

# IEEE Standard for Metal-Clad Switchgear

Sponsor

**Switchgear Committee**  
of the  
**IEEE Power Engineering Society**

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**Abstract:** Metal-clad (MC) medium-voltage switchgear that contains drawout electrically operated circuit breakers is covered. MC switchgear is compartmentalized to isolate all components such as instrumentation, main bus, and both incoming and outgoing connections with grounded metal barriers. Rated maximum voltage levels for metal-clad switchgear range from 4.76 kV to 38 kV with main bus continuous current ratings of 1200 A, 2000 A, and 3000 A. MC switchgear also contains associated control, instruments, metering, relaying, protective, and regulating devices, as necessary. Service conditions, ratings, temperature limitations and classification of insulating materials, insulation (dielectric) withstand voltage requirements, test procedures, and applications are discussed.

**Keywords:** control, cumulative loading, current transformers, drawout, indoor, instrumentation, load current-carrying, metal-clad (MC) switchgear, metal-enclosed (ME) power switchgear, outdoor, protection, qualifying terms, switchgear assemblies, transformer accuracy, voltage transformers

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# Introduction

(This introduction is not part of IEEE Std C37.20.2-1999, IEEE Standard for Metal-Clad Switchgear.)

This standard has been revised to reflect needed technical changes that have been suggested since the last revision to C37.20.2 was published in 1993. The major revision in this edition is the removal of station-type cubicle switchgear. Other significant changes are as follows:

- Inclusion of IEEE Std C37.20.2b-1994, Supplement to IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear: Current Transformer Accuracies, upgrading current transformer requirements<sup>a</sup>
- Addition of new definitions for mechanism-operated contact (MOC) and truck-operated contact (TOC) switches, as used in metal-clad (MC) switchgear
- Expansion of the momentary and short-time current withstand test requirements for buses and connections of the switchgear, as well as the addition of a momentary withstand test for the auxiliary equipment connections
- Clarification/expansion of the mechanical testing requirements, including an increase in the number of endurance cycles, a clarification of drawout interlocking, and a new requirement for circuit breaker mechanical endurance testing in the upper compartment of two-high assemblies
- Expansion of nameplate requirements to list a complete set of ratings

Additionally, this standard recognizes IEEE Std 4-1978 instead of the 1995 revision because the methods of correction for relative air density and humidity appropriate for metal-clad switchgear are not included in the 1995 revision. When the 1995 version is suitably revised to include rod gaps, it will supersede the 1978 version.

It is also noted that the altitude correction factors listed in Table 8 of this standard are under review by an IEEE Switchgear Committee working group. The old values are included in this document for reference until the working group releases the new values, at which time the new values will supersede those in the current Table 8.

This standard includes only the requirements for metal-clad switchgear. These requirements were previously a part of IEEE Std C37.20-1969, IEEE Standard for Switchgear Assemblies Including Metal-Enclosed Bus (1974 consolidated edition). Other types of equipment previously included in IEEE Std C37.20-1969 are incorporated in separate publications.

For many years, IEEE Std C37.20-1969 covered all switchgear assemblies, including metal-enclosed bus. Standards committees of the IEEE Switchgear Assemblies Subcommittee and the NEMA Power Switchgear Assemblies Technical Committee recommended that the document be further developed and, where appropriate, that the various sections be identified with their own standards. This approach also coordinates with the Conformance Test Procedure Standards.

The IEEE Switchgear Assemblies Subcommittee was responsible for this revision.

This publication is one of a series covering Switchgear Assemblies. Other members of the series are as follows:

IEEE Std C37.20.1-1993, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.

<sup>a</sup>Information on references can be found in Clause 2.

IEEE Std C37.20.2-1999, IEEE Standard for Metal-Clad Switchgear.

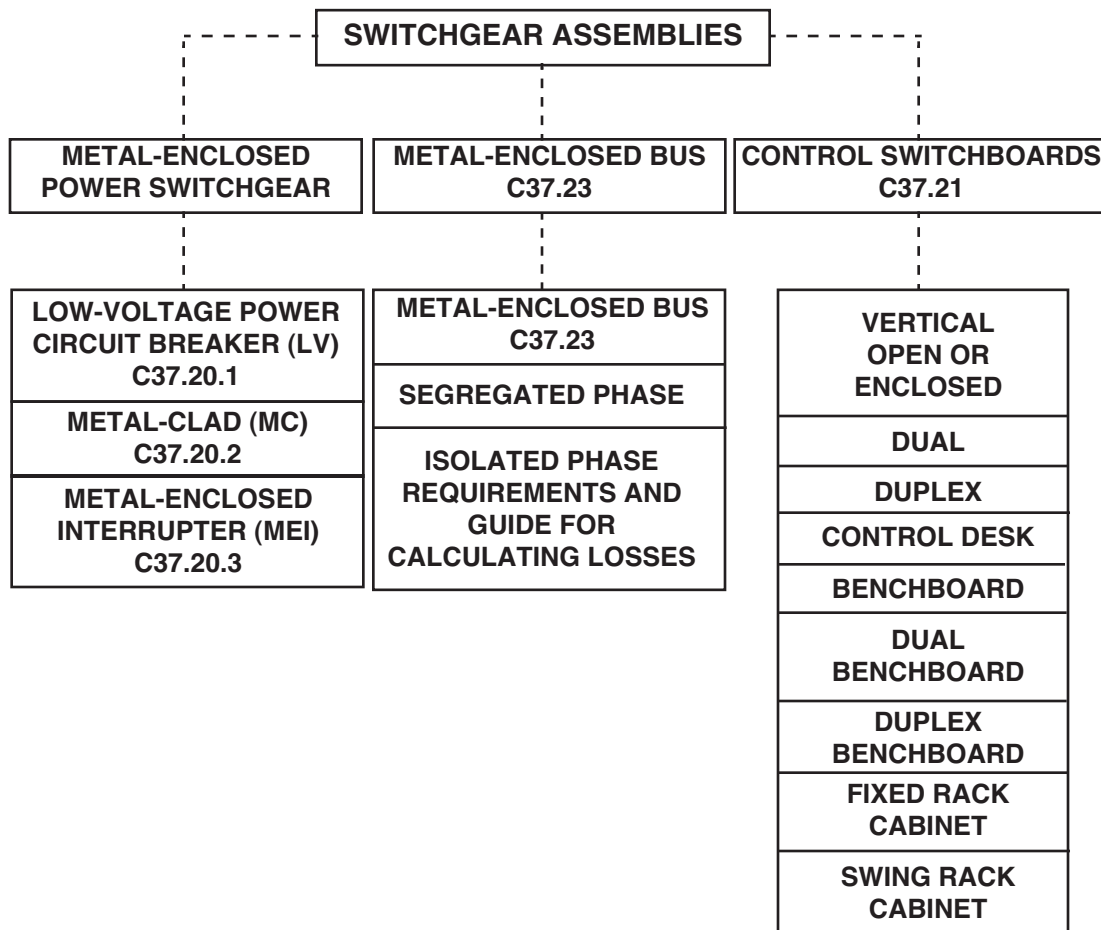
IEEE Std C37.20.3-1987 (Reaff 1992), IEEE Standard for Metal-Enclosed Interrupter Switchgear.

IEEE PC37.20.7/D14 Guide for Testing Metal-Enclosed Switchgear for Internal Arcing Faults.<sup>b</sup>

IEEE Std C37.21-1985 (Reaff 1998), IEEE Standard for Control Switchboards.

IEEE Std C37.23-1987 (Reaff 1991), IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated Phase Bus.

The following diagram depicts types of switchgear assemblies.



<sup>b</sup>This IEEE standards project was not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining a draft, contact the IEEE.

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# IEEE Standard for Metal-Clad Switchgear

## 1. Scope

This standard covers metal-clad (MC) switchgear containing, but not limited to, devices such as power circuit breakers, other interrupting devices, switches, control, instrumentation and metering, and protective and regulating equipment. It includes, but is not specifically limited to, equipment for the control and protection of apparatus used for power generation, conversion, and transmission and distribution.

This standard is concerned with enclosed, rather than open, indoor and outdoor switchgear assemblies rated above 1000 V ac. Included is equipment that is part of primary and secondary unit substations. Gas insulated substation equipment is not included.

## 2. References

This standard shall be used in conjunction with the following publications. When the standards referenced in this document are superseded by an approved revision, the revision shall apply in all cases except for IEEE Std 4, which shall remain the 1978 revision.

Accredited Standards Committee C2-1997, National Electrical Safety Code<sup>®</sup> (NESC<sup>®</sup>).<sup>1</sup>

ANSI C37.06-1997, American National Standard for Switchgear—AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.<sup>2</sup>

ANSI C37.06.1-1997, American National Standard Trial-Use Guide for High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis Designated “Definite Purpose for Fast Transient Recovery Voltage Rise Times.”

ANSI C37.22-1997, American National Standard Preferred Ratings and Related Required Capabilities for Indoor AC Medium-Voltage Switches Used in Metal-Enclosed Switchgear.

<sup>1</sup>The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

<sup>2</sup>ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

ANSI C37.54-1996, American National Standard Conformance Test Procedures for Indoor Alternating-Current Medium-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclosed Switchgear Assemblies.

ANSI C37.55-1989 (Reaff 1994), American National Standard for Metal-Clad Switchgear Assemblies—Conformance Test Procedures.

ANSI Z535.4-1998, American National Standard for Product Safety Signs and Labels.

ANSI/UL 486A-1991, Wire Connectors and Soldering Lugs for Use With Copper Conductors.<sup>3</sup>

ASTM B117-97, Standard Practice for Operating Salt Spray (Fog) Apparatus.<sup>4</sup>

ASTM D229-96, Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation.

ASTM D714-87 (Reapproved 1994), Standard Test Method for Evaluating Degree of Blistering of Paints.

ASTM D1535-97, Standard Practice for Specifying Color by the Munsell System.

ASTM D1654-92, Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.

ASTM D2303-96, Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials.

ASTM G21-96, Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.

IEEE Std 1-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.<sup>5</sup>

IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (to be superseded by the 1995 revision when the 1995 revision is supplemented to include methods for correction of relative air density and humidity using rod gaps).

IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).

IEEE Std 241-1990 (Reaff 1997), IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book).

IEEE Std 242-1986 (Reaff 1991), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).

IEEE Std 344-1987 (Reaff 1993), IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

IEEE Std 446-1995, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book).

IEEE Std C37.04-1999, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.09-1999, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

<sup>3</sup>UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

<sup>4</sup>ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

<sup>5</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

IEEE Std C37.010-1999, IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.2-1996, IEEE Standard Electrical Power System Device Function Numbers and Contact Designations.

IEEE Std C37.11-1997, IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.20.4-1996, IEEE Trial-Use Standard for Indoor AC Medium-Voltage Switches for Use in Metal-Enclosed Switchgear.

IEEE Std C37.20.6-1997, IEEE Standard for 4.76 to 38 kV Rated Grounding and Test Devices Used in Enclosures.

IEEE Std C37.24-1986 (Reaff 1998), IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear.

IEEE C37.81-1989 (Reaff 1994), IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies.

IEEE C37.90.1-1989 (Reaff 1994), IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.

IEEE C37.90.2-1987, IEEE Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interferences from Transceivers.

IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear.

IEEE C37.110-1996, IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes.

IEEE Std C57.13-1993, IEEE Standard Requirements for Instrument Transformers.

NEMA CC 1-1993, Electrical Power Connectors for Substations.<sup>6</sup>

NEMA LI 1-1989, Industrial Laminated Thermosetting Products.

NEMA WC 5-1992, Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

NEMA WC 7-1998, Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

NEMA 260-1996, Safety Labels for Pad-mounted Switchgear and Transformers Sited in Public Areas.

NFPA 70-1999, National Electrical Code<sup>®</sup> (NEC<sup>®</sup>).<sup>7</sup>

### 3. Definitions, qualifying terms, and common or related terms

The definitions of terms contained in this standard, or in other standards referred to in this standard, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject matter treated in this standard.

<sup>6</sup>NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

<sup>7</sup>The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>). Copies are also available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

If a term is not defined in this standard, the definition in IEEE Std C37.100-1992 applies. An asterisk (\*) after a definition indicates that the definition in this standard is not contained in IEEE Std C37.100-1992, while a dagger (†) indicates that the definition differs from that in IEEE Std C37.100-1992.

## 3.1 General

**3.1.1 auxiliary compartment:** That portion of the switchgear assembly that is assigned to the housing of auxiliary equipment, such as voltage transformers, control power transformers, or other miscellaneous devices.\*

**3.1.2 circuit breaker compartment:** That portion of the switchgear assembly that contains one circuit breaker or other removable primary interrupting device and the associated primary conductors.\*

**3.1.3 design tests:** Tests made by the manufacturer to determine the adequacy of the design of a particular type, style, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions, if specified, and that may be used to demonstrate compliance with applicable standards of the industry.†

### NOTES

1—Design tests are made on representative apparatuses or prototypes to verify the validity of design analyses and calculation methods and to substantiate the ratings assigned to all other apparatuses of basically the same design. These tests are not intended to be made on every design variation or to be used as part of normal production. The applicable portion of these design tests also may be used to evaluate modifications of a previous design and to ensure that performance has not been adversely affected. Test data from previous similar designs also may be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

2—Design tests are sometimes called type tests.

**3.1.4 mechanism-operated contact (MOC):** A circuit breaker mechanism-operated auxiliary switch that is mounted in the stationary housing and is operated by linkage that cooperates with the circuit breaker mechanism.\* *Syn:* **mechanism-operated cell switch.**

**3.1.5 metal-clad (MC) switchgear:** Metal-enclosed power switchgear characterized by the following necessary features:

- a) The main switching and interrupting device is of the removable (drawout) type arranged with a mechanism for moving it physically between connected and disconnected positions and equipped with self-aligning and self-coupling primary disconnecting devices and disconnectable control wiring connections.
- b) Major parts of the primary circuit, that is, the circuit switching or interrupting devices, buses, voltage transformers, and control power transformers, are completely enclosed by grounded metal barriers that have no intentional openings between compartments. Specifically included is a metal barrier in front of, or a part of, the circuit interrupting device to ensure that, when in the connected position, no primary circuit components are exposed by the opening of a door.
- c) All live parts are enclosed within grounded metal compartments.
- d) Automatic shutters that cover primary circuit elements when the removable element is in the disconnected, test, or removed position.
- e) Primary bus conductors and connections are covered with insulating material throughout.
- f) Mechanical interlocks are provided for proper operating sequence under normal operating conditions.
- g) Instruments, meters, relays, secondary control devices, and their wiring are isolated by grounded metal barriers from all primary circuit elements with the exception of short lengths of wire such as at instrument transformer terminals.

- h) The door through which the circuit-interrupting device is inserted into the housing may serve as an instrument or relay panel and also may provide access to a secondary or control compartment within the housing.

#### NOTES

1—Auxiliary vertical sections may be required for mounting devices or for use as a bus transition.

2—The term metal-clad (as applied to switchgear assemblies) is correctly used only in connection with switchgear conforming fully to the definition for metal-clad switchgear given in 3.1.5. Metal-clad switchgear is metal-enclosed, but not all metal-enclosed switchgear can be correctly designated as metal-clad.

**3.1.6 metal-enclosed (ME) power switchgear:** A switchgear assembly completely enclosed on all sides and the top with sheet metal (except for ventilating openings and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors or removable covers or both.†

**3.1.7 production tests:** Tests made for quality control by the manufacturer on every device or representative samples, or on required parts or materials to verify during production that the product meets the design specifications and applicable standards.†

#### NOTES

1—Certain quality assurance tests on identified critical parts of repetitive high-production devices may be tested on a planned statistical sampling basis.

2—Production tests are sometimes called routine tests.

**3.1.8 tin-surfaced or equivalent:** Metallic materials having satisfactory long-term performance that operate within the limits established for tin-surfaced electrical contact parts and conduction mechanical joints.\*

**3.1.9 truck-operated contact (TOC):** A circuit breaker truck-operated auxiliary switch that is mounted in the compartment of a removable circuit breaker and is operated by the circuit breaker frame.\* *Syn:* truck-operated cell switch

## 3.2 Qualifying terms

Qualifying terms are defined in The IEEE Standard Dictionary of Electrical and Electronics Terms [B1]<sup>8</sup> and IEEE Std C37.100-1992<sup>9</sup>, and the user is referred to the definitions given therein.

## 3.3 Common or related terms

Common or related terms are defined in IEEE Std C37.100-1992, and the user is referred to the definitions given therein.

## 4. Service conditions

Standards for the design and performance of MC switchgear are based on usual service conditions as described below. The selection of equipment for a particular application can be based on the construction and ratings as defined in this standard provided that the following usual service conditions exist:

- a) The temperature of the cooling air (ambient air temperature) surrounding the enclosure of the MC switchgear is within the limits of  $-30^{\circ}\text{C}$  and  $40^{\circ}\text{C}$ .

<sup>8</sup>The numbers in brackets correspond to those of the bibliography in Annex B.

<sup>9</sup>Information on references can be found in Clause 2.

- b) The altitude of the installation does not exceed 1000 m (3300 ft).
- c) The effect of solar radiation is not significant. (The principles stated in IEEE Std C37.24-1986 may be used for guidance.)
- d) Unusual service conditions, such as those outlined in 8.1, do not prevail.

The user should review 8.1 for unusual service conditions and other considerations when preparing specifications for MC switchgear because those unusual conditions impact the equipment design.

## 5. Ratings

### 5.1 General

The ratings of a switchgear assembly are designations of operating limits under specified conditions of ambient temperature, temperature rise, etc. Where the switchgear assembly includes a combination of primary and secondary circuits, each may be given ratings. MC switchgear shall have the following ratings:

- a) Rated maximum voltage
- b) Rated power frequency
- c) Rated insulation levels
- d) Rated continuous current
- e) Rated momentary withstand current
- f) Rated short-time withstand current

The designated ratings in this standard are preferred but are not considered to be restrictive.

In addition to these ratings, a switchgear assembly may have interrupting or switching capabilities, which are determined by the rating of the particular interrupting and switching devices that are integral parts of the switchgear assembly. Refer to specific standards for the ratings of these devices.

### 5.2 Voltage and insulation levels

#### 5.2.1 Rated maximum voltage

The rated maximum voltage of MC switchgear is the highest rms voltage for which the equipment is designed and is the upper limit for operation.

NOTE—MC switchgear may utilize voltage-sensitive components such as voltage transformers and surge arresters with a rated maximum voltage less than the rated maximum voltage of the MC switchgear. The upper limit for operation may be determined by the rating of these components.

#### 5.2.2 Rated insulation levels

The rated insulation levels of MC switchgear shall consist of the following:

- a) Power-frequency withstand voltage
- b) Lightning impulse withstand voltage (BIL)

### 5.2.3 Voltages and insulation levels

The rated maximum voltages and corresponding insulation levels for MC switchgear are listed in Table 1.

### 5.3 Rated power frequency

The rated power frequency of a device or an assembly is the frequency of the circuit for which it is designed. All ratings in this standard are based on a rated power frequency of 60 Hz.

**Table 1—Preferred voltage and insulation levels for MC switchgear**

| Rated maximum voltage (kV rms) | Insulation levels                  |                                       |                                          |
|--------------------------------|------------------------------------|---------------------------------------|------------------------------------------|
|                                | Power frequency withstand (kV rms) | Lightning impulse withstand (kV peak) | Reference <sup>a</sup> dc withstand (kV) |
| 4.76                           | 19                                 | 60                                    | 27                                       |
| 8.25                           | 36                                 | 95                                    | 50                                       |
| 15.0                           | 36                                 | 95                                    | 50                                       |
| 27.0                           | 60                                 | 125                                   | b                                        |
| 38.0                           | 80                                 | 150                                   | b                                        |

<sup>a</sup>The column headed dc withstand is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or implies that a dc withstand test represents an acceptable alternative to the power frequency withstand tests specified in this standard for design tests, production tests, conformance tests, or field tests. In making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of 1 min.

<sup>b</sup>Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before dc withstand tests are applied to the switchgear.

NOTE—For field test values, see 6.5.

### 5.4 Rated current

#### 5.4.1 Rated continuous current

The rated continuous current of MC switchgear is the maximum current in rms amperes at the rated power frequency, which can be carried continuously by the primary circuit components, including buses and connections, without causing temperatures in excess of specified limits for

- Any primary or secondary circuit component.
- Any insulating medium or structural or enclosing member.

The specified temperature limits applicable to switchgear assemblies are given in 5.5.1 through 5.5.6.

#### 5.4.2 Continuous current ratings

The continuous current ratings of the main bus in MC switchgear are 1200 A, 2000 A, and 3000 A.

The continuous current rating of the individual circuit breaker compartment shall be equal to the ratings of the switching and interrupting devices used, except as may be modified by lower continuous current ratings of current transformers, power fuses, etc.

#### 5.4.3 Rated momentary withstand current

The rated momentary withstand current of MC switchgear is the maximum rms total current that it shall be required to withstand. The current shall be the rms 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 symmetrical current shall be the rated short-time current and the peak current value shall be 2.6 times its rated short-time current at the major peak of the maximum cycle (this is also referred to as the peak withstand current).

#### 5.4.4 Momentary withstand current rating

The momentary withstand current rating of the individual circuit breaker compartments of MC switchgear shall be equal to one of the following:

- a) The circuit breaker rated close and latch capability
- b) Switch rated fault closing current
- c) Momentary withstand current ratings or peak withstand current ratings of the switching devices used

See ANSI C37.06-1997 and/or ANSI C37.22-1997.

#### 5.4.5 Rated short-time withstand current

The rated short-time withstand current of the MC switchgear assembly is the average rms symmetrical current that the bus and connections shall carry for 2 s.

NOTE—This is based on the maximum permissible tripping delay (Y) for indoor circuit breakers. Refer to IEEE Std C37.04-1999 and ANSI C37.06-1997, Table 1.

#### 5.4.6 Short-time withstand current rating

The short-time withstand current ratings of the individual circuit breaker compartments of the MC switchgear shall be equal to the short-time ratings of the circuit breaker used. The use of certain current transformers and protective devices in the MC switchgear assembly may limit the duration to a value less than 2 s. When this occurs, it does not reduce the requirements for the bus and connections. The reduced duration shall be that of the current transformer or protective device utilized (see IEEE Std C57.13-1993).

### 5.5 Temperature limitations

#### 5.5.1 Limiting temperature

The limiting temperature for MC switchgear is the maximum temperature permitted for

- a) Any component, such as insulation, buses, instrument transformers, and switching and interrupting devices
- b) Air in cable termination compartments
- c) Any non current-carrying structural parts
- d) Air surrounding devices

### 5.5.2 Temperature limits for insulating materials

The total temperature to which insulating materials are subject shall not exceed the values listed in Table 2 for the various classes of insulating materials.

**Table 2—Temperature limits for insulating materials as used in switchgear assemblies**

| Class of insulating material | Limit of hottest-spot temperature rise (°C) | Limit of hottest-spot total temperature (°C) |
|------------------------------|---------------------------------------------|----------------------------------------------|
| Class 90                     | 50                                          | 90                                           |
| Class 105                    | 65                                          | 105                                          |
| Class 130                    | 90                                          | 130                                          |
| Class 155                    | 115                                         | 155                                          |
| Class 180                    | 140                                         | 180                                          |
| Class 220                    | 180                                         | 220                                          |

NOTE—For additional information on temperature limits, see IEEE Std 1-1986.

### 5.5.3 Temperature limits for buses and connections

The total temperature of buses and connections shall not exceed the values listed in Table 3.

**Table 3—Temperature limits for buses and connections as used in switchgear assemblies**

| Type of bus or connection                                                 | Limit of hottest-spot temperature rise (°C) | Limit of hottest-spot total temperature (°C) |
|---------------------------------------------------------------------------|---------------------------------------------|----------------------------------------------|
| Buses and connections with unplated copper-to-copper connecting joints    | 30                                          | 70                                           |
| Buses and connections silver-surfaced or equivalent connecting joints     | 65                                          | 105                                          |
| Buses and connections tin-surfaced or equivalent connecting joints        | 65                                          | 105                                          |
| Connection to insulated cables unplated copper-to-copper <sup>a</sup>     | 30                                          | 70                                           |
| Connection to insulated cables silver-surfaced or equivalent <sup>a</sup> | 45                                          | 85                                           |
| Connections to insulated cables tin-surfaced or equivalent <sup>a</sup>   | 45                                          | 85                                           |

<sup>a</sup>Based on 90 °C insulated cable. Refer to 5.5.5.

#### NOTES

1—All aluminum buses shall have silver-surfaced or equivalent, or tin-surfaced or equivalent connecting joints. Welded bus connections are not considered connecting joints.

2—Refer to IEEE Std C37.100-1992 for the definition of *silver-surfaced or equivalent*.

#### 5.5.4 Temperature limitations for air surrounding devices within an enclosed assembly

The temperature of the air surrounding all devices within an enclosed assembly, considered in conjunction with their rating and loading as used, shall not cause these devices to operate outside their rated temperature range when the enclosure of the assembly is surrounded by air within an ambient temperature range of  $-30^{\circ}\text{C}$  through  $40^{\circ}\text{C}$ .

#### 5.5.5 Temperature limitations for air surrounding insulated power cables

The temperature of the air surrounding insulated cables within any compartment of an enclosed assembly shall not exceed  $65^{\circ}\text{C}$  when the assembly is

- a) Equipped with devices having maximum current rating for which the assembly is designed.
- b) Carrying rated continuous current at rated voltage and rated power frequency.
- c) In an ambient air temperature of  $40^{\circ}\text{C}$ .

NOTE—This temperature limitation is based on the use of  $90^{\circ}\text{C}$  insulated power cables. Use of lower temperature rated cables requires special consideration.

#### 5.5.6 Temperature limitations for external parts subject to contact by personnel

- a) External parts handled by the operator in the normal course of his or her duties shall have no higher total temperature than  $50^{\circ}\text{C}$ .
- b) External surfaces accessible to an operator in the normal course of his or her duties shall have no higher total temperature than  $70^{\circ}\text{C}$ .
- c) External surfaces not accessible to an operator in the normal course of his or her duties shall have no higher total temperature than  $110^{\circ}\text{C}$ .

### 5.6 Current transformer ratings

#### 5.6.1 Current transformer mechanical rating

The mechanical ratings of current transformers shall be such that they will successfully withstand the momentary current for which the associated circuit interrupting devices are applied. When the primary circuit is protected by current-limiting fuses, the current transformers shall successfully withstand the maximum let-through current of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the momentary current shall be considered as being 10 cycles.

#### 5.6.2 Current transformer thermal ratings

The thermal ratings of current transformers shall be such that they will successfully withstand the short-circuit current for which the associated circuit interrupting devices are applied. When the primary circuit is protected by fuses, the current transformers shall successfully withstand the maximum  $I^2t$  of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the short circuit current shall be considered as 1 s.

#### 5.6.3 Current transformer ambient temperature

Current transformers for use in switchgear assemblies shall be rated on the basis of at least  $55^{\circ}\text{C}$  ambient temperature in accordance with IEEE Std C57.13-1993.

## 5.7 Current transformer accuracies

For installation in MC switchgear, the standard current transformer accuracies for metering and relaying are listed in Table 4. Accuracies tabulated hereafter are the minimum that shall be supplied. The manufacturer should be consulted if higher accuracies are required by the purchaser. It should be recognized that wound-type current transformers with higher accuracies may not meet the requirements of 5.6.

When multi-ratio current transformers are supplied, the metering and relaying accuracies listed in Table 4 apply only to the full winding in accordance with IEEE Std C57.13-1993.

**Table 4—Standard accuracy class ratings<sup>a</sup> for current transformers in MC switchgear**

| Ratio  | B0.1 | B0.2             | B0.5             | B0.9 <sup>b</sup> | B1.8 <sup>b</sup> | Relaying accuracy <sup>c</sup> |
|--------|------|------------------|------------------|-------------------|-------------------|--------------------------------|
| 50:5   | 1.2  | 2.4 <sup>d</sup> | —                | —                 | —                 | C or T10                       |
| 75:5   | 1.2  | 2.4 <sup>d</sup> | —                | —                 | —                 | C or T10                       |
| 100:5  | 1.2  | 2.4 <sup>d</sup> | —                | —                 | —                 | C or T10                       |
| 150:5  | 0.6  | 1.2              | 2.4 <sup>d</sup> | —                 | —                 | C or T20                       |
| 200:5  | 0.6  | 1.2              | 2.4 <sup>d</sup> | —                 | —                 | C or T20                       |
| 300:5  | 0.6  | 1.2              | 2.4 <sup>d</sup> | 2.4 <sup>d</sup>  | —                 | C or T20                       |
| 400:5  | 0.3  | 0.6              | 1.2              | 1.2               | 2.4 <sup>d</sup>  | C or T50                       |
| 600:5  | 0.3  | 0.3              | 0.3              | 1.2               | 2.4 <sup>d</sup>  | C or T50                       |
| 800:5  | 0.3  | 0.3              | 0.3              | 0.6               | 1.2               | C or T50                       |
| 1200:5 | 0.3  | 0.3              | 0.3              | 0.3               | 0.3               | C100                           |
| 1500:5 | 0.3  | 0.3              | 0.3              | 0.3               | 0.3               | C100                           |
| 2000:5 | 0.3  | 0.3              | 0.3              | 0.3               | 0.3               | C100                           |
| 3000:5 | 0.3  | 0.3              | 0.3              | 0.3               | 0.3               | C100                           |
| 4000:5 | 0.3  | 0.3              | 0.3              | 0.3               | 0.3               | C100                           |

<sup>a</sup>See IEEE Std C57.13-1993.

<sup>b</sup>Note that these were formerly standard burdens of B1.0 and B2.0, respectively, which now are classified as relaying burdens in IEEE Std C57.13-1993.

<sup>c</sup>These accuracies may not be sufficient for proper relaying performance under all conditions. To ensure proper relaying performance, the user should make a careful analysis of CT performance considering the relaying requirements for the specific short circuit currents and secondary circuit impedances (see 8.7.1).

<sup>d</sup>This metering accuracy is not in IEEE Std C57.13-1993.

## 6. Tests

### 6.1 General

This subclause establishes physical and electrical conditions for tests and methods of determining temperatures and test values. All circuit breakers, apparatuses, and devices in the power circuit shall be mounted in their normal locations during tests. When the design allows for a circuit breaker to be located in

an upper or lower position, unless the position is specified by this document, tests shall be conducted with the circuit breaker in the position offering the more severe conditions. No statement in this subclause is to be construed as modifying the test requirements for devices included in switchgear assemblies.

Tests are classified as design tests, production tests, conformance tests, and field tests. These tests are defined in Clause 3.

NOTE—Except for the main switching or interrupting device, other devices such as voltage transformers and surge arresters that are mounted in the switchgear assemblies, must be disconnected during dielectric tests. Such devices are individually tested in accordance with the standards that apply to them.

## 6.2 Design tests

Design tests, as applicable, shall be made in accordance with 6.2.1 through 6.2.10. All design tests shall be made on representative arrangements of MC switchgear, as described below, to demonstrate the capability of the MC switchgear design to meet its assigned ratings and to operate under normal service conditions as outlined in Clause 4.

Each test arrangement construction shall contain a vertical circuit breaker section and an auxiliary section. There shall be a main bus in each section, and the test arrangement shall include a main bus splice. The main bus shall be typical and of the same current rating as the circuit breaker.

Each test arrangement shall include the maximum available number of current transformers per phase of standard accuracy class or greater, in accordance with Table 4, and shall be installed in the circuit breaker vertical section's standard locations. Current transformers shall have the secondary windings short-circuited and grounded for all tests and be rated as follows:

| Circuit breaker rating (A) | Current transformer ratio |
|----------------------------|---------------------------|
| 1200                       | 1500:5                    |
| 2000                       | 3000:5                    |
| 3000                       | 4000:5                    |

An auxiliary section of the test arrangement shall contain within one of its compartments a voltage transformer assembly with a disconnecting means and three voltage transformers connected wye-wye.

In the same test arrangement, a control power transformer disconnecting primary fuse assembly also shall be installed in one of the remaining compartments of the auxiliary section. Its primary stationary contacts also shall be connected to the main bus; however, connections from the load side contacts to a control power transformer are not required. Two fuses shall be installed for a standard line-line connection.

Exceptions to this arrangement or additional specifications are indicated in the individual test descriptions.

### 6.2.1 Dielectric tests

Power frequency withstand tests (see 6.2.1.1) and lightning impulse withstand tests (see 6.2.1.2) shall be performed on switchgear assemblies, as described in 6.2, to demonstrate the ability of the insulation system

to withstand rated voltages in accordance with Table 1. In addition, dielectric tests shall be made on the bus-bar insulation, as specified in 6.2.1.3.

The tests on the insulation system shall be made under the temperature and humidity conditions normally prevailing at the test site with appropriate correction factors for relative air density and humidity applied as outlined in IEEE Std 4-1978. Humidity correction factors shall be based on curves for rod gaps as stated in IEEE Std 4-1978, Table 1.3. The equipment shall be clean and in good condition.

Test voltages shall be applied between the primary circuits and ground in the following manner:

- a) For equipment with stationary mounted devices and for equipment with drawout devices with the removable elements in the connected position:
  - 1) With the switching device contacts closed; between each phase of the switchgear assembly individually with the frame and all other phases grounded.
  - 2) With the switching device contacts open; between each terminal (incoming and outgoing) of the switchgear assembly with the frame and other terminals grounded.
- b) For equipment with drawout devices with the removable elements in the test position and the main switching devices in the closed position, apply the test voltage to primary circuits:
  - 1) Simultaneously to all the incoming terminals of the switchgear assembly with the frame and outgoing terminals grounded. Repeat tests by applying test voltage to the outgoing terminals with the frame and incoming terminals grounded.
  - 2) Simultaneously between all incoming and outgoing terminals of the switchgear assembly. The test shall be made with a value of voltage 10% higher than that specified in Table 1. This test may be omitted if the equipment has grounded metal shutters (see 7.8).

#### NOTES

1—For the test across the open gap at 10% higher voltage, an intermediate point of the voltage source may, if practicable, be connected to ground and to the frame of the assembly so that the voltage between any live part and the frame will not exceed that specified in Table 1. If this is not practical, the frame may be insulated from ground.

The power contacts of the removable element need not be grounded, although the frame will be grounded.

2—Successful completion of these tests does not necessarily provide assurance that with the circuit breaker in the test position, it will always flashover to ground instead of across the gap between line and load terminals. Switchgear insulation does not provide surge protection for the open gap. Where surge protection of the gap is required, suitable protective devices must be applied.

Power-frequency withstand tests, lightning impulse withstand tests and, where applicable, bus-bar insulation tests and wet tests on entrance bushings shall be made as outlined in the following subclauses.

##### 6.2.1.1 Power frequency withstand tests

The ac test voltage shall have a crest value equal to 1.414 times the rms value specified in Table 1. The wave shape shall be essentially sinusoidal. The frequency shall be within  $\pm 20\%$  of the rated power frequency. The test voltage is to be increased gradually from zero to reach the required test value within 60 s and shall be held at that value for 1 min.

##### 6.2.1.2 Lightning impulse withstand tests

The standard lightning impulse is a full wave impulse with a virtual front time of 1.2  $\mu\text{s}$  and a virtual time to half the value as specified in Table 1 of 50  $\mu\text{s}$ . It is described as a 1.2  $\mu\text{s} \times 50 \mu\text{s}$  impulse test wave. In these tests, three positive and three negative impulse voltages shall be applied to each point without causing damage or flashover. If flashover occurs on only one test during any group of three consecutive tests, nine

more tests shall be made (referred to as the  $3 \times 9$  test). If the equipment successfully withstands all nine of the second group of tests, the flashover in the first group shall be considered as a random flashover and the equipment shall be considered as having successfully passed the tests. The wave shape, used to define the limits, is described in IEEE Std 4-1978.

#### NOTES

1—Some insulating materials retain a charge after an impulse test, and in 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 impulses of the reverse polarity at lower voltage before the tests, is recommended.

2—An alternative test consisting of 15 positive and 15 negative impulse voltages as described above may be applied. A total of two flashovers can occur during any of the 15 consecutive tests (referred to as the  $15 \times 2$  test). If the equipment withstands 13 of the 15 tests, it is considered to have passed the test.

### 6.2.1.3 Test for bus-bar insulation

The insulated bus-bar sample shall have a rated maximum voltage at the 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 construction that is typical of bus bars, elbows, splices, and joints as used in the manufacturer's design. The ac test voltage shall have a value not less than the appropriate rated maximum voltage as shown in Table 1. The ac test voltage shall have a crest value greater than or equal to 1.414 times the rms value, and the wave shape shall be essentially sinusoidal. The test voltage shall be applied for 1 min.

#### NOTES

1—Suggested external electrodes are conductive paint and metallic foil or equivalent. For higher voltages, the sample may be immersed in a suitable insulation media, such as oil, to minimize the sample size. Care must be taken to prevent the external insulation media from penetrating the test area between the sample insulation and the electrodes.

2—This test is required on only one insulated bus-bar test sample for each rated voltage.

### 6.2.1.4 Wet tests on entrance bushings

These tests are to be conducted in accordance with IEEE Std 4-1978.

## 6.2.2 Rated continuous current tests

To determine compliance with continuous current ratings, it is necessary to determine that temperatures of the various components of the switchgear assembly, as described in 6.2, are within the limits set forth in 5.5. Temperature measurements shall be made in accordance with 6.2.2.1 through 6.2.2.7.

### 6.2.2.1 Test arrangements

#### 6.2.2.1.1 Equipment configuration

If the equipment is designed for circuit breakers in an upper compartment or for stacking circuit breakers in the same vertical section, the following configurations must be tested:

- a) Lower compartment only with highest rated circuit breaker utilized
- b) Upper compartment only with highest rated circuit breaker utilized
- c) Both compartments with circuit breakers applied as described in Table 12

#### 6.2.2.1.2 Test area conditions

Temperature tests shall be conducted in a test area that is reasonably free from drafts.