UL 891

STANDARD FOR SAFETY

Switchboards

UL Standard for Safety for Switchboards, UL 891

Twelfth Edition, Dated July 19, 2019

Summary of Topics

This new edition of ANSI/UL 891 covers switchboards nominally rated at 1 000 V or less and intended for use in accordance with the Canadian Electrical Code, Part I (CE Code, Part I), the National Electrical Code (NEC), ANSI/NFPA 70, and the Mexican Standard for Electrical Installations (Utility), NOM-001-SEDE.

The requirements are substantially in accordance with Proposal(s) on this subject dated April 27, 2018 and November 9, 2018.

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NMX-J-118/2-ANCE-2019
Fourth Edition

CSA Group
CSA C22.2 No. 244:19
Second Edition

Underwriters Laboratories Inc.
UL 891
Twelfth Edition

Switchboards

July 19, 2019

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 Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL 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 UL 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 inquires@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 Twelfth Edition.

The most recent designation of ANSI/UL 891 as an American National Standard (ANSI) occurred on July 19, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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

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Preface

This is the harmonized ANCE, CSA Group, and UL standard for Switchboards. It is the Fourth edition of NMX-J-118/2-ANCE, the Second edition of CSA-C22.2 No. 244, and the Twelfth edition of UL 891. This edition of NMX-J-118/2-ANCE supersedes the previous edition published on October 31, 2012. This edition of CSA-C22.2 No. 244 supersedes the previous edition published on July 26, 2005. This edition of UL 891 supersedes the previous edition published on July 26, 2005.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Subcommittee, 17D – Panelboard and Switchboard 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 switchboard manufacturers and users.

This standard was reviewed by CSA C232(ICSP) – Integrated Committee on Switchgear Products, 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 equivalent standard for ANCE, CSA Group and UL.

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

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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Switchboards

1 General

1.1 Scope and object

1.1.1 This Standard applies to switchboards nominally rated at 1 000 V or less and intended for use in accordance with the Canadian Electrical Code, Part I (CE Code, Part I), the National Electrical Code (NEC), ANSI/NFPA 70, and the Mexican Standard for Electrical Installations (Utility), NOM-001-SEDE.

1.1.2 In this standard the term switchboard is intended to refer to a dead-front switchboard.

1.1.3 These requirements do not cover the following switchboard types: preset and dimmer control (theater), live front, railway control or electrification; or constructions intended only for receiving motor control center units.

1.1.4 These requirements cover switchboards for use on circuits having available short-circuit currents of not more than 200 000 A.

1.1.5 These requirements do not cover switchboards with short-time current ratings.

2 General

2.1 Undated references

2.1.1 For undated references to standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this standard was approved. For dated references to standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the standard was approved. See Annex B.

2.2 Multiple countries codes

2.2.1 When compliance with multiple countries' codes or Standards is required, but the product is not intended for use in all three countries, the product need only comply with the codes or Standards for the country or countries in which it is intended to be used.

2.3 Products for Canada

2.3.1 For products intended for use in Canada general requirements are given in Reference Item No. 15 of Annex B.

2.4 Components

2.4.1 A component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of Standards covering components generally used in the products covered by this Standard. A component shall comply with the Underwriters Laboratories Inc. Standards, the ANCE Standards, and the Canadian Standards Association Standards for the component. When a product is not intended for use in all three countries, a component need only comply with the component Standards for the country or countries in which it is intended to be used.

2.4.1.1 A component need not comply if it is:

a) used in a Class 2 circuit; and

b) treated as an arcing part as covered in 8.2.1.3.1.1 and 8.8.1.8.5.

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

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

b) Is superseded by a requirement in this standard.

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

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

3 Definitions

3.1 For the purposes of this standard, the following definitions apply:

3.2 **Accessible, front:** an enclosure in which incoming and outgoing field termination points are accessible from the front. Other connections shall be permitted to be rear or side accessible. If necessary, a limited number of barriers or covers shall be permitted to be removed to achieve this accessibility.

3.3 **Accessible, rear:** an enclosure in which all incoming and outgoing field termination points are accessible from the rear. Other connections shall be permitted to be front or side accessible. If necessary, a limited number of barriers or covers shall be permitted to be removed to achieve this accessibility.

3.4 **Ambient temperature:** the temperature of the surrounding medium that comes in contact with the switchboard. For an enclosed switchboard, it is the temperature of the medium outside the enclosure.

3.5 **Ampacity:** the current in amperes a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

3.6 **Barrier:** a partition for the insulation or isolation of electric circuits or electric arcs.

3.7 **Bonding:** the permanent joining of metallic parts to form an electrically conductive low impedance path that will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

3.8 **Bus:** a conductor, or group of conductors, that serves as a common connection for two or more circuits.

3.9 **Bus, branch:** a bus that originates at a section bus and terminates in one or more overcurrent devices.

3.10 **Bus, ground:** a bus to which the equipment grounding conductors from individual pieces of equipment are connected and which, in turn, is connected to the grounding electrode conductor at one point. It provides a continuous ground in multiple equipment sections through which it passes. See Figure 1, Figure 2, and Figure 3.

3.11 **Bus, neutral:** a bus having the appropriate number of terminals to provide for the connection of the neutral line and load conductors.

3.12 **Bus, section:** a portion of a bus structure which serves one or more overcurrent devices in the switchboard section and comprises that part of the bus between the through bus and branch bus. See Figure 1.

3.13 **Bus, splice:** a bus that electrically connects switchboard sections. See Figure 1.

3.14 **Bus structure:** an assembly of bus conductors with associated connecting joints and insulating supports.

3.15 **Bus, through:** a bus that extends through a switchboard section. It is sometimes called a horizontal, cross or main bus.

3.16 **Circuit breaker:** a device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overcurrent, without injury to itself when properly applied within its rating.

3.17 **Circuit breaker, molded case:** a circuit breaker which is assembled as an integral unit in a supporting and enclosing housing of insulating material.

3.18 **Compartment:** an area within the equipment that is constructed to isolate devices in that compartment from the surrounding area except for openings used for interconnections, control or ventilation.

3.19 **Continuous current:** the amount of current a conductor, a device or a piece of equipment can carry continuously for an indefinite period of time without exceeding its allowable temperature rise.

3.20 **Control wiring:** the wiring for the circuit(s) of a piece of equipment that carries the electrical signals directing the performance of the devices in that equipment, but which does not carry power current.

3.21 **Current rating:** the designated maximum direct or alternating current in rms amperes at rated frequency that a device can carry continuously under specified conditions.

3.22 **Dead-front switchboard:** a switchboard which has no exposed live parts on the front.

3.23 **Device:** a component of an electrical system that is intended to carry or control, but not utilize, electrical energy.

3.24 **Dielectric voltage withstand tests:** tests to determine the ability of the insulating materials and spacings to withstand overvoltages.

3.25 **Disconnecting means:** a device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

3.26 **Distribution section:** a switchboard section having branch or feeder circuit switching and overcurrent protective devices.

3.27 **Double-ended switchboard (multiple source):** a switchboard construction that provides for the connection of two sources of power. See Figure 2 and Figure 3.

3.28 **Dummy fuse:** a current carrying part made of copper 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.

3.29 **Enclosure:** a surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specified environmental conditions.

3.30 **Filler plate:** a plate intended to close an opening that would otherwise be closed by the subsequent installation of a circuit breaker or other device.

3.31 **Frame size:** applies to a group of molded case circuit breakers that are physically interchangeable with each other. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group. Groups may or may not be physically interchangeable with each other whether furnished by one manufacturer or by various manufacturers.

3.32 **Fuse:** a protective device which opens by the melting of a current-sensitive element during specified overcurrent conditions.

3.33 **Fusible switch:** a switch in which one or more poles have a fuse in series in a composite unit.

3.34 **Ground-fault protector (GFP):** a ground-fault protector is a device or system that provides protection for equipment (not for personnel) by opening the circuit in case of a predetermined ground-fault current. A ground-fault protector includes a ground-fault current sensing device and relaying equipment or a combination of ground-fault current sensing device and relaying equipment that will operate to cause a disconnecting means to function at a predetermined value of ground-fault current.

3.35 **Individually mounted device:** a device which is not panel-mounted and which may or may not be enclosed in its own compartment.

3.36 **Inlet:** a permanently mounted plug intended to receive power from a cable connector.

3.37 **Interlock:** an electrical or mechanical component actuated by the operation of a device or other means, with which it is directly associated to govern succeeding operations of the same or allied devices.

3.38 **Interrupting rating:** the highest current at rated voltage that a device is intended to interrupt under standard test conditions.

3.39 **Isolated:** (as applied to location) not readily accessible to persons unless special means for access are used.

3.40 **Main device:** a single device that disconnects all ungrounded conductors, other than control power conductors when used, from the supply bus. See Figure 1.

3.41 **Main section(s):** a portion of a switchboard where the main or service disconnect device(s) is located. The section shall also be permitted to contain utility meters or other instruments. Incoming line conductors may be terminated in this section.

3.42 **Neutral:** neutral refers to a conductor (when one exists) of a polyphase circuit or single-phase, 3-wire circuit which is intended to have a voltage such that the voltage differences between it and each of the other conductors are approximately equal in magnitude and are equally spaced in phase, such as:

a) the center point of a wye connected system;

b) the midpoint of a 3-wire, single phase system;

c) the midpoint of one side of a delta connected system.

3.43 **Outlet:** a device that is intended to provide power to an inserted plug, and that is installed as a fixed receptacle on equipment.

3.44 **Peak let-through current:** the maximum instantaneous current through an overcurrent device during the total clearing time.

3.45 **Rating:** a designated limit of operating characteristics based on definite conditions.

3.46 **Rating Plug:** a self-contained portion of a circuit breaker that is interchangeable and replaceable in a circuit breaker trip unit by the user. It sets the Rated Current (In) of the circuit breaker.

3.47 **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 cutoff of the supply.

3.48 **Short-circuit current rating:** the maximum RMS prospective (available) current to which a device can be connected. The rating is expressed in amperes and volts.

3.49 **Switch:** a device, manually operated, unless otherwise designated, for opening and closing or for changing the connection of a circuit.

3.50 **Switchboard:** a large single panel, structural frame or assembly of panels or structural frames on which may be mounted, on the face or back or both: switches, overcurrent, and other protective devices, buses, and instruments.

Note: Switchboards may be accessible from the rear as well as from the front and are not intended to be installed in cabinets.

3.51 **Switchboard enclosure:** an enclosure intended to:

a) enclose one or more switchboard sections or switchboard interiors; or

b) provide auxiliary wiring space for an adjacent switchboard section.

3.52 **Switchboard interior:** the interior part of a switchboard intended to be installed in a switchboard enclosure to become the equivalent of a switchboard section.

3.53 **Switchboard section:** that portion of a switchboard that is prevented by the structural framework from being physically separated into smaller units.

Note: Framework that is welded or joined with steel rivets over 6.4 mm (1/4 in) in diameter is considered to constitute a single section. However, framework that is joined with one-way (tamper-proof) bolts is not considered to constitute a single section. An assembly consisting of an enclosure and terminal blocks or bus bars is considered to be a switchboard section.

3.54 **Symmetrical current:** symmetrical current is alternating current having no offset or transient component and, therefore, having a wave form essentially symmetrical about the zero axis. Symmetrical current is expressed in terms of rms amperes.

3.55 **Tap:** A terminal or provision for a terminal intended for field wiring that is located on the supply side of the service disconnecting means, for uses permitted by the installation rules of the country of installation.

4 Units of measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4.2 Unless indicated otherwise all voltage and current values mentioned in this standard are root-mean-square (rms).

5 Electrical characteristics of assemblies

5.1 General

5.1.1 A switchboard shall be rated in amperes, volts, frequency and short circuit current. An alternating-current rating shall include the number of phases, if other than single-phase.

5.1.2 If a switchboard section or interior is intended to be connected to more than one energy source, including any incoming control circuit, each source shall be rated as indicated above.

5.2 Rated voltages

5.2.1 The voltage rating of a switchboard section or interior shall be nominally rated at 1 000 V or less and is the maximum value for which the assembly has been evaluated. Common ratings are shown in Table 1.

5.2.2 The voltage rating of any individual part (such as a switch or circuit breaker) that is provided in the switchboard section or interior and that is connected to the main supply circuit shall equal or exceed the nominal voltage of the circuit to which it shall be connected.

5.2.3 A switchboard section or interior containing a transformer, other than a control or potential transformer, with a secondary circuit leaving the section shall have a secondary voltage rating.

5.3 Continuous current rating

5.3.1 Supply rating

5.3.1.1 A switchboard section or interior shall be assigned a continuous current supply rating that shall not exceed the ampacity of the supply or through bus or wire that is provided with the section or interior, or that is specified for field installation.

5.3.1.1.1 Through or splice bus bars which extend beyond the point where the section bus bars are connected may have reduced ampacity as described in 8.8.1.6.16.1 – 8.8.1.6.16.2. Such reduced rating shall be shown if the next section is to be installed at some future time.

5.3.1.2 The supply rating of a switchboard section or interior shall not be less than the percent of the sum of the continuous ampere range of the assembled meter positions specified in Table 2 if the switchboard:

a) is marked to indicate it is suitable for use as service equipment;

b) has provision for two or more watthour meters without provision for current transformers; and

c) is not provided with a single main disconnect. A single main disconnect is required in Canada.

5.3.2 Section rating

5.3.2.1 A switchboard section or interior shall be assigned a rating for current that shall not exceed the ampacity of the section bus, as covered in 8.8.1.6.9 – 8.8.1.6.16.2, or the main switch, main fuseholder, main circuit breaker, or circuit breaker frame, if such are provided in the section.

5.3.2.2 If there is provision for mounting branch circuit units both above and below the point where the section bus is connected to the supply, the switchboard section or interior may be assigned both upper and lower section bus ratings.

5.3.2.3 If the ampacities of the various phase bus bars covered in 5.3.1.1 and 5.3.2.1, including the neutral bus bar as covered in 8.8.1.6.8, are not identical, the rating for current shall specify the ampacity of each bus bar or terminal.

5.4 Short-circuit current rating

5.4.1 The short-circuit current rating of a switchboard section or interior shall be one or more of the values shown in Table 3.

5.5 Rated peak withstand current (I_{pk}) (of a circuit of an assembly)

Reserved.

5.6 Rated conditional short-circuit current (I_{cc}) (of a circuit of an assembly)

Reserved.

5.7 Rated fused short-circuit current (I_{cf}) (of a circuit of an assembly)

Reserved.

5.8 Rated diversity factor

Reserved.

5.9 Rated frequency

5.9.1 An AC switchboard shall be rated in frequency.

6 Information to be given regarding the assembly

6.1 Nameplates

6.1.1 Locations

6.1.1.1 Markings shall be located as specified in Table 4. Markings in location category A shall be visible without removing the trim or the cover of the enclosure. This includes the front of the enclosure or on the inside of a hinged door. It also includes the front of a dead-front within a Type 3R enclosure if the door may be opened regardless of the position of the disconnecting means. Markings in location category B shall be visible without disassembly or the removal of a device and when the trim or cover of the enclosure is

removed. Markings in location category B may be located as specified for location category A but shall remain visible with the cover removed and upon installation of any additional component permitted by marking.

6.1.2 Letter height

6.1.2.1 The characters in the markings described in 6.2.1.2 (c), 6.2.1.3, 6.2.1.4, 6.2.1.6, 6.2.1.9 – 6.2.1.12, 6.2.2.1, 6.2.3.1 – 6.2.3.5, 6.2.3.7 – 6.2.3.11, 6.2.5.3, 6.2.7.3 – 6.2.7.6, 6.2.7.15, 6.2.10.1, 6.2.11.1, 6.2.13.2, 6.2.15.1, and 6.3.2.1 shall not be less than 2.4 mm (3/32 in) high.

6.1.3 Permanence of marking

6.1.3.1 A required marking shall comply with the permanence of marking requirements in Reference Item No. 12, Annex B.

Note: Etched or stamped markings on metal nameplates are considered permanent.

6.2 Markings

6.2.1 General

6.2.1.1 All markings shall be in the appropriate language for the country in which the switchboard will be installed. (Spanish for Mexico, English for the USA, English for Canada). A manufacturer may choose to utilize multiple languages on a switchboard.

Note: In Canada, there are two official languages, English and French. Annex C provides French translations of the markings specified in this standard. Markings required by this standard may have to be provided in other languages to conform with the language requirements of the country where the product is to be used.

6.2.1.2 A switchboard section or separate switchboard interior shall be marked with:

a) the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified (hereafter referred to as manufacturer's name);

b) catalog number, a general type designation, or other mark used for distinguishing purposes;

c) the electrical characteristics. (See clause 5). Both supply and section ratings shall be included, if different. If all phases and neutral are not the same, ratings of each shall be marked or indicated on a wiring diagram.

1) Voltage – See Table 1 for common values. Voltage shall be followed by:

i) volts or V,

ii) the symbol for alternating current (see Figure 4) and/or for direct current (see Figure 5).

2) Frequency – If alternating current the frequency number shall be followed by Hz or hertz.

3) Phases – if alternating current and other than single-phase, the symbol Φ (Greek letter phi) may be used in place of the word phase.

4) Current – Current shall be expressed as the ampere rating followed by A or Ampere(s).

5) Short-circuit current – See Table 3 for values. See clauses 6.2.1.12 – 6.2.1.15.

Note: The use of k to denote thousands is acceptable.

6.2.1.2.1 If a manufacturer produces or assembles switchboard sections, interiors, or enclosures at more than one factory, each finished switchboard section, interior, or enclosure shall have a distinctive marking, that may be in code, by which it may be identified as a product of a particular factory.

6.2.1.3 If a switchboard section is intended for stock and is rated for several different voltages or number of phases or wires, the individual voltage and phase ratings may be on a wiring diagram provided with the switchboard or attached in location category B in accordance with Table 4 (see footnote a to Table 4) if the maximum voltage is shown on the outside of the section and there is a reference to the wiring diagram.

6.2.1.4 If a switchboard section or interior is provided with provision for connection to two or more supply sources or with devices to which both line and load connections are to be made in the field, the current and voltage ratings for each supply source or each device shall be given. The marking may be on one or more nameplates. If the marking is on only one nameplate, it shall clearly indicate the buses and devices involved and their ratings, or shall refer to a wiring diagram provided in location category A in accordance with Table 4.

6.2.1.5 If a switchboard section or interior is provided with provision for connection to an external source of control circuit power, terminals for that connection shall be identified, and the current and voltage ratings for the source shall be marked or indicated on a wiring diagram.

6.2.1.6 A switchboard enclosure shall be marked as required by 6.2.1.2 (a) and (b), and if intended and marked for field installation of a particular switchboard interior, the enclosure shall be marked with electrical ratings, unless the markings on the interior will be visible after installation.

6.2.1.7 Switchboard Sections shall be marked with section numbers as follows:

a) A single section switchboard shall be marked "1 of 1".

b) A section of a multi-section switchboard shall be marked "___ of ___". The first blank shall be filled in with a number indicating the position that the section occupies in the series of sections constituting the switchboard. The section on the left side when facing the front of the switchboard shall be section 1. The second blank shall be filled in with the total number of sections in the switchboard.

c) A switchboard section mounted on top of one or more sections shall be marked "____T" where the blank is filled with the number of the initial section covered.

d) A switchboard enclosure (pull or auxiliary section) may be included in the numbering sequence if it is located at either end of the switchboard and shall be included in the numbering sequence if located between switchboard sections.

6.2.1.8 A switchboard shall be marked with the following or equivalent wording (see 6.2.1.1):

"Maximum continuous loads not to exceed 80 percent of the overcurrent protective device (circuit breaker and fuses) ratings employed in other than motor circuits, except for those circuits employing circuit breakers marked as suitable for continuous operation at 100 percent of their ratings."The marking shall be provided in location category B in accordance with Table 4.

6.2.1.9 With regard to 8.8.1.6.9 – 8.8.1.6.13 and 8.8.2.3.8, if the supply rating of a switchboard section or interior having a main fuseholder or circuit breaker frame or the ampacity of a branch bus or wire in series with a fuseholder or interchangeable circuit breaker trip unit is less than the rating of the largest fuse accommodated by a fuseholder or the largest trip unit of an interchangeable trip circuit breaker, there shall be a clear and permanent marking, plainly visible when the fuse or trip unit is being changed, prohibiting the use of a fuse or trip unit having a rating greater than the ampacity of the bus bar or wire. The marking shall be provided in location category B in accordance with Table 4.

6.2.1.10 With regard to 8.6.6.8 – 8.6.8.4 and 8.6.15.2, if a fuseholder for a miscellaneous or miniature (supplemental) fuse is provided, there shall be a marking near the fuseholder specifying the voltage and current rating of the fuse. The marking shall indicate the manufacturer and type designation of the fuse but may also include "or equivalent." A fuseholder for a 10.3 mm by 38.1 mm (13/32 by 1-1/2 inches) miscellaneous fuse may also indicate that a Class CC fuse may be used.

6.2.1.11 A switchboard section or interior supplied with branch circuit bus bars to which a branch circuit unit (circuit breaker, switch, or fuseholder) may be added in the field shall be plainly marked (on a wiring diagram, or in some other location) to indicate the ampacity of that bus bar, unless:

a) the ampacity of the bus bar is not less than the maximum current rating of any unit that is intended to be connected to it; or

b) the ampacity of the bus bar is not less than the section current rating.

6.2.1.12 A switchboard section or interior shall be marked with the following or the equivalent information:

a) the phrase "Short-Circuit Current Rating," the short-circuit current rating in amperes or rms symmetrical amperes for alternating current (See Table 3);

b) if the switchboard contains meter mounting equipment other than those for use with current transformers, it shall be marked with the phrase "Watt-hour meter not included in short-circuit current rating.";

c) the maximum voltage rating for each short-circuit current rating;

d) a phrase indicating that an additional or replacement device (other than a fuse) shall be of the same manufacturer, type designation, and equal or greater interrupting rating. This may be accomplished by specific reference to the device if the interrupting rating of the device is not less than any marked short-circuit-current rating of the switchboard. For a fuse, the class of fuses shall be specified;

e) the ampere rating of the devices if not all of the same type designation are acceptable for the short-circuit current rating of the switchboard;

f) when applicable, the identity of the combinations of integral or remote main and branch-circuit overcurrent-protective devices that are required when applying the marked short-circuit current rating (See 6.2.1.14);

g) a statement that the short-circuit current rating is limited to the lowest short-circuit current rating of any switchboard section connected in series, any installed circuit breaker or fused switch other than those located in a control circuit, the short-circuit current rating marked on the switchboard of any installed combination series-connected circuit breaker or any installed panelboard having a marked short-circuit current rating. See Annex D.

6.2.1.12.1 A switchboard section containing only a transformer and associated wiring need not be marked with a short-circuit current rating.

6.2.1.12.2 Switchboards with inlets (see 8.8.4.2) shall be marked with an additional short circuit rating where a different rating exists when connected to the inlets.

6.2.1.13 The short-circuit current rating of a switchboard section or interior shall be an integral part of:

a) a marking containing the manufacturer's name, trade name, trademark, or the like as specified in 6.2.1.2; or

b) another required marking.

If there is more than one short-circuit current rating, all such ratings shall appear together in location category A or B in accordance with Table 4.

6.2.1.14 If the short-circuit current rating of a switchboard is dependent upon the use of specific overcurrent devices ahead of the switchboard, the switchboard in addition to the marking specified in 6.2.1.12 shall be marked "When protected by _____ ampere maximum Class R + fuse or (Manufacturer's name and type designation) circuit breaker rated not more than _____ amperes this switchboard is suitable for use on a circuit capable of delivering not more than _____ rms symmetrical (for AC circuits) amperes, _____ volts maximum" or the equivalent. The value of amperes shall correspond to the values given in Table 3.

Note: Class CC, G, J, L, T, or R. RK1 or RK5 may be specified in place of or in addition to Class R.

6.2.1.15 A switchboard section or interior shall be marked with a short-circuit current rating as specified in Table 3 that does not exceed the short-circuit current rating of any overcurrent device or panelboard intended to be installed therein, the remote main overcurrent protective device with which it is intended to be used for that rating, or any other component as covered by its marking or Table 16.

6.2.1.15.1 A circuit breaker connected to the load side of the integral or remote main overcurrent protective device may have a short-circuit current or interrupting rating less than the marked short-circuit current rating of the switchboard section if the combination is tested in accordance with 9.1.1.6 and the switchboard is marked as specified in 6.2.1.12(g)

6.2.1.15.2 The switchboard section or interior short-circuit current rating may exceed the component short-circuit current rating marked on the component or in accordance with Table 16 if the component short-circuit rating is adequate for the assumed available short-circuit current as covered in 8.5.1.2 and 8.5.1.3.

6.2.1.15.3 The short-circuit current rating of the switchboard may exceed that of a factory- or field-installed circuit breaker or a fused switch under the following conditions:

a) the marking covered in 6.2.5.3 specifies at least one circuit breaker or fused switch that has a short-circuit current rating not less than that of the section or interior; and

b) the circuit breaker or fused switch identified by the marking is physically interchangeable with the factory- or field-installed circuit breaker or fused switch.

6.2.1.15.4 For switchboards with inlets (see 8.8.4.2) and an additional short circuit current rating as specified in 6.2.1.12.2, that portion of the switchboard circuit which will only be powered when connected to the alternate source may include components with short circuit current ratings less than the rating marked on the section or interior, but not less than the rating noted in 6.2.1.12.2.

6.2.2 Marking for service equipment

6.2.2.1 If a switchboard is intended for use as service equipment, it shall be marked as follows:

a) in the case of an insulated neutral, one of the following:

1) "Suitable for use as service equipment"; or

2) "Suitable for use as service equipment when not more than six main disconnecting devices are installed."

b) in the case of a factory bonded neutral, one of the following:

1) "Suitable only for use as service equipment"; or

2) "Suitable only for use as service equipment. Install no more than six main disconnecting devices."

6.2.2.2 If a switchboard section or interior is marked "Suitable for use as service equipment" or "Suitable for use as service equipment when not more than six main disconnecting devices are provided," the marking "Service disconnect" shall be provided in the form of pressure sensitive labels in an envelope, or on a card, with instructions to apply near the disconnect handles if the equipment is used as service equipment. If the switchboard is intended for a particular installation in which it is known that it will be used as service equipment, the markings may be applied at the switchboard factory.

6.2.2.3 If a switchboard section or interior is marked "Suitable for use as service equipment," instructions for installing the bonding means shall be provided.

6.2.2.4 If a switchboard is marked "Suitable only for use as service equipment," each service disconnecting device for ungrounded conductors shall be marked: "Service disconnect" on or adjacent to the switch or circuit breaker handles.

6.2.2.5 A switchboard section or interior rated 3-phase, 4-wire and having a solidly grounded neutral but not provided with ground fault protection as covered in 8.1.13.2(b) shall be marked for the use specified as follows (not for Canada):

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."

6.2.2.6 A switchboard section or interior that is marked "Suitable only for use as service equipment" or "Suitable for use as service equipment" and not provided with ground fault protection as covered in 8.1.13.2(c) shall be marked for:

a) supplying a fire pump;

b) an alternate source for legally required standby service (not for Canada); or

c) use as the disconnecting means for a second-building on the property where ground-fault protection is provided on the supply side of this disconnecting means (not for Canada).

6.2.2.7 A switchboard section or interior that has ground fault protection with only an audible or visual signal shall be marked for an alternate source for an emergency system as covered in 8.1.13.5.1 (not for Canada).

6.2.2.8 Marking for Canadian utility compartment

6.2.2.8.1 A switchboard compartment for the electric utility supply authority use shall be marked as such (see 6.2.1.1).

Note: This is a requirement only for switchboards intended to be installed in Canada.

6.2.2.9 Switchboard assemblies intended for service entrance use and constructed in accordance with 8.1.12.13 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, ..."). (For Canada only.)

Note: *Each manufacturer shall add specific instructions applicable to the particular construction.

6.2.3 Switching devices

6.2.3.1 A switch not rated for operation under load shall be identified by a conspicuous marking on the front of the switchboard stating "For isolating use only do not open under load."

6.2.3.2 If a tie-switch has not been tested for reverse line and load connection, the switchboard shall be marked to indicate that the tie-switch is not to be opened under load (not for Canada).

6.2.3.3 A switchboard intended to be connected to multiple sources shall be marked to alert the user that both ends of a disconnecting device may be energized. The marking shall be provided on all covers that give access to the disconnecting device.

6.2.3.4 The markings indicating the "ON" and "OFF" positions for switches and circuit breakers shall be visible without removing the switchboard trim or dead-front.

6.2.3.5 If the handle of a circuit breaker, or a simple extension of that handle, assumes other than the "OFF" position when the breaker is tripped, the switchboard shall be marked to indicate the tripped position of the handle. The method of resetting the breaker shall be marked.

6.2.3.5.1 Marking to indicate the "tripped" position is not required in the case of a separate, external operating handle – other than a simple handle extension – that is not part of the circuit breaker. Such a handle may remain in the “ON” position.

6.2.3.6 Unless overcurrent protection is provided within the section on the load side, a molded case switch (non-automatic circuit interrupter) installed in a switchboard shall be marked on or adjacent to the device where visible without removing a trim or dead front, "Does not provide for overcurrent protection" or equivalent wording. The marking shall be a minimum 4.8 mm (3/16 inch) high letters.

6.2.3.7 A switch or circuit breaker that controls all load circuits from a single switchboard section or interior containing more than one load circuit shall be marked "Section Main," and no other switching device in the switchboard section shall be marked merely "Section Main" or "Main." The marking is not required if the switchboard section or interior is marked for use as service equipment.

6.2.3.8 If several sections are intended to be installed in a group, a switch or circuit breaker that controls all load circuits, including any through bus, shall be plainly and permanently marked "Main" and shall appear on or adjacent to the switches or circuit breakers. The marking is not required if the switchboard section or interior is marked for use as service equipment.

6.2.3.9 A switch or circuit breaker that serves as a main for a panelboard within a switchboard section, but is not a section main shall be marked "Panelboard Main," "Submain" or some other descriptive term other than just "Main."

6.2.3.10 A circuit breaker or switch that serves as a main for another section or a panelboard in another section, but is not a main for the complete group of switchboard sections shall be appropriately marked such as "Main (or submain) for Panelboard _____ (or section _____)”; and the corresponding section or panelboard shall be similarly identified.

6.2.3.11 If a transformer providing control voltage for ground-fault protection or an instrument or control circuit fuse is connected to the line side of the main disconnect, this disconnect may be identified as the "main" but the switchboard shall be marked adjacent to the main disconnect to alert the user that it does not disconnect control and instrument circuits.

6.2.4 Emergency circuits

6.2.4.1 Other than as allowed in 8.6.11.13(c) for an automatic transfer switch, a tap, circuit, section, or switchboard shall not be marked for emergency use.

6.2.5 Field-installed equipment

6.2.5.1 If a switchboard section or interior has provision for the mounting of units (switches, circuit breakers, or fuseholders) or a neutral terminal assembly for use with a field-installed panelboard, instructions for the installation and wiring of such units shall be provided with the unit or switchboard. If the construction and orientation of the additional units make the installation method obvious, then instructions are not required.

6.2.5.2 If branch bus bars are to be added in the field as described in 8.1.1.2.2, the switchboard shall be marked to indicate the manufacturer and catalog designation of the bus bar kit to be used with a particular switch, circuit breaker, or fuseholder.

6.2.5.2.1 The bus bar kit shall be marked on the bus or on or in the packaging carton with the identification of the manufacturer, the kit catalog designation, and the installation instructions.

6.2.5.3 If a switchboard section or interior has provision for the mounting of additional equipment (circuit breaker, fuseholder, contactor, meter socket, switch, or the like), the section shall be marked with the manufacturer's name, or trademark of the manufacturer, or other descriptive marking by which the organization responsible for the equipment may be identified and the catalog designation or the equivalent of the equipment that may be added. This marking is not required for a plug-in meter, test block, transformer (current or potential), or the like, to be provided by a utility.

6.2.5.4 A switchboard intended for use with a field-installed filler plate shall be marked to indicate the catalog number of the filler plate with which it may be used.

6.2.5.5 Each filler plate intended to be installed in the field or its unit container shall be marked with the manufacturer's name, trademark, and a catalog number or equivalent.

6.2.6 Field-installed interiors (not for Canada)

6.2.6.1 A switchboard enclosure that is intended for use with a field-installed switchboard interior or panelboard shall be marked to indicate the manufacturer and the catalog number or equivalent of the switchboard interior or panelboard to be used.

This Clause does not apply for Canada.

6.2.6.2 A switchboard interior, as described in 3.28, shall be marked to indicate the manufacturer and type of the switchboard enclosure for which it is intended.

This Clause does not apply for Canada.

6.2.7 Terminals

6.2.7.1 If any terminal of a switchboard section or interior is marked to indicate that aluminum wire may be used at that terminal (such as by being marked with the symbol "AL"), and, if such marking is visible under the conditions described in 6.2.7.2, the switchboard section shall be marked in accordance with 6.2.7.3, 6.2.7.5, or 6.2.7.6.

6.2.7.2 The term visible as used in 6.2.7.1 refers to a marking that will be visible when a front, trim, or dead front has been removed, or is visible when a hinged cover of a component has been opened. A marking on a separately supplied connector or on a connector or part thereof that is likely to be removed or displaced during the wiring operation is considered to be visible.

6.2.7.3 If, because of wiring space or other factors, a terminal of the switchboard section is not acceptable for use with aluminum wire, the switchboard shall be marked: "Use copper wire only."

6.2.7.4 If a switchboard is acceptable for aluminum wire only, the switchboard shall be marked "Use aluminum wire only."

6.2.7.5 If the wiring space and other factors are such that all terminals of the switchboard section are rated for use with aluminum conductors as well as with copper conductors, the switchboard sections shall be marked "Use copper or aluminum wire."

6.2.7.6 If the wiring space and other factors are such that some terminals of the switchboard section or interior are rated for use with aluminum conductors as well as with copper conductors, while the remainder of the terminals are for use with copper conductors only, the switchboard section shall be marked "Use copper wire only except at terminals...." The marking shall positively identify the terminals that are for use with aluminum wire.

6.2.7.7 The word "terminal" as used in6.2.7.1 – 6.2.7.6 signifies any terminal of the switchboard section or interior as well as a terminal of any component unit (circuit breaker, switch, or the like) that is installed or intended to be installed in the switchboard and to which conductors are to be connected in the field.

6.2.7.8 A marking employing a wording differing from that given in6.2.7.1 – 6.2.7.7 may be accepted if it clearly and completely conveys the significant information. Any abbreviation designating copper and aluminum shall be "AL-CU," "CU-AL," or equivalent.

6.2.7.9 If a wire terminal has been investigated for securing more than one conductor in an opening and is intended for such use, a marking indicating the number and size of conductors shall be provided. The marking shall be on the wire connector if visible, or in another visible location, such as next to the terminal or on a wiring diagram.

6.2.7.10 A terminal of a switchboard capable of securing two or more combinations of conductors in multiple, any of which has an ampacity acceptable for the application, shall be identified and marked unless the switchboard is acceptable for use with the combination of wires requiring the largest wiring space in accordance with 8.8.3.1.2. The terminal shall be identified by a prominent marking, such as on a wiring diagram, on the switchboard that will state the number and size of wires for which the terminal is acceptable.

6.2.7.11 If pressure terminal connectors are not provided on the equipment as shipped, the equipment shall be marked stating which pressure terminal connector or component terminal assemblies are for use with the equipment.

6.2.7.12 The terminal assembly packages covered in 6.2.7.11 shall carry an identifying marking, wire size, and manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified. The marking shall also include the required tightening torque in accordance with 6.2.7.13 unless the value of tightening torque is included along with the switchboard markings as covered in 6.2.7.11.

6.2.7.13 A switchboard shall be marked to indicate the specific tightening torque for each wire connector in the switchboard that is intended for field wiring. If different connectors are used for line, load, neutral, or ground, the specific torques to be applied to each connector shall be clearly indicated.

6.2.7.13.1 The value of tightening torque for a field wiring terminal provided on a component such as a circuit breaker, switch, or the like, need not be marked on the switchboard.

6.2.7.13.2 The value of tightening torque for a wire binding screw or stud and nut type terminal need not be provided.

6.2.7.14 With regard to 6.2.7.13, the torque to be marked for each connector shall be determined as specified in 8.8.2.3.2. An example of a typical torque marking is shown in Annex E.

6.2.7.15 If a pressure wire connector provided in a switchboard for field installation of conductors requires the use of a specific tool other than a common screwdriver or wrench for securing the conductor, the necessary instructions for using the tool shall be provided with the switchboard in a readily visible location, such as on the connector, on a wiring diagram, or on a tag secured to the wire connector.

6.2.7.16 A switchboard using a tool-applied compression wire connector shall be marked with:

a) the tool and die information along with the number of crimps as specified with the wire connector; or

b) reference to the wire connector manufacturer's tool, die, and crimp information as provided with the switchboard or in installation instructions provided with the switchboard.

6.2.7.17 If an equipment grounding assembly is intended for field installation:

a) the switchboard section or interior shall be marked to indicate the catalog or type number of the terminal assembly intended to be used; and

b) 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.

6.2.7.18 A switchboard shall be provided with a marking readily visible prior to wiring to indicate the required temperature rating of field-installed conductors.

6.2.7.19 If a circuit breaker is to be installed in the field, the marking shall indicate that the circuit breaker is to be marked either 60/75°C or 75°C if conductors sized for 75°C ampacity are to be used.

6.2.7.20 A switchboard or field wiring circuit rated more than 125 A shall be marked for use with conductors sized for 75°C ampacity.

6.2.7.21 With respect to 6.2.7.18, a switchboard that is marked to indicate that only 60°C field-installed conductors are to be used shall not reference a field-installed unit that has been investigated for 75°C conductors only.

6.2.7.22 A switchboard requiring access to field wiring terminals from the rear as covered in 8.8.2.3.15 shall be marked on the front: "Rear access required to make field connections."

6.2.7.22.1 The marking may be omitted if the statement is included in the conduit location instructions covered in 8.8.3.3.3.1 and 6.3.4.1.1.

6.2.7.23 If the temperature rise exceeds 50°C on a wiring connector as covered in item 6 of Table 13, a marking shall be provided near the wiring connector indicating that 90°C wire shall be used and it shall be sized based on the ampacity of wire rated 75°C. If the switchboard is marked for use with aluminum or

copper-clad aluminum conductors, there shall be a marking to indicate that the wire connectors shall be identified AL9, AL9CU, or CU9AL. The marking shall be:

a) provided by the switchboard manufacturer if not already provided on the switch or circuit breaker; and

b) visible after installation.

6.2.8 Motor circuits

6.2.8.1 With respect to 8.6.17.2, a wiring diagram and a current element table for overload relays shall be provided for each motor circuit. The table shall be that provided for the open-type motor starter unless the table is verified by calibration testing in the switchboard. The table and a diagram shall be attached to the switchboard section at a plainly visible location. Attachment to the inside of a door or cover is acceptable. Tables, diagrams, and electrical rating information for individual motor circuits may be provided at a central location on or in the switchboard section in a pocket expressly provided for the purpose. The individual motor controller 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.

6.2.8.2 With respect to 8.6.15.5, if a controller can be set to an automatic reset mode, and if a wiring diagram indicates that 2-wire control may be used, a marking shall be located where visible when making field connections to the control circuit to indicate that a motor connected to the circuit may start automatically when the relay is in the automatic reset position.

6.2.8.3 A marking shall be located at a control circuit disconnect as covered in 8.6.15.3 to identify it as such.

6.2.9 Enclosure environmental conditions

6.2.9.1 An enclosure shall be marked with the environmental Type number or numbers, as specified in Table 12. An enclosure that complies with the requirements for more than one type of enclosure may be marked accordingly with multiple type designations.

6.2.9.1.1 A Type 3R enclosure may also bear the supplemental marking "Rainproof." If used, the supplemental marking shall be an integral part of marking containing the manufacturer's name or trademark, unless it is an integral part of other required markings.

6.2.9.2 A switchboard section or switchboard enclosure marked "Type 3R" and provided with means to accommodate one or more separable conduit hubs or closure fittings shall be marked with the name or trademark of the manufacturer and with the conduit size and corresponding catalog designation of those fittings that can be used with that enclosure.

6.2.9.2.1 A separable conduit hub and a closure fitting shall be marked with the manufacturer's name or trademark and the catalog number or equivalent. Such a hub or fitting may be shipped separately, and any gaskets, hardware, and instructions necessary for installation shall be shipped with the fitting or packaged with the enclosure.

6.2.10 Phase identification

6.2.10.1 A switchboard intended for use on a 240/120-volt, 3-phase, 4-wire, delta system shall be marked to clearly identify the different bus bars with reference to the voltages between them or, if the switchboard is intended for use only on this system, the main bus bar having the higher voltage to ground may be identified by a marking that is orange or by tagging. For Canada the higher phase shall be A phase

and colored Red. The switchboard shall also be marked by means such as a diagram to indicate the necessary voltage rating of the device for each branch-circuit overcurrent-protective-device position.

6.2.11 Meter sockets

6.2.11.1 If a switchboard section or interior has provision for one or more watt-hour meters, the current rating of the meter positions shall be marked on the switchboard section or the interior. If the meter position is rated for continuous duty, the marking shall be "_____ Amps continuous." If the meter position is rated for a maximum rating, the marking shall be "_____ A (_____ A continuous)," in which case the maximum amperes shall not be more than 125 percent of the continuous duty amperes.

6.2.11.2 If a meter socket is provided with a device that will automatically render load circuit parts live when the meter is not in place, the enclosure shall be marked with the following or the equivalent: "Removal of meter does not de-energize circuit." The marking shall appear next to the meter socket.

6.2.11.3 If a meter socket is provided with a manually operated device that will render load circuit parts live when the meter is not in place, the enclosure shall be marked, next to the meter socket, to caution that the circuit may be live with the meter removed.

6.2.12 Neutral

6.2.12.1 If 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.

6.2.12.2 If the main bonding jumper, the grounding electrode conductor terminal, and the neutral disconnecting means are not in the same section as the service disconnect, the section (s) of a multi-section switchboard in which they are located shall be marked to indicate that condition. In Canada, this arrangement is not permitted.

6.2.12.3 A switchboard provided with a high-impedance grounded neutral system shall be marked with the following or equivalent: "The system neutral conductor shall not be connected to ground at the switchboard or at the source (utility or generator) except through the grounding impedance."

6.2.12.4 With regard to 8.4.8.12, the switchboard section containing the grounding impedance shall be marked with the rated thermal current and rated time of the impedance.

6.2.13 Ground fault protection

6.2.13.1 If ground fault protection is provided in a switchboard section or interior, 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 switchboard with the switchboard cover removed, a separate marking such as on a wiring diagram shall be provided.

6.2.13.2 In a switchboard section or interior with ground fault protection, that part of the neutral bus for load terminations shall be marked with the following or equivalent: "Do not connect grounding conductors to these or any other neutral terminals; to do so will defeat ground fault protection." The marking shall be located on or adjacent to the neutral.

6.2.13.3 If a component of a ground fault protection system is located in an adjacent section, a complete wiring diagram of both sections shall be provided in each of the sections.

6.2.13.4 When connected to an external source, the control circuit for ground fault protection shall be identified by a permanent marking: "External source connection for control circuit of ground fault sensing and relaying equipment volts (ac or dc)" or equivalent.

6.2.14 Field-installed busway

6.2.14.1 If the ground bus does not extend to the busway as covered in 8.4.4.2, the switchboard section shall be marked to indicate that a bonding jumper sized in accordance with Table 14 shall be installed between the ground bus of the switchboard and the busway ground bus or enclosure serving as a ground bus.

6.2.15 Transformers

6.2.15.1 A switchboard section or interior containing a power transformer feeding circuits leaving the section from a secondary winding not conductively connected to the primary shall be marked to indicate the need for connecting the secondary neutral conductor to a grounding electrode in accordance with existing installation requirements pertaining to separately derived systems.

6.2.15.1.1 The marking is not required if the grounding electrode conductor terminal is not required in accordance with 8.4.7.2.1.

6.2.15.2 If a switchboard section or interior contains a transformer and the secondary circuit leaves the section or interior, the section or interior shall be marked with the secondary voltage or voltages as covered in 5.2.3.

6.2.15.3 If a switchboard section or interior contains a power transformer rated more than 25 kVA, the section or interior shall be marked with the kVA rating and percent impedance unless the markings are on the transformer and are visible with the cover removed.

6.2.16 Taps

6.2.16.1 A terminal or provision for a terminal intended to be used as a tap, other than those to be used by the supply utility for voltage metering pick-up, shall be marked "Tap."

6.2.17 Restricted access switchboards

6.2.17.1 A switchboard intended to be accessible only to qualified persons shall be marked: "This switchboard shall be located where accessible only to qualified persons," or equivalent. See 8.4.2.1.

6.2.18 Switchboards with provisions for cord connections

6.2.18.1 Switchboards provided with single pole separable connectors (input or output connections) that are not mechanically interlocked shall be marked:

a) "FOR USE BY QUALIFIED PERSONNEL ONLY", or equivalent, and

b) With instructions as to the proper order of connection and disconnection, as noted in the below example:

WARNING – Risk of Electric Shock

Plug connection should be in the following order;

1) Equipment grounding conductor connectors;

2) Grounded circuit conductor connectors; and

3) Ungrounded conductor connectors.

Disconnection should be in the reverse order.

6.2.18.2 The marking required by 6.2.18.1 shall be located adjacent to the point of connection.

6.2.18.3 Switchboards with inlets shall be marked to indicate the type of derived system that the switchboard is intended to interconnect in accordance with either (a) or (b):

a) Switchboards that do not switch the neutral conductor shall be marked with the following: “WARNING - For Connection of a Nonseparately Derived (Floating Neutral) System Only.”

b) Switchboards that switch the neutral conductor shall be marked with the following: “WARNING - For Connection of a Separately Derived (Bonded Neutral) System Only”

6.2.18.4 Switchboards with inlets shall be marked to indicate the short circuit current rating when the switchboard is powered by a source that is connected through the use of the inlets. See 6.2.1.12.2.

6.3 Instructions for installation, operation and maintenance

6.3.1 General

6.3.1.1 With regard to 8.2.1.1.2.3, a switchboard section omitting one side shall be marked to indicate either:

a) which separate side panel to order; or

b) which stock sections it is intended to connect to.

6.3.2 Through or splice bus

6.3.2.1 If there is provision for the installation of either a through or a splice bus, and if the through bus or splice bus is not supplied, the switchboard section or interior shall have a marking that is legible and plainly visible during and after installation, stating the proper conductor required.

6.3.3 Bracing

6.3.3.1 With respect to 9.2.4.2.4.1, 9.2.4.2.7.1 and 9.2.4.2.7.2, a marking indicating the type of bracing to be added to cables routed through the switchboard between the point of entry or exit and the terminals shall be located adjacent to the incoming terminals or provided in the installation instructions.

6.3.4 Installation instructions

6.3.4.1 Conduit location instructions

6.3.4.1.1 With respect to 8.8.3.3.3.1, instructions and drawings showing the intended conduit or raceway location shall be supplied. Instructions and drawings need not be supplied by the switchboard manufacturer if the conduit or raceway location information is supplied by the customer or installer to the switchboard manufacturer and the switchboard construction provides the clearance above the conduit or raceway entry point covered in 8.8.3.3.3.

6.3.4.2 Field-installed busway

6.3.4.2.1 A switchboard section or enclosure intended for connection to a busway shall be marked to indicate the manufacturer and type of busway or this information may be provided on the specifications supplied to the installer.

6.3.4.3 Field testing of ground fault protection of equipment

6.3.4.3.1 To provide for system performance testing, each ground fault relay or apparatus incorporating a ground fault relay or its functions intended for protection of a solidly grounded wye service rated more than 150 V to ground but not exceeding 1 000 V phase-to-phase shall be provided with information sheets describing system testing instructions, and with a test form. The form shall include a space for the date the test was performed and the results, and shall state that the form should be retained by those in charge of the building's electrical installation in order to be available to the authority having jurisdiction. The instructions shall include the following items and shall basically prescribe only that information necessary to perform the tests. The instructions shall be separate and apart from any more elaborate test detail that the manufacturer may wish to provide. The instructions shall specify that:

a) The interconnected system shall be investigated in accordance with the switchboard manufacturer's detailed instructions, and that this investigation shall be undertaken by qualified personnel.

b) The location of the sensors around the bus of the circuit to be protected shall be determined. This can be done visually, with knowledge of which bus is involved.

c) The grounding points of the system shall be verified to determine that ground paths do not exist that would bypass the sensors. The use of high-voltage testers and resistance bridges may be suggested.

d) The installed system shall be tested for correct response by the application of full scale current into the equipment to duplicate a ground fault condition, or by equivalent means such as by a simulated fault current generated by:

1) a coil around the sensors; or

2) a separate test winding in the sensors.

6.3.4.3.2 The results of the test shall be recorded on the test form provided with the instructions.

6.3.4.4 Multiple source switchboard

6.3.4.4.1 A multiple source switchboard for parallel operation, without synchronization equipment provided integral to the switchboard (as permitted in 8.6.5.2) shall include the following statement on the installation instructions or factory supplied drawings: “CAUTION - This switchboard is constructed for parallel source applications from multiple sources. Synchronization equipment shall be provided by _____” or equivalent. The blank shall be populated with the name of the synchronizing equipment manufacturer.

7 Service conditions

Reserved

7.1 Normal service conditions

Reserved

7.2 Special service conditions

Reserved.

7.3 Conditions during transport, storage, and erection

Reserved.

8 Design and construction

8.1 Mechanical design

8.1.1 General

8.1.1.1 All screws and nuts shall be staked, headed over, upset or otherwise prevented from loosening, if loosening would result in less than the required spacings.

8.1.1.2 A switchboard section shall be complete, other than identified field installable devices and kits, when it is shipped from the factory.

8.1.1.2.1 If switches, circuit breakers, or the like mounted in a switchboard section must be interconnected in order for the section to perform its intended function, such interconnecting busing or wiring shall be complete before the section is shipped from the factory.

8.1.1.2.2 A switchboard section or interior may have provision for the installation of additional equipment such as branch, splice or through-busses, meter socket bases, circuit breakers, switches, panelboards, terminal connectors, or the like, if it is marked to identify the equipment to be installed.

8.1.1.2.2.1 If a field installable item requires a barrier to comply with the spacing requirements in 8.1.16, the barrier shall be attached to the switchboard or to a required part of the field-installed item.

8.1.1.2.3 A switchboard section or interior which has provision for a field installed meter socket, shall have covers for the meter opening which comply with the requirements in framework and enclosure, clause 8.2.1 or filler plates. See 8.1.18.

8.1.1.2.4 In a switchboard section or interior constructed to house utility installed current transformers and associated equipment, the current transformers and the busing or wiring for the transformer and metering equipment may be omitted if their connection means are provided.

8.1.1.3 A switchboard shall be designed so that any component intended to be field installed can be installed without the use of a special tool.

8.1.1.4 If a space can physically accommodate a branch circuit switch or circuit breaker that is not intended for this use, it shall have any hole for securing a branch bus bar to the section bus bar plugged with a solid metal rivet or one way screw. A dead-front shield over the portion of bus with holes may not be used in place of plugging or omitting the holes in the bus bars. A separate shield secured by one-way screws onto the mounting pan behind the removable dead-front shield is acceptable in lieu of plugging holes in the bus bars.

8.1.1.5 A switchboard enclosure may be provided with means of support for bus bars extending from an adjacent section, and, if marked for use with a switchboard interior, may include a neutral terminal assembly.

8.1.1.6 If a switchboard enclosure contains one or more factory-installed switchboard interiors, bus bars are considered to be part of the interior but they may be supported by the back of the switchboard enclosure.

8.1.1.7 An edge, projection, corner, opening, frame, guard, knob, handle, or the like of a switchboard section, interior, or enclosure shall be smooth and rounded and not sharp enough to cause a cut type injury when contacted during intended use or user maintenance.

8.1.1.8 Any load circuit extending beyond the switchboard is considered to be a branch circuit except for a through main bus, a tap, or a switchboard section mounting a single switch (or circuit breaker) that is intended to serve as the main switch (or circuit breaker) for other switchboard sections.

8.1.1.9 If the inside dimensions of the enclosure of a switchboard section are less than 1.65 m (65 inches) high or 305 mm (12 inches) deep, the enclosure shall be judged under the requirements of this standard, but the internal parts and wiring shall be judged by the applicable requirements in Reference Item No. 1, Annex B.

8.1.1.10 A switchboard interior may be provided without an enclosure if marked in accordance with 6.2.6 (not for Canada).

8.1.2 Corrosion protection

8.1.2.1 Iron and steel parts of enclosing cases, walls, and barriers (whether of sheet steel or cast iron), all springs and other parts upon which intended mechanical operation may depend, and sheet steel parts of fastening devices shall be fabricated of stainless steel or shall be protected against rust by enameling, galvanizing, sherardizing, plating, or equivalent means. The requirement does not apply to bearings, or the like, whose protection is impracticable.

8.1.3 Mechanical assembly

8.1.3.1 A switchboard section, interior or enclosure shall be constructed to provide strength and rigidity in order that it will keep its shape and that doors will close tightly.

8.1.3.2 Metal into which a screw is threaded shall provide for the engagement of at least two full threads. A rivet, screw, bolt, or similar fastener into sheet metal shall have a diameter at least 50 percent greater than the thickness of the finished sheet metal with which the fasteners are used.

8.1.3.3 Sheet metal may be extruded at a tapped hole so as to provide the thickness necessary for two full threads, if the original metal is not less in thickness than the pitch of the thread.

8.1.3.4 An adhesive that is used in the switchboard construction and that is relied upon to reduce a risk of fire, electric shock, or injury to persons (for example, barriers or wire positioning devices) shall comply with the applicable requirements for adhesives Reference Item No. 14, Annex B, and be evaluated for the specific application. Adhesives shall not be used to secure components that include bare live parts.

8.1.3.5 The requirement in 8.1.3.4 also applies to an adhesive used to secure a conductive part (including a switchboard nameplate) that may, if loosened or dislodged:

a) cause an accessible dead metal part to become energized;

b) make a live part accessible;

c) reduce spacings below the minimum required values specified in Table 6; or

d) short-circuit live parts.

8.1.3.6 A single-threaded nut constructed to slip over the edge of sheet metal to receive a retaining screw may be used to secure a dead front to supports, a unit such as a switch or circuit breaker to a mounting panel, or a mounting pan to an enclosure if:

a) the nut is protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means; and

b) the threads do not strip when a torque of 3.4 N·m (30 pound-inches) is applied. See 9.2.10.

8.1.4 Observation windows

8.1.4.1 Observation windows not exceeding 305 mm (12 inches) on any side shall comply with the requirements in Reference Item No. 2 in Annex B. Observation windows exceeding 305 mm (12 inches) on any side shall comply with the impact and pressure test in 9.2.11.

8.1.5 Doors and covers

8.1.5.1 Doors and covers shall comply with the requirements for sheet metal in 8.2.1.2.

8.1.5.2 If bare live parts are exposed by the opening of doors or covers, means requiring the use of a tool to open, or provision for locking, shall be provided to secure them in the closed position. A door over one or more fuses as described in 8.6.7.9 shall be permitted to be held closed with a latch only.

8.1.5.3 A door over a live part shall be provided with a stop to prevent the door from contacting the live part. The stop shall be independent of any other door or removable cover.

8.1.5.4 A metal cover plate intended to be opened for inspection purposes shall not exceed 1.12 m^2 (12 ft^2) in area or 27 kg (60 pounds) in weight unless it is equipped with lifting means or hinges.

8.1.5.5 The enclosure shall be constructed so that any hinged door intended for examination, adjustment, servicing or maintenance of internal components while energized is able to be opened a minimum of 90 degrees from the closed position. Doors that are readily removable or hinged at the top need not comply with this requirement.

8.1.6 Flanges for metallic enclosures

8.1.6.1 Flanges for metallic enclosures shall comply with the requirements for flanges in Reference Item No. 2 in Annex B except as specified in 8.1.6.2 and 8.1.6.3.

8.1.6.2 If a barrier is located behind the flanged opening as shown in Figure 6, and if there are no live parts in the open area, and if the construction complies with 8.2.1.3.1 – 8.2.1.3.2, clearances between flanges shall be 6.4 mm (1/4 inch) maximum.

8.1.6.3 Hinged or unhinged covers secured with screws may be constructed as shown in Figure 7.

8.1.7 Fastenings

8.1.7.1 A removable front panel or trim shall be secured by at least four fastenings. There shall be at least one fastening located not more than 152 mm (6 inches) from each of the four corners, and fastenings shall be spaced not more than 610 mm (24 inches) apart along any vertical side.

8.1.7.1.1 Any front panel or cover may be fastened by a single screw in each of the two opposite sides, when any of the following conditions are met.

Note: The screws need not be at the center of the sides if the construction is such as to hold the front panel or cover against the adjacent flange of the section.

a) having dimensions not exceeding 152 mm (6 inches) high by 508 mm (20 inches) wide; or

b) flanged on all four sides and having dimensions not exceeding 220 mm (9 inches) high by 508 mm (20 inches) wide, or 152 mm (6 inches) wide by 914 mm (36 inches); or

c) flanged on all four sides 12.7 mm (1/2 inch) minimum, one side not more than 220 mm (9 inches), and having an area not exceeding 139 000 mm^2 (215 $inches^2$). A removable panel more than 610 mm (24 inches) long on any side that is flanged 12.7 mm (1/2 inch) minimum may have fastenings spaced not more than 914 mm (36 inches) apart and not more than 254 mm (10 inches) from each of the four corners if the fastenings are not less than 6.4 mm (1/4 inch) in diameter.

8.1.7.1.2 The cover over a meter socket for an individual meter may be secured to the assembly by two fastenings. For these meter socket covers, a latch or overlapping flange shall be considered as a fastening.

8.1.7.1.3 The cover over a meter socket may be fastened by any of the methods permitted by the requirements in Reference Item No. 20 in Annex B.

8.1.7.2 Fastening screws or the screws of clamps or hinges shall not be less than 4.0 mm (5/32 inch) in diameter (No. 8 screw size) for a panel 2323 cm^2 (360 $inches^2$) or less in area and not less than 4.8 mm (3/16 inch) in diameter (No. 10 screw size) for a larger front panel or cover.

8.1.7.3 Fastenings may be omitted along the vertical side of a panel that is adjacent to a panelboard, or the like, if the panel is supported at all four corners and if the panel is either:

a) flanged the full length of both the longer sides; or

b) flanged the full length of one of the longer sides, with the unflanged side secured to a rigid switchboard member.

8.1.8 Latches

8.1.8.1 Each door shall be provided with a positive latch or a captive screw. A captive screw shall be operable by hand or by a conventional tool. A captive screw may be the simple 1/4 or 1/2 turn or multi-turn type. Where the hinged construction is not necessary under these requirements, a non-captive screw fastening is permitted to be used.

8.1.8.2 A door more than 1.22 m (48 inches) long on the hinged side shall be fastened at two or more latch points.

8.1.8.3 A knob, door handle, or a captive screw or other fastening shall be provided for opening a door.

8.1.9 Mounting

8.1.9.1 A switchboard section or enclosure other than the floor supported or freestanding shall be provided with means for mounting.

8.1.10 Bases and supports – insulating material

8.1.10.1 Insulation material in contact with live parts shall have the minimum values specified in Table 5. Molded thermoplastic bases and supports shall be subjected to the Mold Stress Relief test in 9.2.8.

8.1.10.2 An insulation material having values below those contained in Table 5 may be accepted based on acceptable end-product performance tests, as outlined in Reference Item No. 3 in Annex B.

Note No. 1: This requirement does not apply in Canada.
Note No. 2: Reference Item 3 in Annex B contains guidance in selecting and performing such tests to evaluate material weaknesses.

8.1.11 Service equipment use (not for Canada)

8.1.11.1 A switchboard section or interior marked for service equipment use shall be provided with both overcurrent protection and disconnecting means for all incoming conductors. Both single-disconnect and multiple-disconnect constructional approaches are covered by the Standard.

a) Single Disconnect Construction – In this construction, disconnection of all ungrounded load conductors from the source of supply shall be achievable by the operation of one disconnect device. Switchboards using this construction shall be marked as required by 6.2.2.1(a)(1) or 6.2.2.1 (b)(1).

b) Multiple-Disconnect Construction – This construction requires that disconnection of all ungrounded load conductors from the source of supply be achievable by the operation of not more than six operating handles. Switchboards using this construction shall be marked as required by 6.2.2.1(a)(2) or 6.2.2.1(b)(2).

Note: A switchboard section or interior intended for use with multiple sources of supply and marked "Service Equipment" is to be provided with a means to disconnect load conductors from all sources of supply terminated in that section. Switchboard assemblies intended for use with multiple sources may be provided with nonservice-rated sections. Nonservice sources may terminate in nonservice sections without a means to disconnect load conductors from the nonservice rated source of supply.

8.1.11.1.1 In determining the allowable number of disconnects, a device used solely for disconnecting power monitoring equipment, surge-protective devices, or the control circuit of power operable service disconnecting means, including a ground-fault protection system, shall not be considered a service disconnecting means. This provision is only applicable to those disconnects that provide control to the equipment identified above which are installed as part of the switchboard by the switchboard manufacturer.

8.1.11.2 In a group of sections having a main switch or circuit breaker, only the main section/ compartment shall be marked for service equipment use.

8.1.11.3 A switchboard interior or a section marked for service equipment use shall be provided with a grounding electrode conductor terminal, and, if a neutral is provided, means for disconnecting the neutral service conductors, and, if rated for alternating current, a main bonding jumper.

8.1.11.4 In a multi-section switchboard, 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.

8.1.11.5 In a multi-section switchboard, 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.

8.1.12 Service equipment for use in Canada

8.1.12.1 A switchboard assembly intended for use as service equipment shall comply with 8.1.12.2 – 8.1.12.14 and 6.2.2.1(a)(1).

8.1.12.2 A switchboard assembly 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.

8.1.12.3 Equipment marked for service use as described in 6.2.2.1(a)(1) shall have a single, load-rated, manually operable service-disconnecting fused switch or circuit-breaker that opens all ungrounded conductors.

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

8.1.12.5 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 the same interrupting ability as the main overcurrent device. 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.

8.1.12.6 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.

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

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

8.1.12.9 A compartment provided for supply authority use shall be lockable or have provision for sealing and shall be marked as specified in 6.2.2.8.1.

8.1.12.10 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:

Note: For installations including transfer switches see 8.1.12.11.

a) incoming (grounded) neutral conductor;

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

c) service-grounding conductor;

d) bonding conductor to the enclosure;

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

8.1.12.11 Where the service equipment also functions as a transfer switch and where the neutral assembly is located within the service-disconnecting compartment a second neutral assembly may be installed outside the service-disconnecting compartment and within the service equipment enclosure and

shall be connected to the neutral assembly located in the service-disconnecting compartment by the conductor sized in accordance with the Canadian Electrical Code, Part I.

Note: Examples of situations where a second neutral assembly may be installed are:

a) if the metering is supplied ahead of the switchboard; or

b) if it is known that the emergency generator will be installed after commissioning of the switchboard is completed.

8.1.12.11.1 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 the Canadian Electrical Code, Part 1.

8.1.12.12 With reference to (d) of 8.1.12.10, the specified bonding connection may be omitted and a non-ferrous 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 inch) diameter for switches rated over 100 A and up to and including 225 A, and 7.9 mm (0.31 inch) diameter for switches rated over 225 A and up to and including 400 A.

8.1.12.13 The neutral assembly described in 8.1.12.12 shall be insulated from the enclosure, bonded to the enclosure before shipment, and marked in accordance with 6.2.2.9.

8.1.12.14 Ground fault protection and ground fault indicating equipment shall comply with the requirements of Canadian Electrical Code, Part I).

8.1.13 Ground fault protection

8.1.13.1 A switchboard section or interior 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 a maximum time delay shall be 1 second for ground fault currents equal to or greater than 3 000 A.

Note: In addition the Canadian Electrical Code also requires ground fault protection in solidly grounded circuits rated 150 V or less to ground and 2 000 A or more.

8.1.13.2 Ground fault protection need not be provided for a switchboard section or interior:

a) identified for use only on a 3-phase, 3-wire supply or on high-impedance grounded neutral systems;

b) marked in accordance with 6.2.2.5 (not for Canada); or

c) marked in accordance with 6.2.2.6.

8.1.13.3 If each 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 sensors and relaying equipment may be in a separate section of the switchboard if several sections are intended for use in a group.

8.1.13.4 With regard to 8.1.13.1, the rating of a service disconnecting means is determined as specified in (a), (b), or (c), as follows:

a) for a fused switch, the rating of the disconnecting means is determined by the largest fuse that can be installed in the switch;

b) for a circuit breaker frame with an interchangeable trip unit (rating plug), the rating of the disconnecting means is determined by the rating of the factory installed trip unit (rating plug); or

c) for a circuit breaker with a non-interchangeable trip unit (rating plug), the rating of the disconnecting means is determined by the rating of the circuit breaker with the adjustable long-time pickup, if provided, set at its maximum value.

8.1.13.4.1 A pilot light, or equivalent indication of power, shall be provided to indicate that the ground fault protection control circuit is energized with the ground fault control circuit disconnect in the "ON" position. The pilot light, or equivalent, shall be visible with all covers in place.

8.1.13.4.1.1 A pilot light is not required for a circuit breaker or switch in the power circuit that also serves as the control circuit disconnect.

8.1.13.4.1.2 A pilot light is not required if the ground fault protector is actuated by the fault current so that no separate control circuit is required.

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

8.1.13.5 If ground fault protection is provided, though not required as covered in 8.1.13.1, it shall comply with the requirements for the installation of ground fault protection equipment in this standard.

8.1.13.5.1 If marked in accordance with 6.2.2.7, the ground fault protection may initiate an audible or visual signal rather than open a source intended for an emergency system (not for Canada).

8.1.13.6 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.

8.1.13.7 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.

8.1.13.8 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 switchboard section that may be made to the neutral.

8.1.13.8.1 Connections to the neutral may be made as covered in 8.1.16.10 and 8.4.6.4.3.

8.1.13.9 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 to prevent reclosure of the tripped disconnect until the reset operation is performed, or such means shall be incorporated in the disconnect device.

8.1.13.10 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 parts (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 as covered in 8.6.6.8.1 or 8.6.8.1 shall be installed ahead of the transformer or control circuit. Overcurrent protection is not required for the control circuit if wired to the load side of the main 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 covered in 6.2.3.11 or 6.2.13.4 shall be provided if the transformer is not connected to the load side of the main disconnect.

8.1.13.10.1 In a switchboard section or interior not marked for use at services, the fused disconnect switch may be replaced with a fuseholder as covered in 8.6.7.8.1.

8.1.13.11 The control circuit of a ground fault protection system shall be connected on the line side of the main disconnect if a test or monitor panel is provided and if such connection is required for intended functioning of the panel.

8.1.14 Neutral disconnecting means

8.1.14.1 In a switchboard section or interior that has a neutral and that is marked for service equipment use, means as specified in 8.1.11.3 shall be provided for disconnecting the neutral service conductors. This may be incorporated in the disconnecting means referred to in 8.1.11.1 or may be:

a) a disconnect link;

b) a similar conducting piece;

c) removal of the conductor from its terminal; or

d) removal of the terminal.

8.1.14.1.1 The disconnecting means shall be on the load side of the grounding electrode conductor terminal and of the main bonding jumper.

8.1.14.1.2 In a multi-section switchboard the neutral disconnecting means may be located in another section as covered by 8.1.11.5.

8.1.14.2 The disconnect link mentioned in 8.1.14.1 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 is not acceptable. A splice bus may be used as a neutral disconnect link if there is no branch circuit leaving the first section in the group.

8.1.14.3 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 will 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 of the disconnect link).

8.1.15 Equipment on supply side of service disconnect (not for Canada)

8.1.15.1 Except for the following, equipment shall not be connected to the supply side of the service disconnecting means:

a) meters nominally rated not in excess of 1 000 V located in the switchboard;

b) instrument transformers (current and potential), high-impedance shunts, Type 1 surge-protective devices, and load management devices;

c) control circuits of power operable service disconnecting means, if suitable overcurrent protection and disconnecting means are provided, see 8.1.11.1.1;

d) Ground-fault protection systems or surge-protective devices, if suitable overcurrent protection and disconnecting means are provided, see 8.1.11.1.1; and

e) taps used to supply load management devices, circuits for stand-by power systems, fire pumps, and fire and sprinkler alarms.

8.1.15.2 Overcurrent protection requirements for equipment connected on the supply side of a service disconnect shall be per 8.5.1.5 and disconnecting means requirements per 8.6.7.8, as applicable.

8.1.16 Spacings

8.1.16.1 The spacings in a switchboard section shall be as indicated in Table 6.

8.1.16.2 Spacings within a component within a switchboard section, and located on the load side of the service disconnect and overcurrent protection (on the load side of the motor or branch circuit short-circuit protection in the case of a combination motor controller), shall comply with the requirements applicable to the component. Spacings between exposed live parts of the component and the overall enclosure (other than inherent spacings) and spacings between exposed live parts of individual components shall comply with Table 6 or Table 7 as applicable.

8.1.16.3 Other than a device serving as a service disconnect as described in 8.1.16.12, spacings in an instrument or a control circuit may be as covered in Table 7.

8.1.16.4 Spacings are not specified in a Class 2 circuit rated not more than 30 VAC rms or 42.4 V_{pk}.

8.1.16.5 With respect to footnote (e) in Table 13, a live screw head, rivet, or nut on the underside of a base designed for surface mounting shall be countersunk not less than 3.2 mm (1/8 inch) in the clear, and covered to a depth of not less than 3.2 mm (1/8 inch) with a waterproof, insulating sealing compound that will not soften at a temperature of 90°C (194°F) as determined by the test for softening point by ring and ball apparatus in Reference Item No. 6 of Annex B.

8.1.16.5.1 The test is not required for a thermosetting material.

8.1.16.6 If the screw or nut mentioned in 8.1.16.5 is prevented from loosening by being staked or upset, by a lock washer, or by other means, it may be insulated from the mounting surface by material other than sealing compound or by providing a spacing through air or over surface and from the mounting surface not less than indicated in Table 6 and Table 7.

8.1.16.7 In applying Table 6 and Table 7 it shall be assumed that:

a) the voltage from a live part (other than the neutral) to grounded metal equals the line-to-line voltage of the system;

b) the voltage from a live part on an insulated neutral to grounded metal equals the line-to-neutral voltage of the system;

c) spacings at a fuseholder shall be measured with a fuse in place; the fuse being of the maximum standard dimensions including the maximum projections for assembly screws and rivets; and

d) spacings shall be measured through cracks unless the construction has complied with the clamped joint test described in 9.2.3.4 Also see Figure 8.

8.1.16.8 With respect to Table 6 and Table 7:

a) An isolated 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 metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

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

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

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

8.1.16.10 If the enclosure or ground bus is factory bonded to the neutral, any conductive part connected to the neutral on the load side of a ground fault protection system shall be insulated and provided with at least 3.2 mm (1/8 inch) spacings through air or over surface to the enclosure.

8.1.16.11 The spacings (through air and over surface) shall not be less than 3.2 mm (1/8 inch) between uninsulated live parts of the same polarity:

a) on the load side of their respective switches or circuit breakers for parts in different circuits; and

b) on the line and load sides of a fuseholder, switch, or circuit breaker.

8.1.16.12 Spacings of a component serving as a service disconnect shall comply with Table 6 and with 8.1.16.11. Through air spacings in a meter socket base less than those specified in Table 6 are subjected to a dielectric voltage-withstand test in accordance with the 9.2.3.1.1.

8.1.16.12.1 Spacings within a circuit breaker or a molded case switch may be as covered by the requirements applicable to that component.

8.1.16.13 Spacings shall be measured with all terminals both unwired and then wired with conductors determined in accordance with 8.8.2.3.6 – 8.8.2.3.9, but no conductor smaller than 3.3 mm^2 (12 AWG) shall be used.

8.1.16.14 In areas where conduit is permitted to enter an enclosure, spacings between live parts and bushings shall not be less than those specified in Table 6. In measuring between an uninsulated live part and a bushing installed at a knockout, it to be assumed that a bushing having the dimensions indicated in Table 8 (but without a locknut inside the enclosure) is in place.

8.1.16.15 Other than as indicated in 8.1.16.16, a soldering lug or pressure wire connector shall be prevented from turning so as to reduce spacings below the required values by a reliable restraint such as a shoulder or boss. A lock washer alone is not acceptable for this purpose.

8.1.16.16 Means to prevent turning as mentioned in 8.1.16.15 need not be provided if spacings are not less than the minimum acceptable values when:

a) a lug or connector and any lug or connector of opposite polarity have each been turned 30 degrees toward the other; and

b) a lug or connector has been turned 30 degrees toward any other opposite-polarity live part and toward grounded dead metal parts.

8.1.17 Insulating barriers

8.1.17.1 Insulating barriers are insulating materials that separate uninsulated live parts of opposite polarity, or separate an uninsulated live part and a grounded metal part – including the enclosure – where the through-air spacing between the parts would be less than the required value.

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

a)of material as indicated below:

1) as covered in 8.1.10; or

2) in compliance with Table 9; or

3) 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

4) based on the end-product tests specified in Reference Item 3 in Annex B. 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 inch).

8.1.17.2.1 A barrier of insulating material other than vulcanized fiber may have a thickness less than 0.71 mm (0.028 inch) if it withstands a 60 Hz dielectric-withstand voltage of 5 000 V applied in accordance with 9.2.3.6.

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

a) of a material as covered in 8.1.17.2, or comply with Table 10, or as follows:

1) vulcanized fiber with a minimum thickness of 0.71 mm (0.028 inch) and used in conjunction with a minimum 0.071 mm (0.0028 inch) air space; or

2) a barrier based on the end-product tests specified in Reference Item 3 in Annex B (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 inch).

1) Material other than vulcanized fiber may have a thickness less than 0.71 mm (0.028 inch) if it withstands a 60 Hz dielectric-withstand voltage of 5 000 V applied in accordance with the requirements in 9.2.3.6.

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 inch) ;or

ii) less than 0.33 mm (0.013 inch) if it withstands a 60 Hz dielectric-withstand voltage of 2 500 V applied in accordance with the requirements in 9.2.3.6.

8.1.17.4 A wrap of thermoplastic tape, rated for use as sole insulation, may be used as a barrier if all of the following conditions are met:

a) At a point where the spacing prior to the application of the tape is not less than half the required through air spacing, the wrap is not less than 0.33 mm (0.013 inch) thick and is applied in two or more layers.

b) At a point where the spacing prior to the application of the tape is less than half the required through air spacing, the wrap is not less than 0.71 mm (0.028 inch) thick.

c) Its temperature rating is not less than the temperature rise observed during the temperature test plus 25°C (77°F) for indoor switchboards or plus 40°C (104°F) for a Type 3R switchboard. If a temperature test is not required or if the temperature test is conducted using dummy fuses, the temperature rating shall be 80°C (176°F) for an indoor switchboard or shall be 105°C (221°F) for a Type 3R switchboard.

d) The tape is not subject to compression.

e) The tape is not wrapped over a sharp edge.

8.1.17.5 If spacings would otherwise be less than the minimum values specified in Table 6 or Table 7, thermoplastic tubing may be used as a barrier if all of the following conditions are met:

a) It is not subjected to compression, repeated flexure, or sharp bends.

b) All edges of the conductor covered 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 inch) for tubing 12.7 mm (1/2 inch) or less in diameter, not less than 0.69 mm (0.027 inch) for tubing 14.3 or 15.9 mm (9/16 or 5/8 inch) in diameter, and not less than 0.71 mm (0.028 inch) for larger tubing.

e) Its temperature marking is not less than the temperature rise observed during the temperature test plus 25°C (77°F) for an indoor switchboard or plus 40°C (104°F) for a Type 3R switchboard. If a temperature test is not required or if the temperature test is conducted using dummy fuses, the temperature marking shall be 80°C (176°F) for an indoor switchboard or shall be 105°C (221°F) for a Type 3R switchboard.

8.1.17.6 A switchboard section or interior in which a branch bus bar may be mounted in the field shall be such that support will be provided for such addition. A barrier that is provided, because spacings would be less than the minimum acceptable values or for any other reason, shall be an integral part of the switchboard section or interior unless the barrier is furnished as an integral part of the branch circuit bus bar, or is integral with a member necessary for mounting the branch circuit switch or circuit breaker. A base

for supporting a bus bar shall be assembled in place in the switchboard section or interior before it is shipped from the factory.

8.1.17.6.1 A barrier need not be provided at each end of a two-way branch circuit bus bar intended for field installation (a bus bar to each end of which a circuit breaker may be connected).

8.1.18 Filler plates

8.1.18.1 Filler plates complying with the requirements in this section shall be available for each switchboard section in which one or more units (circuit breakers, fuseholders, or the like) may be installed in the field. If any branch unit is factory-installed, the remaining spaces shall be filled with factory-installed filler plates.

8.1.18.2 A sheet-steel filler plate shall have an average thickness not less than 1.35 mm (0.053 inch) excluding coatings.

8.1.18.2.1 The average thickness may be not less than 0.81 mm (0.032 inch) excluding coatings if the plate is not larger than 25.4 mm by 76.2 mm (1 inch by 3 inches) or it is employed behind a door or a cover.

8.1.18.3 A filler plate of insulating material shall:

a) be of material that is in accordance with Table 11;

b) not be less than 2.4 mm (3/32 inch) thick at any point; and

c) unless otherwise investigated, have one dimension (length or width) not larger than 76.2 mm (3 inches) and have the other dimension not larger than 25.4 mm (1 inch).

8.1.18.4 Filler plates shall be secured in place by means which will prevent it from being dislodged as a result of normal use but shall also be readily removable.

8.1.18.5 A filler plate shall:

a) be of such size and shape that it will extend at least 0.8 mm (1/32 inch) on all sides beyond the opening that it is intended to close;

b) have a 6.4 mm (1/4 inch) or wider right-angle flange or the equivalent around its perimeter that, except at the ends of a row of units, will closely abut a similar flange or the equivalent around the edge of the opening that the plate is intended to close; or

c) overlap as specified in 8.1.18.5(a) on one, two, or three sides and shall have a flange or the equivalent as described in 8.1.18.5(b) on the remaining side or sides.

8.1.18.6 A filler plate shall close the opening to at least the same extent as the unit (switch or circuit breaker) in place of which the filler plate is mounted.

8.1.18.7 A filler plate may have dimensions larger than those specified in 8.1.18.3 (c) if it has been investigated and found to be acceptable for the purpose.

8.2 Enclosure and degree of protection

8.2.1 Framework and enclosure

8.2.1.1 Frame

8.2.1.1.1 Unless specified otherwise in this standard, an enclosure shall comply with the requirements in Reference Item No. 2 of Annex B.

8.2.1.1.2 A switchboard shall be enclosed on the front, back, top, and sides, and shall be a type as specified in Table 12.

8.2.1.1.2.1 Side covers are not required between adjoining sections of a multi-section switchboard.

8.2.1.1.2.2 If intended to be assembled to an existing switchboard that would complete the enclosure, a switchboard enclosure marked "Type 1" may omit the side panel that will be adjacent to the existing switchboard.

8.2.1.1.2.3 A switchboard section marked "Section 1 of 1" that is manufactured for stock and that may be assembled to an existing switchboard marked as specified in 6.3.1.1 may omit one side.

8.2.1.2 Sheet metal

8.2.1.2.1 Metals shall not be used in combinations such that galvanic action may cause an adverse effect on any part of the product.

8.2.1.2.2 Except as provided in 8.2.1.2.2.1, door and cover thickness shall comply with the enclosure thickness tables in Reference Item No. 2, Annex B.

8.2.1.2.2.1 The cover thickness may comply with the requirements in the 6.4 mm (1/4 inch) maximum deflection in Reference Item No. 2, Annex B.

8.2.1.2.3 If two or more covers or panels are provided to close a single opening, the thickness of each cover or panel shall not be less than a single sheet that would cover the complete opening or in the "without supporting frame" columns of the appropriate enclosure thickness tables in Reference Item No. 2 in Annex B.

8.2.1.2.3.1 If two or more covers or panels are provided to close a single opening, the adjacent edges of such multiple panels or covers shall:

a) be flanged at least 12.7 mm (1/2 inch);

b) be supported against an inward force at 254 mm (10 inches) maximum intervals;

c) overlap each other at least 12.7 mm (1/2 inch) and be secured together at 254 mm (10 inches) maximum intervals; or

d) comply with the 9.5 mm (3/8 inch) maximum deflection test for telescoping doors or covers specified in Reference Item No. 2, Annex B.

8.2.1.2.4 A switchboard that has a supporting frame around a single door or cover shall use metal having a thickness not less than specified in the "with supporting frame" columns of the appropriate enclosure thickness tables in Reference Item No. 2 in Annex B. A door that is not part of the required enclosure need not comply with the requirement.

8.2.1.2.5 Regardless of the size of the door or cover, the metal thickness may be reduced to not less than 1.35 mm (0.053 inch) excluding coatings if steel, or 1.91 mm (0.075 inch) if aluminum, copper, or brass, if:

a) the door or cover has the strength and rigidity to maintain its shape when open or un-mounted; and

b) the construction complies with the 9.5 mm (3/8 inch) maximum deflection test for telescoping doors or covers specified in Reference Item No. 2, Annex B.

8.2.1.2.6 A dead-front shield of sheet steel shall have a thickness not less than 0.81 mm (0.032 inch) excluding coatings and shall be supported independent of support provided by units that will be installed in the field.

8.2.1.3 Ventilation

8.2.1.3.1 A ventilation opening in a switchboard section or enclosure shall be constructed, located, or provided with a barrier so that:

a) no flame or molten metal will be emitted due to arcing encountered during the operation of a fuse, switch, or circuit breaker; and

b) access to an uninsulated live part will be limited as covered in 8.2.1.3.2 – 8.2.1.3.5.

8.2.1.3.1.1 With regard to an arcing part, the barrier may be omitted if:

a) during the Short-Circuit Test, 9.2.4, there is no emission of flame or molten material from the opening; or

b) the opening is located at least 305 mm (12 inches) from the arcing part.

8.2.1.3.1.2 With regard to a non-arcing uninsulated live part, the barrier may be omitted if:

a) the opening is located at least 102 mm (4 inches) from the live part; or

b) the live part is part of the neutral circuit.

8.2.1.3.2 The barrier specified in 8.2.1.3.1 shall comply with 8.7.1.1 or 8.7.1.2 and shall be of such dimensions and located so that a straight line drawn from any live part past the edge of the barrier will intersect the enclosure a minimum of 6.4 mm (1/4 inch) from the edge of the opening. Typical constructions complying with this requirement are shown in Figure 9.

8.2.1.3.3 An enclosure, when completely assembled, shall have no opening other than a ventilation opening that will permit the entrance of a 3.2 mm (0.125 inch) diameter rod.

8.2.1.3.3.1 If the distance between an opening and the nearest live part is more than 102 mm (4 inches) , the opening shall not permit the entrance of a rod having a diameter greater than 12.7 mm (0.500 inch).

8.2.1.3.4 A ventilation opening in an enclosure or dead front, including a perforated hole, a louver, or an opening protected by means of a ventilated closing panel; for example, wire screening, expanded metal, or a perforated cover, shall be of such size or shape that no opening will permit passage of a rod having a diameter greater than 12.7 mm (0.5 inch).

8.2.1.3.4.1 If the distance between any uninsulated live part and the opening is more than 102 mm (4 inches), the opening shall not permit passage of a rod having a diameter greater than 19.05 mm (0.750 inch).

8.2.1.3.5 A louver shall be 305 mm (12 inches) or less in length.

8.2.1.3.6 The total area of enclosure material removed from a wall for ventilation, together with the total area of ventilating openings as a result of forming the parent material, shall not exceed 25 percent of the area of the entire surface of any wall in which such ventilating openings are located unless reinforcing means such as stiffeners are used.

8.2.1.3.7 The area of any ventilating opening, as defined by the opening in the parent metal, shall not exceed 290 cm^2 (200 $inches^2$) if the ventilated closing panel is formed from material having a thickness less than that of the parent metal. A ventilating closing panel lighter than 1.52 mm (0.060 inch) thick uncoated steel, or 1.91 mm (0.075 inch) aluminum, copper, or brass, or 2.1 mm^2 (14 AWG) or lighter wire mesh shall not be used to close an opening of more than 516 cm^2 (80 $inches^2$).

8.2.1.3.8 A ventilating opening in the top of the enclosure shall be covered by a hood or provided with a protective shield so spaced with respect to the opening to prevent the entry of foreign material

8.2.1.4 Enclosures – specific environmental conditions

8.2.1.4.1 An external operating means – such as that for a disconnect, a pilot device, or a resetting operation – mounted on or through an enclosure shall withstand the tests specified for the enclosure unless otherwise indicated.

8.2.1.4.2 An enclosure shall be subjected to the tests specified in Table 12, and shall comply with the construction requirements applicable to an enclosure of the type number or numbers with which it is marked.

8.2.1.4.3 A watertight connection at a conduit entrance shall be a conduit hub or the equivalent, such as a knockout or fitting, located so that when conduit is connected and the enclosure is mounted in the intended manner the enclosure is found to be acceptable when subjected to the tests specified in Table 12.

8.2.1.4.4 An enclosure marked "Type 2" shall have provision for drainage. Provision for the entrance of conduit at the top or sidewalls shall be a conduit hub or the equivalent.

8.2.1.4.5 An enclosure marked "Type 3R" shall have a conduit hub or the equivalent for a watertight connection when the conduit entrances are at a level higher than the lowest live part in accordance with 8.2.1.4.3, provision for drainage, and if a door is provided, provision for locking the door.

8.2.1.5 Type 3R enclosures

8.2.1.5.1 If the marking specified in 6.2.9.1.1 is to be used, a Type 3R enclosure shall comply with 8.2.1.5.2 – 8.2.1.5.7 and 8.4.2.1 and be subjected to the rain test in Reference Item 2 of Annex B. A switch, circuit breaker, receptacle (complete with its associated attachment plug), fuseholder, or similar device, as well as any opening associated with an operating handle, shall be shielded from rain. If any live part is directly below a meter, water that may enter a Type 3R enclosure through a ringless-type meter opening shall be channeled to the outside by a permanent structure.

8.2.1.5.2 In an enclosure intended for horizontal pad mounting, any live part shall be located at least 102 mm (4 inches) above the enclosure mounting surface.

8.2.1.5.3 A hole for conduit in an enclosure shall be threaded unless it:

a) is entirely located below the lowest live part within the enclosure; or

b) accommodates a specific hub or closure fitting.

8.2.1.5.3.1 The area surrounding a threaded conduit hole shall be reinforced to provide metal at least 6.4 mm (1/4 inch) thick. A threaded hole for conduit shall be provided with a conduit end stop unless the thread is tapered.

8.2.1.5.4 In a switchboard enclosure or an individual section, any external connection to a wireway, auxiliary gutter, or busway shall be provided with a gasket or the like to provide for compliance with 3R requirements. If the opening is for attachment of a busway, the gasket is normally part of the busway fitting. The busway type for which the switchboard is marked shall be constructed so that water does not enter along any bus bar.

8.2.1.5.5 Aluminum in a switchboard section or switchboard enclosure shall be located so that it cannot be in contact with the concrete mounting pad.

8.2.1.5.6 In a switchboard section or enclosure marked as a "Type 3R" enclosure, guides for latch rods shall comply with the latch pull test in 9.2.9.

8.2.1.5.7 Switchboard sections supplied with and located in walk-in switchboard enclosures configured as shown in Figure 10 and Figure 11 (dimensions A – D) shall comply with the working clearance requirements of the installation rules of the country in which they are to be installed.

8.2.1.5.8 A switchboard section or group of sections under a common top supplied in a non-walk-in switchboard enclosure shall comply with the dimensional requirements shown in Figure 12. Other than as indicated in Figure 12, working clearances requirements of the installation rules do not apply within this enclosure.

8.3 Temperature rise

8.3.1 Temperature test

8.3.1.1 If a switchboard section is tested under the conditions described in 9.2.2.1 – 9.2.2.15, the results are acceptable if:

a) the temperature at any point is not sufficiently high to cause a fire or to adversely affect any material used; and

b) no temperature rise at specific points is higher than as specified in Table 13.

8.4 Protection against electric shock

8.4.1 General

8.4.1.1 An uncovered opening may be provided in the enclosure for field installation of metering equipment in accordance with the requirements of the serving agency (electric utility or electric power company, as shown by specifications of the serving agency for the switchboard in question.)

8.4.1.2 The accessibility of a live part in a pullout switch shall be judged under Reference Item No. 1 of Annex B.

8.4.1.3 The design of a dead-front shield or removable cover, and the structure to which it is mounted, shall be such as to reduce the risk of the shield or cover falling backward into the enclosure to contact any live part, or damage insulation of a live part inside the enclosure.

8.4.1.3.1 The design is considered to comply with the requirement if the only direction an unfastened shield or cover can be moved initially is outward and away from the enclosure without involving an intended sliding or twisting motion. The initial direction of removal may involve a sliding or twisting motion if the shield or cover is supported by the switchboard frame during removal.

8.4.1.4 Other than as covered in 8.6.7.8.1 and 8.6.7.9.1, a component that requires renewal, replacement, adjustment, or the like under conditions of use shall be accessible without the exposure of live parts or wiring.

8.4.1.5 A fuse and fuseholder, including a pullout switch, shall be located behind a hinged, sliding, or similarly attached door having the fastening required in 8.1.8.1.

8.4.1.5.1 A cover or a dead front to replace a fuse in a fused circuit breaker may be removed and the integral cover in a circuit breaker over the fuse may be exposed through an opening in the switchboard cover.

8.4.1.5.2 A fuse in an instrument or control circuit may be located behind a screwed-on cover or a locked cover that is accessible to a qualified person.

8.4.1.6 If a disconnect is not provided for the control circuit fuses and if a live part would be exposed to possible contact as a result of fuse replacement, a barrier shall be provided to prevent such contact.

8.4.1.6.1 A barrier is not required as shown in Figure 13 if the live part is located greater than 152 mm (6 inches) from any side of the fuse holder or puller and greater than 914 mm (36 inches) from the fuse in the direction of fuse removal.

8.4.2 Dead-front Construction

8.4.2.1 A switchboard section shall be constructed so that no uninsulated live part will be exposed from the front to contact by the operator during intended operation. There shall be no unnecessary opening in the front of the switchboard. Openings around a circuit breaker or for a switch unit shall not be larger than necessary to allow practical fabrication and assembly.

8.4.2.1.1 This requirement does not apply to the renewal of fuses.

8.4.2.1.2 This requirement does not apply to single pole separable connectors covered in 6.2.18.

8.4.2.1.3 A disconnecting device provided for isolating the switchboard or a section thereof from the source of supply for maintenance purposes and not serving as a service disconnect need not comply with the requirement in 8.4.2.1 if such a device is plainly marked as specified in 6.2.3.1 and is located behind a hinged door that is held in the closed position by means of:

a) a latch; or

b) a captive screw operable by hand or by a conventional tool.

8.4.2.2 An opening may be provided for a closely fitting operating handle if the clearance between the edge of the hole and the handles does not exceed 2.4 mm (3/32 inch) on either side (one side only) and 3.2 mm (1/8 inch) total (both sides). The clearance shall be measured with the handle in the "ON" and

"OFF" positions and with the handle and its supporting member assembled in any position that will result from ordinary factory assembly.

8.4.3 Grounding and bonding

8.4.3.1 The grounding and bonding terms used in this section are in accordance with the UL column in the Key to Figure 14. The corresponding CEC and ANCE terms are also provided for information. In Canada reference item No. 17, Annex B applies other than where specifically detailed in this clause.

8.4.3.1.1 There shall be provision for grounding exposed metal parts.

8.4.3.2 There shall be provision for grounding a switchboard section frame or structure and, in addition, where accessible to other than qualified persons:

a) the case or frame of an instrument transformer;

b) the case of an instrument, meter, or relay; or

c) the secondary circuit of a current or potential transformer.

8.4.3.2.1 The grounding connection shall not depend solely on solder.

8.4.3.3 A switch operating handle of conducting material need not be grounded if it is insulated.

8.4.3.4 The case or frame of a current transformer, the primary of which is not over 150 V to ground and that is used exclusively to supply current to a meter, need not be grounded.

8.4.3.5 The case of an instrument, relay, meter, or similar device, if mounted on a grounded metal surface and secured thereto by means of metal screws, is considered to be grounded.

8.4.3.6 Receptacles shall have all exposed non-current carrying metal parts and the grounding contact connected to the grounding means by:

a) an equipment grounding conductor as covered in Table 14; or

b) direct connection with the enclosure or frame and complying with the bonding resistance test 9.2.7. Not permitted in Canada.

8.4.3.7 The following connections shall meet the requirements of the bonding resistance test in 9.2.7:

a) between adjacent switchboard sections;

b) between a busway, ground bus, wireway or an auxiliary gutter and a switchboard section; and

c) between the switchboard 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.

8.4.3.8 The provisions to ground a metal barrier that covers uninsulated live parts need not be included if the barrier is provided with means for effectively and adequately insulating it from live parts or if the barrier is located so that it is unlikely to become energized.

8.4.3.9 A pressure wire connector provided for termination of the grounding conductor shall be capable of receiving and holding a conductor of the size indicated in Table 14.

8.4.3.10 Wire insulation or covering with continuous green color or a continuous green color with one or more yellow stripes shall be reserved for use only for grounding or bonding conductors.

8.4.3.10.1 Power-limited, Class 2 or Class 3 circuit cables containing only circuits operating at less than 50 volts shall be permitted to use a conductor with green insulation for other than equipment grounding purposes.

Note: Class 3 circuits are not recognized in Canada.

8.4.3.10.2 Integral leads of components are not required to meet this requirement.

8.4.4 Ground bus

8.4.4.1 A multi-section switchboard shall include a ground bus sized in accordance with Table 14 (columns 1 – 3) and Table 15 based on the switchboard supply ampere rating. A section having through bus bars extending beyond the section bus bars with provision for another section to be added at a later time is considered part of a multi-section switchboard. The ground bus shall extend into all sections of the switchboard.

8.4.4.1.1 A switchboard enclosure not intended to receive a switchboard interior may omit the ground bus if there is an opening for a grounding conductor between the switchboard enclosure and the adjacent section near the ground bus in the section.

8.4.4.2 If a switchboard section is intended for connection to a busway, the ground bus or an equivalent bonding jumper shall extend to the busway ground bus or busway enclosure serving as a ground bus unless the switchboard section is marked as covered in 6.2.14.1.

8.4.4.3 If a ground bus is not provided in a single switchboard section, at least two terminals shall be provided on the frame or enclosure:

a) for an equipment grounding conductor to ground the switchboard frame; and

b) for an equipment grounding conductor to bond all outgoing conduits to the switchboard frame.

8.4.4.3.1 The terminal in 8.4.4.3(a) may be omitted if the enclosure is factory bonded to the neutral, and a grounding electrode conductor terminal is located on the neutral.

8.4.4.3.2 The terminal in 8.4.4.3 (b) may be omitted if the bottom of the switchboard section has a complete metallic bottom that will bond the conduits and if the short-circuit current rating of the switchboard section does not exceed 10 000 A.

8.4.4.4 The first connector mentioned in 8.4.4.3 shall accommodate a grounded service conductor sized in accordance with:

a) columns 6 and 7 of Table 14 if the switchboard does not have a neutral and is marked for use as service equipment;

b) columns 2 and 3 of Table 14 if the switchboard is not marked for service equipment use;

c) columns 4 and 5 of Table 14 if the switchboard is marked suitable only for service equipment use; or

d) the largest of columns 2 – 5 of Table 14 if the switchboard is marked for service equipment use but not suitable only for service equipment use.

8.4.4.4.1 The second connector shall accommodate an equipment grounding conductor in accordance with columns 2 and 3 of Table 14 corresponding to the largest branch circuit.

8.4.4.5 With respect to 8.4.4.4(a), an additional connector shall be provided for a grounding electrode conductor sized in accordance with columns 4 and 5 of Table 14.

8.4.4.6 In addition to the terminals specified in 8.4.4.3, a switchboard section without a ground bus shall have provision for attaching additional terminals or grounding terminal assemblies to accommodate equipment grounding wires used with outgoing nonmetallic or under floor raceway. Size the terminals per Table 14.

8.4.4.7 If there is provision for a field-installed equipment grounding conductor terminal assembly, the assembly shall comply with Reference Item 1, Annex B, and the switchboard section or interior shall be marked in accordance with 6.2.7.17.

8.4.4.8 In addition to the required grounding means, a switchboard not having a factory bonded neutral may have an additional equipment grounding bus bar or terminal strip that is insulated from the enclosure.

8.4.5 Grounding electrode conductor terminal

8.4.5.1 A switchboard or interior marked for service equipment use shall have a terminal sized in accordance with Table 14 for the connection of the grounding electrode conductor to the ground bus.

8.4.5.2 Except as permitted by 8.4.5.2.1 and 8.4.5.2.2 a switchboard section or interior not limited to direct current, the grounding electrode conductor terminal shall be located such that the enclosure is not in the ground path from the grounding electrode to the grounded conductor.

8.4.5.2.1 In a single section switchboard or interior without a ground bus, the terminal may be located on the frame or enclosure.

8.4.5.2.2 In a switchboard or interior rated for alternating current only and containing a grounded conductor, the terminal may be located on the grounded conductor on the line side of the disconnect means as specified in 8.1.11.1 or 8.1.14.2.

8.4.6 Main bonding jumper

8.4.6.1 In a switchboard section or interior rated for alternating current, containing a grounded conductor, and marked for use as service equipment, a main bonding jumper shall be provided to bond the ground bus to the grounded conductor.

8.4.6.1.1 For a single section switchboard or interior without a ground bus, the main bonding jumper shall bond the frame or enclosure to the grounded conductor.

8.4.6.1.2 For a switchboard that is not factory bonded, the construction shall be such that when the bonding means is not used, the spacings specified in Table 6 will exist.

8.4.6.1.3 As specified in 8.1.11.4, only one section need contain a main bonding jumper in a multi-section switchboard.

8.4.6.1.4 For high-impedance grounded neutral systems, grounding shall be as specified in 8.4.8, high-impedance grounded neutral systems.

8.4.6.2 A main bonding jumper shall be sized as specified in Table 14 and Table 15 based on the largest supply ampere rating of any section in the group of sections. In determining the size of the main bonding jumper, no credit shall be given for another main bonding jumper in another section.

8.4.6.2.1 The connection of the main bonding jumper to the neutral shall be on the supply side of the neutral disconnecting means.

8.4.6.3 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.

8.4.6.4 The enclosure or ground bus shall not be bonded to the neutral when the switchboard is shipped.

8.4.6.4.1 In Canada, equipment marked as described in 6.2.2.1(a)(1) shall have the ground bus bonded to the neutral when the switchboard is shipped. See 8.1.12.

8.4.6.4.2 A switchboard section or interior that is not rated for direct current may have the main bonding jumper factory connected to the neutral bus and to the ground bus (or to the switchboard frame if a ground bus is not provided), if marked in accordance with 6.2.2.1(b).

8.4.6.4.3 In a switchboard section or interior incorporating ground fault protection of the ground return type as described in 8.1.13.1, the main bonding jumper shall be factory connected to the neutral bus and to the ground bus (or the switchboard frame if a ground bus is not provided) and the section or interior shall be marked in accordance with 6.2.2.1(b).

8.4.6.4.4 A switchboard section or interior as described in 8.4.7.2 shall be factory bonded.

8.4.7 Transformer secondary grounding

8.4.7.1 A secondary circuit of a power or control power transformer shall be grounded under any of the following conditions if the circuit extends or may 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; or

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

8.4.7.2 If a transformer secondary is required to be grounded in accordance with 8.4.7.1, a main bonding jumper shall be factory connected to the transformer secondary and to the ground bus (or to the enclosure if a ground bus is not provided). The size of the main bonding jumper shall be as specified in Table 14 and Table 15, based on the transformer secondary current rating. A grounding electrode conductor connector sized in accordance with Table 14 (columns 4 and 5) and Table 15 shall be provided on the ground bus and a marking as specified in 6.2.15.1 shall be provided.

8.4.7.2.1 If the transformer is rated not more than 1 000 Va and supplies only remote control and signaling circuits, the grounding electrode conductor terminal may be omitted and the main bonding jumper shall not be smaller than a 2.1 mm^2 (14 AWG) copper or 3.3 mm^2 (12 AWG) aluminum conductor, but otherwise need be not larger than the phase conductors connected to the transformer secondary.

8.4.7.2.2 For high-impedance grounded neutral systems, grounding shall be as specified in 8.4.8, high-impedance grounded neutral systems.

8.4.8 High-impedance grounded neutral systems

8.4.8.1 High-impedance grounded neutral systems may be used on 3-phase alternating current systems rated 480 V, 600 V or 1 000 V (wye or delta). Provision for line to neutral loads shall not be provided.

8.4.8.2 The grounding impedance shall be installed between the ground bus or the grounding electrode conductor terminal and the system neutral. If a neutral is not available, the grounding impedance shall be installed between the ground bus or the grounding electrode conductor terminal and the derived neutral.

8.4.8.3 The terminal on the ground bus for the grounding electrode conductor, the terminal on the neutral, and the terminal on the ground bus for conductors to the grounding impedance shall be located in the same or adjacent switchboard section as the system disconnecting means. The grounding impedance may be located in any section of a group of sections.

8.4.8.4 The size of the grounding electrode conductor terminal shall be as specified in Table 14.

8.4.8.5 The size of the neutral line terminal shall be as specified in Table 14 for the main bonding jumper.

8.4.8.6 A conductor connected to the grounding impedance located within the switchboard shall have an ampacity not less than the maximum current permitted by the impedance and shall not be less than 8.4 mm^2 (8 AWG) copper.

8.4.8.7 Ground-fault detectors that will give a visual or audible signal shall be provided.

8.4.8.8 Neutral grounding devices not having a continuous rating shall be permitted where:

a) provision is made to automatically de-energize the system on the detection of a ground fault; and

b) the time rating of the device is coordinated with the time/current rating of the protective devices of the system.

8.4.8.8.1 A disconnecting means is not required for a grounding impedance rated for continuous duty.

Note: The Canadian Electrical Code, Part I limits the continuous rating to 5A or less.

8.4.8.9 A continuous duty grounding autotransformer or transformers used to provide a specified magnitude of ground-fault current for operation of a ground responsive protective or signaling device on a 3-phase, 3-wire ungrounded system shall comply with the following:

a) The transformer shall have a continuous current rating sufficient for the ground-fault current at the maximum phase to neutral voltage.

b) For high impedance-grounded systems where the maximum ground-fault current is designed to be over 10 A, an overcurrent protective device that will open all ungrounded conductors simultaneously upon operation shall be installed on the supply side of the grounding transformer circuit and shall be rated or set at a current not exceeding 125 percent of the transformer continuous per phase current rating (or 42 percent of the continuous current rating of any series connected devices in the transformer neutral circuit). Delayed tripping for temporary overcurrents to permit operation of devices on the main system may be used but shall not exceed levels that are greater than the short-time current rating of the grounding transformer or any series connected device in the neutral circuit.

For Canada:

If the transformer overcurrent devices are used, there shall be a provision for tripping the main AC system device.

Note: Opening of the AC system is required in accordance with the Canadian Electrical Code, Part I.

c) For high impedance-grounded systems where the maximum ground-fault current is designed to be 10 A or less, an overcurrent device rated not more than 20 A that will simultaneously open all ungrounded conductors shall be installed on the line side of the grounding autotransformer.

For Canada:

If the transformer overcurrent devices are used, there shall be a provision for tripping the main AC system device.

Note: Opening of the AC system is required in accordance with the Canadian Electrical Code, Part I.

Note: The Canadian Electrical Code, Part I limits the continuous rating to 10A or less.

8.4.8.10 Means shall be provided to lock the handle of a grounding transformer overcurrent protective device in the energized position. A pilot light shall be provided to indicate that the high-impedance ground fault sensing circuit is energized. The pilot light shall be visible with all covers in place.

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

8.4.8.11 The grounding impedance shall be subjected to the tests specified in 9.2.2.17. A temperature test as specified in the Temperature Test, 9.2.2, may be required based on consideration of the location of the grounding impedance from other components, location of the switchboard section containing the grounding impedance with other sections, and location of ventilation openings.

8.4.8.12 A switchboard provided with a high-impedance grounded neutral system shall be marked as specified in 6.2.12.3 and the switchboard section containing the grounding impedance shall be marked as specified in 6.2.12.4.

8.5 Short-circuit protection and short-circuit withstand strength

8.5.1 General considerations regarding short-circuit current, peak current, and overcurrent protection.

8.5.1.1 A component not marked with a short-circuit current rating is considered rated for use in a circuit having a maximum available fault current as shown in Table 16. Bus bars, bus bar supports, wires, and wire connectors are considered to have a minimum short-circuit current rating of 10 000 A.

8.5.1.2 The short-circuit current available in the secondary circuit of a transformer rated 10 kVA or less and not less than 120 V is considered to be 5 000 A or less.

8.5.1.3 The short-circuit current available on the load side of a 600 V or less 15 A circuit breaker marked as a current limiting circuit breaker or 15 A Class CC, G, J, RK1, RK5, or T fuse is considered to be 5 000 A. In a single phase 120 V circuit the short-circuit current available on the load side of a 20 A circuit breaker or 20 A Class CC, G, J, RK1, RK5, or T fuse is considered to be 10 000 A or less.

8.5.1.4 For other than a plug-in meter, a current-sensing meter in a switchboard section or interior shall be a type that has been subjected to a 60 Hz rms short-circuit current of 12 000 A for 4 electrical cycles and a peak current of 30 000 A for 1/2 electrical cycle, and shall be provided with overcurrent protection as described in 9.2.4.3.2.1. A plug-in meter such as a watthour meter to be plugged into a meter socket base is not considered to be a part of the switchboard.

8.5.1.4.1 A meter need not have been tested nor provided with overcurrent protection if it is intended for use with a current transformer.

8.5.1.4.2 A meter need not have been tested nor provided with overcurrent protection if it is used across a shunt that has been subjected to a short-circuit test as specified in the 9.2.4, short-circuit test.

8.5.1.4.3 A meter need not have been subjected to a peak current of 30 000 A nor provided with overcurrent protection if the short-circuit current rating of the switchboard or the available fault current of the circuit at the meter is 14 000 A or less.

8.5.1.4.4 The electrical four cycle test may be reduced to 10 000 A if the short circuit current rating of the switchboard is 10 000 A or less.

8.5.1.5 A fuse or circuit breaker pole shall be provided for the protection of each ungrounded conductor except as follows:

a) taps used to supply load management devices, circuits for stand-by power systems, fire pumps, and fire and sprinkler alarms;

b) through or splice bus or wire;

c) in a Class 2 circuit;

d) for copper wire smaller than 16 AWG (1.3 mm^2) if the wire is treated as an arcing part in the application of 8.2.1.3.1 and 8.8.1.8.5;

e) for high-impedance shunt circuits, lightning arresters, Type 1 surge protective devices, and instrument transformers (current) installed on the supply side of the service disconnecting means;

f) for meters nominally rated not in excess of 1 000 V that do not include potential coils; and

g) as stated in 8.6.6.8.1.2.

8.6 Switching devices and components installed in assemblies

8.6.1 General

8.6.1.1 See 2.4.1.

8.6.2 Meter sockets

8.6.2.1 A meter socket base shall be mounted independent of the cover unless it is intended to be used with current transformers.

8.6.2.2 Any live part within a 76.2 mm (3 inches) radius of the center of the meter socket base shall be recessed not less than 12.7 mm (1/2 inch) behind the front plane of:

a) the meter mounting rim of a ring type meter socket as shown in Figure 15; or

b) the meter support of a ringless-type meter socket.

8.6.2.3 If a meter socket base is secured independent of the cover, the construction of a ring-type meter socket shall be such that removal of the cover necessitates a procedure tending to guide the cover clear of any uninsulated live part.

8.6.2.3.1 The guiding means or the insulation of a live part is not required if the jaws or other live part of the meter socket are recessed at least 1.6 mm (1/16 inch) behind the front plane of the meter socket cover.

8.6.2.4 The diameter of a ringless-type meter opening shall not be less than 166 mm (6.55 inches).

8.6.3 Components mounted on doors or covers

8.6.3.1 An electrical component shall be mounted independent of a door or removable cover.

8.6.3.1.1 A meter base may be mounted on a door as covered in 8.6.2.1.

8.6.3.1.2 Metering and monitoring equipment provided by the serving agency (electric utility or power company) may be mounted on a door or cover.

8.6.3.1.3 A meter, selector switch, pilot light, or push button station may be mounted on a cover not exceeding 305 mm (12 inches) in height nor 610 mm (24 inches) in width if a fuse is not located behind the cover.

8.6.3.1.4 A component may be mounted on a door if it complies with 8.6.3.2 – 8.6.3.5.

8.6.3.2 A wire subject to flexing when a door is opened shall:

a) be stranded and if larger than 13.3 mm^2 (6 AWG) shall have copper conductors of the extra flexible type; and

b) be cabled, routed, secured, and protected so that the wire will not be damaged during opening and closing of the door.

8.6.3.3 If a wire larger than 3.3 mm^2 (12 AWG) is used for connecting components mounted on a door, the door shall:

a) be hinged on one side and secured on the opposite side with screws or means for locking;

b) serve as access only to a bus bar, a wiring space, a terminal block, or similar component not requiring replacement, adjustment, resetting, or removal; and

c) be provided with means for keeping it open while installing field wiring.

8.6.3.4 A door having wire not larger than 3.3 mm^2 (12 AWG) may provide access to:

a) a fuse, if the construction also complies with 8.6.7.8; and

b) any part requiring adjustment, or the like, after the original installation of the switchboard, if the construction also complies with 8.4.1.4.

8.6.3.5 Any uninsulated live part involving a potential of more than 42.4 V peak mounted on the inside of a door shall be guarded, recessed, or enclosed to provide protection against unintentional contact. Methods to accomplish this include:

a) providing a fiber barrier at least 0.71 mm (0.028 inch) thick that is secured in place; and

b) providing an interlock so that no part subject to contact on the door would involve a potential of more than 42.4 V peak with the door open.

8.6.4 Service disconnecting devices

8.6.4.1 A service disconnecting device shall be either a switch or circuit breaker. Two single pole circuit breakers mounted side by side and having handle ties for simultaneous operation shall be considered as having but one handle.

8.6.4.2 Service disconnecting devices shall be capable of external manual operation to simultaneously disconnect, under rated load conditions, all ungrounded conductors of the circuit controlled by the device. An electrically operated switch or circuit breaker need not be capable of being externally operable by hand to the closed position. For Canada, manual operation of a service disconnecting means shall comply with the Canadian Electrical Code, Part I.

8.6.4.2.1 Service disconnecting devices located behind doors or covers shall be considered capable of external manual operation so long as the devices may be accessed without the use of a tool.

8.6.5 Multiple source switchboards

8.6.5.1 Unless intended for parallel operation, the disconnect identified in Figure 2 and Figure 3 as the tie-breaker shall be provided with mechanical, key, or electrical interlocking with the service disconnects shown in the figures so that sources cannot be paralleled. If the tie-breaker is omitted, all disconnects shall be provided with mechanical, electrical, or key interlocking so that the sources cannot be paralleled (unless intended for parallel operation).

8.6.5.2 If a switchboard is intended to parallel different sources, synchronizing equipment shall be provided integral to the switchboard.

8.6.5.3 When synchronizing equipment is provided integral to the switchboard, setup and operating instructions shall be included.

8.6.5.4 A switch or circuit breaker marked "line and load" or a fused switch shall not be used as a:

a) tie-switch;

b) tie-breaker; or

c) source disconnect if the source is intended to be paralleled with other sources.

8.6.5.4.1 A tie-switch or parallel source disconnect shall be a type that is tested for reversed line and load connections.

8.6.5.4.2 Fused switches may be used if the ends of each fuseholder are disconnected from both voltage sources when the switch is in the "OFF" position.

8.6.5.4.3 A tie-switch that has not been tested for reversed line and load connection may be used if the switchboard is marked to indicate that the tie switch is not to be opened under load as described in 6.2.3.1 (not for Canada). This allowance does not apply to circuit breakers or parallel source disconnects.

8.6.5.5 A switchboard intended to be connected to multiple sources shall be marked as specified in 6.2.3.3.

8.6.5.6 In a switchboard intended for parallel source operation, means shall be provided to automatically detect the loss of a source and to disconnect all ungrounded conductors of that source. It shall not be possible to reconnect the ungrounded conductors until the source is restored.

8.6.5.7 In a switchboard intended for parallel source operation, means shall be provided to automatically disconnect all ungrounded conductors of a 3-phase source if one of the phases of the source opens.

8.6.6 Overcurrent protection

8.6.6.1 A fuse or circuit breaker used in a direct-current circuit shall be rated for direct current.

8.6.6.2 The overcurrent protection required in 8.1.11.1 may consist of a main overcurrent device (a fuse or a circuit breaker pole) in series with each ungrounded service conductor, or not more than six overcurrent devices connected on the line side to each ungrounded service conductor and that feed separate loads. (Not for Canada.)

8.6.6.3 No overcurrent device shall be placed in any permanently grounded conductor unless it simultaneously opens all conductors of the circuit.

8.6.6.4 Each branch circuit shall be provided with overcurrent protection.

8.6.6.5 An accessible circuit breaker or switch shall be provided in a switchboard section or interior so that each branch circuit can be independently de-energized.

8.6.6.5.1 A circuit breaker or switch located behind a hinged, sliding, or similarly attached door having the fastening required in 8.1.8.1, is considered to be accessible.

8.6.6.6 A snap switch rated 30 A or less shall have overcurrent protection not in excess of 200 A.

8.6.6.7 For other than motor control circuit conductors as specified in 8.6.15, the conductors of a remote control switch circuit shall be protected by overcurrent devices rated at not more than 15 A. Overcurrent protection for control circuit conductors within the switchboard shall not exceed 7 A for 0.82 mm^2 (18 AWG) and 10 A for 1.3 mm^2 (16 AWG) conductors.

8.6.6.7.1 If the remote control circuit conductors within the switchboard are 2.1 mm^2 (14 AWG) minimum and the control circuit is tapped from the power circuit it controls, the branch-circuit short-circuit and ground-fault protective device may be rated 45 A or less.

8.6.6.8 Overcurrent protection of control devices

8.6.6.8.1 An instrument, pilot light, transformer with a primary rating of 12 A or less, or other switchboard device having a potential coil shall be operated from a circuit protected by either a circuit breaker or branch circuit type fuse rated at not more than 15 A. See 8.6.8.1 for transformers having primary ratings exceeding 12 A.

8.6.6.8.1.1 A fuse rated 2 A or less may be a miscellaneous or miniature (supplemental) fuse if not relied upon for protection of wiring leaving the switchboard section and if a marking as specified in 6.2.1.10 is provided and if the fuse is factory installed.

Note: Miscellaneous and miniature fuses may have limited interrupting rating at 250 V.

8.6.6.8.1.2 Overcurrent protection is not required:

a) for a current transformer;

b) if operation of the protective device may introduce undesired operation of the device; however, overcurrent protection is required for a ground fault protection control circuit connected to an external source ahead of the main disconnect as covered in 8.1.13.1;

c) for the operating coil of a fused power circuit device or the shunt trip coil of a circuit breaker or switch used with ground fault protection if the coil is connected to the load side of:

1) the fuses of the controlled switch; or

2) the circuit breaker as covered in 8.1.13.10.

d) on a control circuit complying with 8.6.6.7.1;

e) on the secondary of a transformer as specified in 8.6.8.4; or

f) for connection to a meter socket or a meter fitting unless required as specified in 9.2.4.3.2.1.

8.6.6.8.2 Overcurrent protection of control circuit conductors of a motor controller may be as covered in 8.6.15.1 – 8.6.15.2.

8.6.6.8.3 Overcurrent protection shall not be placed in the secondary circuit of a current transformer. Overcurrent sensors in the secondary circuit of a current transformer shall not operate to open the secondary circuit.

8.6.7 Fuses

8.6.7.1 A cartridge fuse or fuseholder rated 300 V shall not be used in a circuit of more than 300 V between conductors.

8.6.7.1.1 A cartridge fuse or fuseholder rated 300 V may be used in single phase, line-to-neutral circuits supplied from three-phase, four-wire solidly grounded neutral systems where the line-to-neutral voltage does not exceed 300 V.

8.6.7.2 A fuseholder shall be of the cartridge type.

8.6.7.3 A fuseholder in a switchboard section or interior having a short-circuit current rating in excess of 10 000 A shall have provision for accommodating a Class CC, G, J, L, R, or T fuse. Such a fuseholder shall not accommodate a miniature, miscellaneous (supplemental), Class H, or Class K fuse.

8.6.7.4 If a marking as specified in 6.2.1.10 is provided, a fuseholder in a maximum 125 V circuit may accommodate a miniature, miscellaneous (supplemental) fuse in accordance with any of the following conditions:

a) the circuit does not leave the switchboard;

b) the fuseholder is in a Class 2 circuit; or

c) the fuseholder is in a motor control circuit tapped from a motor branch circuit as specified in 8.6.15.2.

For Mexico, the maximum voltage rating of a circuit is 127 V.

8.6.7.5 A fuseholder accommodating a Class H or K fuse may be provided in a circuit having a maximum available fault current of 10 000 A.

8.6.7.6 A fuseholder in a circuit having a maximum voltage rating of 125 V and available fault current of 10 000 A may accommodate a miniature, miscellaneous (supplemental) fuse.

For Mexico, the maximum voltage rating of a circuit is 127 V.

8.6.7.7 A fuseholder used in series with a circuit breaker in a switchboard section having a marked short-circuit current rating higher than the interrupting capacity rating of the circuit breaker shall have provision for accommodating a Class CC, G, J, L, R, or T fuse. The fuseholder shall not accommodate a Class H or K fuse nor a supplemental (miscellaneous or miniature) fuse.

8.6.7.8 A disconnecting means shall be provided on the supply side of each cartridge fuse. The disconnecting means shall be located in the same section as the fuse.

8.6.7.8.1 In a switchboard section or interior that is not marked for use as service equipment, the disconnecting means need not be provided in an instrument circuit or control circuit if

a) it can be demonstrated that the fuses will be accessible to qualified persons only (such as by being located behind a screwed-on or a locked cover and a barrier if necessary in accordance with 8.4.1.6); and

b) if a marking as described in 6.2.3.11 is provided in the case of a switchboard with a main disconnect.

8.6.7.9 A switchboard section shall be designed and constructed so that fuses will be readily accessible, when the disconnecting means is open, so that they may be replaced without a person touching any live part. Exposed wiring shall be neatly cabled or otherwise out of the way.

8.6.7.9.1 A live part may be exposed as covered in 8.6.7.8.1.

8.6.8 Transformer overcurrent protection

Note: For equipment to be installed in Canada, transformer overcurrent protection may be provided in accordance with the CEC, Part I.

8.6.8.1 Each transformer shall be protected by an individual overcurrent device on the primary side rated or set at not more than 125 percent of the rated primary current of the transformer.

8.6.8.1.1 Overcurrent protection may be provided as covered in 8.6.6.8, 8.6.8.2, or 8.6.8.3.

8.6.8.2 A transformer having an overcurrent device in the secondary connection, rated for or set at not more than 125 percent of the rated secondary current of the transformer, is not required to have an individual overcurrent device in the primary connection provided the primary feeder overcurrent device is rated for or set to open at a current value not more than 250 percent of the rated primary current of the transformer.

8.6.8.3 A transformer, equipped by the manufacturer with coordinated thermal overload protection arranged to interrupt the primary current, is not required to have an individual overcurrent device in the primary connection if the primary feeder overcurrent device is rated for or set to open at a current value of not more than six times the rated current of the transformer for transformers having not more than 6 percent impedance and not more than four times the rated current of the transformer for transformers having more than 6 but less than 10 percent impedance. In Canada, this clause applies only to liquid filled transformers.

8.6.8.4 With regard to 8.6.6.4, 8.6.6.7, and 8.6.6.8, a conductor on the secondary side of a transformer can be considered protected by an overcurrent device in the primary circuit if both of the following limitations are met:

a) the transformer is single phase with a 2-wire (single voltage) secondary; and

b) the primary protection is in accordance with 8.6.8.1 – 8.6.8.3 and does not exceed the value required as determined by multiplying the secondary conductor ampacity by the secondary to primary voltage ratio.

8.6.9 Panelboards

8.6.9.1 If a switchboard section or interior contains a panelboard, the panelboard shall comply with the Panelboard requirements specified in Reference Item No. 1, Annex B.

8.6.9.2 If one panelboard is mounted above another in the same vertical section of a switchboard, the panelboards shall be separated by a horizontal barrier. The barrier shall be firmly secured in position and the dimensions of the barrier shall be at least 50.8 mm (2 inches) greater than the width and depth of the panelboard.

8.6.10 Reserved

8.6.11 Circuit breakers and switching devices

8.6.11.1 A switching means shall be acceptable for the particular application and shall have a current and voltage rating not less than the circuit it controls.

8.6.11.1.1 Switches marked “for isolating use only” and connected to the power bus and operating at a nominal voltage more than 250 V shall be interlocked to prevent operation under load.

8.6.11.2 An overcurrent protective device connected to the high leg (higher voltage to ground) of a 240/120 V, 3-phase, 4-wire delta system shall be rated at least 240 V (not 120/240 V).

8.6.11.3 A two-pole circuit breaker intended for use on a 3-phase load shall be marked “1Ø – 3Ø” when installed in a switchboard for use on a corner grounded delta system.

8.6.11.4 An interchangeable circuit breaker trip unit need not be factory installed if it can be mounted in place without disassembly of any electrical connection other than terminal connectors.

8.6.11.5 A switching device controlling a coil shall be rated for both the inrush and sealed or steady state current of the coil.

8.6.11.6 A device that is rated for across the line motor starting of an alternating-current motor may be used for alternating-current pilot duty without further tests if the power factor for the motor test was 0.5 or less and the overload test current was at least 150 percent of the pilot duty inrush current at the same voltage. Switching devices rated in accordance with Table 18 are considered to comply. The volt-ampere ratings of magnetic coils used in relays and starters is as marked on the coil or, if not marked, as specified in Table 19.

8.6.11.7 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use. This would include a switch used for switching a voltmeter, frequency meter, and power factor meter between various phases. An ammeter switch shall be investigated for such use.

8.6.11.8 A snap switch that controls a general purpose external circuit or controls a lampholder for an incandescent lamp other than a 15 W or smaller pilot or indicating lamp shall be acceptable for use with tungsten filament lamps, or shall have a current rating at least equivalent to six times the steady state tungsten load for alternating current, or ten times the steady state load for direct current.

8.6.11.9 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multi-circuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240 V, 2-pole switch may control a separate 120 V load, or both poles may be used to control both legs of a single 240 V load. Each pole of a snap switch rated as a 240 V, 3-pole switch may control a separate load not exceeding 139 V or three poles may be used to control the three legs of a 3-phase, 240 V load.

8.6.11.10 A 240 V or 250 V snap switch used in a circuit involving more than 120 V to ground shall be rated for such use.

8.6.11.11 A switch shall not disconnect the grounded conductor of a circuit.

8.6.11.11.1 The grounded conductor of the circuit may be disconnected by a switch that simultaneously disconnects all conductors of the circuit.

8.6.11.11.2 The grounded conductor may be disconnected by a switch that is arranged so that the grounded conductor cannot be disconnected until the ungrounded conductors of the circuit have been disconnected.

8.6.11.12 A power switching device, fused power circuit device, molded case circuit breaker, or transfer switch incorporating Class L fuses, that is rated for continuous operation at 100 percent of its current rating shall be installed in accordance with instructions provided by the manufacturer for such a unit concerning minimum compartment size, amount of necessary ventilation, type and size of conductor, and the like.

8.6.11.12.1 Variation from the instructions are acceptable if the construction is tested with acceptable results in accordance with Sections 9.1.1 and 9.2.2 – 9.2.4 and the requirements covering the device.

8.6.11.13 An automatic transfer switch marked for connection to an emergency system may be located in a switchboard section under the following conditions:

a) An open-type device shall be located in a space as covered in 8.1.1.2 or as indicated in the marking for the device.

b) Overcurrent protection shall be provided for control wiring that is intended to leave the switchboard section to supply a remote test switch or pilot light.

c) Markings in accordance with 6.2.4.1 shall be provided.

d) A barrier, as covered in 8.7.1.1 and 8.7.1.2.1, shall be provided to completely separate field-installed emergency circuit wiring and devices from non-emergency circuit wiring and devices that are located in the same switchboard section.

e) A barrier is not required within a compartment containing a transfer switch if the only wiring is that connected to the transfer switch.

f) The conductors feeding the normal circuit line terminals of the transfer switch shall be routed in such a way that it is not likely to come into contact with emergency circuit conductors within the transfer switch compartment.

8.6.11.14 A single throw knife switch shall be mounted so that gravity will not tend to close it and shall be connected so that the blade or blades will be deenergized when the switch is open. A double throw switch constructed so that gravity will tend to close it shall be provided with means to hold it in the "OFF" position.

8.6.11.15 A switch or circuit breaker shall be installed so that the center of the grip of the operating handle of the switch or circuit breaker, when in its highest position, will not be more than 2 m (6 ft 7 inches)

above the bottom of the switchboard. If the handle grip is not clearly defined, the center of the handle grip shall be considered to be a point 76.2 mm (3 inches) in from the end of the handle.

8.6.11.15.1 If the switchboard is intended for a particular installation where it is known that a raised working platform will be provided, the handle may be more than 2 m (6 ft 7 inches) above the bottom of a switchboard but not more than 2 m (6 ft 7 inches) above the platform.

8.6.11.15.2 The handle of a circuit breaker may be located above the 2 m (6 ft 7 inches) level if the circuit breaker is provided with a separate manual tripping means located not higher than 2 m (6 ft 7 inches) above the bottom of the switchboard.

8.6.11.16 There shall be a positive "OFF" position for operating handles of switching devices. Operating handles shall not create undue strain on the switching devices.

8.6.11.17 A handle or other member that indicates the position of switch or breaker contacts ("Closed" or "Open") shall be designed so that the door, front, or cover cannot be secured in place in the intended manner so that the handle or member indicates off with the switch blades or contacts in the closed position.

8.6.11.18 If a circuit breaker or switch is operated such that movement of the operating handle is vertical between the "ON" and "OFF" positions resulting in one position being above the other position, then the upper position shall be the "ON" position. A switch having more than one "ON" position, such as a transfer switch or a double throw switch, need not comply with this requirement. This requirement does not apply to operating handles that operate rotationally and shall be applied with the switchboard installed in the intended position.

8.6.11.19 Screws and nuts serving to attach operating parts to a movable member shall be staked, upset, or otherwise locked in position to prevent loosening under continued use.

8.6.11.20 If there are both switches and fuses in either mains or branches, the current rating of a switch shall not be less than the maximum rating of the fuse the fuseholder will accommodate.

8.6.11.21 A circuit breaker used to control a fluorescent lighting fixture or fixtures in a switchboard shall be a type marked "SWD."

8.6.11.22 A circuit breaker or switch used as the disconnecting means for a service, feeder, or branch circuit, shall be mounted such that the operating handle of the circuit breaker or switch is located not more than 150 mm (6 inches) behind the deadfront from the side of the switchboard that would be exposed to the working space. The exposed working space shall be determined based on that space that exists when the equipment is mounted as intended, and in compliance with the installation rules of the country in which the equipment is to be installed.

8.6.12 Transformers

8.6.12.1 A transformer used in a switchboard section shall be rated 10 kVA maximum. For an autotransformer, the maximum transformed power shall be 10 kVA.

8.6.12.1.1 A transformer rated greater than 10 kVA may be used if the switchboard section is tested in accordance with 9.2.2, or if the transformer is mounted in a separate switchboard compartment and the ventilation requirements are in accordance with the transformer manufacturer specifications.

8.6.12.2 Wiring within a transformer compartment shall comply with 8.8.1.8.5.

8.6.12.3 A transformer in a switchboard section shall be provided with overcurrent protection as covered in 8.1.13.10, 8.1.13.11, 8.6.6.7, 8.6.6.8, and 8.6.8.1 – 8.6.8.4.

8.6.12.4 The secondary circuit of a transformer shall be grounded as covered in 8.4.7.1 and 8.4.7.2.

8.6.12.5 Markings as covered in 6.2.15.2 and 6.2.15.3 shall be provided.

8.6.13 Class 2 circuits

8.6.13.1 A transformer located within a switchboard and supplying a Class 2 circuit shall comply with the applicable requirements specified in Reference Item No. 8, Annex B.

8.6.14 Reserved

8.6.15 Control circuits

8.6.15.1 Overcurrent protection shall be provided for the control circuit conductors of a motor controller. The means of overcurrent protection shall be:

a) located within the switchboard enclosure; and

b) sized in accordance with Table 20.

8.6.15.1.1 Overcurrent protection for the control circuit conductors is not required if:

a) the motor control circuit is tapped from the load side of a motor branch-circuit short-circuit and ground-fault protective device that is intended to control a motor or motors connected to the circuit; and

b) the rating of the short-circuit and ground-fault protective device is not greater than that specified in Table 21.

8.6.15.1.2 Overcurrent protection is not required in addition to the branch-circuit or short-circuit and ground-fault protective device if opening of the control circuit would create an undesired condition, such as opening the control circuit of a fire pump.

8.6.15.1.3 Conductors supplied by the secondary side of a single-phase transformer having only a two-wire (single-voltage) secondary may be protected by overcurrent protection provided on the primary (supply) side of the transformer, if this protection does not exceed the value determined by multiplying the appropriate maximum rating of the overcurrent device for the secondary conductor from Table 20 by the secondary-to-primary voltage ratio. Transformer secondary conductors (other than two-wire) are not considered to be protected by the primary overcurrent protection.

8.6.15.1.4 Overcurrent protection is not required in the secondary circuit of a Class 2 or 3 control transformer.

Note: Class 3 circuits are not recognized in Canada.

8.6.15.2 If the motor control circuit is tapped from the load side of a motor branch-circuit short-circuit and ground-fault protective device exceeding the maximum values specified in Table 21, the conductor shall be provided with overcurrent protection in accordance with Table 20. This overcurrent protection may be provided by a miscellaneous or miniature fuse (supplementary type) if a marking as specified in 6.2.1.10 is provided.

8.6.15.3 If the motor circuit disconnect does not also disconnect the control voltage within a motor controller compartment, an individual pilot duty rated disconnect switch for each control circuit identified as covered in 6.2.8.3 shall be located within the same compartment as the specified motor controller or shall be in a compartment adjacent to the motor controller.

8.6.15.4 Uninsulated live parts on the line side of the control circuit disconnect covered in 8.6.15.3, and on the line side of the disconnect device covered in 8.6.18.3, shall be located or protected so that the thermal relay of the motor controller may be adjusted or heaters changed without the risk of contacting such live parts.

8.6.15.5 Means shall be provided to prevent setting a motor controller to an automatic reset mode unless the marking as specified in 6.2.8.2 is provided.

8.6.15.6 Resetting means of the overload relay of a motor controller shall be externally operable.

8.6.15.7 If the wiring diagram of a magnetic motor controller indicates that one side of the control circuit is, or may be, grounded, the control circuit shall be arranged so that an unintentional ground in the remote control device will not cause the motor to start. To accomplish this, single pole switching devices shall be located in the ungrounded side of the control circuit.

8.6.16 Motor controller compartment

8.6.16.1 A magnetic motor controller shall be located in a compartment to prevent a part or a tool from falling onto a live part of equipment mounted below, to prevent contact with a live part of a different circuit, and to prevent load wiring from another controller from being routed through the compartment. The compartment walls may be of expanded metal or screen provided the individual openings are each not larger than 1.6 cm^2 (1/4 $inch^2$) in area. An open type motor controller shall be installed in a space equivalent to or larger than that used when evaluating it as a component.

8.6.16.1.1 An open-type motor controller may be located in a space smaller than that used when evaluating it as a component if acceptable results are obtained when the switchboard section containing the controller is subjected to a temperature, short-circuit, and overload relay calibration test, if applicable.

8.6.17 Motor circuit

8.6.17.1 Each bus bar and wire in the motor circuit shall have an ampacity as specified in Table 23, Table 25, and Table 28 for at least 125 percent of the motor running current as shown in Table 22 corresponding to the motor starter horsepower rating at the voltage rating of the switchboard section.

8.6.17.2 A current-sensing element of an overload relay shall be located in an ungrounded conductor of a single phase motor circuit and in each phase of a 2-phase motor circuit. Three current-sensing elements, one in each phase, shall be provided in a 3-phase motor circuit. Marking as specified in 6.2.8.1 shall be provided.

8.6.18 Motor circuit disconnect and short circuit protection

8.6.18.1 With respect to the full load current of any assigned horsepower rating at the voltage rating of the switchboard, the ampere rating or setting of a molded case circuit breaker (sometimes referred to as an inverse-time circuit breaker) shall not be more than three times that value. The rating of the circuit breaker shall not exceed the value shown on the current element table for any current element in the table. A circuit breaker shall not be used in lieu of a fuse if the overload relay is marked for use with a fuse only.

8.6.18.1.1 If there is provision for more than one motor or a motor and additional loads on the same branch circuit, the rating of a molded case circuit breaker may exceed three times the motor current rating

provided the particular combination of circuit breaker and overload relay has been investigated and found acceptable.

8.6.18.1.2 The ampere rating or setting of a molded case circuit breaker may be between three and four times the motor full load current if the motor full load current is 100 A or less.

8.6.18.1.3 A molded case circuit breaker rated 15 A may exceed four times the motor full load current.

8.6.18.2 If an instantaneous trip circuit breaker is used to provide short-circuit protection for a motor controller, the particular combination (manufacturer, type, electrical rating) of motor controller and instantaneous trip circuit breaker shall have been investigated and found acceptable for use together.

8.6.18.3 Provision shall be made for locking the disconnect device in the open position when the door is closed. The design shall be such as to provide that the switch is open and the switch position indicator shows open before locking can be accomplished.

8.6.18.4 The door over a magnetic motor controller 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. Provision may be made for deactivating the interlock for inspection purposes while the disconnecting device is closed.

8.7 Internal separation of assemblies by barriers or partitions

8.7.1 Restricting barriers

8.7.1.1 A sheet steel barrier shall not be less than 1.35 mm (0.053 inch) thick excluding coatings.

8.7.1.1.1 A dead-front shield may have a thickness as specified in 8.2.1.2.5.

8.7.1.1.2 A metal barrier may be of steel of less thickness if 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.

8.7.1.2 A nonmetallic barrier shall be not less than 6.3 mm (1/4 inch) thick and shall be supported to give adequate strength and rigidity. The thickness of a nonmetallic barrier may be less than 6.3 mm (1/4 inch) if the barrier is so located that it will not be subject to mechanical abuse during installation and is so located and supported that it will have adequate physical strength and rigidity.

8.7.1.2.1 If the barrier is spaced away from live parts by at least the distance specified in Table 6 or Table 7 for live parts to grounded metal, the material shall have a minimum flammability of HB, minimum HWI of 30, and minimum HAI of 60. See reference Item No. 16 of Annex B.

(Note: HAI = High current arc ignition.)

8.7.1.3 If a bolted pressure contact switch or AC or DC power circuit breaker or protector is mounted above other equipment in the same vertical section of a switchboard, 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 inches) beyond the vertical projection of each side of the switch base. If space does not permit the 152 mm (6 inches)

extension, the barrier shall extend to the side wall of the compartment. Any edge of the barrier not in contact with a compartment wall shall have an upturned flange at least 19.1 mm (3/4 inch) high.

8.7.1.4 With regard to 8.7.1.3, a metal barrier shall comply with the requirements in 8.2.1.2.6. The barrier may be of expanded metal or screen if the openings are not larger than 1.6 cm^2 (1/4 $inch^2$). A nonmetallic barrier shall be at least 1.6 mm (1/16 inch) thick and shall be reinforced if necessary to provide mechanical strength.

8.7.1.5 In a switchboard section or interior marked as being suitable for use as service equipment, any uninsulated ungrounded bus bar or terminal on the line side of a service disconnect shall be isolated by a barrier so that with every service disconnect in the off position, no uninsulated live part is exposed to inadvertent contact by persons while servicing any load terminal, including a neutral load terminal, a branch circuit equipment grounding terminal, or the neutral disconnect link. Openings in barriers shall comply with the requirements in 8.2.1.3.4.

Note: For Canada, also see 8.1.12.

8.7.1.6 The barrier specified in 8.7.1.5 shall comply with the requirements in 8.7.1.3 and 8.7.1.4 if the uninsulated live parts ahead of the service disconnect are located below any load terminal or below the neutral disconnect link in such a way that a falling tool or other metal part would contact them.

8.7.1.7 A barrier similar to that covered in 8.7.1.3 shall be provided below a fuseholder if there are uninsulated parts located below the fuseholder that may be live while the disconnect switch ahead of the fuseholder is in the off position.

8.7.1.8 An opening in a metal barrier through which a factory-installed wire or cable, or a field-installed wire may pass shall be provided with a bushing or shall be formed or protected so that insulated conductors will not come in contact with sharp edges.

8.7.2 Separation of circuits

8.7.2.1 Factory- or field-installed Class 2, Class 3, and other low voltage wiring shall be separated from other field- or factory-installed wiring in the same switchboard section by a barrier as described in 8.7.1.1 or 8.7.1.2.

Note: Class 3 circuits are not recognized in Canada.

8.7.2.1.1 In a space where field-installed wire will not be present, a barrier is not needed for factory-installed Class 2 or Class 3 wiring if:

a) such wiring is located or secured so that it will not contact uninsulated live parts of other circuits; or

b) the factory installed wire has insulation intended for the highest voltage that could be contacted.

8.7.2.2 If multiple factory-installed Class 2 or Class 3 circuits are in the same space, they shall be insulated for the highest voltage involved or shall be separated.

8.7.2.3 Power and control conductors need not be separated if all conductors are insulated to the highest voltage of the grouped conductors.

8.7.2.4 In Canada, where a switchboard is supplied from a 4-wire delta-connected system the grounded conductor shall be located in a compartment provided for single-phase connections and the phase

conductor referred to in 6.2.10.1 having the higher voltage-to-ground shall be suitably barriered from that compartment.

8.8 Electrical connections inside an assembly: bars and insulated conductors

8.8.1 Current carrying parts

8.8.1.1 General

8.8.1.1.1 A current carrying part shall be of silver, copper, aluminum, alloys of these metals, or the equivalent and shall be of rigid construction.

8.8.1.1.2 Iron or steel shall not be used for a part that is depended upon to carry current.

8.8.1.1.3 A plated steel screw, nut, and stud may be used to secure a soldering lug, pressure wire connector, or bus bar.

8.8.1.1.3.1 A No. 10/M5 and larger plated steel wire binding screw may be used at a terminal, in connection with a nonferrous terminal plate.

8.8.1.1.4 Copper and brass are not acceptable for plating wire binding screws, nuts, and stud terminals.

8.8.1.1.5 Each bus bar shall be plated at each joint with tin, silver, or nickel.

8.8.1.1.5.1 A welded or brazed joint need not be plated.

8.8.1.1.5.2 Copper bus bars need not be plated if the current at the joint is 600 A or less.

8.8.1.2 Bus bars

8.8.1.2.1 The bending of a bus bar shall not result in visible cracks, but roughening or slight surface crazing is acceptable.

8.8.1.2.2 The phase arrangement of the supply, through, and section bus bars in a 3-phase switchboard section or interior but not including the connections to meter sockets shall be A, B, C from front to back, top to bottom, or left to right as viewed from the front of the switchboard section or interior.

8.8.1.2.2.1 Other bus bar arrangements are permitted for a switchboard section or interior manufactured for addition to existing installations or for connection to meter sockets, transformers, or current transformers if the arrangement of the bus bars is indicated by a marking.

8.8.1.2.2.2 The phase arrangement in a 240 V, 3-phase, 3-wire switchboard section or interior employing two phase buses and a neutral and intended for use on a grounded B phase system shall be A, C with the neutral as the B phase.

8.8.1.2.3 A construction other than as described in 8.8.1.3.1, 8.8.1.4.1, and 8.8.1.5.1 may be used if it is investigated in accordance with the requirements for a clamped joint specified in the clamped joint temperature test, clause 9.2.2.18.

8.8.1.2.4 Spring-loaded connections to bus bars, such as at plug-in circuit breakers and switches, shall be investigated in accordance with the applicable requirements in Reference Item No. 1, Annex B.

8.8.1.2.5 A switchboard section marked for use with a busway as covered in 6.3.4.2.1 shall be provided with any necessary bus jumpers for joining the bus bars of the busway to those of the switchboard. For a switchboard with a short-circuit current rating greater than 10 000 A, the jumpers shall be provided with bracing equivalent to the supply bus or shall be tested as covered in the short-circuit test, clause 9.2.4, or the short-circuit test at reduced voltage, Annex F.

8.8.1.3 Riveted construction

8.8.1.3.1 Each riveted connection involving current carrying parts shall have a spring washer at one end and either a spring washer or a flat washer at the other end.

8.8.1.3.1.1 Washers may be omitted in a construction that has been tested in accordance with the clamped joint temperature test, clause 9.2.2.18.

8.8.1.3.1.2 Washers may be omitted in a connection rated 225 A or less having copper bus bars only.

8.8.1.4 Bolted construction

8.8.1.4.1 A spring washer shall be used at one end of a bolt securing current carrying parts together unless tested in accordance with 9.2.2.18.

8.8.1.4.1.1 A spring washer may be replaced with a split-ring lock washer and flat washer if each aluminum bus in the joint has a tensile yield strength of at least 20 000 pounds per square in (138 MPa).

8.8.1.4.1.2 A flat washer, a split-ring lock washer, or a bolt head that has an outer diameter of at least 150 percent of the bolt shaft may be used in place of a spring washer if:

a) the joint does not include any aluminum;

b) aluminum bolts are used with aluminum bus bars; or

c) the only aluminum in the joint is the tang of a pressure terminal connector.

8.8.1.4.1.3 A type of fastening means specified in the installation instructions supplied with a pressure terminal connector may be used with such a connector.

8.8.1.4.1.4 A spring washer is not required at a bolted contact of an aluminum alloy conductor (bus) used in a grounding circuit within the switchboard.

8.8.1.4.2 Unless investigated for such use as specified in 9.2.2.18, a bolted connection between two bus bars or between a bus bar and another current carrying part shall not depend on polymeric insulation to maintain the clamping force and shall not depend on thermoplastic material in any case.

8.8.1.4.3 A bolted joint in a bus bar shall be accessible for tightening without removing insulating tape.

8.8.1.4.4 Bolts, nuts, and washers as specified in 8.8.1.4.1 shall be provided for connecting through bus to other sections. The length of the bolts shall be such that spacings in accordance with Table 6 are maintained.

8.8.1.5 Washers

8.8.1.5.1 The flat washer specified in 8.8.1.3.1 and 8.8.1.4.1.1 shall have a thickness of at least 1/6 the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 percent of the rivet shank or bolt but not less than the outer diameter of the spring washer.

8.8.1.5.2 A spring washer as mentioned in 8.8.1.3.1 and 8.8.1.4.1.1 is a dished washer of stainless or hardened and tempered steel having an outer diameter not less than 150 percent of the bolt diameter, a thickness not less than 1/8 of the bolt diameter, and dished not less than 3-1/2 percent of the bolt diameter.

8.8.1.6 Ampacity

8.8.1.6.1 Bus bar ampacity is determined by compliance with the temperature test requirements of Section 9.2.2 or as specified in 8.8.1.6.2 – 8.8.1.6.8.

8.8.1.6.2 Other than as covered in 8.8.1.6.3, the ampacity or size of a bus bar is considered sufficient if the current density is not more than that specified in Table 23 or the size is not less than that specified in Table 25.

8.8.1.6.2.1 The values of ampacity shown in Table 23 do not apply to constructions as covered in 8.1.1.9.

8.8.1.6.2.2 The ampacity of a clamped joint may be higher as covered in 8.8.1.6.17.

8.8.1.6.3 A bus bar shall be sized in accordance with Table 24 if it is connected to a power switching device, fused power circuit device, molded case circuit breaker, or transfer switch incorporating Class L fuses, any of which is rated over 2 500 A for continuous use at 100 percent of its rating.

8.8.1.6.3.1 A smaller bus bar may be used if it is covered in the installation instructions described in 8.6.11.12.

8.8.1.6.3.2 Beyond a minimum distance of 1.2 m (4 ft) along the current path from the 100 percent rated device, the bus bar may be reduced in size, in accordance with the limitations specified in Table 23.

8.8.1.6.4 A single bus bar intended to carry 800 A or less may be sized in accordance with Table 25 if plated and bolted joints are used.

8.8.1.6.5 The cross section of a bus as covered in Table 23, Table 24, or Table 25 may be reduced by not more than 5 percent due to rounding, shaping, or dimensional tolerances.

8.8.1.6.6 Part of the bus material may be removed for slots or holes (whether used or not) if the remaining material at any cross section along the length of the bus bar has at least 70 percent of the required ampacity and the remaining metal in any 152 mm (6 inches) length of bus is at least 93 percent of the metal of a bus having the required ampacity in accordance with 8.8.1.6.5 and Table 23, Table 24, or Table 25. For example, a 25.4 mm (1 inch) wide bus could have 7.1 mm (9/32 in) holes on 25.4 mm (1 inch) centers or a 102 mm (4 inches) wide bus could have 10.3 mm (13/32 inch) wide slots 81.3 mm (3.2 inches) long every 152 mm (6 inches).

8.8.1.6.6.1 Bus bars with a larger amount of material removed may be used if the construction is acceptable under the Temperature Rise Test conditions outlined in 9.2.2.16. If the amount of removed material is greater than 11.1 by 20.7 mm (0.438 by 0.813 inch) then the construction shall also be short circuit tested in accordance with 9.2.4.

8.8.1.6.7 The limitations on current density mentioned in Table 23 or Table 25 do not apply to:

a) a connecting strap, bus, or the like, comprising a part of a circuit breaker, switch, or fuseholder employed in the switchboard; or

b) a portion of a strap, bus, jumper, or the like, adjacent and connected to a terminal of a switch, circuit breaker or fuseholder [but not more than 25.4 mm (1 inch) from the terminal], if a reduced

cross section in that portion is necessary because of the recessing of the terminal or because of barriers adjacent to it.

8.8.1.6.8 The neutral ampacity shall not be less than the main bus ampacity unless the neutral is a least 200 A and is clearly marked on the nameplate or on a wiring diagram referenced by the nameplate.

8.8.1.6.9 The ampacity of a bus bar shall not be less than its marked rating as described in 5.3 and 6.2.1.9 – 6.2.1.11 and not less than required in 8.8.1.6.10 – 8.8.1.6.18. After the first branch, a section bus may have reduced ampacity but not less than that required in 8.8.1.6.13 and 8.8.1.6.14 and:

a) if the section or interior is marked with a single ampere rating, the combined ampacities of the section buses shall not be less than the single section or interior ampere rating; or

b) with regard to 5.3.2, if the section or interior is marked with two ampere ratings, the ampacity of each of the two section buses shall not be less than their respective section or interior ampere ratings.

8.8.1.6.10 A wire or bus bar leading to a fuseholder shall have an ampacity not less than the rating of the largest fuse the fuseholder will accommodate unless marked in accordance with 6.2.1.9.

8.8.1.6.11 A wire or bus bar leading to a non-interchangeable trip circuit breaker shall have an ampacity not less than the current rating of the breaker.

8.8.1.6.12 A wire or bus bar leading to a circuit breaker frame designed for use with interchangeable trip units shall have an ampacity not less than the maximum current rating of the frame unless marked in accordance with 6.2.1.9.

8.8.1.6.13 The ampacity of a branch, section, or supply bus bar or wire supplying more than one overcurrent protective device shall not be less than the percentage of the sum of the ratings for the number of branch circuit overcurrent protective devices provided as specified in Table 26. The overcurrent protective device rating used in the calculations shall correspond with the branch bus ampacity required in 8.8.1.6.10 – 8.8.1.6.12.

8.8.1.6.13.1 A switchboard that is intended for a specific installation where the loading is known may have a bus or wire with a current carrying capacity less than that required in 8.8.1.6.10 – 8.8.1.6.14.

8.8.1.6.13.2 The section or supply bus ampacity need be not greater than:

a) the supply rating of the switchboard section as specified in 5.3.1.1; or

b) the rating of the overcurrent device used to protect the bus as a main or sub-main.

8.8.1.6.14 If provision is made for the future installation of one or more specific branch circuit units (fused switches or circuit breakers), the branch or section bus ampacity shall be calculated with the current value for the additional units added to the current value for the factory-installed units. If space is provided for an unspecified future use, the calculated ampacity required of the branch or section bus shall be increased by the multiplying factor specified in Table 27.

8.8.1.6.14.1 The section or supply bus ampacity may be as noted in 8.8.1.6.13.2.

8.8.1.6.15 If there are both upper and lower section bus ratings, as covered in 5.3.2.2, the bus supplying the section buses shall have an ampacity not less than:

a) 80 percent of the sum of the upper and lower section bus ratings; or

b) the supply bus rating, whichever is smaller.

8.8.1.6.16 The ampacity of a through or splice bus shall not be less than the supply rating required in 5.3.1.1.

8.8.1.6.16.1 The ampacity of the through and splice bus on the load end beyond the section bus may be less than the supply rating provided that it is not less than the supply rating of the next section of the group.

8.8.1.6.16.2 The ampacity of the through and splice bus on the load end beyond the section bus may be equal to a reduced separately marked rating as indicated in 5.3.1.1.1 when the next section of the group is to be installed at some future time.

8.8.1.6.17 For the following constructions, the contact area may result in current densities greater than the maximum of 31 A per cm^2 (200 A per $inch^2$) specified in 8.8.1.6.2 and Table 23 and Table 24:

a) The contact area between a plated bus bar and circuit breaker or switch shall not be less than the area on the pressure wire connector that is supplied with a breaker of appropriate rating, or not less than the contact area available for back connection.

b) If the full available contact area between a bus bar and pressure terminal connector is not used, the contact area shall not be less than the area that would result when two of the same type connectors are bolted together back-to-back with wires leaving in opposite directions or at right angles, whichever results in the smallest area.

8.8.1.6.18 In determining the area of contact surfaces of bolted or riveted connections, no subtraction shall be made for diameters of holes containing bolt or rivets, and no additions shall be made for the diameters and areas of screws, bolts, washers, or rivets.

8.8.1.7 Support and securement of live parts

8.8.1.7.1 A bus bar shall either be supported independently of any unit to which it is connected (switch, circuit breaker, or the like) or shall be supported by units that are factory installed and that do not depend on the bus bar for support.

8.8.1.7.2 A bus bar or uninsulated live part, other than a pressure wire connector as mentioned in 8.1.16.16, shall be secured so that ordinary vibration will not loosen the securing means and shall be prevented from turning or shifting in position if any spacings less than half those shown in Table 6 would result from such turning or shifting. A bus bar provided with one or more insulators that must be removed when a branch circuit unit is installed shall be prevented from any turning that would result in spacings less than one-half those specified in Table 6 with all insulators in place, or that would result in spacings less than 3.2 mm (1/8 inch) for a voltage up to 250 V, or 6.4 mm (1/4 inch) for a voltage between 251 to 1 000 V, with any insulators omitted.

8.8.1.7.3 Friction between surfaces may not be used as a means to prevent turning or shifting of an uninsulated live part. Turning or shifting may be prevented by the use of two screws or rivets; by noncircular shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method. No reliance shall be placed on a single branch circuit fuseholder, circuit breaker, or switch unit for preventing turning of the branch bus feeding such unit if such turning would reduce spacings to less than those specified in 8.8.1.7.2 or Table 6.

8.8.1.7.4 In determining the adequacy of means to prevent turning or shifting, any screw or nut shall be loosened and retightened finger-tight without a tool. The bus shall then be pushed to the extent limited by the screws or other means and the resulting spacings checked.

8.8.1.7.5 If a branch circuit unit (circuit breaker or switch unit) rated 600 A or less is removable from the front of the panel, the replacement or removal of such unit shall not result in the likelihood of a short circuit from turning or dropping of parts.

8.8.1.7.6 A bolt, nut, or washer used to secure a branch circuit unit is not considered likely to fall if it is visible and readily reached. A branch bus is considered likely to fall if the bolts that secure the branch circuit unit to the branch bus are the same as those used to secure the branch bus to the bus on its line side.

8.8.1.8 Wiring

8.8.1.8.1 With regard to Table 28, an insulated conductor provided as part of a switchboard assembly shall be rated for the particular application (voltage and temperature) and shall have an ampacity not less than the maximum current rating of the circuit in which it is connected. Insulated wire shall be a type that has been investigated and found acceptable. See Table 29 for the minimum required insulation thickness of thermoplastic appliance wiring material. Type V wire, if used, shall be flame retardant. The ampacity of a branch circuit shall be determined by the rating of the circuit breaker or fuse used in the circuit. The ampacity of a motor circuit shall be determined as covered in 8.6.17.1.

8.8.1.8.1.1 The size of wire for motor control circuits may be as specified in 8.6.15.1 and 8.6.15.2.

8.8.1.8.2 A wire within an enclosure, compartment raceway, or the like shall be located or protected to prevent contact with any sharp edge, burr, fin, moving part, or the like, that can damage the conductor insulation.

8.8.1.8.3 Bending or installation of a factory-installed conductor shall not result in cracking or other damage to the conductor insulation.

8.8.1.8.4 Factory-installed wires shall be of a type rated for at least 75°C (167°F).

8.8.1.8.5 Means shall be provided to space field- or factory-installed wiring at least 76.2 mm (3 inches) away from a power transformer, ballast, heating element or unenclosed arcing parts such as switch contacts that are not provided with arc chutes.

8.8.1.8.5.1 Wiring attached to the terminals of a transformer, ballast or heating element may be within 76.2 mm (3 inches) of such a unit.

8.8.1.8.5.2 Wiring installed in the factory and rated for 75°C (167°F) may be within 6.4 mm (1/4 inch) of the enclosure of a ballast or an enclosed power transformer.

8.8.1.8.5.3 If the wire or insulating tubing secured over the wire is rated for at least 90°C (194°F), the wire or tubing may be in contact with the enclosure of such units. This does not apply to an open core and coil transformer, a heating element, or a resistor.

8.8.1.8.5.4 Wires may be spaced closer than specified if the results of a temperature test show such spacing to be acceptable.

8.8.1.8.6 If the conductors of an alternating current circuit pass through a wall or partition of metal having magnetic properties, all the conductors of the circuit including the neutral shall be run through the same opening.

8.8.1.8.6.1 The requirement does not apply to a component unit such as a panelboard or switch which has been evaluated for the application.

8.8.1.8.6.2 The secondary conductors of a current transformer at a meter and meter socket may be run through a different opening from the neutral conductor.

8.8.1.8.7 With respect to the requirement in 8.8.1.8.6 and to Figure 16, 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 for all the conductors of the circuit if no metal bracket, brace, or the like is placed across the insulating material between the conductors.

8.8.1.8.8 Conductors in sizes 53.5 mm^2 (1/0 AWG) and larger may be run in multiple if the arrangement is such as to provide equal division of total current among all conductors involved. All of the multiple conductors shall be of the same length, conductor material, circular-mil area, and insulation type, and terminated in the same manner; that is, if mechanical setscrew connectors are used, all connectors in the arrangement shall be of the mechanical setscrew type.

8.8.1.8.9 Aluminum wire, insulated or uninsulated, used for internal wiring interconnections between current carrying parts shall be terminated at each end by a method rated for the combination of the metals involved at the connection point.

8.8.1.8.10 Wiring in operating aisles of outdoor switchboard assemblies shall be installed in accordance with the installation codes.

8.8.2 Wiring terminals

8.8.2.1 General

8.8.2.1.1 A terminal (pressure wire connector or wire binding screw) shall be provided for connection of each conductor intended to be field-installed in the switchboard section or interior. Connections may be provided for cord-connected equipment, see Cord-Connectors, 8.8.4.

8.8.2.1.1.1 Terminals are not required in a switchboard section or interior designed for connection to bus bars as covered in 8.8.1.2.5 and 8.8.1.2.4.

8.8.2.1.1.2 Terminals are not required as noted in 8.8.2.1.3.

8.8.2.1.2 A terminal (pressure wire connector or wire binding screw) shall be of the same type used during the short-circuit test.

8.8.2.1.2.1 Alternative wire connectors such as crimp for crimp, mechanical for mechanical, or crimp for mechanical may be used in a switchboard section or interior rated 85 000 A maximum, or 100 000 A maximum if supplied by an overcurrent protective device, without conducting a short-circuit test under the conditions in (a) or (b):

a) the switchboard short-circuit current rating divided by the number of conductors per phase results in a current of 50 000 A or less per conductor.

b) the switchboard short-circuit current rating divided by the number of conductors per phase is greater than 50 000 A and both of the following conditions are met:

1) the number of conductors per phase is equal to or greater than the number of conductors as tested; and

2) the average force required to pull the wire from the connector is equal to, or greater than, the average force required to pull the same type wire from the connector used in the

equipment during the short-circuit test. Three samples shall be used to obtain the average force.

8.8.2.1.3 Terminals or kits for line or feed-through terminals, or both, neutral terminals or neutral assemblies, tap-off connectors and ground terminals or ground terminal assemblies may be installed in the field provided that:

a) they can be installed without the disassembly of factory-assembled parts (other than those parts normally disassembled for installation and wiring and other than main terminal wire connectors), and without the use of a special tool, unless such a tool and the instructions for its use are furnished with each kit;

b) the design of the switchboard and the terminal or kit is such that with the terminal or kit installed, spacings will be maintained; and

c) the terminals or kits and switchboards with which they are intended to be used are marked to identify the field installable equipment.

Note: A neutral kit cannot be field installed for service equipment use in Canada.

8.8.2.1.4 A switchboard 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 bus bars. A switchboard section intended for connection to a busway shall be marked as covered in 6.3.4.2.1.

8.8.2.2 Wire binding screws

8.8.2.2.1 A wire-binding screw or stud of a wiring terminal shall not have more than 32 threads per in (0.80 mm pitch) and shall not be smaller than No. 10/M5, except that a No. 8/M4 copper-alloy machine screw may be used at a terminal intended only for the connection of a 2.1 mm^2 (14 AWG) conductor. The terminal shall be provided with upturned lugs, a cupped washer, or the equivalent capable of retaining a 2.1 mm^2 (14 AWG) solid conductor even though the screw or nut becomes slightly loose.

8.8.2.2.2 Except as noted in 8.8.2.2.5, a terminal plate for a wire-binding screw shall not be less than 1.27 mm (0.050 inch) thick.

8.8.2.2.3 There shall not be fewer than two full threads in the metal terminal plate.

8.8.2.2.4 A terminal plate may have the metal extruded at the tapped hole to provide at least two full threads, if the thickness of the unextruded metal is not less than the pitch of the thread.

8.8.2.2.5 A terminal plate not less than 0.76 mm (0.030 inch) thick may be used if the tapped threads have equivalent mechanical strength.

8.8.2.3 Pressure wire connectors

8.8.2.3.1 A pressure wire connector provided with or specified for use with a switchboard shall comply with Reference Item No. 9 or 10, Annex B. Pressure wire connectors that comply with Reference Item No. 10, Annex B shall not be provided in a switchboard having a short-circuit current rating greater than 10 000 A unless the switchboard using the wire connectors is tested for the higher short-circuit current rating.

8.8.2.3.1.1 A pressure wire connector used at an equipment grounding terminal shall comply with the requirements for such devices. The connector:

a) may be of iron or steel, if plated; and

b) need not comply with the requirements for the static heating or heat cycling tests.

8.8.2.3.1.2 A pressure wire connector that complies with Reference Item No. 10, Annex B may be used in a switchboard having a short-circuit current rating greater than 10 000 A if the wire connector complies with the pullout test specified in Reference Item No. 9 or 10, Annex B for the largest conductor to be used.

8.8.2.3.2 The tightening torque for a field-wiring pressure terminal connector shall be as specified by the switchboard manufacturer and shall be marked as required in 6.2.7.13. The specified tightening torque shall not be more than 100 percent nor less than 90 percent of the value used in the connector static heating test as specified in Reference Item No. 9 or 10, Annex B, for that wire size corresponding to the ampere rating of the switchboard.

8.8.2.3.2.1 The torque value may be less than 90 percent if the connector is investigated with the assigned torque value in accordance with Reference Item No. 9 or 10, Annex B.

8.8.2.3.2.2 A tightening torque value is not required for a crimp type connector as covered in 6.2.7.15 and 6.2.7.16.

8.8.2.3.3 A wire connector intended for field wiring shall be tested as covered in the strength test of insulating base and support, 9.2.1.

8.8.2.3.4 Markings in accordance with 6.2.7.1 – 6.2.7.18 and 6.2.7.23 shall be provided for a wire connector intended for connection of wire in the field.

8.8.2.3.5 The point of attachment of a pressure wire connector or wirebinding- screw terminal shall have the necessary mechanical strength to maintain the spacings required by Table 6 and Table 7.

8.8.2.3.6 A main terminal shall be capable of securing the smallest conductor (or group of conductors in multiple) of standard AWG size having an ampacity not less than the supply rating of the switchboard section or interior as covered in 5.3.1.1,6.2.7.1 – 6.2.7.10, 8.8.1.6.8, and 8.8.2.3.10.

8.8.2.3.7 A terminal for a branch circuit conductor shall be capable of securing the smallest conductor (or group of conductors in multiple) of standard AWG size having an ampacity in accordance with the application, as determined from the considerations set forth in 8.8.2.3.8 and 8.8.2.3.9.

8.8.2.3.8 With respect to 8.8.2.3.7, it is assumed that the ampacity of a wire or wires to be connected in the field to a terminal of:

a) a fuseholder is any value within the range of current ratings of fuses that the fuseholder will accommodate, unless the maximum permissible fuse size is marked in accordance with 6.2.1.9;

b) a circuit breaker designed for use with interchangeable trip units of different current ratings is acceptable for the rating of the installed trip unit or for the marked permissible rating in accordance with 6.2.1.9; or

c) a circuit breaker not designed for use with interchangeable trip units of different ratings is acceptable for the current rating of the breaker.

8.8.2.3.9 With respect to 8.8.2.3.7 and Table 28, the size and type of a field installed conductor shall be determined as follows:

a) For currents as indicated in Table 28:

1) wire rated at 75°C (167°F) will be used for 53.5 mm^2 (1/0 AWG) and larger sizes and

2) the use of wire rated 60°C (140°F) for all wire sizes 42.4 mm^2 (1 AWG) and smaller, except the conductor size shall be based on the use of wire rated 75°C if the switchboard has been subjected to the temperature test using 75°C wire and is marked for 75°C field-installed wire at any terminals.

b) It is assumed that aluminum wire will be used at any terminal identified on a wiring diagram or the like as covered in 6.2.7.1 – 6.2.7.8 as being rated for use with such wire, whether or not that terminal is also identified as being rated for use with copper wire.

8.8.2.3.10 The requirements in 8.8.2.3.6 and 8.8.2.3.7 do not preclude use of a connector that will also accommodate a wire (or wires) of an additional size (or sizes) different from that specified in those paragraphs.

8.8.2.3.11 If its terminal is not directly connected by a screw threaded into the bus bar, a circuit breaker or switch shall be secured independently of its terminal connection.

8.8.2.3.12 The number of individual branch circuit neutrals shall be at least 100 percent of the maximum number of installed circuits provided for in the switchboard. Neutral terminals are not required for circuits not utilizing a neutral connection.

8.8.2.3.13 A wiring terminal shall be located so that:

a) it will be accessible for examination; and

b) connections may be tightened or branch-circuit wires removed without loosening any screws that secure a bus bar, switch, circuit breaker, fuseholder, or the like.

8.8.2.3.13.1 With reference to 8.8.2.3.13 (a), a construction is acceptable even though it may be necessary to remove a circuit breaker cover, trim, or the like to make a connection accessible.

8.8.2.3.14 Load terminals for field wiring shall be located as follows:

a) Connections to the ground bus for load equipment grounding conductors shall be so located that it is not necessary to reach across uninsulated ungrounded bus in order to make connections.

b) Where multiple branch or feeder neutral load terminals are grouped together in one location, these terminals shall be so located that it is not necessary to reach across uninsulated ungrounded bus in order to make connections.

c) Where only one branch or feeder set of neutral load terminals are grouped with its associated ungrounded load terminals, they shall be so located that it is not necessary to reach across energized uninsulated bus in order to make connections. Bus on the line side of service, branch, or feeder disconnects is considered energized with respect to its associated load side circuits.

d) Ungrounded load terminals shall be so located that it is not necessary to reach across energized uninsulated bus in order to make connections. Bus on the line side of service, branch, or feeder disconnects is considered energized with respect to its associated load side circuits.

e) Connections referenced in b, c, or d shall be so located that a tool not longer than 254 mm (10 inches) used to tighten these connections will not contact a live part that is not obvious to the person making the connection. This shall be determined with branch units connected.

8.8.2.3.15 If it is necessary to make connections from the rear or side of the switchboard, the switchboard shall be marked in accordance with 6.2.7.22.

Note: In accordance with the country specific standard for electrical safety in the workplace, an electrically safe work condition should be established prior to working on electrical equipment. Accessibility requirements do not endorse working on energized electrical equipment.

8.8.2.3.16 If a switchboard incorporates ground fault protection, the load termination part of the neutral bus, marked in accordance with 6.2.13.2 shall be insulated from the enclosure and shall have no terminal or other provision for grounding or bonding.

Note: In Canada the load part of the neutral cannot be used for bonding equipment to ground.

8.8.2.3.16.1 If the ground fault protection is of the zero sequence or residual type, all neutral load terminations on the neutral bus shall be on the load side of the sensing elements but provision for grounding and bonding shall be on the line side of the sensing element.

8.8.2.3.16.2 For ground fault protection of the ground return type, grounding and bonding of the neutral shall be effected only by means of a conductor (or conductors) the current through which is detected by the sensing element.

8.8.3 Wiring space

8.8.3.1 General

8.8.3.1.1 There shall be space within the enclosure of a switchboard section for the installation of those wires and cables likely to be used in connecting the mains and branch circuits, including feed through conductors that may continue to another section.

8.8.3.1.2 The adequacy of wiring space shall be judged using:

a) the size, type, and conductor material of a wire used at a terminal in accordance with Table 28 and with 8.8.2.3.6 – 8.8.2.3.9 except that for ampacities of 110 A or less the size shall be based on 60°C (140°F) insulated conductors although the marking specifies 75°C (167°F) wire;

b) the full complement of branch circuit devices which necessitate that the largest wiring space will be installed; and

c) at least one neutral terminal for each branch circuit position identified in (b).

8.8.3.1.2.1 If a terminal is for use with two or more combinations of conductors in multiple, each of which would be appropriate for that terminal in accordance with 8.8.2.3.6 – 8.8.2.3.9, the combination necessitating the largest wiring space shall be used, unless there is a marking in accordance with 6.2.7.10. If a terminal is provided for conductors in multiple, the size of each conductor shall be based on the use of multiple conduits.

8.8.3.2 Wire bending space

8.8.3.2.1 Wire bending space for field installed wires including grounding conductors shall be provided opposite any wire connector and also opposite any opening or knockout for a conduit or wireway as specified in 8.8.3.1.2 and either 8.8.3.2.2 or 8.8.3.2.3.

8.8.3.2.2 If a conductor is likely to enter or leave the enclosure surface or open bottom opposite its wire connector, the wire bending space shall be as specified in Table 30 and Table 31. A wire is considered likely to enter or leave a top, back, or side surface if there is an opening or knockout for a wireway or conduit.

8.8.3.2.2.1 The wire bending space may be in accordance with Table 32 if:

a) a barrier is provided between the connector and the opening; or

b) drawings are provided specifying that the conductors shall not enter or leave the enclosure directly opposite the wire connector.

8.8.3.2.3 If a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 32.

8.8.3.2.4 If there is no barrier between two sections of a group, up to one-third of the required wire bending space may be in the adjacent section.

8.8.3.2.5 If a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance shall be measured from the end of the barrier.

8.8.3.2.6 The distance mentioned in 8.8.3.2.1 – 8.8.3.2.3 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any means provided to prevent its turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like shall be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure. 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.

8.8.3.2.6.1 When measuring bending space for compliance with Table 32, the distance may be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal.

8.8.3.2.7 A wiring space in which one or more knockouts are provided shall be of a width that will accommodate (with respect to bending) conductors of the maximum size likely to be used at that knockout. The values of the minimum width of a wiring space, with respect to conductors entering a knockout, are the same as the values of minimum bending space given in Table 32. In the determination of the available width of a wiring gutter, no credit is given for the space within or immediately above a terminal compartment intended for an ungrounded conductor.

8.8.3.2.7.1 The wiring space may be of less width if knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that will accommodate the conductors in question, and the knockout or knockouts at such other points can be conveniently used in the intended wiring of the device.

8.8.3.2.8 A terminal compartment is considered to be a space into which wires will normally be brought only for connection to terminals in that space.

8.8.3.3 Clear wiring space

8.8.3.3.1 The clear wiring space, independent of all projections, obstructions, or interference from moving parts of a switching mechanism shall:

a) not be smaller in width or in depth than the values indicated in Table 33; and

b) accommodate the wiring of the device, and shall not be smaller in total area than 250 percent of the total cross-sectional area of the maximum number of wires that may be used in such space.

8.8.3.3.2 In determining wiring space requirements, consideration shall be given to the actual size of wires that will be used in that space; but it shall be assumed that wires smaller than 3.3 mm^2 (12 AWG) will not be used. In computing the area of a wiring space, consideration shall be given to all the available space that may be used for the placement of wires. Minimum areas of the more common multiple wire connections are given in Table 33. The area occupied by a terminal compartment, as well as the area above such a compartment is not included when wiring space is determined; but space above or around an individual terminal or neutral located in a gutter is considered to be available space.

8.8.3.3.3 The minimum wiring space between the bottom of an enclosure where conduit or other raceway may enter and between insulated or uninsulated bus bars shall:

a) be 203 mm (8 inches) for insulated bus bars, their supports, or other obstructions; and

b) be 254 mm (10 inches) for uninsulated bus bars.

8.8.3.3.3.1 A bus bar or other obstruction may be located lower than specified if the clearances of 8.8.3.3.3 (a) or (b) will exist in the area directly above the conduit or raceway entry point if:

a) the section is intended for a specific installation where the conduit or raceway location is so specified (as covered in 6.3.4.1.1); or

b) if information about intended conduit or raceway location is contained in the manufacturer's catalog (including the catalog number or other designation that also appears on the switchboard).

8.8.3.3.4 An operating mechanism and its relation to the wiring space shall be such that it will not damage wires with which it may come in contact during its operation.

8.8.3.3.5 Wiring space and other compartments intended to enclose wire shall be smooth and free from any sharp edge, burr, fin, or the like, that might damage the conductor insulation.

8.8.3.3.6 No uninsulated live part shall be located within a wiring space for field-installed conductors.

8.8.3.3.7 To determine if a switchboard complies with the requirement in 8.8.3.3.6, consideration shall be given to the probable ways in which it may be wired, considering the number, size, and relative location of knockouts and terminals.

8.8.3.3.8 A neutral bus or terminal strip with its line connections is a live part. It is considered as being in the wiring compartment unless covered or located so that circuit wires other than those connected to it will not be brought into contact with it.

8.8.3.3.9 An individual terminal is not considered as being in a wiring compartment if it is countersunk 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 will not be in contact with a straight edge placed across the walls. In general, more than one terminal in the same recess may not be used unless additional protection is provided.

8.8.4 Switchboards with Inlets and Outlets

8.8.4.1 General

8.8.4.1.1 If provided with inlets and/or outlets for cord-connected equipment, the associated connectors shall comply with 8.8.4.

Note: The term "connector" refers to the mating component which attaches to the flexible cord or conductor and allows connection to the circuit by insertion into an inlet or outlet.

8.8.4.1.2 Connectors for cord-connected equipment shall be located so that neither the connector mounted in an inlet or outlet, nor the flexible cord attached to the connector, will be likely to interfere with the operation of any switch or circuit breaker handle.

8.8.4.1.3 An opening through which field installed wiring may pass shall be provided with a bushing or shall be formed so that there are no sharp edges with which conductors may come in contact.

8.8.4.1.4 All field wiring conductors of an alternating-current circuit that pass through a wall or partition of metal having magnetic properties, including the neutral, shall be run through the same opening. See 8.8.1.8.6.

8.8.4.1.5 Each integral multiple pole inlet and/or outlet and associated connector shall have sufficient number of poles to accommodate the ground, neutral, and all ungrounded supply conductors in one connector.

8.8.4.1.6 An integral multiple pole inlet and/or outlet shall be of a design such that the ground connection is the first connection made when inserting a connector, and is the last connection to be opened when removing the connector.

8.8.4.1.7 Multipole inlets rated below 200 A shall be suitable for connection and disconnection under load.

8.8.4.1.8 Where single pole inlets and/or outlets with associated mating connectors are provided, there shall be a sufficient number to accommodate the ground, neutral, and all ungrounded supply conductors, and these shall be grouped together

8.8.4.2 Input connections

8.8.4.2.1 An integral multiple pole inlet or single pole inlet shall be of a construction with male phase and neutral mating contacts, and shall have a rating no less than the rating of the overcurrent device to which it is connected. The neutral and ground connector of a single-pole inlet shall be permitted to be female.

8.8.4.2.2 Inlets shall be arranged such that exposed current carrying parts of inlets are energized only when a mating attachment connector is connected to the inlet. For switchboards with multiple inlets per phase, covers or caps that are affixed to the switchboards shall be provided, or the inlets shall be located behind a cover or door, such that live parts of unused inlets are not exposed.

8.8.4.2.3 Switchboards with an inlet shall be rated for outdoor use in wet locations and shall comply with the requirements for Type 3, 3R, 3S, 4, or 4X enclosures, as detailed in 8.2.1.4, Enclosure, with the cord connector installed as well as with the connector removed.

8.8.4.2.4 Single pole inlets shall be mechanically interlocked in such a manner that connectors or plugs must be connected in the following sequence and disconnected in the reverse order:

a) Equipment-grounding conductor connection;

b) Grounded circuit conductor connection; and

c) Ungrounded conductor connection.

8.8.4.2.5 Switchboards with single pole inlets rated above 200 A need not comply with 8.8.4.2.4 when marked in accordance with 6.2.18.1.

8.8.4.2.6 Switchboards with an inlet shall be provided with branch circuit protection for the circuits supplied through the inlet. The rating of the branch circuit protection shall not be greater than the rating of the inlet.

8.8.4.3 Output connections

8.8.4.3.1 Multiple pole outlets (receptacles)

8.8.4.3.1.1 A receptacle shall be rated for the voltage involved and shall be of the type having a terminal intended for use only with an equipment grounding conductor.

8.8.4.3.1.2 Overcurrent protection for a receptacle branch circuit shall be provided within the section or in another section of a group of sections intended to be used together.

8.8.4.3.1.3 A single receptacle installed on an individual branch circuit shall have an ampere rating of not less than that of the branch circuit.

8.8.4.3.1.4 Where connected to a branch circuit supplying two or more receptacles (including a duplex receptacle), receptacle ratings shall comply with the values listed in Table 34.

8.8.4.3.1.5 A receptacle in a switchboard marked “Type 3R” shall comply with 8.2.1.5.1, 8.8.4.3.1.8, and 8.8.4.3.1.9.

8.8.4.3.1.6 After installation a receptacle face shall project a minimum of 0.38 mm (0.015 inch) from the faceplate or surrounding cover. A faceplate shall be installed so as to seat against a mounting surface.

8.8.4.3.1.7 The receptacle face shall be flush with, or project from, a faceplate or surrounding cover of insulating material.

8.8.4.3.1.8 Class A ground-fault circuit interrupter protection shall be provided for all 130 V and less, single-phase, 15- or 20 A receptacles used in a switchboard marked as having a Type 3R enclosure or intended for outdoor use.

8.8.4.3.1.9 All 15- and 20 A, 125- and 250 V nonlocking receptacles used in a switchboard marked as having a Type 3R enclosure or other Type designation intended for outdoor use shall be rated as "weather-resistant" type.

8.8.4.3.2 Single pole outlets

8.8.4.3.2.1 A single pole outlet shall be of a construction with female phase and neutral mating contacts, and shall have a rating no less than the rating of the overcurrent device to which it is connected.

8.8.4.3.2.2 Overcurrent protection for single pole outlets shall be provided within the section or in another section of a group of sections intended to be used together.

8.8.4.3.2.3 Single pole outlets shall be mechanically interlocked in such a manner that connectors or plugs must be connected in the following sequence and disconnected in the reverse order:

a) Equipment-grounding conductor connection;

b) Grounded circuit conductor connection; and

c) Ungrounded conductor connection.

8.8.4.3.2.4 Switchboards with single pole outlets rated above 200 A need not comply with 8.8.4.3.2.2 when marked in accordance with 6.2.17.1.

8.9 Requirements for electronic equipment supply circuits

Reserved.

8.10 Electromagnetic compatibility

Reserved.

9 Test specifications

9.1 Classification of tests

9.1.1 General

9.1.1.1 An operating handle for a circuit breaker or switch that is not supplied as part of the circuit breaker or switch shall be subjected to a no load endurance test together with the particular circuit breaker or switch. The number of operations shall be the same as for the circuit breaker or switch.

9.1.1.2 A switchboard section shall be subjected to the applicable short-circuit current tests specified in the short-circuit test, 9.2.4.

9.1.1.2.1 A switchboard section with a short-circuit current rating of 10 000 A or less need not be tested if:

a) all overcurrent devices have a short-circuit current rating not less than the short-circuit current rating of the section unless series connected as covered in 9.1.1.6; and

b) motor controllers rated 37.3 kW (50 hp) or less, industrial control switches, snap switches, or clock-operated switches are used in a switchboard section with a 5 000 A short-circuit current rating or have a short-circuit current rating not less than the short-circuit current rating of the section unless used in accordance with 9.1.1.2.4.

9.1.1.2.2 A short-circuit current test is not required for a switchboard section or interior consisting of a single switch or circuit breaker if the short-circuit current rating of such a switchboard is not greater than the interrupting rating of the switch or circuit breaker, the section has provision only for field connection directly to the terminal of the switch or circuit breaker, and the section or interior is supplied with covers secured by screws or a combination of screws and hinges, or the equivalent.

9.1.1.2.3 A switchboard section or interior consisting of a single panelboard without additional wiring or buses need not be tested if the short-circuit current rating assigned to the switchboard section is not greater than that of the panelboard and:

a) no door or cover is provided; or

b) the door or cover in the switchboard section is representative of the door or cover used in testing the panelboard.

9.1.1.2.4 A control device in the primary or secondary of a control transformer or in a control circuit that does not extend beyond the switchboard need not be subjected to short-circuit testing.

9.1.1.2.5 A transformer need not be subjected to a short-circuit test.

9.1.1.2.6 If the switchboard section or interior is marked for use on the load side of fuses as covered in 6.2.15, a short-circuit test is not required if the same bus and support system has been previously tested with acceptable results, and the value of peak current Ip recorded in the previous test is greater than the let through characteristic of the fuse as shown in Table 36.

9.1.1.2.7 Short-circuit tests are not required for a switchboard section constructed per Annex G and having a short-circuit current rating of:

a) 65 000 A or less; or

b) 100 000 A or less with a single integral or remote main molded-case circuit breaker, AC or DC power circuit breaker or fused switch.

9.1.1.3 A motor controller in combination with its overcurrent device shall have a short-circuit current rating not less than that of the switchboard section in which it is installed.

9.1.1.4 With respect to 9.2.4.3.2.1, a meter socket base used without current transformers together with the overcurrent protective device with which it is used shall be investigated for use at the short circuit current rating of the switchboard section in which it is installed.

9.1.1.5 A representative number of sizes and ratings of switchboard sections of each design shall be tested as covered in the short-circuit test, 9.2.4.

9.1.1.6 If the short-circuit current rating of the switchboard section exceeds the interrupting rating of the load side circuit breaker, the circuit breaker used on the load side of an overcurrent protective device shall be tested in accordance with requirements for series-connected molded case circuit breakers. See Reference Item No. 7, Annex B.

9.1.1.7 A switchboard section constructed in accordance with 8.8.1.6 – 8.8.1.8 is presumed to have temperature characteristics within the limits given in Table 13, and the temperature test mentioned in 9.2.2 is not required. A separate test for a neutral bus is not required if the neutral has been tested in accordance with the requirements in Reference Item No. 1, Annex B.

9.1.1.8 A switchboard section containing a transformer, an autotransformer with a transformed power greater than 10 kVA, or transformers with a total kVA rating in excess of 10, or heating elements with a total rating exceeding 250 W, will require a temperature test in accordance with 9.2.2.

9.1.1.8.1 Switchboard sections containing heating elements controlled by a thermostat set at 40°C (104° F) or less would not require a temperature test.

9.1.1.8.2 A test is not required if the transformer is mounted in a separate switchboard compartment and the ventilation requirements are in accordance with the transformer manufacturer specifications. See 8.6.12.1.1.

9.2 Type tests

9.2.1 Strength test of insulating base and support

9.2.1.1 An insulating base or support and the bus or strap upon which wire connectors for field wiring are mounted shall be subjected to the force created when the connectors, securing short lengths of conductors of rated ampacity, are torqued to 110 percent of the value marked on the switchboard. The results are acceptable if the base is not damaged as defined in 9.2.1.2.

9.2.1.1.1 The test is not required for wire connectors that are part of a unit (circuit breaker, switch, or the like).

9.2.1.2 Damage is considered to have occurred if the base insulating material cracks or rotates; bosses, recesses, or other means to prevent turning do not perform their intended function; straps or bus bars bend or twist; or members other than the wire connector move at electrical joints. Minor chipping or flaking of brittle insulating material is acceptable if the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is acceptable.

9.2.2 Temperature test

9.2.2.1 During the test the switchboard section shall be mounted or supported as in service and operated under conditions approximating those of intended operation. The test shall be made with fuses installed in fuseholders. Currents shall be as shown in 9.2.2.7.

9.2.2.1.1 If testing of a complete switchboard is impractical, testing of a representative individual section may be considered acceptable.

9.2.2.1.2 Dummy fuses or the equivalent may be used in place of Class H, K, or R fuses and 0 – 200 A Class J fuses.

9.2.2.2 If there are branch circuit units (circuit breakers or fused switches) in the section, the selection of ratings of branch circuit units to carry current shall be in accordance with the requirements of Reference Item No. 1 of Annex B.

9.2.2.3 If the section contains a power transformer, the transformer shall be loaded so that the primary current is equal to the primary rating of the transformer.

9.2.2.3.1 The current in a transformer may be less if the secondary current is equal to 80 percent of the sum of the ratings of the maximum size and number of secondary overcurrent protective devices that can be installed, or if the primary current is adjusted to 80 percent of the rating of the overcurrent protection on the line side of the transformer.

9.2.2.4 Coils and heating elements shall be energized by a source of voltage of 120, 240, 480, or 600 V for ratings of 110 – 120, 220 – 240, 440 – 480, or 550 – 600 V, respectively. Other coils or heating elements shall be energized by a source of rated voltage. For other than a coil or heating element, any convenient voltage supply may be used as long as the specified current is caused to flow.

9.2.2.5 A minimum of 1.22 m (4 ft) of wire shall be attached to each field wiring terminal. The size of wire to be used shall be the smallest size having an ampacity in accordance with Table 28 and with 8.8.2.3.9(a) of at least 125 percent of the motor full load current and at least 100 percent for other loads. If the terminal will not receive the size of wire required for testing in accordance with 9.2.2.6, the maximum allowable wire size shall be used.

9.2.2.5.1 For wire of 42.4 mm^2 (1 AWG) or smaller, the size wire used is to correspond to the 75°C (167° F) ampacities of Table 28 if the switchboard is marked to use 75°C rated conductors for circuits rated 110 A or less.

9.2.2.6 For a combination motor control circuit having a current element table showing minimum and maximum full-load motor running currents, the temperature test shall be conducted using the maximum full load current shown in the current element table (even though that current exceeds the maximum current rating of the combination motor control circuit). For a combination motor control unit having a current element table showing only tripping current, the maximum heater table current is considered to be 87 percent of the maximum tripping current shown in that table.

9.2.2.7 The current used during the test shall be as shown in Table 35, but the current in the smallest branch circuit unit may be less to produce the required section bus current.

9.2.2.8 All values in Table 13 are applicable for test conducted at any ambient temperature within the range of 10 – 40°C (50°F – 104°F). However, if the operation of an automatic thermal control during the test limits the temperatures under observation, an observed temperature higher than 25°C (77°F) plus the specified maximum rise is not acceptable.

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

a) level with the top of the structure;

b) 305 mm (12 inches) above the bottom of the structure; and

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

All thermometers are to be placed 914 mm (36 inches) from the structure, and in locations unaffected by drafts caused by the structure or appreciable radiation from the equipment. When the ambient temperature is subject to variations that might result in errors in taking the temperature rise, the thermometers for determining the ambient temperature should be immersed in a liquid such as oil in a heavy metal cup.

9.2.2.10 The acceptability of insulating materials, other than those specified in Table 13, shall be determined with respect to properties such as flammability, arc resistance, and the like, based on the temperature rise plus 40°C (104°F).

9.2.2.11 Temperatures are to be measured by thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG). The thermocouples and related instruments are to be accurate and calibrated.

9.2.2.11.1 As specified in 9.2.2.13, the temperature of a coil may be determined by the change of resistance method.

9.2.2.12 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material where the temperature is being measured.

9.2.2.13 The temperature rise of a winding is determined by the change-of-resistance method by comparing the resistance of the winding at the temperature to be determined with the resistance of the winding at a known temperature, in accordance with the following formula:

$$\Delta t = \frac{R}{r}(k + \frac{t}{1}) - (k + \frac{t}{2})$$

In which:

Δt is the temperature rise;

R is the resistance of the coil at the end of the test;

r is the resistance of the coil at the beginning of the test;

t_1 is the room temperature °C at the beginning of the test;

t_2 is the room temperature °C at the end of the test; and

k is 234.5 for copper or 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades shall be determined.

9.2.2.14 With regard to 8.8.1.6.7(a), a connecting strap or branch bus having less ampacity than shown in Table 23 or Table 25 and not provided as part of a switch, circuit breaker, or fuseholder shall be tested in a complete section as described in 9.2.2.1 – 9.2.2.13, or as follows. The strap shall be connected to the intended number of units (circuit breakers, switches, or fuseholders) and caused to carry full rated current in all poles. Fuses as described in 9.2.2.1 (except dummy fuses) are to be installed in fuseholders. The test shall be conducted in open air, free of drafts. A minimum of 1.2 m (4 ft) of insulated copper conductor, rated for 75°C (167°F) and of proper ampacity as shown in Table 28, shall be used to complete the circuit. After temperatures have stabilized, the temperature rise shall not exceed 50° C (122° F) at field wiring terminals nor 55°C (131°F) on the strap or branch bus bar.

9.2.2.15 A temperature is considered to be constant if three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test (but not less than 15 minute intervals) indicate no change. The thermocouples and related instruments are to be accurate and calibrated.

9.2.2.16 A bus bar having more slots or holes than provided for in 8.8.1.6.6 shall be tested in a complete section as covered in 9.2.2.1 – 9.2.2.15 or a comparison test is to be conducted. For a comparison test, two bus bars having the holes or slots shall be connected alternately with two bus bars having the required ampacity. If holes or slots are repeated in the bus, the length of each of the four bus bars is to equal the maximum length of the bus bar with holes as used in the switchboard. If the holes or slots are not repeated, the length of each of the four bus bars is to equal the minimum length of the bus bars with holes as used in the switchboard. The test circuit shall be completed using copper cable of rated ampacity as shown for 75°C (167°F) conductors in Table 28. The test shall be conducted in open air free of drafts at full rated current of the bus. If the temperature rise of the bus bar with holes does not exceed that of the other bus bars, they are considered to have the same ampacity.

9.2.2.17 With regard to 8.4.8.11, the grounding impedance shall have no temperature rise at specific points higher than as specified in Reference Item No. 11 in Annex B. The test shall be conducted first with rated thermal current and then with rated continuous duty current.

9.2.2.18 Clamped joint temperature test

9.2.2.18.1 A switchboard section or interior that has a clamped joint construction shall be subjected to the test described in 9.2.2.18.2. The temperature rise at the joint during the 500th cycle shall not be more than 15°C higher than the temperature rise at the 25th cycle.

9.2.2.18.2 The test sample is to consist of an assembly of bus bars connected together to form a series circuit. The bus bars are to be clamped together with the joint construction used in actual production. The number and size of the bus bars are to represent the maximum ampere rating and the maximum current density in which the joint construction is used. This may necessitate more than one test. The maximum length of each bus bar shall be 610 mm (2 ft). The bus bar shall be connected to a power supply by any convenient means that will not affect the joint temperature. The power supply shall be adjusted to deliver a value of current that will result in a temperature of 75°C (167°F) above room temperature at the joint. The assembly shall then be subjected to a 500 cycle test. At the end of the 24th cycle, the current shall be re-adjusted to bring the temperature of the joint to 75°C above room temperature. At the end of the 25th and 500th cycles, the temperatures shall be recorded. The temperatures shall be measured on both sides of the joint as close as possible to the bolt or rivet. The cycling rate shall be 3 hours on and 1 hour off. The on period during which temperatures are recorded may be extended to more than 3 hours if necessary for the joint to attain thermal equilibrium.

9.2.3 Dielectric voltage withstand test

9.2.3.1 A switchboard section or interior shall be subjected for 1 minute to the application of a 60 Hz essentially sinusoidal potential of 1 000 V plus twice the rated voltage under the following conditions. A transformer, coil, or other device connected between lines of opposite polarity shall be disconnected from one side of the line during the test in (b). The results are acceptable if there is no dielectric breakdown between:

a) a live part and a grounded metal part with all switching devices closed; and

b) live parts of opposite polarity, with all switching devices closed.

9.2.3.1.1 If a watthour meter socket base incorporates through-air spacings less than those shown in Table 6, the test potential applied to it shall be 10 times the voltage rating of the switchboard section or interior, but not less than 5 000 volts.

9.2.3.1.2 Where a neutral is involved, the dielectric strength test between the neutral and the other current-carrying parts and the neutral and grounded metal shall be permitted to be based on the lower voltage that normally exists between them.

9.2.3.2 If the overcurrent devices, such as fuses or interchangeable trip units, are not in place during the tests described in 9.2.3.1(a) and 9.2.3.1(b), it is necessary to repeat these tests on the load side of the switching devices or to install shorting links in place of the missing fuses or trip units during the tests.

9.2.3.3 The test potential shall be supplied from a 500 volt ampere 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; it shall be held at that level for 1 minute.

9.2.3.3.1 A 500 volt ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter to measure directly the applied output potential.

9.2.3.4 Clamped insulating joint dielectric

9.2.3.4.1 A clamped joint between two insulators shall be tested using two samples.

a) The first sample shall have the clamped joint opened up to produce a space 3.2 mm (1/8 inch) wide. This may be accomplished by loosening the clamping means or by drilling a 3.2 mm (1/8 inch) diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 60 Hz dielectric breakdown voltage through this hole is then determined by applying a gradually increasing voltage (500 V per second) until breakdown occurs.

b) The second sample with the clamped joint intact shall be subjected to a gradually increasing 60 Hz voltage until 110 percent of the breakdown voltage of (a) has been reached. If the breakdown voltage of (a) was less than 4 600 V rms, the voltage applied to the second sample shall be further increased to 5 000 V rms and held for 1 second. The clamped joint is acceptable if there is no dielectric breakdown of the second sample.

9.2.3.5 After short circuit dielectric

9.2.3.5.1 In accordance with 9.2.3.3 and with every switching device closed, a switchboard that has been subjected to a short-circuit test shall be subjected for 1 minute to the application of a 60 Hz essentially

sinusoidal potential of twice the maximum rated voltage, plus 1 000 V as follows. The results are acceptable if there is no dielectric breakdown:

a) between wiring terminals of opposite polarity; and

b) between an uninsulated live part and the enclosure.

9.2.3.5.1.1 If breakdown occurs within a switching device, the device may be removed and the test repeated.

9.2.3.6 Insulating barrier dielectric

9.2.3.6.1 With regard to 8.1.17.2 and 8.1.17.3, 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 inch) in diameter with edges rounded to a 0.8 mm (1/32 inch) radius. The test potential shall be increased to the test value and shall be maintained for 1 second. The result is acceptable if there is no dielectric breakdown.

9.2.4 Short circuit

9.2.4.1 General

9.2.4.1.1 Sample Selection

9.2.4.1.1.1 The switchboard sections selected for tests are to represent:

a) the weakest bus bar and bracing structure; and

b) the stiffest bus structure most likely to transmit the greatest force to the bus support for the rating and bus configuration being tested.

9.2.4.1.1.2 Representative samples are to be tested to determine the performance of each principal bus configuration or cable arrangement, or both. If provision is made for line cables, the sample selection and test program is to include cables of the minimum cross-sectional area that would be used for field connection for each size of wire connector used.

9.2.4.1.1.3 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 could result in bus bar distortion;

d) strongest bus bar structure that will transmit the maximum forces to the bracing; and

e) various incoming bus and terminal configurations provided. The bus jumper supplied to connect the switchboard bus to a busway need not be tested if the switchboard supply bus that was tested is representative of these jumpers. To be representative, the jumpers to the busway bus bars shall use the same type supports with the supports spaced along the bus bar not further apart than for the switchboard bus that was tested. The jumpers to the busway shall not be face-to-face if the tested bars were edge-to-edge. The center-to-center distance between jumpers of different polarity shall not be less than for the switchboard bus that was tested.

9.2.4.1.1.4 An alternative bus support need not be subjected to a short-circuit test if it has the same shape, and the material has mechanical strength at least equal to the support that was subjected to a short-circuit test.

9.2.4.1.1.5 The neutral bus shall be subjected to a separate short-circuit test if it has a smaller cross section, uses different supports, is face-to-face with a phase bus while the phase buses are edge-to-edge, or has the supports spaced farther apart than the line voltage buses that were tested. The neutral test may be with a 3-phase test, substituting the neutral bus for the line voltage bus farthest from the neutral, or a single phase test conducted at phase to neutral voltage using the neutral bus and the line voltage bus closest to the neutral.

9.2.4.1.1.6 A construction of the panelboard type design may be tested in accordance with the applicable requirements in Reference Item No. 1 in Annex B.

9.2.4.1.2 Through bus withstand

9.2.4.1.2.1 The sample for each through bus withstand test is to include through bus and its associated splice bus.

9.2.4.1.3 Section bus withstand – individually mounted devices

9.2.4.1.3.1 The sample for each section bus withstand test for individually mounted devices is to consist of a section with representative bus for the connection of individually mounted devices. A unit may be installed in the section in the location that will provide the least support for the section bus.

9.2.4.1.4 Branch line and load bus withstand – individually mounted devices

9.2.4.1.4.1 Each configuration of branch line and load bus for individually mounted devices shall be tested in a representative switchboard section with the maximum ampere rated section and through buses and the maximum ampere rated overcurrent device with which it is intended to be used. If fuses are used, see 9.2.4.2.8.1.

9.2.4.1.5 Branch line and load bus maximum voltage

9.2.4.1.5.1 A switchboard section having supply and section buses and having the maximum ampere rating for the construction shall be tested.

9.2.4.1.5.1.1 In the case of an individually mounted device, a maximum voltage test need not be made if a test has been made on the device in an enclosure, and if:

a) the enclosure in the switchboard has equal or greater volume than the test enclosure;

b) the distance from an arcing part to the nearest live part or grounded metal surface in the switchboard is equal to or greater than in the test enclosure; and

c) the hinges and latch or screws in the switchboard construction are equal to or stronger than those in the test enclosure, or the equivalent.

9.2.4.1.5.1.2 A construction of the panelboard type need not be tested if it has been tested in accordance with Reference Item No. 1 in Annex B, in a panelboard enclosure, and if:

a) the enclosure in the switchboard has equal or greater volume than the test enclosure;

b) the distance from any arcing part to the nearest live part or grounded metal surface in the switchboard is equal to or greater than in the test enclosure; and

c) the hinges and latch or screws in the switchboard construction are equal to or stronger than those in the test enclosure.

9.2.4.1.5.2 In determining the relative strength of hinges, latches, and screws with respect to 9.2.4.1.5.1.1(c) and 9.2.4.1.5.1.2(c), the following characteristics shall be compared:

a) metal thickness of all parts;

b) type and size of fasteners;

c) diameter of hinge pins and design of hinge joint;

d) distance between hinges, latches, and screws;

e) number of hinges, latches, and screws; and

f) size of door or cover.

9.2.4.1.5.3 If a maximum voltage test is required, a circuit breaker having the maximum ampere rating for each frame size shall be tested in locations within the switchboard and in the combinations with other circuit breakers or with blank spaces that are most likely to cause unacceptable results. Such other circuit breakers are to be in the "ON" position but are not to be provided with load conductors. Filler plates shall be mounted over blank spaces. This may require more than one test.

9.2.4.1.5.4 With respect to 9.2.4.1.5.3, consideration should be given to the following:

a) the venting of a circuit breaker toward or near a live part or a grounded metal part (shortest uninsulated electrical spacing);

b) the blocking or partial blocking of a vent in a circuit breaker;

c) the location that will cause a maximum let through current in the circuit breaker under test; and

d) the mounting of a circuit breaker where its vents are directly opposite the vents in another circuit breaker.

9.2.4.2 Sample preparation

9.2.4.2.1 General

9.2.4.2.1.1 The switchboard section shall be mounted and supplied as in the intended installation. All unused openings, other than ventilation openings or as described in the 9.2.4.2.2.1.1, are to be closed.

9.2.4.2.1.2 The enclosure shall be connected through a 30 A, non-delay-type 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 1.2 – 1.8 m (4 – 6 ft) long.

9.2.4.2.1.3 If the switchboard section has provision for a current transformer, a bus bar representative of the current transformer may be installed in its place.

9.2.4.2.2 Doors and fronts

9.2.4.2.2.1 If the switchboard is provided with a door, it shall be closed and latched in its intended manner during the test. A door, cover, or filler plate shall be installed over any unused branch circuit device space. All covers shall be in place during the test.

9.2.4.2.2.1.1 The covers may be omitted if the cover does not give access to a circuit breaker included in the test circuit and if the test does not result in movement of live parts toward the location of the covers that would result in a reduction of spacings.

9.2.4.2.3 Circuit breakers

9.2.4.2.3.1 A circuit breaker having adjustable trip features is to have all adjustments set at the maximum current and time setting.

9.2.4.2.4 Line connections

9.2.4.2.4.1 The switchboard terminals are to be supplied by means of cable having an ampacity as shown in Table 28, based on 75° C (167° F) insulation nearest to but not less than the rating of the switchboard. Separate short-circuit tests shall be conducted with copper cable and with compact aluminum cable. The cable is to enter the line end of the switchboard at a point that will provide the maximum length of unsupported cable within the switchboard enclosure. The line terminals are to be wired and tightened to the torque marked on the switchboard as specified in 6.2.7.13 and 8.8.2.3.2. There shall be no bracing of the cable inside the enclosure unless the construction includes instructions for bracing the conductors as covered in 6.3.3.1. The provision for bracing may or may not be provided with the section. Bracing hardware not provided as part of the switchboard section shall be available to the installer. A cable may be braced as it leaves the enclosure on the supply side.

9.2.4.2.4.1.1 The test sample shall be tested with copper cable if the switchboard section is restricted to use with copper cable in accordance with 6.2.7.3.

9.2.4.2.4.1.2 The test sample may be tested with aluminum or copper cable if the short-circuit current rating divided by the number of cables per phase results in a current of 50 000 A per cable or less.

9.2.4.2.4.1.3 A switchboard section that does not have provision for wire connection shall be connected to the source with bus bars of the same ampacity as the supply bus.

9.2.4.2.4.1.4 If the short-circuit test current rating is greater than 50 000 A per conductor, the test sample may be tested with either compact aluminum or copper cable if the type of cable used for the short circuit test has a lower pull-out force than the untested cable material as covered in 8.8.2.1.1.

9.2.4.2.4.1.5 The value of tightening torque specified for meter mounting equipment that is used in a switchboard shall be used if the tightening torque information appears on the switchboard.

9.2.4.2.4.2 With respect to 9.2.5.1, 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.

9.2.4.2.4.3 In a switchboard provided with an integral main fusible switch, the supply cable shall be connected to the terminals of the switchboard. The test fuse mentioned in 9.2.4.2.8.1 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 may be inserted:

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

b) on the load side of the branch device, section bus, or through bus being tested; or

c) on the line side of the fusible switch.

9.2.4.2.4.3.1 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 the supply cable and of all other leads, other

than the leads on the load side of a branch bus, shall be part of the calibrated circuit or shall be in accordance with 9.2.4.2.4.2.

9.2.4.2.4.4 When a separate main device is used, the method of line connection shall be as shown in Figure 17. In the case of a separate fusible main, fuses shall be installed in an external fuseholder, as shown in Figure 18. The main device terminals shall be connected by cable in accordance with 9.2.4.2.4.1, and the combined length of each cable (line, external fuseholder, and connections between the separate main device and switchboard) shall not exceed the length described in 9.2.4.2.4.2 by more than 2.4 m (8 ft).

9.2.4.2.5 Through bus connection

9.2.4.2.5.1 The through bus under test shall be short circuited to cause fault currents to pass through the splice bus and the complete through bus. Current shall not pass through the section bus unless it is necessary to feed the through bus.

9.2.4.2.5.2 The through bus shall be short circuited directly by means of bus of minimum length and of at least the ampacity of the through bus.

9.2.4.2.6 Section bus connection

9.2.4.2.6.1 The section 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 means of bus of minimum length and of at least the ampacity of the section bus.

9.2.4.2.7 Branch circuit connection

9.2.4.2.7.1 If the branch circuit device used in this test is a circuit breaker, the field wiring load terminals are to be short circuited by cable having a length of 1.2 m (4 ft) per terminal and an ampacity not less than the rating of the circuit breaker. There shall be no bracing of the cable inside the enclosure unless the construction includes instructions for bracing the conductors as covered in 6.3.3.1. The provision for bracing may or may not be provided with the section. Bracing hardware not provided as part of the switchboard section shall be available to the installer. The cable may be lashed outside the enclosure to prevent whipping during the test. The load terminal cables or the instrument shunts may be short circuited by bus.

9.2.4.2.7.2 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 not less than the rating of the switch shall be run from each field wiring load terminal to the test fuses located outside the switchboard. There shall be no bracing of the cable inside the enclosure unless the construction includes instructions for bracing the conductors as covered in 6.3.3.1. The provision for bracing may or may not be provided with the section. Bracing hardware not provided as part of the switchboard section shall be available to the installer. The load terminals of the test fuses or the instrument shunts are to 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 9.2.4.2.7.3, shall be installed in each fuseholder of the switch under test.

9.2.4.2.7.3 The copper bus bar, tube, or dummy fuse shall have a cross section not 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, tube, for dummy fuse shall be secured in place in the same manner as a fuse in intended service.

9.2.4.2.8 Fuses

9.2.4.2.8.1 Each test fuse shall have such characteristics that, when tested on a single-phase circuit in accordance with the requirements for the class of fuse used in the switchboard, it will permit a let-through current I_p and clearing I_2t not less than the corresponding values specified in Table 36, for the ampere rating of the largest fuse intended for use in or with the switchboard. To obtain the required values it may be necessary to employ a fuse of a different class or having a higher current rating than that of the fuse the switchboard accommodates. The values of I_2t and I_p are to be determined at the voltage rating of the fuse except that with the concurrence of those concerned the determination may be made at the voltage rating of the switchboard.

9.2.4.2.9 Meter mounting position

9.2.4.2.9.1 If a switchboard section uses meter mounting equipment, a watthour meter shall be in place during any required short-circuit test.

9.2.4.2.9.1.1 Copper bars may be used in the jaws of meter mounting equipment when such equipment is used in conjunction with current transformers. The cross sectional dimensions of such bars shall be 2.4 by 19.2 mm (3/32 by 3/4 inch).

9.2.4.3 Short-circuit procedure

9.2.4.3.1 General

9.2.4.3.1.1 A 3-phase switchboard section shall be tested on a 3-phase circuit using three overcurrent devices in the branch circuit positions as illustrated in Figure 18. These tests will qualify:

a) a 3-phase, 4-wire switchboard;

b) a single phase, 3-wire switchboard using nonadjacent main bus bars of the 3-phase construction; and

c) a DC switchboard.

9.2.4.3.1.1.1 If only single-pole or double-pole branch-circuit devices are accommodated in a 3-phase, 4-wire switchboard, the switchboard shall be tested on a single-phase circuit using adjacent main bus bars and two branch circuit poles, following the same test procedure as for the 3-phase circuit, except that the test circuit shall be controlled so that closing occurs within 10 electrical degrees of the zero point of the supply-voltage wave.

9.2.4.3.1.2 A single phase switchboard section employing adjacent main bus bars of the 3-phase construction shall be tested on a single phase circuit, controlled as specified in 9.2.4.4.2.1. The single phase test will qualify a DC switchboard.

9.2.4.3.1.3 A switchboard section having the following shall be tested with a line to neutral fault as well as a line to line fault:

a) a short-circuit current rating for a line to neutral fault higher than a phase to phase fault;

b) a neutral bus that is smaller in cross section than the line bus;

c) a neutral bus that is spaced closer to a line bus than the spacing between adjacent line buses; or

d) a different means of support for the neutral bus.

9.2.4.3.1.4 The open circuit voltage (alternating or direct current) at the supply connection shall be 100 – 105 percent of the rated voltage for the test being conducted. The supply frequency for alternating current shall be in the range of 48 – 62 Hz.

9.2.4.3.1.4.1 For a test not involving any overcurrent device in the test circuit, the voltage may be less than rated, but not less than 100 V, if the through bus withstand current is determined to be the value that would have resulted if tested at rated voltage. The method of calculating the reduced voltage test current is specified in the short-circuit test at reduced voltage, Annex F.

9.2.4.3.2 Maximum peak let-through current for switchboards containing meter sockets

9.2.4.3.2.1 The overcurrent protection and other features of a switchboard having a short-circuit-current rating in excess of 14 000 A shall limit the let through current of a direct-connected meter as specified in 9.2.4.3.2.2.

9.2.4.3.2.2 The maximum peak let-through current shall be measured during the short-circuit testing of switchboards with meter-mounting equipment. The short-circuit-current rating of the switchboard shall be such that the measured value does not exceed 30 000 A.

9.2.4.3.2.2.1 This measurement need not be made if:

a) the I_p value of the overcurrent protective device is known to be 30 000 A or less; or

b) the meter-mounting equipment is on the secondary side of current transformers.

9.2.4.3.2.2.2 This measurement need not be made if the short-circuit-current rating of the switchboard or the assumed rms symmetrical shortcircuit- current rating of the circuit containing the meter as specified in 8.5.1.2 and 8.5.1.3 is 14 000 A or less.

9.2.4.3.3 Time

9.2.4.3.3.1 The duration of a short-circuit test shall not be less than three cycles unless limited by an integral or separate overcurrent device.

9.2.4.4 Short-circuit operation

9.2.4.4.1 General

9.2.4.4.1.1 A switchboard shall be subjected to the applicable tests as specified in 9.2.4.4.3.1 – 9.2.4.4.6.1.

9.2.4.4.2 Closing

9.2.4.4.2.1 Controlled closing shall be used in all tests as specified in Table 37.

9.2.4.4.2.1.1 Random closing may be used:

a) in the case of a 3-phase short-circuit test involving overcurrent devices; or

b) for a single-phase test maximum voltage conducted in accordance with 9.2.4.4.6.1.

9.2.4.4.3 Through bus withstand

9.2.4.4.3.1 With the line end of the through bus connected to the test circuit and the load end short circuited by a bus bar having an ampacity not less than that of the through bus, the test circuit shall be closed on the switchboard.

9.2.4.4.3.2 If the switchboard includes main fuses or is marked for use on the load side of fuses as covered in 6.2.1.14, a through bus and section bus withstand test is not required if:

a) the same bus and support system has been previously tested with acceptable results; and

b) the peak let through current, I_p, recorded in the previous test is greater than the let through characteristics of the fuse as shown in Table 36.

9.2.4.4.4 Section bus maximum current test-individually mounted devices

9.2.4.4.4.1 With the line end of the through bus connected to the test circuit and the load end of the section bus closest to the supply short circuited by a bus bar having an ampacity not less than that of the section bus, the test circuit shall be closed on the switchboard section.

9.2.4.4.5 Branch line and load bus maximum current test-individually mounted devices

9.2.4.4.5.1 With the branch circuit device (either a fused switch or circuit breaker) and any main overcurrent protective device (integral or separate) in the fully closed position, the test circuit shall be closed on the switchboard. If the enclosure is provided with a door, it shall be closed during the test.

9.2.4.4.5.1.1 If agreeable to those concerned, the branch circuit device may be replaced by a dummy device that provides equivalent support for the branch and load buses.

9.2.4.4.6 Branch line and load bus maximum voltage

9.2.4.4.6.1 If a maximum voltage test is required as specified in 9.2.4.1.5.1, the circuit breaker shall be connected in the open position to a circuit capable of delivering rated short-circuit current corresponding to the maximum rated voltage of the switchboard, and shall be operated to the closed position.

9.2.4.5 Short-circuit investigation

9.2.4.5.1 After a switchboard section has been tested under any of the short circuit conditions described, the results are acceptable if the switchboard is effectively in the same mechanical condition as prior to the test, and if:

a) there is no permanent distortion or displacement of a bus bar or strap that would affect the intended functioning of the switchboard or reduce an electrical spacing to less than 75 percent of the values specified in Table 6;

b) a bus bar insulator or 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. Other cracks, chips, or the like, which are not considered to reduce the structural integrity of the support may be used if the resulting spacings are not reduced to less than 75 percent of the values specified in Table 6. The cracks may be considered acceptable if, after a repeated short-circuit test on the same sample, the switchboard complies with the Dielectric Voltage-Withstand Test, 9.2.3, and the electrical spacings are not reduced to less than 75 percent of the values specified in Table 6.

c) the ground fuse has not opened;

d) the enclosure or a part of the enclosure such as a filler plate, door, or the like, has not been damaged nor displaced to the extent that a live part is accessible to:

1) a test rod 13.2 mm (33/64 inch) in diameter for any opening less than 102 mm (4 inch) from an uninsulated live part; or

2) a test rod 19.4 mm (49/64 inch) in diameter for any opening 4 inches or more from such a part.

e) A door shall not open. A supplemental door over circuit breaker handles may open, but not more than 60 degrees from the closed position.

f) there is no evidence of arcing between live parts of opposite polarity;

g) no conductor pulls out of a terminal connector, and there is no damage to the conductor insulation or to the conductor;

h) the switchboard complies with the Dielectric Voltage-Withstand Test, 9.2.3; and

i) in the case of a plug in or draw out unit, the point of contact shall be essentially the same both mechanically and electrically as before the test.

j) in the case of a switchboard containing a direct connected meter socket, the maximum peak let-through current measured during the short circuit test did not exceed 30 000 A, when measured as required in 9.2.4.3.2.

9.2.5 Test circuit calibration

9.2.5.1 The available rms symmetrical current shall be determined at the line terminals of the separate main device or, if no separate main device is used, at the line terminals of the switchboard.

9.2.5.1.1 For circuits rated 25 000 A or less, the available current may be determined at the test station terminals.

9.2.5.1.2 The available current may be determined at the test station terminals if:

a) for circuits between 25 001 – 50 000 A, the available current is determined to be 5 percent higher than the required test current; or

b) for circuits between 50 001 – 200 000 A, the available current is determined to be 10 percent higher than the required test current.

9.2.5.1.3 If the available current is determined at the test station terminal and the physical arrangement in the test station requires leads longer than specified, the additional length of leads shall be included in the circuit calibration.

9.2.5.2 The magnitude of the test current, the power factor of an alternating current circuit, and the time constant of a direct-current circuit are to be determined by the applicable requirements for Reference No. 7, Annex B. The power factor shall be in accordance with Table 17.

9.2.5.2.1 The recovery voltage need not comply with the applicable requirements for molded case circuit breakers if the calibrated circuit is only to be used in withstand tests not involving any overcurrent device.

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

9.2.6 Investigation of ground fault protection field test instructions

9.2.6.1 Using the field test instructions provided in accordance with the field testing of ground fault protection of equipment, 6.3.4.3, a dead-front switchboard containing ground fault protection shall be investigated to determine that the ground fault protection system functions.

9.2.7 Bonding resistance test

9.2.7.1 The resistance shall not exceed 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, or shall not exceed 0.005 ohm between the ground bus and the grounding contact of a grounding type receptacle rated more than 30 A.

9.2.7.2 The resistance shall not exceed 0.005 ohm at the connection:

a) between adjacent switchboard sections; and

b) between a busway, ground bus, wireway or an auxiliary gutter and a switchboard section enclosure; and

c) between the switchboard 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.

9.2.7.3 With regard to 9.2.7.1 and 9.2.7.2, paint shall be removed as necessary to keep the resistance within the above limits. Resistance values shall be determined in accordance with 9.2.7.2.

9.2.7.4 With regard to 9.2.7.1 and 9.2.7.2, the 0.005 and 0.10 ohm values of bonding resistance are to be determined by measuring the millivolt drop across the joint while passing a known current, usually 30 A through the joint.

9.2.7.4.1 The bonding resistance need not be determined for a bolted joint without any paint between the flat joint surfaces.

9.2.7.4.2 The bonding resistance between a conductive switch handle in contact with a metal enclosure need only be determined periodically on typical samples.

9.2.8 Mold stress relief test

9.2.8.1 Except for rigid thermosetting materials, conditioning of the equipment as described in 9.2.8.2 shall not cause softening of the material as determined by handling immediately after the conditioning, nor shall there be any shrinkage, warpage, or other distortion as judged after cooling to room temperature, that results in any of the following:

a) reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible grounded metal, uninsulated live parts and the enclosure below the minimum acceptable values;

b) making uninsulated live parts or internal wiring accessible to contact, or defeating the integrity of the enclosure so that unacceptable mechanical protection is not afforded to internal parts of the equipment; or

c) causing interference with the intended operation or servicing of the equipment.

9.2.8.2 One representative sample of the insulating material assembled as intended shall be placed in a full draft circulating air oven maintained at a uniform temperature at least 10°C (50°F) higher than the

maximum temperature of the material measured during the Temperature test, but not less than 70°C (158° F) in any case. The sample shall remain in the oven for 7 hours. After its removal from the oven and return to room temperature, the sample shall be investigated for compliance with 9.2.8.1.

9.2.9 Latch pull test

9.2.9.1 Latch rods for a Type 3R enclosure shall not be deformed when subjected to a direct pull of 890 N (200 pounds) applied to the door handle for 1 minute in the direction the door will open.

9.2.10 Single threaded nut test

9.2.10.1 When required by clause 8.1.3.6, the threads of a single threaded nut shall withstand a torque of 3.4 N·m (30 pound-in) applied in the direction of tightening. As a result of the test, the threading shall not be stripped, the nut shall capable of functioning.

9.2.11 Impact and pressure test – Observation windows

9.2.11.1 Observation windows with dimensions exceeding 305 mm (12 inches) as covered in 8.1.4, shall not shatter, crack, or become dislodged when both sides of the observation window in turn are subjected to the tests described in 9.2.11.2 and 9.2.11.3.

9.2.11.2 A force of 890 N (200 pounds) shall be exerted perpendicular to the surface in which the observation window is mounted. This force shall be evenly distributed over an area of 103 cm^2 (16 $inches^2$), at the geometric center of the observation window. If the observation window has an area less than 16 square in, the force shall be evenly distributed over the entire viewing area. The 200 pound force shall be sustained for 1 minute.

9.2.11.3 The observation window shall be subjected to an impact of 6.8 N˙m (5 foot-pounds) using a steel ball weighing (0.535 kg) 1.18 pounds and 50.8 mm (2 inches) in diameter.

9.2.11.4 Separate samples may be used for each of the tests described in 9.2.11.2 and 9.2.11.3.

9.3 Routine tests

9.3.1 Dielectric voltage-withstand test

9.3.1.1 As a routine factory test, each switchboard section or interior produced is to comply with the dielectric voltage-withstand requirements in 9.2.3.1 – 9.2.3.3.1.

9.3.1.1.1 The manufacturer may apply for 1 second a 60 Hz essentially sinusoidal potential equal to 120 percent of the test potential indicated in 9.2.3.1.

9.3.1.2 The test equipment is to include a visible indication of application of the test potential and an audible or visible indication of breakdown.

9.3.2 Ground fault protection test

9.3.2.1 With a simulated (see 9.3.2.4) ground-fault current flowing, the primary of the control transformer, if any, shall be energized at 57 percent of its voltage rating. The relay may be set for any convenient pick-up value. Following this test, with simulated ground-fault current no longer flowing, an attempt shall be made to close the main switch or circuit breaker without pushing any reset button. If the switch or breaker will stay closed, the simulated ground-fault current shall be reapplied and the ground-fault-protection system shall function.

9.3.2.2 The applied voltage may be approximately rated voltage if the particular combination of transformer, ground-fault-sensing and -relaying equipment, and disconnecting means has been previously tested at 57 percent of rated voltage.

9.3.2.3 The factory test is not required for a residual-type ground-fault protector if:

a) operation is powered by the fault current itself so that no other control-circuit potential is required; and

b) the ground-fault protection other than the neutral-current sensor is contained within and has been investigated with the circuit breaker or switch.

9.3.2.4 One method of simulating a ground-fault current is by wrapping a number of turns of wire through the sensor. A current approximately 125 percent of the pick-up setting of the relay divided by the number of turns is passed through the wire to simulate the ground-fault current.

10 Tables

Table 1
Common voltage ratings

(See 5.2.1, 6.2.1.2)

System		Common voltage ratings	
Number of phases	**Number of wires**	**Alternating current, V**	**Direct current, V**
1 (or direct current)	2	120, 240, 277, or 347	125 or 250
1 (or direct current)	3	120/240, 208Y/120, 480Y/277, or 600Y/347	125/250
3 (derived from 3-phase, 4 wire system)	3	208Y/120, 220Y/127, 440Y/254, 480Y/277, or 600Y/347	–
3	3	120[a], 240, 480, or 600	–
3	4 wire delta with the neutral at midpoint of one phase	240/120	–
3	4 wire wye with neutral	208Y/120, 220Y/127, 440Y/254, 480Y/277, or 600Y/347	–

[a] Normally for marine applications.

Note: For Mexico and Canada, see also item No. 12 in Annex B.

Table 2
Minimum ampere rating of assembly

(See 5.3.1.2)

Number of meter positions assembled together	Percent of sum of ampere ratings
2	50
3 – 5	45
6	44

Table 3
Short circuit current rating, RMS symmetrical or DC

(See 5.4.1, 6.2.1.2, 6.2.1.12, 6.2.1.14, 6.2.1.15)

Amperes		
7 500	25 000	85 000
10 000	30 000	100 000
14 000	35 000	125 000
18 000	42 000	150 000
20 000	50 000	200 000
22 000	65 000	

NOTE – See 8.5.1.4 for equipment that uses a watthour meter. Short-circuit fault currents may adversely affect the accuracy and operation of a watthour ammeter.

Table 4
Location of required markings

(See 6.1.1.1, 6.2.1.3, 6.2.1.4, 6.2.1.9, 6.2.1.13)

Marking	Reference clauses	Location category[a]
Identification	6.2.1.2(a), 6.2.1.7	A
	6.3.1, 6.2.1.2(b), 6.2.9.1	B
Ratings	6.2.1.2(c), 6.2.1.4, 6.2.1.6	A
	6.2.1.3, 6.2.1.8, 6.2.1.9 – 6.2.1.11	B
Short-circuit current rating	6.2.1.12 – 6.2.1.14	A[b]
Phase identification	6.2.10.1	B
Meter sockets	6.2.11.1 – 6.2.11.3	B
Service equipment	6.2.2.1, 6.2.2.2, 6.2.2.4	A
Neutral	6.2.12.1	B
	6.2.12.2	A
Ground fault protection	6.2.13.1 – 6.2.13.4	B
	6.2.2.5	A
	6.2.2.6 – 6.2.2.7	B
Switching devices	6.2.3.1 – 6.2.3.11	A
Emergency circuits	6.2.4.1	B
Field-installed units	6.2.5.1 – 6.2.5.5	B
Field-installed busway	6.2.14.1, 6.3.4.2.1	B
Field-installed interiors. This entry does not apply for Canada.	6.2.6.1 – 6.2.6.2	B
Through or splice bus	6.3.2.1	B
Terminals	6.2.7.1 – 6.2.7.21	B
	6.2.7.22	A
	6.2.7.23	B
Transformers	6.2.15.1 – 6.2.15.3	B
Type 3R	6.2.9.2	B
Motor circuits	6.2.8.1, 6.2.8.2	B

Table 4 Continued on Next Page

Table 4 Continued

Marking	Reference clauses	Location category[a]
	6.2.8.3	A
Bracing	6.3.3.1	B
Enclosure type designation	6.2.9.1	A
Taps	6.2.16.1	B

[a] The location categories are described as follows:

Category A – The marking shall be visible without removing the trim or the cover of the enclosure as covered in 6.1.1.1.

Category B - The marking:

1) Shall be visible without disassembling or removing a device,

2) Shall be visible when the trim or cover of the enclosure is removed, and

3) May be visible with the trim or cover in place as covered in 6.1.1.1.

[b] An exterior marking may be provided to indicate that required short-circuit current ratings are located behind the closed cover.

Table 5
Minimum values for insulating materials

(See 8.1.10.1, 8.1.10.2 and Table 11)

Test specified	Flammability rating of materials			
	V-0	V-1	V-2	HB
Hot Wire Ignition (HWI)[e], ignition time in sec. (Reference Item No. 4 in Annex B)	7	15	30	30
High Current Arc Ignition (HAI)[d], number of arcs (Reference Item No. 6 in Annex B)	15	30	30	30
Comparative Tracking Index (CTI) Under Moist Conditions[c], Volts (Reference Item No. 5 in Annex B)	175[a,b]	175[a,b]	175[a,b]	175[a,b]

[a] A material having a minimum comparative tracking index value of 100 may be used if the voltage involved is 250 V or less.

[b] Not applicable if the over surface spacing is greater than or equal to 12.7 mm (1/2 inch).

[c] Material surface is in contact with or in close proximity (within 0.8 mm (1/32 inch) to:

1) uninsulated live parts of opposite polarity or

2) uninsulated live parts and either:

i) metal parts that may be grounded in service or

ii) any surface exposed to contact.

[d] Material is in contact with or in close proximity to uninsulated live parts 0.8 mm (1/32 inch) for non-arcing parts or 12.7 mm (1/2 inch) for arcing parts.

[e] Material is in contact with or close proximity to uninsulated live parts (within 0.8 mm (1/32 inch).

Table 6
Minimum spacings

(See 8.1.3.5, 8.1.16.1, 8.1.16.2, 8.1.16.6, 8.1.16.7, 8.1.16.8, 8.1.16.11, 8.1.16.14, 8.1.17.5, 8.4.6.1.2, 8.7.1.2.1, 8.8.1.4.4, 8.8.1.7.2, 8.8.1.7.3, 8.8.2.3.5, 9.2.3.1.1, 9.2.4.5.1)

Voltage involved		Minimum spacing between live parts of opposite polarity				Minimum spacing through air and over surface between live parts and grounded metal	
		Through air		Over surface			
Greater than	Maximum	mm	(in)	mm	(in)		
0	130	12.5	(1/2)	19.0	(3/4)	12.5	1/2
130	250	19	(3/4)	31	(1-1/4)	12.5	1/2
250	600	25	(1)	50	(2)	25[a]	1[a]
600	1 000	25	(1)	50	(2)	25[a]	1[a]

[a] A through air spacing of not less than 12.5 mm (1/2 inch) may be used:

1) At a circuit breaker or a switch, other than a snap switch;

2) Between uninsulated live parts of a meter mounting base and grounded metal; and

3) Between grounded metal and the neutral of a 3-phase, 4-wire switchboard.

NOTE 1 – Exceptions to these minimum spacings are covered in 8.1.16.2 – 8.1.16.6 and Table 7.

NOTE 2 – The SI units are minimum values and are not a direct conversion from the corresponding values in inches.

Table 7
Instrument or control circuit spacings

(See 8.1.16.2, 8.1.16.3, 8.1.16.6, 8.1.16.7, 8.1.16.8, 8.1.17.5, 8.7.1.2.1 and Table 6)

Voltage involved		Minimum spacings					
		Between uninsulated live parts of opposite polarity and between an uninsulated live part and an exposed or uninsulated metal part other than the enclosure				Between uninsulated live parts and the walls of a metal enclosure, including fittings for conduit or armored cable	
		Through air[a]		Over surface		Shortest distance	
More than	Maximum	mm	(in)	mm	(in)	mm	(in)
0	150	3.2	(1/8)	6.4	(1/4)	12.5	(1/2)
150	300	6.4	(1/4)	9.5	(3/8)	12.5	(1/2)
300	600	9.5	(3/8)	12.5	(1/2)	12.5	(1/2)
600	1 000	14	(0.55)	21.6	(0.85)	(25.4)[b]	(1)[b]

[a] The spacing between wiring terminals of opposite polarity shall not be less than 6.4 mm (1/4 inch) in any case 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 footnote if deformation of the enclosure is likely to reduce the spacing between the metal piece and a live part.

[b] Through air spacings between uninsulated live parts and the walls of a metal enclosure, including fittings for conduit or armored cable, may be 20.3 mm (0.8 inch).

Table 8
Bushing dimensions

(See 8.1.16.14)

Trade size of conduit	Overall diameter		Height	
	mm	(in)	mm	(in)
1/2	25.4	(1)	9.5	(3/8)
3/4	31.4	(1-15/64)	10.7	(27/64)
1	40.5	(1-19/32)	13.1	(33/64)
1-1/4	49.2	(1-15/16)	14.3	(19/16)
1-1/2	56.0	(2-13/64)	15.1	(19/32)
2	68.7	(2-45/64)	15.9	(5/8)
2-1/2	81.8	(3-7/32)	19.1	(3/4)
3	98.4	(3-7/8)	20.6	(13/16)
3-1/2	112.7	(4-7/16)	23.8	(15/16)
4	126.2	(4-31/32)	25.4	(1)
4-1/2	140.9	(5-31/32)	27.0	(1-1/16)
5	158.0	(6-7/32)	30.2	(1-3/16)
6	183.4	(7-7/32)	31.8	(1-1/4)

Table 9
Minimum values for barrier used in place of spacing

(See 8.1.17.2)

	Flammability rating of materials			
Test Specified	V-0 or VTM-0	V-1 or VTM-1	V-2 or VTM-2	HB
Hot Wire Ignition (HWI), ignition time in sec. (Reference Item No. 4 in Annex B)	7	15	30	30
High Current Arc Ignition (HAI), number of arcs (Reference Item No. 6 in Annex B)	15	30	30	60
Comparative Tracking Index (CTI) Under Moist Conditions, Volts (Reference Item No. 5 in Annex B)	175[a,b]	175[a,b]	175[a,b]	175[a,b]

[a] A material having a minimum comparative tracking index value of 100 may be used if the voltage involved is 250 V or less.

[b] Phenolics having minimum comparative tracking index values of 100 are acceptable.

NOTES

1) Barrier located within 0.33 mm (0.013 inch) of contact with live parts.

2) In addition, the properties of the material with respect to mold-stress relief shall comply with 9.2.8.

Table 10
Minimum values for barrier used in place of spacing in conjunction with minimum air space of 0.33 mm (0.013 inch)

(See 8.1.17.3)

	Flammability rating of materials			
Test Specified	**V-0 or VTM-0**	**V-1 or VTM-1**	**V-2 or VTM-2**	**HB**
Hot Wire Ignition (HWI) , ignition time in sec. (Reference Item No. 4 in Annex B)	7	15	30	30
High Current Arc Ignition (HAI), number of arcs (Reference Item No. 6 in Annex B)	15	30	30	60
Comparative Tracking Index (CTI) Under Moist Conditions, Volts (Reference Item No. 5 in Annex B)	100	100	100	100
NOTE – In addition, the properties of the material with respect to distortion under load and mold-stress relief shall comply with 9.2.8.				

Table 11
Minimum insulating filler plate requirements

(See 8.1.18.3 and Table 5)

	Flammability rating of materials			
Test Specified	**V-0**	**V-1**	**V-2**	**HB**
High Current Arc Ignition (HAI)[a], number of arcs (Reference Item No. 6 in Annex B)	15	30	30	60
[a] If the through air spacing between the insulating filler plate and the live part is 1.6 mm (1/16 inch) or greater, but less than 12.7 mm (1/2 inch), then consideration can be given to conducting the High Current Arc Ignition Test at the resulting spacing. If the through air spacing is 12.7 mm (1/2 inch) or greater, then this requirement is not applicable. NOTE – If the spacing between the insulating filler plate and the live part is less than 0.8 mm (1/32 inch) (either through air or over surface) the material shall be considered as in contact with the live part and shall comply with Table 5.				

Table 12
Enclosure types

(See 6.2.9.1, 8.2.1.1.2, 8.2.1.4.2)

Type number	Intended use and description	Qualification tests as specified in:	
		Reference item No. 2 of Annex B	**This Standard**
1	Indoor use primarily to provide a degree of protection against contact with the enclosed equipment	Corrosion Protection or Rust Resistance	Rod Entry – 8.2.1.3.3
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt	Corrosion Protection or Rust Resistance and Drip	Rod Entry – 8.2.1.3.3
3R	Outdoor use to provide a degree of protection against falling rain, sleet, and external ice formation	Rain, Icing, and Protective Coating	Rod Entry – 8.2.1.3.3 Latch Pull – 9.2.9
* In addition to one of the Enclosure types noted in Table 12, switchboards may be evaluated for enclosure Types as specified in Reference Item No. 2 of Annex B. When applying additional enclosure Types, the Rod Entry (8.2.1.3.3) and, where rated for outdoor use, the Latch Pull (9.2.9) requirements in this Standard apply.			

Table 13
Maximum temperature rises

(See 6.2.7.23, 8.1.16.5, 8.3.1.1, 9.1.1.7, 9.2.2.8 and Table 28)

Materials and components	°C
Bus bars	
1. Any bus bar within 150 mm (6 inches) of a fuseholder along the current path when tested with dummy fuses.	30
2. Unplated bus bars or unplated joints other than those covered in Item 1.	50
3. Plated bus bars at point of connection to a circuit breaker.	65[a]
4. Plated bus bars other than as covered in Items 1 and 3.	65[a, g]
Wiring terminals	
5. Pressure terminal connectors for field installed conductors except as covered in items 6 and 7.	50[g]
6. Pressure terminal connectors for field wiring to switches and circuit breakers as covered in items 2, 3 and 5 – 7 of Table 35 if marked as in 6.2.7.23.	60
7. Pressure terminal connectors for circuit breakers rated 125 A or less and marked for use with 75°C wire.	65[b]
8. For internal copper conductor wiring.	60[b,g]
9. For internal aluminum conductor wiring.	50[c,g]
Insulating materials[d]	
10. Wire insulation or insulating tubing.	35[g]
11. Electrical tape.	55[g]
12. Varnished cloth insulation.	60[g]
13. Fibre employed as electrical insulation.	65[g]
14. Sealing compound[e].	50[g]
15. Phenolic composition employed as electrical insulation.	125[g]
16. Other insulating materials.	f,g
Other	
17. Any part that may be contacted by field wiring.	50[g]
18. External metal handles, knobs, and other surfaces subject to contact by a person[h].	35
19. External nonmetallic handles, knobs, and other surfaces subject to contact by a person[h].	60
Windings: For Canada see Annex B, Reference Items 17 and 18	
20. Coil winding by change-of-resistance method except as covered in item 21:	
Open motors:	
Class 105 insulation system	75
Class 130 insulation system	95
Totally enclosed motors:	
Class 105 insulation system	80
Class 130 insulation system	100
Relays and solenoids:	
Class 105 insulation system	85
Class 130 insulation system	105
Transformers 10 kVA or less:	
Class 105 insulation system	70
Class 130 insulation system	95

Table 13 Continued on Next Page

Table 13 Continued

Materials and components	°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
21. Coil winding by change-of-resistance method for transformers with encapsulated coils or that are compound filled:	
Class 105 insulation system	70
Class 130 insulation system	95
Class 155 insulation system	115
Class 180 insulation system	135
Class 200 insulation system	150
Class 220 insulation system	165

[a] Both surfaces of a joint shall be plated but not necessarily the entire length of the bus bar.

[b] Applicable for the following combinations of conductor and connector:

1) Copper conductor terminated in a copper or copper alloy bodied connector.

2) Copper or aluminum conductor terminated in an aluminum bodied connector, provided the connector has a rating of 90°C.

3) Aluminum conductor terminated in a copper or copper alloy bodied connector, provided the connector has a rating of 90°C.

[c] The temperature rise may be increased to 60°C if connectors suitable for the higher temperature are used.

[d] These limitations do not apply to insulated conductors or other materials that have been investigated and found acceptable for higher temperatures.

[e] The softening point shall be at least 40°C higher than the temperature rise at the point where the compound is employed but not less than 90°C.

[f] See 9.2.2.10 for other insulating materials.

[g] In a switchboard tested with dummy fuses, the recorded temperature rise shall be increased 20°C to represent the heating of fuses. The increase shall only apply to items along the current path and within 150 mm (6 inches) of the dummy fuses.

[h] This temperature rises are based on a 25°C ambient. In no case shall the total temperature exceed this value plus 25°C.

Table 14
Size of bonding, equipment grounding, and grounding electrode conductors and ground bus

(See 6.2.14.1, 8.4.3.6, 8.4.3.9, 8.4.4.1, 8.4.4.4, 8.4.4.5, 8.4.4.6, 8.4.5.1, 8.4.7.2, 8.4.8.4, 8.4.8.5)

Maximum ampere rating[a]	Size of equipment grounding or bonding conductor, minimum (AWG or kcmil)		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
15	14 AWG	12 AWG	–	–	–	–
20	12	10	–	–	–	–
30	10	8	–	–	–	–
40	10	8	–	–	–	–
60	10	8	–	–	–	–
90	8	6	8 AWG	6 AWG	8 AWG	6 AWG

Table 14 Continued on Next Page

Table 14 Continued

Maximum ampere rating[a]	Size of equipment grounding or bonding conductor, minimum (AWG or kcmil)		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
100	8	6	6	4	6	4
150	6	4	4	4	6	4
200	6	4	3	2	4	2
300	4	2	1/0	1/0	2	1/0
400	3	1	2/0[b]	3/0[b]	1/0[b]	3/0[b]
500	2	1/0	3/0	3/0	1/0	3/0
600	1	2/0	3/0	4/0	2/0	4/0
800	1/0	3/0	3/0	4/0	2/0	4/0
1 000	2/0	4/0	3/0	250 kcmil	3/0	250 kcmil
1 200	3/0	250 kcmil	3/0	250	250 kcmil[c]	250
1 600	4/0	350	3/0	250	300[c]	400[c]
2 000	250 kcmil	400	3/0	250	400[c]	500[c]
2 500	350	600	3/0	250	500[c]	700[c]
3 000	400	600	3/0	250	600[c]	750[c]
4 000	500	800	3/0	250	750[c]	1000[c]
5 000	700	1200	3/0	250	900	1250
6 000	800	1250	3/0	250	1250	1500

[a] Maximum supply ampere rating of switchboard or circuit overcurrent device ahead of equipment grounding means.

[b] If the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG copper or two 250 kcmil aluminum conductors but will not accept a 600 kcmil conductor, these values may be reduced to 2 AWG copper or 1/0 AWG aluminum.

[c] The cross section may be reduced to 12.5 percent of the total cross section of the largest main service conductor of the same material (copper or aluminum) for any phase on switchboards rated 1 200 A and above. This applies when the cross section of the service conductors is limited by the wire terminal connectors provided.

NOTE – See Table 15 for equivalent area of bus and metric equivalents of conductors. Size of ground bus to be per Table 15 based on columns 1 – 3 of this table.

Table 15
Equivalent cross-sectional areas

(See 8.4.4.1, 8.4.6.2, 8.4.7.2 and Table 14

Wire size (AWG or kcmil)	Minimum cross section	
	mm^2	(in^2)
14 AWG	2.1	(0.003)
12	3.3	(0.005)
10	5.3	(0.008)
8	8.4	(0.013)
6	13.3	(0.021)
4	21.1	(0.033)
3	26.7	(0.041)
2	33.6	(0.052)
1	42.4	(0.066)

Table 15 Continued on Next Page

Table 15 Continued

Wire size (AWG or kcmil)	Minimum cross section	
	mm²	(in²)
1/0	53.5	(0.083)
2/0	67.4	(0.105)
3/0	85.0	(0.132)
4/0	107	(0.166)
250 kcmil	127	(0.196)
300	152	(0.236)
350	177	(0.275)
400	203	(0.314)
500	253	(0.393)
600	304	(0.471)
700	355	(0.550)
750	380	(0.589)
800	405	(0.628)
1 000	507	(0.785)
1 200	608	(0.942)
1 250	633	(0.982)
1 500	760.0	(1.178)

Table 16
Assumed maximum short-circuit current rating for unmarked components

(See 8.5.1.1)

	Components	Short circuit current rating, kA
1	Circuit Breaker	5
2	Clock-Operated Switch	5
3	Fuseholder	10
4	Lighting fixture (circuit) (Not for Canada)	5
5	Industrial Control Equipment:	
	a. Auxiliary Devices	5
	b. Switches	5
6	Meter Socket Base	10
7	Motor Controller, rated in horsepower (kW)	
	a. 1.5 – 50 (1.1 – 37.3)	5
	b. 51 – 200 (38 – 149)	10
	c. 201 – 400 (150 – 298)	18
	d. 401 – 600 (299 – 447)	30
	e. 601 – 900 (448 – 671)	42
	f. 901 – 1 600 (672 – 1 193)	85
8	Photoelectric Switches	5

Table 16 Continued on Next Page

Table 16 Continued

	Components	Short circuit current rating, kA
9	Receptacle (GFCI Type)	2[a]
10	Receptacle (other than GFCI Type)	10
11	Snap Switch	5
12	Terminal Block	10
13	Thermostat	5
14	Direct Connected Meters	b

[a] The short-circuit current available in a 120 V secondary circuit of a transformer rated 5 kVA or less is considered to be 2 kA or less.

[b] See 8.5.1.4.

Table 17
Power factor of test circuits

(See 9.2.5.2)

Test Circuit in RMS symmetrical amperes		Maximum power factor
More than	Not more than	
0	10 000	0.5
10 000	20 000	0.3
20 000	200 000	0.2

Table 18
Horsepower rating versus pilot duty rating

(See 8.6.11.6)

Switch rating, horsepower (kW)	Controlled load, volt-amperes
1/10 (0,075)	144
1/8 (0,093)	182
1/6 (0,124)	211
1/4 (0,187)	278
1/3 (0,249)	345
1/2 (0,343)	470
3/4 (0,560)	662
1 (0,746	768

Table 19
Magnetic coil ratings

(See 8.6.11.6)

Maximum contact rating, amperes	Coil rating, VA
10	30
30	30
50	75
100	100
150	100
300	125

Table 20
Maximum rating of overcurrent protection for control circuit conductors

(See 8.6.15.1, 8.6.15.1.3, 8.6.15.2)

Copper conductor size		Maximum ampere rating of overcurrent protective device
AWG	(mm^2)	
18	(0.82)	7
16	(1.30)	10
14	(2.10)	15
12	(3.30)	20
NOTE – This table is not applicable if the construction complies with the limitations specified in 8.6.15.1.1.		

Table 21
Maximum branch circuit short-circuit protection

(See 8.6.15.1.1, 8.6.15.2)

Copper control circuit conductor size		Maximum ampere rating of branch circuit protective device[a]	
AWG	(mm^2)	Interior control circuit conductors	Exterior control circuit conductors
18	(0.82)	25	7
16	(1.30)	40	10
14	(2.10)	100	45
12	(3.30)	120	60
NOTE – This table applies if the construction complies with the limitations specified in 8.6.15.1.1.			
[a] Does not apply if as specified in 8.6.15.2.			

Table 22
Full-load motor-running currents in amperes corresponding to various alternating-current horsepower (kilowatt) ratings

(See 8.6.17.1)

AC Ratings		110 – 120 V			220 – 240 V[a]			440 – 480 V		550 – 600 V	
Horsepower (kilowatt)		Single phase	Two phase	Three phase	Single phase	Two phase	Three phase	Two phase	Three phase	Two phase	Three phase
1/6	0.124	4.4			2.2						
1/4	0.187	5.8			2.9						
1/3	0.249	7.2			3.6						
1/2	0.373	9.8	4.0	4.4	4.9	2.0	2.2	1.0	1.1	0.8	0.9
3/4	0.563	13.8	4.8	6.4	6.9	2.4	3.2	1.2	1.6	1.0	1.3
1	0.746	16	6.4	8.4	8.0	3.2	4.2	1.6	2.1	1.3	1.7
1-1/2	1.119	20	9.0	12	10	4.5	6.0	2.3	3.0	1.8	2.4
2	1.492	24	11.8	13.6	12	5.9	6.8	3.0	3.4	2.4	2.7
3	2.238	34			17	8.3	9.6	4.2	4.8	3.3	3.9
5	3.73	56			28	13.2	15.2	6.6	7.6	5.3	6.1
7-1/2	5.60	80			40	19	22	9.0	11	8.0	9.0
10	7.46	100			50	24	28	12	14	10	11
15	11.19					36	42	18	21	14	17
20	14.92					47	54	23	27	19	22
25	18.65					59	68	29	34	24	27
30	22.38					69	80	35	40	28	32
40	22.84					90	104	45	52	36	41
50	37.30					113	130	56	65	45	52
60	44.76					133	154	67	77	53	62
75	55.95					166	192	83	96	66	77
100	74.60					218	248	109	124	87	99
125	93.25					270	312	135	156	108	125
150	111.9					312	360	156	180	125	144
200	149.2					416	480	208	240	167	192
250	186.5								302		242
300	223.8								361		289
350	261.1								414		336
400	298.4								477		382
450	335.7								515		412
500	373.0								590		472

[a] To obtain full-load currents for 100- and 208 V motors, increase corresponding 220 and 240 ratings by 15 and 10 percent, respectively.

Table 23
Ampacity of single or multiple bus bars and clamped joints

(See 8.6.17.1, 8.8.1.6.2, 8.8.1.6.4, 8.8.1.6.5, 8.8.1.6.6, 8.8.1.6.7, 9.2.2.14 and Table 25)

Bus bar material[a]	Current, amperes	Current density			
		Bus bar cross section[b]		Contact area at clamped joints[c]	
		amperes/cm^2	(amperes/in^2)	amperes/cm^2	(amperes/in^2)
Copper	0 – 600	155[d]	(1 000)[d]	31	(200)
Copper	Over 600[h]	155[d,e]	(1 000)[d,e]	31[f]	(200)[f]
Aluminum[g]	Any[h]	116[d,e]	(750)[d,e]	31[f]	(200)[f]
Brass	0 – 600	78	(500)	31	(200)

[a] Multiple bus bars in parallel shall be of the same material.

[b] See 8.8.1.6.1 – 8.8.1.6.8 and 9.2.2.8.

[c] See 8.8.1.6.18.

[d] See also Table 25 for 800 A maximum single bus bars.

[e] For a 100 percent rated device rated 3 000 A or more, see Table 24.

[f] Joints bolted and plated with silver or tin.

[g] Minimum conductivity of 55 percent of International Annealed-Copper Standard.

[h] In Canada, the maximum value is 3 000 A.

Table 24
Minimum bus bar size for a 100 percent rated device

(See 8.8.1.6.3, 8.8.1.6.5, 8.8.1.6.17 and Table 23)

Device rating amperes	Size of bus bar[a]						
	Number of bus bars per conductor[b]	Copper		Aluminum			
		mm	(in)	mm	(in)	mm	(in)
3 000	3	6.35 by 152.4[c]	(0.25 by 6)[c]	6.35 by 203.2[d]	(0.25 by 8)[d]	7.42 by 152.4[d]	(0.292 by 6)[d]
3 000	4	–	–	6.35 by 152.4[d]	(0.25 by 6)[d]	–	–
3 000	4	6.35 by 101.6[c]	(0.25 by 4)[c]	6.65 by 127.0[d]	(0.262 by 5)[d]	8.36 by 101.6[d]	(0.329 by 4)[d]
3 000	5	–	–	6.35 by 127.0[d]	(0.25 by 5)[d]	6.65 by 101.6[d]	(0.262 by 4)[d]
3 000	6	–	–	6.35 by 101.6[d]	(0.25 by 4)[d]	–	–
4 000	4	6.35 by 127.0	(0.25 by 5)	6.35 by 169.2	(0.25 by 6.662)	8.36 by 127.0	(0.329 by 5)
4 000	5	6.35 by 101.6	(0.25 by 4)	6.35 by 152.4	(0.25 by 6)	6.65 by 127.0	(0.262 by 5)
4 000	6	–	–	6.35 by 114.3	(0.25 by 4.5)	6.93 by 101.6	(0.273 by 4)
5 000	4	9.53 by 127.0	(0.375 by 5)	–	–	16.61 by 127.0	(0.654 by 5)
5 000	5	6.35 by 152.4	(0.25 by 6)	6.35 by 203.2	(0.25 by 8)	7.42 by 152.4	(0.292 by 6)
5 000	5	7.49 by 152.4	(0.295 by 6)	–	–	–	–
5 000	6	6.35 by 127.0	(0.25 by 5)	6.35 by 169.2	(0.25 by 6.662)	6.93 by 152.4	(0.273 by 6)
5 000	8	–	–	6.35 by 127.0	(0.25 by 5)	7.82 by 101.6	(0.308 by 4)
6 000	6	6.35 by 152.4	(0.25 by 6)	6.35 by 203.2	(0.25 by 8)	8.36 by 152.4	(0.329 by 6)

Table 24 Continued on Next Page

Table 24 Continued

Device rating amperes	Size of bus bar[a]						
	Number of bus bars per conductor[b]	Copper		Aluminum			
		mm	(in)	mm	(in)	mm	(in)
6 000	8	–	–	6.35 by 152.4	(0.25 by 6)	7.49 by 127.0	(0.295 by 5)

[a] Joints bolted and plated.

[b] Spacing between bus bars to be approximately the thickness of one bus bar.

[c] For a 3 000 A AC power switching device, three 6.35 by 127.0 mm (0.25 by 5 inches) copper bus bars may be used.

[d] For a 3 000 A AC power switching device, three 6.35 by 169.2 mm (0.25 by 6.662 inches) or 11.07 by 127.0 mm (0.436 by 5 inches) aluminum bus bars may be used.

Table 25
Rating and sizes of single bus bars – 800 amperes maximum

(See 8.6.17.1, 8.8.1.6.2, 8.8.1.6.4, 8.8.1.6.5, 8.8.1.6.6, 8.8.1.6.7, 9.2.2.14 and Table 23)

Current rating in amperes	Copper bus				Aluminum bus			
	Bus size		Cross section		Bus size		Cross section	
	mm	(in)	mm^2	(in^2)	mm	(in)	mm^2	(in^2)
225	3.2 by 22.2	(0.125 by 0.875)	70.3	(0.109)	6.4 by 22.2	(0.250 by 0.875)	141.3	(0.219)
400	6.4 by 38.1	(0.250 by 1.500)	242.0	(0.375)	6.4 by 50.8	(0.250 by 2.000)	322.6	(0.500)
600	6.4 by 50.8	(0.250 by 2.000)	322.6	(0.500)	See Table 23	(See Table 23)	516.1	(0.800)
800	6.4 by 76.2	(0.250 by 3.000)	483.9	(0.750)	See Table 23	(See Table 23)	688.4	(1.067)

[a] Minimum conductivity of 55 percent International Annealed-Copper Standard.

NOTES

1) See 8.8.1.6.4 –8.8.1.6.7 and 9.1.1.8.

2) For multiple buses in parallel refer to Table 23.

3) Except as noted in 8.8.1.6.18, the current density at a joint shall not exceed 31 A per cm^2 (200 A per $inch^2$).

4) Joints bolted and plated with silver or tin.

5) A bus bar having other dimensions may also be used if it has not less than the cross-sectional area specified in the table and if it has equivalent rigidity.

6) A bus connection to a device rated for continuous use at 100 percent of its rating shall be sized in accordance with Table 23 and Table 24.

Table 26
Minimum ampacity of section or branch bus

(See 8.8.1.6.13)

Number of branch circuit overcurrent protective devices supplied	Percent of the sum of the ratings
1	100
2 – 3	80
4 – 6	70
7 – 12	60
Over 12	50

Table 27
Multiplying factor for section bus ampacity involving field-installed units

(See 8.8.1.6.14)

Unspecified space in percent of total section space	Multiplying factor
0 – 10	1.00
11 – 25	1.25
26 – 40	1.50
41 – 60	1.75
Above 60	2.00

Table 28
Ampacity of insulated conductors

(See 8.6.17.1, 8.8.1.8.1, 8.8.2.3.9, 8.8.3.1.2, 9.2.2.5, 9.2.2.5.1, 9.2.2.14, 9.2.4.2.4.1)

Wire size		60°C[a]		75°C[a]		90°C	
AWG or kcmil	$(mm)^2$	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
14 AWG	(2.1)	15	–	15	–	15[b]	–
12	(3.3)	20	15	20	15	20[b]	15[b]
10	(5.3)	30	25	30	25	30[b]	25[b]
8	(8.4)	40	30	50[c] (45)	40[c] (30)	55[b]	45[b]
6	(13.3)	55	40	65[c]	50[c]	75[b]	60[b]
4	(21.2)	70	55	85[c]	65[c]	95[b]	75[b]
3	(26.7)	85	65	100[c]	75[c]	110[b]	85[b]
2	(33.6)	95 (100)	75	115[c]	90[c]	130[b]	100[b]
1	(42.4)	100	85	130[c]	100[c]	150[b]	115[b]
1/0[d]	(53.5)[d]	e	e	150	120	170[b]	135[b]
2/0[d]	(67.4)[d]	e	e	175	135	195[b]	150[b]
3/0[d]	(85.0)[d]	e	e	200	155	225[b]	175[b]
4/0[d]	(107.2)[d]	e	e	230	180	260[b]	205[b]
250[d]	(127)[d]	e	e	255	205	290[b]	230[b]
300[d]	(152)[d]	e	e	285	230	320[b]	255[b]
350[d]	(177)[d]	e	e	310	250	350[b]	280[b]
400[d]	(203)[d]	e	e	335	270	380[b]	305[b]
500[d]	(253)[d]	e	e	380	310	430[b]	350[b]
600	(304)[d]	e	e	420	340	475[b]	385[b]
700[d]	(355)[d]	e	e	460	375	520[b]	420[b]
750[d]	(380)[d]	e	e	475	385	535[b]	435[b]
800[d]	(405)[d]	e	e	490	395	555[b]	450[b]
900[d]	(456)[d]	e	e	520	425	585[b]	480[b]
1 000	(506)	e	e	545	445	615[b]	500[b]
1,250	(633)	e	e	590	485	665[b]	545[b]
1,500	(760)	e	e	626	520	705[b]	585[b]

Table 28 Continued on Next Page

Table 28 Continued

Wire size		60°C[a]		75°C[a]		90°C	
AWG or kcmil	$(mm)^2$	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
1,750	(887)	e	e	650	545	735[b]	615[b]
2 000	(1 013)	e	e	665	560	750[b]	630[b]

[a] The numbers 60°C, 75°C, and 90°C indicate the wire temperature rating.

[b] The ampacity of 90°C wire shall be considered to be the same as 75°C wire. However, the 90°C ampacity may be used for internal wiring if the wires:

1) will not contact field-installed wires,

2) are not connected to a molded case circuit breaker or fused switch except where the circuit breaker or switch is marked for use with this size and type of wire, and

3) terminates in connectors that have been investigated for 90°C operation (such as being marked AL9CU) when aluminum wire is used.

Also, the current carried by these wires may exceed the values for the 75°C wire as described in item 6 and footnotes a, b, and c to Table 13.

Values in parentheses apply to products for use in Canada.

[c] The ampacity of these sizes shall be considered to be the same as for 60°C wire when connected to molded case circuit breakers unless the breaker is marked 75°C.

[d] For a multiple conductor connector at a terminal, the ampacity value shall be multiplied by the number of conductors that the terminal will accommodate [53.5 mm^2 (1/0 AWG) and larger].

[e] For wire sizes 53.5 mm^2 (1/0 AWG) and larger, it is assumed that wire with at least a 75°C temperature rating will be used.

NOTES

1) For internal wiring, ampacities larger than those specified in this table may be permitted on the basis of a temperature test.

2) These values of ampacity are based on a maximum of three current carrying conductors being field installed in a single conduit for the purposes of sizing the terminals.

Table 29
600 volt thermoplastic appliance wiring material insulation

(See 8.8.1.8.1)

Conductor size		Minimum thickness			
		Average		At any point	
AWG/kcmil	mm^2	in	(mm)	in	(mm)
14 – 9	2.1 – 6.6	0.030	(0.76)	0.027	(0.69)
8 – 7	8.4 – 10.4	0.045	(1.14)	0.040	(1.02)
6 – 2	13.3 – 33.6	0.060	(1.52)	0.054	(1.37)
1 – 4/0	42.4 – 107.2	0.080	(2.03)	0.073	(1.83)
250 – 500	127 – 253	0.095	(2.41)	0.086	(2.16)
550 – 1 000	279 – 506	0.110	(2.79)	0.099	(2.51)

Table 30
Minimum wire bending space at terminals in inches

(See 8.8.3.2.2)

All other conductors		Compact stranded AA-8000 Aluminum Alloy conductors (* Not for Canada)		Minimum bending space, in							
				Wires per terminal (pole)							
Wire size, AWG or kcmil	mm^2	Wire size, AWG or kcmil	mm^2	1		2		3		4 or more	
14 – 10	2.1 – 5.3	12 - 8	2.1 – 8.4	Not specified		–		–		–	
8	8.4	6	13.3	(1-1/2)		–		–		–	
6	13.3	4	21.2	(2)		–		–		–	
4	21.2	2	33.6	(3)		–		–		–	
3	26.7	1	42.4	(3)		–		–		–	
2	33.6	0	53.5	(3-1/2)		–		–		–	
1	42.4	2/0	67.4	(4-1/2)		–		–		–	
1/0	53.5	3/0	85.0	(5-1/2)		(5-1/2)		(7)		–	
2/0	67.4	4/0	107	(6)		(6)		(7-1/2)		–	
3/0	85.0	250	127	(6-1/2)	[6]	(6-1/2)	[6]	(8)		–	
4/0	107.2	300	152	(7)	[6]	(7-1/2)	[6]	(8-1/2)	[8]	–	
250	127	350	177	(8-1/2)	[6-1/2]	(8-1/2)	[6-1/2]	(9)	[8]	(10)	
300	152	400	203	(10)	[7]	(10)	[8]	(11)	[10]	(12)	
350	177	500	253	(12)	[9]	(12)	[9]	(13)	[10]	(14)	[12]
400	203	600	304	(13)	[10]	(13)	[10]	(14)	[11]	(15)	[12]
500	253	700 – 750	355 – 380	(14)	[11]	(14)	[11]	(15)	[12]	(16)	[13]
600	304	800 – 900	405 – 456	(15)	[12]	(16)	[13]	(18)	[15]	(19)	[16]
700	355	1 000	507	(16)	[13]	(18)	[15]	(20)	[17]	(22)	[19]
750	380	–	–	(17)	[14]	(19)	[16]	(22)	[19]	(24)	[21]
800	405	–	–	(18)		(20)		(22)		(24)	
900	456	–	–	(19)		(22)		(24)		(24)	
1 000	506	–	–	(20)		–		–		–	
1 250	633	–	–	(22)		–		–		–	
1 500 – 2 000	760 – 1 013	–	–	(24)		–		–		–	

NOTE – The values in this Table are for References Purposes Only. The values in [ ] brackets are in inches and apply to:

1) only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal) and

2) the removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

Table 31
Minimum wire bending space at terminals in millimeters

(See 8.8.3.2.2)

All other conductors		Compact stranded AA-8000 Aluminum Alloy conductors (* Not for Canada)		Minimum bending space, mm							
				Wires per terminal (pole)							
Wire size, AWG or kcmil	mm^2	Wire size, AWG or kcmil	mm^2	1		2		3		4 or more	
14 – 10	2.1 – 5.3	12 – 8	2.1 – 8.4	Not specified		–		–		–	
8	8.4	6	13.3	38.1		–		–		–	
6	13.3	4	21.2	5.8		–		–		–	
4	21.2	2	33.6	76.2		–		–		–	
3	26.7	1	42.4	76.2		–		–		–	
2	33.6	0	53.5	88.9		–		–		–	
1	42.4	2/0	67.4	114		–		–		–	
1/0	53.5	3/0	85.0	140		140		178		–	
2/0	67.4	4/0	107	152		152		191		–	
3/0	85.0	250	127	165	[152]	165	[152]	203		–	
4/0	107	300	152	178	[152]	191	[152]	216	[203]	–	
250	127	350	177	216	[165]	216	[165]	229	[203]	254	
300	152	400	203	254	[178]	254	[203]	279	[254]	305	
350	177	500	253	305	[229]	305	[229]	330	[254]	356	[305]
400	203	600	304	330	[254]	330	[254]	356	[279]	381	[305]
500	253	700 – 750	355 – 380	356	[279]	356	[279]	381	[305]	406	[330]
600	304	800 – 900	405 – 456	381	[305]	406	[330]	457	[381]	483	[406]
700	355	1 000	507	406	[330]	457	[381]	508	[432]	559	[483]
750	380	–	–	432	[356]	483	[406]	559	[483]	610	[533]
800	405	–	–	457		508		559		610	
900	456	–	–	483		559		610		610	
1 000	507	–	–	508		–		–		–	
1 250	633	–	–	559		–		–		–	
1 500 – 2 000	760 – 1 010	–	–	610		–		–		–	

NOTE – The values in [] brackets are in millimeters and apply to:

1) only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal) and

2) the removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

Table 32
Minimum width of gutter and wire bending space

(See 8.8.3.2.2.1, 8.8.3.2.3 and 8.8.3.2.7)

Size of wire		Minimum bending space, terminal to wall, mm (in)									
		Wires per terminal (pole)									
AWG or kcmil	(mm^2)	1		2		3		4		5	
14 – 10	(2.1 – 5.3)	Not specified		–		–		–		–	
8 – 6	(8.4 – 13.3)	38.1	(1-1/2)	–		–		–		–	
4 – 3	(21.1 – 26.7)	50.8	(2)	–		–		–		–	
2	(33.6)	63.5	(2-1/2)	–		–		–		–	
1	(42.4)	76.2	(3)	–		–		–		–	
1/0 – 2/0	(53.5 – 67.4)	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	(85.0 – 107)	102	(4)	152	(6)	203	(8)	–		–	
250	(127)	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	(152 – 177)	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	(203 – 253)	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	(304 – 355)	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	(380 – 900	203	(8)	305	(12)	356	(14)	406	(16)	457	(18)
1 000 – 1 250	(507 – 633	254	(10_	–		–		–		–	
1 500 – 2 000	(760 – 1 010)	305	(12)	–		–		–		–	

NOTE – The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

Table 33
Wire space

(See 8.8.3.1 and 8.8.3.3.2)

Maximum size of wire or cable involved,		Minimum width and depth of wiring space,		Minimum areas required for multiple wires based on a factor of 2.5											
				2 wires,		3 wires,		4 wires,		5 wires,		6 wires,		7 wires,	
AWG or kcmil	(mm^2)	mm	(in)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)
12 AWG	3.3	9.5	3/8	0.9	0.14	1.4	0.21	1.8	0.28	2.3	0.35	2.7	0.42	3.2	0.49
10	5.3	9.5	3/8	1.5	0.23	2.2	0.34	3.0	0.46	3.7	0.57	4.4	0.68	5.2	0.80
8	8.4	12.7	1/2	2.8	0.43	4.1	0.64	5.5	0.85	6.9	1.07	8.3	1.28	9.7	1.50
6	13.3	1539	5/8	4.0	0.62	6.0	0.93	8.0	1.24	10.0	1.55	12.0	1.86	14.0	2.17
4	21.2	19.1	3/4	5.2	0.80	7.7	1.20	10.3	1.60	12.9	2.00	15.5	2.40	18.1	2.80
3	26.7	19.1	3/4	5.9	0.91	8.8	1.36	11.7	1.82	14.6	2.27	17.6	2.72	20.5	3.18
2	33.6	22.2	7/8	6.6	1.03	10.0	1.55	13.3	2.06	16.6	2.58	20.0	3.10	23.3	3.61

Table 33 Continued on Next Page

Table 33 Continued

Maximum size of wire or cable involved,		Minimum width and depth of wiring space,		Minimum areas required for multiple wires based on a factor of 2.5											
				2 wires,		3 wires,		4 wires,		5 wires,		6 wires,		7 wires,	
AWG or kcmil	(mm^2)	mm	(in)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)	cm^2	(in^2)
1	42.4	25.4	1	8.8	1.36	13.2	2.04	17.6	2.72	21.9	3.40	26.3	4.08	30.7	4.76
1/0	53.5	25.4	1	10.0	1.55	15.0	2.33	20.0	3.10	25.0	3.88	30.1	4.66	35.0	5.43
2/0	67.4	25.4	1	11.5	1.79	17.3	2.68	23.1	3.58	28.8	4.47	34.6	5.36	40.4	6.26
3/0	85.0	28.6	1-1/8	13.4	20.8	20.1	3.11	26.8	4.16	33.5	5.19	40.1	6.22	46.9	7.27
4/0	107.2	31.8	1-1/4	15.6	2.42	23.4	3.63	31.2	4.84	39.0	6.05	46.8	7.26	54.6	8.47
250 kcmil	127	34.9	1-3/8	19.1	2.96	28.6	4.44	38.2	5.92	47.7	7.40	57.3	8.88	66.8	10.36
300	152	38.1	1-1/2	22.1	3.42	33.1	5.13	44.1	6.84	55.2	8.55	66.2	10.26	77.2	11.96
350	177	38.1	1-1/2	24.6	3.81	36.9	5.72	49.2	7.62	61.5	9.53	73.8	11.44	86.1	13.34
400	203	41.3	1-5/8	27.0	4.18	40.4	6.27	53.9	8.36	67.4	10.45	80.9	12.54	94.4	14.63
500	253	44.5	1-3/4	31.7	4.92	47.6	7.38	63.5	9.84	79.4	12.30	95.2	14.76	111.1	17.22
600	304	47.6	1-7/8	38.5	5.97	57.8	8.96	77.0	11.94	96.3	14.93	115.6	17.92	134.8	20.90
700	355	50.8	2	43.1	6.68	64.6	10.02	86.2	13.36	107.7	16.70	129.3	20.04	150.8	23.38
750	380	50.8	2	45.4	7.04	68.1	10.56	90.8	14.08	113.5	17.60	136.3	21.12	159.0	24.64
800	405	54.0	2-1/8	47.7	7.39	71.6	11.09	95.4	14.78	119.2	18.48	143.1	22.18	166.9	25.87
900	456	57.2	2-1/4	52.2	8.09	78.3	12.13	104.4	16.18	130.4	20.22	156.5	24.26	182.6	28.31
1 000	506	57.2	2-1/4	56.6	8.77	84.8	13.15	113.2	17.54	141.4	21.92	169.7	56.30	198.0	30.69
1 250	633	63.5	2-1/2	71.2	11.03	106.8	16.55	142.3	22.06	177.9	27.58	213.6	33.10	249.1	38.61
1 500	760	69.8	2-3/4	82.2	12.74	123.3	19.11	164.4	25.48	205.5	31.85	246.6	38.22	287.7	44.59
1 750	887	73.0	2-7/8	93.2	14.45	139.8	21.67	186.4	28.90	233.0	36.12	279.6	43.34	326.3	50.57
2 000	1 013	79.4	3-1/8	103.5	16.4	155.2	24.06	207.0	32.08	258.7	40.10	310.4	48.12	362.2	56.14

Table 34
Receptacle ratings when branch circuit supplying two or more receptacles

(See 8.8.4.3.1.4)

Branch circuit rating, A	Receptacle rating, A
15	Not over 15
20	15 or 20
30	30
40	40 or 50
50 and higher	Receptacle rating shall not be less than the branch circuit rating

Table 35
Current through fuseholders and other overcurrent devices

(See 9.1.1.2.6, 9.2.2.7, 9.2.4.2.8.1 and Table 13)

Type device	Percent of device rating
1. Dummy fuse	100
2. AC power switching devices and fused power circuit devices	100
3. Molded case circuit breakers marked for 100 percent loading	100
4. Combination motor control circuits	See 9.2.2.6
5. Class L fuses in fused power circuit devices or in transfer switches	100
6. Class L fuses in miscellaneous switches 1 200 A or less	80
7. 200 – 1 200 A Class T and 400 – 600 A Class J fuses	80
8. All other fuses or circuit breakers	80

Table 36
Peak-let-through currents and clearing I^2t for fuses

(See 9.2.4.2.8.1 and 9.2.4.4.3.2)

Fuse rating, Amperes	Between threshold and 50 kA		100 kA		200 kA	
	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
Class CC Fuses						
0 – 15	3	2	3	2	4	3
16 – 20	3	2	4	3	5	3
21 – 30	6	7	7.5	7	12	7
Class G Fuses						
0 – 1	–	–	1	0.8	–	–
2 – 3	–	–	1.5	1.2	–	–
4 – 6	–	–	2	1.8	–	–
7 – 10	–	–	3	2.8	–	–
11 – 15	–	–	4	3.8	–	–
16 – 20	–	–	5	5	–	–
21 – 25	–	–	6	6	–	–
26 – 30	–	–	7	7	–	–
31 – 35	–	–	8	14	–	–
36 – 40	–	–	8.5	17	–	–
41 – 45	–	–	9	18.5	–	–
46 – 50	–	–	9.5	21	–	–
51 – 60	–	–	10.5	25	–	–
300 V Class T Fuses						
0 – 30	5	3.5	7	3.5	9	3.5
31 – 60	7	15	9	15	12	15
61 – 100	9	40	12	40	15	40
101 – 200	13	150	16	150	20	150
201 – 400	22	550	28	550	35	550
401 – 600	29	1 000	37	1 000	46	1 000
601 – 800	37	1 500	50	1 500	65	1 500

Table 36 Continued on Next Page

Table 36 Continued

Fuse rating, Amperes	Between threshold and 50 kA		100 kA		200 kA	
	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$
801 – 1 200	50	3 500	65	3 500	80	4 000
Class J and 600-Volt Class T Fuses						
0 – 30	6	7	7.5	7	12	7
31 – 60	8	30	10	30	16	30
61 – 100	12	60	14	80	20	80
101 – 200	16	200	20	300	30	300
201 – 400	25	1 000	30	1 100	45	1 100
401 – 600	35	2 500	45	2.500	70	2 500
601 – 800[b]	50	4 000	55	4 000	75	4 000
Class L Fuses						
601 – 800	80	10 000	80	10 000	80	10 000
801 – 1 200	80	12 000	80	12 000	120	15 000
1 201 – 1 600	100	22 000	100	22 000	150	30 000
1 601 – 2 000	110	35 000	120	35 000	165	40 000
2 001 – 2 500	–	–	165	75 000	180	75 000
2 501 – 3 000	–	–	175	100 000	200	100 000
3 001 – 4 000	–	–	220	150 000	250	150 000
4 001 – 5 000	–	–	–	350 000	300	350 000
5 001 – 6 000	–	–	–	350 000	350	500 000
Class RK5 Fuses[a]						
0 – 30	11	50	11	50	14	50
31 – 60	20	200	21	200	26	200
61 – 100	22	500	25	500	32	500
101 – 200	32	1 600	40	1 600	50	2 000
201 – 400	50	5 200	60	5 000	75	6 000
401 – 600	65	10 000	80	10 000	100	12 000

[a] The value for a Class RK5 fuse shall be used when a Class RK1 fuse is specified for overcurrent protection.

[b] 800 A values apply to 600 V Class T fuses only.

Table 37
Closing angle

(See 9.2.4.4.2.1)

Number of phases	Bus bar relationship	Bus most likely to cause failure[a]	Closing angle electrical degrees[b, c]
1	All	All	0
3	All	A phase	−13
3	All	C phase	+13
3	All	B phase	±13

[a] With the phase arrangement established in accordance with 8.8.1.2.2.

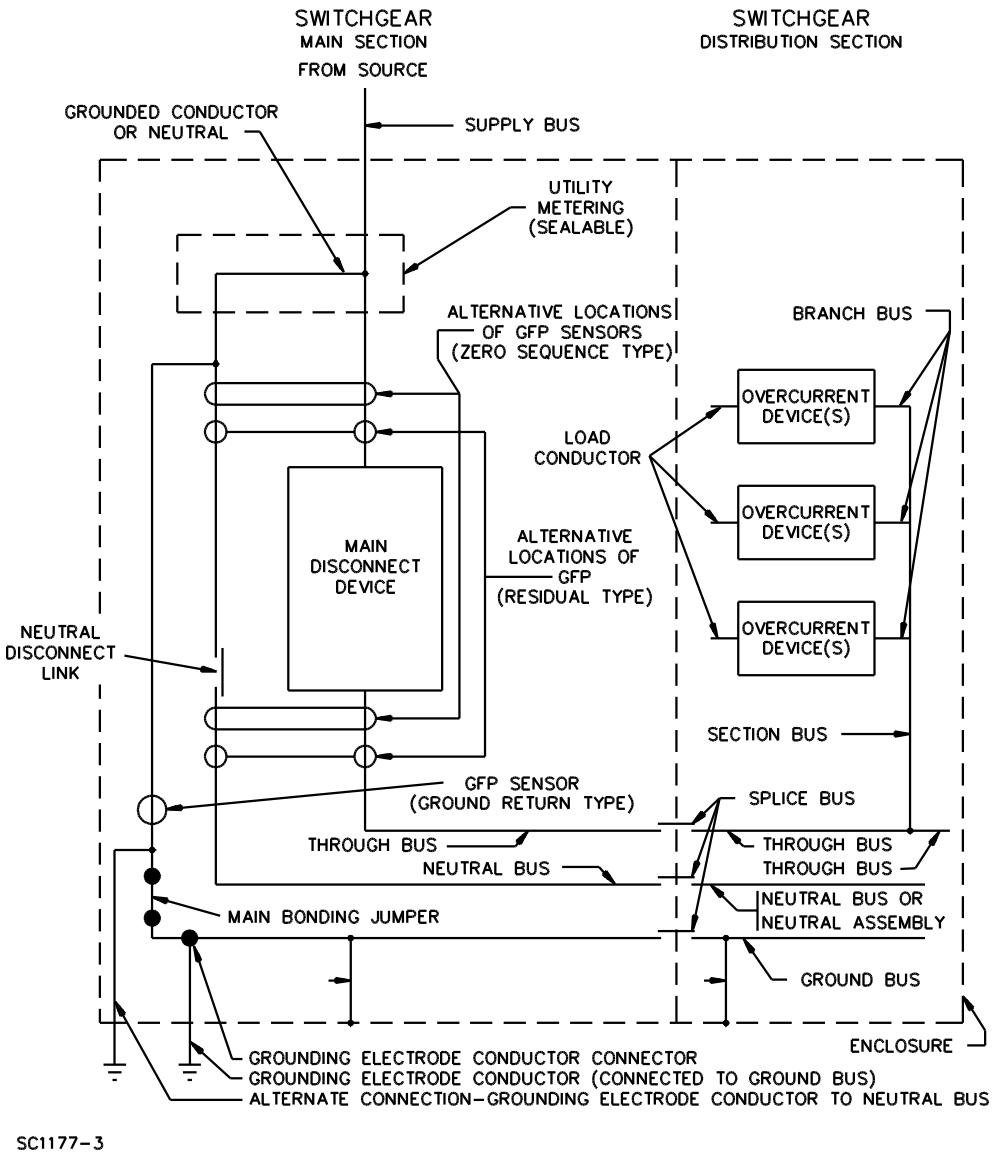
[b] The closing angle is determined with respect to the zero point of the supply voltage, on a phase to neutral basis in the case of a 3-phase circuit.

[c] Tolerance is ±10 degrees.

11 Figures

Figure 1
Typical dead-front switchboard layout

(See 3, 3.9, 3.12, 3.28)



Notes:

1. For Canada the grounding electrode conductor terminal must be in the service section.

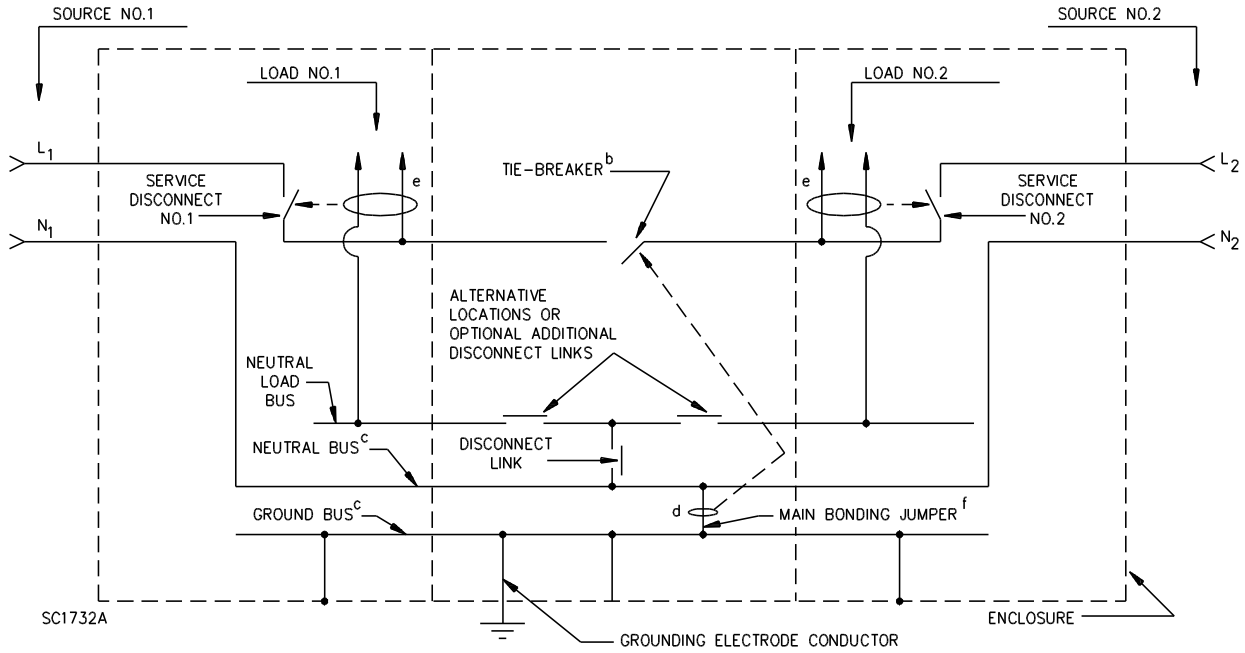
2. The neutral disconnect link is not mandated in Canada but would be acceptable.

3. Terminology in Figure No. 1 is based on the NEC. For Canadian Electrical Code terminology, reference Figure 14.

4. This figure is to demonstrate the use of terminology and does not represent actual construction.

Figure 2
Typical double-ended switchboard

(See 3, 3.9, 3.26, 8.6.5.1)



[a] Other variations are possible.

[b] Tie breaker disconnect (not a circuit breaker marked "Line" and "Load" nor a fused switch).

[c] 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" (Not for Canada).

[d] Ground return type ground fault protection sensor located on tie breaker only.

[e] Zero sequence or residual type ground fault protection sensor.

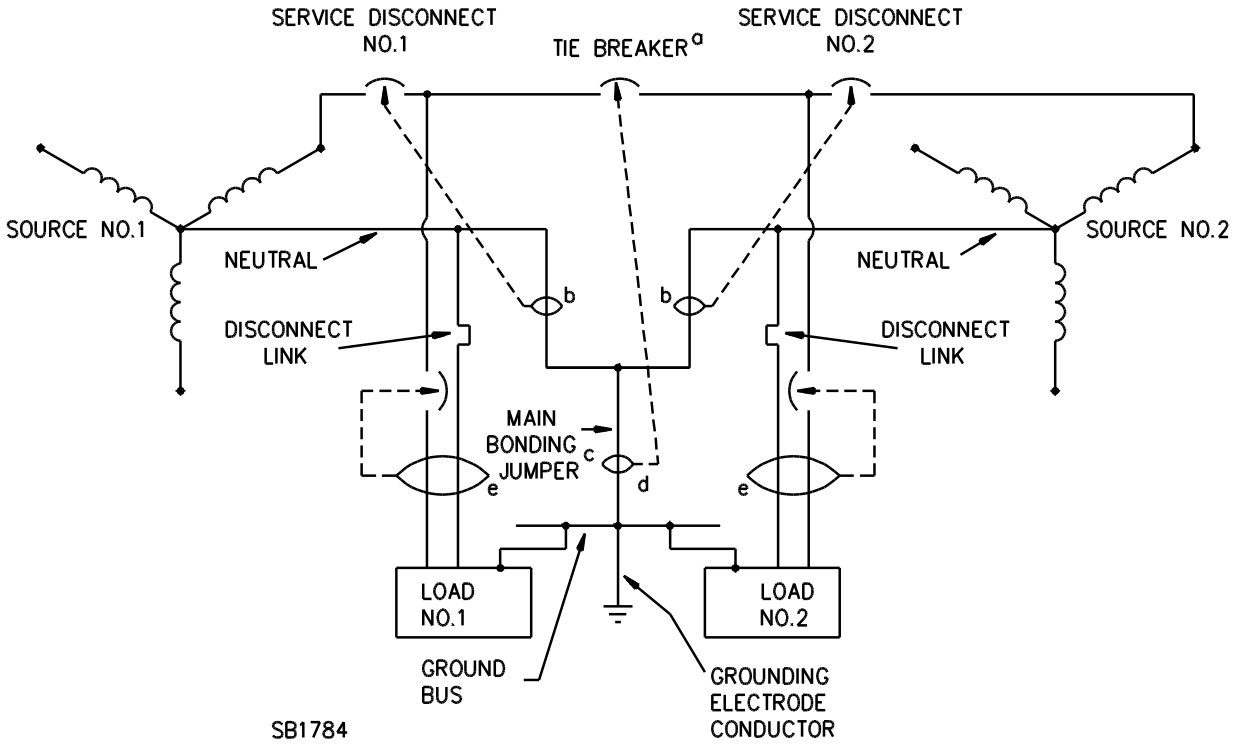
[f] Size of main bonding jumper based on largest service disconnect.

[g] Terminology in Figure 2 is based on the NEC. For comparison of terminology, reference Figure 14.

[h] This figure is to demonstrate the use of terminology and does not represent actual construction.

Figure 3
Typical double-ended switchboard

(See 3, 3.9, 3.26, 8.6.5.1)



[a] Tie breaker disconnect (not a circuit breaker marked "Line" and "Load" nor a fused switch).

[b] Additional ground return type ground fault protection sensors utility interlocked with sensor specified in note d so as to function only when fault current is also sensed as covered in note d.

[c] Size of main bonding jumper based on largest service disconnect (Not for Canada).

[d] Ground return type ground fault protection sensor located on the mains and tie breaker.

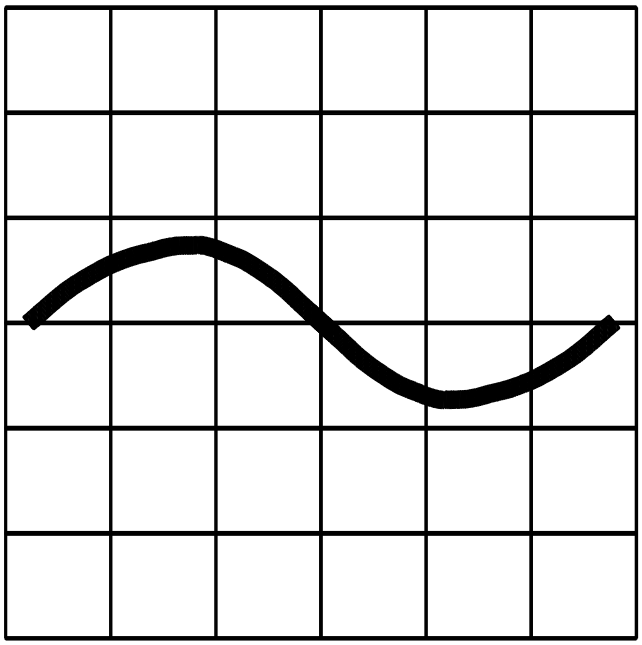
[e] Zero sequence or residual type ground fault protection sensor.

[f] Terminology in Figure 3 is based on the NEC. For comparison of terminology, reference Figure 14.

[g] This figure is to demonstrate the use of terminology and does not represent actual construction.

Figure 4
AC Voltage symbol

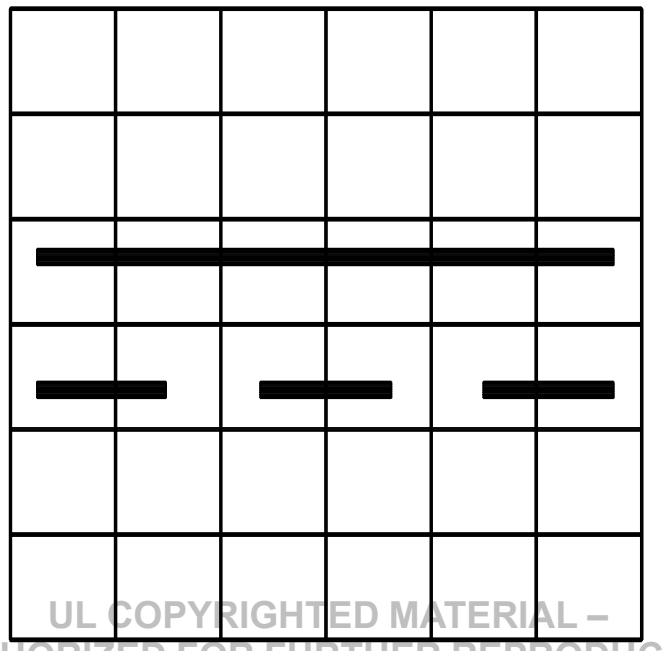
(See 6.2.1.2, 6.2.2)



SM1344

Figure 5
DC Voltage symbol

(See 6.2.1.2, 6.2.2)



SM1345

Figure 6
Barrier behind flanged opening

(See 8.1.6.2, 8.1.12.1)

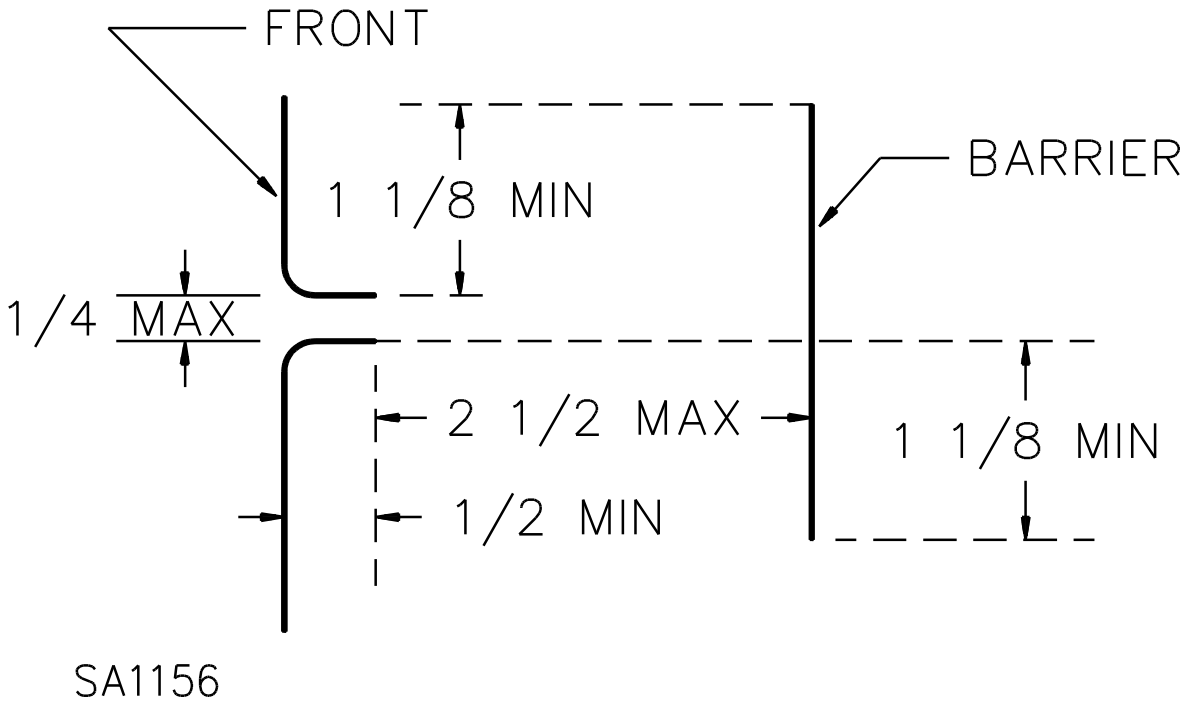
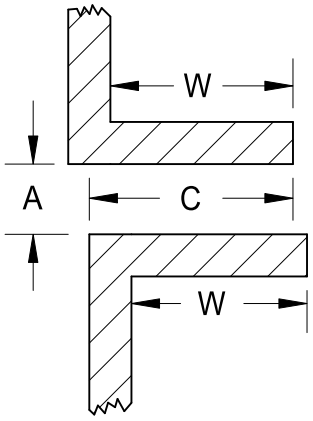


Figure 7
Flanged cover construction

(See 8.1.6.3)



su0694

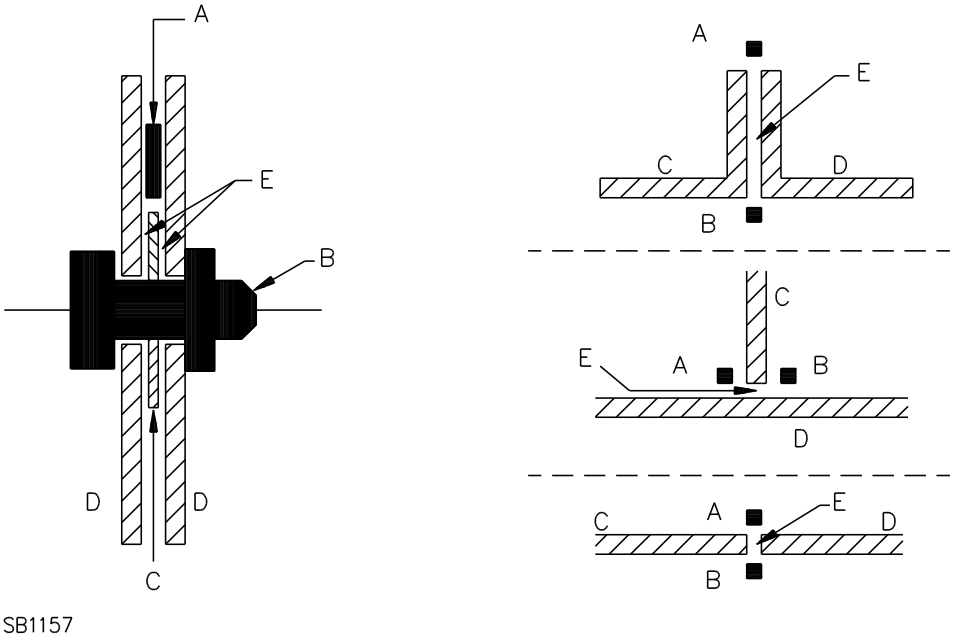
Dimensions for flanged cover constructions

Dimensions					
W Minimum flange width,[a]		A Maximum space between parts,		C Minimum overlap,	
mm	(inch)	mm	(inch)	mm	(inch)
12.7	(1/2)	3.2	(1/8)	11.1	(7/16)

[a] Tolerance: Minus 1.6 mm (1/16 inch)

Figure 8
Clamped joint

(See 8.1.16.7)



SB1157

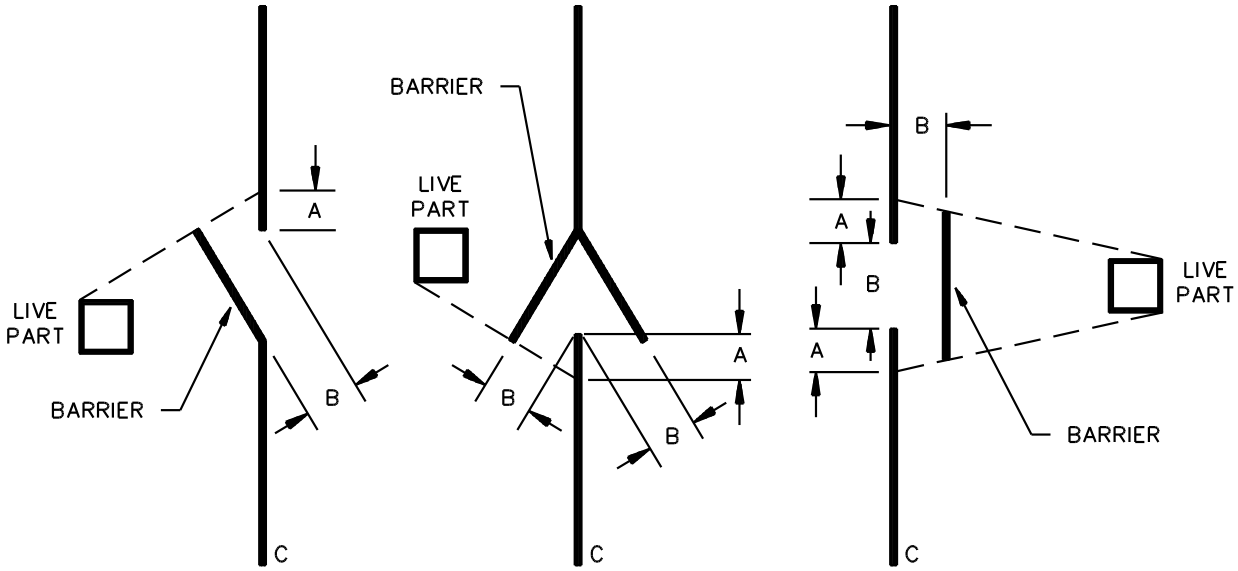
Parts A, B – Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required in Table 6 or Table 7

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between Parts A and B is greater than the equivalent air spacing.

E – The clamped joint (shown in an exaggerated state).

Figure 9
Ventilation openings

(See 8.2.1.3.2)



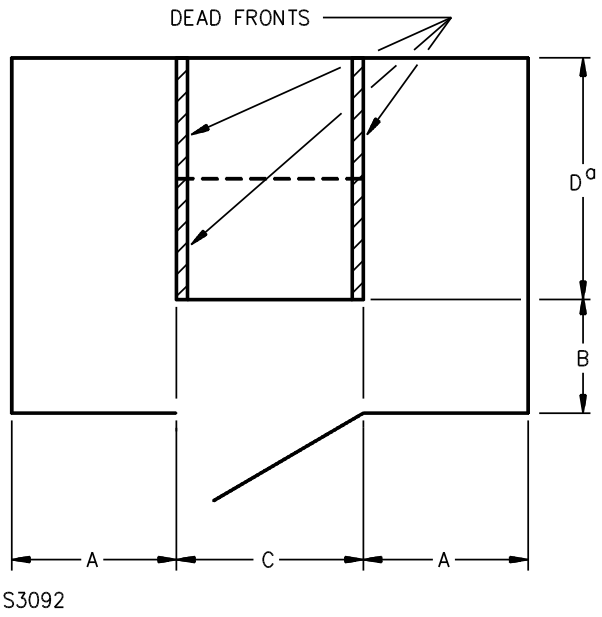
A – The minimum 6.4 mm (1/4 inch) distance specified in 8.2.1.3.2

B – Opening sized in accordance with 8.2.1.3.4

C – Enclosure wall.

Figure 10
Two sided walk-in enclosed construction

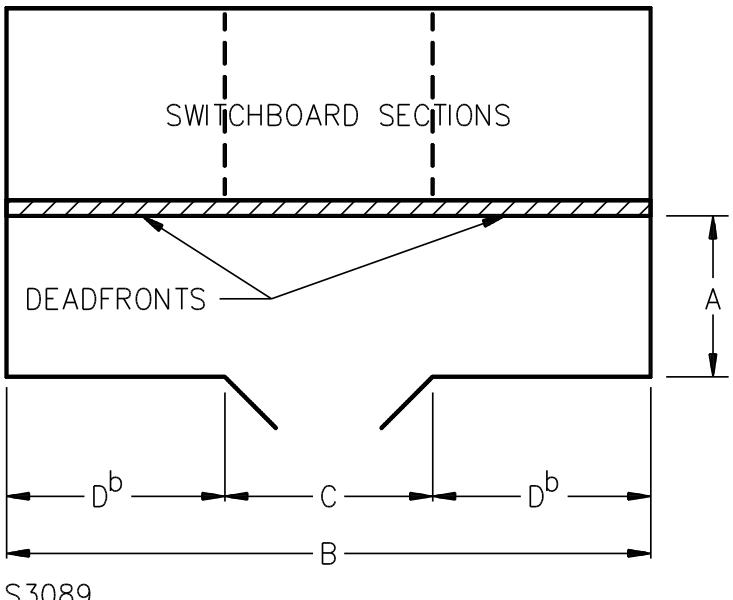
(See 8.2.1.5.7)



Note – A through D dimension indicators are shown only to indicate areas of concern for working clearances. See 8.2.1.5.7.

Figure 11
Single sided walk-in enclosed construction

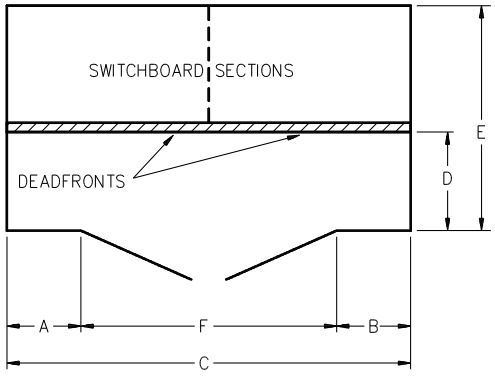
(See 8.2.1.5.7)



Note – A through D dimension indicators are shown only to indicate areas of concern for working clearances. See 8.2.1.5.7.

Figure 12
Single sided non-walk in enclosed switchboard

(See 8.2.1.5.8)



Values of variables

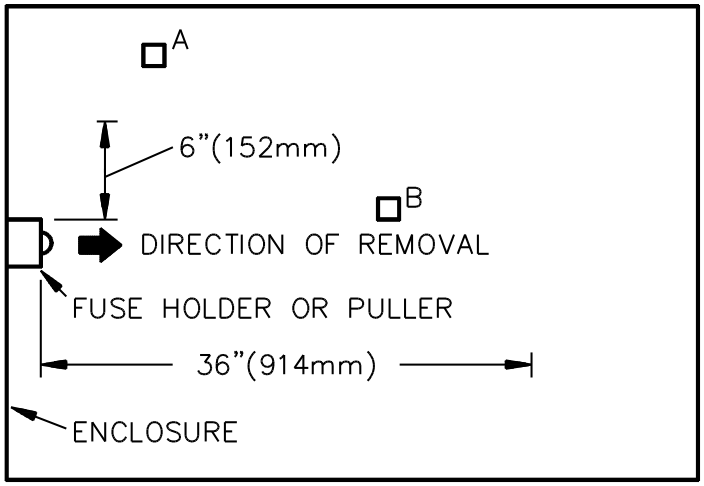
A (maximum)[a]		B (maximum)[a]		C (minimum)		D		E (maximum)[b]		F (minimum)	
mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
12.7	(1/2)	12.7	(1/2)	Not specified		Not specified		610	(24)	Not specified	
76.2	(3)	76.2	(3)	356 (A + B)	14 + (A + B)	Not specified		610	(24)	356	(14)
76.2	(3)	76.2	(3)	610 + (A + B)	24 + (A + B)	Not specified		610	(24)	610	(24)

[a] If the value of dimension A or B is exceeded, then Figure 11 shall apply.

[b] If back access panels are provided, dimension E is not specified. If back access panels are not provided and dimension E exceeds 610 mm (24 inches), then Figure 11 shall apply

Figure 13
Protection of live parts

(See 8.4.1.6.1)



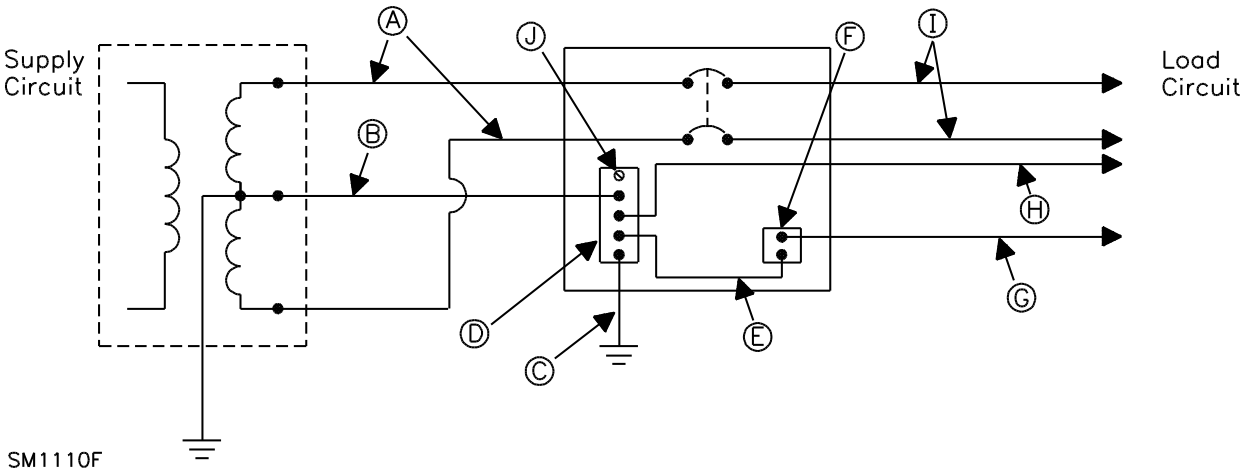
S3093A

A – Exposed Live Part – No Barrier Required

B – Exposed Live Part – Barrier Required

Figure 14
Grounding and bonding terminology

(See 8.4.3.1)



Note: this figure is only intended to show the use of terminology it is not intended to represent construction practices.

LETTER CODE	UL TERMS	CEC TERMS	ANCE TERMS
A	UNGROUNDED SERVICE CONDUCTOR	UNGROUNDED SERVICE CONDUCTOR	CONDUCTORES DE FASE DE LA ACOMETIDA
B	GROUNDED SERVICE CONDUCTOR	GROUNDED SERVICE CONDUCTOR	CONDUCTOR DE ACOMETIDA PUESTO A TIERRA
C	GROUNDING ELECTRODE CONDUCTOR	GROUNDING ELECTRODE CONDUCTOR	CONDUCTOR DEL ELECTRODO DE PUESTA A TIERRA
D	INSULATED NEUTRAL BUS	NEUTRAL BUS	BARRA PARA NEUTRO
E	MAIN BONDING JUMPER	MAIN BONDING JUMPER	PUENTE DE UNION PRINCIPAL
F	GROUND BUS	BONDING BUS/BONDING CONNECTOR	BARRA PARA PUESTA A TIERRA
G	EQUIPMENT GROUNDING CONDUCTOR	BONDING CONDUCTOR	CONDUCTOR DE PUESTA A TIERRA DEL EQUIPO
H	GROUNDED CIRCUIT CONDUCTOR	IDENTIFIED CIRCUIT CONDUCTOR	CONDUCTOR DEL CIRCUITO PUESTO A TIERRA
I	UNGROUNDED CIRCUIT CONDUCTOR	UNGROUNDED CIRCUIT CONDUCTOR	CONDUCTORES DE FASE DEL CIRCUITO
J	SCREW AS BONDING JUMPER	BONDING SCREW	RORRILLO QUE SIRVE COMO PUENTE DE UNION

Figure 15
Ring type meter socket

(See 8.6.3.2)

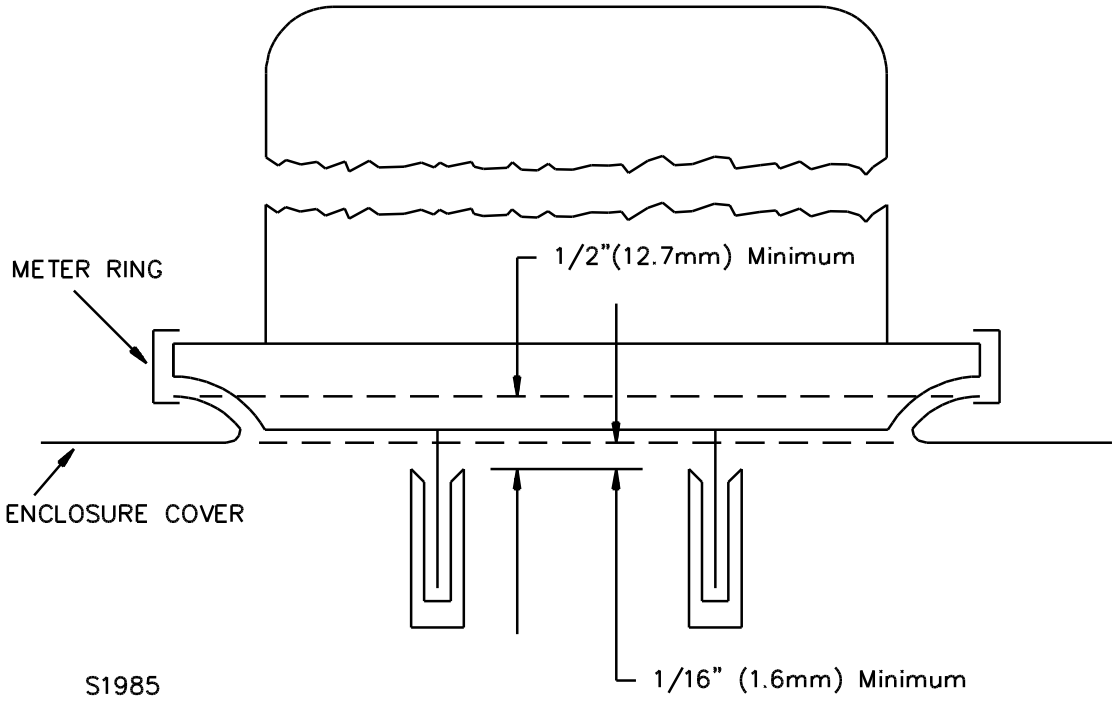


Figure 16
Conductors through openings

(See 8.8.1.8.7)

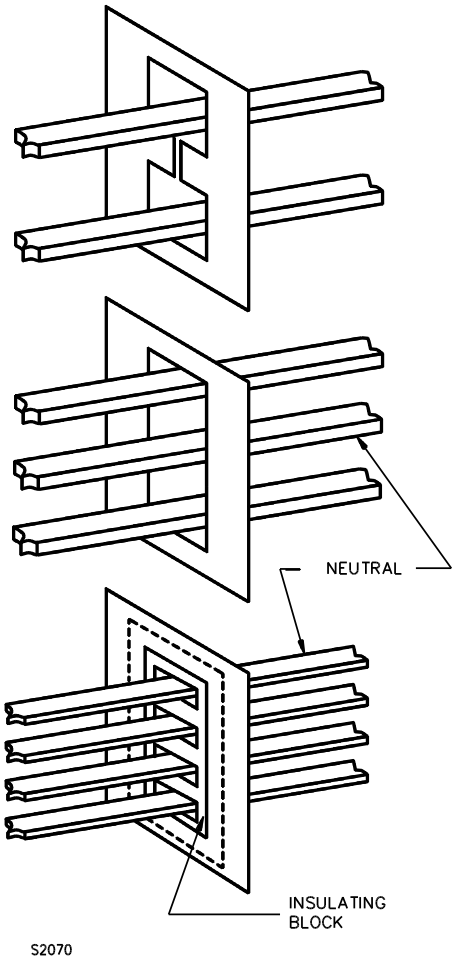


Figure 17
Line connection for tests

(See 9.2.4.2.4.4)

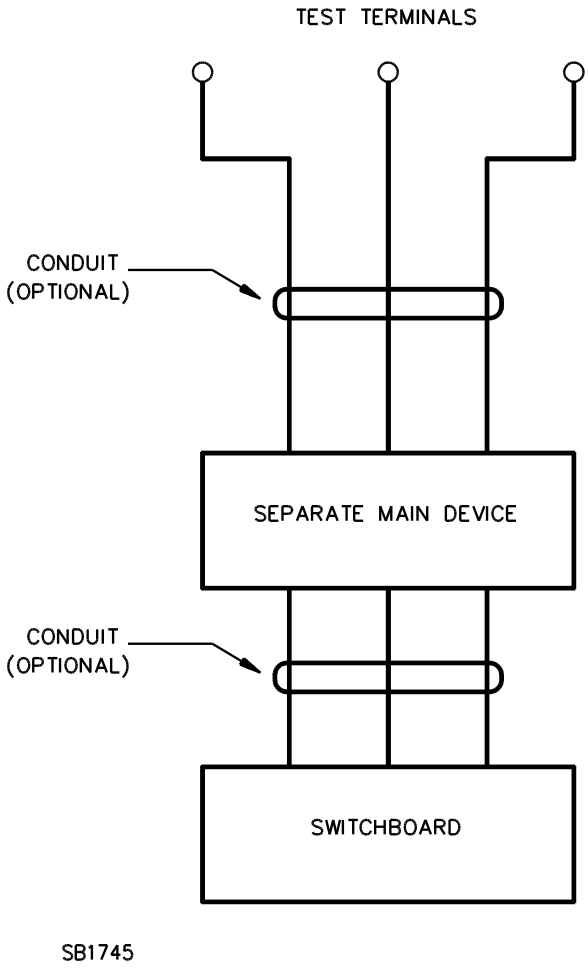
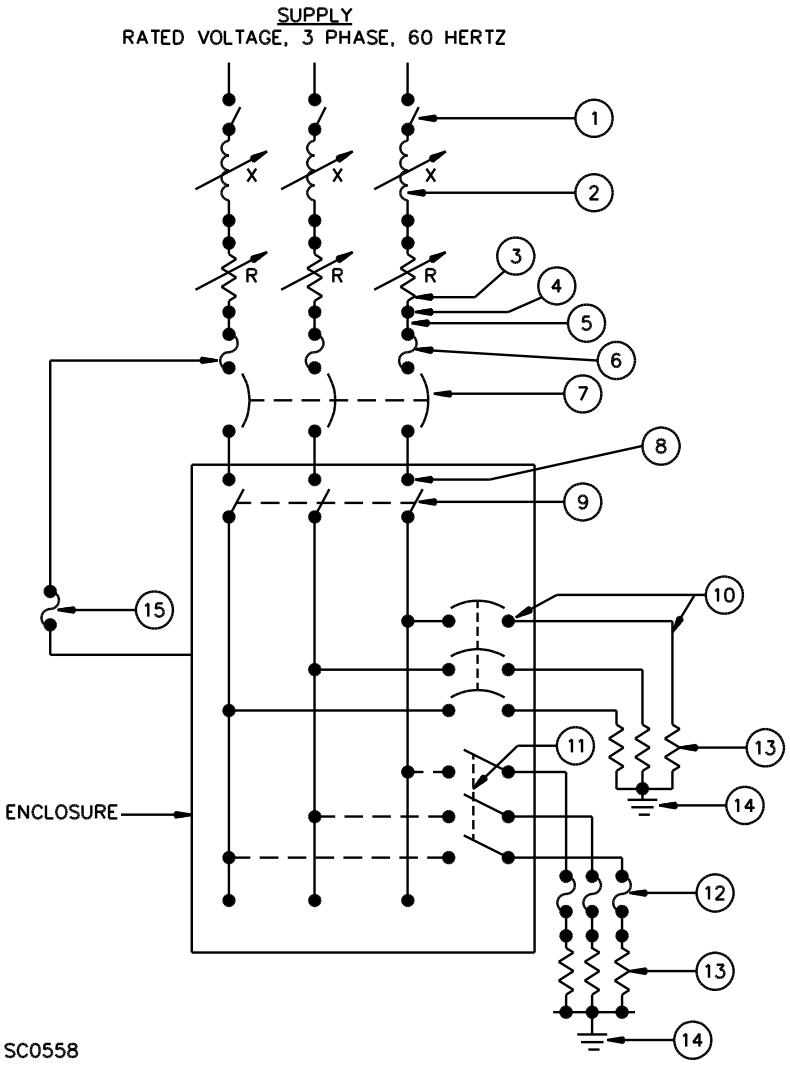


Figure 18
Test circuit wiring diagram

(See 9.2.4.2.4.4, 9.2.4.3.1.1)



1 Closing switch
2 Variable tap air-core reactors
3 Variable resistors
4 Test station terminals
5 Line leads
6 External fuseholder, see 9.2.4.2.4.4
7 Separate main circuit breaker
8 Switchboard line terminals
9 Main circuit breaker or fusible switch. For locations of main fuses, see 9.2.4.2.4.3.
10 Branch circuit breaker and load connection
11 Branch circuit fusible switch with dummy fuses
12 Fuses, see 9.2.4.2.4.2
13 Instrument shunts (if needed)
14 Ground connection (if needed)
15 See 9.2.4.2.1.2

Annex A
(Informative)

Standards for Components

The ANCE, CSA Group, and UL Standards listed below are used for evaluation of components and features of products covered by this Standard. These Standards shall be considered to refer to the latest edition and all amendments published to that edition up to the time when this Standard was approved.

ANCE Standards

NMX-J-451-ANCE, Thermoset insulated wires and cables
NMX-J-235/1-ANCE, Enclosures for Electrical Equipment – Part 1: General requirements
NMX-J-235/2-ANCE, Enclosures for Electrical Equipment – Part 2: Specific requirements
NMX-J-436-ANCE, Flexible cords
NMX-J-118/1-ANCE, Panelboards
NMX-J-010-ANCE, Wires and cables, thermoplastic insulated
NMX-J-162-ANCE, Enclosed and Dead-Front Switches
NMX-J-009/248/1-ANCE, Low-Voltage Fuses – Part 1: General Requirements
NMX-J-009/248/2-ANCE, Low-Voltage Fuses – Part 2: Class C Fuses
NMX-J-009/248/3-ANCE, Low-Voltage Fuses – Part 3: Class CA and CB Fuses
NMX-J-009/248/4-ANCE, Low-Voltage Fuses – Part 4: Class CC Fuses
NMX-J-009/248/6-ANCE, Low-Voltage Fuses – Part 6: Class H Non-Renewable Fuses
NMX-J-009/248/7-ANCE, Low-Voltage Fuses – Part 7: Class H Renewable Fuses
NMX-J-009/248/8-ANCE, Low-Voltage Fuses – Part 8: Class J Fuses
NMX-J-009/248/9-ANCE, Low-Voltage Fuses – Part 9: Class K Fuses
NMX-J-009/248/10-ANCE, Low-Voltage Fuses – Part 10: Class L Fuses
NMX-J-009/248/12-ANCE, Low-Voltage Fuses – Part 12: Class R Fuses
NMX-J-009/248/15-ANCE, Low-Voltage Fuses – Part 15: Class T Fuses
NMX-J-009/248/16-ANCE, Low-Voltage Fuses – Part 16: Test Limiters
NMX-J-543-ANCE, Wire connectors
NMX-J-266-ANCE, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures
NMX-J-515-ANCE, Distribution and control equipment – Safety general requirements
NMX-J-148-ANCE, Busways
NMX-J-520-ANCE, Ground-Fault Circuit-Interrupters
NMX-J-719-ANCE, Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type

CSA Standards

CSA C9-02, Dry-Type Transformers
CSA C22.2 No. 0.15-01, Adhesive Labels
CAN/CSA C22.2 No. 0.17-92, Evaluation of Properties of Polymeric Materials
CSA C22.2 No. 0.5-1982, Threaded Conduit Entries
CAN/CSA C22.2 No. 4-04, Enclosed and Dead Front Switches
CSA C22.2 No. 5-04, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures
CSA C22.2 No. 14-95, Industrial Control Equipment
CSA C22.2 No. 18-98, Outlet Boxes, Conduit Boxes, and Fittings
C22.2 No. 24-93, Temperature-Indicating and -Regulating Equipment (typical)
CSA C22.2 No. 27-00, Busways
CSA C22.2 No. 29-M1989, Panelboards and Enclosed Panelboards
CSA C22.2 No. 39-M1987, Fuseholder Assemblies
CSA C22.2 No. 40-M1989, Cutout, Junction, and Pull Boxes
CSA C22.2 No. 42-99, General Use Receptacles
CAN/CSA-C22.2 No. 47-M90, Air-Cooled Transformers (Dry Type)
CSA C22.2 No. 55-M1986, Special Use Switches
C22.2 No. 66.1-06, Low Voltage Transformers – Part 1: General Requirements
C22.2 No. 66.2-06, Low Voltage Transformers – Part 2: General Purpose Transformers
C22.2 No. 66.3-06, Low Voltage Transformers – Part 3: Class 2 Transformers

CSA C22.2 No. 65-03, Wire Connectors
CSA C22.2 No. 75-03, Thermoplastic Insulated Wire and Cables
CAN/CSA C22.2 No. 94-M91, Special Purpose Enclosures
C22.2 No. 111-00, General Use Switches
C22.2 No. 115-M1989, Meter-Mounting Devices
CSA C22.2 No. 144-M91[R1997], Ground Fault Circuit Interrupters
CSA C22.2 No. 158-1987, Terminal Blocks
CAN/CSA-C22.2 No. 177-92, Clock-Operated Switches
CSA C22.2 No. 178.1-17, Automatic Transfer Switches
CSA C22.2 No. 182.1-17, Plugs, receptacles, and cable connectors of the pin and sleeve type
CSA C22.2 No. 182.2-02, Industrial Locking Type, Special Use Attachment Plugs, Receptacles, and Connectors
CSA C22.2 No. 182.3-M1987, Industrial Type Special Use Attachment Plugs, Receptacles and Connectors
CSA C22.2 No. 197-M1983, PVC Insulating Tape
CSA C22.2 No. 198.1-99, Extruded Insulated Tubing
CSA C22.2 No. 229-M1988, Switching and Metering Centres
CSA C22.2 No. 248.1-00, Low Voltage Fuses – Part 1: General Requirements
CSA C22.2 No. 248.2-00, Low Voltage Fuses – Part 2: Class C Fuses
CSA C22.2 No. 248.3-00, Low Voltage Fuses – Part 3: Class CA and CB Fuses
CSA C22.2 No. 248.4-00, Low Voltage Fuses – Part 4: Class CC Fuses
CSA C22.2 No. 248.5-00, Low Voltage Fuses – Part 5: Class G Fuses
CSA C22.2 No. 248.6-00, Low Voltage Fuses – Part 6: Class H Non-renewable Fuses
CSA C22.2 No. 248.7-00, Low Voltage Fuses – Part 7: Class H Renewable Fuses
CSA C22.2 No. 248.8-00, Low Voltage Fuses – Part 8: Class J Fuses
CSA C22.2 No. 248.9-00, Low Voltage Fuses – Part 9: Class K Fuses
CSA C22.2 No. 248.10-00, Low Voltage Fuses – Part 10: Class L Fuses
CSA C22.2 No. 248.12-00, Low Voltage Fuses – Part 12: Class R Fuses
CSA C22.2 No. 248.15-00, Low Voltage Fuses – Part 15: Class T Fuses
CSA C22.2 No. 248.16-00, Low Voltage Fuses – Part 16: Test Limiters
CSA C22.2 No. 1691-12, Single pole locking-type separable connectors

UL Standards

General Use Snap Switches – UL 20
Thermoset-Insulated Wires and Cables – UL 44
Enclosures for Electrical Equipment, Non-Environmental Considerations –UL 50
Flexible Cord and Fixture Wire – UL 62
Panelboards – UL 67
Wires and Cables, Thermoplastic-Insulated – UL 83
Plastic Materials for Parts in Devices and Appliances, Test for Flammability of – UL 94
Enclosed and Dead-Front Switches – UL 98
Tubing, Extruded Insulating – UL 224
Low-Voltage Fuses – Part 1: General Requirements – UL 248-1
Low-Voltage Fuses – Part 2: Class C Fuses – UL 248-2
Low Voltage Fuses – Part 3: Class CA and CB Fuses – UL 248-3
Low Voltage Fuses – Part 4: Class CC Fuses – UL 248-4
Low Voltage Fuses – Part 6: Class H Non-Renewable Fuses – UL 248-6
Low Voltage Fuses – Part 7: Class H Renewable Fuses – UL 248-7
Low Voltage Fuses – Part 8: Class J Fuses – UL 248-8
Low Voltage Fuses – Part 9: Class K Fuses – UL 248-9
Low Voltage Fuses – Part 10: Class L Fuses – UL 248-10
Low-Voltage Fuses – Part 12: Class R Fuses – UL 248-12
Low-Voltage Fuses – Part 15: Class T Fuses – UL 248-15
Low-Voltage Fuses – Part 16: Test Limiters – UL 248-16
Knife Switches – UL 363
Meter Sockets – UL 414
Wire Connectors – UL 486A-486B
Molded Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures – UL 489
Attachment Plugs and Receptacles – UL 498

Specialty Transformers – UL 506
Industrial Control Equipment – UL 508
Tape, Polyvinyl Chloride, Polyethylene, and Rubber Insulating – UL 510
Fuseholders – Part 1: General Requirements – UL 4248-1
Fuseholders – Part 4: Class CC – UL 4248-4
Fuseholders – Part 6: Class H – UL 4248-6
Fuseholders – Part 8: Class J – UL 4248-8
Fuseholders – Part 9: Class K – UL 4248-9
Fuseholders – Part 12: Class R – UL 4248-12
Fuseholders – Part 15: Class T – UL 4248-15
Conduit, Tubing and Cable Fittings – UL 514B
Polymeric Materials – Short Term Property Evaluations – UL 746A
Polymeric Materials – Long Term Property Evaluations – UL 746B
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C
Polymeric Materials – Fabricated Parts – UL 746D
Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards – UL 746E
Busways – UL 857
Reference Standard for Service Equipment – UL 869A
Temperature-Indicating and -Regulating Equipment – UL 873
Clock-Operated Switches – UL 917
Ground-Fault Circuit-Interrupters – UL 943
Marking and Labeling Systems – UL 969
Fused Power-Circuit Devices – UL 977
Transfer Switch Equipment – UL 1008
Sheathed Heating Elements – UL 1030
Ground-Fault Sensing and Relaying Equipment – UL 1053
Special-Use Switches – UL 1054
Terminal Blocks – UL 1059
Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures – UL 1066
Electrical and Electronic Measuring and Testing Equipment – UL 1244
Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment – UL 1332
Pullout Switches – UL 1429
Electrical Analog Instruments – Panel Board Types – UL 1437
Systems of Insulating Materials – General – UL 1446
Dry-Type General Purpose and Power Transformers – UL 1561
Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve – UL 1682
Single Pole Locking-Type Separable Connectors – UL 1691
Low Voltage Transformers – Part 1: General Requirements – UL 5085-1
Low Voltage Transformers – Part 2: General Purpose Transformers – UL 5085-2
Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers – UL 5085-3

Annex B
(Normative)

Standards Referenced in the Trinational Switchboard Standard

Where reference is made to other organization's standards, such reference shall be considered to refer to the latest edition and all amendments published to that edition up to the time when this standard was approved.

Ref. No.	United States	Canada	Mexico
1	UL 67, Panelboards	C22.2 No. 29, Panelboards and Enclosed Panelboards	NMX-J-118/1-ANCE-2000, Electrical Products – Panelboards – Specifications and Test Methods
2	UL 50, Enclosures for Electrical Equipment, Non-Environmental Considerations and 50E, Enclosures for Electrical Equipment, Environmental Considerations	C22.2 No. 94.1 and C22.2 No. 94.1 94.2 and 94.2, Enclosures for Electrical Equipment	NMX-J-235/1-ANCE-2008 Enclosures for Electrical Equipment, Non-Environmental Considerations and NMX-J-235/2-ANCE-2014, Enclosures for Electrical Equipment Environmental Considerations
3	UL 746C, Standard for Polymeric Materials – Used in Electrical Equipment Evaluations	CAN/CSA-C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	NMX-J-565/3-ANCE-2006, Safety Requirements – Flammability of Plastic Materials for Parts in Devices and Appliances – Test Methods
4	ASTM D3874, Standard Test Method for Ignition of Materials by Hot Wire Sources	C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	No equivalent
5	ASTM D3638, Standard Test Method for Comparative Tracking Index for Electrical Insulating Materials	C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	No equivalent
6	UL 746A, Standard for Polymeric Materials – Short Term Property Evaluations	C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials	No equivalent
7	UL 489, Molded Case Circuit Breakers, Molded Case Switches, and Circuit Breaker Enclosures	C22.2 No. 5, Molded Case Circuit Breakers, Molded Case Switches and Enclosures for Circuit Breakers	NMX-J-266-ANCE-2014, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit- Breaker Enclosures
8	UL 5085-1, Low Voltage Transformers – Part 1: General Requirements UL 5085-2, Low Voltage Transformers – Part 2: General Purpose Transformers UL 5085-3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers	C22.2 No. 66.1, Low Voltage Transformers – Part 1: General Requirements C22.2 No. 66.2, Low Voltage Transformers – Part 2: General Purpose Transformers C22.2 No. 66.3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers	No equivalent
9	UL 486A-486B, Wire Connectors	C22.2 No. 65, Wire Connectors	NMX-J-543-ANCE-2013, Connectors – Wire Connectors – Specifications and Test Methods
10	UL 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors	No equivalent	No equivalent
11	ANSI/IEEE 32-1991, Terminology, and Test Procedures for Neutral Grounding Devices	C22.2 No. 295, Neutral Grounding Devices	No equivalent
12	UL 969, Marking and Labelling Systems	C22.2 No. 0.15, Adhesive Labels	NMX-J-515-ANCE, Distribution and control equipment – Safety general requirements
13	No equivalent	C235, Preferred voltage Levels for AC Systems, 0 to 50 000V	NMX-J-098-ANCE, Standard Voltages

Ref. No.	United States	Canada	Mexico
14	UL 746C, Polymeric Materials – Used in Electrical Equipment Evaluations	No equivalent	No equivalent
15	No equivalent	C22.2 No. 0, General Requirements	No equivalent
16	UL 746C, Polymeric Materials – Used in Electrical Equipment Evaluations	C22.2 No. 0.17 Evaluation of Properties of Polymeric Materials	No equivalent
17	No equivalent	C22.2 No. 0.4, Bonding and Grounding of Electrical Equipment (Protective Grounding)	No equivalent
18	No equivalent	C22.2 No. 47, Air-Cooled Transformers (Dry Type)	No equivalent
19	No equivalent	C22.2 No. 100, Motors and Generators	No equivalent
20	UL 414, Meter Sockets	C22.2 No. 115, Meter-Mounting Devices	No equivalent

Annex C
(Informative)

Markings Required to be Translated and Suggested French Translations

Clause	English	French
6.2.1.8	MAXIMUM CONTINUOUS LOADS NOT TO EXCEED 80 percent OF THE OVERCURRENT PROTECTIVE DEVICE (CIRCUIT BREAKER AND FUSES) RATINGS EMPLOYED IN OTHER THAN MOTOR CIRCUITS, EXCEPT FOR THOSE CIRCUITS EMPLOYING CIRCUIT BREAKERS MARKED AS SUITABLE FOR CONTINUOUS OPERATION AT 100 percent OF THEIR RATINGS	LES CHARGES CONTINUES MAXIMALES POUR LES DÉRIVATIONS NE DOIVIENT PAS ÊTRE SUPÉRIEURES À 80 percent DU COURANT NOMINAL DES DISJONCTEURS UTILISÉS POUR DES CIRCUITS AUTRES QUE DES CIRCUITS DE MOTEUR. TOUTEFOIS, CETTE MESURE NE S'APPLIQUE PAS AUX CIRCUITS MUNIS DE DISJONCTEURS CONVENANT POUR SERVICE CONTINU À 100 percent DE LEURS CARACTÉRISTIQUES NOMINALES.
6.2.1.14	WHEN PROTECTED BY _____ AMPERE MAXIMUM CLASS R+ FUSE OR (MANUFACTURER'S NAME AND TYPE DESIGNATION) CIRCUIT BREAKER RATED NOT MORE THAN _____ AMPERES THIS SWITCHBOARD IS SUITABLE FOR USE ON A CIRCUIT CAPABLE OF DELIVERING NOT MORE THAN _____ RMS SYMMETRICAL (FOR AC CIRCUITS) AMPERES, _____ VOLTS MAXIMUM	ATTENTION : LORSQUE LA PROTECTION EST ASSURÉE PAR UN FUSIBLE HPC NOMINAL MAXIMAL DE _____A, OU UN DISJONCTEUR (NOM DU FABRICANT ET DISIGNATION DU TYPE) AYANT UN COURANT NOMINAL NON SUPÉRIEUR À _____ A, CE TABLEAU DE CONTRÔLE CONVIENT POUR UTILISA.TION SUR UN CIRCUIT POUVANT DÉBITER _____ A (VALEUR EFFICACE SYMÉTRIQUE), _____ V, AU MAXIMUM.
6.2.7.23	USE _____ AWG 90 °C WIRE	UTILISER DU CONDUCTEUR _____ AWG, 90 °C.
6.2.2.1(a)(1)	SUITABLE FOR USE AS SERVICE EQUIPMENT	ACCEPTABLE COMME APPAREILLAGE DE BRANCHEMENT
6.2.2.8.1	COMPARTMENT FOR ELECTRICAL SUPPLY AUTHORITY USE ONLY	COMPARTIMENT RÉSERVÉ AU DISTRIBUTEUR D'ÉLECTRICITÉ.
6.2.17.1	THIS SWITCHBOARD SHALL BE LOCATED WHERE ACCESSIBLE ONLY TO QUALIFIED PERSONS	LE TABLEAU DE CONTRÔLE DOIT ÊTRE SITUÉ OÙ IL EST ACCESSIBLE SEULEMENT AUX PERSONNES QUALIFIÉS
6.2.18.1(a)	FOR USE BY QUALIFIED PERSONNEL ONLY	RÉSERVÉ AU PERSONNEL QUALIFIÉ
6.2.18.1(b)	WARNING – RISK OF ELECTRIC SHOCK PLUG CONNECTION SHOULD BE IN THE FOLLOWING ORDER: 1) EQUIPMENT GROUNDING CONDUCTOR CONNECTORS; 2) GROUNDED CIRCUIT CONDUCTOR CONNECTORS; AND 3) UNDERGROUND CONDUCTOR CONNECTORS. DISCONNECTION SHOULD BE IN THE REVERSE ORDER	AVERTISSEMENT - RISQUE D'ÉLECTROCUTION LE BRANCHEMENT DEVRAIT ÊTRE FAIT SELON L'ORDRE SUIVANT: 1) LES CONNECTEURS DES CONDUCTEURS DE MISE À LA TERRE DE L'ÉQUIPEMENT; 2) LES CONNECTEURS DES CONDUCTEURS DES CIRCUITS MIS À TERRE; 3) LES CONNECTEURS DES CONDUCTEURS NON MIS À TERRE. LE DÉBRANCHEMENT DEVRAIT ÊTRE FAIT SELON L'ORDRE INVERSE.
6.2.18.3(a)	WARNING – FOR CONNECTION OF A NONSEPARATELY DERIVED (FLOATING NEUTRAL) SYSTEM ONLY	AVERTISSEMENT – POUR CONNEXION D'UN SYSTÈME NON DÉRIVÉ SÉPARÉMENT (NEUTRE FLOTTANT) SEUMEMENT
6.2.18.3(b)	WARNING – FOR CONNECTION OF A SEPARATELY DERIVED (BONDED NEUTRAL) SYSTEM ONLY	AVERTISSEMENT – POUR CONNEXION D'UN SYSTÈME DÉRIVÉ SÉPARÉMENT (NEUTRE MIS À LA MASSE) SEUMEMENT
6.3.4.4.1	CAUTION – THIS SWITCHBOARD IS CONSTRUCTED FOR PARALLEL SOURCE APPLICATIONS FROM MULTIPLE SOURCES. SYNCHRONIZATION EQUIPMENT SHALL BE PROVIDED.	ATTENTION – CE TABLEAU DE CONTRÔLE EST CONSTRUIT POUR LES APPLICATIONS DE SOURCE PARALLÈLE DE SOURCES MULTIPLES. L'ÉQUIPMENT DE SYNCHRONISATION DOIT ÈTRE FOURNI AUTREMENT.

Annex D
(Informative)

Example of Series Short-Circuit Current Rating Marking

D.1 As specified in 6.2.1.12(g), a switchboard section or interior shall be marked as follows:

a) "The short-circuit current rating of this switchboard is equal to the lowest interrupting rating of any installed circuit breaker or fused switch, but not more than ____ rms symmetrical (for AC circuits) amperes at _____ volts, 3-phase (for AC circuits), or _____ rms symmetrical (for AC circuits) amperes at _____volts, single phase (for AC circuits) ;" and

b) "The interrupting rating of a circuit breaker is 5 000 rms symmetrical amperes and for a fused switch is 10 000 rms symmetrical amperes", or as marked on the device, except for the following series combination ratings:

Load side circuit breakers				**Line side circuit breakers**			**Interrupting rating**		
Mfr.	Type	Poles	Ampere rating	Mfr.	Type	Ampere rating	Symmet. amperes rms	Volts ac	Phases
Load side circuit breakers				**Line side fused switch**			**Interrupting rating**		
Mfr.	Type	Poles	Ampere rating	Fuse class	Volts ac	Amperes	Symmet. amperes rms	Volts ac	Phases

The indication of a voltage rating for a line-side fused switch is necessary only for Class T fuses.

Annex E
(Informative)

Example of Terminal Torque Marking

E.1 With regard to 6.2.7.14, an example of a typical torque marking is shown in Table E1. The example is based on a 400 A switchboard equipped with the following wire connectors:

a) Main terminals – A connector for paralleling with 7.9 mm (5/16 in) socket head screws; the wire range of the connector is 21.2 – 152 mm^2 (4 AWG – 300 kcmil), copper or aluminum.

b) Neutral terminals:

1) Main connector – A connector with a 7.9 mm (5/16 in) socket head screw, and a wire range of 21.2 – 152 mm^2 (4 AWG – 300 kcmil), copper or aluminum.

2) Large branch connector – A connector with a slotted screw larger than 4.8 mm (No. 10) diameter, a slot wider than 1.2 mm (0.047 inch), and a slot length more than 6.4 mm (1/4 inch). The wire range of the connector is 53.5 – 2.1 mm^2 (1/0 – 14 AWG), copper or aluminum.

3) Small branch connector – A connector with a slotted No. 10 screw, a slot 1.2 mm (0.047 inch) wide and 6.4 mm (1/4 inch) long. The wire range of the connector is 21.2 – 2.1 mm^2 (4 – 14 AWG), copper or aluminum.

c) Equipment grounding terminal – A connector with two different size conductor openings as follows:

1) Large hole – A connector with a slotted screw larger than 4.8 mm (No. 10) diameter, a slot less than 1.2 mm (0.047 inch) wide and more than 6.4 mm (1/4 inch) long. Note that this connector requires an assigned torque to achieve one wire combination. For single conductors, the wire range of this hole is 53.5 – 2.1 mm^2 (1/0 – 14 AWG), copper or aluminum. Multiple conductor combinations with a solid configuration are as follows:

No. of conductors	Size		Material
	AWG	(mm^2)	
2	10	(5.3)	Cu
2	12	(3.3)	Cu
2	14	(2.1)	Cu
2	10	(5.3)	Al
2	12	(3.3)	Al
3	10	(5.3)	Cu
3	12	(3.3)	Cu
3	14	(2.1)	Cu
3	10	(5.3)	Al
3	12	(3.3)	Al

2) Small hole – A connector with a slotted 4.8 mm (No. 10) diameter screw, a slot width of 1.2 mm (0.047 inch), and a slot length less than 6.4 mm (1/4 inch). For single conductors, the wire range of this hole is 13.3 – 2.1 mm^2 (6 – 14 AWG), copper or aluminum. Multiple conductor combinations with a stranded configuration are as follows:

No. of conductors	Size		Material
	AWG	(mm^2)	
2	14	(2.1)	Cu
2	12	(3.3)	Cu
2	12	(3.3)	Al

Table E1
Example of typical torque marking

(See E.1)

Tightening torque for wire connectors	
Main terminals	31.1 N·m (275 pound-inches)
Neutral terminals:	
Main	31.1 N·m (275 pound-inches)
Large Branch (Connector or Hole)	Torque screw to applicable value shown in Column B of the table for the conductor size installed
Small Branch (Connector or Hole)	Torque screw to applicable value shown in Column A of the table for the conductor size installed.
Equipment Grounding Terminals:	
Large Hole	For three 5.3 mm^2 (10 AWG) solid copper conductors, torque screw to 5.1 N·m (45 pound-in). For all other wire combinations, torque screw to value shown in column B of the table for the conductor size installed.
Small Hole	Torque screw to applicable value shown in Column A of the table for the conductor size installed.
Field-Installed Devices	Torque screw to value indicated on (or with) the device.

Tightening torque table					
Wire size installed in connector		Tightening torque			
		A		B	
(mm^2)	AWG	Newton·meters	(Pound-in)	Newton·meters	(Pound-in)
(0.82 – 5.3)	18 – 10	2.3	(20)	4.0	(35)
(8.4)	8	2.8	(25)	4.5	(40)
(13.2 – 21.2)	6 – 8	4.0	(35)	5.1	(45)
(26.7)	3	4.0	(35)	5.7	(50)
(33.5)	2	4.5	(40)	5.7	(50)
(42.4)	1	–	–	5.7	(50)
(53.5)	1/0	–	–	5.7	(50)
(67.4)	2/0	–	–	5.7	(50)

Annex F
(normative)

Short-Circuit Test at Reduced Voltage

F1 Voltage

F1.1 While not required for calculation purposes, the actual potential of the test is determined for the record. The test potential shall be not less than 100 V.

F2 Current

F2.1 The power factor and the magnitude of the actual test current required to pass through the bus bars of the test sample shall be adjusted so that, for a single phase test, the maximum single phase peak instantaneous amperes, and, for a 3-phase test, the average rms asymmetrical amperes, are each equal to or higher than the calculated values for a test made at rated voltage.

F2.2 The magnitude of the rms symmetrical test current that would pass through the bus bars of the test sample, when tested at rated voltage, shall be calculated by the following formulas:

a) For a 3-phase switchboard:

$$I_{T3} = \frac{V_3}{\sqrt{(A\frac{V_3}{I_{R3}} + 6\sqrt{3}\ R_3)^2 + (B\frac{V_3}{I_{R3}} + 6\sqrt{3}\ X_3)^2}}$$

In which:

I_{T3} is the test current in symmetrical amperes that would flow at a 3-phase rated voltage test.

A and B are cosine and sine multiplying factors from Table F1.

V_3 is the voltage rating of the switchboard (line to line).

I_{R3} is the RATED 3-phase short-circuit current in symmetrical amperes at voltage V_3.

R_3 is the alternating-current resistance of the buses in ohms per foot on a line to neutral basis.

X_3 is the reactance of the buses in ohms per foot on a line to neutral basis.

Maximum required average rms total current is $M^a I_{T3}$, using the ratio M^a from Table F2 based on the value of X_{T3}/R_{T3}.

In which:

M^a is the ratio from Table F2 of average 3-phase rms total asymmetrical amperes at 1/2 cycle to symmetrical rms amperes.

X_{T3} is the total reactance of the test current source and the switchboard if tested on a source of rated voltage.

R_{T3} is the total alternating-current resistance of the test current source and the switchboard if tested on a source of rated voltage.

And:

$$\frac{X_{T3}}{T_{T3}} = \frac{B\,V_3 + 6\sqrt{3}\,X_3\,I_{R3}}{A\,V_3 + 6\sqrt{3}\,R_3\,I_{R3}}$$

b) For a single phase switchboard:

$$I_{T1} = \frac{V_1}{\sqrt{(A\frac{V_1}{I_{R1}} + 6R_1)^2 + (B\frac{V_1}{I_{R1}} + 6X_1)^2}}$$

In which:

I_{T1} is the TEST current in symmetrical amperes that would flow at a rated voltage test.

A and B are cosine and sine multiplying factors from Table F1.

V_1 is the voltage rating of the switchboard (line to line)

I_{R1} is the RATED single-phase short-circuit current in symmetrical amperes at voltage V_1.

R_1 is the alternating-current resistance of the buses in ohms per foot for the single phase connection.

X_1 is the reactance of the buses in ohms per foot for the single phase connection.

Maximum required single phase peak instantaneous amperes is M_pI_{T1}, using the ratio M_p from Table F2 based on the value of X_{T1}/R_{T1}.

In which:

M_p is the ratio from Table F2 of maximum single-phase instantaneous peak amperes during the first cycle to symmetrical amperes.

X_{T1} is the total reactance of the test current source and the switchboard if tested on a source of rated voltage.

R_{T1} is the total alternating-current resistance of the test current source and the switchboard if tested on a source of rated voltage.

And:

$$\frac{X_{T1}}{R_{T1}} = \frac{BV_1 + 6X_1\,I_{R1}}{AV_1 + 6R_2\,I_{R1}}$$

F2.3 The formulas specified in F2.2 give values of test currents that will produce short-circuit stresses closely comparable to those that will occur if the short-circuit test is conducted at rated voltage.

F2.4 The magnitude of the test current shall be determined from an oscillogram. For an alternating-current test, single phase peak instantaneous amperes and 3-phase rms asymmetrical total current shall be determined with the buses short circuited on the load end so that the test current flows through the buses. The rms asymmetrical total current is to include the direct current component, if any. It shall be measured at an instant 1/2 cycle after the short circuit occurs and shall be calculated in accordance with the latest revisions of the Guide for Calculation of Fault Currents for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis, ANSI/IEEE C37.5-1979 and Methods for Determining the values of a Sinusoidal Current Wave and a Normal-Frequency Recovery Voltage for AC High-Voltage Circuit Breakers, ANSI C37.05-1964. The rms symmetrical current shall be determined with the supply terminals short-circuited by measuring the a-c component of the wave at an instant 1/2 cycle (on the basis of a power frequency timing wave) after the initiation of the short-circuit. The current shall be calculated in

accordance with the Test Procedure for AC High-Voltage Circuit Breakers Rated On A Symmetrical Current Basis, ANSI/IEEE C37.09-1979.

Table F1
Sine and cosine factors

Rated short-circuit current, symmetrical amperes		Multiplying factors	
More than	Not more than	A	B
0	10 000	0.500	0.866
10 000	20 000	0.300	0.954
20 000	200 000	0.200	0.980

Table F2
Short-circuit parameters

(See Clause F2.2)

Short-circuit power factor percent	Short-circuit X/R ratio	Ratio to symmetrical RMS amperes	
		Minimum 1-phase instantaneous peak amperes M_p	Average 3-phase asymmetrical RMS amperes at 1/2 cycle M_A
0	4	2.828	1.394
1	99.995	2.785	1.374
2	49.990	2.743	1.354
3	33.318	2.702	1.336
4	24.980	2.663	1.318
5	19.975	2.625	1.302
6	16.637	2.589	1.286
7	14.251	2.554	1.271
8	12.460	2.520	1.256
9	11.066	2.486	1.242
10	9.9499	2.455	1.229
11	9.0357	2.423	1.216
12	8.2731	2.394	1.204
13	7.6270	2.364	1.193
14	7.0725	2.336	1.182
15	6.5912	2.309	1.172
16	6.1695	2.282	1.162
17	5.7967	2.256	1.152
18	5.4648	2.231	1.144
19	5.1673	2.207	1.135
20	4.8990	2.183	1.127
21	4.6557	2.160	1.119
22	4.4341	2.138	1.112
23	4.2313	2.116	1.105
24	4.0449	2.095	1.099
25	3.8730	2.074	1.092
26	3.7139	2.054	1.087
27	3.5661	2.034	1.081
28	3.4286	2.015	1.076
29	3.3001	1.996	1.071

Table F2 Continued on Next Page

Table F2 Continued

Short-circuit power factor percent	Short-circuit X/R ratio	Ratio to symmetrical RMS amperes	
		Minimum 1-phase instantaneous peak amperes M_p	Average 3-phase asymmetrical RMS amperes at 1/2 cycle M_A
30	3.1798	1.978	1.066
31	3.0669	1.960	1.062
32	2.9607	1.943	1.057
33	2.8605	1.926	1.053
34	2.7660	1.910	1.050
35	2.6764	1.894	1.046
36	2.5915	1.878	1.043
37	2.5109	1.863	1.040
38	2.4343	1.848	1.037
39	2.3611	1.833	1.034
40	2.2913	1.819	1.833
41	2.2246	1.805	1.029
42	2.1608	1.791	1.027
43	2.0996	1.778	1.025
44	2.0409	1.765	1.023
45	1.9845	1.753	1.021
46	1.9303	1.740	1.019
47	1.8780	1.728	1.017
48	1.8276	1.716	1.016
49	1.7790	1.705	1.014
50	1.7321	1.693	1.013
55	1.5185	1.641	1.008
60	1.3333	1.594	1.004
65	1.1691	1.553	1.002
70	1.0202	1.517	1.001
75	0.8819	1.486	1.0004
80	0.7500	1.460	1.00012
85	0.6197	1.439	1.00002
90	0.4843	1.424	1.00000
95	0.3287	1.416	1.00000
100	0.0000	1.414	1.00000

F2.5 If testing at less than rated voltage, the determination of the switchboard characteristics of X and R shall be made as follows:

a) The electrical characteristics of the switchboard are calculated for measurements of current and power input and voltage drop across the two switchboard sections. The electrical characteristics are used in calculating the current required when a short-circuit test is conducted at other than rated voltage. The test set up shall be made as shown in Figure F1, modified if necessary to record values for a single phase or direct-current rated switchboard.

b) The test current may be derived from any convenient source of potential. The value of current used shall be that of the supply circuit rating of the switchboard. For a 3-phase test circuit, the rms symmetrical current shall be the average of the currents in the three phases. However, the rms symmetrical current in any one phase shall not be less than 90 percent of the value of the rated current.

c) The value of voltage drop shall be measured by observing the input voltage between pairs of input terminals of the sample with rated current flowing in all bus bars with the load or output terminals shorted together by the shortest practical length of bus of the same ampacity as the

through bus of the switchboard. The test and readings shall be conducted with the sample heated to constant temperature. The voltage drop value used in calculations is the average of the observed values for a polyphase rated switchboard, and the actual observed value for a single phase or direct-current rated switchboard. The voltage drop is measured at the input end of the switchboard with the short circuit applied between the elements at the load end.

d) The power input for a 3-phase test is obtained from the sum of observed wattmeter readings. For a single phase test, the power input is determined with the potential coil of the wattmeter connected between the line bus bars.

e) The calculations in are to be made where the length of the sample is L (ft) and V, I, and P are the measured volts, amperes, and watts, respectively.

Table F3
Calculations for switchboard impedance and resistance characteristics

(See F2.5)

Solving for	Calculation	
	Single-phase units	3-phase units
Impedance: Ohms per foot on a line-to-neutral basis	$Z_1 = \frac{V}{IL}$	$Z_3 = \frac{V}{IL\sqrt{3}}$
AC resistance: Ohms per foot on a line-to-neutral basis	$R_1 = \frac{P}{I^2L}$	$R_3 = \frac{P}{3I^2L}$
Reactance: Ohms per foot on a line-to-neutral basis	$X_1 = \sqrt{Z^2_1 - R^2_1}$	$X_3 = \sqrt{Z^2_3 - R^2_3}$

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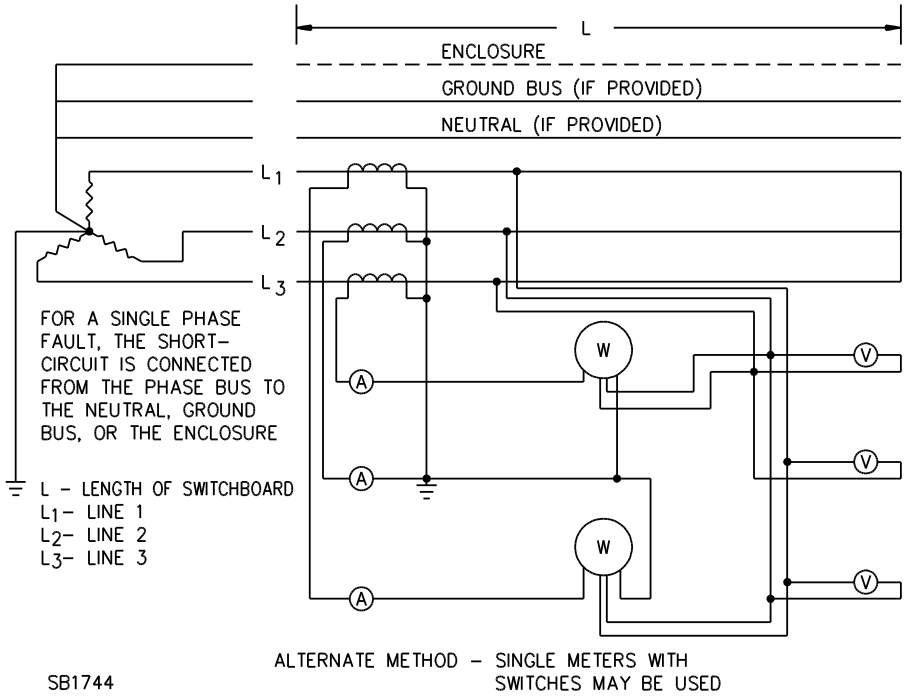
Figure F1
Test circuit

(See F2.5)



Annex G
(normative)

Maximum 100 000 Ampere Short-Circuit Current Rating Without Short-Circuit Test

G1 Scope

G1.1 These requirements cover switchboard sections and current transformer compartments having a short-circuit current rating for which short-circuit tests may be waived. These requirements, which are applicable to products intended for use in Canada, Mexico or the United States, do not otherwise amend the requirements in this standard.

G2 Glossary

G2.1 For the purposes of this Annex, the following definitions apply.

G2.2 Brace – a mechanical assembly that is secured to bus bars to restrict relative motion between the bus bars.

G2.3 Support – a mechanical assembly that is secured to bus bars and that is further secured to a rigid structural member such as the enclosure or a separate member secured to the framework.

G3 Construction

G3.1 General

G3.1.1 A maximum short-circuit current rating as shown in Table G3.1 may be assigned to a through bus (which includes a splice bus), a tap, and a section bus, of a switchboard rated as specified in Table G3.1 without conducting short-circuit tests if all the following conditions are met:

a) The construction complies with the requirements in G3.1.2 – G3.3.5.

b) The performance complies with requirements in G4.1.1 – G4.3.1.

c) The switchboard is marked in accordance with G5.1.

G3.1.2 For a maximum assigned short-circuit current rating of 100 000 A, the switchboard (consisting of one or more sections) shall contain a single integral main molded-case circuit breaker, AC power circuit breaker, or fused switch having a short-circuit rating not less than that of the switchboard, or shall be marked for use with a remote device of one of these types as covered in 6.2.1.14 having a short-circuit current rating not less than that of the switchboard. Supply bus bars ahead of the main overcurrent protective device shall be located in the same section or an adjacent section.

G3.1.3 Copper or aluminium bus bars shall be nominally 6.4 mm (1/4 inch) thick and have a width as described in Table G3.1; holes in bus bars shall not be larger than 11.1 by 20.7 mm (0.438 by 0.813 inch) with the larger dimension limited to use along the axis of the bus bar.

Exception: Larger holes may be provided as specified in G3.1.4 for provision of current transformers.

G3.1.4 With regard to Figure G3.1, copper or aluminium bus bars shall be minimum 6.4 mm (1/4 inch) thick and 50.8 – 102 mm (2 – 4 inches) wide; holes in bus bars at supports shall not be larger than 10.3 by 19.1 mm (0.406 by 0.750 inch) and holes for bus bar type current transformers shall not be larger than 14.3 by 35.7 mm (9/16 by 1-13/32 inches). A bus bar shall be prevented from rotating by means other than the mounting bolt specified in G3.3.3.

Table G3.1
Switchboard ratings and characteristics

(See G3.1.1, G3.1.3, G3.1.7, G3.2.1, G3.2.2 and Figure G3.2, and Figure G3.4 – Figure G3.7)

Max. RMS sym. short-circuit current	Min. ampere rating	Max. ampere rating	Max. voltage rating (single or three-phase, or DC)	Min. bus bar width		Max. bus bar width[a]		Bus bars FF or EE[b]	No. of phases	Minimum distance between opposite polarity bus bars[c]				Maximum distance between supports or fraction thereof[d]		Ref. Figures
										Closest point		Center to center				
amps	amps	amps	volts	in.	(mm)	in.	(mm)			in.	(mm)	in.	(mm)	in.	(mm)	
100 000[e]	800	4 000[f]	480[f]	4	102	7	178	EE	3	1	25.4	5	127	21[g]	533	Figure G3.2 – Figure G3.6
									1	2[g]	50.8	6[g]	152			
100 000[e]	800	4 000[f]	480[f]	4	102	7	178	FF	3	4	102	6	152	13[h]	330	Figure G3.7
									1	5	127	7	178			
65 000	800	4 000[f]	480[f]	4	102	7	178	EE	3	1	25.4	5	127	21[g]	533	Figure G3.2 – Figure G3.6
									1	2[g]	50.8	6[g]	152			
65,00-0	800	4,000[f]	480[f]	4	102	7	178	FF	3	4	102	6	152	21[i]	533	Figure G3.7
									1	5	127	7	178			
50 000	800	4 000[f]	480[f]	2	50.8	4	102	EE[j]	3	1-1/2	38.1	3-1/2	88.9	14	356	Figure G3.2 – Figure G3.6
									1	2	50.8	6	152			
50 000	800	4 000[f]	480[f]	2	50.8	4	102	FF	3	4	102	6	152	21[i]	533	Figure G3.7
									1	5	127	7	178			
42 000	200	1500	480	2	50.8	4	102	EE[j]	1,3	5	127	9	229	21	533	Figure G3.1

[a] Bus bars nominally 6.4 mm (1/4 inch) thick aluminum or copper, one to four per phase. Refer to G3.1.3 and G3.1.4 for mounting and support hole size.

[b] Refer to G3.1.7 (EE – bus bars arranged edge to edge; FF – bus bars arranged face to face).

[c] Refer to G3.2.2 – G3.2.5 and Figure G3.8 and Figure G3.9. Spacing between bus bars crossing at right angles may be as covered in G3.2.3.

[d] Refer to G3.1.4 – G3.3.5 and Figure G3.1 – Figure G3.7, Figure G4.1, and Figure G4.2.

[e] Integral or remote main circuit breaker or fused switch required as described in G3.1.2 . Ratings are not applicable to a tap.

[f] The maximum voltage rating may be 600 V if the current rating does not exceed 2 000 A.

[g] The minimum distance may be 25.4 mm (1 inch) for the closest point and 127 mm (5 inches) center to center if the distance between supports is no more than 432 mm (17 inches).

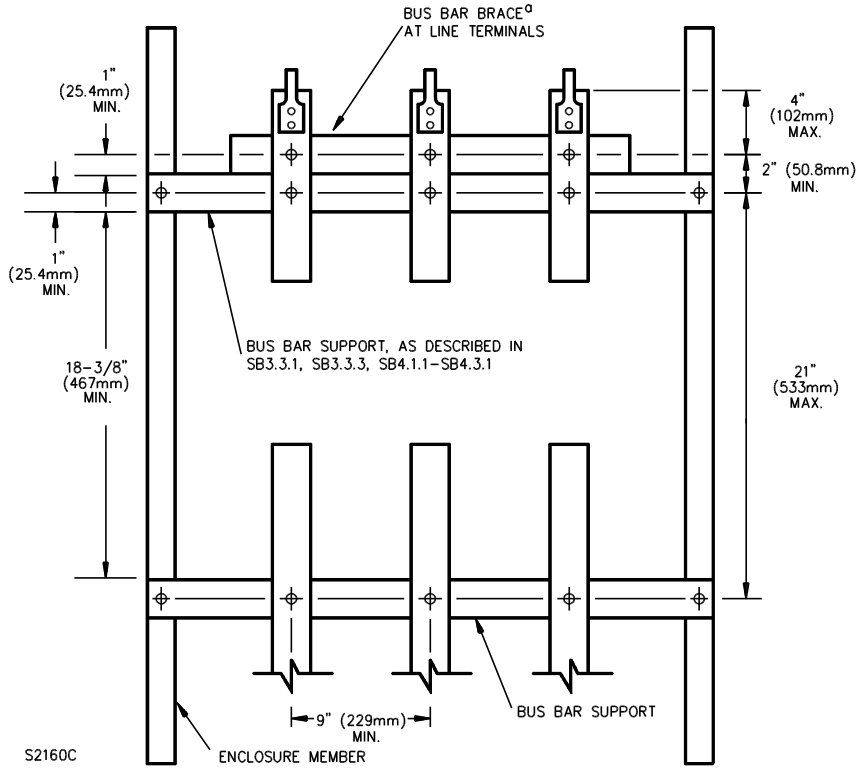
[h] Supports may be located a maximum of 1219 mm (48 inches) apart if braces are located maximum 330 mm (13 inches) apart. See Figure G3.7.

[i] Supports may be located a maximum 1219 mm (48 inches) apart if braces are located maximum 533 mm (21 inches) apart. See Figure G3.7.

[j] Bus bars greater than 50.8 mm (2 inches) in width may be L-shaped as covered in the Exception to G3.1.5.

Figure G3.1
Current transformer (CT) compartment

(See Clauses G3.1.4, G3.1.7, G3.3.4, G3.3.5 and Table G3.1)

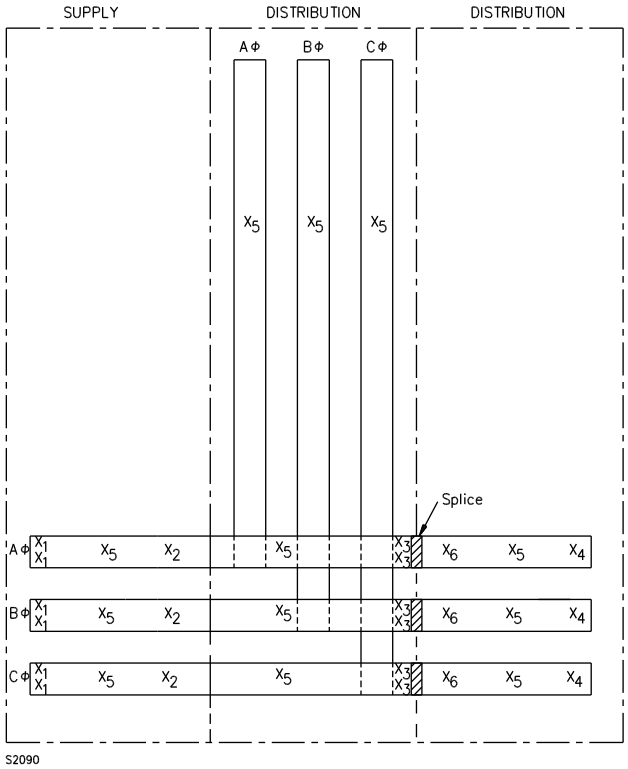


NOTE – Constructions shown in Figure G3.2 – Figure G3.6 may also be used at connection to current transformers.

[a] See G3.3.5.

Figure G3.2
Location of supports for edge-to-edge connection of bus bars for a switchboard marked for use without a main or for use with a remote main

(See G3.1.7, G3.2.3, G3.3.4, Figure G3.1, Figure G3.3, Figure G3.5, Figure G3.6, Figure G3.7 and Table G3.1)



In which:

X – Bus supports (bolts to nonmetallic channel, standoff insulator, or steel channel) as shown in Figure G3.10 – Figure G3.12.

X_1X_1 – Two at end of bus in supply section except that one support may be used with a single bus bar 50.8 – 76.2 mm (2 – 3 inches) wide with a short-circuit current rating of 50 000 A or less.

X_2 – At end of section. One support when horizontal bus is continuous.

X_3X_3 – When splice plate is used, two supports for copper bus, one support for aluminum bus, except that one support may be used for a single copper bus bar 50.8 – 76.2 mm (2 – 3 inches) wide with a short-circuit current rating of 50 000 A or less.

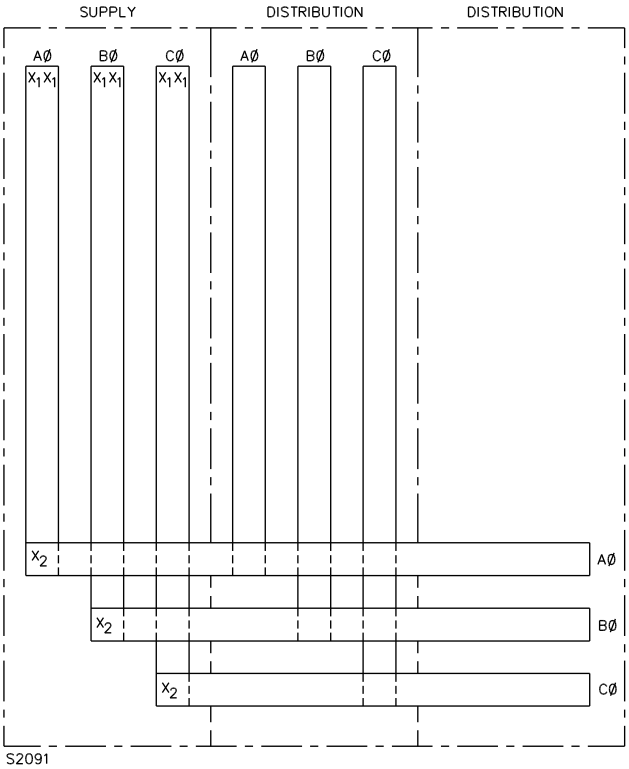
X_4 – One support required at end of horizontal bus.

X_5 – One support required at intervals as described in Table G3.1. Connection of vertical bus to horizontal bus may serve as a support for the vertical bus but not for the horizontal bus. See G3.2.3 for spacings between bus bars at cross-overs.

X_6 – At the load of splice bus, one support required.

Figure G3.3
Location of supports for right-angle connection of edge-to-edge bus bars for a switchboard without a main or marked for use with a remote main

(See Clause G3.1.7, G3.2.3, G3.3.4, Figure G3.1, Figure G3.7 and Table G3.1)



In which:

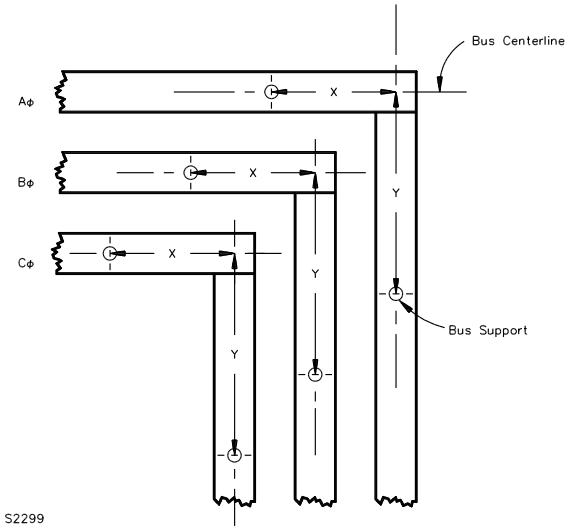
X_1X_1 – Two supports required at line terminal end except one support may be used for single bus bar 50.8 – 76.2 mm (2 – 3 inches) wide with a short-circuit current rating of 50 000 A or less.

X_2 – One support required at connection of vertical to horizontal bus or as shown in Figure G3.4.

Note – For all other supports see Figure G3.2.

Figure G3.4
Distance between supports

(See Clauses G3.1.7, G3.2.3, G3.3.4, Figure G3.1, Figure G3.3, Figure G3.5, Figure G3.6 and Table G3.1)

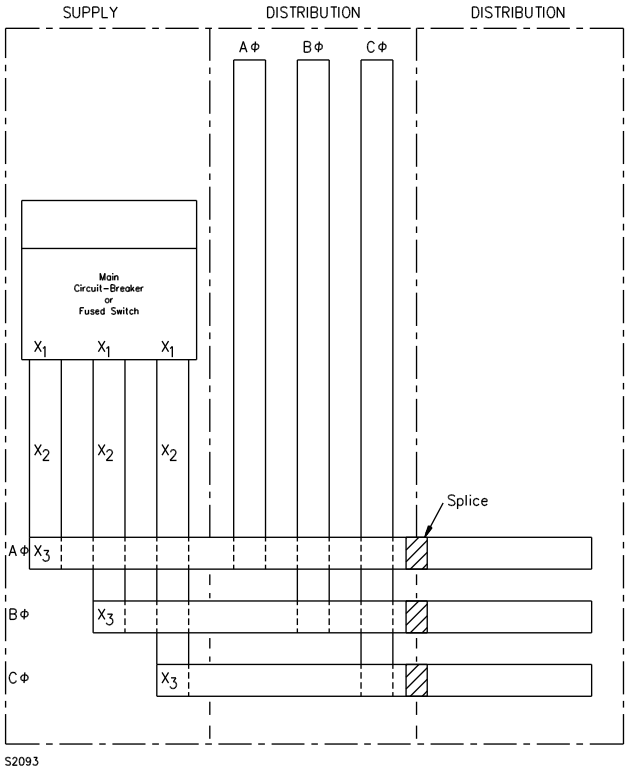


Distance X+Y equals maximum distance allowed between supports.

Distance X plus Y is maximum distance between supports as shown in Table G3.1.

Figure G3.5
Location of supports for edge-to-edge connection of bus bar with cables connected directly to main

(See Clauses G3.1.7, G3.2.3, G3.3.4 and Table G3.1)



In which:

X_1 – For the purposes of determining distances from Table G3.1, this point is considered a support.

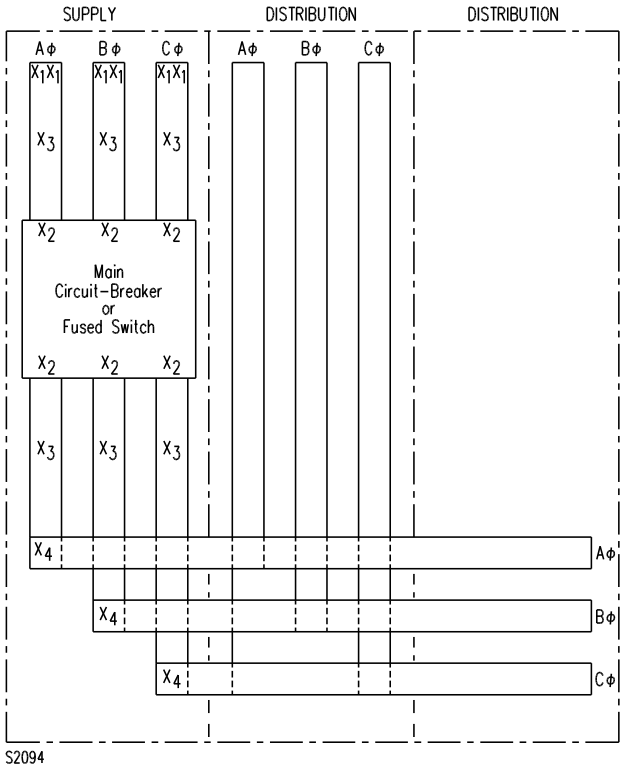
X_2 – One support required at intervals as specified in Table G3.1.

X_3 – Support at connection of vertical bus to horizontal or as shown in Figure G3.4.

Note – For all other supports see Figure G3.2.

Figure G3.6
Location of supports for right-angle connection of edge-to-edge bus bar with cables not connected directly to main

(See Clauses G3.1.7, G3.2.3, G3.3.4, Figure G3.1, and Table G3.1)



In which:

X_1X_1– Two supports required at line terminal and except only one support may be used for a single bus bar 50.8 – 76.2 mm (2 – 3 inches) wide with a short-circuit current rating of 50 000 A or less.

X_2 – For the purposes of determining distances from Table G3.1, this point is considered a support.

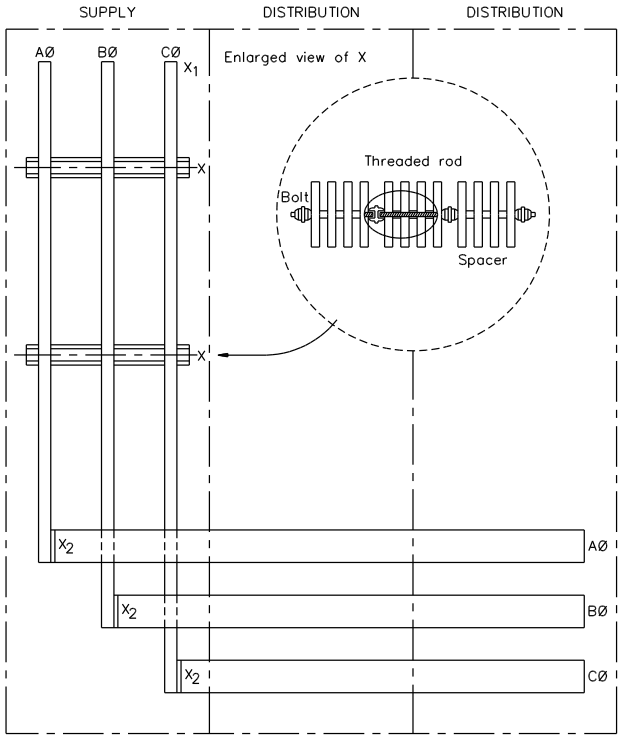
X_3 – One support required at intervals as specified in Table Table G3.1.

X_4 – One support required at connection of vertical to horizontal bus or as shown in Figure G3.4.

Note – For all other supports see Figure G3.2.

Figure G3.7
Location of supports and braces for face-to-face connection of bus bars

(See Clauses G3.1.7, G3.2.3, G3.3.4, and Table G3.1)



In which:

X_1 – Line connection – support provided by transformer or busway stub connected to enclosure.

X – Mechanical bracing between bus bars, support located at intervals described in Table G3.1 starting at X_1. Bracing not required to be secured to enclosure.

X_2 – One support located not more than 1.2 m (48 inches) from X_1. For supports along horizontal bus see Figure G3.2 and Figure G3.3. See G3.2.3 for spacing between bus bars at cross over.

Figure G3.8
Distances between edge-to-edge bus bars of opposite polarity

(See Clauses G3.1.7, G3.2.1, and Table G3.1)

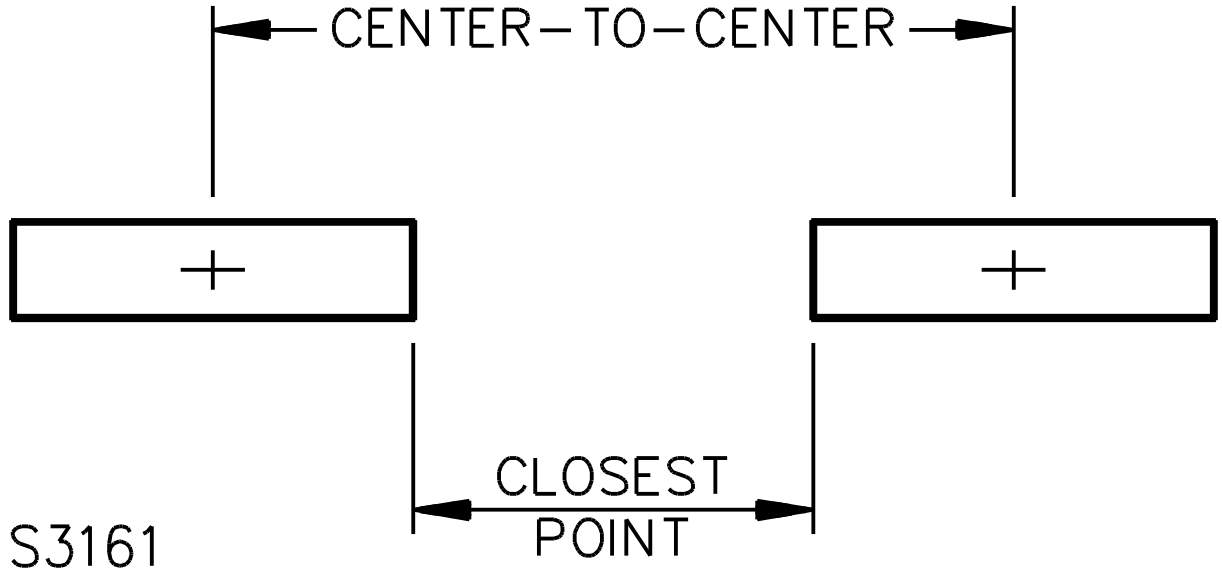


Figure G3.9
Distances between face-to-face bus bars of opposite polarity

(See Clauses G3.1.7, G3.2.2, and Table G3.1)

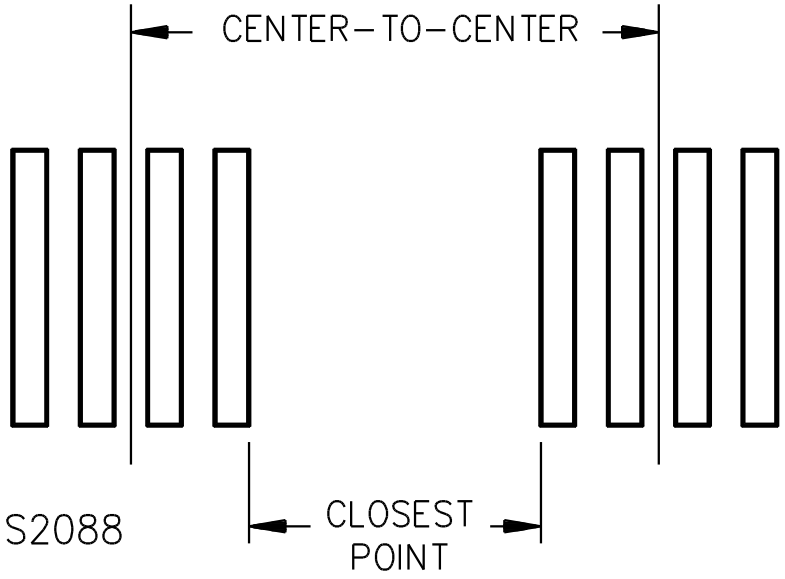


Figure G3.10
Steel channel bus bar support dimension

(See Clause G3.3.1 and Figure G3.2)

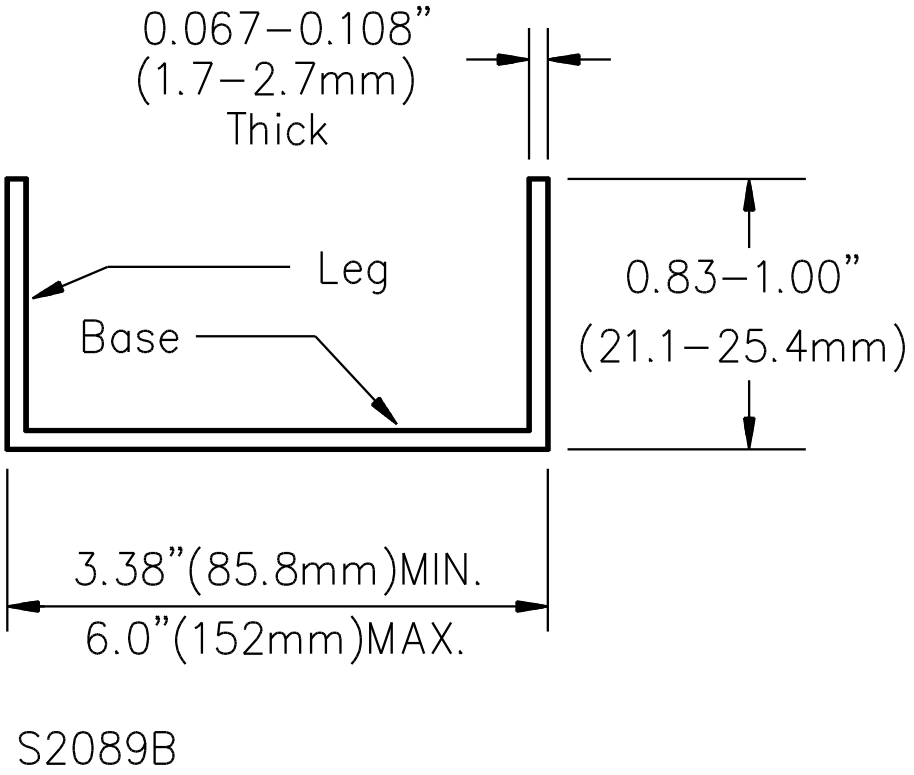


Figure G3.11
Bus bar support with standoff insulators mounted on leg of steel channel

(See Clause G3.3.1 and Figure G3.2)

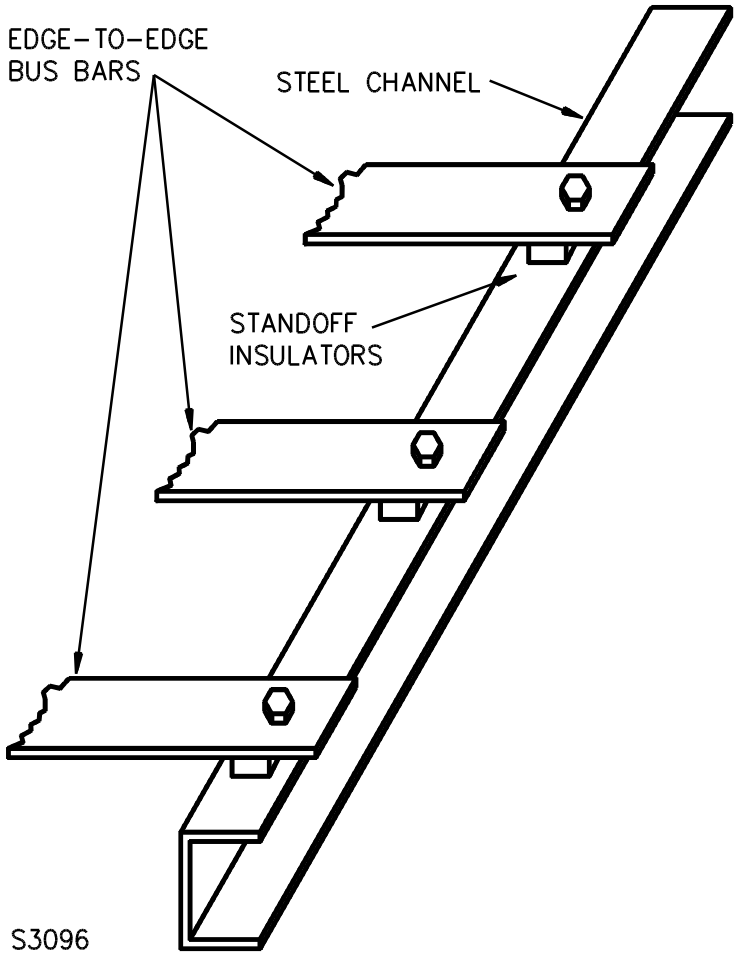
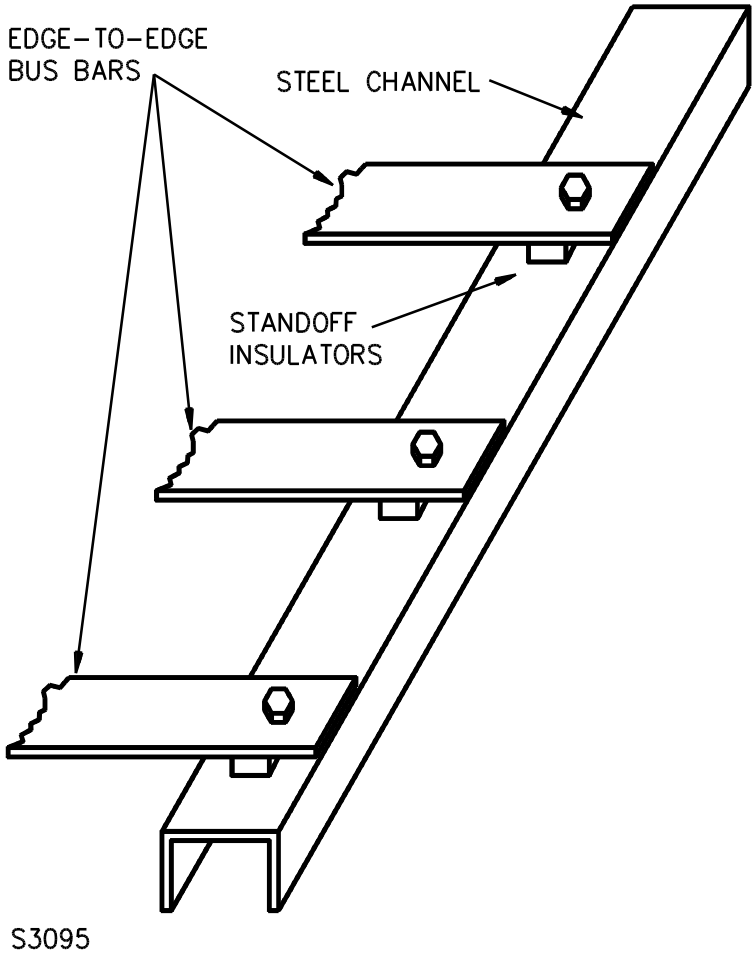


Figure G3.12
Bus bar support with standoff insulators mounted on base of steel channel

(See Clause G3.3.1 and Figure G3.2)



G3.1.5 Bus bar configurations shall be flat and rectangular.

Exception: An L-shaped bus bar may be used if:

a) considered as a face to face configuration or

b) the unsupported leg does not extend more than 50.8 mm (2 inches) from the bus support.

G3.1.6 The number of bus bars shall not exceed four for each phase.

G3.1.7 Phase bus bars, including neutral bus bars, shall be arranged edge-to-edge or face-to-face as described in Table G3.1 and as shown in Figure G3.1 – Figure G3.9.

Exception: A neutral bus bar need not comply with this requirement if the spacing between the adjacent surface of the neutral bus bar and the nearest phase bus bar is:

a) at least 133 mm (5-1/4 inches); or

b) 127 mm (5 inches) if the short-circuit current rating of the switchboard does not exceed 50 000 A.

G3.1.8 Stacked bus bars shall not exceed a height of 44.5 mm (1-3/4 inches) measured from the top of the standoff insulator or non-metallic channel base to the top of the highest bus bar.

Exception No. 1: At a splice bus or a joint, the height of stacked bus bars shall not exceed 50.8 mm (2 inches).

Exception No. 2: The height may be greater than 1-3/4 inches for constructions using L-shaped bus bars as specified in the Exception to G3.1.5.

G3.2 Spacings

G3.2.1 The spacing between adjacent edges of bus bars of opposite polarity, arranged or mounted edge-to-edge as shown in Figure G3.8, shall not be less than as described in Table G3.1. The center-to-center distance shall also be not less than as shown in Table G3.1. The distance between bolts to standoff insulators or non-metallic channels along the bus bar shall comply with the dimensions specified in Table G3.1. Bus bars to which terminal connectors are secured shall extend not more than 102 mm (4 inches) from the center of the first bolt to a standoff insulator on a non-metallic channel.

G3.2.2 The center-to-center spacing between adjacent groups of bus bars of opposite polarity, arranged or mounted face-to-face as shown in Figure G3.9, shall not be less than as described in Table G3.1. The distance between closest points of opposite polarity shall also be not less than as shown in Table G3.1.

G3.2.3 The spacing between bus bars crossing at right angles as shown in Figure G3.2, Figure G3.3, Figure G3.5, Figure G3.6, and Figure G3.7 shall not be less than 25.4 mm (1 inch).

G3.2.4 The spacing between live parts of bus bars mounted or arranged edge-to-edge and grounded dead metal shall not be less than 34.9 mm (1-3/8 inch) in any direction. A barrier shall be disregarded when measuring this spacing.

Exception: The spacing between the flat face of an insulated neutral bus bar and grounded dead metal shall not be less than 12.7 mm (1/2 inch) for a short-circuit current rating of 42 000 A or less.

G3.2.5 The spacing between live parts of bus bars mounted or arranged face-to-face and grounded dead metal, measured perpendicular to the face of the bus bar, shall not be less than 152 mm (6 inches); and, measured perpendicular to the edge of the bus bar, shall not be less than 34.9 mm (1-3/8 inches). A barrier shall be disregarded when measuring this spacing.

Exception No. 1: The spacing between the flat face of a neutral bus bar measured perpendicular to the face of the bus bar and grounded dead metal shall not be less than 50.8 mm (2 inches).

Exception No. 2: The spacing to grounded metal may be 1-3/8 inches minimum within 76.2 mm (3 inches) of the bus bar support.

G3.3 Supports

G3.3.1 A standoff insulator support used for direct support of live parts shall be secured by a bolt of the type described in G3.3.3 to a steel channel having the dimensions shown in Figure G3.10. The bolt shall pass through a clearance hole in the steel channel and shall not thread into it. Typical constructions are shown in Figure G3.11 and Figure G3.12.

Exception: A non-metallic channel that is investigated in accordance with G4.1.1 – G4.3.1 may be used in place of the standoff insulator and steel channel.

G3.3.2 A bus bar shall be secured to a standoff insulator, a non-metallic channel, or a splice bus bar by a bolt of the type described in G3.3.3.

G3.3.3 A bolt used to secure a bus bar or standoff insulator shall be 3/8-16 steel or larger and shall be torqued to 27.1 N·m (20 pound-feet). A steel washer with an outside diameter of 25.4 mm (1 inch) or larger and a maximum inside diameter of 14.3 mm (9/16 inch) shall be located between the bolt head and the bus bar and also between the bolt head or nut and a steel or non-metallic channel. The washer shall be minimum 2.0 mm (0.078 inch) thick. A bolt or threaded rod shall be SAE grade 5 minimum.

G3.3.4 The spacing and number of bus supports shall be in accordance with Figure G3.1 – Figure G3.7 as applicable.

G3.3.5 The line terminal brace shown in Figure G3.1 shall be secured to the line terminal bus bars by bolts of the type described in G3.3.3.

Exception: The line terminal brace is not required in a construction having bussed line connections.

G4 Performance

G4.1 General

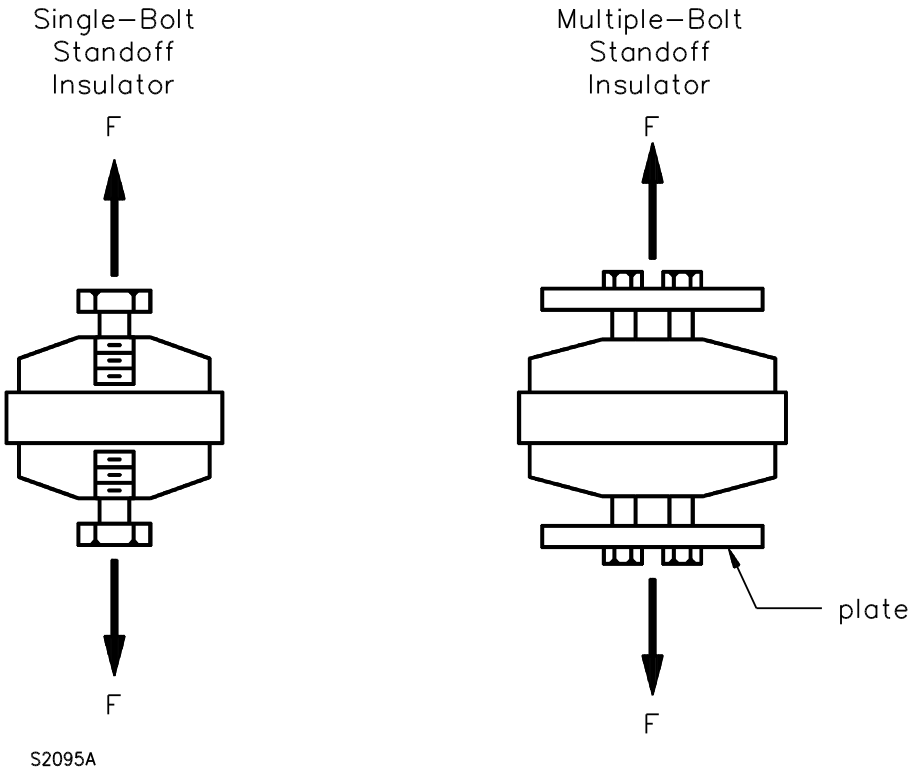
G4.1.1 A standoff insulator or non-metallic channel shall be subjected to the tests described in G4.2.1 and G4.3.1. Three samples shall be subjected to each test. The results are acceptable if the standoff insulator or non-metallic channel does not crack.

G4.2 Tensile

G4.2.1 The bus bar support or representative samples shall be subjected to a minimum tensile force of 8229 N (1850 pounds) applied between the simulated enclosure supporting means and bus bar support along the centerline of the mounting bolts. See Figure G4.1 for typical constructions. The force shall be applied by machine parts moving apart at a rate of 254 mm (10 inches) per minute.

Figure G4.1
Method of applying tensile force

(See Clause G4.2.1)

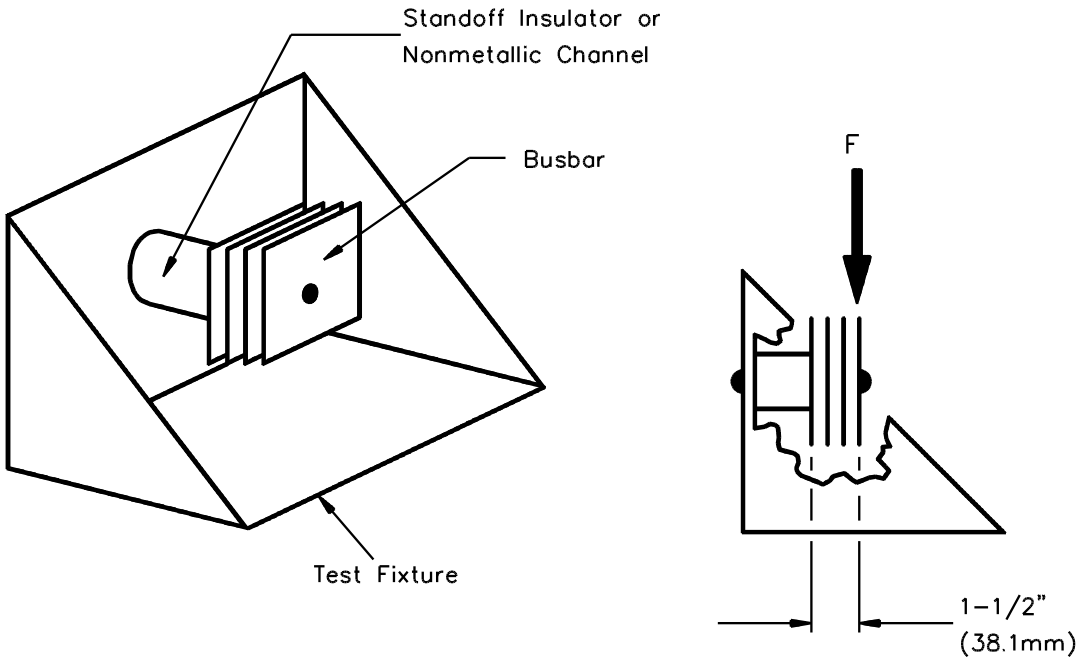


G4.3 Cantilever

G4.3.1 The standoff insulator or non-metallic channel or representative sample shall be mounted to a simulated enclosure steel plate and subjected to a minimum force of 3003 N (675 pounds), applied as specified and as shown in Figure G4.2. A 102 mm (4 inches) length of 50.8 by 6.4 mm (2 by 1/4 inches) copper bus bar shall be mounted to the support at a distance of 38.1 mm (1-1/2 inches) from the standoff insulator or non-metallic channel. Single or multiple spacers not greater than 25.4 by 25.4 mm (1 by 1 inch) are to be used. The force shall be applied perpendicular to the 2 by 1/4-inch edge of the bus bar. The force shall be applied by parts of a machine moving apart at a rate of 254 mm (10 inches) per minute.

Figure G4.2
Method of applying force in cantilever test

(See G4.3.1)

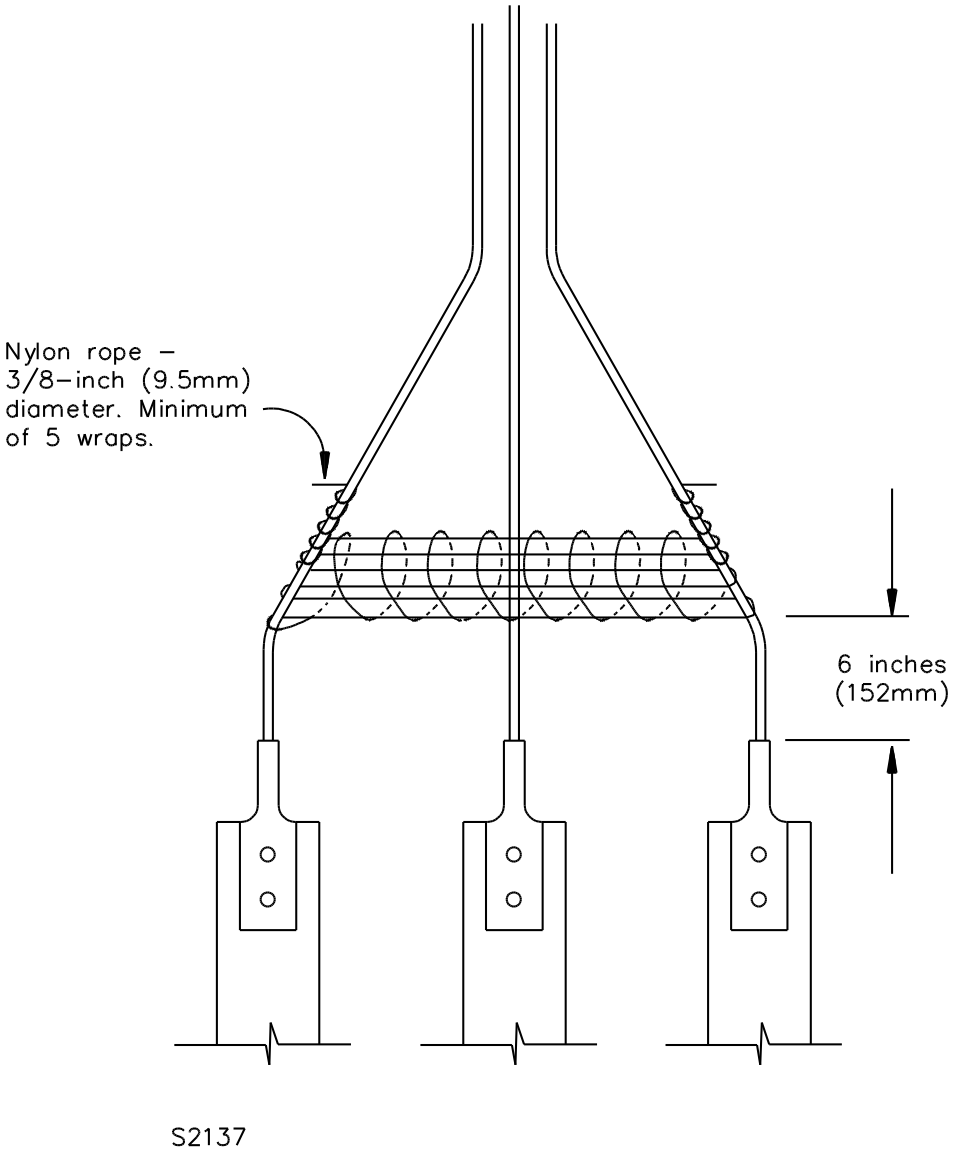


G5 Marking

G5.1 The switchboard shall be marked in accordance with 6.3.3.1 with the following or the equivalent: "Wrap line cables together and, if provided, tap cables together with nominal 9.5 mm (3/8 inch) nylon rope or rope having a minimum tensile strength of 8896 N (2000 pounds) at (1) 152 mm (6 inches) and 305 mm (12 inches) from the line terminals with five wraps and (2) every additional 6 inches with five wraps or every 25.4 mm (1 inch) with one wrap." It is also recommended that a drawing as shown in Figure G5.1, or the equivalent, be provided with the switchboard.

Figure G5.1
Securement of cable

(See G5.1)



Supplement SA
Use of Components Not UL Listed or Recognized

(For U.S. Only)

SA1 Scope

SA1.1 These requirements are applicable to switchboards intended for use in the United States and cover the use in dead-front switchboards of components that are not Listed or Recognized by Underwriters Laboratories Inc. The switchboards are otherwise in compliance with the requirements of this standard.

SA1.2 In a switchboard containing a transfer switch or where multiple sources are intended for parallel operation as covered in 8.6.5.1 – 8.6.5.7, the requirements in this Annex are not applicable to a component that functions:

a) to cause the opening of a circuit in the case of over-current, short circuit, or a ground fault;

b) in a synchronizing circuit intended to preclude paralleling sources that are not in synchronization; or

c) in a generator control in a manner such that the generator might be prevented from being on line if the component malfunctioned.

SA1.3 Components covered under this program include a switching device, relay, or a similar component that controls loads or other devices within the switchboard, but do not include an external power-consuming product such as a motor, heater, or the like other than as covered in SA2.4.

SA2 Conditions of Use

SA2.1 A component may be used without further investigation in a control circuit if all of the following conditions are met:

a) An uninvestigated control device is contained within the switchboard enclosure.

Exception: An uninvestigated component may extend through an opening in the switchboard enclosure if the component housing material is fabricated from:

a) A polymeric material, the area of which does not exceed 194 cm^2 (30 square inches), or

b) Metal and glass of which the area of exposed glass does not exceed 645 cm^2 (100 square inches).

b) With respect to 8.2.1.3.1 and 8.1.16.5, the uninvestigated component is treated as an arcing part.

c) All other inputs to or outputs from the uninvestigated component are through UL Listed or Recognized components as shown in SA2.2 – SA2.4 and Figure SA2.1.

d) Records are maintained as covered in SA5.1(c) and in SA5.2.

SA2.2 With respect to items D, E, and F of Figure SA2.1, the following conditions shall be met:

a) The circuit shall be supplied by a Listed or Recognized transformer, with isolated secondary rated 115 – 120 or 230 – 240 V nominal supplying a load not in excess of its rating.

b) One side of the secondary circuit shall be grounded.

c) The secondary circuit shall be overcurrent protection as indicated in Overcurrent Protection, SA3.

d) The secondary circuit shall be protected by a Listed, Class A (6 mA trip) circuit breaker and ground fault circuit interrupter (CBGFCI) as indicated in Circuit Breaker and Ground Fault Circuit Interrupter, SA4.

Exception: Instead of CBGFCI, the ground fault circuit interrupter may be Listed "receptacle-style" ground fault circuit interrupter of the feed through type (mounted in the intended manner) with the load connected to terminals (not plugged into receptacle). Marking on or adjacent to the receptacle (if any) indicates that the receptacle is not to be used for external connections. If the ground fault circuit interrupter has a receptacle, it shall be mounted such that the receptacle is not accessible to the user from the outside of the enclosure.

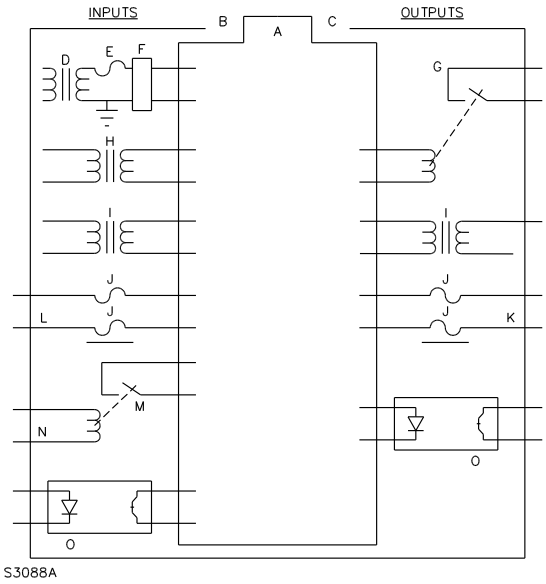
e) The switchboard shall have a marking that states:

1) "WARNING – Use of the following components is dependent upon the additional protection afforded by the ground fault circuit interrupter and the overcurrent protective device provided. Do not remove or defeat these protective devices." and

2) that the ground fault circuit interrupter should be checked periodically for intended operation.

Figure SA2.1
Uninvestigated component

(See Clauses SA2.1(c), SA2.2, SA2.3 and SA2.4)



A – Component not Listed or Recognized by UL.

B – Switchboard enclosure.

C – Component may extend through switchboard enclosure – see the Exception to SA2.1(a).

D – Listed or Recognized Component transformer with a 115 – 120 or 230 – 240 V secondary.

E – Fuse or circuit breaker sized in accordance with SA3.1 or Table SA3.1.

F – Listed or Recognized Component ground fault circuit interrupter. See SA2.1(d) or SA4.1. See also marking in SA2.2(e)(1).

G – Listed or Recognized Component relay. Marking provided to give relay contact rating.

H – Listed or Recognized Component current transformer.

I – Listed or Recognized Component Class 2 transformer. See 2.4.1.1(a). A Listed or Recognized Class 3 transformer may also be used for an input.

J – Listed or Recognized Component fuse, rated 0.5 A maximum. If the input circuit is not grounded or if it is not known if the output circuit is grounded, both lines of the involved circuit shall be fused. A fuse shall not be provided in a grounded circuit. Marking provided in accordance with SA2.4.

K – To a switch or other load. Marked to indicate maximum of 30 V dc or 30 V rms.

L – Marking provided in accordance with SA2.3.

M – Listed or Recognized Component relay.

N – Marking to indicate coil voltage rating of relay.

O – Recognized Component opto-isolator with 2 500 V rated isolation voltage.

SA2.3 With respect to item L of Figure SA2.1, if a circuit is intended to be supplied by a source located external to the switchboard, it may be directly connected to an uninvestigated component within the switchboard if the circuit is connected through a one-half ampere fuse as covered in item J of Figure SA2.1 and involves a potential not exceeding 30 V between live parts of opposite polarity and between a live part and ground. Field wiring terminals provided for the connection of such circuits shall be permanently marked in the area adjacent to the terminals with the word "CAUTION" and the following or the equivalent: "Risk of electric shock. Connections to these terminals shall not involve a potential greater than 30 V between live parts of opposite polarity and between a live part and ground."

SA2.4 With respect to items J and K of Figure SA2.1, if the control circuit is intended to be connected to an external switch or load, all ungrounded conductors that extend beyond the enclosure are to be protected by a fuse rated not more than 0.5 A. The fuse shall be located within the enclosure and as close as is practical to the field wiring terminals. A permanent marking shall be provided near the fuse with the word "CAUTION" and the following or the equivalent: "Risk of fire. Replace only with same type and rating of fuse." The circuit supplied by a source originating from the uninvestigated component shall have a potential of 30 V or less between live parts of opposite polarity and between a live part and ground.

SA3 Overcurrent Protections

SA3.1 The overcurrent protection required shall be as indicated in Table SA3.1 (which is an expansion of Table 130 F of Electrical Standard for Metalworking Machine Tools, NFPA 79, to include a nominal 230 V secondary).

Table SA3.1
Required overcurrent protection

(See Clause SA3.1 and Figure SA2.1, Note E)

Control transformer size in volt-ampere	Maximum rating of overcurrent device, amperes	
	115 – 120 V	230 – 240 V
50	0.5	0.25
100	1.0	0.5
150	1.6	0.8
200	2.0	1.0
250	2.5	1.25
300	3.2	1.6
500	5	2.5
750	8	4
1 000	10	5
1 250	12	6
1 500	15	7.5
2 000	–	10
3 000	–	15

[a] If a larger transformer is used to supply one or more circuits in addition to the uninvestigated circuit, the uninvestigated circuit is protected at not more than 15 A and the total secondary is protected at not more than 125 percent of the secondary current rating of the transformer.

SA4 Circuit Breaker and Ground Fault Circuit Interrupter

SA4.1 The CBGFCI referred to in Condition of Use, Section SA2, shall be provided to interrupt the electrical circuit to the load when a fault current to ground exceeds 6 milliamperes. If a relay is used with a CBGFCI in a 3-phase, 4-wire secondary circuit, the combination shall comply with the requirements for ground-fault circuit-interrupters, UL 943.

SA5 Tests and Records By the Manufacturer

SA5.1 The manufacturer shall comply with (a) – (c) as follows:

a) conduct appropriate tests to determine that the ground fault circuit interrupter will protect against all likely ground faults,

b) review the application to determine that the overcurrent protection will protect against possible short circuits, and

c) maintain records of the use of non-Listed or non-Recognized components for periodic review and determination by UL personnel of when added detailed investigation of the component shall be required, such as for those components that have repeated use.

SA5.2 Records of non-Listed or non-Recognized component usage shall be maintained in the form shown in Table SA5.1 or the equivalent.

Table SA5.1
Record of use

(See SA5.2)

Component designation	Component, manufacturer's name	Catalog designation	Number used	Switchboard identification	Date	Ground fault testing
Relay, pilot light, or the like				Name, wiring diagram, or the like		

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