] These values are approximate and shall be used when the manufacturer does not specify fuse sizes but refers to a maximum percent level (e.g., "Fuse not to exceed 300 % of motor full-load amps").

[c] See Clause 9.12.5.2.

[d] Tests with 400 % non-time-delay fuses cover use with 225 % time-delay fuses.

[e] Tests with non-time-delay fuses rated less than 400 % but equal to or greater than 300 % cover use with 175 % time-delay fuses.

[f] Tests with less than 300 % non-time-delay fuses require additional testing with 225 % (or as marked) time-delay fuses.

[g] The product is marked to indicate the level of protection and that the branch-circuit protective device is sometimes required to be of the time-delay type. See Clause 6.3.71.

[h] If the calculated value of the fuse is between two standard ratings as specified in Clause 9.12.5.2, a fuse of the nearest standard rating but not more than three times the full-load motor-current rating shall be used.

[i] The protective device may be a non-time-delay fuse smaller than the size specified in note h if the product is marked to indicate this limit of protection.

Table 29
Maximum temperature rises

(Clauses 8.2.8.3, 8.3.3, 9.3.2, 9.3.10, and 9.3.13)

Material and components	°K
A. Components	
1. Bus	
a. Vertical bus of the motor control center at the plug-in connections, and the plug-in connections	50[a,b]
b. Vertical bus of the motor control center at the plug-in connections, and the plug-in connections	65[a,c]
c. Horizontal bus of the motor control center, buses, and connecting straps or bars	65[a, m]
d. Plated bus bars at the point of connection to a circuit breaker.	65
2. Capacitors	d
3. Fuse clips	
a. Fuse clip on a fused switch for use with 60 °C wire tested with dummy fuses	30
b. Fuse clip on a fused switch for use with 75 °C wire tested with dummy fuses	50
c. Fuse clip tested with Class J (rated more than 200 A) and Class L fuses	85

Table 29 Continued on Next Page

Table 29 Continued

Material and components	°K
4. Pressure terminal connectors	
a. Pressure terminal connectors for field-installed conductors except as noted in sub-item 4b.	50[e]
b. Pressure terminal connectors marked for use with 75 °C (167 °F) wire	65[f,g]
5. Knife-switch blades and contact jaws	30
6. Resistors and rheostats	
a. On the embedding material of a resistor, a rheostat, and a wall-mounted dimmer with an embedded resistive element	300
b. On the embedding material of a rheostatic dimmer having embedded resistive conductors	350
c. On bare resistor material, thermocouple method	375
7. Contacts	
a. Solid and built-up silver, silver alloy, and silver faced	h
b. All other metals	65
B. Conductors	
1. Conductor having rubber or thermoplastic insulation	35[i,j]
C. Electrical insulation – general	
1. Fibre employed as electrical insulation	65
2. Phenolic composition employed as electrical insulation or as a part, the deterioration of which could result in a risk of fire or electric shock	125[i]
3. Varnished-cloth insulation	60
4. Electrical tape	55[i]
5. Sealing compound	k
6. Other insulating materials	l
7. Coil winding by change-of-resistance method	
a. Relays and solenoids	
Class 105 insulation system	85
Class 130 insulation system	105
b. Transformers 10 kVA or less	
Class 105 insulation system	70
Class 130 insulation system	95
c. Transformers greater than 10 kVA	
Class 105 insulation system	55
Class 130 insulation system	60
Class 155 insulation system	85
Class 180 insulation system	110
Class 200 insulation system	130
Class 220 insulation system	150
D. Surfaces	
1. Wood and other combustible material	65

[a] The limit does not apply to bus bars within 152 mm (6 in) of connections to a source of heat, such as a resistor, fuse, and a current element of an over-load relay.

Table 29 Continued on Next Page

Table 29 Continued

Material and components	°K
[b] Test in accordance with Clause 9.3.2.	
[c] Test in accordance with Clause 9.3.3.	
[d] For a capacitor, the maximum allowable temperature rise shall not exceed the marked temperature limit of the capacitor minus an assumed ambient temperature of 40 °C.	
[e] The temperature on a wiring terminal or lug shall be measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.	
[f] Applicable to a connector for copper wire. Also applicable to a connector for aluminum wire or an aluminum-bodied connector where the connector has a temperature rating of 90 °C. If tested with dummy fuses, the recorded temperature rise shall be increased 20 °C to represent the heating of fuses.	
[g] Equipment marked for 60/75 °C supply wires shall comply with 4a of item A.	
[h] Temperature limited by the temperature limitations on the material for adjacent parts. There shall be no structural deterioration of the contact assembly, loosening of parts, cracking or flaking of materials, loss of temper of spring, annealing of parts, or other visible damage.	
[i] This limitation does not apply to an insulated conductor or other material that has been investigated and found to be acceptable for a higher temperature.	
[j] For standard insulated conductors other than those described in item B, the maximum temperature rise shall not exceed the maximum operating temperature for the wire in question minus an assumed ambient temperature of 40 °C.	
[k] See Clause 8.2.7.2.	
[l] See Clause 9.3.13 for other insulating materials.	
[m] For circuit breakers and other such devices having incorporated special inter-connectors/heat sinks, the temperature rise measurements shall be made on the MCC's buses, connecting straps or bars at the connecting point to such special inter-connectors/heat sinks. Measurements shall not to be made on the circuit breaker itself.	

Table 30
Ratings of inverse-time circuit-breaker used for tests

(Clause 9.12.5.6)

Ratings of inverse-time circuit-breaker used for tests	Circuit-breaker marking requirement	Full-load motor current rating, amperes
4 times rated maximum full-load motor current	No	100 A or less
3 times rated maximum full-load motor current	No	Greater than 100 A
15 A	No	Where calculated value is less than 15 A
Other ratings less than those specified above	Yes	–

Table 31
Standard short-circuit test values (minimum) for combination motor controllers

(Clauses 9.12.6.1, 9.15.1.1, A1, and A3.6)

Ratings		Test current	
kW	(Hp)	A[a]	Power factor
0 – 37	(0 – 50)	5 000	0.7 – 0.8
38 – 149	(51 – 200)	10 000	0.7 – 0.8
150 – 298	(201 – 400)	18 000	0.25 – 0.30
299 – 447	(401 – 600)	30 000	0.20 or less
448 – 671	(601 – 900)	42 000	0.20 or less
672 – 1193	(901 – 1 600)	85 000	0.20 or less
1 194 or more	(1 601 or more)	100 000	0.20 or less

NOTE For current rated controllers, use the equivalent horsepower rating derived from Table 15, Table 16 or Table 17, as applicable.

[a] Symmetrical rms.

Table 32
Unit short-circuit acceptance criteria

(Clauses 8.3.12 and 8.3.15)

1)	The contactor or other control device shall be permitted to be inoperative at the conclusion of the test. The contacts of a contactor in a combination controller shall be permitted to weld or completely disintegrate. However, the protective device shall open the test circuit.
2)	There shall be no discharge of parts outside the unit.
3)	The door or cover shall not be blown open, and it shall be possible to open the door or cover. Deformation of the enclosure shall be acceptable, but shall not result in the accessibility of live parts as determined by the use of the test rod specified in Clause 8.2.2.2.
4)	Burnout of the current element and damage to the overload relay shall be acceptable.
5)	The solid conductor connected between the live pole and the enclosure shall not be open.
6)	There shall be no damage to a conductor or terminal connector, and no conductor shall pull out of a terminal connector.
7)	There shall be no breakage or cracking of insulating bases to the extent that the integrity of the mounting of live parts is impaired.
8)	Contacts within a device that serves as the disconnecting means shall not be permitted to weld to the extent that the disconnecting means cannot be opened manually with the operating handle.
9)	A combination motor controller self-protected control device module may contain load switching means that have welded, provided that the module is located on the load side of the disconnection and branch circuit contacts, and that the module can be replaced.
10)	If provided as part of the equipment, neither end of a protective device such as a fuse or current limiter shall be completely separated from the mounting means, and the line end of a fuse or current limiter shall not bridge from the mounting means to dead metal.

Table 32 Continued on Next Page

Table 32 Continued

11)	Stab-in assemblies, if used, and vertical buses at the point of contact shall be in essentially the same mechanical and electrical condition as before the test.
12)	The fault current shall have been interrupted by the unit branch-circuit protective device or by the current-limiting means of an electronic motor controller.

Table 33
Automatic tripping time

(Clauses 8.3.14.2, 8.3.17.2, 9.14.2.1, and 9.17.2.1)

Current rating 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 – 1 000	20
1 001 – 1 200	24
1 201 – 1 600	26
1 601 – 2 000	28
Over 2 000	30

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

Table 34
Index of tests for motor control centers

(Clauses 8.3.1 and 9.1 and Table 35)

Test number	Test	Performance reference clause	Test reference clause
T1	Calibration	8.3.2	9.2
T2	Temperature	8.3.3	9.3
T3	Overvoltage and undervoltage	8.3.4	9.4
T4	Dielectric voltage withstand (after T2 or T3)	8.3.5	9.5
T5	Current withstand	8.3.6	9.6
T6	Dielectric voltage withstand (after T5)	8.3.7	9.7
T7	Contactor overload	8.3.8	9.8
T8	Dielectric voltage withstand (after T7)	8.3.9	9.9
T9	Short-circuit, bus structure	8.3.10	9.10

Table 34 Continued on Next Page

Table 34 Continued

Test number	Test	Performance reference clause	Test reference clause
T10	Dielectric voltage withstand (after T9)	8.3.11	9.11
T11	Short-circuit, units – standard-level	8.3.12	9.12
T12	Dielectric voltage withstand (after T11)	8.3.13	9.13
T13	Trip-out (after T11 and T12)	8.3.14	9.14
T14	Short-circuit-units – high-level	8.3.15	9.15
T15	Dielectric voltage withstand (after T14)	8.3.16	9.16
T16	Trip-out after T14 and T15	8.3.17	9.17
T17	Strength of insulating base and support	8.3.18	9.18
T18	Comparative deflection test	8.3.19	9.19

Table 35
Sequence of tests for combination motor control units[a]

(Clauses 8.3.1 and 9.1)

Construction type (See Table 11)	Sequence order	Sample number[b]				
		1	2	3	4	5
A	1	T2	T1	T11	–	T14
	2	T3		T12		T15
	3	T4				
C	1	T2	T1	T11	–	T14
	2	T3		T12		T15
	3	T4		T13		T16
D	1	T2	T1	T11	T7	T14
	2	T3	T5	T12	T8	T15
	3	T4	T6	T13		T16
E	1	T2	–	–	–	T14
	2	T3				T15
	3	T4				T16

[a] See Table 34 for explanation of test numbers.

[b] All or any combination of test sequences may be conducted on a single sample if agreeable to those concerned. More than one sample may be used if more than one rating is being tested. One sequence need not be completed as a prerequisite to the starting of another.

Table 36
Power factors for bus short-circuit tests

(Clauses 9.10.7.4, A1, and A3.6)

Test circuit, amperes	Maximum power factor
>0 ≤ 10 000	0.5
>10 000 ≤ 20 000	0.3
>20 000	0.2

Table 37
Closing angle

(Clause 9.10.10.2)

Number of phases	Bus bar relationship	Bus bar most likely to cause breakdown	Closing angle, electrical degrees[a]
1	All	All	0 ±10
3	All	A Phase	-13 ±10
3	All	C Phase	+13 ±10
3	All	B Phase	±13 ±10

[a] With respect to the zero point of the supply voltage on a phase-to-neutral basis in the case of a 3-phase circuit.

Table 38
Required number of test operations

(Clause 9.12.6.2)

Rating, hp	(kW)	Number of poles for a device	Number of current elements[a]	Type of branch circuit protection and number of poles provided		Number of operations[b]
				Fuse	Circuit-breaker (inverse-time and instantaneous)	
0 – 200	(0 – 149)	1 phase, single pole	1	1	Single pole	3 “O”
		1 phase, 2 poles	2	2	2 pole	3 “O”
		3 phase, 3 poles	3	3	3 pole	2 “O”
201 – 1 600	(150 – 1 193)	3 phase, 3 poles	3	3	3 pole	1 “O”

[a] Applies to devices provided with or incorporating a thermal relay.

[b] Number of operations for each current element selected, when device is provided with or incorporates thermal overload relays.

Table 39
Power factors for unit short-circuit tests

(Clauses 9.15.1.6, 9.15.5.2 9.15A.5.2, 9.23.5.2, A1)

Test current, amperes[a]	Power factor[b]
10 000 or less	0.70 – 0.80
10 001 – 20 000	0.25 – 0.30
Greater than 20 000	0.15 – 0.20

[a] Symmetrical rms amperes.

[b] Lower power factor circuits than specified may be used.

Table 40
Required number of test operations

(Clauses 9.15.5.3 and 9.15.5.4)

Disconnecting means provided	Type of test	Number of test operations
Yes	Disconnecting means closed on the circuit ("CO" shot)	1[a,b]
Yes	Motor control device closed on the circuit ("CO" shot)	1[a]
Yes	Circuit closed on equipment ("O" shot)	1
No	Motor control device closed on the circuit ("CO" shot)	1
No	Circuit closed on equipment ("O" shot)	1

[a] If complete physical closure of the switching contact is established during closing tests ("CO" shots), the withstand test ("O" shot) shall not be required.

[b] When a motor control device and its control circuit are supplied from the same source (common control), the closing test on the disconnect switch shall not be required.

Table 41
Values of voltage for test

(Clause 9.8.6)

	Voltage rating of equipment[a]					
Test	110 – 120	220 – 240	254 – 277	380 – 415	440 – 480	560 – 600
Temperature	120	240	277	415	280	600
Overvoltage, ac or dc	132	264	305	457	528	660
Undervoltage, ac	102	204	235	353	408	510
Undervoltage, dc	96	192	222	332	384	480
Overload	120	240	227	415	480	600
Endurance	120	240	277	415	480	600

[a] If the rating of the equipment does not fall within any of the indicated voltage ranges, it shall be tested at its rated voltage, except for the overvoltage and undervoltage tests. See Clause 9.8.6.

Table 42
Time constant of test circuit

(Clauses 9.12.6.1and 9.15.5.2)

Rated interrupting current, amperes	Minimum time constant, s
10 000 or less	0.003
Over 10 000	0.008

Table 43
Minimum material characteristics for the direct support of uninsulated live parts

(Clause 8.2.7.1)

Flame class[i]	RTI elec	Maximum performance level category (PLC)		
		HWI[b,c]	HAI[d,e]	CTI[f,g,h]
HB	a	2	1	3
V-2	a	2	2	3
V-1	a	3	2	3
V-0	a	4	3	3

Relative Thermal Index (RTI)

[a] The electrical RTI value of a material shall be determined in accordance with the test requirements referenced in Annex C, item 30, or by use of the generic RTI from Table 44. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, Clauses 8.2.8.3, 8.3.3, and 9.3.13.

Hot Wire Ignition (HWI)

[b] The HWI Performance Level Category (PLC) value of a material shall be determined by the hot wire ignition test referenced in Annex C, item 29. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

[c] A material without an HWI Performance Level Category (PLC) value at the minimum thickness or with a HWI PLC value greater (worse) than the value required by Table 43 shall be subjected to the end-product Abnormal Overload Test or the Glow Wire End-Product Test requirements referenced in Annex C, item 9.

High Current Arc Resistance to Ignition (HAI)

[d] The HAI value of a material shall be determined by test in accordance the requirements referenced in Annex C, item 29. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e.

[e] A material without a HAI PLC value at the minimum thickness or with an HAI PLC value greater (worse) than the value required by Table 41 shall be subjected to the end-product Arc Resistance Test referenced in Annex C, item 9.

Comparative Tracking Index (CTI)

[f] The CTI PLC value of a material shall be determined by test in accordance with the requirements referenced in Annex C, Item 29. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness. The CTI value applies to insulating materials used in pollution degree 3 environments for voltages of 600 V or less. For equipment where pollution degree 1 or 2 is maintained, an insulating material shall have a CTI PLC of 4 or less. For equipment rated 601-1000 volts, see footnote h.

[g] A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 41 shall have a proof tracking index of 175 when used in pollution degree 3 environment or a proof tracking index of 100 when used in pollution degree 1 or 2 environments as determined by the end-product Proof Tracking Test requirements referenced in Annex C, item 9.

[h] For equipment rated 601 – 1 000 volts, the insulating material shall not track beyond one inch in less than 60 minutes using the time to track method of the Inclined Plane Tracking Test referenced in Annex C, item 29. The voltage for the Inclined Plane Tracking Test shall be not less than the rated voltage of the equipment.

Flammability Classification

[i] The flame class of a material shall be determined by the horizontal burning or vertical burning test requirements referenced in Annex C, item 28.

Table 44
Generic materials for other than direct support of uninsulated live parts

(Clause 8.2.28.6)

Generic material	Minimum thickness		RTI, °C
	Inch	(mm)	
Any cold-moulded composition (e.g., concrete)	No limit		No limit
Ceramic, porcelain, and slate	No limit		No limit
Diallyl phthalate	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Melamine	0.028	(0.71)	130
Melamine-phenolic	0.028	(0.71)	130
Phenolic	0.028	(0.71)	150
Unfilled nylon	0.028	(0.71)	105
Unfilled polycarbonate	0.028	(0.71)	105
Urea formaldehyde	0.028	(0.71)	100

NOTE: Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test, Clauses 8.2.8.3, 8.3.3, and 9.3.13.

Table 45
Short time durations

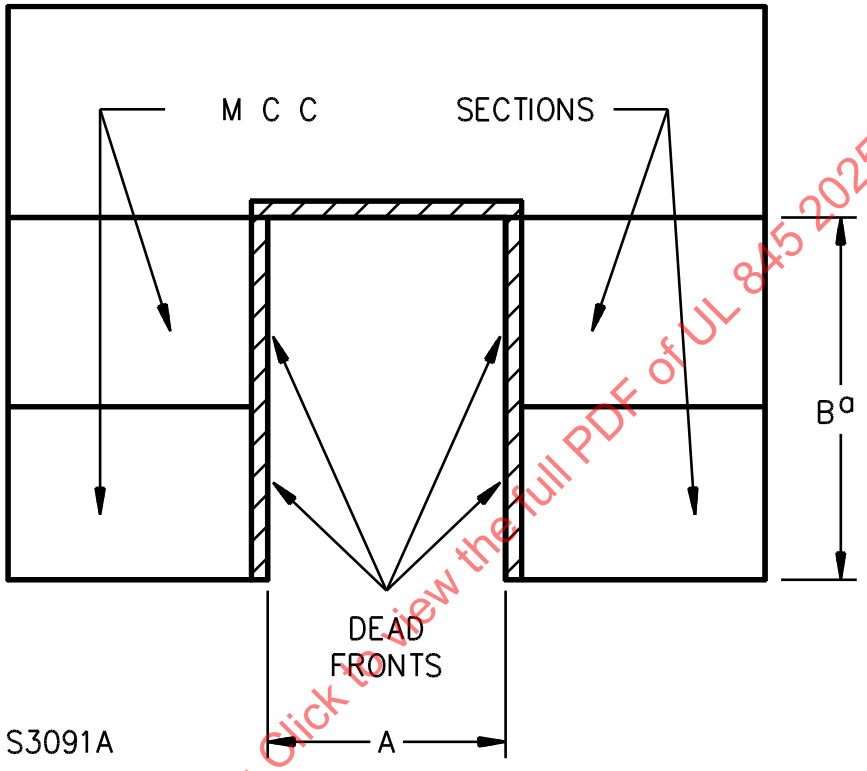
(Clauses 5.4.1.4 and 5.4.4.2)

Short time duration (s)
0.050
0.067
0.083
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
0.500

FIGURES

Figure 1
U-shaped construction

(See Clause 8.2.5.1)



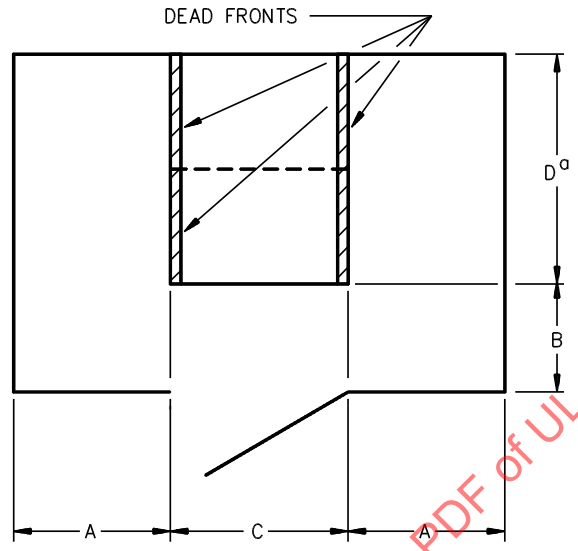
Values of variables in Figure 1						
Voltage to ground	Canada Minimum work space A[a]		Mexico Minimum work space A[a]		United States Minimum work space A[a]	
	m	(ft)	m	(ft)	m	(ft)
0 – 150	1.0	(3.25)	0.9	(3)	0.9	(3)
151 – 600	1.0	(3.25)	1.2	(4)	1.2	(4)
601 – 1 000	–	–	–	–	1.5	(5)

[a] For a motor control center rated 1200 A or more, the A dimension shall be doubled if the B dimension shown in Figure 1 exceeds 1.8 m (6 ft).

Figure 2

Two-sided enclosed construction

(See Clause 8.2.5.1)



Canada
Values of variables in Figure 2

Horizontal bus rating	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
<1200 A	1.0	3.25	0.6	2.0	0.6	2.0
>1200 A or > 750 V	1.5	4.92	0.6	2.0	0.6	2.0

Mexico
Values of variables in Figure 2

Voltage to ground	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
0 – 150	0.9	3	0.6	2	0.6	2
151 – 600	1.0	3.25	0.6	2	0.6	2

United States
Values of variables in Figure 2

Voltage to ground	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
0 – 150	0.9	3	0.6	2	0.6	2
151 – 600	1.0	3.25	0.6	2	0.6	2
601 – 1 000	1.2	4	0.6	2	0.6	2

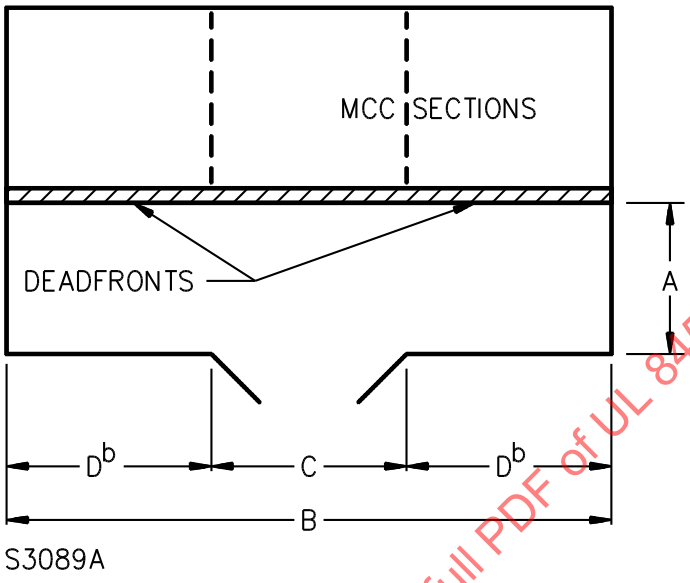
[a] If the motor control center is rated 1200 A or more and if the D dimension exceeds 1.8 m (6 ft), an additional minimum 0.6 m (2 ft) wide door shall be located at each opposite side of the enclosure, or the A dimension shall be doubled.

[b] The door shall be at least 2 m (6.5 ft) high and shall open outward or be of the sliding type.

Figure 3

Single-sided enclosed construction

(See Clause 8.2.5.1)



Canada
Values of variables in Figure 3

Horizontal bus rating	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
<1200 A	1.0	3.25	0.75	2.5	0.6	2.0
>1200 A or > 750 V	1.5	4.92	0.75	2.5	0.6	2.0

Mexico
Values of variables in Figure 3

Voltage to ground	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
0 – 150	0.9	3	0.75	2.5	0.6	2
151 – 600	1.1	3.5	0.75	2.5	0.6	2

United States
Values of variables in Figure 3

Voltage to ground	Minimum work space					
	A[a]		B		C[b]	
	m	ft	m	ft	m	ft
0 – 150	0.9	3	0.75	2.5	0.6	2
151 – 600	1.1	3.5	0.75	2.5	0.6	2
601 – 1000	1.2	4	0.75	2.5	0.6	2

[a] If the D dimension is greater than 76.2 mm (3 in), the B dimension is greater than 1.8 m (6 ft), and the motor control center is rated 1200 A or more, the A dimension shall be doubled, or a door shall be provided at each end.

[b] The door shall be at least 2 m (6.5 ft) high and shall open outward or be of the sliding type.

Figure 4

Conductors through openings

(Clause 8.2.13.9)

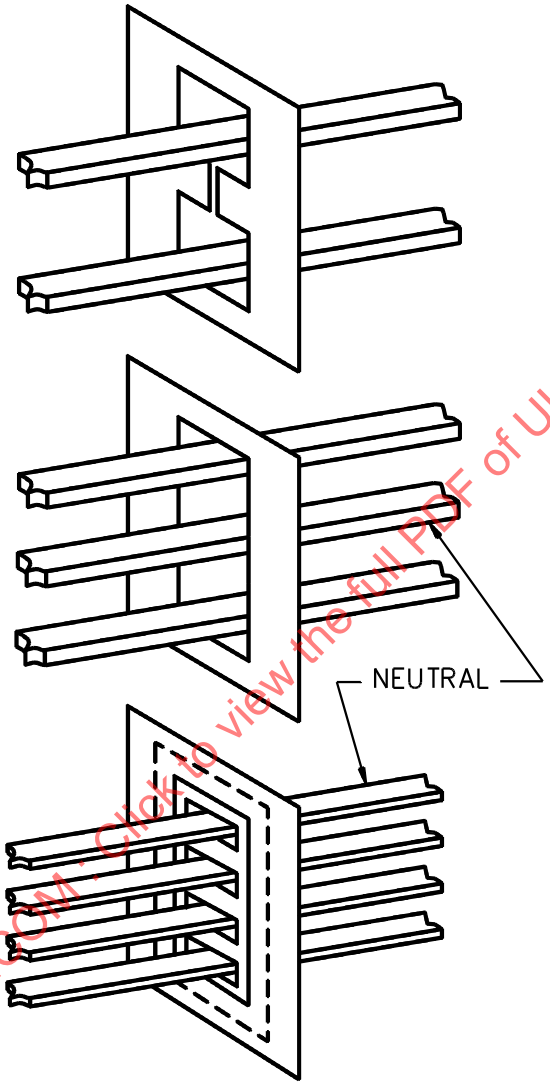
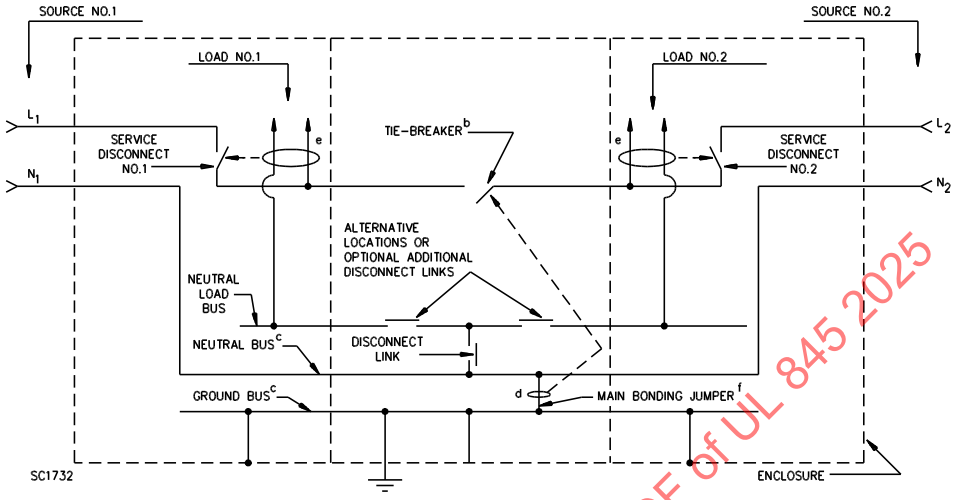


Figure 5

Typical double-ended motor control center[a]

(Clauses 8.2.24.1 and Annex G)



[a] Other variations are possible.

[b] Tie breaker disconnect (not a circuit-breaker marked "Line" and "Load" nor a fused switch). See Clauses 8.2.24.1 and 8.2.24.2.

[c] In Mexico and the United States, the neutral bus and ground bus may be combined if ground-return-type ground-fault protection is not used and the sections are marked "Suitable only for use as service equipment."

In Canada, this construction shall not be permitted.

[d] Ground-return-type ground fault protection sensor in accordance with Clause 8.2.21.14.

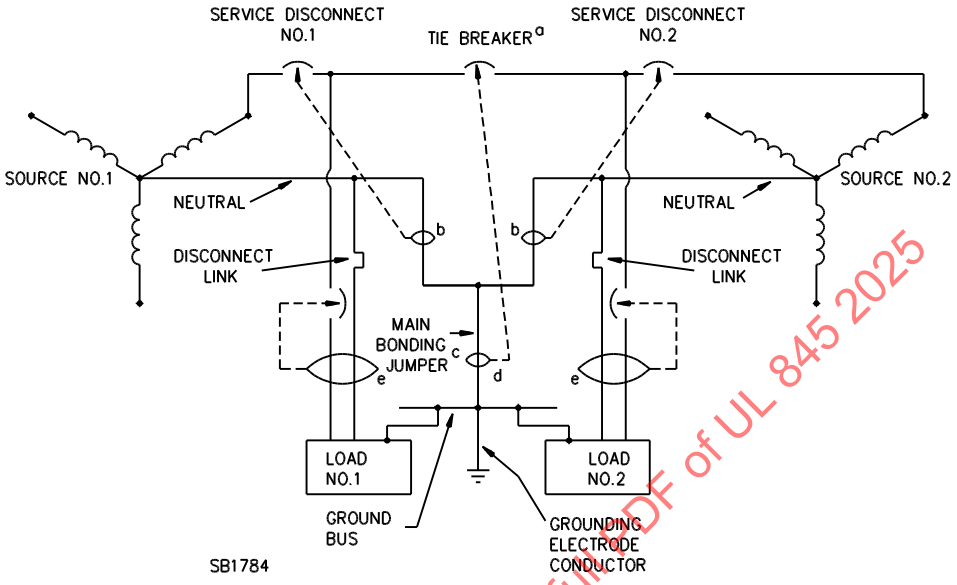
[e] Zero-sequence-type or residual-type ground-fault protection sensor in accordance with Clauses 8.2.21.12 and 8.2.21.13.

[f] Size of main bonding jumper shall be based on largest service disconnect.

Figure 6

Typical double-ended motor control center

(Clause 8.2.24.1)



[a] Tie-breaker disconnect (not a circuit-breaker marked "Line" and "Load" nor a fused switch). See Clauses 8.2.24.1and 8.2.24.2.

[b] Additional ground-return-type ground-fault protection sensor's utility shall be interlocked with sensor specified in note d so as to function only when fault current is also sensed as specified in note d.

[c] Size of main bonding jumper shall be based on largest service disconnect.

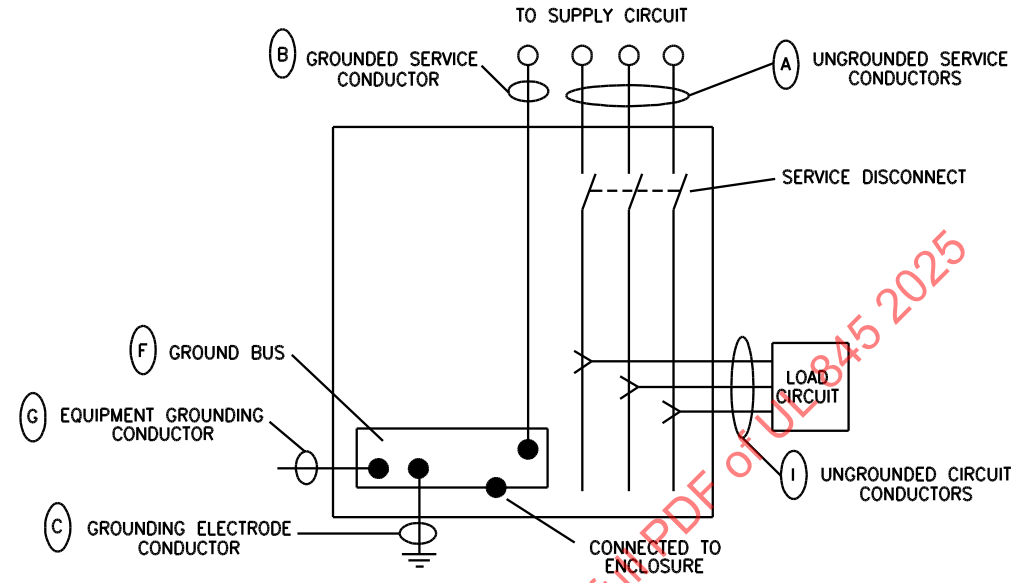
[d] Ground-return-type ground-fault protection sensor in accordance with Clause 8.2.21.14.

[e] Zero-sequence-type or residual-type ground-fault protection sensor in accordance with Clauses 8.2.21.12 and 8.2.21.13.

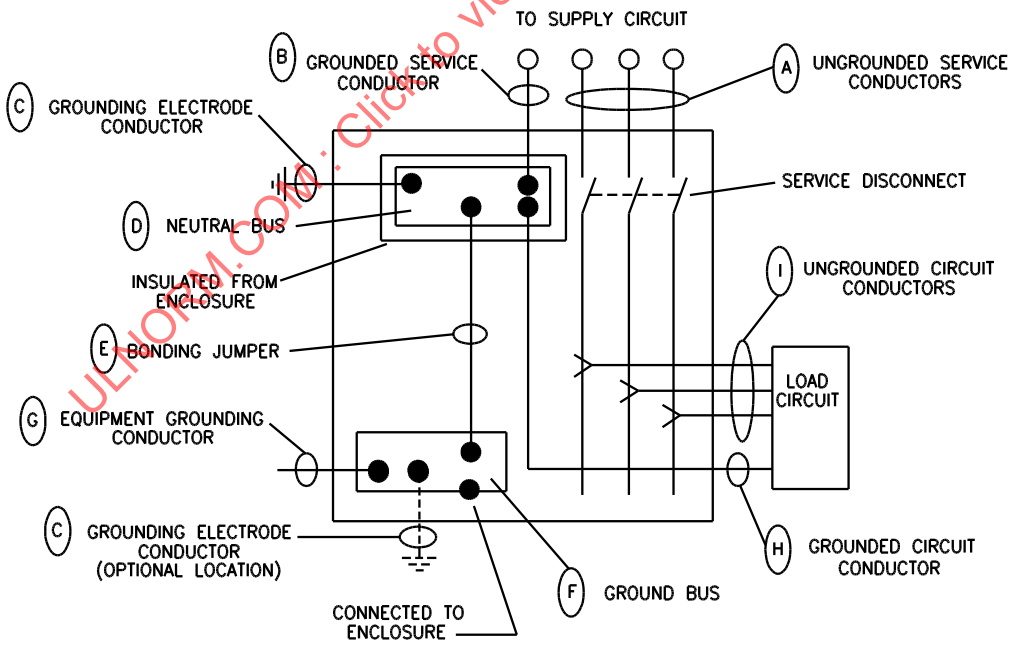
Figure 7

Grounding/bonding terms

(Clause 8.2.30.1)



TYPICAL THREE PHASE, FOUR WIRE MOTOR CONTROL CENTER
(THREE PHASE, THREE WIRE DISTRIBUTION)



THREE PHASE, FOUR WIRE MOTOR CONTROL CENTER
(THREE PHASE, FOUR WIRE DISTRIBUTION)

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