

IEEE Standard for Metal-Clad Switchgear

IEEE Power and Energy Society

Developed by the
Switchgear Committee

IEEE Std C37.20.2™-2022
(Revision of IEEE Std C37.20.2-2015)

STANDARDS

IEEE Standard for Metal-Clad Switchgear

Developed by the

Switchgear Committee
of the
IEEE Power and Energy Society

Approved 21 September 2022

IEEE SA Standards Board

Abstract: Metal-clad (MC) medium-voltage switchgear that contains drawout electrically operated circuit breakers is covered. MC switchgear is compartmentalized to isolate components such as instrumentation, main bus, and both incoming and outgoing connections with grounded metal barriers. Ranges from 4.76 kV to 48.3 kV with main bus continuous current ratings of 1200 A, 2000 A, 3000 A, and 4000 A are the rated maximum voltage levels for metal-clad switchgear. Associated control, instruments, metering, relaying, protective, and regulating devices, as necessary, are also contained by MC switchgear. 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, IEEE C37.20.2™, indoor, instrumentation, load current-carrying, metal-clad (MC) switchgear, metal-enclosed (ME) power switchgear, outdoor, protection, switchgear assemblies, transformer accuracy, voltage transformers

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Introduction

This introduction is not part of C37.20.2-2022, 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 IEEE C37.20.2™ was published in 2015. The significant changes include:

- Harmonization of control wiring requirements by adding the content of C37.20.2 Amendment A
- Clarification of ground and test device testing requirements
- Clarification of test requirements for drawout auxiliary components
- Clarification/expansion of the requirements for viewing window placement
- Deletion of requirements for air temperature surrounding cables in the cable compartment
- Updates to Annex C for partial discharge testing and Annex D for voltage dividers

The reader is reminded that the changes made to this revision of IEEE Std. C37.20.2 do not apply retroactively. Metal-clad switchgear designed, tested, and manufactured to earlier versions of the standards must be applied in accordance with the versions of the standards that were in effect when the specific metal-clad switchgear was manufactured.

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).¹ 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 that, where appropriate, 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. Members of the series are as follows:

- IEEE Std C37.20.1™, IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear^{2,3}
- IEEE Std C37.20.2™, IEEE Standard for Metal-Clad Switchgear
- IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear (1 kV–38 kV)
- IEEE Std C37.20.4™, IEEE Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear

¹ Information on references can be found in Clause 2.

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³ IEEE publications are available from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

- IEEE Std C37.20.6™, IEEE Standard for 4.76 kV to 38 kV Rated Ground and Test Devices Used in Enclosures
- IEEE Std C37.20.7™, IEEE Guide for Testing Switchgear Rated up to 52 kV for Internal Arcing Faults
- IEEE C37.20.9™, IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52kV Incorporating Gas Insulating Systems
- IEEE Std C37.21™, IEEE Standard for Control Switchboards
- IEEE Std C37.23™, IEEE Standard for Metal-Enclosed Bus
- IEEE Std C37.24™, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

Figure 1 depicts types of switchgear assemblies and related standards documents.

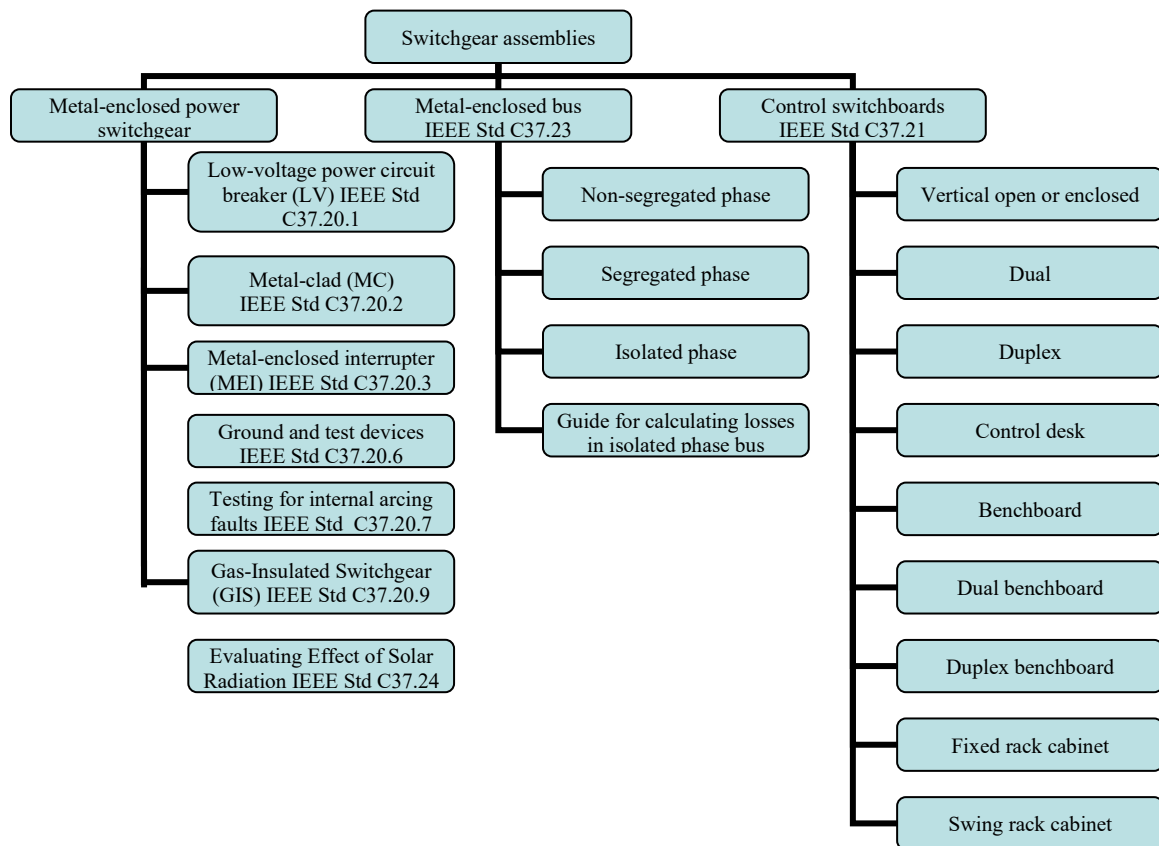


Figure 1—Switchgear assemblies and related standards documents

Contents

1. Overview	12
1.1 Scope	12
1.2 Purpose	12
1.3 Word usage	12
2. Normative references	13
3. Definitions	15
4. Service conditions	17
5. Ratings	18
5.1 General	18
5.2 Voltage and insulation levels	19
5.3 Rated power frequency	20
5.4 Rated current	20
5.5 Temperature limitations	21
5.6 Current transformer ratings	23
5.7 Current transformer accuracies	23
5.8 Voltage transformers	24
5.9 Other devices	24
6. Tests	24
6.1 General	24
6.2 Design tests	25
6.3 Production tests	44
6.4 Field dielectric tests	45
6.5 Optional tests	46
7. Construction	46
7.1 Buses and primary connections	46
7.2 Grounding and bonding	47
7.3 Control and secondary circuits and devices	47
7.4 Miscellaneous	52
7.5 Materials, finishes, and color	53
7.6 Precautionary labels	54
7.7 Metallic barriers	54
7.8 Shutters	55
7.9 Insulating materials for covering buses and connections	55
7.10 Interlocks	56
7.11 Interchangeability of removable switching and interrupting devices	56
7.12 Primary fuses and transformers	56
7.13 Secondary disconnect devices	57
7.14 Control wiring	57
7.15 Handling device	57
7.16 Test cabinet	57
7.17 Indoor MC switchgear, access, and ventilation	58
7.18 Outdoor MC switchgear, access, and ventilation	58
7.19 Circuit breaker open/close position indication	58
7.20 Enclosure categories	58
7.21 Ground and test devices	58
7.22 Load interrupter switches	59
7.23 Voltage dividers	59

8. Application guide for MC switchgear	59
8.1 Unusual service conditions	59
8.2 System characteristics—voltage and frequency	62
8.3 Overvoltage considerations—insulation levels.....	63
8.4 Continuous current rating and overload capability	63
8.5 Short-circuit considerations	69
8.6 Nuclear power plant application	70
8.7 Associated devices often used in MC switchgear.....	70
8.8 Protection and isolation of switchgear connected to other circuit protective equipment.....	71
9. Guide for handling, storage, and installation.....	72
9.1 General	72
9.2 Handling	72
9.3 Preoperation check	74
9.4 Removable elements.....	74
9.5 Interlocks	74
9.6 Energizing.....	75
Annex A (informative) Bibliography	76
Annex B (normative) Guide for enclosure categories and related requirements	78
B.1 Introduction.....	78
B.2 Enclosure categories	78
B.3 Enclosure requirements.....	79
Annex C (informative) Partial discharge testing	84
C.1 General.....	84
C.2 Definitions	84
C.3 Application.....	85
C.4 Test procedure.....	86
C.5 Maximum permissible repeatedly occurring partial discharge quantity.....	88
C.6 Reference material	88
Annex D (normative) Voltage dividers	90
D.1 Introduction	90
D.2 Definitions	90
D.3 Construction.....	90
D.4 Performance.....	91

IEEE Standard for Metal-Clad Switchgear

1. Overview

1.1 Scope

This standard covers metal-clad switchgear assemblies where air at ambient pressure is the primary insulating medium. The switchgear contains, but is not limited to, such devices 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.

In this standard, metal-clad switchgear will be called *MC switchgear*.

1.2 Purpose

This standard provides information essential to the designing and testing of MC switchgear. Included herein are preferred ratings, required design test procedures, and acceptance criteria. A detailed description of construction requirements, including required functional performance features, structural materials, insulation, and interlocking, is provided. Additionally, information on equipment application with respect to operating conditions, dielectric capabilities, and detailed application information regarding continuous current capabilities under differing ambient temperature conditions and application involving short-term overloading is included.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{4,5}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

⁴ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁵ The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2, National Electrical Safety Code® (NESC®).^{6, 7}

ANSI C37.54, American National Standard for Indoor Alternating Current High-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclosed Switchgear—Conformance Test Procedures⁸.

ANSI C37.55, American National Standard for Medium-Voltage Metal-Clad Switchgear- Assemblies—Conformance Test Procedures.

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

ANSI/NEMA CC 1, Electric Power Connections for Substations.⁹

ANSI/UL 94, Standard for Safety for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.¹⁰

ANSI/UL 486A-486B, Standard for Safety for Wire Connectors.

ANSI/UL 510, Standard for Safety for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape.

ANSI/UL 1332, Standard for Safety for Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment.

ASTM A90/A90M, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.¹¹

ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.

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

⁶The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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⁹NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA. (<http://global.ihs.com>)

¹⁰UL standards are available from [UL Standards Sales Site](http://www.shopulstandards.com) (<https://www.shopulstandards.com>).

¹¹ASTM publications are available from the ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

ASTM D714, Standard Test Method for Evaluating Degree of Blistering of Paints.

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

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

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

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

IEC/IEEE 62271-37-013TM, International Standard for High-voltage switchgear and controlgear—Part 37-013: Alternating-current generator circuit-breakers.¹²

IEEE Std 4TM, IEEE Standard for High-Voltage Testing Techniques.^{13, 14}

IEEE Std 693TM, IEEE Recommended Practice for Seismic Design of Substations

IEEE Std C37.04TM, IEEE Standard for Ratings and Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V.

IEEE Std C37.06.1TM, IEEE Recommended Practice for Preferred Ratings for High-Voltage (> 1000 Volts) AC Circuit Breakers Designated Definite Purpose for Fast Transient Recovery Voltage Rise Times

IEEE Std C37.09TM, IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V.

IEEE Std C37.010TM, IEEE Application Guide for AC High-Voltage Circuit Breakers Rated > 1000 Vac on a Symmetrical Current Basis.

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

IEEE Std C37.11TM, IEEE Standard Requirements for Electrical Control for AC High-Voltage (> 1000 V) Circuit Breakers.

IEEE Std C37.20.4TM, IEEE Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear.¹⁵

IEEE Std C37.20.6TM, IEEE Standard for 4.76 kV to 38 kV Rated Ground and Test Devices Used in Enclosures.

IEEE Std C37.20.10TM, IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies.

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¹⁴ IEEE publications are available from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

¹⁵ IEEE Std C37.20.4 has been revised to incorporate preferred ratings previously contained in ANSI C37.22, American National Standard Preferred Ratings and Related Required Capabilities for Indoor AC Medium-Voltage Switches Used in Metal-Enclosed Switchgear.

IEEE Std C37.24™, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear.

IEEE Std. C37.41™, IEEE Standard Design Tests for High-Voltage (>1000 V) Fuses and Accessories.

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.

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

NEMA WC70/ICEA S-95-658, Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy.

NFPA 70, National Electrical Code® (NEC®).¹⁶

3. Definitions

For the purposes of this document, the following terms and definitions apply.

When multiple definitions exist, the definitions shall be evaluated in the following priority:

- a) Definitions embedded in this Standard shall be used.
- b) For terms not defined within this standard, the definitions within IEEE Std C37.20.10¹⁷ shall be used.
- c) For terms not defined in either this Standard or IEEE Std C37.20.10, the *IEEE Standards Dictionary Online* should be consulted.¹⁸

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.

auxiliary compartment: That portion of the switchgear assembly that encloses auxiliary equipment, such as voltage transformers, control power transformers, or other miscellaneous devices.

auxiliary primary fuse assembly: A removable or withdrawable part consisting of primary disconnecting devices and primary fuses for use with separately mounted control power or voltage transformers.

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.

control power transformer assembly: A removable or withdrawable part consisting of primary and secondary disconnecting devices, a control power transformer and primary fuses.

insulation, barrier: Insulation material used primarily to separate one item or area from another item or area within the equipment. Barrier insulation may be subdivided into two general types: Type 1 barriers that are not in contact with, and are not penetrated by, energized parts; and Type 2 barriers that are in contact with, or are penetrated by, energized parts.

¹⁶NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

¹⁷Information on references can be found in Clause 2.

¹⁸*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

NOTE—Examples are as follows: a) interphase barriers between poles of an interrupter switch; b) bus barriers separating the bus compartment of one vertical section of switchgear from another; and c) barriers used to shield grounded metal from electrical or thermal effects of circuit interruption within the equipment.¹⁹

insulation, bus: Insulating material used to cover primary voltage conductors except where that conductor is a cable or wire. Bus joint insulation is excluded from this category and is treated separately.

NOTE—The primary functions of bus insulation are to impede arc movement and to allow closer spacing of conductors than would be possible with bare conductors. Bus insulation may also serve a secondary function as an element of the bus support insulation system.

insulation, bus joint: Insulating material used to cover joints or connections in the primary voltage conductors. Otherwise, it is similar to bus insulation.

insulation, bus support: Insulation used primarily to physically support a conductor and prevent or limit its movement under specified operating conditions. Bus support insulation includes both conductor-to-conductor and conductor-to-structure supports.

insulation, bus tap: Insulating material used to cover low current taps to the main primary voltage conductors.

NOTE—These taps include voltage and control power transformer primary leads, connections to surge arresters and surge capacitors, and other similar connections. Bus taps may be in the form of a wire, rod, or bar insulated in a manner similar to bus insulation for this service or in the form of an insulated wire or cable.

insulation, ceramic: Insulation made of a vitrified ceramic material, such as porcelain or glass.

insulation, nonceramic: Insulation made of a material other than vitrified ceramic. This category includes all organic insulating materials.

mechanism-operated contact (MOC): A circuit breaker (or other removable primary interrupting device) mechanism-operated auxiliary switch that is mounted in the stationary housing and is operated by linkage that cooperates with the circuit breaker (or other removable primary interrupting device) mechanism. *Synonym:* **mechanism-operated cell switch.**

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 except for small openings for wires, wire bundles, mechanical linkages, or items of similar nature. Specifically included is a metal barrier in front of, or a part of, the circuit interrupting device so 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 cover primary circuit elements when the removable element is in the disconnected, test, or removed position.

¹⁹ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

- 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.

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

NOTE 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**. Metal-clad switchgear is *metal-enclosed*, but not all metal-enclosed switchgear can be correctly designated as *metal-clad*.

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, viewing panes, or similar items) 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.

NOTE—Metal-clad switchgear, metal-enclosed interrupter switchgear, and low-voltage power circuit breaker switchgear are specific types of metal-enclosed power switchgear.

primary disconnecting device bushing: Penetration insulator that supports the stationary side of a primary disconnecting device.

removable part: A part of a metal-enclosed switchgear that is not mechanically attached to the enclosure and can be moved to position(s) within the switchgear in which a safe distance or segregation between the primary circuit contacts is established.

NOTE—Removal of this device from the enclosure does not require unbolting connections or removing mounting supports.

truck-operated contact (TOC): A circuit breaker (or other removable primary interrupting device) truck-operated auxiliary switch that is mounted in the compartment of a removable circuit breaker (or other removable primary interrupting device) and is operated by the circuit breaker (or other removable primary interrupting device) frame. *Synonym:* **truck-operated cell switch**.

voltage transformer assembly: A removable or withdrawable part consisting of primary and secondary disconnecting devices, up to three voltage transformers and primary fuses.

4. Service conditions

Standards for the design and performance 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 $-30\text{ }^{\circ}\text{C}$ and $40\text{ }^{\circ}\text{C}$. If ambient temperatures below $-5\text{ }^{\circ}\text{C}$ will be experienced while in service, the manufacturer should consider addition of space heating or other means to enable proper circuit breaker operation.

NOTE—If the circuit breaker is suitable for operation correctly in an ambient of $-30\text{ }^{\circ}\text{C}$ (instead of the IEEE Std C37.04 minimum ambient of $-5\text{ }^{\circ}\text{C}$), no special measures are required.

- 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 may be used for guidance.)
- d) The ambient air is not significantly polluted by dust, smoke, corrosive gas vapors, or salt. The pollution does not exceed the site pollution severity (SPS) class “light” according to IEEE Std C37.04.

NOTE—For additional information on site pollution severity (SPS) class and examples of typical environments, see Annex C of IEEE Std. C37.04.

- e) The conditions of humidity are as follows:
 - 1) The average value of the relative humidity measured over a period of 24 h does not exceed 95%.
 - 2) The average value of the water vapor pressure over a period of 24 h does not exceed 2.2 kPa.
 - 3) The average value of the relative humidity over a period of one month does not exceed 90%.
 - 4) The average value of the water vapor pressure over a period of one month does not exceed 1.8 kPa.

For these conditions, condensation may occasionally occur.

NOTE 1—Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2—Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear. Condensation may also be due to ground level rainwater, or for underground applications, from incoming cable raceways connected to switchgear.

- f) Vibration due to causes external to the switchgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the low performance level defined in IEEE Std 693.

NOTE—The interpretation of the term *insignificant* is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic event, or the analysis shows the risk is *insignificant*.

- g) 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, and so forth. 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 (V) or (U_r)
- b) Rated power frequency (f_r)
- c) Rated insulation levels (U_d), (U_p)
- d) Rated continuous current (I_r)
- e) Rated peak withstand (momentary) current (I_p)
- f) Rated short-time withstand current (I_k)

The designated ratings values 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 line-to-line rms voltage for which the equipment is designed and is the upper limit for operation (see 8.2).

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 (also referred to as *basic impulse level* or *BIL*)

5.2.3 Voltages and insulation levels

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

Table 1—Preferred voltage and insulation levels for MC switchgear

Rated maximum voltage (kV rms)	Insulation levels	
	Power frequency withstand voltage (kV rms)	Lightning impulse withstand voltage (BIL), (kV peak)
4.76	19	60
8.25	36	95
15.0	36	95
27.0	60	125
38.0	80	150
48.3	105	250
NOTE—For field dielectric test values, see 6.4.		

Incorporating generator circuit breakers rated in accordance with IEC/IEEE 62271-37-013 in MC switchgear does not alter the requirements shown in Table 1. The overall assembly shall have preferred ratings for power frequency withstand voltage and for lightning impulse withstand voltage (BIL) in accordance with Table 1. MC switchgear may utilize components such as voltage transformers, control power transformers, or other components with rated insulation levels (power frequency withstand voltage or lightning impulse withstand voltage, or both) that are less than the levels shown in Table 1. In such cases, the operating limits of the switchgear assembly are those of the lowest rated component in the switchgear assembly.

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.

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 that can be carried continuously by the primary circuit components, including buses and connections, without causing temperatures or temperature rises in excess of specified limits for:

- a) Any primary or secondary circuit component
- b) Any insulating medium or structural or enclosing member

The specified temperature limits and temperature rise limits applicable to switchgear assemblies are given in 5.5.1 through 5.5.5.

5.4.2 Continuous current rating

The preferred continuous current ratings of the main bus in MC switchgear are 1200 A, 2000 A, 3000 A, and 4000 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 switching or interrupting devices, current transformers, power fuses, and so forth.

5.4.3 Rated peak withstand (momentary) current

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

For assemblies including only generator circuit breakers (and no other switching devices) complying with IEC/IEEE 62271-37-013, the peak current value shall be 2.74 times the rated short-time withstand current. If the assembly includes other switching devices not complying with IEC/IEEE 62271-37-013, the peak value for the complete assembly shall be 2.6 times the rated short-time current.

5.4.4 Peak withstand (momentary) current rating

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

- a) The circuit breaker rated closing and latching current capability
- b) Switch rated fault closing current
- c) Peak withstand (momentary) current ratings of the switching devices used

Refer to IEEE Std. C37.04, IEEE Std. C37.20.4, or IEC/IEEE 62271-37-013 as applicable.

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. This is based on the maximum permissible tripping time delay (Y) for circuit breakers in accordance with IEEE Std. C37.04.

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).

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 surrounding devices
- c) Any noncurrent-carrying structural parts
- d) External parts subject to contact by personnel

5.5.2 Temperature limits for insulating materials

The 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 105	65	105
Class 120	80	120
Class 130	90	130
Class 155	115	155
Class 180	140	180
Class 220	180	220

For additional information on temperature limits, see IEEE Std 1™ [B5].²⁰

5.5.3 Temperature limits for buses and connections

The temperature limit and temperature rise 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 ^{a,b,c}	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 ^d	30	70
Connection to insulated cables silver-surfaced or equivalent ^d	45	85
Connections to insulated cables tin-surfaced or equivalent ^d	45	85

^a All aluminum buses shall have silver-surfaced or equivalent or tin-surfaced or equivalent connecting joints.

^b Welded bus connections are not considered connecting joints.

^c When buses or connections have differing materials or coatings, the allowable temperature rise and temperature values shall be those of the conductor or coating having the lowest value permitted in the table.

^d Based on 90 °C insulated cable.

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 °C through 40 °C.

5.5.5 Temperature limitations for external parts subject to contact by personnel

- External parts handled by the operator in the normal course of his or her duties shall have no higher total temperature than 50 °C.
- External surfaces accessible to an operator in the normal course of his or her duties shall have no higher total temperature than 70 °C.

²⁰The numbers in brackets correspond to those in the bibliography (Annex A).

- 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 °C.

5.6 Current transformer ratings

5.6.1 Current transformer mechanical rating

The mechanical ratings of current transformers shall be such that they can 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 withstand the maximum let-through current (see IEEE Std C37.41) of the fuses. Unless specifically limited to a shorter time by the associated protective equipment, the duration of the momentary current shall be considered to be 10 cycles.

5.6.2 Current transformer thermal ratings

The thermal ratings of current transformers shall be such that they can 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 withstand the maximum let-through and I^2t (total clearing time) of the fuses (see IEEE Std C37.41). Unless specifically limited to a shorter time by the associated protective equipment, the duration of the short-circuit current shall be considered to be 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 °C ambient temperature in accordance with IEEE Std C57.13.

5.7 Current transformer accuracies

For installation in MC switchgear, the typical 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.

Table 4—Standard accuracy ratings^a for current transformers in MC switchgear

Ratio	Metering Accuracy at Standard Burden					Relaying accuracy ^c
	B0.1	B0.2	B0.5	B0.9 ^b	B1.8 ^b	
50:5	1.2	2.4 ^d	—	—	—	C or T10
75:5	1.2	2.4 ^d	—	—	—	C or T10
100:5	1.2	2.4 ^d	—	—	—	C or T10
150:5	0.6	1.2	2.4 ^d	—	—	C or T20
200:5	0.6	1.2	2.4 ^d	—	—	C or T20
300:5	0.6	1.2	2.4 ^d	2.4 ^d	—	C or T20
400:5	0.3	0.6	1.2	1.2	2.4 ^d	C or T50
600:5	0.3	0.3	0.3	1.2	2.4 ^d	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
5000:5	0.3	0.3	0.3	0.3	0.3	C100

^aSee IEEE Std C57.13.

^bThese were formerly standard burdens of B0.1 and B0.2, respectively, which now are classified as relaying burdens in IEEE Std C57.13.

^cThese accuracies may not be sufficient for proper relaying performance under all conditions. To enable proper relaying performance, the user should make an analysis of CT performance considering the relaying requirements for the specific short-circuit currents and secondary circuit impedances (see 8.7.1).

^dThis metering accuracy is not in IEEE Std C57.13.

5.8 Voltage transformers

Voltage transformers used for metering and relay applications shall meet the requirements of IEEE Std C57.13.

5.9 Other devices

Upon agreement between the manufacturer and user, current sensing devices such as Rogowski coils or other types of current sensors may be utilized with compatible relays or instruments in place of conventional current transformers. Rogowski coils and other low-power passive current transformers shall comply with the parts of IEC 61869-10 [B1] that are applicable to the particular type of current sensing device. If the switchgear design does not provide means for utilizing conventional current transformers, the requirement specified in 6.2 for current transformers included in the test arrangement is not applicable, and the test arrangement shall include the maximum number of physically largest Rogowski coils or other type of current sensors suitable for the equipment. If the switchgear design provides means for utilizing conventional current transformers, the test arrangement specified in 6.2 is applicable in addition to the inclusion of the maximum number of physically largest Rogowski coils or other type of current sensors suitable for the equipment.

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, apparatus, and devices in the power circuit shall be mounted in their normal locations during tests. When the design allows for a circuit breaker (or other

removable primary interrupting device) 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.

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

Design tests may reduce the ability of the tested parts to perform satisfactorily during subsequent use in service. Therefore, test arrangements used for design testing shall not be provided to the user, unless the user is notified in writing and has provided written acceptance of the tested arrangement.

6.2 Design tests

Design tests, as applicable, shall be made in accordance with 6.2.1 through 6.2.9. 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 functional elements in accordance with Table 5. When required, there shall be a main bus in each section, and the test arrangement shall include a main bus splice. When required, the main bus shall be typical and of the same current rating as the circuit breaker.

Test arrangements that require current transformers 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
4000	5000:5

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

Table 5—Test arrangement functional elements

Functional element	Test type				
	Dielectric tests ^a	Rated continuous current	Peak withstand (momentary) current	Short-time withstand current	Mechanical endurance
Circuit breaker compartment vertical section and circuit breaker	X ^h	X	X	X	X ^b
Separable control contacts	X	O	O	O	X
Current transformers	X	X	O	O	O
Removable element position interlocks ^f	X	O	O	O	X
Stored energy mechanism interlocks ^e	X	O	O	O	X
Mechanism-operated cell switches (MOC) ^f	X ^g	O	O	O	X
Truck-operated cell switches (TOC) ^f	X ^g	O	O	O	X
Main bus	X	X	X	X	O
Main bus splice	X	X	X	X	O
Auxiliary compartment vertical section	X	X	X	X	X ^b
Voltage transformer assembly	X ^c	O	Y ^{c,d}	O	X
Control power transformer assembly	X ^c	O	Y ^{c,d}	O	X
Auxiliary primary fuse assembly	X ^c	O	Y ^{c,d}	O	X
CPTA primary fuse access interlocks ^e	X	O	O	O	X
Auxiliary device separable primary contacts ^h	X	O	Y	O	X
Auxiliary device separable control contacts ^h	X	O	O	O	X

X—Required O—Optional Y—Required for the test in 6.2.5

^a Not applicable to 6.2.1.3, test for bus-bar insulation, bus joint insulation, and bus tap insulation.

^b Circuit breaker compartment vertical section is optional for auxiliary compartment vertical section tests. Auxiliary compartment vertical section is optional for circuit breaker vertical section tests.

^c Includes connecting bus or cable for voltage transformer (VT) and control power transformer (CPT)

^d If a common design of primary disconnecting devices is used for both VT and CPT disconnecting primary fuse assemblies, the test is required only on the assembly that utilizes fuses having the highest maximum clearing I_t let-through current.

^e When applicable

^f Auxiliary switches mounted on the stationary housing using the maximum number of cell switch contacts permitted by the design

^g Where the separable control contacts, switch, operating mechanism assembly, and electrical connections are completely isolated from the components of the power circuit by grounded metal, this device may be omitted from the test enclosure configuration.

^h Applicable to voltage transformers, control power transformer, and auxiliary primary fuse assemblies

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 power frequency and lightning impulse withstand 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 4TM (method 2). Humidity correction factors shall be based on curves for rod-rod gaps as stated in IEEE Std 4 (method 2). 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).

NOTE 1—Tests described in 6.2.1 b) are performed to prove the dielectric withstand capability of the open gap. 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 does not exceed that specified in Table 1. If this is not practical, the frame may be insulated from ground.

NOTE 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 open gap between line and load terminals. Switchgear insulation does not provide surge protection for the open gap. Where surge protection of the open gap is required, suitable protective devices should be applied.

- c) For voltage transformer assemblies (VTA), control power transformer assemblies (CPTA), and auxiliary primary fuse assemblies (APFA) in the connected position; between each phase of the switchgear assembly individually with the frame and all other phases grounded.

For the tests described in 6.2.1 c), all components within the conductive path shall be included in the test circuit up to the connection point of the transformer. The transformer itself is not required but may be present at the manufacturer's discretion. If the transformer is not included, the connection point shall be supported by insulating means suitable for the voltage rating of the equipment and shall not materially alter the insulation system isolating the connection point. The connection point shall be located to represent the smallest phase-to-phase and phase-to-ground clearances for the design. These requirements apply to both transformers mounted on the removable or withdrawable part and mounted elsewhere in the equipment.

For voltage transformer assemblies (VTA), control power transformer assemblies (CPTA), and auxiliary primary fuse assemblies (APFA), fuses are not required but may be present at the manufacturer's discretion. If the fuses are not included, a conductive mock-up—appropriately insulated to match the fuse design and representing the largest physical size fuse for the equipment rating—shall be placed in the conductive path to complete the circuit. When fuses are used for dielectric testing, the fuse element shall remain intact through the test sequence. When the transformer or transformers are present for the dielectric tests, the requirements of 6.2.1.2 shall be met.

Power frequency withstand tests, lightning impulse withstand tests, and bus-bar insulation tests 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 waveshape 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.

The equipment is considered to have passed the test if the test voltage is held for 1 min without flashover.

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 μs and a time to half the value as specified in Table 1 of 50 μs . It is described as a 1.2/50 (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, which is referred to as the 3×9 test (procedure C of IEEE Std 4). 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 waveshape, used to define the limits, is described in IEEE Std 4.

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.

An alternative test consisting of 15 positive and 15 negative impulse voltages as described above may be applied, which is referred to as the 15/2 test (procedure B of IEEE Std 4). The switchgear is considered to have passed the impulse test if the following conditions are fulfilled:

- a) Each series has at least 15 tests.
- b) The number of disruptive discharges shall not exceed two for each complete series.
- c) No disruptive discharge on non-self-restoring shall occur. This is confirmed by five consecutive impulse withstands following the last disruptive discharge.

This procedure leads to a maximum possible number of 25 impulses per series.

6.2.1.3 Test for bus-bar insulation, bus joint insulation, and bus tap insulation

The insulated conductor 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, joints, and taps 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.

The equipment is considered to have passed the test if the voltage is held for 1 min without insulation breakdown.

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

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