UL 347

STANDARD FOR SAFETY

Medium-Voltage AC Contactors, Controllers, and Control Centers

UL Standard for Safety for Medium-Voltage AC Contactors, Controllers, and Control Centers, UL 347

Seventh Edition, Dated November 23, 2020

Summary of Topics

This revision of ANSI/UL 347 dated September 30, 2022 includes the following changes in requirements:

– Restructuring of Scope; 1.1.1 – 1.1.5

– Chiller Duty or OEM Defined Duty for Motor Starting Reduced Voltage Autotransformers; 4.204.1.3, 6.5.5.104

– Wire Bending Space; 5.210.1, 5.210.2

– Requirement for Terminals; 5.206.1

– Temperature Test Following Short Time Capability Test; 6.5.1

– Revision of Table 2 to Add Higher Rated Insulation Systems

– Addition of Earthing Switch to UL 347; 3.4.104, Section 4.206, 5.10.207, 5.11.207, 5.12.203, 5.205.1.4, 6.101.3, Section 6.209, Figure 11

– Color Coding of Insulating Conductors; 5.205.1.4

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated February 11, 2022 and July 15, 2022.

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Commitment for Amendments

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This ANSI/UL Standard for Safety consists of the Seventh Edition including revisions through September 30, 2022.

The most recent designation of ANSI/UL 347 as an American National Standard (ANSI) occurred on September 30, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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CONTENTS

No Text on This Page

Preface

This is the harmonized ANCE, CSA Group, and UL standard for medium-voltage ac contactors, controllers, and control centres. It is the third edition of NMX-J-564/106-ANCE, the third edition of CSA C22.2 No. 253:20, and the seventh edition of UL 347. This edition of NMX-J-564/106-ANCE supersedes the previous edition published on January 2016. This edition of CSA C22.2 No. 253 supersedes the previous edition published on January 2016. This edition of UL 347 supersedes the previous edition published on January 29, 2016. This harmonized standard has been jointly revised on September 30, 2022. For this purpose, CSA Group and UL are issuing revision pages dated September 30, 2022, and ANCE is issuing a new edition dated September 30, 2022.

This harmonized Standard was prepared by the Association of Standardization and Certification, CSA Group and Underwriters Laboratories Inc. The efforts and support of the medium-voltage control manufacturing industry and the CANENA Technical Harmonization Subcommittee THSC TC17 WG1 – Medium Voltage Controllers, which includes representatives of UL, CSA Group, ANCE, and North American medium voltage control manufacturers, 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 GTD – Generación, Transmisión y Distribución from the Comité de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE, with the collaboration of the medium-voltage controller manufacturers and users.

This Standard was reviewed by the CSA Integrated Committee on Industrial Control, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

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 was prepared by comparing UL 347, existing CSA Group standards, and ANCE and IEC 60470-2000 requirements. These requirements were reviewed, compared, and, where possible, harmonized. Where harmonization was not possible due to local installation codes, the differing requirements are noted in the text of the document. When conflicts between existing North American and IEC practices existed, the practice in North America is retained.

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.

Formatting

This Standard is formatted to facilitate comparison to IEC 60470:1999 requirements, and to IEC 60694:1996, which is the common clauses document to which IEC 60470 is subservient. Requirements are categorized and arranged in the clause numbering structure used for IEC 60470. Where the requirements in this Standard were equivalent to those in IEC 60470, the subclause was assigned the equivalent IEC subclause number. Where this Standard does not include a subclause equivalent to those in IEC 60470, the entry "[Vacant]" was shown for the IEC 60470 subclause number. Where this Standard includes a requirement not shown in IEC 60470, the subclause was assigned a number of a higher numerical value than those used in the IEC document.

Note: IEC 60470 has since been replaced by IEC 62271-106 and IEC 60694 has since been replaced by IEC 62271-1.

In order to simplify the cross-referencing of corresponding requirements, the following clause numbering system is used:

- The clauses follow the IEC 60470 (and IEC 60694) format for clauses 1 through 7.
- Subclauses numbered .1 through .99 (but not subdivisions, e.g., those numbered .1.1, .1.2, .1.3, etc.) correspond to subclauses in IEC 60470 (and IEC 60694).
- Subclauses numbered .101 through .199 correspond to subclauses in IEC 60470.
- Subclauses numbered .201 through .299 are CANENA requirements not found or numbered in IEC 60470.

The purpose of this Standard is to harmonize as far as practicable all rules and requirements of a general nature in order to obtain uniformity of requirements and tests throughout the corresponding range of equipment and to avoid the need for testing to different standards.

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.

MEDIUM-VOLTAGE AC CONTACTORS, CONTROLLERS, AND CONTROL CENTERS

1 General

1.1 Scope

1.1.1 This standard is applicable to ac contactors applied at voltages in the range of 1 501V to 15kV, and metal-enclosed contactor-based controllers, control centers, and other control assemblies and associated equipment applied at voltages in the range of 751V to 15kV, designed for operation at frequencies of 50 or 60 Hz on three-phase systems. These requirements apply to equipment intended for use in ordinary (non-hazardous) locations and installed in accordance with the applicable local installation codes and standards (see Annex A, Item 1). These requirements, as modified by the applicable national standards for fire pump controllers, also apply to fire pump controllers (see Annex A, Item 2).

1.1.2 This standard also includes requirements for controllers intended for service entrance applications. (See Annex A, Item 3 and Clause 5.204.)

1.1.3 This standard also includes requirements for equipment incorporating solid state switching elements intended for starting, stopping, regulating, controlling, or protecting heating and other resistive loads, having ac voltage ratings in the range of 1501V to 15kV.

1.1.4 This standard also includes requirements for reduced-voltage solid-state controllers.

1.1.5 This standard does not apply to:

a) equipment for use in classified (hazardous) locations as defined in the applicable installation codes or standards;

b) components contained in contactors and contactor-based controllers for which individual component standards exist;

c) auxiliary low voltage control assemblies (see Annex A, Item 4);

d) equipment consisting solely of electronic or solid-state devices, circuits, or systems;

e) electronic variable speed motor controllers (power conversion equipment); and

f) controllers using only solid-state devices in the main circuit.

1.2 Normative references, component standards, and general requirements

1.2.1 General

Products covered by this standard shall comply with the reference installation codes and standards noted in Annex A.

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.

1.2.2 Component standards

1.2.2.1 Components utilized in the products covered by this standard shall comply with the appropriate standards for these components and shall be used in accordance with their recognized ratings and other limitations of use (see Annex D). A component shall comply with the ANCE, CSA Group, or UL Standards as appropriate for the country where the product shall be used.

1.2.2.2 A component need not comply with a specific requirement that:

a) involves a feature or characteristic not needed in the application of the component in the product covered in this standard, or

b) is superseded by a requirement in this standard.

1.2.3 General requirements

1.2.3.1 Canadian requirements

In Canada, general requirements as indicated in Annex A, Item 5, are also applicable.

1.2.3.2 Units of measurement

The values given in SI (metric) units shall be normative. Any other values given shall be for information purposes only.

2 Normal and Special Service Conditions

2.1 Normal service conditions

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

a) For equipment that is cooled by air, either ventilated or nonventilated, the temperature of the air outside of the enclosure and the ambient temperature is above 0°C but does not exceed 40°C, and its average value, measured over a period of 24 h, does not exceed 35°C.

b) The equipment is located where:

i) the influence of solar radiation is not significant, such as indoors or similarly protected locations;

ii) the altitude does not exceed 1 000 m (3 300 ft);

iii) the ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapors, or salt (for Mexico refer to Annex A item 22); and

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

2.2 Special service conditions

2.2.1 Altitude

Installation at altitudes above 1000 m up to 3000 m is also recognized in this standard. Variations in the design will in some cases be required. For example, considerations should be made for temperature rise, insulation level, and mechanical parameters affected by lower ambient pressures. Manufacturers should be prepared to supply any de-rating factors to be applied to the normal service condition ratings and any necessary setting adjustments.

NOTE: Special conditions are in some cases also necessary for some types of operating mechanisms.

2.2.2 Solar radiation

If the effects of solar radiation are significant, the principles stated in Annex A, Item 11, may be used for guidance.

2.2.3 Evaluations and exceptions

Conditions that equipment will experience should be evaluated in terms of the manufacturer's designated ratings and limitations. Service conditions that are outside the limits described in Clause 2.1 should be called to the controller manufacturer's attention, since special construction or protection will in some cases be required.

3 Definitions

NOTE: Definitions that correspond to definitions in the International Electrotechnical Vocabulary (IEV) (IEC 60050-441) have been so identified with their corresponding IEV designation.

In Canada, the definitions that are contained in the Canadian Electrical Code, Part I shall apply.

3.1 General terms

3.1.101 **controller and controlgear:** A controller consists of a contactor, overload protection, a manual externally operated disconnector, and a short-circuit protective device, mounted and wired in an enclosure specifically designed and dimensioned for its application, in which all tests are conducted, and which may also include a grounding function. An auxiliary compartment may be provided if necessary to complete the function of the controller.

NOTE: “Controlgear” is a general term covering controllers and auxiliary equipment supplied with controller vertical sections and in medium-voltage control centers.

3.1.102 **overcurrent:** A current exceeding the rated continuous current.

NOTE: Overcurrents can result from motor starting, overload, short-circuit, or ground faults.

3.1.103 **short-circuit current (often called fault current):** An overcurrent resulting from a short-circuit due to a fault or an incorrect connection in an electric circuit. [IEC 60050-441:1984, 441-11-07]

3.1.104 **overload:** Operating conditions in an electrically undamaged circuit that cause an overcurrent. [IEC 60050-441:1984, 441-11-02]

3.1.105 **conductive part:** A part which is capable of conducting current, although it is not necessarily used for carrying current. [IEC 60050-441:1984, 441-11-09, modified]

3.1.106 **ambient air temperature:** The temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse. [IEC 60050-441:1984, 441-11-13]

NOTE: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

3.1.201 **medium-voltage:** For this standard, ac voltage in the range of 1 501V to 15kV (in Canada, 751V to 15kV).

NOTE: The applicable installation codes will in some cases refer to this voltage range as “high-voltage.”

3.1.202 **medium-voltage compartment:** A compartment containing one or more medium-voltage components.

3.1.203 **low-voltage:** For this standard, ac voltage in the range of 50 to 1 500 V (in Canada, 30 to 750 V).

NOTE: The applicable installation codes refer to voltages above 600 Vrms (750 Vrms in Canada) as “high voltage”.

3.1.204 **low-voltage control compartment:** A compartment containing only low-voltage components.

3.1.205 **auxiliary compartment:** A compartment containing components and busing as needed to complete the functional requirements of an individual controller or a control center beyond the operational functions provided by individual controllers.

3.1.206 **line contactor:** Contactor whose line terminals are energized when the isolating means is closed.

3.1.207 **connected position of a drawout (withdrawable) element:** The position of a drawout (withdrawable) element in which it is fully connected to the main and secondary circuits.

3.1.208 **test position of a drawout (withdrawable) element:** The position of a drawout (withdrawable) element in which an isolating distance or segregation is established in the main circuit and in which the auxiliary circuits are connected. [IEC 60050-441:1984, 441-16-27, modified]

3.1.209 **Class E controller:** Class E controllers are intended for controlling and protecting medium-voltage electric motors or other electrical loads, including transformers, capacitors, resistive loads, and branch circuits.

3.1.210 **Class E1 controller:** Class E1 controllers utilize the main contactor to make and break all currents up to and including the breaking capacity of the controller.

3.1.211 **Class E2 controller:** Class E2 controllers utilize the main contactor to make and break load and operating overload currents and utilize medium-voltage fuses for interrupting fault currents that exceed the breaking capacity of the main contactor.

3.1.212 **medium-voltage control center (or control center):** A floor-mounted assembly of one or more enclosed vertical sections, principally containing controller(s) in medium-voltage compartments, and designed to provide power to more than one medium-voltage compartment by a common power bus.

NOTE: Also referred to as “controlgear”.

3.1.213 **assembly:** A combination of controllers or controlgear completely assembled with all internal electrical and mechanical interconnections. [IEC 60050-441:1984, 441-12-01, modified]

3.1.214 **barrier (or partition):** A part of an assembly separating one compartment from other compartments. [IEC 60050-441:1984, 441-13-05]

3.1.215 **blank space:** An unusable compartment containing no components or bus, and not intended for future installation of additional components.

3.1.216 **space for future controller unit:** An empty compartment, suitable for future installation of a specified controller. This compartment does not include connections to power bus, but is suitable for future installation of connections to power bus.

3.1.217 **factory-prepared space for future controller unit:** A compartment suitable for future installation of a complete controller. This compartment includes connections to power bus.

3.1.218 **partially completed controller unit:** A compartment equipped as a complete controller, except without power fuses, CTs, and load-side power connections.

NOTE: These elements (power fuse rating, CT ratio, load-side power connections, etc.) are excepted, because they can only be sized correctly with specific motor data.

3.1.219 **spare controller unit:** A fully equipped (complete) controller, suitable for immediate use, with a specific rating, but without a specific controller (load) designation.

3.1.220 **clearance:** The distance between two conductive parts along a string stretched the shortest way between these conductive parts. [IEC 60050-441:1984, 441-17-31]

3.1.221 **control power transformer (CPT):** A transformer utilized to supply voltage for control circuits and auxiliary devices.

3.1.222 **ground (earth):** A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth or to some conducting body of relatively large extent that serves in place of the earth.

NOTE: See Figure 8 for examples of the use of the terms “grounding” and “bonding”, with corresponding terms for Canada and Mexico.

3.1.223 **insulation class:** The classification of insulation materials for the purpose of establishing temperature limits for the use of the material.

3.1.224 **grounding kit:** A grounding terminal means intended to be field-connected or factory-installed, consisting of connectors (lugs) and hardware, such as bolts, studs, or screws, etc., and suitable for connecting a conductor 14 AWG (2.08 mm^2) or larger to equipment required to be grounded, which is in addition to the means for securing conduit or cable armor.

NOTE 1: It is not intended that a grounding kit consist merely of screws for direct attachment of grounding conductors.

NOTE 2: In Canada, a grounding kit can also be referred to as a bonding kit.

3.2 Assemblies of controlgear

[Vacant]

3.3 Parts of assemblies

[Vacant]

3.4 Switching devices

3.4.101 **switching device:** A device designed to make or break the current in one or more electric circuits. [IEC 60050-441:1984, 441-14-01]

3.4.102 **mechanical switching device:** A switching device designed to close and open one or more electric circuits by means of separable contacts. [IEC 60050-441:1984, 441-14-02]

NOTE: Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g., air, SF_6, oil.

3.4.103 **isolating means (isolating switch or disconnector):** A mechanical switching device that provides, in the open position, isolating distance in the main circuit from the source of power. [IEC 60050-441:1984, 441-14-05, modified]

3.4.103.201 **service disconnecting means:** Isolating means that disconnects all conductors into a building or other structure from the service entrance conductors.

3.4.104 **grounding (earthing) switch:** A permanently installed mechanical three-pole open air switching device used to connect the load side of a de-energized medium voltage controller power circuit to ground (earth) for maintenance purposes.

3.4.105 **contactor:** A mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying, and breaking currents under normal circuit conditions, including operating overload conditions. [IEC 60050-441:1984, 441-14-33]

3.4.106 **electromagnetic contactor:** A contactor in which the force for closing the normally open main contacts or for opening the normally closed main contacts is provided by an electromagnet.

NOTE: Unless otherwise identified, the term “contactor” as used in this standard refers to an “electromagnetic contactor”.

3.4.107 **vacuum contactor:** A contactor in which the main contacts open and close within a highly evacuated envelope.

3.4.108 **SF_6 contactor:** [Vacant]

3.4.109 **latched contactor:** A contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized. [IEC 60050-441:1984, 441-14-34]

NOTE: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

3.4.110 **starter (motor controller):** A controller used to start and stop a motor.

3.4.110.1 **full-voltage starter:** A starter that connects the full line voltage across the motor terminals in one step.

3.4.110.2 **reversing starter:** A starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections even when the motor is rotating.

3.4.110.3 **two-direction starter:** [Vacant]

3.4.110.4 **reduced-voltage starter:** A starter that reduces the starting voltage of the motor, and then transitions to full voltage. Reduced-voltage starters include autotransformer, reactor, solid-state, wye-delta, part winding, and wound-rotor starters.

3.4.110.5 **autotransformer starter:** A reduced-voltage starter that uses reduced voltages derived from an autotransformer to start a motor. It includes the necessary switching devices to provide full voltage.

3.4.110.6 **rheostatic starter:** [Vacant]

3.4.110.7 **wound-rotor starter (or a rheostatic rotor starter):** [Vacant]

3.4.110.8 **reactor starter (often referred to as a primary reactor starter):** A starter that includes a reactor connected in series with the stator winding of an alternating current motor to furnish reduced voltage for starting. It includes the necessary switching devices to provide full voltage.

3.4.110.9 **electromagnetic starter (electromagnetic controller):** [Vacant]

3.4.110.10 **n-step starter:** [Vacant]

3.4.111 **controller, combination starter:** [Vacant]

3.4.112 **short-circuit protective device (SCPD):** A device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them; in this standard, typically a medium-voltage fuse.

3.4.113 **Class C1:** A device with a low probability of restrike during capacitive current breaking as demonstrated by the type tests in Clause 6.109.

3.4.114 **Class C2:** A device with a very low probability of restrike during capacitive current breaking as demonstrated by the type tests in Clause 6.109.

3.4.201 **vacuum interrupter:** An interrupter in which the contacts open and close within a highly evacuated envelope.

3.4.202 **reduced-voltage solid state controller:** A controller that includes solid state devices connected in series with the stator winding of an alternating current motor to furnish reduced voltage for starting.

NOTE: It might or might not include the necessary mechanical switching devices to provide a bypass function.

3.4.203 **automatic bypass function:** A circuit that automatically shunts the solid state devices to provide full voltage to the output terminals.

NOTE: An automatic bypass function might or might not include provisions for automatic return of control to the solid state devices.

3.4.204 **solid state resistive load controller:** A Class E2 controller that includes solid state devices connected in series with a resistive load to provide control of power consumed by the resistive load, such as heaters.

NOTE: It might or might not include the necessary mechanical switching devices to provide a bypass function.

3.5 Parts of a controller

3.5.101 **pole of a switching device:** The portion of a controller associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together.

NOTE: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multi-pole (two-pole, three-pole, etc.), provided that the poles are, or can be, coupled in such a manner as to operate together.

3.5.102 **main circuit:** All the current-carrying parts of a controller included in the medium-voltage circuit it is intended to open or close.

3.5.103 **control circuit:** The circuit that carries the electric signals directing the performance of a control device, but does not carry the power that the device controls.

3.5.104 **auxiliary circuit:** All the conductive parts of controller that are intended to be included in a circuit, other than the main circuit and the control circuits of the device.

NOTE: Some auxiliary circuits fulfill supplementary functions, such as signalling, interlocking, etc., and, as such, can be part of the control circuit of another switching device.

3.5.201 **interlock (interlocking device):** A device that makes the operation of a movable element (e.g., a switching device, door, or the like) dependent upon the position or operation of one or more other movable elements. [IEC 60050-441:1984, 441-16-49, modified]

3.5.202 **drawout (withdrawable) element:** A removable part of controller that can be moved to one or more positions in which an isolating distance or a segregation between open contacts is established. [IEC 60050-441:1984, 441-13-09]

NOTE: The isolating distance or the segregation always relates to the main circuit, and in some cases refers to the auxiliary circuits or to control circuits.

3.5.203 **cover:** The unhinged portion of an enclosure that covers an opening.

3.5.204 **door:** A hinged portion of an enclosure that covers an opening.

3.5.205 **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.

NOTE: See also Annex A, Item 6.

3.5.206 **vertical section:** That portion of a medium-voltage control center assembly between two successive vertical delineations. A vertical section includes top, vertical side panels, front and rear doors or covers containing power bus, low-voltage and medium-voltage compartments, or other components as required for the intended application.

3.5.207 **power bus:** A conductor or group of conductors that serves as a source of supply to two or more power circuits within or between vertical sections.

3.5.208 **extendable power bus:** That portion of the power bus that is capable of being extended to connect two or more vertical sections.

3.5.209 **non-extendable power bus:** Those portions of the power bus that are not extendable and connect power circuits within a vertical section, with short direct terminations, to not more than three controllers.

3.6 Operation

3.6.101 **operation (of a mechanical switching device):** The transfer of the moving contact(s) from one position to an adjacent position. [IEC 60050-441:1984, 441-16-01]

NOTE 1: This can be a closing operation or an opening operation.

NOTE 2: If distinction is necessary, an operation in the electrical sense, e.g., make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g., close or open, is referred to as a mechanical operation.

3.6.102 **operating cycle (of a mechanical switching device):** [Vacant]

3.6.103 **closing operation "C" (of a mechanical switching device):** An operation by which the device is brought from the open position to the closed position. [IEC 60050-441:1984, 441-16-08]

3.6.104 **opening operation "O" (of a mechanical switching device):** An operation by which the device is brought from the closed position to the open position. [IEC 60050-441:1984, 441-16-09]

3.6.105 **closed position (of a mechanical switching device):** The position in which the predetermined continuity of the main circuit of the device is secured. [IEC 60050-441:1984, 441-16-22]

3.6.106 **open position (of a mechanical switching device):** The position in which the predetermined clearance between open contacts in the main circuit of the device is secured. [IEC 60050-441:1984, 441-16-23]

3.6.107 **position of rest (of a contactor):** The position which the moving elements of the contactor take up when its electromagnet is not energized. [IEC 60050-441:1984, 441-16-24 modified]

3.6.108 **overload relay or release:** [Vacant]

3.6.109 **thermal overload relay or release:** [Vacant]

3.6.110 **current setting of an overload relay or release:** [Vacant]

3.6.111 **current setting range of an overload relay or release:** [Vacant]

3.6.112 **phase failure sensitive overload relay or release:** [Vacant]

3.6.113 **under-current (under-voltage) relay or release:** [Vacant]

3.6.114 **starting time (of a rheostatic starter):** [Vacant]

3.6.115 **starting time (of a reduced-voltage starter):** [Vacant]

3.6.116 **open transition (of an autotransformer starter):** [Vacant]

3.6.117 **closed transition (of an autotransformer starter):** [Vacant]

3.6.118 **inching (jogging):** [Vacant]

3.6.119 **plugging:** [Vacant]

3.7 Characteristic quantities

3.7.1 **isolating distance (gap):** The clearance between the line and load side contacts of the isolating means when in the open position.

3.7.2 **degree of protection:** The extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects, and/or ingress of water, and verified by standardized test methods (see Annex A Item 12).

3.7.101 **breaking current (of a switching device or a fuse):**

3.7.102 **breaking capacity (of a switching device or a fuse):** A value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behavior. [IEC 60050-441:1984, 441-17-08]

NOTE 1: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant publications.

NOTE 2: For switching devices, the breaking capacity can be termed according to the kind of current included in the prescribed conditions, e.g., line charging breaking capacity, cable charging breaking capacity, single capacitor bank breaking capacity, etc.

3.7.103 **making capacity (of a switching device):** A value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behavior. [IEC 60050-441:1984, 441-17-09]

NOTE: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant specifications.

3.7.104 **take-over current:** See Clause 3.7.115.

3.7.105 **short-time withstand current:** The current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behavior. [IEC 60050-441:1984, 441-17-17]

3.7.106 **recovery voltage:** The voltage that appears across the terminals of a pole of a switching device or a fuse after the breaking of the current. [IEC 60050-441:1984, 441-17-25, modified]

NOTE: This voltage can be considered in two successive intervals of time, the first in which a transient voltage is superimposed on an essentially constant power-frequency voltage, followed by a second interval in which the power-frequency or the steady-state recovery voltage alone exists.

3.7.107 **transient recovery voltage (TRV):** The recovery voltage during the time in which it has a significant transient character. [IEC 60050-441:1984, 441-17-26]

NOTE 1: The transient recovery voltage can be oscillatory or non-oscillatory, or a combination of these, depending on the characteristics of the circuit and the switching device. It includes the voltage shift of the neutral of a polyphase circuit.

NOTE 2: The transient recovery voltage in three-phase circuits is, unless otherwise stated, that across the first pole to clear, because this voltage is generally higher than that which appears across each of the other two poles.

3.7.108 **power-frequency recovery voltage:** The recovery voltage after the transient voltage phenomena have subsided. [IEC 60050-441:1984, 441-17-27] See Figure 6.

3.7.109 **prospective current (of a circuit and with respect to a combination situated therein):** The current that would flow in the circuit if each pole of the combination were replaced by a conductor of negligible impedance. [IEC 60050-441:1984, 441-17-01, modified]

NOTE: For testing, the prospective current is determined by calibrating the test circuit with a short circuit placed directly across the incoming terminals of the test specimen.

3.7.110 **prospective peak current:** The peak value of a prospective current during the transient period following initiation. [IEC 60050-441:1984, 441-17-02, modified]

NOTE 1: For testing, the prospective current is determined by calibrating the test circuit with a short circuit placed directly across the incoming terminals of the test specimen.

NOTE 2: The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g., polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

3.7.111 **maximum prospective peak current (of an ac circuit):** The prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value. [IEC 60050-441:1984, 441-17-04]

NOTE: For a multi-pole device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

3.7.112 **prospective breaking current (of a switching device or fuse):** [Vacant]

3.7.113 **minimum breaking current:** [Vacant]

3.7.114 **let-through current (sometimes called cut-off current):** The maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse.

3.7.115 **take-over current:** The current coordinate of the intersection between the time-current characteristics of two overcurrent protective devices. [IEC 60050-441:1984, 441-17-16]

NOTE: Historically referred to as cross over current.

3.7.116 **minimum take-over current:** Current determined by the point of intersection of the time-current characteristics of the medium-voltage fuse and the contactor corresponding to:

a) the maximum break time plus, where applicable, the maximum operating time of an external overcurrent or ground-fault relay, and

b) the minimum pre-arcing time of the medium-voltage fuse.

See also Figure 7.

3.7.117 **maximum take-over current:** Current determined by the point of intersection of the time-current characteristics of the medium-voltage fuse and the contactor corresponding to:

a) the minimum opening time of the contactor, or minimum response time if operated by an overcurrent relay and/or time delay devices; and

b) the maximum operating time of the medium-voltage fuse of highest rated current.

See also Figure 7.

3.7.118 **maximum acceptable power dissipation:** [Vacant]

3.7.119 **fused short-circuit current:** [Vacant]

3.7.120 **applied voltage (for a switching device):** The voltage that exists across the terminals of a pole of a switching device just before the making of the current. [IEC 60050-441:1984, 441-17-24]

NOTE: This is normally the line-to-line voltage divided by 1.732.

3.7.121 **prospective transient recovery voltage (of a circuit):** [Vacant]

3.7.122 **opening time (of a contactor):** The opening time of a contactor is defined according to the tripping method as stated below, including any time-delay device forming an integral part of the contactor, adjusted to a specified setting:

a) For an electromagnetic contactor, the opening time is the interval of time between the instant at which the control circuit initiates contactor opening and the instant when the arcing contacts have separated in all poles.

b) For a latched contactor, the opening time is the interval of time between the instant of energizing the opening release and the instant when the arcing contacts have separated in all poles.

3.7.123 **minimum opening time (of the contactor):** [Vacant]

3.7.124 **maximum opening time (of the contactor):** [Vacant]

3.7.125 **arcing time (of a pole or a fuse):** The interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction of that pole or the fuse. [IEC 60050-441:1984, 441-17-37]

3.7.126 **break time (of the contactor):** The interval of time between the beginning of the opening time of the contactor and the instant of final arc extinction in all poles.

3.7.201 **supply voltage:** The voltage to which the line terminals of a device are connected.

3.7.202 **creepage distance:** The shortest distance along the surface of an insulating material between two conductive parts.

3.7.203 **disruptive discharge:** The phenomena associated with the failure of insulation under electric stress; these include a collapse of voltage and the passage of current. The term applies to electrical breakdown in solid, liquid, and gaseous dielectrics, and combinations of these dielectrics.

3.7.204 **ultimate trip current:** The minimum value of continuously applied current that will cause an overload relay to operate (trip).

3.101 Fuses

3.101.1 **fuse:** A device that, by the melting and severing of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device. [IEC 60050-441:1984, 441-18-01, modified]

3.101.2 **striker:** [Vacant]

3.101.3 **pre-arcing time:** The interval of time between the beginning of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated. [IEC 60050-441:1984, 441-18-21]

NOTE: Pre-arcing time is also referred to as melting time.

3.101.4 **total clearing time (sometimes called operating time):** The sum of the pre-arcing time and the arcing time. [IEC 60050-441:1984, 441-18-22, modified]

3.101.5 **joule integral (I^2t):** [Vacant]

3.201 Medium-voltage fuse

3.201.1 **medium-voltage fuse:** A current-limiting fuse intended for use in medium-voltage circuits, capable of interrupting all currents from the rated maximum interrupting current down to the rated minimum interrupting current (where applicable).

NOTE: See Annex D, Item 23 , which categorizes different types of current-limiting fuses based on their minimum interrupting current capability:

a) Backup current-limiting fuse: a current-limiting fuse capable of interrupting all currents from its rated maximum interrupting current down to its rated minimum interrupting current.

b) Full-range current-limiting fuse: a current-limiting fuse capable of interrupting, under specified conditions, all currents from its rated maximum interrupting current down to the minimum continuous current that can cause the fusible element to melt.

c) General-purpose current-limiting fuse: a current-limiting fuse capable of interrupting all currents from its rated interrupting current down to the current that causes melting of the fusible element(s) in one hour or more.

3.201.2 **foldback action:** A protective feature (a type of overload protection) that may be incorporated in reduced-voltage solid-state controllers. When the load attempts to draw excessive overcurrent through the solid-state portion of the controller, this action reduces both output voltage and current to lower values so as to avoid damage to the solid-state portion of the controller.

3.202 Index of definitions

4 Controller and Control Center Ratings and Characteristics

A contactor, starter, or combination in the correct condition of maintenance and adjustment shall be able to withstand all the stresses that occur in service, provided that these do not exceed its rated characteristics.

The characteristics of a contactor, starter, or combination, including its operating devices and auxiliary equipment, that shall be used to determine the ratings are given in this clause.

Under this heading, consideration is also given to the characteristics which are not necessarily ratings but need to be taken into consideration in the specification and design stages.

The rating of a controller is dependent on the medium-voltage fuse used.

A Class E controller intended for use with non-motor loads, such as transformers or capacitors, will in some cases require special considerations not included in this standard.

Where preferred ratings are specified in this standard, these ratings are not restrictive; ratings other than preferred ratings may be specified. Ratings which are not specifically identified as preferred ratings are mandatory values.

4.1 Rated maximum voltage (U_r)

The rated maximum voltage indicates the upper limit of the highest voltage of the system voltage for which the device or assembly is intended. Standard values of rated voltages are 2.5 kV, 3.6 kV, 5.0 kV, 7.2 kV, 12.0 kV and 15.0 kV.

NOTE: Standard values of rated voltage in Mexico are 3.6 kV, 5.0 kV, and 7.2 kV.

4.1.201 Rated supply voltage (U_a)

The rated supply voltage is the voltage to which the line side of the controller is designed to be connected.

4.2 Rated insulation level (U_d), (U_p)

The rated insulation level is the impulse test voltage (BIL) (U_p) and the power-frequency withstand test voltage (U_d) from Table 1 that the controller is expected to withstand.

4.2.101 Rated rotor insulation level

[Vacant]

4.2.102 Rated starting voltage of an autotransformer controller (U_{tap})

The rated starting voltage of an autotransformer controller is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage (U_{tap}) are 50%, 65%, or 80% of the rated supply voltage.

4.2.103 Rated starting voltage of a reactor starter (U_{tap})

The rated starting voltage of a reactor controller is the reduced voltage derived from the impedance of the reactor and the motor current before rotation.

Preferred values of rated starting voltage (U_{tap}) are 50%, 65%, or 80% of the rated supply voltage.

4.3 Rated frequency (f_r)

The rated frequency is the supply frequency for which the device is designed and to which the other characteristic values correspond. The standard values of the rated frequency are 50 Hz and 60 Hz.

The preferred rated frequency is 60 Hz.

4.4 Rated continuous current and temperature rise

4.4.1 Rated normal current

[Vacant]

NOTE: See Clauses 4.4.101 and 4.4.201.

4.4.2 Temperature rise

The temperature rise of any part of a contactor or controller at an ambient air temperature not exceeding 40°C shall not exceed the limits of temperature rise specified in Table 2 when tested in accordance with Clause 6.5.

4.4.101 Rated continuous current (thermal current rating) (I_{th})

The rated continuous current (thermal current) is the maximum current carried on a continuous basis without the temperature rise of the various parts exceeding the limits specified in Table 2.

NOTE: Selection from the R10 series is not applicable.

4.4.201 Control center rated continuous current

Preferred ratings of extendable power bus are 800 A, 1 000 A, 1 200 A, 1 600 A, 2 000 A, and 3 000 A.

Ratings of non-extendable power bus shall equal or exceed the maximum continuous current of the connected loads.

The current rating of individual controllers, when grouped within a vertical section, may be less than the rating of the controller alone when tested in accordance with Clause 6.5.

4.5 Rated short-time withstand current (I_k)

The rated short-time withstand current is the maximum symmetrical rms value of the short-circuit current that the extendable power bus and ground bus can withstand. See Clause 4.7 for duration. See Clause 6.6.2 for test details.

The preferred values are 40 kA and 50 kA.

The non-extendable power bus is not required to have a short-time withstand current rating.

4.6 Rated peak and momentary withstand current

4.6.1 Rated peak withstand current (I_p)

The rated peak withstand current is the prospective peak current associated with the first major loop of the rated short-time withstand current that the contactor, controller, and non-extendable power bus can withstand in the closed position during the fault interruption test.

The prospective peak current value shall be equal to 2.6 times (60 Hz) or 2.5 times (50 Hz or below) the rated short-time withstand current. See Clause 6.6.3 for test requirements.

The non-extendable power bus shall withstand the maximum peak let-through fault current among the connected assemblies.

4.6.2 Rated momentary withstand current

The rated momentary withstand current is the maximum total current that the extendable power bus and ground bus shall be required to withstand. The current shall be the value, including the dc component, at the major peak of the maximum cycle as determined from the envelope of the current wave of the maximum offset phase during a test period of at least 10 cycles.

The peak current value shall be equal to 2.6 times (60 Hz) or 2.5 times (50 Hz or below) the rated short-time withstand current. See Clause 6.6.2 for test requirements.

NOTE: The momentary current is expressed as the peak current.

The symmetrical current shall be the rated short-time withstand current.

The non-extendable power bus is not required to have a momentary withstand current rating.

4.7 Rated duration of short-circuit (t_k)

4.7.1 General

The rated duration of short-circuit is the interval of time for which a controller or control center can carry a current equal to its rated short-time withstand current.

4.7.2 Rated duration of short-circuit for extendable power bus

The standard value of rated duration of short-circuit is 10 cycles (0.167 s at 60 Hz).

If necessary, a value other than 10 cycles (0.167 s at 60 Hz) may be chosen. The recommended values are 0.5 s, 1 s, and 2 s.

4.7.3 Rated duration of short-circuit for non-extendable power bus

The rated duration of short-circuit withstand current is the clearing time of the medium-voltage fuse (for Class E2) or controller (for Class E1).

4.8 Rated supply voltage of operating devices and of auxiliary and control circuits (U_a)

4.8.1 General

The supply voltage of closing and opening devices and auxiliary and control circuits shall be understood to mean the voltage measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

4.8.2 Rated supply voltage (U_a)

Common values for the rated control circuit supply voltages are as follows:

Rated supply frequency	Canada United States	Mexico
60 Hz	120 V ac	127 V ac
50 Hz	230 V ac	NA
dc	125 V dc	125 V dc

4.8.3 Supply voltage range

The range of ac and dc power supply voltage in normal duty measured at the input of the auxiliary equipment (electronic controls, supervision, monitoring and communication) is 85% to 110%. See Clause 6.101.1 for test procedure.

4.9 Rated supply frequency of closing and opening devices and of control circuits

The standard values of rated supply frequency are dc, 50 Hz and 60 Hz.

4.10 Rated pressure of compressed gas supply for installation and/or operation

[Vacant]

4.101 Rated operational current or rated operational power (I_e)

[Vacant]

4.102 Rated duties

[Vacant]

4.103 Rated making and breaking capacities

A contactor shall be capable of making and breaking the maximum current at which the overload relays alone cause current interruption (take-over current). The rating is determined by the make and break capacity test described in Clause 6.102.

4.104 Utilization category

[Vacant]

4.105 Mechanical endurance (standard and optional)

With respect to its endurance against mechanical wear, a contactor or starter is characterized by the number of no-load operating cycles (i.e. without current on the main contacts) that can be made before it becomes necessary to replace any parts.

The minimum number of operations for the required standard rating is 10 000 and shall be verified in accordance with the test described in Clause 6.101.2.

An optional rating above 10 000 may be provided. The preferred optional ratings, expressed in millions of operations, are 0.03, 0.1, 0.3, 1 and 3.

4.106 Electrical endurance

[Vacant]

4.107 Coordination with medium-voltage fuses

Class E2 controllers are characterized by the type, ratings, and characteristics of the power fuses. Current-limiting fuses, to be used to provide overcurrent delineation between the contactor(s) and medium-voltage fuses, shall be coordinated with the contactor. The contactor interrupting rating and breaking time shall be coordinated with the medium-voltage fuses such that the contactor does not attempt to interrupt currents above its breaking capacity.

The medium-voltage fuses shall preferably be located on the supply side of the controller, and shall have a short-circuit breaking capacity not less than the prospective current (symmetrical) under short-circuit conditions at its location.

The medium-voltage fuses shall not operate in place of the contactor for currents up to the maximum overload levels in normal service (including stalled current of the motor).

For additional coordination information, refer to Clauses 4.201 and 4.202.

4.108 Types and characteristics of automatic change-over devices and automatic acceleration control devices

[Vacant]

4.109 Types and characteristics of autotransformers or reactors

Autotransformers or reactors shall be characterized by:

a) the supply voltage;

b) the number of taps available for adjusting the starting torque and current;

c) the rated starting voltage (see Clauses 4.2.102 and 4.2.103);

d) the current they can carry for a specified duration;

e) the rated starting duty (see Clauses 4.204 and 4.204.1); and

f) the method of cooling (e.g., free air, forced air, liquid immersion).

The autotransformer or reactor may be either built into the controller or provided separately.

4.110 Types and characteristics of the starting resistors for rheostatic motor starters

[Vacant]

4.111 Characteristics dependent on starter type

[Vacant]

4.112 Rated capacitive switching currents

A capacitive switching current rating is optional. The rating of a switching device for capacitive current switching shall include one or both of the following, where applicable:

a) Rated single capacitor bank breaking current and inrush making current.

b) Rated back-to-back capacitor bank breaking current and inrush making current.

The values of rated capacitive switching currents shall be given by the manufacturer.

Two classes of switching devices are defined according to their restrike performances:

- Class C1: low probability of restrike during capacitive current breaking as demonstrated by the type tests.

- Class C2: very low probability of restrike during capacitive current breaking as demonstrated by type tests.

NOTE 1: The probability is related to the performance during the series of type tests stated in 6.109.

NOTE 2: The same switching device may have different classes depending on the application.

4.112.1 Rated single capacitor bank breaking current

The rated single capacitor bank breaking current is the maximum capacitor current that the switching device shall be capable of breaking at its rated maximum voltage U_r under the conditions of use and behavior prescribed in this standard. This breaking current refers to the switching of a shunt capacitor bank where no shunt capacitors are connected to the source side of the switching device.

4.112.2 Rated back-to-back capacitor bank breaking current

The rated back-to-back capacitor bank breaking current is the maximum capacitor current that the switching device shall be capable of breaking at its rated maximum voltage U_r under the conditions of use and behavior prescribed in this standard.

This breaking current refers to the switching of a shunt capacitor bank where one or several shunt capacitor banks are connected to the source side of the switching device giving an inrush making current equal to the rated back-to-back capacitor bank inrush making current.

4.112.3 Rated single capacitor bank inrush making current

No rated values are defined. Inrush currents associated with single capacitor banks are not considered critical.

4.112.4 Rated back-to-back capacitor bank inrush making current

The rated back-to-back capacitor bank inrush making current is the peak value of the current that the switching device shall be capable of making at its rated maximum voltage U_r and with a frequency of the inrush current. The values shall be given by manufacturer.

4.201 Characteristics of Class E2 controllers

4.201.1 Running overcurrent protective units for Class E2 controllers shall be selected to:

a) prevent continuous operation above the rated continuous current of the controller,

b) provide protection of branch circuit conductors and connected loads in accordance with Annex A, item 1; and

c) operate before any fuse melts at all currents below the rated minimum interrupting current of the power circuit fuses.

4.201.2 Power circuit fuses shall be selected to be able to:

a) permit repetitive switching of the load, with consideration given to inrush current and time, without damaging a fuse,

b) interrupt faults at or beyond the controller load terminals, and

c) continuously carry overload relay ultimate trip current.

4.201.3 Contactors shall be selected to:

a) continuously carry overload relay ultimate trip current, and

b) interrupt normal running currents and operating overload currents up to the rated minimum interrupting current of the power circuit fuses.

4.202 Fault-interrupting rating

The interrupting rating of a Class E controller is expressed in terms of the maximum symmetrical fault current and specific line-to-line voltage it can interrupt at the controller incoming line terminals, according the fault interruption test described in Clause 6.104.

Standard fault-interrupting ratings for Class E2 controllers, based on power fuse interrupting rating, are 40 kA and 50 kA rms symmetrical.

4.203 Control center short-circuit rating

The short-circuit rating of a control center is equal to the lowest of the:

a) fault-interrupting rating of the installed controllers;

b) rated short-circuit current of protective devices; or

c) the rated short-time withstand current of the extendable power bus.

4.204 Starting duty of reduced-voltage starters

The locked-rotor current at full voltage is assumed to be 6 times full load current. Ratings shall be determined as follows:

4.204.1 The starting duties for motor starting autotransformers and reactors:

4.204.1.1 Medium duty: The starter shall be rated based on the following test sequence:

a) On 30 s off 30 s, repeat two times for a total of three on/off operations.

b) Rest one hour.

c) Repeat step (a).

4.204.1.2 Heavy duty: The starter shall be rated based on the following test sequence:

a) On 1 min off 1 min, repeat four times for a total of five on/off operations.

b) Rest two hours.

c) Repeat step (a).

4.204.1.3 Optional Duty: Optional duty includes a starting current, specified as a multiple of full load current, and a test sequence defined by the following parameters:

a) On time (in seconds).

b) Off time (in seconds).

c) Number of consecutive on/off operations.

d) Rest time (in hours).

e) Repeat step (a) through (d) for specified number of sequences.

Optional duty starters shall have their duty cycle capabilities clearly and completely marked on the nameplate and drawings.

4.204.2 The starting duty for reduced-voltage solid state starters:

Reduced voltage solid state starters shall have a rated starting duty. The preferred starting duty is medium duty in accordance with Clause 4.204.2.1. Optional starting duty may be assigned, using the format in accordance with Clause 4.204.2.2.

4.204.2.1 Medium duty: The starter shall be rated with current of 4 times the rated full load current and on the following test sequence:

a) On time of 30 s.

b) Off time of 30 s.

c) Repeat 2 times for a total of 3 consecutive on/off operations.

d) Rest 1 hour.

e) Repeat step (a), (b) and (c) for a total of two sequences.

4.204.2.2 Optional Duty: Optional duty includes a starting current, specified as a multiple of full load current, and a test sequence defined by the following parameters:

a) On time (in seconds).

b) Off time (in seconds).

c) Number of consecutive on/off operations.

d) Rest time (in hours).

e) Repeat step (a) through (d) for specified number of sequences.

4.205 Duty rating for solid state resistive load controllers

4.205.1 Continuous duty (no bypass contactor)

The controller shall be capable of operating at its maximum rated continuous current continuously, without exceeding the temperature limits specified in Clause 6.5.5.201.

4.205.2 Intermittent duty (with or without bypass contactor)

The controller shall be capable of operating at its maximum rated continuous current for a duty as specified by the manufacturer and defined in a test sequence defined by the following parameters, without exceeding the temperature limits specified in Clause 6.5.5.201:

a) On time (in seconds or minutes).

b) Off time (in seconds or minutes).

c) Number of consecutive on/off operations.

d) Rest time (in hours).

e) Repeat step (a) through (d) for specified number of sequences.

4.206 Grounding switch characteristics

4.206.1 Grounding switch operating

Grounding switches shall be manually operated. Power operated devices may be used, providing they have provisions to be operated by hand.

Grounding switches shall have provisions to be padlocked in the closed position or shall have provisions to padlock the access to the operating means for the grounding switch such that the switch cannot be opened.

If the grounding switch has provisions for electrical operation, padlocking in the closed position shall prevent the switch from opening when an attempt is made to electrically open the switch.

4.206.2 Grounding switch mechanical endurance

A grounding switch shall be capable of performing 1000 operations without voltage on or current through the circuit.

See Clause 6.101.3 for testing requirements.

4.206.3 Grounding switch electrical ratings

4.206.3.1 Grounding switches are intended to be used on de-energized power circuits.

Grounding switches shall have the following electrical ratings:

a) Rated maximum voltage for the line side terminals, when in the open position; and

b) Rated insulation level for the line side terminals, when in the open position.

These ratings shall be equal to or greater than the controller ratings.

See Clause 6.2 for testing requirements for these ratings.

4.206.3.2 A grounding switch that is intended to ground a load that may contain stored electrical energy, such as a capacitor bank, shall have the following additional manufacturer defined ratings:

a) Short time withstand current – The maximum symmetrical rms value of the prospective short-circuit current that the grounding switch can carry when in the closed position.

b) Short time withstand duration – The time the grounding switch can carry the rated short time withstand current, when in the closed position.

c) Peak closing current – The maximum value of prospective peak current, of a stored energy circuit, that the grounding switch could be closed into.

d) Peak making voltage – The maximum peak voltage, of a stored energy circuit, that the grounding switch could be closed into.

Grounding switches provided with closing ratings shall be constructed such that the contact operating speeds and pressure are independent of the operating speed of the manual handle.

See Clause 6.209 for testing requirements for these ratings.

4.206.4 Grounding switch construction

Vacuum or any other type of sealed switching devices are not suitable to be used as grounding switches.

5 Design and Construction

5.1 Requirements for liquids

[Vacant]

5.2 Requirements for gases

[Vacant]

5.3 Provisions for protective grounding

5.3.201 Terms

The grounding and bonding terms are identified in Figure 8. The terms used in this standard are in accordance with the UL column in Figure 8. The corresponding CSA C22.1 Canadian Electrical Code, Part 1 (CE Code) terms and ANCE terms are also provided for information in Figure 8.

5.3.202 Grounding of exposed metal parts

An enclosure shall have provision for permanent and effective grounding of exposed non-current-carrying metal parts. The means for grounding shall consist of a ground bus or ground stud with provisions for the mounting of pressure terminal connectors acceptable for use with conductors of the size indicated in Table 3. At all points of connection between the ground bus or the equipment grounding conductor and the assembly, any nonconductive coating, such as paint, shall be removed or penetrated to provide a good electrical connection. Bolts or screws engaging at least two full threads in the penetrated metal shall be considered to have provided adequate penetration.

There shall be provision for permanently and effectively grounding a metal plate that covers uninsulated live parts. All dead metal parts that are likely to be touched by persons and are likely to become energized shall be grounded.

If the above requirements cannot be visually verified, the grounding provisions shall be tested in accordance with Clause 6.205.

In Canada, provision for grounding and bonding shall also comply with Annex A, Item 13.

5.3.203 Ground bus

A ground bus shall be provided for all controllers having extendable power bus, and for all assemblies consisting of multiple vertical sections.

When a ground bus is provided, it shall be of equivalent cross-sectional area to the conductors shown in column 2 or 3 of Table 3. Splice bars shall be provided for field splicing sections as needed.

When a ground bus is not provided, at least two terminals shall be provided on the frame or enclosure:

a) for an equipment-grounding conductor of a size in accordance with Table 3 to ground the control center frame; and

b) for an equipment-grounding conductor to bond all outgoing conduits to the enclosure frame. The second connection shall accommodate an equipment-grounding conductor in accordance with Table 3 corresponding to the largest branch circuit.

5.3.204 Provision for ground termination

Controllers shall include one of the following provisions for the termination of the grounding conductor associated with each incoming or outgoing circuit, or provision for field installation of wire connectors suitable for that purpose:

a) for each circuit, a suitable stud or bolt mounted on the grounding bus or controller structure, together with a standard complement of hardware to secure a suitable wire connector (the connector need not be furnished);

b) for each circuit, a wire connector, located either on the grounding bus or elsewhere on the controller structure, or

c) for each circuit, a termination pad with drilling in accordance with Annex A, Item 21.

Refer to Clauses 5.3.207 and 5.208 for grounding kit requirements.

5.3.205 Grounding of drawout elements

The metal frame of the drawout element shall be grounded in the test and connected positions and in all locations between these positions.

When in the test position, all dead metal parts that are likely to be touched by persons and are likely to become energized shall be grounded. A dead metal part shall be considered likely to become energized if the part contains or encloses live parts above 50 V.

5.3.206 Grounding of instrument and control circuits

The metal cases or frames of instrument transformers, instruments, meters, relays, and similar equipment shall be considered adequately grounded when mounted directly on the grounded metal structure. When not mounted directly on the grounded metal structure, metal cases shall have a grounding conductor of at least 12 AWG (3.31 mm^2) copper or equivalent.

Secondary circuits of internally mounted current and voltage transformers shall be grounded. The grounding conductor for secondary circuits of current and voltage transformers and for instrument cases shall not be smaller than 12 AWG (3.31 mm^2) copper or equivalent.

5.3.207 Wire, cable, bus connector, and grounding kits

Controllers intended to be terminated with field wiring larger than 10 AWG (5.26 mm^2) need not have the wire connectors attached if connector and grounding kits that will properly accommodate conductors suitable for the ampere rating of the device are made available by the manufacturer and identified for use in accordance with Clause 5.10.204(v). Grounding kits may be provided for all sizes of conductors. See Clause 5.208 for connector and grounding kit requirements.

5.3.208 Connection of conductor shields

There shall be provisions for bonding of conductor shields to the ground bus.

These provisions shall be located:

a) Such that the shield bonding conductor need not exceed 1m (3.3 ft), and

b) In the same compartment as the wiring terminal for the associated shielded conductors.

5.4 Auxiliary and control equipment

Auxiliary equipment and components utilized in control centers shall comply with the requirements for the subassembly or component, as applicable. See Annex D for a list of standards covering components generally used in products covered by this standard.

5.5 Dependent power operation

[Vacant]

5.6 Stored energy operation

[Vacant]

5.7 Independent manual operation

[Vacant]

5.8 Operation of releases

[Vacant]

5.9 Low- and high-pressure interlocking and monitoring devices

[Vacant]

5.10 Markings

All markings shall be in the appropriate language (or symbols as noted in this standard), as necessary for the country in which the controller will be installed (Spanish for Mexico, English for Canada and the United States). Caution and warning markings shall be in English and French in Canada. A manufacturer may choose to utilize multiple languages on a controller.

Unless otherwise stipulated, markings are not required to be located on the outside of an enclosure provided they are readily visible by opening a door or removing a cover after installation.

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

Contactors and Class E controllers shall be legibly and permanently marked as specified in Clauses 5.10.201 to 5.10.206 to identify the equipment and ensure that it is suitable for the particular installation. In Mexico, reference Annex A, Item 4.

5.10.201 General markings required for contactors and controllers

The following markings are required:

a) manufacturer's name or trademark;

b) catalog or manufacturer's identification;

c) serial number, date code, or equivalent markings;

d) number of phases;

e) frequency;

f) rated continuous current, rms amperes;

g) fault interrupting rating (V and rms symmetrical amperes);

h) rated maximum voltage;

i) rated insulation level [impulse test level (BIL)];

j) control voltage, including control frequency if different from item (e); and

k) manufacturing location.

5.10.202 Additional marking for controllers

The following markings are required:

a) rated supply voltage;

b) class E1 or E2 controller, as appropriate;

c) load rating (as appropriate based on application);

d) power circuit fuse type and size for Class E2 controller;

e) rated continuous current of extendable bus system, where supplied;

f) enclosure type (see Annex A, Item 6);

g) diagram number(s), if applicable;

h) for controllers arranged for more than one supply (power) circuit, the required marking for each supply circuit, i.e. voltage, current, frequency, number of phases, etc., as applicable; and

i) for reduced voltage controllers, the starting duty (medium or heavy duty). For solid state devices with starting duties other than medium or heavy duty, the marked starting duty shall include specified parameters in Clause 4.204.2.2.

5.10.203 Additional markings for control centers

In addition to the above markings, the following are required for control centers with extendable power bus:

a) rated continuous current of extendable power bus;

b) ground bus size;

c) rated momentary withstand current of extendable power bus; and

d) rated short-time withstand current and duration of extendable power bus.

5.10.204 Conditional markings

Where applicable, equipment shall be legibly marked as follows:

a) Doors and covers of compartments containing medium-voltage components shall be provided with a warning marking on the outside of the door or cover providing access, stating “DANGER High Voltage Keep Out” or “DANGER: ____ V” (with system voltage or voltage class inserted in the blank space).

b) The external manual release operator of a latched contactor shall be marked to indicate its function.

c) Equipment for use with either copper or aluminum conductors shall be marked “CU-AL” or the equivalent. Equipment for use with copper conductors shall be marked “CU Only” or the equivalent.

d) The volt-ampere (VA) rating, or the equivalent, of any operating coil circuit which requires a remote control device with a sealed rating of more than 125 VA shall be indicated.

e) Permanent, legible marking shall be installed on panels or doors that give access to live parts warning of the danger of opening while energized.

f) Unless the proper wiring connections are plainly evident, wiring terminals shall be marked, or the equipment shall be provided with a suitable wiring diagram to indicate the connections.

g) If a controller uses current transformers and overload relays with removable overload elements, it shall be marked "WARNING: This controller furnished with current transformers. Do not operate without overload elements installed" or the equivalent.

h) Any barrier intended to be removed during routine maintenance or servicing (such as barriers required to be removed for replacement of fuses or the examination of contacts) shall be marked to indicate that its reinstallation is required.

i) If the design of the controller is such that a low-voltage control circuit fuse is accessible with the CPT or voltage transformers energized, a warning shall be provided in the vicinity of the fuseholder: "WARNING" followed by the statement "Fuses may be energized" or the equivalent.

j) Controllers with overload protective units arranged to energize signals only in accordance with Clause 5.203(c) shall be marked to state that the motor running protective units do not open the motor circuit, and shall reference the applicable national installation code requirement (including article and clause).

k) Controllers employing an automatic reset overload relay and a wiring diagram indicating two-wire control shall be marked to indicate that a load connected to the circuit can start automatically when the relay is in the automatic reset position.

l) An enclosure provided without a bottom shall be marked "Not for use on combustible floors" or the equivalent.

m) A door that is not interlocked as described in Clause 5.102.204 shall be marked "DANGER – High Voltage – Door is not interlocked – Ensure that all sources of supply are isolated and locked out prior to removing any bolts or opening this door. Close door and tighten all bolts before re-energizing this equipment."

n) Special operating conditions, if applicable, shall be marked.

o) Altitude (if over 1 000 m) shall be marked.

p) Equipment that is energized from more than one circuit and that does not have means for disconnecting all ungrounded conductors within a single enclosure or compartment shall be permanently marked on the outside with the following, or equivalent wording: “WARNING: More than one live circuit. See diagram.”

q) The type and rating of fuses used to provide overcurrent protection in low voltage-control circuits shall be permanently marked adjacent to the fuseholder. This information may be provided by a table permanently affixed to the enclosure, provided the fuseholders are appropriately identified.

r) The current element table of an overload relay, and associated markings, when provided, shall be permanently affixed within the controller where it will be clearly visible,

s) Where control-circuit overcurrent protection is not provided in the equipment, a permanent marking shall be provided on the controller or controller wiring diagram to indicate that such protection is required.

t) If a controller feeds a capacitor load, a danger/warning label shall be provided on the outside of the door or cover providing access, with words to the following effect:

> “Hazardous voltage may be present on load side conductors after contactor and isolating means have been opened. Capacitor internal resistors require 5 minutes to discharge capacitor down to 50 V after de-energization. Wait 5 minutes after disconnecting power and then use proper voltage sensing device to verify voltage before servicing equipment.”
>
> NOTE: This marking is not required if the capacitor is on the same circuit as a motor.

u) A vertical stack arrangement shall be provided with a marking indicating the ampere rating permitted in each position.

v) Terminal kits shall be marked as follows:

i) Identification of the kits that can be installed shall either be marked on the equipment, supplied separately, or included in the manufacturer's catalogs.

ii) The connector kit or its package shall be marked with its identification and the name or trademark of the manufacturer. Information on the range of conductor sizes that the connector is intended to accommodate shall be marked on one of the following: the kit, its container or package, the main device, or its enclosure; or shall be included as a separate sheet.

w) Kits other than terminal kits shall be marked as follows:

i) Identification of the kits that can be installed in medium-voltage control equipment shall be either marked on the equipment, supplied separately, or included in the manufacturer's catalogs.

ii) The kit or its smallest unit package shall be marked with its catalog number (or the equivalent) and the name or trademark of the manufacturer.

iii) Unless proper installation of a kit is clearly evident, assembly instructions shall be provided, either as part of the kit or as part of the medium-voltage control equipment, and shall include:

1) a clear identification of the individual parts, components, or subassemblies;

2) schematic or wiring diagrams, if applicable;

3) explicit assembly information that describes all aspects of assembly;

4) clear identification of the controller(s) in which the kit is intended to be installed; and

5) identification of the parts and components of a kit, if required, in such a manner as to ensure proper matching with the schematic or wiring diagram.

x) An enclosure that meets the test requirements in Clause 6.203 shall be marked “Rainproof” or “Raintight” (in addition to the enclosure type marking in accordance with Annex A, Item 6).

y) Such other marking as may be necessary to ensure safe and proper operation shall be provided.

5.10.205 Marking for service equipment

5.10.205.1 Marking for service equipment (for Mexico and the United States only)

The following requirements shall apply:

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

i) in the case of an insulated neutral, “Suitable for use as service equipment;”

ii) in the case of a factory bonded neutral for other than fire pump controllers, “Suitable only for use as service equipment;” and

iii) in the case of fire pump controllers, “Suitable for use as service equipment.”

b) If equipment is marked “Suitable for use as service equipment,” the marking “Service disconnect” shall be provided in the form of pressure-sensitive labels in an envelope, or on a card, with instructions to apply near the disconnect handle(s) if the equipment is used as service equipment. If the equipment 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 factory. For equipment incorporating multiple service disconnects, this marking shall be provided for each service disconnect.

c) If equipment is marked “Suitable for use as service equipment,” instructions for installing the bonding means shall be provided.

d) If equipment 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 handle(s).

e) Equipment rated three-phase, four-wire and having a solidly grounded neutral but not provided with ground fault protection shall be marked for the use specified as follows:

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

ii) “Suitable for use as service equipment only if supplying a continuous industrial process.”

f) Equipment that is marked “Suitable only for use as service equipment” or “Suitable for use as service equipment” and not provided with ground fault protection shall be marked for:

i) supplying a fire pump;

ii) an alternate source for legally required standby service; or

iii) 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.

5.10.205.2 Marking for service equipment (for Canada only)

The following requirements shall apply:

a) The equipment marking required by Items (i) and (ii) below shall be permanent and plainly visible on the outside of the service compartment:

i) Service equipment shall be marked “Suitable for use as service equipment.”

ii) A compartment in a medium-voltage control assembly that is intended for supply authority use shall be marked with the following or equivalent wording: “Compartment for supply authority use only.”

b) Medium-voltage control assemblies intended for service use and constructed in accordance with Clause 5.204.2.3(c) shall be provided with a temporary tag, instruction sheet, or the equivalent indicating how the bond is to be removed when required by the electrical inspection authorities (e.g., “Where electrical inspection authorities require the neutral assembly to be disconnected from the enclosure, ...").

5.10.206 Additional equipment information

Tables, manuals, and diagrams for individual units shall be provided on or with the equipment. The following information shall be included, as applicable:

a) diagram(s) for the controller(s) to include electrical schematic and terminal identification;

b) effective current transformer ratios (to include ground fault CT ratios if required for relay settings);

c) information for protective relay setting;

d) acceptable replacement fuses; and

e) instructions detailing wiring and termination techniques to be used during installation.

5.10.207 Marking for equipment with grounding switches

The ratings of the grounding switch shall be included on the controller rating label and on the switch. Grounding switches that do not have short time withstand current or peak closing current ratings shall have the ratings, listed in 4.206.3.2, marked as 0. The markings need not be on the grounding switch, if the switch is part of a controller.

Grounding switches that are not part of a controller and do not have integral shorting conductors shall also have the cross-sectional area or cable size of the shorting conductors with which they were tested marked on the switch.

5.11 Interlocks

5.11.201 Isolating means interlocks

Interlocks shall be provided by mechanical means to prevent the isolating means from being opened or closed unless all line contactors are open. It shall also prevent the line contactors from being closed, unless the isolating means is either in the closed position or separated by the isolating distance.

When the sum of the full load ratings of the CPT and any other connected transformers exceeds the interrupting capacity of the isolating means, electrical interlocks shall be provided to disconnect secondary loads of CPTs before the isolating means can be opened (see Clause 6.201).

5.11.202 Drawout element interlocks

5.11.202.1 In addition to the requirements of Clause 5.11.201, controllers using a drawout element shall be provided with mechanical interlocks that will:

a) positively lock the drawout element in the housing when the primary disconnecting devices are in their fully closed or fully connected position;

b) discharge or block stored-energy devices prior to complete removal of the drawout element; and

c) prevent contact with medium-voltage live parts as determined by the rod entry test in Clause 6.207 with the drawout element in the test position and with the drawout element removed from the cubicle.

NOTE: Means to padlock a shutter assembly in a closed position may be used to meet this requirement when the drawout element is removed from the cubicle.

5.11.202.2 In addition to the requirements of Clause 5.11.202.1, a controller using a drawout element that is used as the isolating means shall be provided with an automatic shutter assembly or the equivalent that:

a) is maintained in the closed position in a manner that prevents inadvertent opening. Opening of the shutter shall require a degree of difficulty involving a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty; and

b) complies with the shutter integrity test described in Clause 6.206.

5.11.203 Door interlocks

Mechanical door interlocks shall be provided to meet these requirements:

a) Interlocks shall prevent the opening of a door to a medium-voltage compartment when the isolating means is closed.

b) Interlocks shall prevent the isolating means from being closed when the door of any medium-voltage compartment of the controller is open.

c) Where a controller is being back fed by other power source(s), such as a bypass contactor or an isolating contactor for adjustable speed drive applications, interlocks shall be provided to prevent opening of a door to a medium-voltage compartment when the isolating means of the back-fed power source is closed, and to prevent closing of the isolating means of the back-fed power source when a door to a medium-voltage compartment is open.

NOTE: Key interlocking schemes are considered to meet this requirement.

5.11.204 Contactor interlocks

Any arrangement of two or more contactors that would cause a line-to-line fault if they were in the closed position at the same time shall be mechanically and electrically interlocked to preclude this condition. Examples include:

a) reversing contactors in reversing starters;

b) start and run contactors in autotransformer starters; and

c) dynamic braking contactors and line contactor.

5.11.205 Door interlock defeat

Where a means for circumventing the door interlock described in Clause 5.11.203 is provided for inspection or maintenance purposes, some degree of difficulty shall be required to bypass the interlock.

The degree of difficulty shall involve a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty.

5.11.206 Arrangement for test operation

If provision is made for a test position, the isolating means shall be interlocked to ensure that the isolating distance is established when the drawout (withdrawable) element is in the test position. The control circuit shall be arranged so that it must be disconnected from the normal CPT before it can be connected to a separate source of control power. Should it be necessary to defeat a mechanical interlock in order to close the contactor on test power, the isolating means shall be prevented from being closed until the interlock mechanism has been restored to normal.

5.11.207 Grounding switch interlocks

If a controller is supplied with a grounding switch, the switch shall be interlocked with any isolating means that could energize the circuit that it is intended to ground. Interlocks shall be provided by mechanical means to prevent the grounding switch from being closed unless all associated isolation means are fully open. They shall also prevent the isolation means from being closed unless the grounding switch is fully open. Key interlocking schemes are considered to meet this requirement.

In addition to the interlocking above, if the grounding switch is electrically operated, electrical interlocking shall be supplied to prevent the grounding switch from being closed unless all associated isolation means are open. Interlocking shall also be provided to keep the switch from being electrically operated when manual switching operations are being performed.

See Clause 6.101.3 for testing requirements.

5.12 Position indication

5.12.201 Isolating means – position indication

The isolating means shall provide visible evidence of an isolating distance in the circuit adequate for the rated voltage. Isolating and load-break switches or drawout assemblies shall be provided with position indicators indicating the fully closed and fully open positions.

The isolation gap or a mechanically operated indicator shall be visible through a viewing pane or by opening a door when the isolating gap is open. The mechanical operator shall be actuated by the movement of the actual isolating switch assembly, the shutter of a drawout assembly, or the like. The action of the mechanical indicator shall not be dependent on the movement of the operating handle or mechanism alone.

Isolating and load-break switches other than those described in Clause 5.202.2(c) shall have an observation window (or windows) through which the isolating distance is visible.

An isolating means operator system shall provide indication of “Open” and “Closed” position via one or more of the following means; color coding (red – closed, black or green – open), words (“OPEN,” ”ON,” “CLOSED,” “OFF”) or symbols (See Figure 3).

5.12.202 Marking of open and close method

The action required to open or close the isolating means shall be clearly indicated.

5.12.203 Grounding switch – position indication

Grounding switches shall provide visual indication of their position. If the contact position is not visible, the switch shall be provided with mechanical position indicators indicating the fully closed and fully open positions.

The contacts or indicators shall be visible through a viewing pane or by opening a door when the isolating means of the controller is open. If the indication is provided via a mechanical operator, the mechanical operator shall be actuated by the movement of the actual grounding switch assembly. The action of the mechanical indicator shall not be dependent on the movement of an operating handle or mechanism alone.

A grounding switch operator system shall provide indication of “Open” and “Grounded” (or “Earthed”) position.

5.13 Degrees of protection (optional)

Degrees of protection according to Annex A, Item 12, may be specified for enclosures of controllers containing live parts. If degree of protection is assigned, it shall be IP-2X or better. The enclosure shall comply with Clause 5.102.204.

NOTE: The degrees of protection can be different for other conditions such as maintenance, testing, etc.

5.14 Spacings

5.14.201 General

The electrical through-air and over-surface spacings shall be not less than those indicated in Table 5.

The spacings indicated for control circuits in Table 5 are applicable between live parts of control circuit components and grounded metal and to live parts of other control circuit components.

The spacings in a component device (such as a snap-switch, lampholder, and the like) supplied as part of industrial control equipment, other than in motor circuits, shall not be less than the minimum spacings required for the component device or the spacings indicated in Table 5, whichever are smaller.

The spacings at a field-wiring terminal shall be measured with wire of the appropriate size connected to the terminal as in actual service. The connected wire shall be the next larger size than would be required for the rating except that the required wire size shall be used if:

a) the terminal will not accept the larger size; or

b) the device is marked to restrict the use of oversized conductors.

The spacings at fuses and fuseholders, measured with the fuses in place, shall be based on the use of fuses having maximum standard dimensions and shall not be less than the spacings indicated in Table 5. Where the fuseholder construction permits a fuse to be partially inserted and remain in that position, spacings shall be measured with the fuse in the partially inserted position as well as in the fully inserted position.

An uninsulated live part, including a terminal, shall be so secured to its supporting surface by a method other than friction between surfaces that it will be kept from turning or shifting in position if such motion might result in reduction of spacings to less than those required elsewhere in this standard. The security of a contact assembly shall provide for the continued alignment of contacts.

A pressure terminal connector that is intended for field connection, and that is not capable of receiving a conductor larger than 3/0 AWG (85.0 mm^2), need not be prevented from turning provided no spacings less than those required result when the connectors are turned 30 degrees toward each other, or toward other uninsulated parts of opposite polarity, or toward grounded metal parts.

5.14.202 Spacings with ceramic coatings

Any conductive part with ceramic, vitreous-enamel coating shall be considered uninsulated for the purpose of determining compliance with the spacing requirements of this standard.

Enamel-insulated and similar film-insulated wire shall be considered to be the same as an uninsulated live part in determining compliance of a device with the spacing requirements in this standard.

5.14.203 Considerations for circuits 1 500 V or less to ground

5.14.203.1 An insulated low-voltage conductor shall be considered uninsulated for the purpose of measuring spacings to uninsulated high voltage parts, unless the insulation is acceptable for the higher voltage involved.

5.14.203.2 An insulating barrier or liner used as the sole separation between uninsulated live parts of 1 500 volts or less and grounded dead metal parts (including the enclosure), or between uninsulated live parts of opposite polarity, shall be of material of a type that is acceptable for the mounting of uninsulated live parts and shall be:

a) not less than 0.66 mm (0.025 in) thick;

b) less than 0.66 mm (0.025 in) thick if used as the sole separation between the enclosure and an uninsulated metal part electrically connected to a grounded circuit conductor; or

c) less than 0.66 mm (0.025 in) thick if, upon investigation, it is found to be acceptable as an insulating barrier in accordance with Annex A, Item 4.

5.14.203.3 An insulating barrier or liner used in addition to an air space in place of the required spacing through air shall not be less than 0.66 mm (0.025 in) thick. If the barrier or liner is a fiber material, the air space shall not be less than 0.8 mm (0.032 in), and if the barrier or liner is of other material of a type that is not acceptable for the support of uninsulated live parts, the air space provided shall be such that upon investigation it is found to be acceptable as an insulating barrier in accordance with Annex A, Item 4.

5.14.203.4 Except as provided in Annex A, Item 4, a barrier or liner used in addition to not less than one half the required spacing through air may be less than 0.66 mm (0.025 in) thick but shall not be less than 0.33 mm (0.013 in) thick, provided that the barrier or liner is of a material that is acceptable for the mounting of uninsulated live parts; of necessary mechanical strength if exposed or otherwise likely to be subjected to mechanical damage; effectively held in place, and so located that it will not be affected adversely by operation of the equipment in service.

5.14.203.5 Spacing on printed wiring assemblies operating entirely at 1500 V or less to ground shall be in accordance with the spacing requirements as provided in Annex A, item 4.

5.15 Gas and vacuum tightness

[Vacant]

5.16 Liquid tightness

[Vacant]

5.17 Flammability

Insulating materials shall be rated HB minimum. See Annex A, Item 23

5.18 Electromagnetic compatibility

[Vacant]

5.19 X-ray emission

Devices incorporating vacuum interrupters shall be marked to warn of possible X-ray emission. This marking may appear on the device or on the interrupter itself. Instruction manuals for such devices shall include information regarding X-ray emission. Reference Annex A, Item 17.

5.101 Types of relay or release

[Vacant]

5.102 Enclosures

5.102.201 Requirements in other standards

In addition to the following, the enclosure construction requirements of Annex A, Item 6, apply. If there is a conflict between the requirements in this standard and Annex A, Item 6, the requirements in this standard apply.

5.102.202 General requirements

Enclosures shall be metallic and built to the requirements of Annex A, Item 6. External parts of the controller may be of insulating material, provided that medium-voltage parts are completely enclosed by grounded metallic partitions or grounded shutters. These metallic partitions or shutters shall meet the thickness requirements of Annex A, Item 6. Excepted are inspection windows complying with Clause 5.102.205. The enclosure shall comply with the rod entry test of Clause 6.207.

A nonmetallic plug or other closure assembled as part of the enclosure shall be considered acceptable if evaluated in accordance with Annex A, Item 6.

Enclosures shall be supplied with a bottom plate unless marked in accordance with Clause 5.10.204(l).

5.102.203 Control centers

Control centers shall be substantially complete when shipped by the manufacturer with necessary bus splices, instructions, and hardware for field connecting to provide a completed control center.

A control center may be provided with compartments for field addition of controllers or other components, in which case, provisions shall be made in the design of the vertical sections and compartments to facilitate proper field installation.

Single vertical sections and vertical sections shipped assembled together shall be designed with provisions for lifting, handling, storage, and installation. See Annex A, Item 9, for additional information.

5.102.204 Exterior doors, covers, and similar parts of enclosures

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

If bare live parts are exposed by the opening of such doors or covers, means requiring the use of a tool to open them or provision for locking them shall be provided to secure them in the closed position. If parts operating above 600 V are exposed by the opening of covers or doors, a warning marking shall also be provided in accordance with Clause 5.10.204(a).

Doors shall be provided with a latch or with a captive fastener. Such fasteners shall be located or used in multiples so as to hold the cover closed over its entire length. A door more than 1 220 mm (4 ft) long on the hinged side shall have at least a two-point latch operated by a single knob or handle, or shall have two or more separate latches or captive fasteners.

Doors of compartments containing medium-voltage components that can be opened without the use of a tool other than a key shall be mechanically interlocked in accordance with Clause 5.11.203.

A door of a compartment containing medium-voltage components need not be mechanically interlocked when all the following conditions are met:

a) the door is not provided with handles or latches;

b) the door is bolted on all unhinged sides with a minimum of two bolts per side;

c) no bolts are operable by hand, without the use of a tool;

d) all bolts are captive fasteners;

e) the door does not provide access to withdrawable elements or fuses; and

f) the door is marked in accordance with Clause 5.10.204(m).

Covers of compartments containing medium-voltage components shall be bolted closed.

Where a door must be opened for maintenance of equipment or removal of drawout elements, low-voltage energized uninsulated live parts mounted on the door shall be effectively guarded or enclosed, to provide protection against unintentional contact.

All doors shall be capable of being opened to a minimum of 90 degrees from the closed position.

Low-voltage compartments required to be opened during normal operation, thus exposing bare live parts, shall have:

a) doors hinged such that the door will not come off inadvertently, and

b) barriers installed to prevent inadvertent contact with bare live parts during normal operation.

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

5.102.205 Inspection windows and viewing panes

A transparent material covering an observation opening and forming a part of the enclosure shall:

a) be of clear safety-type glass or wire-reinforced glass or another clear material found suitable with respect to flammability and UV resistance in accordance with Annex A, Item 8;

b) be secured in such a manner that it cannot be removed without tools; and

c) meet the requirements of impact and pressure tests for viewing panes specified in Clause 6.204.

5.102.206 Ventilating openings, vent outlets (openings in enclosures)

Ventilation openings, including perforations, louvers, and openings protected by means of wire screening, expanded metal, or a perforated cover, shall comply with the rod entry test specified in Clause 6.207.

Barriers shall be provided behind all ventilating openings into medium-voltage compartments. The barrier shall be effectively secured in place and shall prevent drawing a straight line from any point outside the enclosure to any medium voltage live part, including insulated parts such as cables (other than shielded cables).

The diameter of the wires of a screen shall be not less than 1.3 mm (0.050 in) if the screen openings are 320 mm^2 (0.497 in^2) or less in area, and shall be not less than 2.06 mm (0.081 in) for larger screen openings.

Perforated sheet steel and sheet steel employed for expanded metal mesh shall be not less than 1.07 mm (0.042 in) thick for mesh openings or perforations 320 mm^2 (0.497 in^2) or less in area, and shall be not less than 2.03 mm (0.080 in) thick for larger openings.

5.102.207 Protection against corrosion

Enclosures shall be designed so that aluminum will not contact a concrete mounting pad when installed in accordance with the manufacturer's instructions.

Ferrous metals shall be suitably protected against corrosion as required by Annex A, Item 6.

5.102.208 External operating handles and control devices

Control, instrument, switch, and operator handles or external handles and pushbuttons shall be located in accordance with the following:

a) Pushbuttons, control switch handles, and transfer switch handles shall be located in a readily accessible location at an elevation above the mounting surface not in excess of 2 m (79 in).

b) Operating handles requiring more than 222 N (50 lbf) to operate shall not be higher than 1.7 m (66 in) in either the open or closed position.

c) Operating handles for infrequently operated devices, such as reset devices, drawout fuses, fused voltage transformer or CPT primary disconnects, and bus transfer switches, need not comply with Items (a) and (b) above.

In determining compliance with these requirements, measurements shall be made from the mounting surface to the center of the handle grip with the handle in its highest possible position. If the handle grip is not clearly defined, the center of the handle grip shall be considered to be at a point 76 mm (3 in) in from the end of the handle.

If the mechanism of a switching device is such that operation of a remote or automatic tripping device will permit sudden movement of an operating handle, the motion of the handle shall be restricted or the handle shall be guarded.

5.102.209 Barriers

When access is required to a compartment that contains energized medium-voltage parts, barriers shall be provided to:

a) prevent unintentional contact with energized parts;

b) prevent tools or other equipment from being dropped on energized parts; and

c) protect against contact with live parts of adjacent functional units.

Any barrier intended to be removed during routine maintenance or servicing (such as barriers required to be removed for replacement of fuses or the examination of contacts) shall be marked in accordance with Clause 5.10.204(h).

5.102.210 Outdoor enclosure considerations

The following requirements shall apply:

a) External hinged doors or covers for equipment intended for use outdoors shall be provided with stops to hold them in the open position.

b) An enclosure intended for use outdoors shall be subjected to the driven rain test described in Clause 6.203.

c) Enclosures intended for outdoor use shall have provisions for locking to prevent access to medium-voltage compartments.

d) Consideration should be given to prevention of condensation and entry of snakes, rodents, etc.

5.201 Latched controllers

5.201.1 Mechanical release

A latched controller shall be provided with an externally operated manual release of the latching mechanism for each latched contactor. Control power shall not be required to open the contactor when using the external manual release. The manual release operator shall be clearly marked as specified in Clause 5.10.204(b).

5.201.2 Electrical release

When protective relay tripping or remote control is required, an electrically operated release means shall be provided in addition to the mechanical release means.

5.201.3 Stored-energy electrical release

When electrical release is required during an undervoltage condition that is below the operating range of the electrical release means, a stored-energy source shall be provided, for example, a capacitor trip device or alternate control power supply (such as connection to system battery or other emergency source).

5.202 Power circuit isolating means

5.202.1 Isolating means – general requirements

The power circuit isolating means shall:

a) be externally-operable gang-operated;

b) provide the isolating distance of the controller complying with the requirements of Clauses 6.2.201 and 6.2.202;

c) include position indication in accordance with Clause 5.12.201 that verifies that the isolating distance has been established;

d) be capable of interrupting the no-load current of the CPT supplied with the controller;

e) be capable of interrupting the full-load current of the CPT supplied with the controller, unless interlocking with the secondary load circuits is provided in accordance with Clause 5.11.201;

f) have provision for being padlocked in the open position;

g) be interlocked in accordance with Clause 5.11; and

h) be arranged so that gravity will not cause movement towards the closed position.

5.202.2 Types of isolating means

The isolating means may be any one of the following:

a) a three-pole switch;

b) a three-pole switch in mechanical combination with medium-voltage fuses; or

c) a drawout assembly, which in some cases can include medium-voltage fuses or contactor.

5.202.3 Operation of isolating means

The isolating means shall be:

a) arranged to be operated from a location where the operator is not exposed to energized parts;

b) arranged to open all ungrounded conductors of the main circuit simultaneously with one operation; and

c) interlocked with the high voltage door in accordance with Clause 5.11.203(a).

5.202.4 Isolating means connections

All switch blades shall be de-energized when the switch is in the open position, unless a switch is required to be energized from both sides (e.g., bus-tie and loop-sectionalizing), in which case:

a) Barriers or enclosures shall be installed over the switches for protection against contact with the energized switch blades; and

b) The switch is marked in accordance with Clause 5.10.204(p).

5.202.5 Isolating means

Isolating switches shall incorporate locking-type hardware, spring washers, or equivalent means to prevent loss of contact pressure and misalignment.

5.202.6 Isolation of fuses

Controllers shall be arranged such that when the medium-voltage isolating means is open all medium-voltage fuses will be readily accessible, so that they may be replaced without a person being exposed to any live parts. The electrical arrangement of a single-throw switch shall be such that, when properly connected, fuse terminals will be de-energized when the switch contacts are open.

5.203 Equipment protection

Medium-voltage Class E controllers shall be provided with the following protective features:

a) Under-voltage protection or under-voltage release (two-wire control), except for latched contactors in special applications or solid state resistive load controllers.

b) Controllers shall be provided with overcurrent protection as follows:

i) Motor controllers shall be provided with an overload current-sensing device in each phase. Overload current-sensing devices shall be arranged to open the contactor and may also energize a signal device. Motor controllers shall be provided with motor circuit overcurrent protection, ground fault protection, and motor running overload protection where required by Annex A, Item 1. Overload relays shall conform to the requirements of Annex A, Item 4.

ii) The fuses used in transformer and resistive load controllers shall be selected to provide branch circuit overcurrent protection and ground fault protection as required by Annex A, Item 1. Ground fault protection shall also be provided as required by Annex A, item 1.

c) For motor controllers in Mexico and the United States, if allowed by local installation codes, when a motor is vital to the operation of a plant, and the motor and motor controller should operate to failure if necessary to prevent a greater hazard to persons, the sensing device(s) may be connected to a supervised annunciator or alarm instead of interrupting the motor circuit. The controller shall be marked in accordance with Clause 5.10.204(j).

NOTE: See Annex A, Item 10.

d) Except as permitted in Clause 5.203(e), an overload relay or any other protective or sensing device that is intended to interrupt the continuous operation of the load shall not automatically reset after tripping.

e) An overload relay and the like may automatically reset after tripping, provided that:

i) a manual operation is required to close the motor circuit; or

ii) for an automatic reset overload relay, if the wiring diagram indicates two-wire control, the motor controller is marked in accordance with Clause 5.10.204(k).

f) For Class E1 controllers, instantaneous-fault overcurrent protection shall also be provided in each ungrounded conductor of the main circuit, and shall be arranged to open the contactor. Instantaneous fault interrupting devices shall not automatically reclose after a fault-interrupting (short-circuit) operation.

g) For Class E2 controllers, power circuit fuses shall be provided for interrupting faults exceeding operating and overload currents.

h) Primary overcurrent protection shall be provided for CPTs. The transformer secondary shall be isolated from the primary and provided with an overcurrent device in each ungrounded leg to which control circuit devices, e.g., pushbuttons, limit switches, etc., are connected.

i) Primary overcurrent protection of no more than 3 A shall be provided for voltage transformers where such transformers are supplied.

j) Reduced-voltage solid state controllers and solid state resistive load controllers shall be provided with open-phase protection. The open-phase protective device shall operate upon loss of power or a half wave condition in one or more conductors of a polyphase output circuit, to cause and maintain the interruption of power in all of the ungrounded conductors of the circuit. The requirement to protect against a half wave condition does not apply to solid state resistive load controllers.

k) Reduced-voltage solid state controllers and solid state resistive load controllers shall be provided with thermal sensors for solid state devices in each phase of the main circuit to detect over temperature conditions and operate to de-energize all of the ungrounded conductors of the main circuit by electrically opening a mechanical switching device. The heat sink that has the highest temperature rise of any heat sink in the complete assembly for each phase, as demonstrated during the temperature rise test of Clause 6.5.5.201.3, shall be provided with a thermal sensor. During the temperature test, the temperature of all heat sinks adjacent to each power semiconductor in the main circuit shall be measured.

l) Reduced-voltage solid state controllers and solid state resistive load controllers shall be provided with the circuitry to detect shorted switching elements. This circuitry shall either de-energize the circuit or provide a visible alarm.

m) Reduced-voltage solid state controllers and solid-state resistive load controllers shall be provided with an electromechanical contactor which opens the main circuit when the controller is in the "off" or "stopped" position.

n) Printed circuit board assemblies, such as gate drive boards, which are electrically connected to solid state switching devices operating at or near line potential, shall be treated as medium voltage circuits, and shall be electrically isolated from low voltage devices and wiring through the use of isolation transformers, voltage dividers, or fiber optic signaling.

o) Voltage dividers, if used, shall comply with Annex E. Devices connected to the low voltage section of voltage dividers shall be considered as isolated from the main circuit.

p) If the wiring diagram of a controller indicates that one side of the control circuit is, or may be grounded, the control circuit shall be so arranged that an unintentional ground in the remote control device circuit will not cause the controller to energize the load.

q) All devices operating at 1500 V or less to ground shall be electrically isolated from devices operating at voltages above 1500 V through the use of isolation transformers, voltage dividers, or fiber optic signaling.

5.204 Service equipment

5.204.1 Service equipment (Mexico and the United States only)

5.204.1.1 General

A medium-voltage control assembly intended for use as service equipment shall be provided with barriers such that no uninsulated, ungrounded parts, including busbars or terminals, on the line side of the service disconnect is exposed to inadvertent contact by persons or maintenance equipment while servicing terminations or other equipment on the load side of the service disconnect. See Clause 5.204.1.6 for guarding against inadvertent contact.

Additionally, the service equipment shall comply with Clauses 5.204.1.2 to 5.204.1.7.

5.204.1.2 Service disconnecting means

The following requirements shall apply:

a) Equipment marked for service equipment use shall be provided with disconnecting means for all ungrounded service conductors. This may be provided by up to six separate service disconnect switches. When more than one service disconnect is provided, each service disconnect shall be located in a separate compartment. Each service disconnect switch shall disconnect all ungrounded service conductors of the circuit which it controls.

b) In determining the allowable number of disconnects, a device used solely for disconnecting power-monitoring equipment, surge-protective devices, or the control circuit of a power-operable service disconnecting means, including a ground fault protection system, shall not be considered a service disconnecting means.

c) In a group of sections having a main service disconnect, only the main section or compartment shall be marked for service equipment use.

d) The service disconnecting means shall be a manually operated means or a power-operated means that can be opened by hand in the event of a power supply failure.

e) The contacts of the service disconnect shall provide visible evidence of an isolating gap. Where the contacts of the service disconnect are not visible (such as when an oil, vacuum, or gas-filled interrupter serves as the disconnecting means), one of the following additional visible means of isolation shall be provided:

i) an isolating switch with visible break contacts shall be provided on the supply side of the service disconnect; or

ii) the service disconnect shall be mounted on a removable truck that cannot be moved unless the service disconnect is open, and all energized parts are automatically disconnected when the truck is moved from the normal operating position.

f) The service disconnect shall be provided with a means for readily connecting the load side conductors to ground when disconnected from the source of supply.

g) The service disconnecting means shall have a fault closing rating not less than the short-circuit withstand rating of the equipment. Where fused switches or separately mounted fuses are installed, the fuse characteristics may contribute to the fault-closing rating of the disconnecting means.

h) Service disconnects for fire pump equipment shall not be located in multi-section equipment with other service disconnects.

i) Only the following equipment may be connected to the supply side of the service disconnect means:

i) instrument transformers (current and voltage);

ii) surge arresters;

iii) control circuits for power-operable service disconnecting means, if suitable overcurrent protection and disconnecting means are provided; and

iv) ground fault protection systems, if suitable overcurrent protection and disconnecting means are provided.

5.204.1.3 Grounding and bonding of neutral circuits

The following requirements shall apply:

a) Equipment marked for service equipment use shall be provided with a grounding electrode conductor terminal and a main bonding jumper.

b) In multi-section equipment, the main bonding jumper and grounding electrode conductor terminal for each service shall be located in the section where the service conductors are terminated.

c) In multi-section equipment, 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.

d) A ground bus shall be provided. For multi-section equipment, this ground bus shall extend into the section where the service conductors are terminated. The ground bus shall have provision for connection of service cable shields. Provision for connection of safety grounds for personnel protection shall be included.

5.204.1.4 Overcurrent protection

The following requirements shall apply:

a) Each ungrounded service conductor shall have overload protection.

b) The service overcurrent device shall be an integral part of the service disconnecting means or be located immediately adjacent thereto.

5.204.1.5 Ground fault protection

Ground fault protection is not required. However, if provided, it shall comply with the following:

a) The ground fault protection system shall open all ungrounded conductors of the faulted circuit.

b) The maximum setting of the ground fault protection shall be 1 200 A.

c) The maximum time delay shall be 1 s for ground fault currents equal to or greater than 3 000 A.

d) Equipment shall be provided with instructions for field testing of the ground fault protection system.

5.204.1.6 Exposure to inadvertent contact

Exposure to inadvertent contact is determined by use of the probe illustrated in Figure 10. If restriction to the line-side of the service disconnect is dependent on the installation of field installed service conductors, conductors sized in accordance with Table 7 shall be installed in the terminals when determining exposure to inadvertent contact. All live parts of the line side service terminal, including the connector body and pressure screw shall be evaluated.

5.204.1.6.1 Metal barriers provided to limit exposure to inadvertent contact shall:

a) have a thickness not less than 0.81 mm (0.032 in) if uncoated, not less than 0.86 mm (0.034 in) if galvanized, and not less than 1.27 mm (0.050 in) if aluminum; and

b) be constructed so that it can be readily removed or repositioned, and then re-installed, without the likelihood of contacting bare live parts or damage the insulation of any insulated live part. Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

5.204.1.6.2 Nonmetallic barriers provided to limit exposure to inadvertent contact shall:

a) comply with requirements for barriers used in conjunction with a minimum air space of 0.33 mm (0.013 in); and

b) be constructed so that it can be readily removed or repositioned, and then re-installed, to allow access to the terminal for servicing. Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

Equipment marked “Suitable for use as service equipment” shall be permitted to provide the protection from inadvertent contact in a field installable kit.

5.204.1.7 Marking

Marking for service entrance equipment shall be in accordance with Clause 5.10.205.1.

5.204.2 Service equipment for use in Canada

5.204.2.1 General

A medium-voltage control assembly intended for use as service equipment shall comply with Clauses 5.204.2.2 to 5.204.2.4 and the requirements of Annex A, Item 3.

5.204.2.2 Service disconnecting means

The following shall apply:

a) Service disconnecting means shall have provisions for the connection of 6 AWG (13.3 mm^2) or larger copper conductors.

b) Service disconnecting means shall have a single, load-rated, manually operable service-disconnecting switch complying with Annex A, Item 20, that opens all ungrounded conductors.

c) The service-disconnecting means and its associated overcurrent devices shall be located in a separate, metal compartment(s). If there are two or more doors or covers for the service compartment(s), they shall be interlocked to prevent access to energized parts. See Clause 5.11.203.

d) Associated equipment that must, by its operation, be connected to the line side of the main full-load interrupter 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.

e) 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.

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

g) A compartment provided for supply authority (utility) use shall be lockable or have provision for sealing, and shall be marked as specified in Clause 5.10.205.2(a)(ii).

5.204.2.3 Grounding and bonding of neutral circuits

The following requirements shall apply:

a) Equipment involving a solidly grounded 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:

i) incoming (grounded) neutral conductor;

ii) corresponding outgoing (load) neutral conductor, if any;

iii) service-grounding conductor;

iv) bonding conductor to the enclosure (removable);

v) bonding conductor to the service conduit (or equivalent); and

vi) bonding conductors to the service cable shields.

b) The connection means for the neutral assembly shall be grouped together and shall utilize pressure-type wire connectors for all field-made terminations. Terminal sizes shall be determined in accordance with Tables 16, 17, 18, and 51 of Annex A, Item 1, of the Canada column, as applicable.

c) The neutral assembly described above shall be insulated from the enclosure, bonded to the enclosure before shipment, and marked in accordance with Clause 5.10.205.2(b).

5.204.2.4 Marking

Marking for service entrance equipment shall be in accordance with Clause 5.10.205.2.

5.205 Internal wiring

5.205.1 Conductors

5.205.1.1 Insulated conductors shall be suitable for the service intended with respect to voltage, temperature, and grouping. Conductors shall be not smaller than 24 AWG (0.205 mm^2), and the temperature rating shall be not less than 90°C unless shown suitable with appropriate temperature rise testing.

NOTE 1: These requirements apply only to the wiring furnished on or in controllers as a part of the equipment. They do not apply to the supply wiring run to control equipment, to loads, or to other apparatus.

NOTE 2: For motor and control-circuit applications, the use of Table 9 together with Table 10 as a guide in selecting the conductor sizes will in some cases obviate the need to perform a temperature test on the wire. Conductor sizes for other applications are subject to investigation.

5.205.1.2 Conductors smaller than 24 AWG (0.205 mm^2) may be used for wiring of printed circuit boards and interconnecting wiring between electronic modules and subassemblies.

Conductors in sizes 1/0 AWG (53.5 mm^2) and larger may be run in parallel if the arrangement is such as to provide equal division of total current among all conductors involved.

5.205.1.3 Conductors in an assembly intended for use in a complete enclosure shall be insulated for the highest voltage normally occurring between such conductors unless wires are grouped so as to segregate the several voltages.

Wires shall be of multi-stranded, flexible, or extra-flexible construction where they make connection to electrical equipment mounted on a hinged door. If the flexing section of the wiring is liable to come in contact with grounded metal parts, that portion of the wiring shall be given additional protection with wrappings of tape or the equivalent or enclosed in nonmetallic flexible tubing or conduit.

5.205.1.4 Insulated grounding and bonding conductors shall be identified by the color green with or without one or more yellow stripes. other conductors shall be so identified. For cables that have an insulation color other than indicated, identification may take the form of paint, tape, or other permanent marking at each end of the conductor. No other conductors shall be so identified.

5.205.2 Support for internal wiring

Internal wiring shall be supported or secured so as not to come in contact with:

a) bare live parts of opposite polarity;

b) bare live parts of other circuits;

c) sharp or abrasive surfaces;

d) heat-producing components such as transformers, power resistors, fuse bodies, semiconductor devices, etc.; or

e) moving parts.

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

5.205.3 Routing through a metal barrier

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

If conductors greater than 10 AWG (5.26 mm^2) of an alternating-current circuit pass through a wall or partition of metal having magnetic properties, all of the conductors of the circuit, including the neutral, shall be run through the same opening. The conductors may pass through individual openings in a wall or partition of metal having magnetic properties if:

a) the openings are connected by slots cut in the metal wall; or

b) during the temperature test, temperatures are recorded on interposed metal to determine that conductor insulation is not adversely affected. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like, is placed across the insulating material between the conductors. See Figure 9.

5.205.4 Equipment above 7200 V

5.205.4.1 For equipment operating above 7200 V, instruments, meters, relays, secondary control devices, and their wiring shall be isolated by grounded metal barriers from the primary circuit elements, with the exception of short lengths of wire such as at instrument transformer terminals and secondary disconnecting devices.

5.205.4.2 The requirements of Clause 5.205.4.1 do not apply to printed circuit board assemblies, such as gate drive boards, which are located in the same high voltage compartment as the devices they control, and are electrically connected to solid state switching devices operating at or near line potential. Such devices shall comply with 5.203(m).

5.206 Terminals and connections

5.206.1 Terminal current carrying capability

Except as provided for by Clause 5.3.207, controllers shall be provided with wiring terminals for the connection of conductors having a current carrying capability not less than the larger of the following:

a) The continuous current rating of the device;

b) 125% of the full-load motor-running current specified for the horsepower rating;

c) 125% of the rated current for resistive heating equipment;

d) 125% of the rated primary current for transformers; or

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

5.206.2 Wiring terminals

5.206.2.1 Terminal parts for field-wiring connections of low voltage conductors shall conform to the following:

a) Ferrous binding head screws, bolts, studs, nuts, and washers may be used if suitably protected with a plating of zinc or equivalent material having a thickness not less than 0.005 mm (0.0002 in).

b) For a 10 AWG (5.26 mm^2) or smaller conductor, the terminal to which wiring connections are made may consist of clamps or binding screws with a terminal plate having upturned lugs or the equivalent to hold the wires in position.

c) A wire-binding screw to which field-wiring connections are made shall be not smaller than No. 8 (4 mm dia.), except that a No. 5 (3 mm dia.) screw may be used at a terminal intended only for connection of a 14 AWG(2.08 mm^2) or smaller conductor, and a No. 6 (3.5 mm dia.) screw may be used at a terminal intended only for connection of a 12 AWG (3.31 mm^2) or smaller conductor.

For Canada, the requirements of Annex A, Item 5, also apply.

5.206.2.2 Terminals for field connection of medium voltage conductors shall conform to any one of the following:

a) Bus bars provided with hole patterns meeting the requirements of NEMA CC1;

b) Connectors complying with Annex A, Item 27, rated for the conductor size required based on the ampacity required by Clause 5.206.1; or

c) Provisions for the use of connector kits as described in Clause 5.3.207.

5.206.3 Terminal plates

A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.75 mm (0.030 in) thick for a 14 AWG (2.08 mm^2) or smaller wire, and not less than 1.25 mm (0.050 in) thick for a wire larger than 14 AWG (2.08 mm^2). There shall be not fewer than two full threads in the plate. Two full threads shall not be required if fewer threads result in a secure connection in which the threads will not strip upon application of a 2.3 N·m (1.7 lbf-ft) tightening torque.

A terminal plate formed from stock having the minimum required thickness specified above may have the metal extruded at the tapped hole for the binding screw to provide two full threads.

5.207 Bus bar connections

Field connections for control centers may be made with bus bars as follows:

a) The control center enclosures shall be provided with a covered access opening allowing sufficient room to make the connections.

b) The bus bars shall be plated with silver, tin, or the like over the intended area of connection between bus bars and splices. Splice conductors shall be sized based upon power bus ampacity and short-circuit requirements.

c) Necessary hardware to perform field splicing and directions for the intended means of connection shall be provided in accordance with Clause 5.102.203.

5.208 Connector and grounding kits

The wire connector kits, bus connector kits, and grounding kits (in the form of either individual terminals or an assembly) shall be constructed so that:

a) installation can be easily accomplished without the use of special tools;

b) live parts are suitably supported after being assembled;

c) reliable connections to terminal pads will be afforded;

d) the grounding terminal means are readily accessible when the controller is mounted as in service, and are not connected directly to a neutral (when provided);

e) each kit can be installed without disassembly of factory-assembled parts (other than those parts normally disassembled for installation and wiring);

f) with the kit installed, spacings will be maintained; and

g) it is marked in accordance with Clause 5.10.204(v).

5.209 Insulating material

Material for the support of an uninsulated live part shall be porcelain, glass polyester, or other material found acceptable for the support of an uninsulated live part. These materials shall withstand the most severe conditions likely to be met in service.

Insulating material, including barriers between parts of opposite polarity and material that may be subject to the influence of the arc formed by the opening of a switch, shall be suitable for the particular application.

Insulating material for above applications, may be substituted as permitted by Annex A, Item 26, Appendix A, without performing a complete series of conformance tests on the equipment.

5.210 Wire-bending space for field-installed conductors

5.210.1 Where field connections are to be made to circuits rated above 1500 V, wire bending space shall be such that, during installation, field-installed conductors need not be bent to a radius less than:

a) 8 times the overall diameter for non-shielded conductors; or

b) 12 times the overall diameter for shielded or lead-covered conductors.

Construction shall take into account the type and maximum size of wire, optional use of stress cones for field terminations, and other instructions provided in accordance with Clause 5.10.206.

5.210.2 Where field connections are to be made to circuits rated 1500 V and below using conductors larger than 10 AWG (5.26 mm^2), wire bending space shall be provided in accordance with Annex A, item 4.

5.211 Field-installed accessories (kits)

This clause applies to accessories (kits) designed for field installation in medium-voltage control equipment and also applies, as appropriate, to field installation of accessories (kits) in medium-voltage control equipment. The following requirements shall apply:

a) Medium-voltage control equipment shall be suitable for use with or without such kits installed.

b) Each kit shall be acceptable for the intended use and shall comply with all applicable requirements of this standard when installed in the intended manner.

c) Each kit shall be capable of being installed without the use of a special tool, unless such a tool and instructions for its use are furnished with each kit.

d) A barrier that is necessary because spacings would otherwise be less than required or for any other reason shall be securely attached to either the kit or the medium-voltage control equipment.

5.212 Blank spaces, provision for future controllers, and spare controllers

5.212.1 Blank space

Blank space(s) (see Clause 3.1.215), when provided, shall include a cover or hinged door over the provided space. The door or cover shall require the use of a tool to open or have provision for locking.

5.212.2 Space for future controller

5.212.2.1 Space for future controller(s) (see Clause 3.1.216), when provided, shall include a cover or hinged door over the compartment. The door or cover shall require the use of a tool to open or have provision for locking. Any energized bus or other electrical component(s) within the compartment shall be fully insulated or isolated.

5.212.2.2 Spaces for future controllers shall be marked with the type or catalog designation of the controller kits that have been investigated or approved for use in this space in accordance with this standard. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.3 Factory-prepared space for future controller

Factory-prepared space for future controller(s) (see Clause 3.1.217), when provided, shall include a cover or hinged door over the compartment. The door or cover shall require the use of a tool to open or have provision for locking. If the factory-prepared space includes a controller isolating switch, the door shall be interlocked with the switch operating handle to prevent opening the door with the isolating switch in the closed position. Any conductive parts on the line side of the disconnect device within the compartment shall be fully insulated or isolated. Spaces for factory-prepared controllers shall be marked with the type or catalog designation of the controller(s) and associated kits that have been investigated or approved for use in this space. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.4 Partially-completed controller compartment

Compartments with partially completed controller(s), when provided, shall comply with all requirements for controllers, except that certain components may be omitted, as indicated in Clause 3.1.218. Compartments with partially completed controllers shall be marked with the type or catalog designation of the kits that have been investigated or approved to complete the controller. See Clause 5.10.204(w) for marking details and Clause 5.211 for kit requirements.

5.212.5 Spare controller

Spare controller(s) (see Clause 3.1.219), when provided, shall comply with all requirements for controllers.

5.213 Insulated bus (optional)

5.213.1 General

An optional system for insulating bus bars and bus joints may be supplied. An insulated bus shall meet the requirements of Clause 5.213.2.

5.213.2 Insulated bus requirements

The following requirements shall apply:

a) Bus joints, other than at shipping joints, shall be completely covered by insulating materials at the factory. For interconnecting bus joints that must be made in the field, insulating material shall be supplied for application in accordance with the manufacturer’s instructions.

b) A representative sample of insulated bus shall withstand without breakdown the test for bus bar insulation described in Clause 6.2.202.5. This test is required on one insulated bus bar test sample for each rated voltage.

NOTE: Purpose of insulation - Insulated bus is provided to minimize the possibility of communicating faults and prevent the development of bus faults that would result if foreign objects momentarily contacted bare bus. This insulating covering is usually only a part of the primary insulation system, and in such cases the outer surface of this insulating covering will not be at ground potential. It should not be assumed, therefore, that personnel can contact this insulating covering safely.

5.214 Controllers – general requirements

Controllers shall be wired and assembled as complete, totally enclosed, and self-supporting units.

6 Type Tests

6.1 General

The performance of medium-voltage industrial control equipment shall be investigated by subjecting a representative sample or samples in commercial form to the tests listed in Table 6 as applicable. When selecting the sample, consideration shall be given to optional features, such as bus structures in multi-unit assemblies and the like, and the effects of such features on performance during the tests. A contactor or controller shall be tested in the smallest enclosure in which it is intended to be used, unless otherwise specified.

The sequence in which these tests shall be conducted is indicated in Table 6. Unless otherwise indicated, these tests shall be conducted at rated frequency.

In some cases (e.g., temperature rise, impulse withstand) it will be necessary to repeat tests previously conducted on individual controllers when controllers are configured together in control center construction. This standard defines the additional tests required on control centers.

Type tests are intended to prove the performance of a given controller design and are not to be considered production tests.

Type tests for ratings other than preferred ratings shall use the same test methods, sequences and acceptance criteria mandated for preferred ratings.

6.2 Dielectric tests

Dielectric tests shall be made on a completely assembled controller. The outside surfaces of insulating parts shall be in clean condition.

If the controller contains wiring assemblies or other electronic circuit components that would be affected adversely by application of the test voltage, or that are specifically designed to protect the equipment from voltage, they shall be removed, disconnected, or otherwise rendered inoperable before the dielectric tests are made. A representative subassembly may be tested instead of an entire unit. The insulation and spacings of circuits using these devices shall then be tested separately for dielectric strength.

If a controller includes a meter or meters in other than the main circuit, such devices shall be disconnected from the circuit and the complete device subjected to a power-frequency voltage withstand test as indicated in Clause 6.2.202. The meter or meters shall be tested separately for power-frequency voltage withstand, with an applied potential of 1 000 V in the case of an ammeter, and 1 000 V plus twice rated voltage in the case of any other device having a voltage circuit. The test potential shall be applied between live parts and the mounting panel, including the meter face, zero adjuster, etc.

For devices incorporating static switching elements, a shorting jumper may be placed across the static switching elements and a shorting jumper across their control terminals during the dielectric tests.

6.2.201 Impulse withstand tests

6.2.201.1 General

Dielectric tests shall be made under the temperature and humidity conditions normally obtained in commercial testing. Appropriate correction factors applied shall be used in accordance with Annex A, Item 16.

Test voltage levels shall be equal to or greater than those in Table 1.

The impulse withstand test is a design test intended to prove the rated insulation level (impulse voltage withstand, or basic insulation level [BIL]) rating of a given controller design. The medium-voltage circuits of a previously untested controller shall be capable of withstanding voltage impulses using a full-wave 1.2 microsecond rise time and a 50 microsecond to half voltage having a peak value in accordance with Table 1.

6.2.201.2 Impulse voltage withstand test methods

Method 1 (3×3 test procedure): This is the historic test method that is no longer valid.

Method 2 (3×9 test procedure): This method is preferred for new tests. This method is procedure (or method) “C” in Annex A, Item 16, in the U.S.A. column. The test voltage shall be as specified in Table 1. In each of these tests, three positive and three negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in Clause 6.2.201.4.

Method 3 (15/2 test procedure): This method is an alternate preferred test method for new tests. This method is procedure (or method) “B” in Annex A, Item 16, in the U.S.A. column. The test voltage shall be as specified in Table 1. In each of these tests, fifteen positive and fifteen negative impulses shall be applied to each phase individually without causing a disruptive discharge, except as noted in Clause 6.2.201.4.

NOTE: Some insulating materials retain a charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of 3 impulses at about 80% of the test voltage in the reverse polarity before the test, is recommended.

6.2.201.3 Impulse voltage withstand test sequence

The test samples shall be subjected to the following sequence of tests. Control and auxiliary circuits shall be grounded in these tests, and the medium-voltage motor circuit fuses (in the case of Class E2 controllers) and control circuit fuses shall be in place:

a) Test 1: With the controller bus installed, the isolating means closed, and the contactor in the open position, the “Common value” of impulse test voltage shown in Table 1 shall be applied between each phase and ground, and between phases, except that the impulse voltage need not be applied across the open gap of the contactor. Load side of contactor need not be grounded.

b) Test 2: Test 1 shall be repeated, except that the contactor shall be closed.

c) Test 3: With the isolating means open, the “Across the isolating distance” impulse test voltage shown in Table 1 shall be applied in each phase individually between the contacts of the isolating means across the isolating gap. Where the isolating means has provision for automatically grounding its load side when in the fully opened position, the test voltage shall be the “Common value” test voltage specified for Tests 1 and 2.

The test shall be conducted using at least one of the test voltage levels from Table 1 without any surge arresters connected. Additional tests may be performed with or without surge arresters. Dry-type core and coil assemblies, such as reduced-voltage-starting reactors, autotransformers, CPTs, and voltage transformers, may also be disconnected at the transformer terminals for this test. Cable and bus connections to the transformer shall be in locations representative of when connected to the transformer, but may be insulated from the terminals.

If a higher impulse level is desired, based on the inclusion of surge arresters, the clamping voltage of the arresters shall be below the impulse levels verified by the initial impulse test. Testing shall demonstrate that no disruptive discharges will occur within the controller at the higher impulse level.

6.2.201.4 Evaluation

The controller shall be considered to have passed the test under the following conditions:

Test method 1, 3×3 test procedure: This method is no longer valid.

Test method 2, 3×9 test procedure: If a disruptive discharge occurs on only one test during any group of three consecutive tests, nine more tests shall be made. If the equipment successfully withstands all nine of the second group of tests, the flashover in the first group shall be considered a random flashover, and the controller shall be considered as having successfully completed the test.

Test method 3, 15/2 test procedure: The controller shall be considered as having successfully completed the test if the following conditions are fulfilled:

a) Each group has at least 15 tests.

b) The number of disruptive discharges does not exceed two for each complete group.

c) No disruptive discharges on non-self-restoring insulation occur. This is confirmed by 5 consecutive impulse withstands without a disruptive discharge following the last disruptive discharge.

NOTE: This procedure leads to a maximum possible number of 25 impulses per group.

6.2.202 Power-frequency voltage withstand test

6.2.202.1 General

Equipment shall be capable of withstanding for 1 min without breakdown the application of a 48 to 62 Hz essentially sinusoidal test voltage, as indicated in Table 1, in the cases described in Clauses 6.2.202.2 to 6.2.202.5.

A transformer, a coil, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during test between terminals of opposite polarity.

The controller shall be tested by means of a 500 VA or larger capacity transformer, whose output is essentially sinusoidal and can be varied. The applied voltage can be determined by measuring the input to the test transformer. A test transformer of less than 500 VA capacity may be used if the applied potential is measured at the output of the test transformer, either directly or through a voltage transformer.

6.2.202.2 Tested at the "Common value" test voltage in Table 1

The test voltage shall be applied:

a) between each phase of the power circuit and ground with the other phases grounded and the controller contacts both open and closed. The control circuit shall be grounded for this test;

b) between the control circuit and ground with the control circuit ungrounded; and

c) for a controller with a vacuum-type interrupter, across the open contacts of the vacuum interrupter. Care shall be taken not to apply a test voltage across the open contacts of a vacuum interrupter that exceeds the manufacturer's recommendation, to avoid generating harmful X-rays.

6.2.202.3 Tested at the "Across the isolating distance" voltage in Table 1

The test voltage shall be applied:

a) across the open contacts of the isolating distance; and

b) if the controller has a test position obtained by means of a drawout element, across the open contacts of the isolating distance, with the drawout element in the test position, both with the contactor contacts open and closed.

6.2.202.4 Power-frequency voltage withstand (repeated) test

Where required by other parts of this standard, the controller shall comply with the requirements of Clauses 6.2.202.2 and 6.2.202.3, except that the test potential shall be as shown for "Power-frequency withstand-voltage test (repeated)" as shown in Table 1.

6.2.202.5 Test for bus bar insulation

If insulation is provided for bus bars, it shall be tested for dielectric strength.

The insulated bus bar sample shall have the rated maximum voltage U_r at rated power-frequency applied from the conductor to an electrode effectively covering the outer surface of the insulation, but sufficiently far from the ends of the sample to be able to withstand the test voltage. The insulated bus bar sample shall have a construction that is typical of bus bars, elbows, splices, and joints as used in the manufacturer's design. The test voltage shall be applied for 1 min.

NOTE: Suggested external electrodes are conductive paint or metallic foil or the equivalent. Care should be taken to prevent the external insulation media from penetrating the test area between the sample insulation and the electrodes.

6.2.203 Partial discharge test

6.2.203.1 General

Controllers with rated maximum voltages (Ur) greater than 7.2 kV shall be subjected to a partial discharge test. Testing shall conform to Annex A, Item 24 and as noted below.

6.2.203.2 Partial discharge test method

The controller used for the partial discharge test shall have been previously subjected to the power frequency voltage withstand test described in Clause 6.2.202. The partial discharge test may be combined with the power frequency voltage withstand test if all the parameters for both tests are met.

With the controller bus installed, the isolating means closed, and the contactor in the open position, the test voltage shall be applied between each phase and ground with the other phases grounded. The test voltage shall first be raised to the rated short-duration power-frequency common value shown in Table 1 and held for no less than 10 s. The voltage shall then be reduced to the minimum CEV (corona extinction voltage) shown in Table 1 and held for one minute.

The test shall be repeated as in the preceding paragraph, except with the contactor in the closed position.

6.2.203.3 Evaluation

At the end of the one minute period, if the measured partial discharge level is 100 pC (picocoulombs) or less, the equipment is considered to have passed the test.

6.3 Radio interference voltage (RIV) test

[Vacant]

6.4 Resistance measurement

6.4.1 Measurement of the resistance of the contactor

A measurement of the resistance of each phase of the contactor shall be made before and after the fault interruption test (see Clause 6.104) to determine that the contactor is capable of carrying its rated continuous current after the test. The following requirements shall apply:

a) Not more than 5 no-load operations of the contactor shall be permitted between the fault interruption test and measurement of resistance.

b) The measurement shall be made with dc by measuring the voltage drop or resistance from the line side terminals of the contactor to the load terminals of the contactor.

c) The current during the measurement shall have any convenient value between 50 A and the continuous current rating.

d) The measurement of the dc voltage drop or the resistance shall be made before the tests, with the contactor at the ambient air temperature, and after the test when the contactor has cooled to a temperature equal to the ambient air temperature. The resistance after the test shall not exceed 200% of the resistance determined before the test.

e) The measured value of the dc voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

6.4.2 Measurement of the resistance of the controller

A measurement of the resistance of each phase of the controller shall be made before and after the fault interruption test (see Clause 6.104) to determine that the controller is capable of carrying its rated continuous current after the test. The following requirements shall apply:

a) Not more than 5 no-load operations of the contactor shall be permitted between the fault interruption test and measurement of resistance.

b) The measurement shall be made with dc by measuring the voltage drop or resistance from the line side terminals of the controller to the load terminals of the controller.

c) The current during the measurement shall have any convenient value between 50 A and the continuous current rating.

d) The measurement of the dc voltage drop or the resistance shall be made before the tests, with the contactor at the ambient air temperature, and after the test when the contactor has cooled to a temperature equal to the ambient air temperature. The resistance after the test shall not exceed 200% of the resistance determined before the test.

e) The measured value of the dc voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

f) Fuses and solid state switching elements if provided shall be shunted or replaced by solid links of negligible resistance during this test.

6.5 Temperature-rise tests

6.5.1 Conditions of the controller to be tested

The temperature-rise test of the main circuits shall be made on a controller or device that was previously subjected to the short time capability test (Clause 6.202), and, if applicable, filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test. A contactor or controller shall be tested in the smallest enclosure in which it is intended to be used.

6.5.2 Arrangement of the equipment

Anti-condensation heaters, representative of the maximum wattage rating to be provided, shall be installed and energized at their rated voltage during the temperature test, unless the anti-condensation heaters are automatically de-energized.

The CPT need not be energized, provided the transformer heat loss is simulated by an equivalent heat source representing the largest transformer available.

Controller and control center sections shall be tested at rated continuous current with 1.2 m (4 ft) of copper wire attached to each field-wiring terminal. The wire shall be of the smallest size having an ampacity of at least 125% of the test current for motor loads and at least 100% for other loads. Wire size shall be determined in accordance with Table 7. The type of insulation is not specified, but the color shall be black. The temperature test may be conducted with conductors having other than black insulation, but reference temperature measurements shall be conducted with black insulated conductors. If the terminal will not receive the size of wire required for testing at rated continuous current, the maximum allowable wire size shall be used.

In a device employing high-voltage motor circuit fuses, live fuses shall be used during the temperature test. If a range of fuse types or ratings is applicable, the fuse type or rating having the highest power loss shall be used. These fuses shall not open during the temperature test.

Conductors supplying two or more motor controllers shall have an ampacity equal to the sum of the full load current rating of all the motor controllers plus 25% of the highest rated motor controller in the group.

Temperature rise tests shall be performed on at least one vertical section containing the maximum number of controllers permitted by the design.

Each controller shall carry maximum rated continuous current for that particular controller and mounting location. Temperature rises shall be recorded for the controllers, non-extendable power bus, and (if provided) on the extendable power bus and splices. If the controllers have been previously tested in accordance with Clause 6.5, temperature rises for the controllers in control centers need only be recorded at the points of highest temperature rise as determined in the individual controller temperature rise tests.

For control center vertical sections designed with extendable power bus, the temperature rise test shall be conducted using representative extendable bus configurations.

If a range of extendable power buses is available, both the highest current density bus configuration and the highest ampacity configuration shall be tested to represent the range of available buses.

The rated continuous current for a controller mounted in a vertical section with more than one controller may be less than the rated continuous current for an individual controller.

Extendable power bus ratings shall be tested using a representative length of bus long enough to pass through at least one complete vertical section and shall include one or more bus connecting splice joints. Tests shall include incoming line power bus configuration(s) that connect to the extendable power bus.

For the temperature rise test, the extendable power bus shall be loaded as follows:

a) A current equal to the extendable power bus rated continuous current shall be passed through the bus of one complete vertical section and one or more splice joint assemblies. Conductors supplying the power bus shall be sized based upon the ampacity of the power bus. Table 7 may be used for determining conductor sizing.

b) The controllers mounted in the vertical section shall be simultaneously loaded as described in this clause.

c) The remainder of the current shall be passed through the outgoing section of the extendable power bus. Conductors shall be sized based on this remaining current. The extendable and non-extendable bus structures may be energized from two separate sources.

Equipment incorporating solid state switching elements shall also comply with Clause 6.5.5.201.

6.5.3 Measurement of the temperature and the temperature rise

6.5.3.201 General

The tests on all parts shall be made simultaneously, as the heating of one part may affect the heating of another part.

6.5.3.202 Measurement of coil temperature by resistance method

The preferred method of measuring the temperature of a coil shall be the resistance method, but temperature measurements by either the thermocouple or resistance method are acceptable. The thermocouple method shall not be employed for a temperature measurement at any point at which supplementary insulation is employed.

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

$$\Delta t = \frac{R}{r}\ times\ (k + t_1) - (k + t_2)$$

where:

Δt = temperature rise,

R = the resistance of the coil at the end of the test, ohms

r = the resistance of the coil at the beginning of the test, ohms

k = 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades must be determined.

t_1 = the ambient temperature at the beginning of the test, °C

t_2 = the ambient temperature at the end of the test, °C

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

6.5.3.203 Measurement of temperature by thermocouple method

The thermocouple method shall consist of the determination of temperature by the application of thermocouples to the hottest accessible parts.

Temperatures shall be measured using thermocouples and related instruments that are accurate and calibrated. Thermocouples shall consist of wires not larger than 30 AWG (0.0509 mm^2). If the thermal mass of the materials whose temperature is being measured is significantly larger than that of the thermocouple wire, larger-size wires may be used, but in no event larger than 24 AWG (0.205 mm^2).

A thermocouple junction and adjacent thermocouple lead wire shall be securely held in good thermal contact with the surface of the material on which the temperature is being measured.

NOTE 1: In most cases, adequate thermal contact will result from securely taping or cementing the thermocouple in place, but if a metal surface is involved, brazing or soldering the thermocouple to the metal will in some cases be necessary.

NOTE 2: Care should be used to keep the bare thermocouple wire from being twisted together ahead of the point of contact with the part, as this will result in the effective junction being some distance from the part and will in some cases result in errors.

The thermocouple wire shall conform with the requirements for special thermocouples as listed in the table of limits of error of thermocouples in Annex A, Item 19.

6.5.3.204 Measurement of temperatures for solid state equipment

Measurement of temperatures for solid-state equipment shall be in accordance with Clauses 6.5.3.202 and 6.5.3.203 when monitoring non-conductive parts or conductive parts that are not energized.

When one or more thermocouples are connected directly to energized parts, care shall be taken for safety and to prevent damage due to voltage differences and grounds.

Measurement of energized parts operating at line voltage can require the use of methods other than the thermocouple method, such as temperature indicating labels. These methods may be used when agreeable to all concerned, and when it can be demonstrated that these methods have accuracy comparable to that of the thermocouple method.

During the temperature test, the temperatures of all heat sinks for solid state devices in the power assembly shall be monitored to determine which heat sink(s) in each phase shall be provided with thermal sensors in accordance with 5.203(k).

6.5.3.205 Test conditions

To determine whether industrial control equipment complies with the temperature test requirements, the device shall be operated under normal conditions and shall carry its rated current until temperatures are constant. An overload relay shall not trip during the test. A source of supply of any convenient voltage may be used for temperature tests on parts other than coils.

A temperature rise shall be considered to be constant when three successive readings, taken at equal intervals of approximately 10% of the previously elapsed duration of the test (but not less than 10 min intervals), are constant within 1°C.

Tests shall be conducted at a frequency not less than the highest rated frequency. Tests conducted at a higher frequency shall be considered representative of lower frequency ratings for convection cooled equipment. Force cooled equipment shall be considered based upon any change in cooling air volume.

6.5.4 Ambient air temperature

The temperature test may be conducted at any ambient temperature within the range of 10 to 40°C, and the ambient temperature may be determined using either thermometers or thermocouples placed in the vicinity of the equipment being tested.

If reference measurements of ambient temperatures are necessary, several thermometers shall be placed at different points around the equipment at a distance of 1 to 2 m (3 to 6 ft). The thermometers shall be located in the path of the cooling medium, but shall be protected from drafts and abnormal heat radiation. The ambient temperature shall be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

When the ambient temperature is subject to variations that might result in errors in taking the temperature rise, the thermometers (for determining the ambient temperatures) should be immersed in a liquid such as oil in a heavy metal cup.

A convenient form for such an oil cup consists of a metal cylinder with a hole drilled partly through it. This hole is filled with oil and the thermometer is placed therein with its bulb well immersed. The response of the thermometer to various rates of temperature change will depend largely upon the size, kind of material, and mass of the containing cup, and can be further regulated by adjusting the amount of oil in the cup. The larger the apparatus under test, the larger the metal cylinder employed as an oil cup in the determination of the cooling air temperature should be. The smallest size of oil cup employed in any case shall consist of a metal cylinder 25 mm (1 in) in diameter and 50 mm (2 in) high.

6.5.5 Temperature-rise test of the auxiliary and control equipment

[Vacant]

6.5.5.101 Temperature-rise tests on control electro-magnets

[Vacant]

6.5.5.102 Temperature-rise tests of auxiliary circuits

[Vacant]

6.5.5.103 Temperature rise of starting resistors for rheostatic rotor starters

[Vacant]

6.5.5.104 Temperature rise (during starting) of motor starting autotransformers and reactors

The current to the connected load shall be the tap ratio multiplied by six times the rated current of the controller. In the case of an autotransformer or reactor with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer or reactor. If the transformer or reactor is designed with constant current density, the losses shall be assumed to be equal. In order to facilitate this test, the tests may be run at reduced voltage with a star-connected impedance used in place of a motor.

The peak temperature rise shall not exceed the rated temperature rise of the device insulation class by more than 15°C. The temperature shall be measured by thermocouples, suitably insulated, and buried into the windings. The temperature shall be monitored throughout the test and until the winding temperatures are shown to be decreasing after the final test cycle.

Test shall be performed as follows:

i. For medium starting duty the starter shall be tested for the following duty cycle: on 30 s, off 30 s, repeat two times for a total of three cycles. Rest 1 h, and then repeat an additional three cycles.

ii. For heavy starting duty the starter shall be tested for the following duty cycle: on 1 min, off 1 min, repeat four times for a total of five cycles. Rest 2 h, and then repeat an additional five cycles.

iii. For optional starting duty as described in 4.204.1.3, the starter shall be tested in accordance with the optional duty cycle marked on the nameplate.

6.5.5.201 Temperature tests for reduced-voltage solid state starters and solid state resistive load controllers

6.5.5.201.1 Equipment without automatic bypass function:

These devices shall be subjected to the temperature test in accordance with Clauses 6.5.1 - 6.5.4. In addition to the temperature limits specified in Table 2, the switching elements shall not exceed the maximum allowable limits established by the manufacturer of the switching elements.

6.5.5.201.2 Equipment incorporating automatic bypass function:

The temperature test shall be conducted with the equipment operating in the bypass mode, in accordance with Clauses 6.5.1 – 6.5.4. In addition, equipment incorporating bypass function shall be tested in accordance with Clauses 6.5.5.201.3 and 6.5.5.201.4.

6.5.5.201.3 The controller shall be operated at the specified starting current of the controller. The test method shall be in accordance with Clauses 6.5.1 - 6.5.4, with operation as follows:

a) Turn on for the specified on time

b) Turn off for the specified off time

c) Repeat (a) and (b) for the specified number of consecutive on/off operations

d) Turn off for the specified rest time

e) Repeat steps (a) though (d) for the specified number of sequences

NOTE: see Clause 4.204.2.

6.5.5.201.4 This test simulates failure of the controller bypass contactor to operate. The controller shall be operated at rated continuous current, with current passing through the solid state switching devices, until the thermal protection operates and terminates the test or until the temperatures are constant. All other parameters of the test shall be in accordance with Clauses 6.5.1 – 6.5.4.

6.5.5.201.5 At the conclusion of the tests, the controller shall not be damaged, and shall remain fully functional. The controller shall comply with Clause 6.5.6 and shall comply with the requirements of the power-frequency voltage withstand test given in Clause 6.2.202.

6.5.6 Interpretation of the temperature-rise tests

Medium-voltage control equipment, tested under the conditions described in Clauses 6.5.1 to 6.5.5, shall not attain a temperature at any point high enough to constitute a fire hazard, or to affect adversely any materials employed in the device, nor show temperature rises at specific points greater than those specified in Table 2, except as permitted by Clause 6.5.5.104.

The temperature rise of insulation materials other than those covered in Table 2 shall not exceed the relative thermal index (see Annex A, Item 7) of the material minus 40°C.

6.6 Short-time, momentary, and peak withstand current bus tests

6.6.1 General

Main circuits of the controller or control center shall be subjected to tests to prove their ability to carry the rated peak, momentary, and short-time withstand currents.

6.6.2 Short-time current withstand and momentary current withstand test

6.6.2.1 General

For short-time withstand tests, the short-circuit current shall be the rated short-time withstand current specified in Clause 4.5. The test duration shall be as specified in Clause 4.7. Random closing is acceptable for this test.

Testing at 60 Hz shall be considered to be representative of 50 Hz ratings, provided that the duration of the short circuit is at least as long as it would be for 50 Hz. 50 Hz tests shall be considered to be representative of 60 Hz ratings, provided that the peak current is as indicated for 60 Hz.

For momentary withstand current tests, test duration and test current shall meet the requirements of Clause 4.6.2 and Table 8.

The assembly shall be connected to a source having a prospective current (symmetrical) equal to the rated short-time withstand current of the control center. The test circuit shall be calibrated with a short-circuiting conductor applied at the incoming terminals of the control center. The test circuit shall be as described in Clause 6.104.202, except the test may be conducted at any convenient voltage. The power and ground bus shall not exceed 3 m (10 ft) each in length, and shall include a typical bus splice assembly as provided for field assembly of control centers.

The short-time withstand and momentary withstand current tests may be combined if all the parameters for both tests are met.

6.6.2.2 Extendable power bus

The test shall be conducted three-phase.

For the withstand tests, a short-circuit shall be applied at the end of the power bus furthest from the test station terminals, with bus bars or cables having a cross-section equal to that of the power bus and a length as short as possible.

6.6.2.3 Ground bus

The test shall be conducted single-phase.

For the withstand tests, a short-circuit shall be applied between the ends of the ground bus and the nearest phase bus furthest from the test station terminals, using bus bars or cables having a cross-section equal to that of the ground bus and a length as short as possible.

6.6.2.4 Test criteria

At the end of the test the sample shall comply with the power-frequency withstand (repeated) test described in Clause 6.2.202.4 and shall have:

a) no breakage of the bus supports;

b) no permanent deformation that impairs mechanical performance; and

c) no permanent deformation of bus bars resulting in more than a 10% reduction of electrical clearance.

Deformation resulting in excess of 10% of electrical clearance is acceptable, provided that the equipment passes the impulse withstand test described in Clause 6.2.201.

6.6.3 Peak withstand current tests

This test is for non-extendable power bus, and may be combined with the fault interruption test described in Clause 6.104.202.

The non-extendable power bus shall be connected to a circuit as described in Clauses 6.104.201 and 6.104.202. This bus shall withstand, without damage, the thermal and electromagnetic effects imposed on it during the interval that the controller requires to interrupt a fault on a system having the prospective peak current at which the controller is rated. The assembly shall be tested so that the various bus structures will be stressed during the interval of fault interruption by the highest rated controller (i.e. highest let-through current) intended to be used in the assembly.

The non-extendable bus to be tested shall be connected to the test circuit, and a short-circuit shall be applied to the load terminals of the selected controller as described in Clause 6.104.203. For multiple controller arrangements, the short-circuit shall be applied to the controller installed furthest from the incoming line terminals, in order to stress the maximum length of bus structure. For multiple controller arrangements, it will in some cases be necessary to conduct more than one test in order to evaluate all the various bus arrangements.

During the test, the enclosure structure shall be grounded through a 3 A or smaller fuse of the appropriate voltage rating, connected as shown in Figure 1 or Figure 2.

The controller unit to which the short-circuit is applied shall have the maximum rating capable of being installed in the selected vertical section. If fused, the controller shall have the highest ampere rated fuses that the controller can accommodate. If the controller is intended to be used with more than one type or make of medium-voltage fuse, the test shall be conducted using the fuse having the highest let-through characteristics. The characteristics referred to are peak let-through current (I_p) and ampere-squared-seconds (I^2t).

The controller used to complete the short-circuit may be replaced by a solid bused connection. In this case, the test circuit shall be maintained for not less than the total clearing time of the maximum rated controller that can be accommodated.

The test shall consist of a single operation in which the test circuit is closed on the test assembly.

At the conclusion of the test, the structure and bus shall be in essentially the same mechanical condition as before the test, and the bus shall be capable of withstanding the power-frequency voltage withstand (repeated) test described in Clause 6.2.202.4.

NOTE: "essentially the same mechanical condition" is determined in accordance with Clause 6.6.2.4.

The 3A fuse shall not open during the test.

6.101 Mechanical tests

6.101.1 Range of operating voltage test (verification of operating limits)

An enclosure is not required for this test.

AC contactors shall withstand 110% of their rated voltage without damage to the closing coils and shall fully close without hesitation at 85% of their rated voltage.

For the test at 110% of rated control voltage, the closing coil shall be energized at 110% of rated control voltage until constant temperature is reached and then tested immediately to demonstrate that full closure results when rated control voltage is reapplied.

For the test at 85% of rated control voltage, the closing coil shall be energized at rated control voltage until constant temperature is reached and then tested immediately to demonstrate that full closure results when 85% of rated control voltage is applied.

Where the contactors of an ac controller are operated from the secondary of a CPT that has its primary winding connected to the controller supply circuit, the controller shall fully close at 90% of rated primary voltage.

The release coil of a latched contactor shall withstand 110% of its rated control voltage without damage, and shall release the latching mechanism without hesitation at 85% of its rated control voltage.

6.101.2 Mechanical endurance tests

A contactor of a controller shall be operated in its intended manner without load for a minimum of 10 000 operations. The test may be conducted at any convenient rate of operation, but not faster than 20 operations per minute.

At the end of this test the sample shall:

a) exhibit no breakage of parts;

b) exhibit no permanent deformation that impairs mechanical performance;

c) exhibit no permanent deformation resulting in more than a 10% reduction of electrical clearance, and

d) comply with the power-frequency voltage withstand (repeated) test requirements of Clause 6.2.202.4.

The ability of any interlock to function in the intended manner shall not have been impaired.

6.101.3 Interlock integrity test

All isolating means and grounding switches shall be subjected to 1 000 mechanical opening and closing operations. After every 100 operations it shall be determined that all interlock functions are operative, by attempting to open any doors, operate electrical circuits, or any other operation intended to be prevented by the interlocking arrangement. See Clause 5.11.

Where drawout components are used, it shall be determined that:

a) the device cannot be inserted in any condition of misalignment that will permit the operation of the device while impairing the effectiveness of the interlocking arrangement; and

b) the device cannot be withdrawn in the closed position.

In the case of a drawout component, one operation shall consist of a cycle of withdrawing from a fully engaged position to the isolated position and return. See Clause 5.202.

The effort required to perform the 1 000th operation shall be essentially the same as that required to perform the first operation. Upon the completion of the 1 000 operations, the sample shall be in substantially the same mechanical condition as at the beginning of the test.

A drawout contactor that is not utilized as the controller isolation means shall be inserted and withdrawn a total of 50 times. The effort required to perform the 50th operation shall be essentially the same as that required to perform the first operation. Upon the completion of the 50 operations, the sample shall be in substantially the same mechanical condition as at the beginning of the test.

6.101.4 Tests of the striker mechanism

[Vacant]

6.102 Make and break capacity

6.102.201 Basic requirement – electromagnetic contactors

A contactor that is part of a class E controller shall be capable of making and breaking the maximum current at which the overload relays alone cause current interruption (take-over current). The take-over point shall be determined from the characteristic curves of the overload relays and the total clearing time curves of the medium-voltage circuit fuses.

6.102.201.1 Procedure

To determine compliance, a contactor shall be subjected to 10 make and break operations at the takeover current or 10 times the rated continuous current of the contactor, whichever is greater. The operations shall be conducted in a single continuous test without intervening maintenance or service. The following requirements shall apply:

a) The contactor shall be operated at the rate of one operation per minute for contactors rated 400 A and less, and one operation per 5 min for contactors rated greater than 400 A, with an ON time of not less than 0.1 s. The test may be conducted at a faster rate.

b) Except as indicated above, the conditions for this test shall be the same as for the overload test described in Clause 6.103.

c) This test may be performed on a separate sample, or in combination with the overload test described in Clause 6.103.

6.102.201.2 Test criteria

When the make and break test is performed on a separate sample, the contactor shall be in substantially the same mechanical condition at the conclusion of the test as at the beginning and shall pass the power-frequency voltage withstand (repeated) test described in Clause 6.2.202.4. The controller shall perform without the emission of dangerous hot gases, flame, or oil from its enclosure. The ground fuse shall not have opened.

6.102.201.3 Combined test

When the make and break test is combined with the overload test, the first 10 operations shall be performed in accordance with Clauses 6.102.201.1 and 6.102.201.2. The remaining 40 operations (without the contactor being serviced) shall be performed in accordance with Clause 6.103.

6.102.202 Basic requirement – solid state controllers

The make and break capacity test is not applicable to solid state resistive load controllers.

Reduced-voltage solid state controllers shall be capable of breaking the maximum prospective current at which the overload relays alone cause current interruption (take-over current). The take-over point shall be determined from the characteristic curves of the overload relays and the total clearing time curves of the medium-voltage circuit fuses.

6.102.202.1 Test procedure

The controller shall be subjected to 10 break only (without making) operations at a specified test current. The prospective test current is the take-over current or 10 times the rated continuous current of the controller, whichever is greater. These operations shall be conducted in a single continuous test without intervening maintenance or service as follows:

a) The controller shall be started and allowed to ramp up to the fully on condition, represented by virtually full (360 degree) conduction. The current in this state may be any convenient current that ensures full continuous conduction. The test load shall then be applied to the controller via a suitable switching means. The load shall remain applied until the controller operates to open the load. The test load shall be such that the prospective test current defined above would flow with the controller shunted by solid links of negligible resistance.

b) The test method described in (a) shall be repeated 9 times, for a total of 10 operations. The rate of operation shall be one operation per minute for controllers rated 400 A and less, and one operation per 5 min for controllers rated greater than 400 A. The test may be conducted at a faster rate.

c) Except as indicated above, the conditions for this test shall be the same as for the overload test described in Clause 6.103.

d) This test may be performed on a separate sample, or the same sample subjected to the overload test described in Clause 6.103.

e) Two separate sets of 10 operations shall be conducted. The first set of 10 operations shall be conducted with the test current flowing through the solid state devices (bypass circuit not activated), and the second set of 10 operations shall be conducted with the starter operating in the bypass condition. The second set of tests need not be performed if the bypass circuit has been separately evaluated per Clause 6.102.201.

6.102.202.2 Test criteria

The controller shall be functional and in substantially the same condition at the conclusion of the test as at the beginning and shall pass the power-frequency voltage withstand (repeated) test described in Clause 6.2.202.4. The switching devices shall perform without the emission of dangerous hot gases, flame, or oil from the enclosure. The ground fuse shall not have opened.

6.102.202.3 Combined test

When the make and break test is combined with the overload test, the first 10 operations shall be performed in accordance with Clauses 6.102.202.1 and 6.102.202.2. The remaining 40 operations (without the controller being serviced) shall be performed in accordance with Clause 6.103.

6.103 Overload test

6.103.201 General

Controllers shall comply with the requirements of Clause 6.103.208 after completion of the testing described in Clauses 6.103.202 through 6.103.206.

6.103.202 Equipment arrangement

The controller shall be mounted with the door or cover closed. Any other openings, except intentional ventilation openings, shall be closed.

Open contactors shall be mounted in an enclosure whose dimensions may be approximately 150% of the dimensions of the contactor, or the contactor may be mounted in an enclosure whose dimensions are representative of the size enclosure in which the contactor will be mounted in actual service. The controller structure and enclosure shall be grounded through a 3 A or smaller fuse of appropriate voltage rating or the equivalent, connected as shown in Figure 1 or Figure 2.

6.103.203 Test circuit

The test shall be performed at the rated maximum voltage and a lagging power factor not greater than 35% except for solid state resistive load controllers in which case the test may be conducted at any power factor, up to and including 1.0. The open-circuit voltage of the supply circuit shall be not less than 100% of the rated maximum voltage of the controller.

The closed-circuit voltage is not specified, but the power-frequency recovery voltage shall be not less than the rated supply voltage of the controller when measured in accordance with Annex A, Item 14. Circuit characteristics shall be determined using either laboratory-type meters or oscillographic means. When oscillographic means are employed, the method described in Annex A, Item 15, shall be used for determining power factor, or a method proven to yield equivalent results.

Tests shall be conducted at a frequency not less than the highest rated frequency. Tests conducted at a higher frequency shall be considered representative of lower frequency ratings.

The controller shall be connected as shown in Figure 1 or Figure 2. All or part of the limiting impedance may be connected on the load side. The test circuit may include any combination of current-limiting reactors, resistors, or transformers in addition to the generating system. No capacitance shall be added in the circuit. The medium-voltage motor circuit fuses may be shunted or replaced with dummy fuses.

In setting up the test circuit, the leads between the reactors and the controller should be made as short as practicable so as to keep the capacitance to ground at the controller terminals small.

Reactive components may be paralleled if of the air-core type, but no reactance shall be connected in parallel with resistance, except that an air-core reactor in any phase may be shunted by resistance, the volt-ampere loss of which is approximately 0.6% of the reactive volt-amperes in the air-core reactor in that phase.

The shunting resistance used with an air-core reactor having negligible resistance may be calculated from the following formula:

$$R = 167\left(\frac{U}{I}\right)$$

where U = the voltage across the air-core reactor with current I flowing as determined by oscillographic measurement during the short-circuit calibration or, by proportion, from meter measurements at some lower current.

6.103.204 Overload test procedure – electromagnetic controllers other than reversing starters

The controller shall make and break 6 times rated continuous current for 50 operations.The rate of operation shall be one operation per minute. These operations may be conducted in groups of 5 with 15 min maximum OFF time between groups. During each operation, the ON time shall be not less than four electrical cycles before contact parting commences as determined by oscillographic or equivalent measurements. When combined with the make and break test, see Clause 6.102.201.3.

6.103.205 Overload test procedure – electromagnetic reversing starters

For a reversing starter, the ON period shall consist of a forward operation immediately followed by a reverse operation. The ON time for each total operation (forward operation and reverse operation) shall be as specified in Clause 6.103.204.

Where the reversing circuit arrangement is such that both closing coils can be energized simultaneously, ten additional test cycles of operation shall be conducted with both coils energized simultaneously.

6.103.206 Overload test procedure – reduced-voltage solid state controllers

6.103.206.1 The ramp time of the controller shall be set to the minimum value. If the controller has an adjustable deceleration time, it shall be set to the minimum value. All other time delay settings and any adjustments for current limit and overload levels shall be sent to maximum.

6.103.206.2 A load of 600 percent of the rated continuous current shall be connected to the controller output. All other parameters of the test shall be as specified in Clause 6.103.203.

6.103.206.3 The controller shall be caused to ramp up into the connected load. If the controller limits the current to a value less than 600% of rated continuous current, this current shall be maintained until the controller shuts down or until temperatures are constant, whichever occurs first. If constant temperatures are reached, the controller shall be stopped by a normal stop command.

6.103.206.4 The operation described in Clause 6.103.206.3 shall be repeated for a total number of 50 operations. There shall be no intentional delay between operations, other than any delay required to allow overload or overtemperature devices to reset prior to restarting the controller. When combined with the make and break test, see Clause 6.102.202.3.

6.103.207 Overload test procedure – solid state resistive load controllers

The controller shall make and break 1.5 times rated continuous current for 50 operations. The rate of operation shall be one operation per minute. These operations may be conducted in groups of 5 with 15 min maximum OFF time between groups. During each operation, the ON time shall be not less than four electrical cycles before contact parting commences as determined by oscillographic or equivalent measurements. When combined with the make and break test, see Clause 6.102.201.3.

6.103.208 Overload test evaluation criteria

At the conclusion of the overload test, the controller shall be functional, and in substantially the same mechanical condition as at the beginning. The controller shall then pass the power-frequency voltage withstand test (repeated) described in Clause 6.2.202.4. The controller shall perform without the emission of dangerous hot gases, flame, or oil from its enclosure. The medium-voltage circuit fuses, if used, and the ground circuit fuse specified in Clause 6.103.202 shall not have opened.

6.104 Fault interruption test

6.104.201 General

Interrupting tests are intended to prove the fault interrupting performance of a given controller design and are not to be considered production tests. Test samples shall be substantially the same as the commercial form, including all normally provided bus.

Tests made to verify the fault interrupting rating of a Class E controller shall be made at line-to-line voltages equal to the rated maximum voltage (U_r) of the controller (see Clause 4.1), with a prospective current (symmetrical) at the line terminals of the controller at least equal to the interrupting rating of the controller.

This current value is based on the average symmetrical current in the three phases (i.e. omitting any dc component). Each test circuit shall be capable of producing in one of the three phases a total rms current, including the dc component, not less than that shown in Table 8.

Tests shall be conducted at a frequency not less than the highest rated frequency. Tests conducted at a higher frequency shall be considered representative of lower frequency ratings.

The tests shall be made in accordance with Clauses 6.104.202 to 6.104.205. The controller shall meet the performance requirements of Clause 6.104.206.

6.104.202 Fault interruption test circuit

There are two test circuits; test circuit 1 (see Figure 1) includes a three phase short circuit on the controller output. Test circuit 2 (see Figure 2) has additional impedance that will produce full voltage output and full conduction through the solid state switching elements. Test circuit 2 also has a shorting device that is used to apply a three phase short circuit by shunting the additional impedance.

The test circuit may be ungrounded or neutral-grounded and include current-limiting reactors, resistors, and transformers in addition to the generating system. In setting up the test circuit, the leads between the reactors and the controllers shall be made as short as practicable so as to keep the capacitance to ground at the controller terminals small. No capacitance shall be added in the circuit.

Reactive components of the impedance in the line may be paralleled if of the air-core type, but no reactance shall be connected in parallel with resistance. Shunt resistance shall not be added to this circuit.

The power-frequency recovery voltage shall be not less than the rated maximum voltage U_r of the controller when measured in accordance with Annex A, Item 14.

The controller structure shall be grounded through a 3 A or smaller fuse of appropriate voltage rating.

6.104.203 Fault interruption test preparation

Before the fault interruption test, the resistance of the contactor main circuit shall be measured in accordance with Clause 6.4.

The test circuit described in Clause 6.104.202 shall be used for the test. In order to obtain the total rms current specified, it will in some cases be necessary to use a larger symmetrical component than that corresponding to the fault-interrupting rating.

The controller test circuit shall be identical to the calibration test circuit, except that the load terminals of the controller under test, or of the drawout cubicle, shall be connected by means of bus bars or cables having a cross-section approximately equivalent to that of the load terminals and a length as short as practical. The fault shall be interrupted by the controller.

NOTE: "approximately equivalent" means no smaller in cross-section. The shorting conductor should not add strength or bracing to the load terminals.

Class E2 controllers shall be tested with fuses of the highest current rating for which the controller is intended to be used. If the controller is intended to be used with more than one type or make of medium-voltage fuse, the test shall be conducted using the fuse having the highest let-through characteristics. The characteristics referred to are peak let-through current (I_p) and ampere-squared-seconds (I^2t).

A cotton pad at least 12.7 mm (0.5 in) thick shall completely cover any opening in a controller during the short-circuit interruption test. Close fitting seams and flanged joints shall not be considered openings. The cotton pad shall be secured to the outside of the enclosure so as not to be dislodged during the test.

All doors on the test enclosure shall be closed and secured by their latching or fastening means. No external padlocks or the like shall be used.

The control circuit power may be derived from a separate supply source or from a transformer connected to the line side of the controller.

6.104.204 Measurements to be taken during the fault interruption test

Measurements shall be made by oscillograph unless otherwise specified in the following paragraphs. Data giving the voltage and current values of the circuit and a description of the operation of the controller during and after the test shall be prepared.

The circuit shall be tested and oscillograms shall be taken to record the three line-to-line voltages. Measurements of the currents shall be made on the calibration oscillograms at each of the time intervals specified in Table 8. The prospective current in each phase shall be the ac component as determined by drawing the envelope of the current wave, measuring the peak-to-peak values at the appropriate instant, and dividing them by 2.828, as described in Annex A, Item 14.

Data to be recorded during the test shall include the following information:

a) measurements to be made in calibrating the test circuit:

i) open-circuit line-to-line voltages of all three phases by voltmeter or oscillograph immediately before the fault is created; and

ii) fault current in each line; and

b) measurements to be made with the controller in the circuit:

i) line-to-line voltages (V1) of all three phases before the short-circuit is initiated;

ii) voltage (V2) between controller line and load terminals before, during, and immediately following the fault; and

iii) currents through controller during the test.

6.104.205 Fault interruption test cycle

A Class E controller shall be subjected to a test cycle consisting of a specified number of unit operations at stated intervals. A unit operation consists of a closing, followed immediately by an opening, of the circuit without purposely delayed action. This operation is designated by the letters "CO", signifying closing, then opening. Random switching shall be used.

6.104.205.1 For electromagnetic starters, the following test duties shall apply:

a) For Class E1 controllers, the test cycle shall be 3 CO unit operations at intervals of 2 min utilizing test circuit 1 (see Figure 1).

b) For Class E2 controllers, the test cycle shall be 3 CO unit operations, utilizing test circuits 1 (see Figure 1), separated by the interval required to renew the fuses and, to inspect and, if necessary, replace any renewable contacts. Replacement of a vacuum interrupter or any other sealed type interrupter shall not be permitted; however, breaking of lightly welded contacts is permitted

6.104.205.2 For Class E1 and Class E2 reduced-voltage solid state controllers

6.104.205.2.1 Test circuit 2 (see Figure 2) shall be used. Ramp time shall be set at minimum and all current sensitivity and time delays shall be set at maximum for this test sequence. The test sequence shall be as follows:

Three operations shall be conducted with a short circuit applied to the controller as follows:

1) The controller shall ramp up to full voltage and full conduction.

2) The load shall then be shorted. The controller shall be operated in this condition until the controller shuts down, main power fuses open (for Class E2), or a test duration of 30 cycles is complete.

3) The test shall be repeated twice for a total of three operations. There shall not be an intentional time delay between operations except to inspect for damage and replace blown fuses (for Class E2).

6.104.205.2.2 Changing of solid state switching elements shall not be permitted, but inspection and replacement of renewable contacts of any contactors in the controller is acceptable. Replacement of a vacuum interrupter or any other sealed type interrupter shall not be permitted; however, breaking of lightly welded contacts is permitted.

6.104.205.2.3 If any of the solid state switching elements is shorted during the first or second operation, the remaining operations shall be conducted without replacement of the solid state switching elements.

6.104.205.2.4 All contactors and related wiring and bus shall be tested in accordance with the requirements in Clause 6.104.205.1 (a) or (b), unless previously investigated as part of an E1 or E2 controller, respectively.

6.104.205.3 For solid state resistive load controllers

6.104.205.3.1 Test circuit 2 (see Figure 2) shall be used. All current sensitivity and time delays shall be set at maximum for this test sequence. The test sequence shall be as follows:

Three operations shall be conducted with a short circuit applied to the controller as follows:

1) The controller shall be operated at full voltage and full conduction. Actuation of the output device to full conduction is attainable by one of the following methods of loading:

a) The connection of a load to the output terminals such that enough loading is provided to actuate the output devices;

b) The connection of a remote circuit to each controller such that the output devices are actuated to a full conduction independent of any loading.

2) Upon actuation of the output devices, a short is introduced across the output terminals. The controller shall be operated in this condition until the controller shuts down or main power fuses open.

3) The test shall be repeated twice for a total of three operations. There shall not be an intentional time delay between operations except to inspect for damage and replace blown fuses.

6.104.205.3.2 Changing of solid state switching elements shall not be permitted, but inspection and replacement of renewable contacts of any contactors in the controller is acceptable. Replacement of a vacuum interrupter or any other sealed type interrupter shall not be permitted; however, breaking of lightly welded contacts is permitted.

6.104.205.3.3 If any of the solid state switching elements is shorted during the first or second operation, the remaining operations shall be conducted without replacement of the solid state switching elements.

6.104.205.3.4 All contactors and related wiring and bus shall be tested in accordance with the requirements in Clause 6.104.205.1 (a) or (b), unless previously investigated as part of an E1 or E2 controller, respectively. The fuses and contactors used in the controller shall be properly coordinated based on this previous testing.

6.104.206 Interrupting performance

An electromagnetic controller shall interrupt the fault current, including any required dc component. A reduced-voltage solid state controller shall either interrupt the fault current or enter the current limit condition. At the end of the tests, the controller shall be in the following condition:

a) The controller, with the exception of the operation of power circuit fuses, shall be in substantially the same mechanical condition as at the beginning of the test as demonstrated in items (b) to (l). Reduced- voltage solid state controllers and solid state resistive load controllers need not be functional at the conclusion of the test.

b) The controller shall pass the power-frequency voltage withstand (repeated) test. See Clause 6.2.202.4.

c) An electromechanical, electromagnetic controller shall be capable of carrying rated continuous current at rated voltage for a limited time, but not necessarily without exceeding the rated temperature rise. After a test cycle at or near its interrupting rating, it shall not be inferred that the controller can again meet its interrupting rating without minor repairs such as the replacement of contacts. In order to verify that the controller can carry its rated current, the resistance test described in Clause 6.4 shall be performed. If the resistance exceeds 200% of the value determined before the interrupting test, a temperature test of the controller shall be performed in accordance with Clause 6.5, except that the total allowable temperature rise may be increased 10°C (18°F). For the purposes of this test, thermocouples need only be placed on current-carrying parts in the vicinity of the contact structure.

d) A controller shall perform without the emission of dangerous hot gases, flame, or oil from its enclosure. For Class E2 controllers, the welding of contacts or shorting of solid state devices shall not be considered a failure. For Class E2 controllers, it is not necessary for the contacts to remain closed during the interrupting cycle.

NOTE: Emission of dangerous hot gases or flame is indicated by ignition of the cotton indicator described in Clause 6.104.203.

e) The 3 A fuse between the controller enclosure and ground shall not have opened.

f) If sealed interrupter contacts have welded during any of the three operations, the weld may be broken and the test program continued. After the third CO operation, an additional CO operation in accordance with the overload test in Clause 6.103 shall be successfully performed. Following the CO operation, the interrupter shall pass the power-frequency voltage withstand test (repeated) described in Clause 6.2.202.4.

g) The cotton indicator described in Clause 6.104.203 shall not ignite.

h) Components containing oil shall not rupture so as to permit loss of oil.

i) The door or cover shall not be blown open during the test, and it shall be possible to open the door or cover in the intended manner at the conclusion of the test. In the case of a Class E2 controller in which the contactor contacts have welded, opening in the intended manner is intended to include defeating the interlock mechanism in accordance with the manufacturer's instructions.

j) The isolating means of a controller shall be capable of being opened in its intended manner at the conclusion of the test. In the case of a Class E2 controller in which the contactor contacts have welded, opening in the intended manner is intended to include defeating the interlock mechanism in accordance with the manufacturer's instructions.

k) There shall be no breakage of insulating bases to the extent that the integrity of the mounting of live parts is impaired.

l) Neither end of a medium-voltage fuse shall be completely ejected from the mounting means, and no line end of a medium-voltage fuse shall bridge from its mounting means to dead metal.

6.105 Verification of operating limits and characteristics of overload relays

[Vacant]

6.106 Verification of coordination with SCPDs

[Vacant]

6.107 Electrical endurance tests

[Vacant]

6.108 Motor switching tests

[Vacant]

6.109 Capacitive current switching tests

Clause 4 of Annex A, item 25 is applicable with the following modifications as set out in Clauses 6.109.1 to 6.109.10.

NOTE: References to circuit-breakers will apply to contactors for this standard.

6.109.1 Applicability

Only capacitor bank (single or back-to-back) current switching tests are applicable.

The values of rated capacitive switching currents shall be given by manufacturer.

6.109.2 General

Tests for capacitor switching shall be performed according to Clause 4 of Annex A, item 25. The equipment is classified according to its restrike performance during this test.

Re-ignitions during the capacitive current switching tests are permitted. Two classes are defined according to their restrike performances:

a) class C1: low probability of restrike during capacitive current breaking as demonstrated by the type tests.

b) class C2: very low probability of restrike during capacitive current breaking as demonstrated by type tests.

6.109.3 Characteristics of supply circuits

Clause 4.5 of Annex A, item 25 is applicable.

6.109.4 Earthing of the supply circuit

Clause 4.5 of Annex A, item 25 is applicable.

6.109.5 Characteristics of the capacitive circuit to be switched

Clause 4.5 of Annex A, item 25 is applicable.

6.109.6 Waveform of the current

Clause 4.6.3 of Annex A, item 25 is applicable.

6.109.7 Test voltage

Clause 4.5 of Annex A, item 25 is applicable.

6.109.8 Test current

The values of capacitive switching test currents shall be given by manufacturer.

6.109.9 Test-duties

Clause 4.8.5 of Annex A, item 25 is applicable with the following modifications.

Only test-duties BC1 and BC2 and test conditions for class C2 are applicable for this standard.

6.109.9.1 Test conditions

6.109.9.1.1 Test-duties for Classes C1 and C2

Clause 4.8.5 of Annex A, item 25 is applicable with the following modifications.

No preconditioning test is necessary.

It is not required to reverse terminal connections between test-duty 1 (BC1) and test-duty 2 (BC2).

6.109.9.1.2 Three-phase capacitor bank (single or back-to-back) current switching tests

Clauses 4.5.2 and 4.6.2 of Annex A, item 25 is applicable with following modification.

If the opening time of the device prevents accurate control of contact separation, the requirement for either the closing angle and/or the minimum arcing times may be ignored.

6.109.9.1.3 Single-phase capacitor bank (single or back-to-back) current switching tests

Clauses 4.5.3 and 4.6.3 of Annex A, item 25 is applicable with following modification.

If the opening time of the device prevents accurate control of contact separation, the requirement for either the closing angle or/and the minimum arcing times may be ignored.

6.109.10 Criteria for classification

6.109.10.1 Class C1

The device shall have successfully passed the tests if no more than five restrikes occurred during test-duties 1 (BC1) and 2 (BC2) conditions given in Clause 6.109.9.1.1.

6.109.10.2 Class C2

The device shall have successfully passed the tests if no restrike occurred during test-duties 1 (BC1) and 2 (BC2) conditions given in Clause 6.109.9.1.1.

If one restrike occurred during the complete test-duties 1 (BC1) and 2 (BC2), then both test-duties shall be repeated on the same apparatus without any maintenance. If no additional restrike happens during this extended series of tests, the device shall have successfully passed the tests. External flashover and phase-to-ground flashover shall not take place.

6.109.201 Data required with capacitive current switching type tests:

The following data shall be recorded:

a) test voltage, in kV;

b) breaking current in each phase, in A;

c) making current in each phase, in kA;

d) frequency of making current for the test circuit;

e) peak values of the voltage between phase and earth, in kV:

1) supply side of controller;

2) load side of controller;

f) number of restrikes (if any); shall be noted;

g) arcing time in ms;

h) closing time, in ms;

i) make time, in ms;

j) opening time, in ms;

k) behavior of controller during tests;

l) condition after tests.

6.201 Switching capacity test – isolating means

6.201.1 General

A controller employing an isolating means other than a full-load interrupting switch complying with Annex A, Item 20, used to interrupt only the magnetizing current of CPTs and voltage transformers, shall be subjected to 25 close-open operations of the isolating means with the transformers unloaded.

An isolating means other than a full-load interrupting switch complying with Annex A, Item 20, that is not interlocked to prevent opening when the CPT and voltage transformers are providing secondary power shall be subjected to 25 close-open operations of the isolating means with the transformers operating at full load.

This test shall be conducted at each rated frequency.

The voltage for this test shall be 110% of the transformer primary voltage rating. The control and instrument transformers to be used for this test shall be selected as follows:

a) The transformers shall have the largest magnetizing current of all transformers intended to be used in the motor controller.

b) The transformer primary voltage rating shall be the highest of all transformers intended to be used in the motor controller.

If both of the above characteristics are not attainable in a single transformer, two tests shall be conducted, one test using a transformer which has the largest magnetizing current, and a second test with a transformer having the highest primary voltage rating. A single test may be performed using a special test transformer or equivalent load having the same characteristics as the transformers mentioned above.

The controller structure and enclosure shall be connected to ground through a 3 A or smaller fuse of appropriate voltage rating.

6.201.2 Evaluation

At the conclusion of the test, the fuse shall not have opened and the controller shall be capable of continuing the test program without servicing or replacement of parts.

6.202 Short-time capability

6.202.1 Electromagnetic controllers

A controller shall carry a current of 15 times rated continuous current for 1 s and 6 times rated continuous current for 30 s. Upon completion of the short-time capability test, the controller shall comply with the requirements of the temperature test given in Clause 6.5 and the power-frequency voltage withstand test given in Clause 6.2.202. Between the short-time capability test and the temperature rise test, there shall be no repair or replacement of parts on the device, and the device shall not be operated except as necessary for the removal of shunts or replacement of dummy fuses with line fuses. A contactor or disconnecting means may be tested separately.

For Class E2 controllers, the overload current elements and the power circuit fuses shall be shunted during these tests.

In conducting this test, any convenient test voltage may be used, providing it can be demonstrated that the required current was caused to flow through all poles simultaneously for the required time. The contacts shall be held in the closed position, prior to the initiation of current flow and during current flow, by energizing the operating coil at its rated voltage.

Tests shall be conducted at a frequency not less than the highest rated frequency. Tests conducted at a higher frequency shall be considered representative of lower frequency ratings.

The sequence in which the tests at 15 and 6 times rated continuous current are conducted is not specified, and the sample may be cooled to ambient temperature between tests. The sample shall be connected in the same manner as required for the temperature test.

6.202.2 Solid state controllers

6.202.2.1 Reduced-voltage solid state controllers

All portions of the controller shall be tested in accordance with Clause 6.202.1 and the following:

The solid state switching elements of the controller shall be tested as follows:

a) Any user adjustable current limit settings shall be at maximum. If there are no user adjustable settings, tests shall be conducted at the maximum factory setting.

b) The controller shall be started and allowed to ramp up to the fully on condition. A load of 15 times rated continuous current shall then be applied to the controller via a suitable switching means. The load shall remain applied for 1 second, unless the controller takes some action to prevent conducting 15 times rated continuous current (such as a trip, bypass, or an action that limits the current). If the controller takes such an action, the circuit shall be continuously applied until ultimate results are obtained.

c) The test described in (b) shall be repeated, except the controller shall be started and ramped into the load of 15 times rated continuous current.

d) The controller shall be started and allowed to ramp up to the fully on condition. A load of 6 times rated continuous current shall then be applied to the controller via a suitable switching means. The load shall remain applied for 30 seconds, unless the controller takes some action to prevent conducting 6 times rated continuous current (such as a trip, bypass, or foldback action). If the controller takes such an action, the circuit shall be continuously applied until ultimate results are obtained.

e) The test described in (c) shall be repeated, except the controller shall be started and ramped into the load of 6 times rated continuous current.

6.202.2.2 Solid state resistive load controllers

All portions of the controller shall be tested in accordance with Clause 6.202.1 and the following:

The solid state switching elements of the controller shall be tested as follows:

a) Any user adjustable current limit settings shall be at maximum. If there are no user adjustable settings, tests shall be conducted at the maximum factory setting.

b) If the controller has a ramp function, the controller shall be started and allowed to ramp up to the fully on condition. A load of 15 times rated continuous current shall then be applied to the controller via a suitable switching means. The load shall remain applied for 1 second, unless the controller takes some action to prevent conducting 15 times rated continuous current (such as a trip, bypass, or an action that limits the current). If the controller takes such an action, the circuit shall be continuously applied until ultimate results are obtained.

c) If the controller has a ramp function, the test described in (b) shall be repeated, except the controller shall be started and ramped into the load of 15 times rated continuous current.

d) For controllers without a ramp function, the controller shall be caused to operate with a load of 15 times rated continuous current. The load shall remain applied for 1 second, unless the controller takes some action to prevent conducting 15 times rated continuous current (such as a trip, bypass, or an action that limits the current). If the controller takes such an action, the circuit shall be continuously applied until ultimate results are obtained.

6.202.3 Conditions of controller after test

At the conclusion of the test, the structure shall be in substantially the same mechanical condition as at the beginning of the test, and the assembly shall comply with the requirements of the temperature rise test in Clause 6.5 and the power-frequency voltage withstand test described in Clause 6.2.202.

NOTE: "substantially the same mechanical condition" is determined in accordance with Clause 6.2.202.4.

6.203 Driven rain test

6.203.1 General

This test is intended to simulate rain driven by a 29 m/s (65 mph) wind.

6.203.2 Test method

The enclosure to be tested shall be fully equipped and complete with all appurtenances, such as roof bushings, conduits, busways, and the like, and mounted in the intended manner in the area to be supplied with artificial precipitation. For multiple-unit construction, a minimum of two units shall be used to test the joints between units, including a roof joint.

The tightening torque for rigid conduit threaded into the opening in the enclosure shall be in accordance with Table 11.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the entire surface or surfaces under test. The various vertical surfaces of an enclosure may be tested separately or collectively, provided that a uniform spray is simultaneously applied to both of the following:

a) the roof surfaces, from nozzles located at an appropriate height; and

b) the floor outside the enclosure for a distance of 1 m (3 ft) in front of the surface under test with the enclosure located at its normal height above the floor level.

The nozzles used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of at least 450 ml/s (7.1 gal per min) at 41.4 N/cm^2 (60 psig) pressure, and a spray angle of approximately 75 degrees. The centerline of the nozzles shall be inclined downward so that the top of the spray is horizontal as it is directed towards the vertical and roof surfaces being tested.

The pressure at the nozzles shall be a minimum of 41.4 N/cm^2 (60 psig) under flow conditions. This is approximately equivalent to rain driven by a 29 m/s (65 mi per h) wind. The quantity of water applied to each surface under test shall be at least 0.5 cm (0.2 in) per unit surface per minute, and each surface so tested shall receive this rate of artificial precipitation for a duration of 5 min. The spray nozzle shall not be more than 3 m (10 ft) from the nearest vertical surface under test.

6.203.3 Evaluation

At the conclusion of the test, an enclosure marked "rainproof" shall be considered to have met the requirements of this test if:

a) no water is visibly observable on primary or secondary insulation;

b) no water is visibly observable on any electrical components or mechanisms of the assembly; and

c) no significant accumulation of water is retained by the structure or other noninsulating parts (to minimize corrosion).

At the conclusion of the test, an enclosure marked “Raintight” shall be considered to have met the requirements of this test if there is no entrance of water.

6.204 Mechanical tests of viewing panes

6.204.1 General

Viewing panes shall not shatter, crack or become dislodged when subjected to the impact and pressure tests described in Clauses 6.204.2 and 6.204.3. The impact and pressure tests shall be applied to the outside surface of the viewing pane. The inside surface of the viewing pane need not be tested. Separate samples may be used for each of the tests.

6.204.2 Pressure test

A force of 890 N (200 lbf) shall be exerted perpendicular to the surface in which the viewing pane is mounted. This force shall be evenly distributed over an area of 0.010 m^2 (16 in^2), as nearly square as possible and as near the geometric center of the viewing pane as possible. If the viewing pane has an area less than 0.010 m^2 (16 in^2), a force of 12.5 psi (86 kPa) shall be evenly distributed over the entire viewing area. The force shall be sustained for a period of 1 min.

6.204.3 Impact test

The viewing pane shall be subjected to an impact of 6.8 N·m (5 ft-lbf) using a steel ball weighing approximately 0.535 kg (1.18 lb) and approximately 50 mm (2 in) in diameter. If the viewing panes are provided with a pivoting or hinged, non-removable protective cover, which by design is always in place except when performing thermal inspections, this test may be performed with the cover in place. When such a protective cover is provided, this test will shall be considered passed if the protective cover is not dislodged and does not shatter or crack, even though the viewing pane may be shattered, cracked or dislodged.

6.205 Enclosure ground integrity test

Exposed dead-metal parts shall be tested to carry 30 A dc with a voltage drop of not more than 3 V to the grounding point provided. Any bolted joint design that has been previously verified to meet this requirement need not be retested.

6.206 Shutter integrity test

Any shutter assembly provided in accordance with Clause 5.11.202.2 shall withstand the application of a 90 N (20 lbf) force using a 12.7 mm (0.5 in) square metal bar at any point on the shutter. During and after the test, the shutter shall not be dislocated to the extent that permits entry of a rod having a diameter of 12.7 mm (0.5 in).

6.207 Rod entry test

This test is conducted to determine accessibility of live parts.

When live parts are less than 102 mm (4 in) from an opening, this test shall be made by attempting to insert a rod having a diameter of 12.7 mm (0.5 in).

When live parts are 102 mm (4 in) or more from an opening, this test shall be made by attempting to insert a rod having a diameter of 19 mm (0.75 in).

The equipment complies with these requirements if the rod cannot enter the opening.

6.208 Operation tests for all solid state controllers

6.208.1 General

6.208.1.1 During each of the operation tests specified in Clauses 6.208.2 through 6.208.5, the equipment shall be mounted as described in the manufacturer's installation instructions. The equipment shall be connected and operated as described in the Temperature Test, Clause 6.5 with the test conducted at rated voltage.

6.208.1.2 To assess the risk of electric shock, a 30 Ampere nontime delay ground fuse shall be connected, by means of a 1.22 – 1.83 m (4 – 6 ft) long 10 AWG (5.26 mm^2) copper wire, in accordance with one of the following:

a) The ground fuse shall be connected between the enclosure and earth ground, with the main input ground connection removed; or

b) The ground fuse shall be connected between the enclosure and the main input power terminal judged least at risk of arcing to earth ground, with the main input ground connection removed. For 3-phase equipment, the main input power terminal judged least at risk of arcing to earth ground is the L2 terminal.

6.208.1.3 The ground fuse required by Clause 6.208.1.2 shall have an Amperes Interrupting Current (A.I.C.) rating equal to or greater than the short circuit rating of the equipment.

6.208.1.4 To assess the risk of fire, surgical cotton shall be placed at all openings, handles, flanges, joints, and similar locations on the outside of the enclosure. At the option of the manufacturer, the cotton may be omitted from the test if all the following conditions are met:

a) Ventilation openings in the enclosure are located 30.38 cm (12 in) or more from any components within the equipment that could be affected by the test;

b) There is no visible flame, smoke, or arc emitted from the equipment during the test; and

c) At the conclusion of the test, the equipment is fully functional and visual examination of the equipment reveals no evidence of any arcing byproducts within the equipment.

In the event that there is any doubt of compliance with item (b) or (c), the test may be considered inconclusive, and the test repeated with the cotton in place to determine compliance.

6.208.1.5 Unless otherwise noted, each test shall be conducted until ultimate results are obtained. Ultimate results have been obtained when the test is terminated by a protective device or solid state protection circuitry, or until temperature rises are considered constant as defined by Clause 6.5.3.205.

6.208.1.6 Upon completion of each of the operation tests, the equipment shall comply with the acceptance criteria of Clause 6.208.5.

6.208.2 Single phasing (applies only to solid state resistive load controllers)

6.208.2.1 Three-phase equipment provided with phase loss protection shall be operated with one line disconnected at the input. The line disconnected shall be the one determined to be the one to which any protective devices are the least responsible. The test shall be conducted by disconnecting one line with the equipment delivering any convenient current to a load at maximum rated voltage and shall be repeated by initially energizing the device with one lead disconnected. The output of the equipment shall be monitored during this test, and the test shall not result in a single phase output for more than 30 seconds.

6.208.3 Inoperative blower motor

6.208.3.1 Equipment having forced ventilation shall be operated at rated load with inoperative blower motor or motors until ultimate results are obtained.

6.208.4 Clogged filter

6.208.4.1 Enclosed equipment that uses forced ventilation that includes filtered ventilation openings shall be operated with the openings blocked to represent clogged filters. The test shall be conducted initially with the ventilation openings blocked approximately 50 percent. The test shall then be repeated under a fully blocked condition until ultimate results are obtained.

6.208.5 Acceptance criteria

6.208.5.1 At the conclusion of the tests in Clauses 6.208.1 – 6.208.4, the equipment shall comply with all of the following:

a) The fuse specified in Clause 6.208.1.2 shall not have opened;

b) If cotton is used as specified in Clause 6.208.1.4, the cotton shall not glow or flame. If cotton is not used, the equipment shall comply with items (a), (b) and (c) of Clause 6.208.1.4;

c) The door or cover shall not have blown open;

d) The door or cover shall be able to be opened; and

e) The enclosure is not prohibited from deforming, however, live parts shall not be accessible.

6.208.5.2 When tests include the use of the cotton indicator, the equipment need not be functional at the conclusion of the operation tests. If the alternate method described in Clause 6.208.1.4 is used, the equipment shall be fully functional at the conclusion of the tests.

6.209 Grounding switch peak closing and short-time withstand current test

6.209.1 General

A grounding switch that has peak closing and short-time withstand ratings shall be subjected to testing to prove its ability to close into the rated peak closing current and to carry the short-time withstand currents. This is a combined test. This test shall be performed at the rated peak making voltage. The test frequency may be either 50 Hz or 60 Hz.

The grounding switch shall be connected to a source having a prospective peak current, in one phase, no less than the rated peak closing current and average symmetrical currents no less than the rated short-time withstand current of the grounding switch. The current duration shall not be less than the rated short-time withstand duration.

The tests shall be made in accordance with Clauses 6.209.2 to 6.209.5.

6.209.2 Test circuit

The test circuit shall be as shown in Figure 11.

The test source circuit may be ungrounded or neutral-grounded and include current-limiting reactors, resistors, and transformers in addition to the generating system. No capacitance shall be added in the circuit. Reactive components of the impedance in the line may be paralleled if of the air-core type, but no reactance shall be connected in parallel with resistance. Shunt resistance shall not be added to this circuit. If the source is ungrounded, a ground shall be connected to the shorting conductors.

The grounding switch be tested as part of a controller or in a representative test enclosure. Regardless of whether the switch is in a controller or not, the test circuit shall be calibrated with a short circuiting conductor applied at the incoming terminals of the grounding switch assembly.

Grounding switches with integral shorting conductors on the grounded side of the switch shall be tested with the integrated shorting conductors.

For grounding switches without integral shorting conductors on the grounded side of the switch, the shorting conductors used during the test shall have a cross-sectional area equal to what is intended to be used in the application. The sum of the lengths of the individual shorting conductors shall not exceed 1 m (3 ft) in total length. The cross-sectional area or cable size of the shorting conductors used shall be recorded in the test record.

6.209.3 Test procedure and cycle

The test circuit shall be identical to the calibration test circuit, except that the ground side terminals shall be shorted.

Grounding switches with integral shorting conductors on the grounded side of the switch shall be tested with the integrated shorting conductors.

For grounding switches without integral shorting conductors on the grounded side of the switch, the shorting conductors used during the test shall have a cross-sectional area equal to what is intended to be used in the application. The sum of the lengths of the individual shorting conductors shall not exceed 1 m (3 ft) in total length. The cross-sectional area or cable size of the shorting conductors used shall be recorded in the test record. For this testing, random closing shall be used.

The switch shall be subjected to 5 make and withstand operations as follows:

The test circuit shall be energized, and the switch closed into the energized circuit and maintained closed. The current shall be maintained for at least the rated withstand time. At the end of this time the test source shall interrupt the current flow. The switch shall then be opened without load. Switch contacts shall not be welded.

The time between these operations shall not be greater than 1 hour.

6.209.4 Test Measurements

Measurements shall be made by oscillograph unless otherwise specified in the following paragraphs. Data giving the voltage and current values of the circuit and a description of the operation of the switch during and after the test shall be prepared.

The circuit shall be tested and oscillograms shall be taken to record the three line-to-line voltages. Measurements of the currents shall be made on the calibration oscillograms.

Data to be recorded during the test shall include the following information:

a) Measurements to be made in calibrating the test circuit:

i) Open-circuit line-to-line voltages of all three phases by voltmeter or oscillograph immediately before the fault is created; and

ii) Fault current in each line; and

b) Measurements to be made with the switch in the circuit:

i) Line-to-line voltages (V1) of all three phases before the short-circuit is initiated;

ii) Voltage (V2) between switch line and load terminals before, during, and immediately following the fault; and

iii) Currents through switch during the test.

6.209.5 Evaluation

At the conclusion of the test, the switch shall be functional and in substantially the same mechanical condition as prior to testing. The switch contacts shall not be welded. The shorting conductors shall not be damaged.

With the grounding switch open, the load side of the controller (or the line terminals of the switch, if tested separately) shall pass the power frequency voltage withstand (repeated) test in Clause 6.2.202.4.

With the grounding switch closed, each pole shall be tested to carry 30 A dc with a voltage drop of not more than 3 V to the grounding point provided.

7 Routine Tests

7.1 Power-frequency voltage withstand test on the main circuit

A power-frequency voltage withstand test shall be applied. The test shall be made according to Clause 6.2.202 on completely assembled apparatus in clean and dry conditions, except the test voltage shall be 2 000 V + (2.25 × rated supply voltage).

The test voltage shall be applied between each phase of the power circuit and ground with the other phases grounded and the controller contacts both open and closed. The control circuit shall be grounded for this test.

For convenience of testing, the duration may be reduced to 1 s if the test voltage is raised to 120% of the value specified for the 1 min test.

7.2 Power-frequency voltage withstand test on auxiliary and control circuits

A power-frequency voltage withstand test shall be applied. The test shall be made according to Clause 6.2.202 on completely assembled apparatus in clean and dry conditions at the test voltage specified in column 2 of Table 1.

Points of application shall be between the control circuit and ground with the control circuit ungrounded. Devices that can be damaged by this test may be disconnected.

For convenience of testing, the duration may be reduced to 1 s if the test voltage is raised to 120% of the value specified for the 1 min test.

7.3 Measurement of the resistance of the main circuit

[Vacant]

7.4 Tightness test (vacuum integrity test)

After assembly of a vacuum contactor, the vacuum integrity of the vacuum interrupters shall be verified by a power-frequency withstand voltage test across the open contacts. The test procedure shall be stated by the manufacturer. The power-frequency withstand voltage test shall be carried out after routine operating tests. Care shall be taken not to apply a test voltage across the open contacts of a vacuum interrupter that exceeds the manufacturer's recommendation, to avoid generating harmful X-rays.

NOTE: For further information, see Annex A, Item 17.

7.5 Design and visual checks

[Vacant]

7.101 Operating tests

Tests are carried out to verify that the contactors open and close correctly when their operating devices are energized. It shall also be verified that operation will not cause any damage.

The following tests shall be done where applicable:

a) at rated supply voltage: five operating cycles;

b) for latched controllers only, at rated supply voltage: five operating cycles with a tripping circuit energized by the closing of the main contacts;

c) auxiliary control and timing relays shall be operated to verify functionality in accordance with the control diagram; and

d) protective relays (e. g., overload relays) shall be operated to verify opening of the line contactor(s), except as permitted by Clause 5.203(c).

The tests may be made without current passing through the main circuit.

During all the foregoing routine tests, no adjustments shall be made, and the operation shall be faultless. The closed and open positions shall be attained during each operating cycle.

After the tests, the controller shall be examined to determine that no parts have sustained damage and that all parts are in a satisfactory condition and all interlocks continue to perform their intended function.

7.102 Tests dependent on controller type

7.102.1 For rheostatic rotor starters

[Vacant]

7.102.2 For two-step autotransformer controllers

Tests shall be performed to verify the proper operation of time-delay relays and the calibration of any other devices used for controlling the rate of starting.

It shall be verified that the open-circuit voltages on the tap terminals of the autotransformer are in accordance with the design figures and that the phase sequence at the motor terminals is correct in both STARTING and RUN positions of the controller.

7.102.3 For two-step reactor starters

Tests shall be performed to verify the proper operation of time-delay relays and the calibration of any other devices used for controlling the rate of starting.

It shall be verified that the impedance of the tap terminals of the reactor is in accordance with the design figures and that the phase sequence at the motor terminals is correct in both the STARTING and RUN positions of the controller.

7.201 Routine tests – general

The routine tests are for the purpose of ensuring the quality and workmanship of the products as assembled. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practicable at the manufacturer's works on each apparatus manufactured, including any control center busing, to ensure that the product is in accordance with the equipment on which the type tests have been passed. By agreement, any routine test may be made on site.

Additional routine tests may be specified.

TABLES

Table 1
Rated insulation levels for rated voltages

(See Clauses 4.2, 6.2.201.1 – 6.2.201.3, 6.2.202.1 – 6.2.202.4, 6.2.203.2, and 7.2)

Rated voltage, U_r V_{rms}	Rated short-duration power-frequency withstand voltage U_d V_{rms}			Rated lightning impulse withstand voltage, U_p kV (peak value)		Minimum CEV[c] kVrms
	Test voltage		Test voltage repeated	Test voltage common value	Test voltage across the isolating distance of the isolating means	
	Common value	Across the isolating distance				
Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**
0 – 750	1 000 V + (2 × rated voltage)	100% of common value	Not applicable	Not applicable	Not applicable	Not applicable
751 – 1 500	2 000 V + (2.25 × rated voltage)	110% of common value	2 × rated voltage	10[b] 20[b]	11[b] 22[b]	Not applicable
1 501 – 3 600	2 000 V + (2.25 × rated voltage)	110% of common value	2 × rated voltage	30[a] 45	33[a] 50	Not applicable
3 601 – 7 200	2 000 V + (2.25 × rated voltage)	110% of common value	2 × rated voltage	45[a] 60	50[a] 66	Not applicable
7 201 – 12 000	2 000 V + (2.25 × rated voltage)	110% of common value	2 × rated voltage	60[a] 75	70[a] 85	8.3
12 001 – 15 000	2 000 V + (2.25 × rated voltage)	110% of common value	2 × rated voltage	75[a] 95	85[a] 110	10.5

[a] These ratings are not applicable in Mexico.

[b] These ratings are not applicable in Mexico or the United States.

[c] Corona extinction voltage

NOTE: Manufacturers may assign one of two levels of impulse voltage withstandability. For additional information, refer to Annex A, Item 18.

Table 2
Limits of temperature and temperature rise for various parts and materials

(See Clauses 4.4.2, 4.4.101, 6.5.5.201.1, and 6.5.6)

Category	Part, material, or place of temperature measurements	Temperature, °C	Rise, °C
1	Insulated wire and cable	(–) [b]	(–)
2	Field-wiring terminals[c,f]	90	50
3	Class 90 insulation systems:		
	Thermocouple method	90	50
	Resistance method	110	70
4	Buses and connecting straps[d,e]	105	65
5	Class 105 insulation systems:		

Table 2 Continued on Next Page

Table 2 Continued

Category	Part, material, or place of temperature measurements	Temperature, °C	Rise, °C
	Thermocouple method	105	65
	Resistance method	125	85
6	Class 130 insulation systems:		
	Thermocouple method	125	85
	Resistance method	145	105
7	Class 155 insulation systems:		
	Thermocouple method	135	95
	Resistance method	155	115
8	Class 180 insulation systems:		
	Thermocouple method	165	125
	Resistance method	200	160
9	Class 200 insulation systems:		
	Thermocouple method	175	135
	Resistance method	195	155
10	Class 220 insulation systems:		
	Thermocouple method	190	150
	Resistance method	215	175
11	Class 240 insulation systems:		
	Thermocouple method	205	165
	Resistance method	235	195
12	Class 105 insulation system on single-layer series coil with exposed surfaces either uninsulated or enameled, thermocouple method	130	90
13	Phenolic composition[a]	165	125
14	Starting autotransformers and reactors	g	g
15	Conductive parts of a switch		
	Silver or nickel-plated	105	65
	Silver or nickel-plated to bare copper	90	50
	Bare copper to bare copper	70	30
16	External surfaces:		
	Accessible parts normally handled by the operator	60	20
	Accessible surfaces not normally handled by the operator	70	30
	External surfaces not normally accessible to the operator	110	70

[a] The limitation on phenolic insulation does not apply to compounds that have been investigated and found to have special heat-resistant properties.

[b] For standard insulated conductors see Annex A, Item 1; the maximum allowable temperature rise shall not exceed the maximum operating temperature specified for the wire in question minus an assumed ambient (room) temperature of 40°C.

[c] The temperature on a wiring terminal or lug is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.

[d] The limit does not apply to connections to a source of heat, such as resistors, current elements of overload relays, contacts, fuses, and the like.

[e] The temperature rise of buses and connecting straps shall be determined by the thermocouple method.

[f] The temperature rise of field wiring terminals shall be determined by the thermocouple method.

[g] Because, in an autotransformer or reactor starter, the autotransformer or reactor is energized only intermittently, a maximum 15°C temperature rise greater than the limits stated for the insulation class is permissible for the windings of the transformer or reactor when the starter is operated according to the requirements of Clauses 4.109 and 4.204.

Table 3
Size of bonding, equipment grounding, grounding electrode conductors, and ground bus[e]

(See Clauses 5.3.202 and 5.3.203)

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
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
15	14[b]	12[b]	–	–	–	–
20	12[b] (14)	10[b] (12)	–	–	–	–
30	10[b] (12)	8[b] (10)	–	–	–	–
40	10[b]	8[b]	–	–	–	–
60	10[b]	8[b]	–	–	–	–
90	8	6	8	6	8	6
100	8	6	6	4	6	4
150	6	4	6	4	6	4
200	6	4	4	2	4	2
300	4	2	2	1/0	2	1/0
400	3	1	1/0[c]	3/0[c]	1/0[c]	3/0[c]
500	2	1/0	1/0	3/0	1/0	3/0
600	1	2/0	2/0	4/0	2/0	4/0
800	1/0	3/0	2/0	4/0	2/0	4/0
1000	2/0	4/0	3/0	250	3/0	250
1200	3/0	250	3/0	250	250[d]	250
1600	4/0	350	3/0	250	300[d]	400[d]
2000	250	400	3/0	250	400[d]	500[d]
2500	350	600 (500)	3/0	250	500[d]	700[d]
3000	400	600	3/0	250	600[d]	750[d]
4000	500	800	3/0	250	750[d]	1 000[d]
5000	700	1 200 (1 000)	3/0	250	900	1 250
6000	800	1 200 (1 250)	3/0	250	1 250	1 500

[a] Maximum ampere rating of center or circuit overcurrent device ahead of equipment-grounding means.

[b] Values are applicable to equipment-grounding conductors only.

[c] If the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG (85.0 mm^2) copper or two No. 250 kcmil (127 mm^2) aluminum conductors but will not accept a No. 600 kcmil (304 mm^2) conductor, these values may be reduced to 2 AWG (33.6 mm^2) copper or 1/0 AWG (53.5 mm^2) aluminum.

[d] The cross-section may be reduced to 12.5% of the total cross-section of the largest main service conductor of the same material (copper or aluminum) for any phase on centers rated 1 200 A and over. This applies when the cross-section of the service conductors is limited by the wire terminal connectors provided.

[e] Refer to Table 4 for approximate metric conductor size equivalents to the AWG (kcmil) sizes shown.

NOTE 1 – Numbers in parenthesis apply in Canada.

NOTE 2 – If bus is used, it shall be of equivalent cross-sectional area to the conductors shown in the table.