

***An American National Standard***

# **IEEE Standard for Control Switchboards**

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

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**American National Standards Institute**

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## Foreword

(This Foreword is not a part of Draft ANSI/IEEE C37.21-1985, IEEE Standard for Control Switchboards.)

This publication includes only the requirements for control switchboards (also called control boards). These requirements were previously a part of ANSI/IEEE C37.20-1969. Other types of equipment previously included in ANSI/IEEE C37.20-1969 are now incorporated in separate publications.

ANSI/IEEE C37.20-1969 for many years covered all switchgear assemblies including metal-enclosed bus. Standards committees of IEEE Switchgear Assemblies Subcommittee and NEMA Power Switchgear Assemblies Technical Committee recommended that the document be further developed and, where appropriate, the various sections be identified with their own standards.

The following documents were developed and have been published for each product type based on ANSI/IEEE C37.20-1969:

- C37.20.1 — Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear (1000 V and below)
- C37.20.2 — Metal-Clad and Station-Type Cubicle Switchgear (above 1000 V)
- C37.20.3 — Metal-Enclosed Interrupter Switchgear (above 1000 V)
- C37.21 — Control Switchboards
- C37.23 — Guide for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus

Through this joint effort over the many years, the Switchgear Assemblies Standards have been of extreme value to the industry and further suggestions for improvement gained in the use of this standard will be welcomed. They should be sent to IEEE.

The Switchgear Assemblies Subcommittee of the IEEE Switchgear Committee, which prepared and approved this document, had the following membership:

**S. C. Atkinson, *Chair***

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The IEEE Working Group that prepared and approved this document had the following membership:

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The NEMA Power Switchgear Assemblies Technical Committee of the NEMA Switchgear Section, which prepared and approved this document, had the following personnel:

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# IEEE Standard for Control Switchboards

## 1. Scope and References

### 1.1 Scope

This standard covers ratings, construction, and testing of dead-front control switchboards containing but not limited to devices such as switches, control devices, instrumentation, metering, monitoring, protective and auxiliary relays, and regulating devices and accessories.

It includes, but is not specifically limited to, switchboards for the control and protection of apparatus used for or associated with power generation, conversion, transmission, and distribution.

It does not apply to 1) industrial controls, 2) communication equipment, 3) switchboards for use on board ship, 4) Class 1E switchboards for use in nuclear generating stations, nor 5) does it address human factor considerations.

### 1.2 References

The following publications shall be used in conjunction with this standard:

- [1] ANSI C2-1987, American National Standard National Electrical Safety Code.<sup>1</sup>
- [2] ANSI Z55.1-1967 (R 1973), American National Standard Gray Finishes for Industrial Apparatus and Equipment.
- [3] ANSI/IEEE C37.90.1-1974 (R 1979), IEEE Guide for Surge Withstand Capability (SWC) Tests.<sup>2</sup>
- [4] ANSI/IEEE C37.100-1981, IEEE Standard Definitions for Power Switchgear.
- [5] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.
- [6] ANSI/NEMA ICS1-1983, General Standards for Industrial Control and Systems.<sup>3</sup>
- [7] ANSI/NFPA 70-1987, National Electrical Code.<sup>4</sup>
- [8] ANSI/UL 44-1985, Safety Standard for Rubber-Insulated Control and Systems.<sup>5</sup>

<sup>1</sup>ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

<sup>2</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.

<sup>3</sup>NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

<sup>4</sup>NFPA publications are available from Publications Sales, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

<sup>5</sup>UL publications are available from Underwriters Laboratories Inc, Publication Stock, 33 Pfingsten Road, Northbrook, IL 60062.

- [9] ANSI/UL 486A-1982, Wire Connectors and Soldering Lugs for Use With Copper Conductors.
- [10] ASTM B117-85, Standard Method of Salt Spray (Fog) Testing.<sup>6</sup>
- [11] ASTM D229-82, Standard Method of Testing Rigid Sheet and Plate Materials Used for Electrical Insulation.
- [12] ASTM D714-56 (R 1981), Standard Method of Evaluating Degree of Blistering of Paints.
- [13] ASTM D1535-80, Standard Method of Specifying Color by the Munsell System.
- [14] ASTM D1654-79 (R 1984), Standard Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.
- [15] ASTM G21-70 (R 1980), Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.
- [16] IEEE C37.2-1987, IEEE Standard Electrical Power System Device Function Numbers.
- [17] NEMA WC5-1973, Thermoplastic Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-61-402).
- [18] NEMA WC7-1971 (R 1976), Cross-Linked-Thermosetting Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-66-524).

## 2. Definitions

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

If a term is not defined in this standard, the definition in ANSI/IEEE C37.100-1981 [4]<sup>7</sup> applies. An asterisk (\*) following a definition indicates that the definition in this standard is not contained in ANSI/IEEE C37.100-1981 while a dagger (†) indicates the definition differs from that in ANSI/IEEE C37.100-1981.

### 2.1 Type of Switchboards (see Fig 1)

**2.1.1 control switchboard:** A type of switchboard including control, instrumentation, metering, protective (relays) or regulating equipment for remotely controlling other equipment. Control switchboards do not include the primary power-switching devices or their connections.

**2.1.2 vertical switchboard:** A control switchboard composed only of vertical panels.

NOTE — This type of switchboard may be enclosed or have an open rear. An enclosed vertical switchboard has an overall sheet metal enclosure (not grille) covering back and ends of the entire assembly, access to which is usually provided by doors or removable covers.

**2.1.3 enclosed switchboard:** A dead-front switchboard that has an overall sheet metal enclosure (not grille) covering back, top, and ends of the entire assembly.<sup>†</sup>

NOTE — Access to the interior of the enclosure is usually provided by doors or removable covers.

**2.1.4 dual switchboard:** A control switchboard with front and rear panels separated by a comparatively short distance (no aisle) and enclosed at both ends and top. The panels on at least one side are hinged for access to the panel wiring.<sup>†</sup>

<sup>6</sup>ASTM publications are available from American Society for Testing and Materials, 1916 Race St, Philadelphia, PA 19103.

<sup>7</sup>The numbers in square brackets refer to those of the references listed in 1.2.

**2.1.5 duplex switchboard:** A control switchboard consisting of panels placed back-to-back and enclosed with a top and ends (not grille). Access space (aisle) with entry doors is provided between the rows of panels.<sup>†</sup>

**2.1.6 control desk (console):** A control switchboard consisting of one or more relatively short horizontal or inclined panels mounted on an assembly of such a height that the panel-mounted devices are within convenient reach of an attendant.<sup>†</sup>

**2.1.7 benchboard:** A combination of a control desk and a vertical switchboard in a common assembly.

**2.1.8 dual benchboard:** A combination assembly of a benchboard and a vertical hinged panel switchboard placed back-to-back (no aisle) and enclosed with a top and ends.

**2.1.9 duplex benchboard:** A combination assembly of a benchboard and vertical control switchboard placed back-to-back and enclosed with a top and ends (not grille). Access space (aisle) with entry doors is provided between the benchboard and vertical switchboard.<sup>†</sup>

**2.1.10 fixed rack (cabinet):** An assembly enclosed at the top and sides, either open or with door(s) for access, with a top-to-bottom front panel opening for equipment mounting (for example, nominal 19-inch-wide chassis and subpanel assemblies).<sup>†</sup>

**2.1.11 swing rack cabinet:** An assembly enclosed at the top, sides, and rear with front hinged door for front access having a swing open frame for equipment mounting (for example, nominal 19-inch-wide chassis in subpanel assemblies).<sup>†</sup>

## 2.2 Qualifying Terms

(Relating to types of enclosures, ventilation methods, etc).

- 1) The following qualifying terms are defined in ANSI/IEEE Std100-1984 [5] and the user is referred to the definitions given therein:
  - accessible (as applied to equipment)
  - alive (live)
  - automatic
  - dead front
  - enclosed (inclosed)
  - enclosed ventilated apparatus
  - insulated
  - insulating
  - isolated
  - manual
  - ventilated
- 2) The following qualifying terms are defined in ANSI/IEEE C37.100-1981 [4] and the user is referred to the definitions given therein:
  - electrical
  - enclosure
  - flame-resistant
  - general-purpose enclosure
  - indoor
  - metal-enclosed
  - outdoor
  - resistant (used as a suffix)
  - secondary (used as an adjective)
  - ventilated enclosure



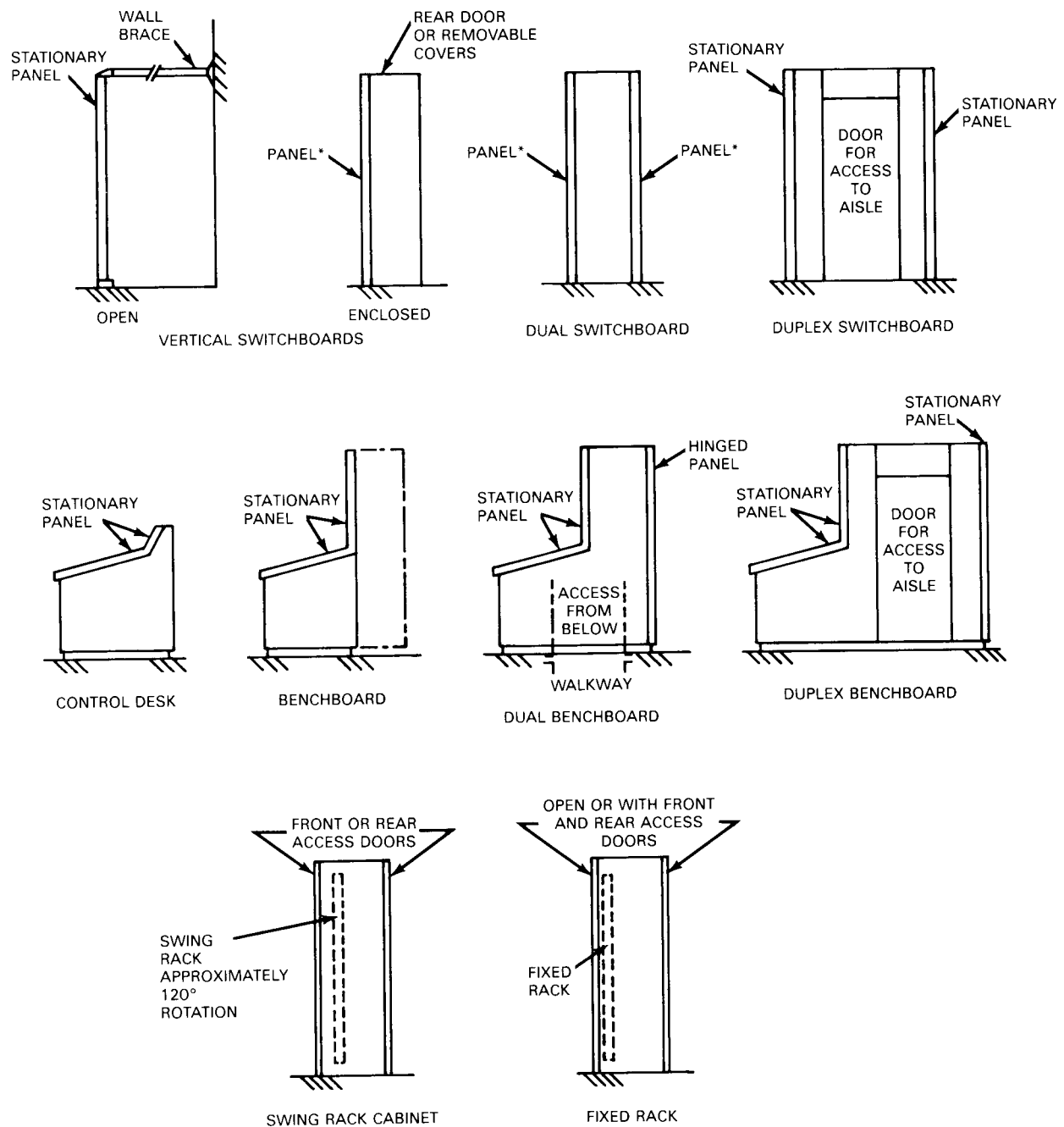


Figure 1— Typical Switchboards (Side Views)

### 2.3 Common or Related Terms

The following common or related terms are defined in ANSI/IEEE C37.100-1981 [4] and the user is referred to the definitions given therein:

bus  
ground bus

live parts  
 mimic bus  
 terminal (terminal connector)  
 terminal block (terminal board)

**2.3.1 ambient air temperature:** The temperature of the surrounding air which comes in contact with equipment.\*

NOTE — Ambient air temperature, as applied to enclosed switchboards, is the average temperature of the surrounding air that comes in contact with the enclosure.\*

**2.3.2 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 which may be used to demonstrate compliance with applicable standards of the industry.†

NOTES:

1 — Design tests are made on representative apparatus or prototypes to verify the validity of design analysis and calculation methods and to substantiate the ratings assigned to all other apparatus of basically the same design. These tests are not intended to be made on every design or to be used as part of normal production. The applicable portion of these design tests may also be used to evaluate modifications of a previous design and to assure that performance has not been adversely affected. These data from previous similar designs may also 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.

**2.3.3 production tests:** Tests made by the manufacturer on every device or representative samples, or on parts or materials as required to demonstrate during production that the products meet the design specifications and applicable standards.†

NOTES:

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

2 — *Production* tests are sometimes called *routine* tests.

**2.3.4 conformance tests:** Conformance tests demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned production tests prior to initiation of the conformance test program.†

NOTE — The conformance tests may or may not be similar to certain design tests. Demonstration of margin (capabilities) beyond the standards is not required.

**2.3.5 field tests:** Tests made after the switch-board has been installed at its place of utilization.†

## 3. Service Conditions

### 3.1 Usual Service Conditions

Switchboards conforming to this standard shall be suitable for operation under the following usual service conditions:

- 1) The temperature of the cooling air (ambient air temperature) surrounding the enclosure of the switchboard is within the limits of  $-20\text{ }^{\circ}\text{C}$  to  $+40\text{ }^{\circ}\text{C}$ .
- 2) The altitude shall not exceed 5000 ft (1500 m).
- 3) The effect of solar radiation is not significant.
- 4) None of the unusual service conditions in 7.1 prevail.

## 4. Nominal Ratings

### 4.1 Nominal Voltage, Current, and Frequency Ratings

Nominal voltage, current, and frequency ratings for switchboards are listed as follows:

Voltage (V)		Nominal CT Secondary Current (A (rms))	Frequency (Hz)	Typical Low Energy Circuits
ac (rms)	dc			
120	24	1	25	0–100 mV
240	48	5	50	4–20 mA
480	125		60	
	250			

The allowable variations from the nominal operating values for switchboard devices are the designated operating limits under specified conditions of the devices, subassemblies, and associated circuits. The voltage rating of a switchboard shall be 600 V or less.

### 4.2 Temperature Limitations for Air Surrounding Devices Within an Enclosed Switchboard

The temperature of the air surrounding all devices within an enclosed switchboard, 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 switchboard is surrounded by air within an ambient temperature range of minus 20 °C to plus 40 °C.

## 5. Tests

### 5.1 General

This section establishes physical and electrical conditions for tests. No statement in this section is to be construed as modifying the test requirements for devices included in the switchboard assemblies. Tests are classified as design tests, production tests, conformance tests, and field tests, as defined in 2.3.

### 5.2 Design Tests

Design tests as applicable shall be made in accordance with 5.2.1 through 5.2.5.

#### 5.2.1 Surge Withstand Capability (SWD) Test

The SWC test is a standard design test of a relay system and in particular a static relay system. The intent of the SWC test is to prove that a given relay system will not misoperate or be damaged when subjected to high voltage transients.

The components which make up a static relay system will vary, depending on system design requirements. Therefore, the user and manufacturer shall determine what constitutes the relay system to be tested. For details of the tests recommended, see ANSI/IEEE C37.90.1-1974 [3].

### 5.2.2 Rain Test for Outdoor Control Switchboard

The enclosure to be tested shall be equipped and complete with typical appurtenances, and placed in the area to be supplied with artificial precipitation. For multiple unit construction a minimum of two units shall be used to test the joints between units. A roof joint shall be included.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the entire surface or surfaces under test. The various vertical surfaces of an enclosure may be tested separately or collectively, provided that a uniform spray is simultaneously applied to both of the following:

- 1) The roof surface, from nozzles located at a suitable height.
- 2) The floor outside the enclosure for a distance of approximately 3 ft (1 m) in front of the surface under test with the enclosure located at floor level.

The nozzles used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of at least 7.1 gals/min (450 cm<sup>3</sup>/s) at 60 lbs/in<sup>2</sup> (414 kPa) pressure and a spray angle of approximately 75°. The center line of the nozzles shall be inclined downward so that the top of the spray is horizontal as it is directed toward the vertical and roof surfaces being tested.

The pressure at the nozzles shall be a minimum of 60 lbs/in<sup>2</sup> (414 kPa) under flow conditions. [This is approximately equivalent to rain driven by a 65 mi/h (29 m/s) wind.] The quantity of water applied to each surface under test shall be at least 0.2 in (0.5 cm) per unit surface per minute, and each surface so tested shall receive this rate of artificial precipitation for a duration of 5 min. The spray nozzle shall not be more than 10 ft (3 m) from the nearest vertical surface under test.

After the test is completed, an inspection shall be made promptly to determine if the enclosure meets the requirements of outdoor construction. More specifically, the equipment shall have satisfactorily met the requirements of this test if the visible inspection indicates:

- 1) No water on primary or secondary insulation.
- 2) No water on any electrical components or mechanisms of the assembly.
- 3) No accumulation of water retained by the structure or other noninsulating parts (to minimize corrosion).

### 5.2.3 Flame Resistance Test

Sheet, molded, or cast insulating material used in a switchboard shall not be classed as flame resistant unless it has a minimum average ignition time of 60 s and a maximum average burning time of 100 s when tested in accordance with Method II in ASTM D229-82 [11].

### 5.2.4 Rod Entry Test

*Ventilated Enclosures.* This test shall be made by attempting to insert a straight rod having diameter of 0.500 in (12.7 mm), except that, if the distance between the openings and the nearest live part is greater than 4 in (101.6 mm), the opening may permit the entry of a straight rod having a diameter greater than 0.500 in (12.7 mm), but does not permit the entry of a straight rod having a diameter greater than 0.750 in (19 mm).

The enclosure is considered to have met the requirements of this test if the appropriate rod cannot enter the enclosure.

### 5.2.5 Paint Qualification Test

The paint qualification test applies to all switchboards incorporating external ferrous parts. Nonferrous switchboards with no external ferrous parts need not be tested.

The paint qualification test shall be performed to ensure the adequacy of paint finishes to inhibit the buildup of rust on ferrous metal materials used for switchboards.

- 1) *Test Specimens.* Representative test panels of a 3" by 6" minimum size that can be accommodated by the test chamber shall be provided. Each specimen shall be uniformly processed in the standard production paint finishing system. At least four panels shall be selected for the test. All the test specimens shall be of standard gauge ferrous metal equivalent to that used for the enclosure. The specimen shall be allowed to age for a minimum of seven days before being tested.
- 2) *Test Apparatus.* The test apparatus shall consist of a fog chamber, salt solution reservoir, compressed air supply, provisions for heating and means of control. The conditions in the salt spray chamber, including the positioning of the specimens, content of the salt solution, and temperature and pressure to be maintained, shall be as defined in ASTM B117-85 [10].
- 3) *Preparation of Test Specimens.* Two of the test panels shall be suitably scribed for testing in accordance with ASTM D1654-79 [14].
- 4) *Exposure of Test Specimens.* All test specimens shall be tested in the salt spray chamber for a period of 200 h continuously, except for the short daily interruptions necessary to inspect the test specimen or replenish the solution in the reservoir.
- 5) *Procedure.* After completion of the exposure period, the scribed specimens shall be processed in accordance with either Method A (tape) or Method B (scraper) as defined in ASTM D1654-79 [14].
- 6) *Evaluation.* The scribed specimens shall then be evaluated for creepage from the scribe mark in accordance with Rating Schedule #1 of ASTM D1654-74 [13]. The nonscribed specimen shall be evaluated for degree of blistering in accordance with ASTM D714-56 [12].
- 7) *Performance.* The scribed specimens shall be judged to have met the requirements of the test if their rating number is five or higher as determined by ASTM D1654-79 [13]. The nonscribed specimens shall be judged to have met the requirements of the test if their blistering size is six or higher, and their frequency designation is F or M as determined by ASTM D714-56 [12].

### 5.3 Production Tests

The following tests shall be made to verify that switchboards are manufactured to specifications.

#### 5.3.1 Control Wiring Dielectric Test

Tests made to verify that switchboard wiring has an adequate insulation level to ground include the following three alternatives:

- 1) A test voltage two times rated circuit voltage plus 1000 V (minimum 1500 V), 60 Hz to ground for one minute.
- 2) A test voltage 20% higher than the 1 min value (minimum 1800 V), 60 Hz to ground for 1 s.
- 3) An insulation-resistance test using a dc voltage level no less than the ac level listed in (1) above times 1.414 for not more than 1 min with a minimum measured insulation resistance of 1 M $\Omega$ .

The procedure is based on the type of circuits and devices on the switchboard. Devices that have been individually tested may be disconnected during the test. Some devices must be disconnected because the applicable industry standard involves a lower or different permissible dielectric test. Equipment and circuits that operate at 50 V or less, unless otherwise specified, shall be tested in the same manner as above using a test voltage of 500 V, 60 Hz for 1 min (Test and Test Procedures, ANSI/NEMA ICS1-1983 [6]).

#### 5.3.2 Electrical Operation, Sequence, and Wiring Tests

Tests shall be made to verify the correctness (including polarities) of the wiring in a switchboard. Verification shall be made preferably by actual electrical operation of the circuit and devices to ensure that the devices function in the proper and intended sequence (functional test) or by individual circuit continuity checks (ring-out).

Instruments shall be tested to ensure that pointers move in proper direction. This does not require tests using primary voltage and current.

## 5.4 Field Dielectric Tests

When dielectric withstand tests are to be made on switchboards after installation in the field, the switchboard shall not be tested at greater than 75% of the test values given in 5.3.1. Some devices must be disconnected because the applicable industry standard involves a lower or different permissible dielectric test.

NOTE — Field tests are recommended when new units are added to an existing installation or after major field modifications. The equipment should be put in good condition prior to the field test. It is not expected that equipment shall be subjected to these tests after it has been stored for long periods of time or has accumulated a large amount of dust, dirt, moisture, or other contaminants without, first being restored to good condition.

## 6. Construction

### 6.1 General Requirements

#### 6.1.1 Phase or Polarity Arrangements

When facing the front of the assembled devices as viewed from the outside of the switchboard, the phase arrangements on a 3-phase control switchboard shall be 1, 2, 3 (or A, B, C) from front to back, top to bottom, or left to right. For inclined panels, the arrangement shall be as viewed perpendicular to the panel. Certain types of equipment may require other phasing arrangements. In these cases the phasing shall be suitably indicated.

#### 6.1.2 Polarities on Direct Current

When facing the front of the assembled devices as viewed from the outside of the switchboard, polarities of direct-current connections shall be positive, negative, front to back, top to bottom, or left to right. For inclined panels, the arrangement shall be viewed perpendicular to the panel. Certain types of equipment may require other polarity arrangements. In these cases the polarities shall be suitably indicated.

#### 6.1.3 Phase Sequence

The phase sequence, unless otherwise specified, shall be such that, when considering voltage to neutral on a poly-phase system with respect to the element of time, the voltage of Phase 1 will reach a maximum ahead of the voltage of Phase 2, Phase 3, etc. This sequence shall be designated as phase sequence in the order 1, 2, 3. Other suitable designations for the same order of rotation may be used.

#### 6.1.4 Grounding

A ground system shall be included that will electrically connect together the structures in a switchboard assembly.

At all points of connection between the ground bus and the assembly any nonconductive coatings, such as paint, shall be removed or penetrated to ensure good electrical contact.

The ground bus for each assembly shall have provision for connection to the station ground bus.

Circuits connected to the ground bus shall be arranged so that each may be disconnected without disturbing the continuity of the ground bus or any other grounded circuit.

Equipment mounted on switchboards shall be grounded as required, including a separate, isolated grounding system for low-energy circuits, if required.

Equipment mounted on switchboard structures, such as cases of instruments, instrument transformers, meters, relays and similar devices, shall be considered as being adequately grounded when secured to these structures by metal mounting screws with adequate provision for penetrating the paint film.

The ground bus shall be a copper conductor—at least one size larger than the largest size conductor used in the switchboard.

## 6.1.5 Control and Secondary Circuits and Devices

### 6.1.5.1 Control and Secondary Wiring

Flame-resistant, 600 V insulated copper wire, with a cross-sectional area not less than #14 AWG (American Wire Gauge) stranded shall be used for wiring on circuits rated 5 A continuous or higher. For circuits rated less than 5 A continuous, single conductors sized no smaller than #18 AWG stranded may be used. Multiple conductor cables of wire size smaller than #18 AWG may be used as required, based on conductor ampacity. Where wire is connected across a hinge #14 wire shall consist of 41 strands of #30 wire, and #18 wire shall consist of 16 strands of #30 wire.

The insulated wire shall be type TBS or SIS, as listed in ANSI/NFPA 70-1987 [7] or an equivalent.

The insulated wire shall meet the flame-resistance test requirements specified in ANSI/UL 44-1985 [8] and the requirements of the following standards' publications, as applicable:

- 1) *Type TBS*. NEMA WC5-1973 (ICEA S-61-402) [17] and
- 2) *Type SIS*. NEMA WC7-1971 (ICEA S-66-524) [18].

NOTE — Thermocouple wire and wire for low energy circuits are excluded from the above requirements. They shall meet the voltage and current requirements of the circuits in which they are used.

No splices shall be allowed in the switchboard wiring.

Wherever control or secondary wiring is run through a metal sheet, barrier, or raceway; a bushing, grommet, or other mechanical protection shall be provided for the wiring.

All wiring shall be adequately supported to prevent stresses on individual conductors.

### 6.1.5.2 Wiring Terminals

Stranded control wire shall have solderless terminals of the type wherein the body of the terminal is crimped or indented onto the conductor or where the wire is formed into an eye and confined within a crimp and flat washer assembly. Solderless terminals are not required for connection to devices that have integral wire terminating provisions. The wire may be soldered into terminals or where desirable directly to devices.

### 6.1.5.3 Terminal Blocks

Terminal blocks incorporating screw or stud-and-nut type terminals shall accommodate wire lugs or similar devices affixed to stranded wire. Screw or stud-and-nut type terminals intended for use with stranded wire shall be such that all strands of the conductor are confined. Terminal blocks incorporating pressure connectors shall not damage (see NOTE) the wire and, when terminating stranded conductors, all strands shall be clamped within the connector. No more than two conductors shall be terminated at any one terminal point. This restriction does not apply to flat preformed jumpers.

Terminal blocks for external connections shall be suitable to accept the user's specified wiring.

NOTE — In the absence within this standard of definitive performance requirements, compliance with this clause can be assessed by referencing ANSI/UL 486A-1982 [9].

#### **6.1.5.4 Device Function Numbers**

Device function numbers shall be in accordance with IEEE C37.2-1987 [16].

#### **6.1.5.5 Polarity of Direct Current Connections to Device Coils**

Where coils on switchboard devices are connected to a direct-current supply and when deenergized are not disconnected from both the positive and negative supply leads, such coils shall be so connected that, when deenergized, they will be left connected to the negative supply lead to minimize the possibility of corrosion.

#### **6.1.5.6 Voltage Circuit Protection**

All voltage circuits used for control, relaying, or metering shall be protected as follows:

- 1) Each circuit supplied from an external source (ac or dc) shall have short circuit protection either at the source or within the switchboard. Short circuit protection may be omitted on circuits from constant-current-type devices, such as voltage sensors and voltage devices.
- 2) Each circuit supplied from an internal source (ac or dc) shall have short-circuit protection within the same section as the supply source. If these circuits are supplied by a control power transformer, this protection may be in the primary circuit only.

Overcurrent protection of voltage circuits may be provided in addition to the required short-circuit protection.

Other circuits supplying loads, such as heaters, receptacles, or lights, shall have overload and short-circuit protection.

#### **6.1.5.7 Current Transformer Secondary Circuit Protection**

Overcurrent protection of current transformer secondary circuits shall not be provided.

#### **6.1.5.8 Equipment Location**

All devices, terminal blocks, etc, shall be located so that their wiring connections and mounting hardware are accessible without removing other equipment or wire.

#### **6.1.5.9 Noise**

Where low-energy circuits are included in the same assembly with power or switching circuits, the use of shielded conductor, metallic conduit, or physical separation (or a combination of these) should be considered to reduce noise problems.

#### **6.1.5.10 Drawings**

Drawings shall be prepared so that they may be used for wiring and checking. The drawings shall show wire destinations and equipment identification.



## 6.1.6 Miscellaneous

### 6.1.6.1 Nameplate Marking

The following minimum information shall be given on the switchboard nameplate:

- 1) Manufacturer's name and address.
- 2) Manufacturer's identification references.
- 3) Other pertinent information as deemed necessary by the manufacturer or user.

### 6.1.6.2 Wiring Devices

Lighting fixtures provided in enclosures shall be of a type and shall be so located that lamps may be safely replaced without deenergizing the other equipment and shall be equipped with protective guards. Convenience outlets shall be of the two-pole, three-wire grounding type with the ground terminal connected to the ground bus.

### 6.1.6.3 Covers

For ease of handling, cover plates that are intended to provide access for inspection and maintenance shall not exceed 12 ft<sup>2</sup> (1.12 m<sup>2</sup>) in area and 60 lbs (27 kg), unless they are equipped with lifting means or hinges.

### 6.1.6.4 Cable Space

Adequate clear cable space for field control cables shall be provided.

### 6.1.6.5 Heaters

Heaters, if used, shall be mounted such that adjacent devices are not adversely affected and personnel safety is not compromised.

## 6.2 Materials and Finish

### 6.2.1 Materials

The materials for switchboards shall be sheet metal suitably supported. The minimum thickness shall be #14 MSG (Manufacturer's Standard Gage) (nominal thickness 0.0747 in or 1.9 mm).

The minimum thickness of sheet metal used for switchboards is based on the use of steel. Where other metals are used the thickness shall be modified to provide equivalent strength and deflection.

NOTE — For example, if aluminum alloy sheet having a yield strength of 20,000 psi is used in the place of sheet steel, to provide equivalent strength and deflection, it is required that the thickness specified above be increased by 50%.

Doors or panels used to support devices shall be increased in thickness or otherwise strengthened as necessary to support the devices.

### 6.2.2 Finishes and Color

All steel surfaces to be painted shall receive a phosphatizing treatment or equivalent prior to application of paint.

External and internal surfaces shall be coated with at least one coat of corrosion-resistant paint. The finish paint system shall comply with the requirements of 5.2.5, paint qualification test.

The undersurfaces of outdoor assemblies shall additionally receive either a corrosion-resistant undercoating or an additional thickness of corrosion-resistant paint.

The preferred color for the finish on control switchboards shall be light gray #61 (see ASTM D1535-80 [13]).

#### NOTES:

- 1 — See gray finishes for industrial apparatus and equipment in ANSI Z55.1-1967 [2].
- 2 — Internal detail parts may have metallic plating or equivalent in lieu of paint finish.
- 3 — For conformance testing, if specified, a recognized, organic-coating system that has been investigated and found Suitable for use as protection against atmospheric corrosion of electrical equipment steel enclosures for outdoor use may be utilized.

### 6.3 Indoor Switchboards

Switchboards for indoor applications shall provide a degree of protection against contact with live equipment in locations where unusual service conditions do not exist.

#### 6.3.1 Features

When completely and properly installed, the enclosure has the following features:

- 1) Shall provide a degree of protection against limited amounts of falling dirt; however, it need not prevent the entry of dust or liquids.
- 2) Shall prevent the insertion of a straight rod of the specified diameter into the equipment cavity of the enclosure.
- 3) Shall not rust when subjected to a paint qualification test for 200 h.

#### 6.3.2 Design Tests

The indoor enclosures shall be tested and evaluated by the following:

- 1) Rod entry test of 5.2.4.
- 2) Paint qualification test of 5.2.5.

NOTE — For open vertical switchboards, only 6.3.1 (3) and 6.3.2 (2) apply.

### 6.4 Outdoor Switchboards

Switchboards for outdoor applications shall be housed in ventilated enclosures which are intended to provide a degree of protection against rain, sleet, and external ice formations.

#### 6.4.1 Features

When completely and properly installed, the enclosures have the following features:

- 1) Shall not permit water to enter the equipment cavity at a level higher than the lowest live part, except if constructed to divert water from live parts, insulation, and wiring; and shall have provisions for drainage.
- 2) Shall require the use of a tool to gain access to the equipment or have provision for locking.
- 3) Shall have doors equipped with latches and stops to hold the doors in the open position.
- 4) Shall prevent the insertion of a straight rod of the specified diameter into the equipment cavity of the enclosure.

- 5) Shall not rust when subjected to a paint qualification test for 200 h.
- 6) Shall have heaters or other effective means to minimize internal condensation.

### 6.4.2 Design Tests

The outdoor enclosures shall be tested and evaluated by the following:

- 1) Rain test of 5.2.2
- 2) Rod entry test of 5.2.4.
- 3) Paint qualification test of 5.2.5.

NOTE — External icing tests are not required because switch boards have no external cavities to trap water when mounted in the normal position.

## 7. General Application Guide

### 7.1 Unusual Service Conditions

It is strongly recommended that the usual service conditions, as described in 3.1, be provided for control switchboard applications (artificially, if necessary). However, if unusual conditions exist and cannot be eliminated, the following considerations apply:

#### 7.1.1 Ambient Air Temperature Above 40°C

When switchboards are applied where the ambient air temperature is higher than 40 °C the performance of various components may be affected and special consideration should be given to these applications.

#### 7.1.2 Ambient Air Temperature Below –20 °C

Special consideration is also required when switchboards are applied where the ambient air temperature is less than –20 °C. Space heating and thermal insulation to minimize the effects of exposure should be considered. If this is not possible, the effect of low temperatures on the functional performance of switchboard components and on materials such as control wire insulation should be considered.

#### 7.1.3 Application at Unusual Altitudes

Switchboards which depend on air for an insulating and cooling medium will have a higher temperature rise and a lower dielectric withstand capability when operated at altitudes above values specified in 3.1.2. For applications at higher altitudes, the rated one-minute power frequency withstand voltage and continuous current rating of the switchboard should be multiplied by the following correction factors to obtain the modified ratings:

Altitude in Feet	Altitude Correction Factors	
	Voltage	Current
5,000 (1500 m) (and below)	1.00	1.00
6,600 (2000 in)	0.95	0.99
11,700 (3550 in)	0.80	0.96

NOTES:

- 1 — Intermediate values may be obtained by interpolation.
- 2 — For devices used in switchboard assemblies, standards covering the specific devices should be used to determine the specific altitude correction factors.

### 7.1.4 Modification of Equipment for Unusual Environments

Successful performance of standard switchboards may be extended to unusual environments by special considerations when developing equipment specifications. Several construction modifications that will mitigate the effects of these environments may be made in accordance with 7.1.4.1 through 7.1.4.5, but the emphasis should be on eliminating such conditions if at all possible.

However, if these undesirable conditions cannot be eliminated, more frequent maintenance may be required.

#### 7.1.4.1 Exposure to Damaging Fumes, Vapors, Steam, Salt Air, and Oil Vapors

Indoor and outdoor equipment should be provided with the following modifications:

- 1) Minimum of two coats of paint, one of which should be a corrosion- or rust-resisting primer, on all structural parts.
- 2) All steel parts that are not painted or plated should be covered with protective grease.
- 3) Coils that are not inherently fungus-resistant should be impregnated with insulating compound and covered with an appropriate protective coating.
- 4) Heaters, in quantity and rating sufficient to minimize condensation in all compartments, should be furnished.

#### 7.1.4.2 Exposure to Excessive, Abrasive, Magnetic, or Metallic Dust

Indoor or outdoor equipment should be provided with the following modifications:

- 1) Ventilation filters for outdoor assemblies: For outdoor assemblies ventilated enclosures may be furnished with the ventilating openings equipped with dust filters. The requirements for these filters vary over such a range that standard specifications for their application are not practicable. Filters are available in both the washable type and the disposable type. Where used, they must be cleaned or replaced at intervals, depending upon the amount of dust in the air. Filters that are not cleaned or changed when required can cause excessive equipment temperature or condensation.
- 2) The type of filter used should be selected based on the size of dust particles encountered and the extent to which dust is to be excluded. Where very fine dust particles are to be excluded, disposable filters soaked in oil should be used. These must be changed at frequent intervals.
- 3) Forced ventilation may be required depending upon the volume of air required for ventilation and the severity of the environment. When furnished due to environment, the blower and filter should be installed on the intake to minimize the possibility of drawing dust or other foreign matter into and throughout the switchboard assembly.

#### 7.1.4.3 Exposure to Hot and Humid Climate

Indoor and outdoor equipment intended for exposure to hot and humid climates should be made fungus-resistant by the following modifications:

- 1) Heaters in quantity and rating sufficient to minimize condensation in all compartments should be furnished.
- 2) Secondary wiring that is not inherently fungus-resistant should have fungus-resistant coating applied. Secondary wiring that has fungus-resistant insulation should not require further treatment.
- 3) All impregnated coils should be given an external treatment with fungus-resistant coating. Coils that are inherently fungus-resistant should not require further treatment.
- 4) Paints such as alkyd enamels, etc, having a fungus- and rust-resistant property should be used.
- 5) Insulation that is not inherently fungus-resistant should have a fungus-resistant coating applied. Insulation in switchboards that is inherently fungus-resistant should not require further treatment. Fungus-resistant coatings should not be applied where they will interfere with proper operation of apparatus. In such cases, the part should be inherently fungus-resistant. These coatings should not reduce the flame-resistant properties.

- 6) The fungus-resistance of materials should be determined in accordance with ASTM G21-70 [15]. Materials to be classified as fungus-resistant should have a rating not greater than 1.
- 7) Materials which are made fungus-resistant by means of a coating should have the coating reapplied at periodic intervals as recommended by the manufacturer.

#### **7.1.4.4 Exposure to Explosive Mixtures of Dust or Gases**

Application of switchboards for explosion-proof requirements is not recommended.

#### **7.1.4.5 Exposure to Abnormal Vibration, Shocks, or Tilting**

Indoor and outdoor equipment is designed for mounting on level structures free from vibration, shock, or tilting.

Since installation conditions vary widely, it is recommended that the manufacturer be consulted for each specific application where vibration, shocks, or tilting are to be encountered.

It is important that the full nature of the abnormal motion be specified. The magnitude and frequency range of the dynamic motion is required so that resonances may be investigated. This is usually specified by means of an acceleration response spectrum curve for the mounting surface on which the switchboard is to be installed. The response spectrum is a plot of the maximum response of single-degree-of-freedom bodies at a damping value expressed as a percent of critical damping of different natural frequencies, when these bodies are rigidly mounted on the surface of interest (that is, on the ground for the ground response spectrum or on the floor for the floor response spectrum) when that surface is subjected to a given abnormal motion as modified by an intervening structure. The response spectrum is useful in designing a test or in making an analysis of the performance of the switchboard equipment mounted on the same surface and subjected to the same motion.

In the case of tilting, it is also important that the maximum angles of tilt, both transverse and longitudinal, be specified. The exact performance requirements should also be defined. It should be recognized that equipment that is specifically designed for a usual installation on a substantially level surface free from excessive vibration, shock, or tilting may be damaged and may not be able to function properly when subjected to excessive motion and displacement. Hence, the application should be carefully analyzed and the essential performance requirements should be precisely defined.

## **8. Handling, Storage, and Installation Guide**

### **8.1 General**

This section is a guide for the handling, storage, and installation of switchboards and emphasizes safety aspects and other considerations when working with this type of equipment. It supplements, but does not replace, the manufacturer's detail instructions on these subjects. The objective is to furnish additional guidelines to promote and enhance a reliable installation.

The manufacturers of switchboards are to supply instruction books and drawings for their equipment, containing detailed recommendations for storage, handling, installation, operation, and maintenance.

Personnel responsible for these functions should review these recommendations before handling the equipment. Particular attention should be given to recommendations for preparation of foundation and forms on which the switchboard is to be mounted. One set of manufacturer's instruction books should remain with the switchboard when in storage or at the installation site.

## 8.2 Handling

### 8.2.1 Shipping

Switchboards should be carefully inspected and packed before leaving the factory. Shock recorders or air ride vans should be considered for sensitive equipment.

### 8.2.2 Receiving

Immediately upon receipt, the equipment should be examined for damage that may have been sustained during transit. If damage is evident or indications of rough handling are visible, the carrier (transportation company) and the manufacturer should be notified promptly.

Only authorized personnel should be permitted to handle the equipment. Care should be exercised in handling each piece of equipment (even if crated) because parts may be damaged.

### 8.2.3 Rigging

Instructions for lifting and handling of the equipment are contained in the manufacturer's instruction books and drawings. The rigging should be adequate for the size and weight of the equipment. Specialized handling instructions shall be marked on the packing.

### 8.2.4 Storage

Indoor switchboards that cannot be installed immediately should be stored in a dry, clean location and should remain covered during the storage period. The longer the period of storage, the greater the care required for protection of the equipment. During storage, the switchboard should be placed on a level surface to prevent unnecessary strain and possible distortion. During the construction period, protection should be provided against dust, dirt, falling objects, dripping water, excessive water, excessive moisture, and other possible causes of damage to the equipment. Any temporary covering should not restrict ventilation and should not be removed until the equipment is ready for installation. It is preferable to store indoor equipment within a heated building. If this is not possible, special precaution should be taken to keep the equipment sufficiently warm with adequate ventilation to prevent condensation during the storage period. If necessary, temporary heating should be installed in the equipment.

If outdoor switchboards cannot be installed and energized, temporary power must be provided for the operation of the space heaters provided in order to prevent condensation of moisture within the housing. (CAUTION: Ensure that normal supply source is open to prevent backfeed.)

Ventilation openings in switchboards should be left open to permit proper circulation of air.

### 8.2.5 Installation

When installing switchboards

- 1) Protect workers adequately from live parts with barriers, screens, etc.
- 2) Observe ANSI C2-1987 [1], rule 124, for guarding live parts.

### 8.2.6 Removal of Shipping Members

Before installation of switchboards a careful check should be made to ensure that all members included for shipping purposes have been removed.

## 8.2.7 Connections

### 8.2.7.1 Control Connections

When a switchboard assembly consists of several shipping sections, control wires between shipping sections should be reconnected as marked by the manufacturer. Connections that are to be connected to terminals in apparatus remote from the switchboard should be carefully checked against the connection diagram. When making connections to terminals, care should be exercised to assure that the connections are properly made.

### 8.2.7.2 Grounding

Sections of ground bus previously disconnected at shipping sections must be reconnected when the units are installed. Make sure that all secondary wiring is connected to the switchboard ground bus as indicated on the drawings. The ground bus should be connected to the system ground with as direct a connection as possible and should not be run in metal conduit unless the conduit is adequately bonded to the circuit. A permanent low-resistance ground is essential for adequate protection and safety.

## 8.3 Pre-operation Check

Care must be exercised to prevent the switchboard from being energized while preliminary tests are being conducted. All internal connections should be examined to ensure that they have not been loosened or damaged during shipment or installation, and all bolted connections and joints should be tightened to ensure good contact. All wiring connections should be checked for tightness, including those at terminal blocks.

Remove all ties and blocking from the relay armatures or discs before the control power is applied.

Protective relays included with the switchboard should be tested for correct connections and operation at the factory. However, the protective device settings for current, voltage, or other quantities must be made by the user in accordance with his operating practices. The manufacturer's instruction books should be studied carefully before setting the protective devices.

It is recommended that the integrity of control buses be checked with an ohm meter to ensure against short circuits in the control wiring. Control wiring should be given a dielectric test or be insulation-resistance tested. After the switchboard has been installed and all interconnections completed, any control schemes should be operationally tested and connections given a final check for phase rotation/sequence before the switchboard is finally energized for service.

## 9. Bibliography

[B1] ANSI Y14.15-1966 (R 1973), American National Standards Electrical and Electronics Diagrams (including supplements: ANSI Y14.15a-1971 and ANSI Y14.15b-1973).

[B2] ANSI/IEEE C37.20.1-1987, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear.

[B3] ANSI/IEEE C37.20.2-1987, IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear.

[B4] ANSI/IEEE C37.20.3-1987, IEEE Standard for Metal-Enclosed Interrupter Switchgear.

[B5] ANSI/IEEE C37.90.1-1974, IEEE Guide for Surge Withstand Capability (SWC) Tests.

[B6] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.

[B7] ANSI/IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).

[B8] ANSI/IEEE Std 142-1982, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book).

[B9] ANSI/IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).

[B10] ANSI/NFPA 70-1987, National Electrical Code.

[B11] ANSI/NFPA 70B-1983, Recommended Practice for Electrical Equipment Maintenance.

[B12] NEMA SG 5-1981, Power Switchgear Assemblies.

[B13] NEMA Engineering Bulletin No 77, Guidelines for Warning Labels.

[B14] NEMA 250-1985, Enclosures for Electrical Equipment (1000 Volts Maximum).