# UL 2202

## STANDARD FOR SAFETY

DC Charging Equipment for Electric Vehicles

UL Standard for Safety for DC Charging Equipment for Electric Vehicles, UL 2202

Third Edition, Dated December 15, 2022

***Summary of Topics***

***This Third Edition of ANSI/UL 2202 dated December 15, 2022 reflects the trinational standard for Canada, Mexico, and the United States.***

The requirements are substantially in accordance with Proposal(s) on this subject dated November 19, 2021.

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Underwriters Laboratories Inc.
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Third Edition

# DC Charging Equipment for Electric Vehicles

December 15, 2022



ANSI/UL 2202-2022

**Commitment for Amendments**

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.



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This ANSI/UL Standard for Safety consists of the Third Edition. The most recent designation of ANSI/UL 2202 as an American National Standard (ANSI) occurred on December 15, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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## CONTENTS

## PROTECTION OF USERS AGAINST INJURY



## PERFORMANCE

## MANUFACTURING AND PRODUCTION TESTS



## MARKING

## INSTRUCTIONS



## ANNEX A (Normative) – REFERENCED STANDARDS

## ANNEX B (Normative for Canada and Mexico and Informative for the US) – FRENCH AND SPANISH TRANSLATIONS

## ANNEX C (Normative) – LIQUID COOLED CHARGER SYSTEMS

## INTRODUCTION



## CONSTRUCTION

# PREFACE

This is the harmonized ANCE, CSA Group, and UL standard for DC Charging Equipment for Electric Vehicles. It is the first edition of NMX-J-817-ANCE, the first edition of CSA C22.2 No. 346, and the third edition of UL 2202. This edition of UL 2202 supersedes the previous edition(s) published on October 2, 2009, titled Electric Vehicle (EV) Charging System Equipment.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Electric Vehicle Supply Equipment of the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA) are gratefully acknowledged.

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican standard was developed by the GT CONANCE from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of different type of manufacturers and users.

This standard was reviewed by the CSA Subcommittee on DC Fast Charging System for Electric Vehicles, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements on Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.



### Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

### Level of Harmonization

This standard uses the IEC format but is not based on, nor is it considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for ANCE, CSA Group and UL.

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

### Reasons for Differences From IEC

This standard provides general requirements for electric vehicle supply equipment for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for these products for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

## Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

# DC Charging Equipment for Electric Vehicles

## INTRODUCTION

## 1 Scope

1.1 These requirements apply to DC conductive charging equipment intended to be supplied with a maximum input voltage of 1000 V ac or 1500 V dc, for recharging the propulsion batteries in over-the-road electric vehicles (EV). DC charging equipment for EV installations are intended for either:

a) Dry location only, or

b) Dry, wet, and damp location.

Equipment is intended to be installed in accordance with the Installation Codes in Annex A, Ref. No. 1.

1.2 The output of the DC charging equipment for EV shall not exceed 1500 V dc.

1.3 For the purposes of this Standard, the term "electric vehicle", designated throughout by the initials "EV", is considered to cover electric vehicles, hybrid electric vehicles, and plug-in versions of these vehicles.

1.4 DC charging equipment for EV that is not a complete assembly and depends upon installation in an end product for compliance with the requirements in this Standard is investigated under the requirements of this Standard and the standard for the end product.

1.5 These requirements do not cover battery chargers covered by Annex A, Ref. Nos. 2 and 3.

1.6 These requirements do not cover on-board chargers.

1.7 These requirements do not cover electric vehicle supply equipment covered by Annex A, Ref. No. 4.

1.8 These requirements do not cover DC charging equipment for EV intended to be used in hazardous locations, such as near fuel dispensing stations.



## 2 Glossary

2.1 In the text of this Standard, the term "unit" refers to any product covered by this standard. The letters "EV" refers to an electric vehicle, a hybrid electric vehicle, or plug-in versions of these vehicles in accordance with 1.2. For the purpose of this Standard, the following definitions apply.

2.2 ACCESSIBLE PART – A part so located that it is capable of being contacted by a person, either directly or by means of an accessibility probe.

2.3 BARRIER – A part inside an enclosure that reduces access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

2.4 BASIC INSULATION – The insulation required for the proper functioning of a device, and for basic protection against electrical hazard.

2.5 BONDED (BONDING) – The permanent joining of metallic parts to form an electrically conductive path that provides electrical continuity and the capacity to conduct any current likely to be imposed without a risk of electric shock or fire.

2.6 BRANCH CIRCUIT – The portion of the building wiring system beyond the final overcurrent protective device on the power-distribution panel that protects the circuit to the field-wiring terminals in a permanently connected unit or to the receptacle outlet for a cord-connected unit.

2.7 CELL – Two electrodes of dissimilar material separated from one another by a common ionically conductive electrolyte, that are intended to convert chemical energy directly into electrical energy.

2.8 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in:

a) Annex A, Ref. Nos. 4 and 5; or

b) Annex A, Ref. No. 6.

2.9 CONTROL CIRCUIT – A circuit that carries electric signals but not main power current.

2.10 ELECTRIC VEHICLE (EV) – An over-the-road automotive-type vehicle for highway use, such as a passenger automobile, bus, truck, van, motorcycle, or similar vehicle, which receives primary or supplementary propulsion power from an electric motor that draws current from a rechargeable storage battery.

2.11 ELECTROLYTE – A semisolid, liquid, or aqueous salt solution that makes ionic conduction between positive and negative electrodes of a cell possible.

2.12 ENCLOSURE – A surrounding case constructed to provide a degree of protection to personnel against access to hazardous parts and to provide a degree of protection to the enclosed equipment against specified environmental conditions.

2.13 EXPOSED – Visible and able to be contacted by an accessibility probe.

2.14 FASTENED IN PLACE – A mounting means for equipment which is specifically designed to permit periodic removal of the equipment for relocation, interchangeability, maintenance, or repair without the use of a tool.

2.15 FIELD-WIRING LEAD – Any lead to which a supply, load, or other wire is intended be connected by an installer.

2.16 FIELD-WIRING TERMINAL – A terminal to which a supply, load, or other wire is intended to be connected by an installer.

2.17 FIXED IN PLACE – A mounting means for equipment that requires a tool to remove the equipment from its mounted position.

2.18 GROUND – A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or to some conducting body that serves in place of the earth.

2.19 GUARD – A part that reduces access to a component that results in a risk of injury to persons. See Enclosures and Guards, Section 40.

2.20 INSULATION, SUPPLEMENTARY – An independent insulation provided in addition to the basic insulation to protect against the risk of electric shock in the event.

2.21 LEAKAGE CURRENT – Electric current which flows through a person upon contact, between accessible parts of a unit and:

a) Ground, or

b) Other accessible parts of the unit.

2.22 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by either a secondary winding of a transformer, one or more resistors complying with 25.10, or a regulating network complying with 25.11.

2.23 LIVE PART – A conductive part, such as metal, within the unit that during intended use has a potential difference with respect to earth ground or any other conductive part.

2.24 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 volts, rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

a) An inherently limited Class 2 transformer or power unit or a not inherently limited Class 2 transformer or power unit and an overcurrent protective device that is:

1) Not of the automatic reclosing type,

2) Trip-free from the reclosing mechanism, and

3) Either not readily interchangeable with a device of a different rating or a marking in accordance with 76.3.8 is provided; or

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 25.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

2.25 MEASUREMENT INDICATION UNIT (MIU) – The output voltage across the meter, in millivolts rms, in the measurement instrument in Figure 46.3, divided by 500 ohms. (The instrument indication is equal to the rms value in milliamperes when the frequency is 60 Hz (sinusoidal current). The reading is not always a direct indication of the rms or other common amplitude quantifier of leakage current when the leakage current is of complex waveform or frequency other than 50 or 60 Hz.)

2.26 PORTABLE UNIT – A unit that has no provisions for permanent mounting or wiring, and is easily carried or conveyed by hand and whose input rating does not exceed 16 ampere, 120 V ac.

2.27 PRESSURE TERMINAL CONNECTOR – A field wiring terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. Examples of pressure terminal connectors are barrel and setscrew type, crimp-type barrel, and clamping plate and screw type.

2.28 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

2.29 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The risk of damage to property or injury to persons, other than by electric shock, from available electrical energy exists when between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more.

2.30 SAFETY CIRCUIT – Any primary or secondary circuit that is used to reduce the risk of fire, electric shock, injury to persons, or electrical energy- high current levels. For example, in some applications, an interlock circuit is considered to be a safety circuit.

2.31 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer. See 27.1.3.

2.32 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment and the risks involved.

2.33 TOOL – A screwdriver, coin, key, or any other object that is used to operate a screw, latch, or similar fastening means.

## 3 Components

3.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard. A component shall comply with the ANCE, CSA, or UL standards as appropriate for the country where the product is to be used.

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

3.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

b) Is superseded by a requirement in this Standard; or

c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

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

3.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable ANCE, CSA, or UL standard(s) that cover devices that provide those functions.

## 4 Units of measurement

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

## 5 Normative References

5.1 Where reference is made to any Standard, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

5.2 Products covered by this Standard shall comply with the reference installation codes and Standards noted in Annex A as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and Standards for all countries where it is intended to be used.

5.3 For products intended for use in Canada, general requirements are given in Annex A, Ref. No. 8. In Mexico and the United States, this does not apply.

**CONSTRUCTION**

## 6 Ratings

6.1 A unit shall have the following ratings:

a) Input rating in volts, number of phases, frequency, and amperes; and

b) Output rating in volts dc and amperes.

## 7 Frame and Enclosure

### 7.1 General

7.1.1 Except as noted in 7.1.2, a unit shall be provided with one or more enclosures that house all live parts. The enclosure shall be formed and assembled so that it has the strength and rigidity to resist the abuses to which it may be subjected to in use without resulting in a risk of fire or electric shock due to total or partial collapse with resulting reduction in spacings, loosening or displacement of parts, or other defects. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy – high current levels shall comply with the applicable enclosure requirements specified in this standard.

7.1.2 Live parts, including terminals, that do not present a risk of electric shock or a risk of electrical energy – high current levels, are not required to be enclosed.

7.1.3 The frame or chassis of a unit shall not be used to carry current during intended operation.

7.1.4 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements.

7.1.5 Except as noted in 7.1.6, when an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure.

7.1.6 A meter complying with the requirements in Annex A, Ref. No. 9 is not required to comply.

### 7.2 Access covers

7.2.1 Except as noted in 7.2.2, an access cover shall be hinged where it gives access to a fuse or other overload-protective device, the functioning of which requires renewal or resetting, or where it is required to open the cover in connection with intended operation of the unit. A means shall be provided to hold the cover positively closed.

7.2.2 A hinged cover is not required when the only overload-protective device enclosed is:

a) Connected in a control circuit, where the protective device and the circuit loads are within the same enclosure,

b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes,

c) An extractor fuse having an integral enclosure, or

d) Connected in a low-voltage, limited-energy circuit.

7.2.3 A door or cover giving access to a fuse shall be tight-fitting.

## 7.3 Cast metal enclosures

7.3.1 Except as noted in 7.3.2, the thickness of cast metal for an enclosure shall be as specified in Table 7.1.

7.3.2 Die-cast metal and cast metal of a lesser thickness is employed when upon investigation (taken into account the shape, size, and function of the enclosure) it is found to have equivalent mechanical strength for the intended use.

**Table 7.1**
**Thickness of Cast-Metal Enclosures**

| Use, or dimension of area involved | Minimum thickness, mm (inch) | | | |
|---|---|---|---|---|
| | Die-cast metal | | Cast metal of other than the die-cast type | |
| Area of 154.8 $cm^2$ (24 square inches) or less and having no dimension greater than 152 mm (6 inches) | 1.6 | (1/16[a]) | 3.2 | (1/8) |
| Area greater than 154.8 $cm^2$ (24 square inches) or having any dimension greater than 152 mm (6 inches) | 2.4 | (3/32) | 3.2 | (1/8) |
| At a threaded conduit hole | 6.4 | (1/4) | 6.4 | (1/4) |
| At an unthreaded conduit hole | 3.2 | (1/8) | 3.2 | (1/8) |

[a] The area limitation for metal 1.6 mm (1/16 inch) thick is obtained by the provision of reinforcing ribs subdividing a larger area.

## 7.4 Sheet metal enclosures

7.4.1 Sheet metal enclosures shall comply with the requirements in Annex A, Ref. No. 10 or 7.4.2.

7.4.2 With reference to 7.4.1, the thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.2 and Table 7.3. Uncoated steel shall not be less than 0.81 mm (0.032 inch) thick, zinc-coated steel shall not be less than 0.86 mm (0.034 inch) thick, and nonferrous metal shall not be less than 1.14 mm (0.045 inch) thick for surfaces of an enclosure at which a wiring system is to be connected. A part of the enclosure that complies with the Mechanical Strength Tests for Metal Enclosures as specified in Annex A, Ref. No. 11, is not required to comply with the thickness specified in Table 7.2 and Table 7.3.

## Table 7.2
## Thickness of Carbon Steel or Stainless Steel Enclosures

| Without supporting frame[a] | | | | With supporting frame or equivalent reinforcing[a] | | | | Minimum thickness mm (inch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum width[b] | | Maximum length[c] | | Maximum width[b] | | Maximum length | | Uncoated | | Metal coated | |
| cm | (inches) | cm | (inches) | cm | (inches) | cm | (inches) | | | | |
| 10.2 | (4.0) | Not limited | | 15.9 | (6.25) | Not limited | | 0.51 | (0.020)[d] | 0.58 | (0.023)[d] |
| 12.1 | (4.75) | 14.6 | (5.75) | 17.1 | (6.75) | 21.0 | (8.25) | | | | |
| 15.2 | (6.0) | Not limited | | 24.1 | (9.5) | Not limited | | 0.66 | (0.026)[d] | 0.74 | (0.029)[d] |
| 17.8 | (7.0) | 22.2 | (8.75) | 25.4 | (10.0) | 31.8 | (12.5) | | | | |
| 20.3 | (8.0) | Not limited | | 30.5 | (12.0) | Not limited | | 0.81 | (0.032) | 0.86 | (0.034) |
| 22.9 | (9.0) | 29.2 | (11.5) | 33.0 | (13.0) | 40.6 | (16.0) | | | | |
| 31.8 | (12.5) | Not limited | | 49.5 | (19.5) | Not limited | | 1.07 | (0.042) | 1.14 | (0.045) |
| 35.6 | (14.0) | 45.7 | (18.0) | 53.3 | (21.0) | 63.5 | (25.0) | | | | |
| 45.7 | (18.0) | Not limited | | 68.6 | (27.0) | Not limited | | 1.35 | (0.053) | 1.42 | (0.056) |
| 50.8 | (20.0) | 63.5 | (25.0) | 73.7 | (29.0) | 91.4 | (36.0) | | | | |
| 55.9 | (22.0) | Not limited | | 83.8 | (33.0) | Not limited | | 1.52 | (0.060) | 1.60 | (0.063) |
| 63.5 | (25.0) | 78.7 | (31.0) | 88.9 | (35.0) | 109.2 | (43.0) | | | | |
| 63.5 | (25.0) | Not limited | | 99.1 | (39.0) | Not limited | | 1.70 | (0.067) | 1.78 | (0.070) |
| 73.7 | (29.0) | 91.4 | (36.0) | 104.1 | (41.0) | 129.5 | (51.0) | | | | |
| 83.8 | (33.0) | Not limited | | 129.5 | (51.0) | Not limited | | 2.03 | (0.080) | 2.13 | (0.084) |
| 103.4 | (38.0) | 119.4 | (47.0) | 137.2 | (54.0) | 167.6 | (66.0) | | | | |
| 106.7 | (42.0) | Not limited | | 162.6 | (64.0) | Not limited | | 2.36 | (0.093) | 2.46 | (0.097) |
| 119.4 | (47.0) | 149.9 | (59.0) | 172.7 | (68.0) | 213.4 | (84.0) | | | | |
| 132.1 | (52.0) | Not limited | | 203.2 | (80.0) | Not limited | | 2.74 | (0.108) | 2.82 | (0.111) |
| 152.4 | (60.0) | 188.0 | (74.0) | 213.4 | (84.0) | 261.6 | (103.0) | | | | |
| 160.0 | (63.0) | Not limited | | 246.4 | (97.0) | Not limited | | 3.12 | (0.123) | 3.20 | (0.126) |
| 185.4 | (73.0) | 228.6 | (90.0) | 261.6 | (103.0) | 322.6 | (127.0) | | | | |

[a] See 7.4.4 and 7.4.5.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an enclosure intended for use in wet and damp locations shall not be less than 0.86 mm (0.034 inch) thick when metal coated and not less than 0.81 mm (0.032 inch) thick when uncoated.

## Table 7.3
## Thickness of Aluminum, Copper, or Brass Enclosures

| Without supporting frame[a] | | | | With supporting frame or equivalent reinforcing[a] | | | | Minimum thickness mm |
|---|---|---|---|---|---|---|---|---|
| Maximum width[b] | | Maximum length[c] | | Maximum width[b] | | Maximum length | | |
| cm | (inches) | cm | (inches) | cm | (inches) | cm | (inches) | (inches) |
| 7.6 | (3.0) | Not limited | | 17.8 | (7.0) | Not limited | | 0.58[d] |
| 8.9 | (3.5) | 10.2 | (4.0) | 21.6 | (8.5) | 24.1 | (9.5) | (0.023) |
| 10.2 | (4.0) | Not limited | | 25.4 | (10.0) | Not limited | | 0.74 |
| 12.7 | (5.0) | 15.2 | (6.0) | 26.7 | (10.5) | 34.3 | (13.5) | (0.029) |
| 15.2 | (6.0) | Not limited | | 35.6 | (14.0) | Not limited | | 0.91 |
| 16.5 | (6.5) | 20.3 | (8.0) | 38.1 | (15.0) | 45.7 | (18.0) | (0.036) |
| 20.3 | (8.0) | Not limited | | 48.3 | (19.0) | Not limited | | 1.14 |
| 24.1 | (9.5) | 29.2 | (11.5) | 53.3 | (21.0) | 63.5 | (25.0) | (0.045) |
| 30.5 | (12.0) | Not limited | | 71.1 | (28.0) | Not limited | | 1.47 |
| 35.6 | (14.0) | 40.6 | (16.0) | 76.2 | (30.0) | 94.0 | (37.0) | (0.058) |
| 45.7 | (18.0) | Not limited | | 106.7 | (42.0) | Not limited | | 1.91 |
| 50.8 | (20.0) | 63.4 | (25.0) | 114.3 | (45.0) | 139.7 | (55.0) | (0.075) |
| 63.4 | (25.0) | Not limited | | 152.4 | (60.0) | Not limited | | 2.41 |
| 73.7 | (29.0) | 91.4 | (36.0) | 162.6 | (64.0) | 198.1 | (78.0) | (0.095) |
| 94.0 | (37.0) | Not limited | | 221.0 | (87.0) | Not limited | | 3.10 |
| 106.7 | (42.0) | 134.6 | (53.0) | 236.2 | (93.0) | 289.6 | (114.0) | (0.122) |
| 132.1 | (52.0) | Not limited | | 312.4 | (123.0) | Not limited | | 3.89 |
| 152.4 | (60.0) | 188.0 | (74.0) | 330.2 | (130.0) | 406.4 | (160.0) | (0.153) |

[a] See 7.4.4 and 7.4.5.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminum for an enclosure intended for use in wet and damp locations shall not be less than 0.74 mm (0.029 inch) thick.

7.4.3 Table 7.2 and Table 7.3 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

7.4.4 With reference to Table 7.2 and Table 7.3, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that are applied via the enclosure surface. A construction has equivalent reinforcement when it produces a structure that is as rigid as one built with a frame of angles or channels.

7.4.5 With reference to 7.4.4 and Table 7.2 and Table 7.3, a construction does not have a supporting frame when it is:

a) A single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

c) An enclosure formed or fabricated from sheet metal; or

d) An enclosure surface loosely attached to a frame – for example, by spring clips.

### 7.5 Nonmetallic enclosures

7.5.1 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in Annex A, Ref. No. 12. See 7.5.2. For units intended for use in wet and damp locations, the material for the enclosure, or part of the enclosure, shall be judged on the basis of the effect of exposure to water and ultraviolet light in accordance with Annex A, Ref. No. 12. See also 7.5.3.

7.5.2 With reference to 7.5.1, for a cord-connected unit that is intended to be supported on a bench, desk, table, or similar apparatus, the flammability requirements for portable equipment specified in Annex A, Ref. No. 12 shall be applied.

7.5.3 Except as noted in 7.5.4, a nonmetallic part that forms part of the enclosure, and is made from a material classed as HB or better, is not required to comply with 7.5.1 under any one of the following conditions:

a) The nonmetallic part covers an opening that has no dimension greater than 25.4 mm (1 inch);

b) The nonmetallic part covers an opening which does not allow access to live parts involving a risk of fire, electric shock, or electric energy-high current levels – or moving parts to the user when the nonmetallic part is removed;

c) The nonmetallic part covers an opening that has no dimension greater than 101.6 mm (4 inches) and there is no source of a risk of fire closer than 101.6 mm (4 inches) from the surface of the enclosure; or

d) The nonmetallic part with a barrier or a device that forms a barrier made of a material classed V-0 between the nonmetallic part and a source of a risk of fire.



7.5.4 A part of a component is not required to be classed V-0, V-1, V-2, or HB when it complies with the flammability class applicable to the component.

7.5.5 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 0.93 $m^2$ (10 square feet) or a single linear dimension greater than 1.83 m (6 feet) shall have a flame-spread rating of 200 or less when tested in accordance with the:

a) Requirements in Annex A, Ref. No. 13; or

b) Radiant-panel furnace method in Annex A, Ref. No. 14.

7.5.6 A material with a flame-spread rating higher than specified in 7.5.5 is a usable alternative for the exterior finish or covering on any portion of the enclosure when the flame-spread rating of the combination of the base material and finish or covering complies with 7.5.5.

7.5.7 Except as noted in 7.5.8, a conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the appropriate requirements in Annex A, Ref. No. 12.

7.5.8 Where flaking or peeling of the coating does not result in a risk of fire or electric shock as a result of a reduction of spacings or the bridging of live parts, then the coating is not required to comply with Annex A, Ref. No. 12.

7.5.9 A nonmetallic enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in Annex A, Ref. No. 10.

## 7.6 Glass covered openings

7.6.1 Glass covering an opening shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 101.6 mm (4 inches) in any dimension shall not be less than 1.6 mm (1/16 inch) thick, and glass for an opening not more than 929 $cm^2$ (144 square inches) in area and having no dimension greater than 305 mm (12 inches) shall not be less than 3.2 mm (1/8 inch) thick. Glass used to cover an area larger than specified above shall not be less than 1/8 inch thick and shall:

a) Be of a non-shattering or tempered type that, when broken, complies with Annex A, Ref. No. 15; or

b) Be subjected to the test described in 61.1.

## 7.7 Openings for wiring

7.7.1 The requirements described in 7.7.2 – 7.7.9 apply to fixed in place units.

7.7.2 When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or when an equivalent construction is employed, there shall not be less than three nor more than five threads in the metal, and the construction of the enclosure shall be such that a conduit bushing is capable of being attached as intended. When threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar material, there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing with an internal diameter the same as that of the corresponding trade size of rigid conduit.

7.7.3 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar material that are supplied as a part of an enclosure shall comply with Annex A, Ref. Nos. 16 and 17.

7.7.4 A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure.

7.7.5 A knockout shall be provided with a flat surrounding surface so that the conduit bushing is capable of being seated as intended, and shall be located so that installation of a bushing at any knockout to be used during installation does not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 23.

7.7.6 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 7.7.5, a bushing having the dimensions specified in Table 7.4 shall be in place, in conjunction with a single locknut installed on the outside of the enclosure.

**Table 7.4**
**Knockout or Hole Sizes and Dimensions of Bushings**

| Metric designator (Trade size) | | Knockout or hole diameter | | Bushing dimensions | | | |
|---|---|---|---|---|---|---|---|
| | | | | Overall diameter | | Height | |
| mm | (inches) | mm | (inches) | mm | (inches) | mm | (inches) |
| 16 | (1/2) | 22.2 | (7/8) | 25.4 | (1) | 9.5 | (3/8) |
| 21 | (3/4) | 27.8 | (1-3/32) | 31.4 | (1-15/64) | 10.7 | (27/64) |
| 27 | (1) | 34.5 | (1-23/64) | 40.5 | (1-19/32) | 13.1 | (33/64) |
| 35 | (1-1/4) | 43.7 | (1-23/32) | 49.2 | (1-15/16) | 14.3 | (9/16) |
| 41 | (1-1/2) | 50.0 | (1-31/32) | 56.0 | (2-13/64) | 15.10 | (19/32) |
| 53 | (2) | 62.7 | (2-15/32) | 68.7 | (2-45/64) | 15.9 | (5/8) |
| 63 | (2-1/2) | 76.2 | (3) | 81.8 | (3-7/32) | 19.1 | (3/4) |
| 78 | (3) | 92.1 | (3-5/8) | 98.4 | (3-7/8) | 20.6 | (13/16) |

7.7.7 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 23 shall be provided between uninsulated live parts and a conduit bushing installed at any location that is to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the unit are ways to specify such a location. The specified location of the openings shall be such that damage to internal parts does not result when openings are made.



7.7.8 With respect to the requirement in 7.7.7, means shall be provided so that an opening for conduit is capable of being made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement is possible by the use of a removable, bolted plate.

7.7.9 A polymeric- or metal-closure plug for an unused conduit opening shall comply with Annex A, Ref. No. 16.

## 7.8 Openings in an enclosure

7.8.1 The enclosure of a unit shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops from exiting the enclosure and falling on combustible materials outside of the enclosure.

## 7.9 Enclosure bottom openings

7.9.1 Except as noted in 7.9.2 – 7.9.5, the requirement in 7.8.1 requires a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 7.1.

7.9.2 An enclosure may be provided with ventilating openings in the bottom panel when noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the unit onto the supporting surface or any other location under the unit. An example of such a baffle is illustrated in Figure 7.2.

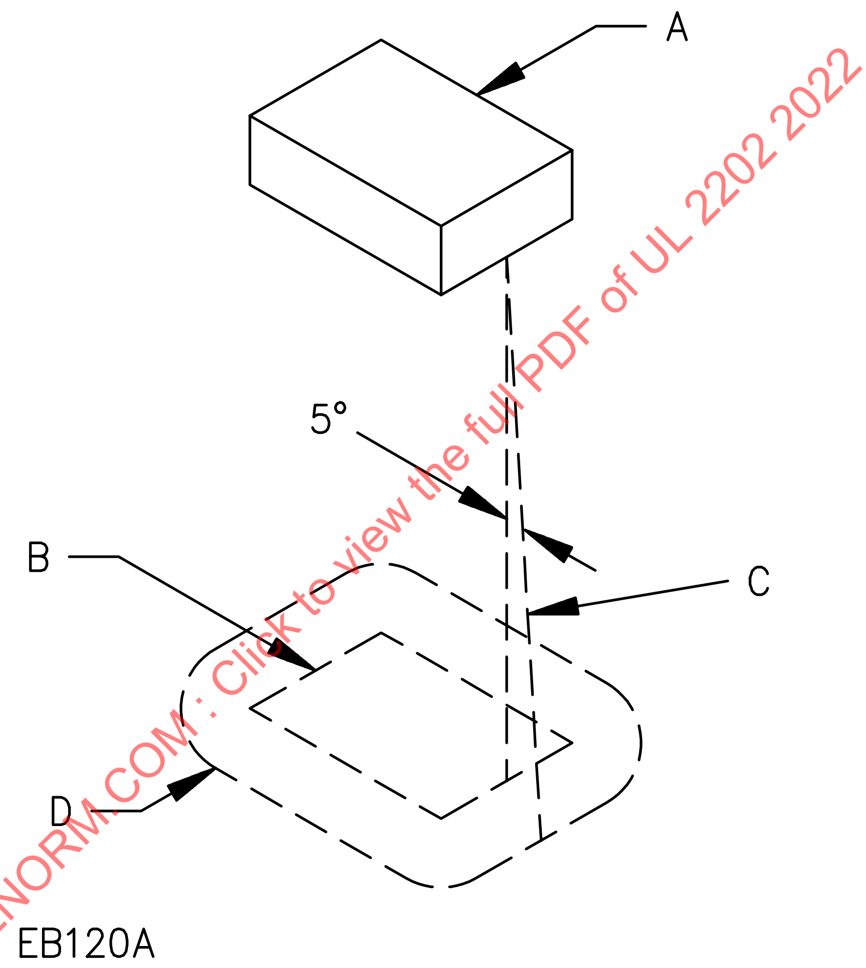
7.9.3 An enclosure may be provided with ventilation openings in the bottom of an enclosure when the openings incorporate a perforated metal plate as described in Table 7.5, or a galvanized or stainless steel screen having a 25.4-mm (14- by 14-mesh per inch) constructed of wire with a diameter of 0.4 mm (0.018 inch) minimum.

7.9.4 The bottom of the enclosure under areas containing only materials classed V-1 or better in accordance with Annex A, Ref. No. 18, shall have openings no larger than 40 $mm^2$ (1/16 square inch).

7.9.5 An enclosure may be provided with ventilating openings without limitation on their size and number and complying with 8.1.7 in the bottom panel in areas that contain only wires, cable, plugs, receptacles, transformers, and impedance protected or thermally protected motors, and in areas that contain only capacitors that are described in Section 30.

**Figure 7.1**

**Enclosure Bottom**





A – Region to be shielded by barrier. This consists of the entire component when it is not otherwise shielded, and of the unshielded portion of a component that is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always: (1) tangent to the component, (2) five degrees from the vertical, and (3) so oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.

**Figure 7.2**

**Example of a Bottom-Enclosure Baffle**

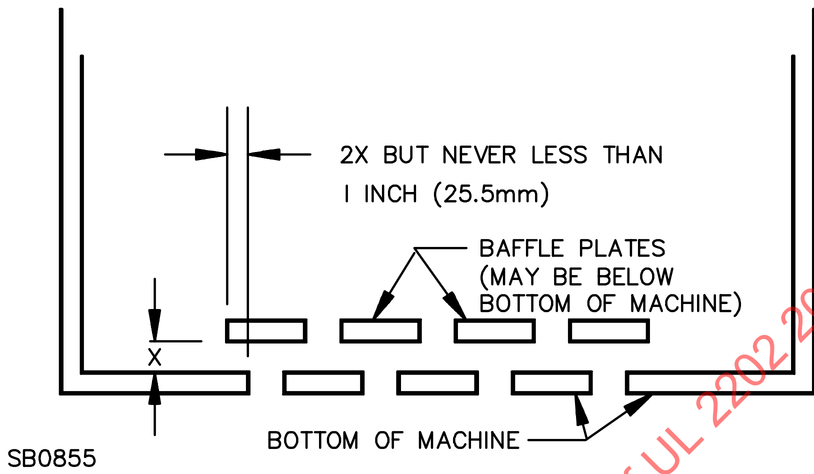





**Table 7.5**
**Perforated Metal Plates for Enclosure Bottom**

| Minimum thickness | | Maximum diameter of holes | | Minimum spacings of holes center to center | |
|---|---|---|---|---|---|
| mm | (inch) | mm | (inch) | mm | (inch) |
| 0.66 | (0.026) | 1.14 | (0.045) | 1.70 | (0.067) |
| | | | | 645 mm$^2$ | (233 holes per inch$^2$) |
| 0.66 | (0.026) | 1.19 | (0.047) | 2.36 | (0.093) |
| 0.76 | (0.030) | 1.14 | (0.045) | 1.70 | (0.067) |
| 0.76 | 0.030) | 1.19 | (0.047) | 2.36 | (0.093) |
| 0.81 | (0.032) | 1.91 | (0.075) | 3.18 | (0.125) |
| | | | | 645 mm$^2$ | (72 holes per inch$^2$) |
| 0.89 | (0.035) | 1.90 | (0.075) | 3.18 | (0.125) |
| 0.91 | (0.036) | 1.60 | (0.063) | 2.77 | (0.109) |
| 0.91 | (0.036) | 1.98 | (0.078) | 3.18 | (0.125) |
| 0.99 | (0.039) | 1.60 | (0.063) | 2.77 | (0.109) |
| 0.99 | (0.039) | 2.00 | (0.079) | 3.00 | (0.118) |
| NOTE – In accordance with 7.9.3. | | | | | |

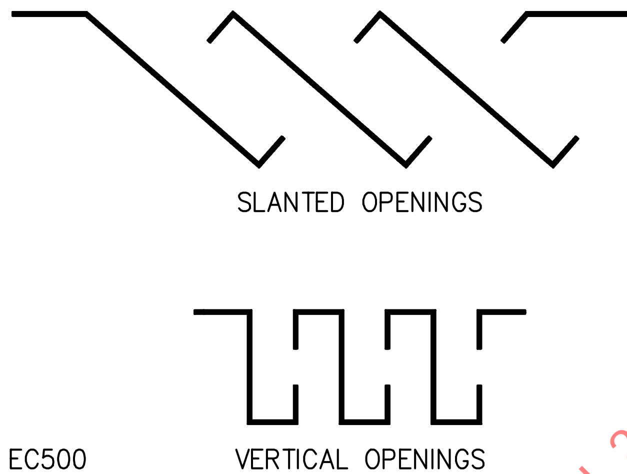
## 7.10 Enclosure top openings

7.10.1 Except as noted in 7.10.2, the minor dimension – see 8.1.6 – of any opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock or electrical energy – high current levels – shall not exceed 4.8 mm (3/16 inch) unless the configuration is such that the risk of direct vertical entry of a falling object to uninsulated live parts is reduced by means of a trap or restriction. See Figure 7.3 for examples of top surface openings that reduce the risk of direct entry.

7.10.2 The 4.8 mm (3/16 inch) limitation does not apply for openings located 1.8 m (6 feet) or higher from the floor, when the unit is installed in accordance with the manufacturer's instructions. Such openings shall comply with the accessibility requirements in Protection of Users – Accessibility and User Servicing, Section 8.

**Figure 7.3**

**Cross Sections of Top-Enclosure Designs**




### 7.11 Enclosures for wet and damp locations

#### 7.11.1 General

7.11.1.1 All enclosures provided for units intended for use in wet and damp locations shall comply with the requirements in 7.11 or as an alternative, enclosures may be marked with a type rating suitable for use in wet and damp locations and shall comply with Annex A, Ref. No. 19.

7.11.1.2 Units intended for use in wet and damp locations shall be evaluated for rain exposure in Section 7.11.2. If the unit makes use of gaskets or support feet to comply with the rain exposure, then the gaskets or support feet are evaluated in accordance with Section 7.11.3. If the polymeric enclosure makes use of metallic coatings for corrosion protection, the coating thickness is evaluated in accordance with Section 7.11.4.

#### 7.11.2 Ingress protection

7.11.2.1 The unit shall comply with minimum Enclosure Type 3R rating in compliance with Annex A, Ref. No. 19.

#### 7.11.3 Gaskets

7.11.3.1 Gaskets depended upon for protection from environmental elements shall comply with Annex A, Ref. No. 19.

#### 7.11.4 Metallic coating thickness

7.11.4.1 With reference to Corrosion Protection, Section 11, a metallic coating with a specified thickness shall have that thickness verified through test.

7.11.4.2 The solution to be used for this test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid ($CrO_3$); and 50 grams per liter of reagent grade concentrated sulfuric acid ($H_2SO_4$). The latter is equivalent to 27 milliliters of reagent grade concentrated sulfuric acid, specific gravity 1.84, containing 96 % of $H_2SO_4$.

7.11.4.3 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.64 mm (0.025 inch) and a length of 140 mm (5.5 inches). The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.025 milliliters each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ±5 drops per minute. Where desired, an additional stopcock is allowed in place of the glass tube to control the rate of dropping.

7.11.4.4 The representative device and the test solution are to be kept in the test room long enough to stabilize at room temperature. The room temperature is to be recorded. The test is to be conducted at an ambient temperature of 21.1 – 32.2 °C (70 – 90 °F).

7.11.4.5 Each representative device is to be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed completely by means of solvents. Representative devices are then to be thoroughly rinsed in water and dried. Care is to be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

7.11.4.6 The representative device to be tested is to be supported 18 – 25 mm (0.7 – 1 inch) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined 45° from horizontal.

7.11.4.7 The stopcock is to be opened and the time in seconds is to be measured until the dropping solution dissolves the protective metallic coating, exposing the base metal. The end point is the first appearance of the base metal recognizable by the change in color at that point.

7.11.4.8 Each representative device of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface at places where the metallic coating is expected to be the thinnest. On enclosure made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

7.11.4.9 To calculate the thickness of the coating being tested, the thickness factor from Table 7.6 applicable for the temperature at which the test was conducted is to be multiplied by the time in seconds required to expose base metal as noted in 7.11.4.7.



**Table 7.6**
**Thickness Factors**

| Temperature | | Thickness factors, 0.0003 mm (0.00001 inch) per second |
|---|---|---|
| °C | (°F) | Zinc platings |
| 21.1 | (70) | 0.980 |
| 21.7 | (71) | 0.990 |
| 22.2 | (72) | 1.000 |
| 22.8 | (73) | 1.010 |
| 23.3 | (74) | 1.015 |
| 23.9 | (75) | 1.025 |
| 24.4 | (76) | 1.033 |
| 25.0 | (77) | 1.042 |
| 25.6 | (78) | 1.050 |

**Table 7.6 Continued on Next Page**

**Table 7.6 Continued**

| Temperature | | Thickness factors, 0.0003 mm (0.00001 inch) per second |
|---|---|---|
| °C | (°F) | Zinc platings |
| 26.1 | (79) | 1.060 |
| 26.7 | (80) | 1.070 |
| 27.2 | (81) | 1.080 |
| 27.8 | (82) | 1.085 |
| 28.3 | (83) | 1.095 |
| 28.9 | (84) | 1.100 |
| 29.4 | (85) | 1.110 |
| 30.0 | (86) | 1.120 |
| 30.6 | (87) | 1.130 |
| 31.1 | (88) | 1.141 |
| 31.7 | (89) | 1.150 |
| 32.2 | (90) | 1.160 |

## 8 Protection of Users – Accessibility and User Servicing

### 8.1 General

8.1.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Protection of Service Personnel, Section 36.

8.1.2 To reduce the risk of unintentional contact that results in electric shock from an uninsulated live part or film-coated wire, electrical energy – high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either one of the following:

a) For an opening that has a minor dimension (see 8.1.5) less than 25.4 mm (1 inch), such a part or wire shall not be contacted by the probe illustrated in Figure 8.1, or

b) For an opening that has a minor dimension of 25.4 mm (1 inch) or more, such a part or wire shall be spaced from the opening as specified in Table 8.1.

**Figure 8.1**

**Articulated Probe**

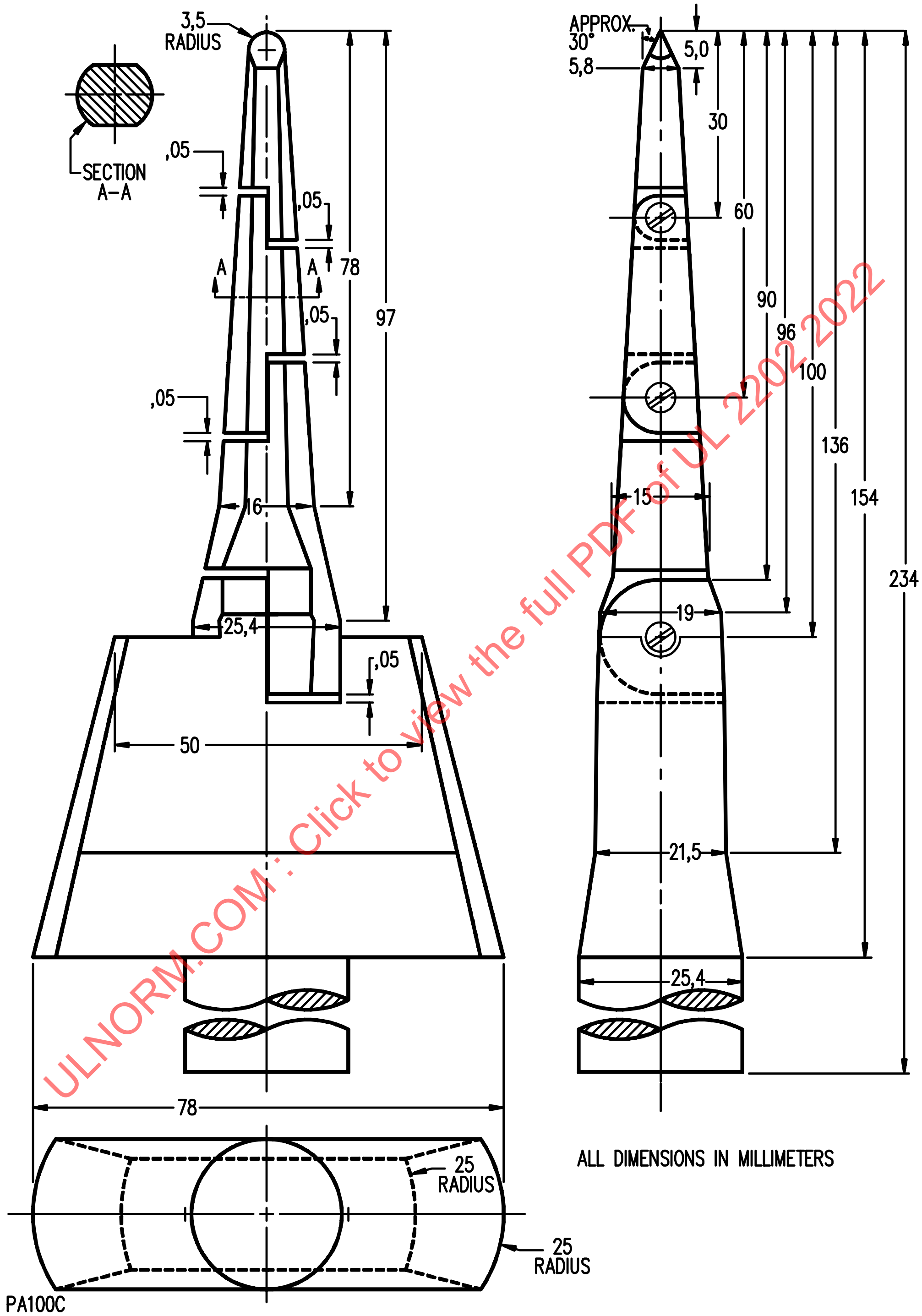


**Table 8.1**
**Minimum Required Distance from an Opening to a Part that Involves a Risk of Electric Shock, Electrical Energy-High Current Level, or Injury to Persons**

| Minor dimension of opening[a,b] | | Minimum distance from opening to part[b] | |
|---|---|---|---|
| mm | (inches) | mm | (inches) |
| 25.4 | (1) | 165.0 | (6-1/2) |
| 31.8 | (1-1/4) | 190.0 | (7-1/2) |
| 38.1 | (1-1/2) | 318.0 | (12-1/2) |
| 47.6 | (1-7/8) | 394.0 | (15-1/2) |
| 54.0 | (2-1/8) | 444.0 | (17-1/2) |
| c | | 762.0 | (30) |

[a] See 8.1.5.

[b] Between 19.1 and 54 mm (3/4 and 2-1/8 inches), interpolation is to be used to determine a value between values specified in the table.

[c] More than 54 mm (2-1/8 inches), and not more than 152 mm (6 inches).



8.1.3 The probe specified in 8.1.2 and illustrated in Figure 8.1 shall be applied to any accessible depth of the opening and shall be rotated or angled before, during, and after insertion through the opening to any position that is required to examine the enclosure. The probe shall be applied in any possible configuration; and, where required, the configuration shall be changed after insertion through the opening.

8.1.4 The probe mentioned in 8.1.3 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with a maximum force of 4.4 N (1 pound).

8.1.5 With reference to the requirements in 8.1.2, the minor dimension of an opening is the diameter of the largest cylindrical probe that is capable of being inserted through the opening.

8.1.6 The test pin illustrated in Figure 8.2, when inserted as specified in 8.1.3 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

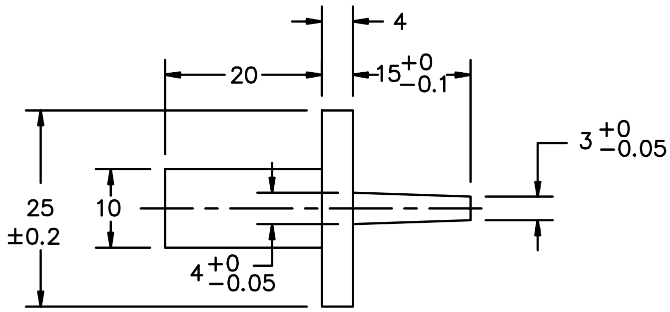
8.1.7 Except as noted in 8.1.8, the probe shown in Figure 8.1 and the test pin shown in Figure 8.2 are to be inserted as specified in 8.1.3 into all openings, including those in the bottom of the unit. The unit is to be moved in whatever way required to make the entire bottom accessible for insertion of the probe.

8.1.8 For a floor-standing unit, the probe and test pin are to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

8.1.9 During the examination of a unit to determine whether it complies with the requirements in 8.1.2, a part of the enclosure that is capable of being opened or removed by the user without using a tool is to be opened or removed. A fastener, such as a slotted-head thumb screw, that is turned by hand, does not require the use of a tool.

**Figure 8.2**

**Test Pin**




1 mm = 0.039 inch

## 8.2 User servicing

8.2.1 Service functions that are intended to be carried out by the user in accordance with the Maintenance Instructions, Section 81, shall comply with the requirements in 8.2.2 and 8.2.3.

8.2.2 The user shall not have access to any circuits or uninsulated parts that exceed the limits for an LVLE circuit. If the user is intended to access circuits or parts of the device above these limits, an interlock system shall be provided that will completely remove the hazard prior to the user accessing the area.

8.2.3 Any user servicing that is intended to be performed shall not require the use of a tool to access the area where the servicing is to be performed, unless the tool is specified and that tool cannot be used to access any other area of the device.

# 9 Electric Shock

## 9.1 Personnel protection systems

9.1.1 Electric vehicle charging system equipment shall be provided with a system of protection in accordance with the requirements in Annex A, Ref. Nos. 20 and 21.

9.1.2 The system of protection shall be either a grounded system or an isolated system.

9.1.3 For grounded systems of protection, the bond/ground connection is intended to be carried on the vehicle as a level of protection of the user. The connection to the vehicle is a bonding connection in accordance with Section 17, and it shall be suitably sized for the current involved in the system.

9.1.4 For isolated systems of protection, the output high voltage circuits on the unit, the high voltage in the output cable, and the high voltage circuits on the vehicle, are to be isolated from all accessible conductive surfaces and the user. The connection to the vehicle will include a functional grounding connection utilized for monitoring the isolation of the vehicle high voltage circuits from the vehicle frame. As the connection is not intended to be a ground bonding connection, it need not be sized for the available fault currents in the system.

## 9.2 Stored energy

9.2.1 The allowable capacitance between capacitor terminals that are accessible as determined by the requirements in Protection of Users – Accessibility and User Servicing, Section 8, and Protection of Service Personnel, Section 36, shall satisfy the following expressions. For cord connected units, capacitors in the primary circuit are considered accessible by contact with the attachment plug blades.

| | |
|---|---|
| $V < 40{,}000$ | where $C < 0.00328$ |
| $V < 729\ C^{-0.7}$ | where $0.00328 \leq C < 2.67$ |
| $V < 367$ | where $2.67 \leq C < 13.9$ |
| $V < 2314\ C^{-0.7}$ | where $13.9\ C \geq 184.5$ in a DRY environment |
| $V < 60$ | where $C \geq 184.5$ in a DRY environment |
| $V < 2314\ C^{-0.7}$ | where $13.9 \leq C < 497$ in a WET environment |
| $V < 30$ | where $C \geq 497$ in a WET environment |

in which:

*C* is the capacitance of the capacitor in microfarads; and

*V* is the voltage across the capacitor in volts. *V* is to be measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover, or similar device. Typical calculated values appear in Table 9.1, and the equation is shown graphically in Figure 9.1.

9.2.2 With reference to 9.2.1, a part involving a potential of more than 40 kilovolts peak is to be investigated to determine whether or not it involves a risk of electric shock.



**Table 9.1**
**Risk of Electric Shock – Stored Energy Current**

| Environment | Capacitance in microfarads[a] | Maximum allowable voltage across the capacitor, in volts |
|---|---|---|
| Wet or Dry | 0.00328 or less | 40,000 |
| | 0.005 | 29,749 |
| | 0.01 | 18,313 |
| | 0.02 | 11,273 |
| | 0.05 | 5,936 |
| | 0.1 | 3,654 |
| | 0.2 | 2,249 |
| | 0.5 | 1,184 |
| | 1.0 | 729 |
| | 2.0 | 449 |
| | 2.0 | 449 |
| | 2.67 to 13.9 | 367 |
| | 20.0 | 284 |
| | 50.0 | 150 |
| | 100.0 | 92.1 |
| | 184.5 | 60.0 |

**Table 9.1 Continued on Next Page**

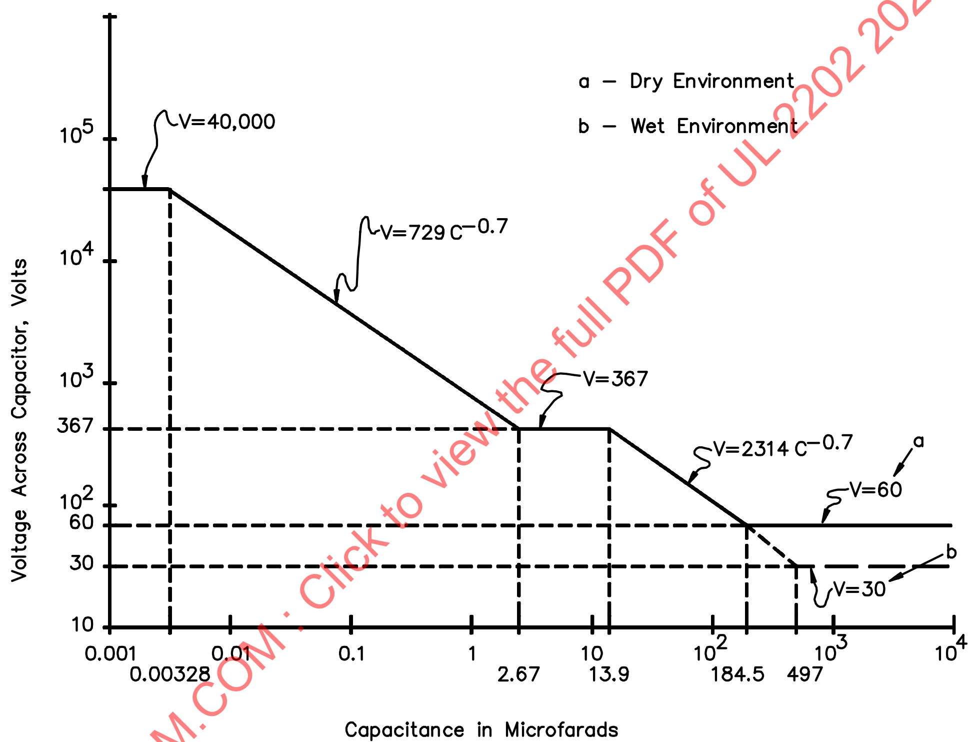
**Table 9.1 Continued**

| Environment | Capacitance in microfarads[a] | Maximum allowable voltage across the capacitor, in volts |
|---|---|---|
| Dry only | 184.5 or more | 60.0 |
| Wet | 200<br>497 or more | 56.7<br>30.0 |

[a] See Figure 9.1.

**Figure 9.1**

**Limits for Voltage Across Capacitance**






## 10 Mounting

10.1 A unit that is intended to be fastened in place shall have provision for mounting it securely in position. Bolts, screws, or other parts used for securing the mounting means shall be independent of those used to secure components of the unit to the frame, base, or panel. The unit shall be removable from the mounting means without the use of a tool.

10.2 Where used, keyhole slots for mounting screws shall be arranged so that wall-mounting screws do not project into a compartment containing electrical parts and reduce spacings to less than those specified in Spacings, Section 23.

10.3 Except as noted in 10.4, for a floor supported unit having bottom ventilation openings, and the supporting feet are made of rubber or neoprene material, then the aging and physical properties of the supporting feet material shall be investigated in accordance with the requirements specified in Accelerated aging tests of supporting feet, Section 73.

10.4 As specified in 49.5 and 52.1.5 for a unit subjected to the temperature and abnormal tests with the supporting means removed, this requirement does not apply.

10.5 A fixed in place unit shall not be provided with casters. For all units that are fixed in place by mounting to a wall, post, pedestal, or other device, the unit shall only be removable with the use of tools. Casters are not prohibited when they are used solely for transporting the unit and provided with leveling feet that are intended to be lowered after the unit is installed.

## 11 Corrosion Protection

11.1 For units intended for use in dry locations only, iron and steel parts shall be protected against corrosion by painting, galvanizing, sherardizing, plating, or other equivalent means. For units intended for use in wet and damp locations, corrosion protection shall be in accordance with 11.3 – 11.11. This requirement applies to all enclosure parts, whether of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation depends. Bearing surfaces shall be of such materials and constructed so that binding due to corrosion is prevented.

11.2 With reference to 11.1, the parts specified in (a) – (d) are not required to be protected against corrosion:

a) Bearings, or similar parts, where such protection is impracticable;

b) A minor part, such as a washer, screw, bolt, or similar parts, where the failure of such unprotected parts does not result in a risk of fire, electric shock, electrical energy-high current levels, or injury to persons, or the operation of the unit being affected adversely;

c) A decorative grille that is not required to form a part of the enclosure; and

d) A part made of stainless steel.

11.3 Metals shall not be used in conjunction such as to cause galvanic action that adversely affects the enclosure.

11.4 Hinges and other attachments shall be resistant to corrosion.

11.5 An enclosure of cast iron or malleable iron at least 3.2 mm (1/8 inch) thick shall be protected against corrosion by:

a) A 0.0038 mm (0.00015 inch) thick coating of zinc, or the equivalent, on the outside surface and a visible coating of such metal on the inside surface, or

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. Whether the paint meets the intent for which it is required, shall be determined by evaluation of its composition or, where required, by corrosion tests.

11.6 An enclosure of sheet steel having a thickness less than 3.2 mm (0.126 inch) when zinc-coated or 3.12 mm (0.123 inch) thick when uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 11.8.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in Annex A, Ref. No. 22 with not less than 40 % of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any applicable method; however, in case of question, the weight of coating shall be established in accordance with Annex A, Ref. No. 23.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.0155 mm (0.00061 inch) on each surface with a minimum thickness of 0.0137 mm (0.00054 inch). The thickness of the coating shall be established by the metallic-coating thickness test described in 7.11.4. An annealed coating shall also comply with 11.10.

c) A zinc coating conforming with 11.7 (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. Whether the paint meets the intent for which it is required shall be determined by evaluation of its composition or, where required by corrosion tests.

11.7 An enclosure of sheet steel 3.20 mm (0.126 inch) thick or more when zinc-coated, or 3.12 mm (0.123 inch) thick or more when uncoated, shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to provide equivalent protection as described in 11.8.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Annex A, Ref. No. 22 with not less than 40 % of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating shall be determined by any applicable method; however, in case of question, the weight of coating shall be established in accordance with Annex A, Ref. No. 23. An A60 (alloyed) coating shall also comply with 11.10.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.0104 mm (0.00041 inch) on each surface with a minimum thickness of 0.0086 mm (0.00034 inch). The thickness of the coating shall be established by the metallic-coating thickness test described in Section 7.11.4. An annealed coating shall also comply with 11.10.

c) Two coats of an organic finish of epoxy or alkyd resin or other outdoor paint on each surface. Whether the paint meets the intent for which it is required shall be determined by evaluation of its composition or, where required, by corrosion tests.

d) Any one of the means specified in 11.6.

11.8 With reference to 11.6 and 11.7, other finishes, including paints, special metallic finishes, and combinations of the two are determined to be equivalent when comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with 11.6(a) or 11.7, as applicable, indicate they provide equivalent protection. Among the factors that are taken into account when judging whether such coating systems meet the intent of the requirement are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water. See Annex A, Ref. No. 24, for investigation of component coatings.

11.9 Test specimens of a finish as described in 11.5(b) or 11.8, 11.6(c), or 11.7(c), when the paint is tested, are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and similar factors.

11.10 A hot-dipped mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that are not exposed to water, as determined by the environmental testing of 7.11, are not required to be painted. The zinc coating is evaluated at the outside radius of the bent or formed section visible at 25 power magnification. Simple sheared or cut edges and punched holes are not formed.

11.11 Additional protection against corrosion is not required for aluminum, stainless steel, polymeric materials, copper, bronze, or brass containing at least 80 % copper.

## 12 Mechanical Assembly

12.1 Loosening of parts in a unit as a result of vibration due to handling and operation of the unit shall not result in a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

12.2 Screws with lock washers applied as intended, screws tightened by means of a power tool, rivets, and staked and upset screws are considered not subject to loosening. See 12.3.

12.3 The construction of staked and upset screws is to consist of an interference fit between the nut and bolt resulting in uneasy turning of the screw. This shall be accomplished by the use of a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

12.4 A rotating part that, when loosened, results in a risk of fire, electric shock, electrical energy – high current levels, or injury to persons shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place. A keyed part, a press fit, a part locked in place with a pin, or equivalent means to hold a rotating part in place is allowed.

12.5 Except as noted in 12.6, a switch, fuseholder, lampholder, attachment-plug receptacle, motor-attachment plug, or other component that is handled by the operator shall be mounted securely, not turn, and comply with the requirements specified in 12.7.

12.6 A switch is not prohibited from turning when all the following conditions are met:

a) The switch is of a plunger, slide, or other type that does not tend to rotate during intended operation (a toggle switch is considered to be subjected to forces that tend to turn the switch);

b) The means of mounting the switch reduces the risk that operation loosens the switch;

c) Spacings are not reduced below the minimum required value where the switch rotates; and

d) Intended operation of the switch is by mechanical means rather than by direct contact by persons.

12.7 The means of securing components mentioned in 12.5 shall include more than friction between surfaces. A lock washer is an example of a means to secure a device having a single-hole mounting means.

12.8 Except as noted in 12.9, a blower or fan motor including the blower or fan blade itself shall be secured by bolts and nuts complying with 12.3, bolts and nuts having holes or slots with cotter pins applied as intended, bolts having a compression type lock nut, rivets, or the equivalent means to reduce the risk of the motor, blower, or fan blade from vibrating loose and falling from its mounting support.

12.9 The following blowers and fans are not required to comply with 12.8:

a) A blower or fan motor, including the blower or fan blade itself, secured by means described in 12.2 and oriented, positioned, or located above a barrier such that either the motor, blower, or fan blade does not contact other components resulting in a risk of fire, electric shock, or electrical energy – high current levels in the event that such parts vibrated loose from their support; and

b) Blowers and fans rated 5.66 cubic meter (200 cubic feet) per minute or less.

## 13 Switches and Controls

13.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner.

13.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 %, such as a transformer or some ballasts and that does not have an inductive rating, shall be either rated not less than twice the maximum load current under normal operating conditions, or be investigated for the application.

13.3 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use.

13.4 A switch or other device controlling a relay, solenoid coil, or similar device shall have a pilot duty rating intended for the application.

13.5 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multi-circuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch may control a separate 120-volt load, and both poles are not prohibited from controlling both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch may control a separate load not exceeding 139 volts and the three poles may control the three legs of a 3-phase, 240-volt load.

13.6 A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use as indicated by a double underlining under the voltage rating.

13.7 A switch shall not disconnect the grounded conductor of a circuit unless:

a) The switch simultaneously disconnects all conductors of the circuit; or

b) The switch is so arranged that the grounded conductor is not disconnected until the ungrounded conductors of the circuit have been disconnected.

13.8 Solid state switches shall comply with the requirements in this standard. Mechanical and electromechanical switches shall comply with the applicable requirements for switches such as in Annex A, Ref. Nos. 25 and 26, or other applicable standards.

13.9 Where a unit switch or circuit breaker is mounted such that movement of the operating handle between the on position and off position results in one position being above the other position, the upper position shall be the on position. This requirement does not apply to a switching device having more than one on position, a double throw switch, a rotationally-operated switch, or a rocker switch.

## 14 Supply Connections

### 14.1 Permanently connected units

#### 14.1.1 General

14.1.1.1 Except as noted in 14.1.1.2, a permanently connected unit shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 14.1.1.4 – 14.1.2.15 or wiring leads as specified in 14.1.1.4 and 14.1.3.1 – 14.1.3.8 and a means for connection of cable or conduit as specified in 14.2.1.

14.1.1.2 The requirements described in 14.1.1.4 – 14.1.3.4 do not apply to the means for connection to accessible signal circuits complying with the requirements specified in Section 26.

14.1.1.3 The requirement in 14.1.1.1 applies to the wiring connection means for the alternating current and direct current input and output power circuits of a unit for connections that are intended to be made in the field when the unit is installed.

14.1.1.4 A wiring terminal or lead shall be used for the connection of a conductor having an ampacity based on Table 310-16 of Annex A, Ref. No.1 (Mexico and US) and Table 2 of Annex A, Ref. No. 1 (Canada) and of no less than 125 % of the maximum current that the circuit carries during rated conditions described in 48.1. For determining the applicable column in Table 310-16, see 78.2(l) and 78.2(m).

### 14.1.2 Wiring terminals

14.1.2.1 A wiring terminal shall comply with the requirement in 14.1.1.4 for the type of conductor for which it is marked. See 76.2.9.

14.1.2.2 Except as noted in 14.1.2.3 and 14.1.2.4, a wiring terminal shall be provided with a pressure terminal connector of other than the crimping type that is securely fastened in place – for example, firmly bolted or held by a screw.

14.1.2.3 A pressure terminal connector, including a crimping type, may be used when field-installed in accordance with 14.1.2.7.

14.1.2.4 A wire-binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 $mm^2$) or smaller conductor where upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

14.1.2.5 Except as noted in 14.1.2.6, a wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

14.1.2.6 A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 14.1.2.7 may turn when the least spacing between adjacent terminals and also between terminals and non-current carrying metal parts, complies with Spacings, Section 23, for when connectors are oriented in such a position that results in these spacings.

14.1.2.7 In accordance with 14.1.2.3 and 14.1.2.6, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are complied with:

a) One or more component terminal assemblies shall be available from the unit manufacturer or others, and they shall be specified in the instruction manual. See 78.2 (b) and (c).

b) The fastening hardware such as a stud, nut, bolt, spring or flat washer, or similar part as mounted on or separately packaged with the unit, or specified in the instruction manual.

c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

d) Where the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions shall be included in the assembly package or with the unit. See 78.2(d).

e) Installation of the pressure terminal connector in the intended manner shall result in a unit complying with the requirements of this standard.

14.1.2.8 An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, Section 59.

14.1.2.9 Except as noted in 14.1.2.10 and 14.1.2.11, a wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

14.1.2.10 A No. 8 (4.2 mm diameter) screw being used at a terminal intended only for the connection of a 14 AWG (2.1 mm$^2$) conductor or a 16 or 18 AWG (1.3 or 0.82 mm$^2$) control-circuit conductor is allowed.

14.1.2.11 A No. 6 (3.5 mm diameter) screw used for the connection of a 16 or 18 AWG (1.3 or 0.8 2 mm$^2$) control-circuit conductor is allowed.

14.1.2.12 A wire-binding screw shall thread into metal a minimum two full threads.

14.1.2.13 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick. A terminal plate less than 1.27 mm (0.050 inch) thick may be used in a LVLE circuit or limited-energy circuit (see 2.24 and 2.22) when the tapped threads withstand the tightening torque specified in Table 14.1 without stripping.

**Table 14.1**
**Tightening Torque for Wire-Binding Screws**

| Size of terminal screw, number | Wire sizes to be tested[a] | | Tightening torque | |
|---|---|---|---|---|
| | mm$^2$ | AWG | Newton meters | (Pound-inches) |
| 6 | 1.31 – 0.824 (ST) | 16 – 18 (ST) | 1.4 | (12) |
| 8 | 2.08 (S) and 1.31 – 0.824 (ST) | 14 (S) and 16 – 18 (ST) | 1.8 | (16) |
| 10 | 5.26 – 2.08 (S) and 1.31 – 0.824 (ST) | 10 – 14 (S) and 16 – 18 (ST) | 2.3 | (20) |

[a] ST – stranded wire; S – solid wire.

14.1.2.14 There shall be two or more full threads in the metal of a terminal plate. When the metal is extruded at the tapped hole, at least two full threads shall be provided. Two full threads are not required for a terminal in a LVLE or limited-energy circuit – see 2.24 and 2.22 – when a lesser number of threads results in a secure connection in which the threads do not strip when subjected to the tightening torque specified in Table 14.1.

14.1.2.15 A terminal for connection of the identified/grounded conductor of an alternating current power circuit shall be identified as described in 76.2.12.

### 14.1.3 Field wiring leads

14.1.3.1 Except as noted in 14.1.3.2 and 14.1.3.3, a field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is connected, and shall not be smaller than 18 AWG (0.82 mm$^2$), for example, a 10 AWG (5.3 mm$^2$) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm$^2$) field-provided conductor. The exposed length of the field-wiring lead shall not be less than 152.4 mm (6 inches) long.

14.1.3.2 A 18 AWG size field-wiring lead may be connected to a 12 AWG (3.3 mm$^2$) size branch-circuit conductor.

14.1.3.3 A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it is connected, and not smaller than 18 AWG (0.82 $mm^2$), when more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the conditions in (a) – (c):

a) A wire connector for connection of the field-provided wire is provided as part of the unit or remote-control assembly, and the wire connector is intended for the combination of wires that are spliced;

b) The factory-provided leads are bunched or otherwise arranged so that stress does not result on an individual lead; and

c) Instructions are provided in accordance with 78.2(e).

14.1.3.4 In the US and Mexico, a field-wiring lead shall consist of general building wire, or other wiring where it has a rubber or thermoplastic insulation, and the insulation shall not be less than 0.8-mm (1/32-inch) thick. In Canada, a field-wiring lead shall be of a type permitted by Table 19 of the Canadian Electrical Code Part I.

14.1.3.5 A field-wiring lead shall be subjected to the test specified in 54.2.3.

14.1.3.6 A field-wiring lead provided for connection to an external line-voltage circuit shall not be connected to a wire-binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field-wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the unit in accordance with 76.2.16.

14.1.3.7 The free end of a field-wiring lead that is not used in every installation, such as a tap for a multi-voltage transformer, shall be insulated. For a grounding lead, see 18.1.8.

14.1.3.8 A field-wiring lead for connection of the identified/grounded conductor shall be identified as described in 76.2.12.



#### 14.1.4 Wiring compartments

14.1.4.1 A wiring compartment on a permanently-connected unit shall be located so that wire connections therein are accessible for inspection, without disturbing either factory or field connected wiring, after the unit is installed in the intended manner.

14.1.4.2 Wiring compartments, raceways, or similar devices for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that are capable of damaging conductor insulation.

### 14.2 Openings for conduit or cable connection

14.2.1 For a permanently-connected unit, an opening or knockout complying with the requirements specified in 7.7.1 – 7.7.8 shall be provided for connection of conduit or cable wiring system. A unit complying with the requirements specified in 7.7.6 and 7.7.7 is not required to be provided with an opening or a knockout.

### 14.3 Openings for Class 2 circuit conductors

14.3.1 An opening for the entry of a conductor or conductors of a Class 2 circuit shall be provided with an insulating bushing. The bushing shall be mounted in place in the opening or shall be within the enclosure so that it is mounted as intended when the unit is installed. The bushing is not required when the opening accommodates armored cable or conduit and the installation instructions indicate that Class 1 wiring methods are to be used as indicated in 78.2(n).

14.3.2 A bushing of rubber or rubber-like material provided in accordance with 14.3.1 shall be at least 3.2 mm (1/8 inch) thick, except that it shall be not less than 1.2 mm (3/64 inch) thick where the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it is not exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or similar objects that are capable of damaging the bushing.

### 14.4 Cord-connected units

#### 14.4.1 General

14.4.1.1 For a portable unit or a fastened in place unit, flexible cords and attachment plugs and receptacles shall be used for connection to the supply circuits. The requirements described in 14.4.2.1 – 14.4.2.5 do not apply to a Class 2 circuit or to an accessible signal circuit complying with the requirements in Accessible Signal Circuits, Section 26.



#### 14.4.2 Cords and plugs

14.4.2.1 The cord shall be Type G, SEOW, SOW, SOOW, STOW, STOOW, SJEOW, SJOW, SJTOW, W, or a cord that is equally serviceable in accordance with Annex A, Ref. No. 27. The length of the cord used for the supply circuit is measured from the face of the attachment plug to the point where the cord emerges from the unit. The length of the power supply cord shall be as follows:

a) For all units in which the interrupting device of the personnel protection system as described in 9.1 is located within 0.3 meters (12 inches) of the receptacle, the power supply cord shall be not more than 4.6 meters (15 feet).

b) For portable units, where the interrupting device of the personnel protection system as described in 9.1 is located within the product enclosure, the power supply cord shall be not more than:

1) For Canada, 1.8 m (6 feet); and

2) For Mexico and the US, 300 mm (12 inches).

c) For fastened in place units, where the interrupting device of the personnel protection system as described in 9.1 is located within the product enclosure and the unit is installed at a height that prevents the power cord from touching the floor when plugged into the proper receptacle, the power supply cord shall be not more than 1.8 m (6 feet).

14.4.2.2 The voltage rating of a flexible cord shall be at least the rated voltage of the unit, and its ampacity shall be at least the current rating of the unit.

14.4.2.3 The attachment plug of a supply cord shall have a current rating in accordance with 14.4.2.4 and have a voltage rating corresponding to the rated voltage of the unit.

14.4.2.4 With reference to 14.4.2.3, the current rating of the attachment plug shall not be less than 125 % of the rating of the unit.

14.4.2.5 In Canada, the attachment plug shall be of the grounding type.

In Mexico and the US, the attachment plug shall be of the non-locking, grounding type.

### 14.5 Strain relief

#### 14.5.1 General

14.5.1.1 Strain relief shall be provided to reduce the risk of mechanical twisting or stress on a flexible power cord or EV cable from being transmitted to terminals, splices, or interior wiring. The means for preventing twisting is to be evaluated by inspection. The means for preventing stress on power supply cords are to be evaluated by the Strain Relief Tests, Section 54, and the Flexing Test, Section 55. The means for preventing stress on EV cables are to be evaluated by the EV Cable Securement Test, Section 56.

14.5.1.2 A knot in a flexible cord shall not serve as means for strain relief.

14.5.1.3 A metal strain relief clamp shall be provided with auxiliary insulation over the cord if damage to the cord insulation results from the Strain Relief Test in Section 56.

14.5.1.4 Means shall be provided to prevent a flexible power cord from being pushed into the equipment through the cord entry hole if such displacement would:

a) Result in mechanical damage to the cord;

b) Expose the cord to temperatures higher than that for which the cord is rated; or

c) Reduce spacings below the minimum acceptable level.

### 14.6 Bushings

14.6.1 At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded surface against which the cord bears.

14.6.2 Insulating bushings shall comply with the requirements in Annex A, Ref. No 28.

14.6.3 A bushing of the same material as is molded integrally with the supply cord may be used when the built-up section is not less than 1.6 mm (1/16 inch) thick at the point at which the cord passes through the enclosure.

### 14.7 Identification

14.7.1 A unit shall have the grounded/bonded conductor connected to the following items when provided: the screw shell of an Edison-base lampholder and the screw shell of an Edison-base fuseholder. The grounded/bonded conductor of a fixed in place unit shall be connected to the field-wiring terminal intended for the connection of a grounded/bonded conductor – see 14.1.2.15 – or shall be connected to the field-wiring lead intended for the connection of a grounded/bonded conductor – see 14.1.3.8. The grounded/bonded conductor of a portable unit shall be connected to the blade of the attachment plug intended for connection to the grounded supply conductor. A single-pole switch or single-pole overcurrent protective device, other than an automatic control without a marked off position shall be connected to the ungrounded conductor. See also 13.8.

## 15 Wire Bending Space

15.1 A permanently connected unit employing pressure terminal connectors for field connection of circuits described in 14.1.1.3 shall be provided with space within the enclosure as specified in 15.3 – 15.7

for the installation of conductors including bonding/grounding conductors that are employed in the installation.

NOTE: In Canada, equipment complying with CSA C22.2 No. 0.12 is considered to comply with this requirement.

15.2 The conductor size used in judging the wiring space is to be based on the use of a conductor sized in accordance with 14.1.1.4.

15.3 Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 15.4 or 15.5 and opening or knockout for a conduit or wireway in a gutter as specified in 15.9.

15.4 When a conductor is capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 15.1. A wire is capable of entering or leaving a top, back, bottom, or side surface when there is an opening or knockout for a wireway or conduit.



**Table 15.1**
**Minimum Wire-Bending Space for Conductors Through a Wall Opposite Terminals in mm (inches)**

| Wire size | | Wires per terminal (pole)[a] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AWG or kcmil | mm² | 1 | | 2 | | | 3 | | | 4 or more | | |
| 14 – 10 AWG | 2.1 – 5.3 | Not Specified | | | – | | | – | | | – | |
| 8 | 8.4 | 38.1 | (1-1/2) | | – | | | – | | | – | |
| 6 | 13.3 | 50.8 | (2) | | – | | | – | | | – | |
| 4 | 21.1 | 76.2 | (3) | | – | | | – | | | – | |
| 3 | 26.7 | 76.2 | (3) | | – | | | – | | | – | |
| 2 | 33.6 | 88.9 | (3-1/2) | | – | | | – | | | – | |
| 1 | 42.4 | 114 | (4-1/2) | | – | | | – | | | – | |
| 0 | 53.5 | 140 | (5-1/2) | 140 | | | 179 | | (7) | | – | |
| 2/0 | 67.4 | 152 | (6) | 152 | | | 191 | | (7-1/2) | | – | |
| 3/0 | 85.0 | 165 | (6-1/2) | 165 | 12.7 | (6-1/2) | 203 | | (8) | | – | |
| 4/0 | 107 | 179 | (7) | 191 | 38.1 | (7-1/2) | 216 | 12.7 | (8-1/2) | | – | |
| 250 kcmil | 127 | 216 | (8-1/2) | 216 | 50.8 | (8-1/2) | 229 | 25.4 | (9) | 254 | | (10) |
| 300 | 152 | 254 | (10) | 254 | 50.8 | (10) | 279 | 25.4 | (11) | 305 | | (12) |
| 350 | 177 | 305 | (12) | 305 | 76.2 | (12) | 330 | 76.2 | (13) | 355 | 50.8 | (14) |
| 400 | 203 | 330 | (13) | 330 | 76.2 | (13) | 355 | 76.2 | (14) | 381 | 76.2 | (15) |
| 500 | 253 | 355 | (14) | 355 | 76.2 | (14) | 381 | 76.2 | (15) | 406 | 76.2 | (16) |
| 600 | 304 | 381 | (15) | 406 | 76.2 | (16) | 457 | 76.2 | (18) | 483 | 76.2 | (19) |
| 700 | 355 | 406 | (16) | 457 | 76.2 | (18) | 508 | 76.2 | (20) | 559 | 76.2 | (22) |
| 750 | 380 | 432 | (17) | 483 | 76.2 | (19) | 559 | 76.2 | (22) | 610 | 76.2 | (24) |
| 800 | 405 | 457 | (18) | 508 | | (20) | 559 | | (22) | 610 | | (24) |
| 900 | 456 | 483 | (19) | 559 | | (22) | 610 | | (24) | 610 | | (24) |
| 1000 | 507 | 508 | (20) | | – | | | – | | | – | |
| 1250 | 633 | 559 | (22) | | – | | | – | | | – | |

**Table 15.1 Continued on Next Page**

**Table 15.1 Continued**

| Wire size | | Wires per terminal (pole)[a] | | | | |
|---|---|---|---|---|---|---|
| AWG or kcmil | mm² | 1 | | 2 | 3 | 4 or more |
| 1500 | 760 | 610 | (24) | – | – | – |
| 1750 | 886 | 610 | (24) | – | – | – |
| 2000 | 1013 | 610 | (24) | – | – | – |

Note – The table includes only those multiple-conductor combinations that are used. Combinations not specified shall be further evaluated.

[a] Wire bending space is not prohibited from being reduced by the number of inches shown in brackets under the following conditions:

1) Only removable or lay-in wire connectors receiving one wire each are used (more than one removable wire connector per terminal is possible) and

2) The removable wire connectors are removed from their intended location without disturbing structural or electrical parts other than a cover, and are installed with the conductor in place.

15.5 Where a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 15.2. The wire bending space is in accordance with Table 15.2 when a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 15.1.

**Table 15.2**
**Minimum Width of Gutter and Wire-Bending Space for Conductors Through a Wall Not Opposite Terminals in mm (inches)**

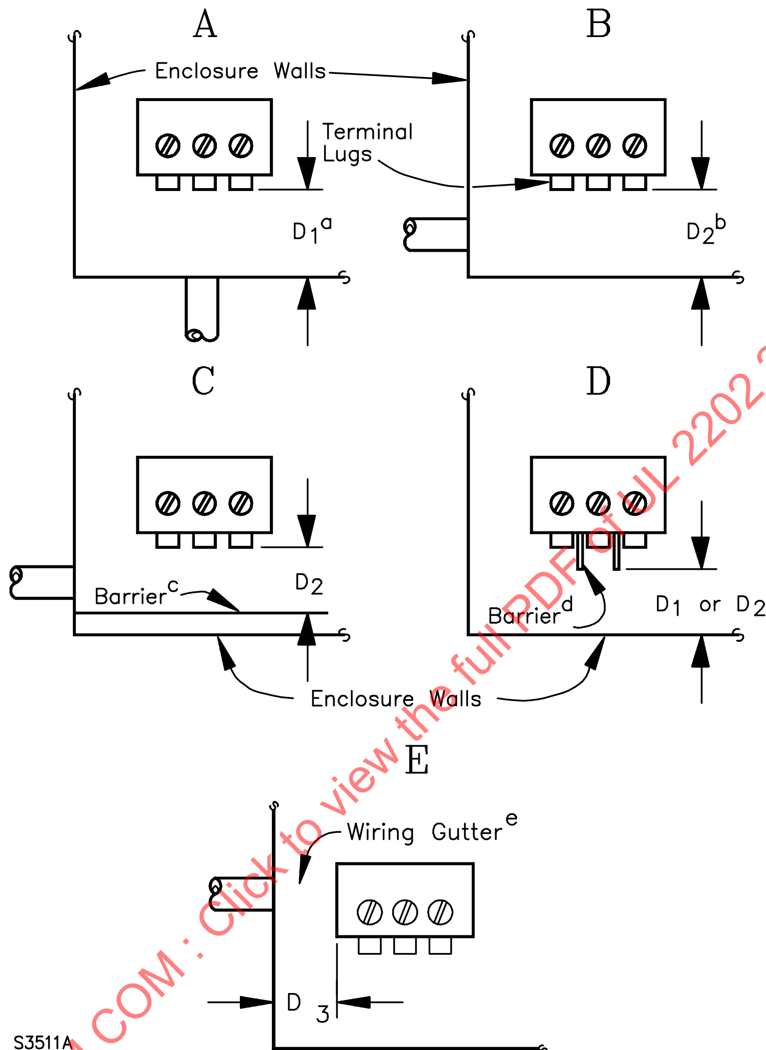
| Wire size | | Wires per terminal (pole) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AWG or kcmil | mm² | 1 | | 2 | | 3 | | 4 | | 5 | |
| 14 – 10 AWG | 2.1 – 5.3 | Not Specified | – | – | | – | | – | | – | |
| 8 – 6 | 8.4 – 13.3 | 38.1 | (1-1/2) | – | | – | | – | | – | |
| 4 – 3 | 21.1 – 26.7 | 50.8 | (2) | – | | – | | – | | – | |
| 2 | 33.6 | 63.5 | (2-1/2) | – | | – | | – | | – | |
| 1 | 42.4 | 76.2 | (3) | – | | – | | – | | – | |
| 1/0 – 2/0 | 53.5 – 7.4 | 88.9 | (3-1/2) | 127 | (5) | 178 | (7) | – | | – | |
| 3/0 – 4/0 | 85.0 – 107 | 102 | (4) | 152 | (6) | 203 | (8) | – | | – | |
| 250 kcmil | 127 | 114 | (4-1/2) | 152 | (6) | 203 | (8) | 254 | (10) | – | |
| 300 – 350 | 152 – 177 | 127 | (5) | 203 | (8) | 254 | (10) | 305 | (12) | – | |
| 400 – 500 | 203 – 253 | 152 | (6) | 203 | (8) | 254 | (10) | 305 | (12) | 356 | (14) |
| 600 – 700 | 304 – 355 | 203 | (8) | 254 | (10) | 305 | (12) | 356 | (14) | 406 | (16) |
| 750 – 900 | 380 – 456 | 203 | (8) | 305 | (12) | 356 | (14) | 406 | (16) | 457 | (18) |
| 1000 – 1250 | 507 – 633 | 254 | (10) | – | | – | | – | | – | |
| 1500 – 2000 | 760 – 1010 | 305 | (12) | – | | – | | – | | – | |

NOTE – The table includes only those multiple-conductor combinations that are frequently used. Combinations not specified shall be further evaluated.

15.6 When a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance is to be measured from the end of the barrier. See illustration D of Figure 15.1.

**Figure 15.1**

**Wire Bending Space**






$D_1$ is the distance between a wire connector or an adjacent barrier and the opposite wall that conductors are intended to pass through.

$D_2$ is the distance between a wire connector or an adjacent barrier and the opposite wall or barrier that conductors are not intended to pass through.

$D_3$ is the width of a wiring gutter having a side through which conductors are intended to pass through.

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs. $D_1$ shall not be less than the minimum wire bending space specified in Table 15.1.

[b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs either is not provided with a knockout or conduit opening or a marking is provided indicating that the conduit opening or knockout is not to be used. $D_2$ shall not be less than the minimum wire bending space specified in Table 15.2.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs, however, a barrier preventing the use of the opening is provided. $D_2$ shall not be less than the minimum wire bending space specified in Table 15.2.

[d] When a barrier or other means is provided restricting bending of the conductor, the distance $D_1$ or $D_2$, as applicable (see notes for $D_1$ and $D_2$ above) is to be measured from the end of the barrier.

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, $D_3$, shall not be less than the minimum wire bending space specified in Table 15.2.

15.7 For a unit not provided with a conduit opening or knockout – see 7.7.6 – the minimum wiring bending space mentioned in 15.4 – 15.6 shall be based on any enclosure wall capable of being used for installation of the conduit or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the unit.

15.8 The distance mentioned in 15.3 – 15.5 is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 15.1. The wire terminal is to be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it is capable of assuming without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar part. A barrier, shoulder, or similar part is to be disregarded where the measurement is being made when it does not reduce the radius to which the wire must be bent. Where a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure. See also 15.6.

15.9 Except as noted in 15.10, the width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size that are used at that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 15.2. See illustration E of Figure 15.1.

15.10 The wiring space is not required to be of this width when knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that accommodates the conductors in question, and the knockout or knockouts at such other points are used in the intended wiring of the unit.

## 16 External Connections and Wiring

### 16.1 Output Cable to the electric vehicle

16.1.1 An EV receptacle, EV plug, vehicle connector, or vehicle inlet shall comply with the requirements in Annex A, Ref. No. 29.

16.1.2 The output cable to the electric vehicle shall be connected to the EV charger and shall interconnect the charger output and the vehicle inlet. The cable shall comply with one of the following:

a) The cable shall be Type EVJ, EVJE, or EVJT, used with chargers having output voltages 300 volts or less, and the conductors shall be suitably sized for the ampacity involved. See 16.1.3.

b) The cable shall be Type EV, EVE, or EVT, used with chargers having output voltages 1500 volts or less, and the conductors shall be suitably sized for the ampacity involved. See 16.1.3.

c) The cable shall be of any type, suitably insulated for the output voltage of the charger, see 16.1.4, and the conductors shall be suitably sized for the ampacity involved. See 16.1.3.

16.1.3 In the US and Mexico, with reference to 16.1.2 (a), (b), and (c), conductors may be sized in accordance with Annex A, Ref. No. 1, Table 400.5(A)(1) for up to 8 AWG, and Table 400.5(A)(2) for 8 AWG and larger. Alternatively, the cable can be tested to show that under continuous conditions of use at rated current values, the insulating materials of the cable do not exceed their maximum rated temperatures.

In Canada, conductors may be sized in accordance with the Annex A, Ref. No. 1, Table 12.

16.1.4 With reference to 16.1.2(c), the suitability of the cable for the voltage involved can be determined by a Dielectric Voltage-Withstand Test, Section 50, across the applicable insulation within the cable.

16.1.5 In the US and Mexico, and in dry locations in Canada, the overall length of the cable intended for connection to an EV shall not exceed 7.63 m (25 feet) unless the charger is equipped with a cable management system that is suitable for the purpose.

In Canada, the overall length shall not exceed 5 m (16.5 feet) unless the charger is equipped with a cable management system that is suitable for the purpose.

16.1.6 External connections of a unit shall be protected by a mechanical interlock or other means so that the connection is not energized unless it is coupled to the EV.

16.1.7 External connections of a unit shall be protected by a means that de-energizes the cable conductors and connector upon exposure to a strain which results in either cable rupture or separation of the cable from the vehicle connector and allows for access to live parts.

### 16.2 Ventilation connections

16.2.1 Some electric vehicles may contain batteries that vent gases during charging. These battery types shall not be charged indoors unless proper ventilation is provided to remove the expelled gases. Permanently connected charging equipment that is designed to charge batteries that require proper ventilation shall be electrically interconnected with the ventilating system such that the charging equipment will not start charging or will terminate charging if the ventilation system is not operational.

16.2.2 The provisions for connection shall consist of:

a) Either wiring terminals as specified in 14.1.1.4 – 14.1.2.15 or wiring leads as specified in 14.1.1.4, 14.1.3.1 – 14.1.3.8, and

b) A means for connection of cable or conduit as specified in 14.2.1.

16.2.3 A permanently connected unit which is not designed to charge batteries that require ventilation shall be marked in accordance with 76.3.17.

16.2.4 A portable unit or a fastened in place unit shall be marked in accordance with 76.3.17.

## 17 EV Bonding



17.1 The personnel protection system required by 9.1 will be either a grounded system of protection or an isolated system of protection. For grounded systems of protection, the output circuit of a unit shall provide a means for bonding the EV when connected. For isolated systems of protection, the vehicle shall be isolated from the source and the bonding means provided for monitoring purposes only. When bonded as part of a grounded system of protection, the bonding conductor shall not be smaller than the conductors supplying current to the EV or the conductor shall be evaluated in accordance with the Bonding Conductor Connection Test, Section 60.

## 18 Equipment Bonding/Grounding

### 18.1 Input circuits

18.1.1 There shall be provisions for bonding/grounding all non-current-carrying conductive parts that are exposed or that possess a risk of being contacted by a person during intended operation or adjustment and that are capable of becoming energized as a result of electrical malfunction.

18.1.2 The provisions for equipment bonding/grounding specified in 18.1.1 shall be provided for the input wiring system to be connected to the alternating current supply. Accessible signal circuits described in Accessible Signal Circuits, Section 26 are not required to have provisions for equipment grounding.

18.1.3 To determine whether a part is capable of becoming energized, factors such as construction, the proximity of wiring, and results of a dielectric voltage-withstand test conducted after the appropriate overload, endurance, and abnormal tests are to be evaluated.

NOTE: In Canada, a construction in compliance with CSA C22.2 No. 0.4 Clause 4.2 is considered to comply with this requirement.

18.1.4 The bonding/grounding means for fixed in place equipment shall consist of an equipment-grounding or bonding terminal or lead.

18.1.5 An equipment-grounding or bonding terminal means or lead shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the risk of inadvertent loosening, the head of the screw or bolt shall not be accessible from outside of the enclosure. The head of a double-nut secured bolt or screw is not required to comply with respect to accessibility.

NOTE: In Canada, a construction in compliance with CSA C22.2 No. 0.4 is considered to comply with this requirement.

18.1.6 An equipment-grounding or bonding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

18.1.7 An equipment-grounding point or bonding means shall be located so that the risk of inadvertently removing the grounding means during servicing is reduced.

18.1.8 A free end of an equipment-grounding or bonding lead shall be insulated (for example, the end is to be folded back and taped to the lead) unless the lead is located so that it does not contact live parts in the event that the lead is not used in the field.

18.1.9 Except as noted in 18.1.10, an equipment-grounding or bonding lead shall be a size intended for the application in accordance with Annex A, Ref. No. 1 (Mexico and US) and Annex A, Ref. No. 1, Table 16 (Canada). The lead shall have a free length of at least 152 mm (6 inches) and the surface of the insulation shall be green with or without one or more yellow stripes. No other lead in a field-wiring compartment or visible to the installer shall be so identified.

In Canada, CSA C22.2 No. 0.4 shall be consulted for alternate markings.

18.1.10 The color coding requirement does not apply to low-voltage Class 2 circuits when the low-voltage leads are:

a) Located remote from the line-voltage connections and the segregation complies with the requirements in Separation of Circuits, Section 28, or

b) Marked in accordance with 76.2.17.

18.1.11 The equipment-grounding/bonding conductor of a power-supply cord shall be connected to the grounding blade of a grounding attachment plug and shall be connected to non-current carrying metal parts within the frame or enclosure by means of a screw not to be removed during ordinary servicing not involving the power-supply cord. The surface of any insulation on the grounding/bonding conductor shall be green with or without one or more yellow stripes and no other conductor shall be so identified. See 76.3.12. An external force applied to the power-supply cord shall not transmit stress to the equipment-grounding/bonding connection on the frame or enclosure before the line-voltage connections are broken.

NOTE: In Canada, a construction in compliance with CSA C22.2 No. 0.4 is considered to comply with this requirement.

18.1.12 An equipment-grounding/bonding conductor shall not be spliced.

18.1.13 A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding/bonding. A quick-connect terminal that is additionally secured by soldering may be used for connection of an equipment-grounding/bonding conductor of a power-supply cord to non-current carrying metal parts within the unit.

NOTE: In Canada, a construction in compliance with CSA C22.2 No. 0.4 is considered to comply with this requirement.

18.1.14 The equipment-grounding/bonding terminal shall be capable of securing a conductor of a size intended for the application in accordance with Annex A, Ref. No. 1, and shall be constructed in accordance with the requirements specified in 14.1.2.1 – 14.1.2.14.

18.1.15 A wire-binding screw employed for the connection of a field-installed equipment grounding/bonding conductor shall have a green colored head that is either hexagonal, slotted, or both, and have a head diameter of not less than that specified for pan head screws in Annex A, Ref. No. 30. A pressure wire connector intended for connection of such a conductor shall be marked as described in 76.2.10.

## 19 Bonding of Internal Parts

19.1 On a unit having provisions for bonding/grounding – see 18.1.1 – all exposed non-current-carrying conductive parts that are capable of becoming energized through electrical fault that involves a risk of electric shock or electrical energy – high current levels, shall be conductively connected to the equipment bonding/grounding means.

19.2 Except as noted in 19.3, in a unit having provisions for bonding/grounding, all uninsulated metal parts of the enclosure, motor frames and mounting brackets, component mounting brackets, capacitors, and other electrical components that involve a risk of electric shock or electrical energy – high current levels, shall be bonded when they are capable of being contacted by the user or inadvertently contacted by the qualified electrical maintenance personnel.

19.3 A non-current carrying metal part as described in (a) – (g) is not required to be bonded:

a) An adhesive-attached metal foil marking label, a screw, a handle, or similar device, that is located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by bonded/grounded metal parts so that the risk of them becoming energized is reduced.

b) An isolated metal part, for example, a magnet frame and an armature, a small assembly screw, or similar device, such that a physical separation is maintained from wiring and uninsulated live parts.

c) A panel or cover that does not enclose uninsulated live parts when wiring is physically separated from the panel or cover so that the risk of them becoming energized is reduced.

d) A panel or cover that is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 0.8 mm (1/32 inch) thick and secured in place.

NOTE: In Canada, an insulating panel and cover construction in compliance with CSA C22.2 No. 0.4 is considered to comply with this requirement.

e) An isolated metal part that is mounted on a printed wiring board – such as transformer and choke cores and heat sinks.

f) In Mexico and the US, an isolated metal part that is marked in accordance with 76.3.11.

In Canada, sub-clause f) is not permitted. Clause 4.2 of C22.2 No. 0.4 shall apply.

g) A capacitor sleeved with insulating tubing complying with 23.2.4.

19.4 In the US and Mexico, an internal connection for bonding internal parts to an enclosure, and not for a field-installed bonding/grounding conductor or for the bonding/grounding conductor in a supply cord, shall not employ a quick-connect terminal unless:

a) The connector is capable of being displaced,

b) The terminal has the dimensions specified in Table 19.1, and

c) The component is limited to use on a circuit having a branch-circuit protective device rated 20 amperes or less.

In Canada, CSA C22.2 No. 0.4 shall apply for quick-connect. See Annex A of No. 0.4.



**Table 19.1**
**Quick-connect Terminals for Bonding Internal Parts**

| Nominal size of terminal, mm (inches) | | | | | |
|---|---|---|---|---|---|
| Width | | Length | | Thickness | |
| 4.7 | (0.187) | 6.4 | (1/4) | 0.5 | (0.020) |
| 4.7 | (0.0187) | 6.4 | (1/4) | 0.8 | (0.032) |
| 5.2 | (0.205) | 6.4 | (1/4) | 0.8 | (0.032) |
| 6.4 | (0.250) | 8.0 | (5/16) | 0.8 | (0.032) |

19.5 Metal-to-metal piano-type hinges are an example of a means for bonding a door for grounding.

19.6 Where the continuity of the bonding/grounding system relies on the dimensional integrity of a nonmetallic material, the material shall be in accordance with the requirements for creep in Annex A, Ref. No. 31. See also 19.10.

19.7 A separate component bonding conductor shall be of copper, a copper alloy, or an equivalent electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by painting, galvanizing, plating, or equivalent means.

19.8 A separate bonding conductor or strap shall be protected from mechanical damage or be located within the outer enclosure or frame, not be secured by a removable fastener used for any purpose other than bonding, unless the bonding conductor is not to be omitted after removal and replacement of the fastener, and not be spliced.

19.9 The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455 °C (850 °F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material, other than as indicated in 19.11.

19.10 With reference to 19.9, when penetration of a nonconductive coating is not determined by examination, a Grounding Impedance Test, 57.1, shall be conducted.

19.11 A connection that depends upon the clamping action exerted by rubber or similar material may be used when it complies with the requirements in the Bonding Conductor Connection Test, Section 60, for bonding conductors under any normal degree of compression applied by a variable clamping device and when the results are not significantly changed after exposure to the effects of oil, grease, moisture, and thermal degradation that occur in service. Also, the effect of assembling and disassembling, for maintenance purposes, such a clamping device is to be considered with particular emphasis on reassembling it in its intended position.

19.12 A separate component-bonding conductor shall either be of size intended for the application in accordance with Annex A, Ref. No. 1, see 19.12, not be smaller than the conductor supplying the component, or comply with the Bonding Conductor Connection Test, Section 60.

NOTE: In Canada, bonding conductors in compliance with CSA C22.2 No. 0.4 is considered to comply with this requirement.

19.13 When more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, when a motor is individually protected by a branch-circuit overcurrent device smaller than other overcurrent devices used with the unit, a bonding conductor for that motor is sized on the basis of the overcurrent device intended for ground-fault protection of the motor.

## 20 Internal Wiring

### 20.1 Wires

20.1.1 The internal wiring of a unit shall be rated for the particular application with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring is subjected.

20.1.2 With respect to 20.1.1, the effects of vibration, impact, and exposure are to be evaluated for wires smaller than 24 AWG (0.21 mm$^2$).

20.1.3 All wiring shall be Appliance Wiring Material (AWM) in accordance with Annex A, Ref. No. 32 and shall be rated and surface marked "VW-1."

20.1.4 Except as noted in 20.1.5 and 20.1.6, helical wraps and other continuous forms of harnessing shall be classed V-2 or less flammable when tested in accordance with Annex A, Ref. No. 18.

20.1.5 A harness is not required to be classed V-2 or less flammable when, after tested as an assembly, the assembly is classed V-2 or less flammable.

20.1.6 Lacing tape, twine, individual cable clamps, and noncontinuous cable ties are not required to be classed V-2 or less flammable.

20.1.7 Wiring that extends from the enclosure to a hinged door or other part that is subject to movement in use other than installation and servicing shall be stranded and the arrangement shall preclude twisting or stressing of conductors as a result of the movement. The wiring shall be routed or protected to reduce the risk of damage to the insulation. The conductors shall be of a jacketed type, such as Type SJ, SJO, or SJT, and provided with strain relief so that stress is not transmitted to terminals or splices.

20.1.8 The conductors of a low-voltage, limited-energy circuit described in 2.24 are not required to comply with 20.1.7.

20.1.9 A bonding lead used for grounding a door is not required to be jacketed in accordance with 20.1.7.

20.1.10 Wiring of a type other than those mentioned in 20.1.7 that is subject to motion, and any supplementary insulation provided on the wire that complies with the Flexing test, Section 55, are not required to comply with 20.1.7.

20.1.11 The length of a power-supply cord inside a unit shall be limited to that needed for electrical connections.

### 20.2 Protection of wiring

20.2.1 Internal wiring shall not be accessible when judged in accordance with Protection of Users – Accessibility and User Servicing, Section 8, unless it is located and secured within the enclosure such that the risk of it being subjected to stress or mechanical damage is reduced.

20.2.2 Wires within an enclosure, compartment, raceway, or similar part shall be located or protected to reduce the risk of unintentional contact with any sharp edge, burr, fin, moving part, or similar part that damages the conductor insulation.

20.2.3 Internal wiring shall be so routed and secured that neither it nor related electrical connections are to be subjected to stress or mechanical damage.

20.2.4 A hole in a sheet-metal wall through which insulated wires pass and on which they bear shall be provided with a smoothly rounded bushing or shall have smooth, rounded surfaces upon which the wires bear, to avoid abrasion of insulation.

20.2.5 A bushing used on other than smooth, rounded surfaces of a hole through which wires pass shall be of material that has mechanical and heat-resistant properties – such as porcelain, phenolic, fiber at least 1.2 mm (3/64 inch) thick, a material complying with Annex A, Ref. No. 12 – see 34.2 – or smooth, rounded metal.

20.2.6 Metal clamps and guides used for routing stationary internal wiring shall be provided with smooth well-rounded edges.

20.2.7 Auxiliary mechanical protection that is not electrically conductive shall be provided under a metal clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 0.76 mm (0.030 inch) thick and no overall braid, and on any wire or wires that are subject to motion. Auxiliary mechanical protection is not required for conductors having cross-linked synthetic insulation.



## 21 Current-Carrying Parts

### 21.1 General

21.1.1 A current-carrying part shall be of silver, copper, a copper-base alloy, stainless steel, aluminum, or the equivalent. Using plated steel for secondary-circuit parts and for some primary-circuit parts (such as for capacitor terminals where a glass-to-metal seal is required and for leads or threaded studs of semiconductor devices) is allowed. Blued steel or steel with equivalent corrosion resistance may be used for the current-carrying arms of mechanically operated leaf switches and within a motor and its governor, motor terminals included, or where the temperature is in excess of 100 °C (212 °F).

21.1.2 An uninsulated live part and a component that has uninsulated live parts shall be so secured to the base or mounting surface that they do not turn or shift in position where such displacement results in a reduction of spacings below the minimum required values in Section 23.

## 21.2 Bus bars

21.2.1 Each bus bar shall be plated at each joint with tin, silver, or nickel, except that:

a) Welded or brazed joints are not required to be plated;

b) Copper bus bars are not required to be plated when the current at the joint is 600 amperes or less;

c) Other coatings used for aluminum bus bars are allowed when investigated for the application in accordance with the requirements for current-carrying parts described in Section 66; and

d) A bus bar provided with an oxide inhibiting compound over the joint surfaces is not required to be plated when the compound is in accordance with 21.3.2.

21.2.2 The bending of a bus bar shall not result in visible cracks with the exception of roughening or slight surface crazing.

21.2.3 Each riveted joint connection shall have a spring washer at one end and either a spring washer or a flat washer at the other end except that:

a) A connection rated 225 amperes or less employing copper bus bars only is not required to comply; and

b) Other constructions employing a rivet may be used when they are investigated in accordance with the applicable requirements in Bus Bar Tests, Section 66.

See 21.2.5 and 21.2.6.

21.2.4 Each joint connection shall employ a spring washer at one end of a bolt except that:

a) The spring washer may be replaced with a split ring lock washer and flat washer when each bus in the joint is copper or when each aluminum bus in the joint has a tensile yield strength of at least 20,000 psi (138 MPa);

b) A flat washer, a split-ring lock washer, or a bolthead that complies with 21.2.5 may be used in place of a spring washer when the joint does not include any aluminum or when aluminum bolts are used with aluminum bus bars; and

c) Other constructions may be used when they are investigated in accordance with the applicable requirements in Section 66.

See 21.2.6.

21.2.5 The flat washer mentioned in 21.2.3 and 21.2.4 shall have a thickness of at least one-sixth that of the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 % of the rivet shank or bolt and not less than the outer diameter of any adjacent spring washer.

21.2.6 A spring washer as mentioned in 21.2.3 and 21.2.4 is a dished washer of stainless, or hardened and tempered steel, having an outer diameter not less than 150 % of the bolt diameter, a thickness not less than one-eighth of the bolt diameter, and dished not less than 3-1/2 % of the bolt diameter.

21.2.7 Unless investigated for such use, a bolted connection between two bus bars or between a bus bar and another current-carrying part shall not depend on the dimensional integrity of a thermoplastic material.

21.2.8 Insulation over bus bars such as tape or tubing as described in 23.2.4 and 23.2.5 shall not be provided over a bolted joint so that tightening of the joint is accomplished without removal of the insulation.

21.2.9 The current density of a bus bar shall not exceed the values specified in Table 21.1 or Table 21.2 unless:

a) The bus bar has characteristics that do not result in maximum bus bar temperatures exceeding the values specified in Table 49.1.

b) The bus bar contained in a unit has forced air ventilation that does not result in maximum bus bar temperatures exceeding the values specified in Table 49.1.

**Table 21.1**
**Ampacity of Single or Multiple Bus Bars and Clamped Joints**

| | | Current density in amperes per square inch (6.45 $cm^2$) | |
|---|---|---|---|
| **Bus bar material[d]** | **Current** | **Bus bar cross section** | **Contact area at clamped joints** |
| Copper | 0 – 600 amperes | 1000[e] | 200 |
| Copper | Over 600 | 1000[e] | 200[a,b] |
| Aluminum[c] | Any | 750[e] | 200[a,b] |

[a] See 21.1.1, 21.2.10 – 21.2.12.

[b] Joints bolted and plated with silver, tin, or nickel.

[c] Minimum conductivity of 55 % of International Annealed-Copper Standard.

[d] Multiple bus bars in parallel shall be of the same material.

[e] See also Table 21.2 for 800 ampere maximum single bus bars.



**Table 21.2**
**Rating and Sizes of Single Bus Bars – 800 Amperes Maximum**

| Current rating in amperes | Copper bus | | | | Aluminum bus[b] | | | |
|---|---|---|---|---|---|---|---|---|
| | Bus size[a,b] | | Cross section | | Bus size[a] | | Cross section | |
| | mm | (Inches) | $mm^2$ | ($Inch^2$) | mm | (Inches) | $mm^2$ | ($Inch^2$) |
| 225 | 3.2 by 22.2 | (0.125 by 0.875) | 70.3 | (0.109) | 6.4 by 22.2 | (0.250 by 0.875) | 141.3 | (0.219) |
| 400 | 6.4 by 38.1 | (0.250 by 1.500) | 242.0 | (0.375) | 6.4 by 50.8 | (0.250 by 2.000) | 322.6 | (0.500) |
| 600 | 6.4 by 50.8 | (0.250 by 2.000) | 322.6 | (0.500) | See Table 21.1 | See Table 21.1 | 518.1 | (0.800) |
| 800 | 6.4 by 76.2 | (0.250 by 3.000) | 483.9 | (0.750) | See Table 21.1 | See Table 21.1 | 688.4 | (1.067) |

NOTES

1 See 21.2.10 – 21.2.12; for multiple buses in parallel, refer to Table 21.1. The minimum contact area at a clamped joint shall provide not less than 6.5 $cm^2$ (1 square inch) per 200 amperes.

2 Bolted joints and bus bars plated with silver, tin, or nickel.

[a] A bus bar having other dimensions is not prohibited when it has not less than the cross-sectional area specified in the table and when it has equivalent rigidity.

[b] Minimum conductivity of 55 % of International Annealed-Copper Standard.

21.2.10 The cross section of a bus as covered in Table 21.1 or Table 21.2 shall be reduced by not more than 5 % due to rounding, shaping, or dimensional tolerances.

21.2.11 Removing part of the bus material for slots or holes (whether used or not) is allowed when:

a) The remaining material at any cross section along the length of the bus bar has at least 70 % of the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.10, and

b) The remaining metal in any 152 mm (6-inch) length of bus is at least 93 % of the metal of a bus having the required ampacity in accordance with Table 21.1 or Table 21.2 and 21.2.10. For example, a 25.4 mm (1-inch) wide bus is capable of having 7.1 mm (9/32 inch) holes on 1-inch centers or a 102 mm (4-inch) wide bus is capable of having 10.3 mm (13/32-inch) wide slots 81.3 mm (3.2 inches) long every 6 inches.

These limitations do not apply to a bus bar having characteristics that do not result in maximum bus bar temperatures exceeding the values specified in Table 49.1 under the test conditions indicated in Temperature Test, Section 49.

21.2.12 The limitations on current density mentioned in Table 21.1 and Table 21.2 do not apply to a:

a) Connecting strap, bus, or similar device comprising a part of a circuit breaker, switch, or fuseholder employed in the unit.

b) Portion of a strap, bus, jumper, or similar part adjacent and connected to a terminal of a switch, circuit breaker, or fuseholder, and not more than 25.4 mm (1 inch) from the terminal, when a reduced cross section in that portion is required because of the recessing of the terminal or because of barriers adjacent to it.

### 21.3 Live heat sinks

21.3.1 A current-carrying, aluminum heat sink shall be plated, conductive anodized, irradiated or the equivalent at surfaces contacting the solid-state component. This requirement does not apply to the following:

a) A live heat sink that is not used to conduct current;

b) A heat sink provided with an oxide inhibiting compound over the heat sink surfaces contacting the solid-state component when the compound is in accordance with 21.3.2; and

c) A heat sink subjected to the heat cycling tests described in Section 63.

21.3.2 An oxide inhibiting compound as referenced in 21.3.1(b) shall be stable at both elevated and low temperatures and the thermal conductivity of the heat sink/solid state component junction shall not be adversely affected by temperature cycling. The elevated temperature is based on the maximum temperature of the live heat sink during the temperature test, or the maximum ambient temperature as specified by the manufacturer, whichever is higher. The lower temperature is equal to the lowest ambient temperature as specified by the manufacturer.

## 22 Electrical Connections

22.1 The requirements described in 22.2 – 22.7 apply to connections of internal wiring that are factory installed in the unit.

22.2 A splice or connection shall be mechanically secure and shall make electrical contact.

22.3 A soldered connection is determined to be mechanically secure when the lead is:

a) Wrapped one full turn around a terminal,

b) Bent at a right angle after being passed through an eyelet or opening, except on printed-wiring boards where components are inserted or secured (as in a surface mounted component) and wave- or lap-soldered, or

c) Twisted with other conductors.

22.4 When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact other uninsulated conductive parts. This is to be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering of all strands together, or by any other equivalent means.

22.5 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with Annex A, Ref. No. 32. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises; all tests shall be conducted in accordance with Annex A, Ref. No. 33.

22.6 An open-end spade lug is not to be used unless an additional means, such as upturned ends on the lug or bosses or shoulders on the terminal, is provided to hold the lug in place when the binding screw or nut loosens.

22.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts. Insulation over the splice is not prohibited from having:

a) A splicing device such as a pressure wire connector, employed when insulated for the voltage and temperature the device is to be subjected;

b) Insulating tubing or sleeving used to cover a splice shall be used in accordance with 23.2.4; or

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, where the voltage involved is less than 250 volts. Thermoplastic tape wrapped over a sharp edge shall not be used. A splicing device, insulating tubing, sleeving, or tape is not required to be used on splices within coil windings. See 27.2.1 – 27.2.3.

## 23 Spacings

### 23.1 General

23.1.1 Except as noted in 23.1.2, the spacings for a unit shall not be less than the applicable values specified in Table 23.1 or as provided in Alternate Spacings – Clearances and Creepage Distances, Section 24.

23.1.2 The following exceptions apply to the requirement in 23.1.1:

a) As provided in 23.2.1 where liners and barriers are used.

b) Between adjacent foils on printed wiring boards provided with a conformal coating complying with the requirements in Annex A, Ref. No. 12. See 23.1.3.

c) On printed-wiring boards having a flammability classification of V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 175 volts, spacings (other than spacings to ground, between primary and secondary circuits, between the battery supply circuit and other circuits, and at field wiring terminals) are not specified between traces of different potential connected in the same circuit where

1) The spacings comply with the requirements in Evaluation of Reduced Spacings on Printed-Wiring Boards, Section 62 or

2) An analysis of the circuit indicates that no more than 12.5 milliamperes of current flows between short-circuited traces having reduced spacings.

d) For multilayer-printed wiring boards, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated-through hole is 1/32 inch (0.8 mm). When these foils are in circuits described in 23.1.13 or 23.1.14, no spacing is specified.

e) The spacing requirements in Table 23.1 do not apply to inherent spacings of a component such as a switch, lampholder, power switching semiconductor, or a motor. See 23.1.6.

f) Spacings within a transformer shall be provided in accordance with Table 27.2 at locations that are not insulated, including those with film-coated magnet wire.

g) Spacing requirements do not apply between adjacent terminals of a power switching semiconductor device including the connection points of the terminals of the device.



23.1.3 With reference to 23.1.2 b) concerning conformal coatings, minimum spacings between adjacent foils are based on voltage transient and dielectric voltage-withstand tests in accordance with Annex A, Ref. No. 12. A conformal coating on printed wiring boards is not to be used as insulation in lieu of spacings between a foil on a printed wiring board and uninsulated live metal parts of opposite polarity or to non-current carrying metal parts.

23.1.4 Where an uninsulated live part is not rigidly secured in position by means other than friction between surfaces or where a movable non-current carrying metal part is in proximity to an uninsulated live part, the construction shall be such that, for any position resulting from turning or other movement of the parts in question, at least the minimum required spacings shall be maintained.

23.1.5 With reference to 23.1.4, a lock washer applied as intended is a method of rigidly securing a part.

**Table 23.1**
**Spacings**

| Potential involved, volts rms (Peak) | | Minimum spacings, mm (inch) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part | | | | Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[a] | |
| | | Through air | | Over surface | | Shortest distance | |
| 0 – 50 | (0 – 70.7) | 1.6 | (1/16)[b,c] | 1.6 | (1/16)[b,c] | 1.6 | (1/16)[b] |
| Greater than 50 to 150 | (70.7 to 212.1) | 3.2 | (1/8)[b,c] | 6.4 | (1/4)[c] | 6.4 | (1/4) |
| Greater than 150 to 300 | (212.1 to 424.2) | 6.4 | (1/4) | 9.5 | (3/8) | 12.7 | (1/2) |
| Greater than 300 to 600 | (424.2 to 848.4) | 9.5 | (3/8) | 12.7 | (1/2) | 12.7 | (1/2) |
| Greater than 600 to 1000 | (848.4 to 1414) | 19.1 | (3/4)[d] | 19.1 | (3/4)[d] | 19.1 | (3/4) |
| Greater than 1000 to 1500 | (1414 to 2121) | 1 | (25.4) | 1-1/5 | (30.5) | 1-1/5 | (30.5) |

**Table 23.1 Continued on Next Page**

**Table 23.1 Continued**

| Potential involved, volts rms (Peak) | Minimum spacings, mm (inch) | | |
|---|---|---|---|
| | Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part | | Between any uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[a] |
| | Through air | Over surface | Shortest distance |

[a] For the purpose of this requirement, a metal piece attached to the enclosure is a part of the enclosure when deformation of the enclosure reduces spacings between the metal piece and uninsulated live parts.

[b] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded non-current carrying metal part shall not be less than 6.4 mm (1/4 inch).

[c] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, a spacing of 1.2 mm (3/64 inch) meets the intent of the requirement.

[d] Between uninsulated high-voltage parts and (1) uninsulated high-voltage parts of opposite polarity or different potentials, (2) earth-grounded metal parts, (3) uninsulated primary-circuit parts, (4) insulated primary-circuit parts, (5) insulated high-voltage parts of opposite polarity, or of different potentials.



23.1.6 Inherent spacings of the components mentioned in 23.1.2 e) shall comply with the requirements for the component in question where the spacings are less than the values specified in this standard. Spacings from such components to another component and to the enclosure shall comply with the applicable spacings specified in this standard.

23.1.7 With respect to judging spacings, an uninsulated live part is at opposite polarity to uninsulated live parts in another circuit. Spacings are to be based on the highest of the circuit voltages. See 50.2.1 – 50.2.3.

23.1.8 Film-coated wire is an uninsulated live part when judging spacings.

23.1.9 Spacings at field-wiring terminals are to be measured with conductors installed in the terminals. The gauge of these conductors is to be based on the rating of the circuit containing the terminals. See 14.1.1.4.

23.1.10 Spacings between uninsulated live parts of different potential and between such parts and non-current carrying metal that are capable of being grounded in service are not specified for parts of LVLE circuits in accordance with 2.24 nor in accessible signal circuits described in Accessible Signal Circuits, Section 26.

23.1.11 Spacings between uninsulated live parts of different potential and between such parts and non-current carrying metal that are capable of being grounded in service are not specified for parts of limited-energy circuits in accordance with 2.22. Spacings in these circuits exceeding 30 volts rms (42.4 volts peak) or 60 volts, dc are judged by the applicable test described in Dielectric Voltage-Withstand Test, Section 50. Also see 51.1.

23.1.12 Spacings within the circuits described in (a) and (b) below that are not safety circuits are not specified. The spacings in these circuits shall be judged on the basis of the Dielectric Voltage-Withstand Test, Section 50. Also see 51.1. Spacings between these circuits and the enclosure, grounded non-current carrying metal, and other circuits shall comply with the applicable spacing requirements.

a) Secondary circuits supplied by a transformer winding of less than 200 volt-amperes or at a potential of 100 volts or less; and

b) Battery circuits at a potential of 100 volts or less. See 23.1.13.

23.1.13 With reference to 23.1.12 (b), spacings within a circuit derived from a battery supply rated over 100 volts are not specified when the voltage within the circuit is limited to 100 volts or less by a regulating network complying with the requirement in 25.11.

23.1.14 Except as noted in 23.1.15, the spacings between live and non-current carrying metal parts within an instrument shall be determined by conducting the applicable dielectric voltage-withstand test described in Dielectric Voltage-Withstand Test, Section 50.

23.1.15 A meter complying with the requirements in Annex A, Ref. No. 9, is not required to be subjected to a dielectric voltage-withstand test.

23.1.16 Epoxy is used to reduce spacings only when the following conditions are met:

a) Spacings of minimum 0.8 mm (1/32 inch) are maintained prior to application of the epoxy;

b) There are no significant voids in the epoxy;

c) The epoxy is minimum 0.8 mm (1/32 inch) thick;

d) The area of reduced spacing, with epoxy applied, withstands the applicable potential specified in the Dielectric Voltage-Withstand Test, Section 50, except when the normal operating potential between the parts under evaluation does not exceed 600 V rms; and

e) The epoxy temperature during the Temperature Test does not exceed 65 °C (117 °F) rise (based on an assumed operating ambient rating of 25 °C (77 °F) or 90 °C (194 °F) limit (when tested at an ambient rating of greater than 25 °C). When the epoxy has been investigated and determined to have a higher operating temperature rating, the temperatures may be exceeded when temperatures do not exceed the material temperature rating.

### 23.2 Insulation barriers

23.2.1 Except as noted in 23.2.2 and 23.2.3, an insulating liner or barrier of material such as vulcanized fiber may be employed in lieu of required spacings mentioned in 23.1.2 a) but not as the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current when it is not less than 0.71 mm (0.028 inch) thick and it is so located that it is not adversely affected by arcing. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current shall comply with the requirements in Annex A, Ref. No.12.

23.2.2 Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is used only when:

a) In conjunction with an air spacing of not less than 50 % of the minimum through air spacing; and

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

23.2.3 Mica not less than 0.165 mm (0.006 inch) may be used as insulation between a heat sink and a live case of a semiconductor device.

23.2.4 Insulating tubing complying with Annex A, Ref. No. 34, may be used as insulation of a conductor including bus bars in lieu of the minimum spacings and a capacitor case in lieu of bonding the case for grounding, only when the following conditions are met:

a) The conductor is not subjected to compression, repeated flexure, or sharp bends;

b) The conductor or case covered with the tubing is well rounded and free from sharp edges;

c) The tubing is used in accordance with the manufacturer's instructions; and

d) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

Insulation provided over a bolted joint of a bus bar as specified in 21.2.8 need not comply with this requirement.

23.2.5 A wrap of thermoplastic tape, complying with the requirements in Annex A, Ref. No. 35 is permitted when all of the following conditions are met:

a) The wrap is no less than 0.33 mm (0.013 inch) thick, is applied in two or more layers, and is used in conjunction with no less than one-half the required through air spacing.

b) The wrap is no less than 0.72 mm (0.028 inch) thick when used in conjunction with less than one-half the required through air spacing.

c) Its temperature rating is no less than the maximum temperature observed during the temperature test.

d) The tape is not subject to compression.

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

f) The tape is not wrapped over a bolted bus bar joint – see 21.2.8.

## 24 Alternate Spacings – Clearances and Creepage Distances

24.1 As an alternative to the spacing requirements of Section 23, as applicable, the spacing requirements in Annex A, Ref. No. 36 is used. The spacing requirements of Annex A, Ref. No. 36 shall not be used for field wiring terminals and spacings to a non-current carrying metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be taken into account and is capable of modifying those characteristics given in 24.2 and 24.3.

24.2 The level of pollution for dry location use equipment shall be pollution degree 2. For equipment intended for use in wet and damp locations, the level of pollution shall be pollution degree 3. Hermetically sealed or encapsulated enclosures, or coated printing wiring boards in compliance with the Printed Wiring Board Coating Performance Test of Annex A, Ref. No. 36, are pollution degree 1.

24.3 The equipment shall be rated overvoltage category III, II, and I as defined in Annex A, Ref. No. 36.

24.4 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

24.5 All printed wiring boards are considered to have a minimum comparative tracking index of 100 without further investigation.

## 25 Control Circuits

25.1 A LVLE circuit as described in 2.24 or a limited-energy circuit as described in 2.22 may be connected to a single-point reference ground.

25.2 Except as indicated in 25.3, a LVLE circuit – see 2.24 – is not required to be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.4, and 33.1.

25.3 Safety circuits shall be judged by the requirements for primary circuits.

25.4 A control circuit, including associated electronic components on printed wiring boards, that does not extend out of the unit is not required to be investigated when the maximum voltage and current are limited to 8 amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 25.5. Printed wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 20.1.1, 20.1.3, and 33.1.

The current values do not apply when the circuit includes an overcurrent protection device as described in 25.8 and 25.9.

25.5 With reference to the current specified in 25.4, the maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current, and not exceeding the value indicated in 25.4.

25.6 With reference to the voltage limit specified in 25.4, measurement is to be made with the unit connected to the voltage specified in 45.1 and with all loading circuits disconnected. Where a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

25.7 When the control circuit mentioned in 25.4 is not limited as to available short-circuit current by the construction of a transformer and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network – see 25.11- the circuits in which the current is limited in accordance with 25.8, 25.9, or 25.10 are not required to be investigated.

25.8 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 25.7 shall be rated or set at not more than the values specified in Table 25.1.

**Table 25.1**
**Rating for Secondary Fuse or Circuit Protector**

| Circuit voltage (Volts, rms) | Maximum overcurrent protection (Amperes) |
|---|---|
| 20 or less | 5 |
| More than 20 but not greater than 60 | 100/V[a] |
| [a] V is the maximum output voltage, regardless of load, with the primary energized. | |



25.9 A fuse or circuit protective device may be connected in the primary of a transformer to limit the current in accordance with 25.7 when the protection is equivalent to that specified in 25.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 58.

25.10 One or more resistors or a regulating network used to limit the current in accordance with 25.7 shall be such that the current under any condition of load including short circuit does not exceed the values indicated in 25.4.

25.11 Where a regulating network is used to limit the voltage or current in accordance with 25.4 – 25.10, and the performance is affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor – the network shall comply with the following:

a) The environmental tests specified in Annex A, Ref. No. 37, and

b) Critical components shall be derated in accordance with 37.4.

25.12 In a circuit of the type described in 25.7, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be investigated in accordance with the applicable requirements in this standard.

## 26 Accessible Signal Circuits

26.1 The requirements in 26.2 and 26.3 apply to accessible signal circuits having provision for external connections such as RS232 communication ports or similar connections.

26.2 A signal circuit that extends out of a unit shall be isolated from internal circuits having a voltage that involves a risk of electric shock – as determined in accordance with Electric Shock, Section 9 – by any of the following or the equivalent:

a) An optical isolator having an isolation voltage rating of not less than the Dielectric Voltage-Withstand test potential required in 50.3.1 and complying with the requirements in Annex A, Ref. No. 38,

b) An isolation transformer complying with the requirements in:

1) Annex A, Ref. Nos. 5 and 6, or

2) Annex A, Ref. No. 7.

c) An electro-mechanical relay complying with Annex A, Ref. No. 26, or

d) A voltage regulating network where

1) The voltage being isolated is not derived from the a-c input circuit, and

2) The network does not show a risk of electric shock to appear at the external signal circuits – as determined in accordance with Electrical Shock, Section 9, as a result of a failure mode and effect analysis in accordance with the method described in Annex A, Ref. No. 37.

26.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 26.1 and 26.2.

26.4 The maximum power available from an accessible signal circuit that employs an overcurrent protection device to limit the current as described in the 25.4 shall not exceed the values specified in Table 26.1.



**Table 26.1**
**Maximum Power of Accessible Signal Circuits**

| Circuit voltage volts, rms | Maximum power, volt-amperes |
|---|---|
| 15 or less | 350 |
| More than 15 but not greater than 60 | 250 |

## 27 Transformers

### 27.1 General

27.1.1 A transformer coil, unless inherently moisture resistant, shall be treated with an insulating varnish and baked, or otherwise impregnated to exclude moisture or acid vapor. Film-coated magnet wire is moisture resistant for this case.

27.1.2 A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this standard. For example, a thermal cutoff shall comply with the applicable requirements in this standard and those in Annex A, Ref. No. 39.

27.1.3 A transformer used to supply an accessible signal circuit as described in Accessible Signal Circuits, Section 26 shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 27.2.1 – 27.2.7 so that there is no electrical connection – under normal and overload conditions- between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.

27.1.4 With reference to the requirement in 27.1.3, a transformer complying with the requirements in any of the following standards complies with this requirement:

a) Annex A, Ref. Nos. 5 and 6;

b) Annex A, Ref. No. 40; or

c) Annex A, Ref. No 7.

## 27.2 Coil insulation

27.2.1 A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, when used, as specified in Table 27.1.

**Table 27.1**
**Transformer Insulation**

| Insulation required | | Type of insulation |
|---|---|---|
| 1. | Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts, rms (42.4 volts peak) | a, b, c, or d |
| 2. | Insulation between the primary and any secondary winding | a, b, c, or d |
| 3. | Insulation between any winding or lead connections and non-current carrying metal parts | b, c, d, e, f, or g |
| 4. | Insulation between the crossover leads and (1) the turns of a different winding, (2) the metal enclosure of a unit, or (3) the core | a, d, e, g, or h |
| a. | Electrical grade paper that is waxed or otherwise treated to retard the absorption of moisture and that has a total thickness of not less than 0.71 mm (0.028 inch); polyethylene terephthalate film, not less than 0.178 mm (0.007 inch) thick; or aramid paper, not less than 0.203 mm (0.0085 inch) thick. | |
| b. | A thermoplastic or thermoset coil form not less than 0.71 mm (0.028 inch) thick. | |
| c. | A material having a thickness less than 0.71mm (0.028 inch) is used only when it is equivalent to note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Transformer Insulating Materials, Section 65. | |
| d. | Using spacings specified in Table 27.2 in place of the specified insulation, is not prohibited. | |
| e. | Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.33 mm (0.013 inch) when used in conjunction with an air spacing of one-half that specified in note d. | |
| f. | Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.71 mm (0.028 inch) inch where the insulation is in contact with the enclosure. | |

**Table 27.1 Continued on Next Page**

### Table 27.1 Continued

| Insulation required | Type of insulation |
|---|---|
| g. A material having a thickness less than that specified in notes e and f is not prohibited where it is equivalent to notes e and f and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note e and 5000 volts for the thickness used for note f as determined by the test described in Section 65. | |
| h. Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 27.2 is not prohibited from being used between a crossover lead and the winding to which it is connected when the construction complies with either of the following:<br>1. The coil withstands the applicable dielectric withstand potential described in 50.3.1. The potential is to be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.<br>2. The coil withstands the induced potential described in 50.5.2 and 50.5.5. | |

### Table 27.2
### Spacings Within a Transformer

| Minimum spacing through air and over surface, mm (inch) | |
|---|---|
| Potential involved, volts | Between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a] |
| 0 – 50 | 1.2 (3/64) |
| Greater than 50 to 125 | 1.6 (1/16) |
| Greater than 125 to 250 | 2.4 (3/32) |
| Greater than 250 to 600 | 6.4 (1/4) |
| Greater than 600 to 1500 | 12.7 (1/2) |
| NOTE – This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated. | |
| [a] Includes turns of a coil having a magnet wire coating. | |



27.2.2 Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure in accordance with Protection of Users – Accessibility and User Servicing, Section 8, shall comply with note (a) or (c) of Table 27.1.

27.2.3 Except as noted in 27.2.4 – 27.2.6, a flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other is allowed. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, is to be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note (a), (b), (c), or (d) of Table 27.1.

27.2.4 A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when:

a) The tape insulation complies with note (a) or (c) of Table 27.1,

b) The tape insulation provides a continuous overlap on the bobbin flanges,

c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 53 – see 27.2.7 – and

d) The transformer complies with the induced potential tests described in 50.5.1 – 50.5.5.

27.2.5 A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when

a) The tape insulation complies with note (a) or (c) of Table 27.2,

b) The coils are layer wound, and

c) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with item d of Table 27.1.

27.2.6 A transformer complying with the requirements in either both Annex A, Ref. Nos. 5 and 6, Annex A, Ref. No. 7, or Annex A, Ref. No. 40 complies with this requirement.

27.2.7 With reference to note c in 27.2.4, the Flanged Bobbin Transformer Abnormal Test, Section 53, is not required when the transformer is supplied from a LVLE circuit in accordance with 2.24, or a limited-energy circuit in accordance with 2.22, or complies with the requirements in 25.4 – 25.12.



## 28 Separation of Circuits

### 28.1 Factory wiring

28.1.1 Insulated conductors of different circuits- see 28.1.2 within a unit, including wires in a terminal box or compartment, shall be either separated by barriers or segregated and shall be so separated or segregated from uninsulated live parts connected to different circuits. When each conductor is provided with insulation intended for the highest of the circuit voltages, no barriers or segregation are required.

28.1.2 For the purpose of the requirement in 28.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer,

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer,

c) Circuits connected to secondary windings of different transformers,

d) Input and output circuits of an optical isolator,

e) AC input power and output AC power circuits,

f) AC input power and DC power circuits, and

g) AC output power and DC power circuits.

Power circuits specified in (e), (f), and (g) that are derived from the taps of an autotransformer or similar device – that does not provide isolation – are not different circuits.

28.1.3 Segregation of insulated conductors is to be accomplished by clamping, routing, or an equivalent means that maintains permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

### 28.2 Separation barriers

28.2.1 A barrier used to provide separation between the wiring of different circuits shall be grounded metal or insulating material complying with the requirements for flammability classification of internal materials specified in Printed Wiring Boards, Section 33, and Insulating Materials, Section 34, no less than

0.71 mm (0.028 inch) thick, and supported so that it is not capable of being readily deformed so as to defeat its purpose.

28.2.2 A barrier used to provide separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall be spaced no more than 1.6 mm (1/16 inch) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

### 28.3 Field wiring

28.3.1 Except as noted in 28.3.2, the equipment shall be constructed so that a field-installed conductor of a circuit shall be separated as specified in 28.3.3 or separated by barriers as specified in 28.2.1 and 28.2.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of either circuit.

b) An uninsulated live part of another circuit and from an uninsulated live part where short circuit with it results in a risk of fire, electric shock, electrical energy involving high current levels, or injury to persons.

c) Field-installed conductors connected to any other circuit unless both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3 and both circuits are insulated for the maximum voltage of either circuit.

28.3.2 With reference to the requirements of 28.3.1:

a) A field-installed conductor is not required to be separated from a field wiring terminal of a different circuit when the field wiring is insulated for the maximum voltage of either circuit and both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3; and

b) For circuits operating at 150 V or less to ground, field installed conductors are not required to be separated from field installed conductors of another circuit provided the unit is marked- see 76.2.18 – indicating one of the following:

1) The Class 2 or Class 3 circuit conductors are to be installed using Class 1 wiring methods or

2) The Class 2 or Class 3 circuit conductors are to be installed using Type CL3, CL3R or CL3P cable.



28.3.3 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit is accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 6.4 mm (1/4 inch). In determining whether a unit having such openings complies with this requirement, it is to be wired as in service including 152.4 mm (6 inches) of slack in each conductor within the enclosure. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

28.3.4 With reference to 28.3.3, where the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the unit, and where each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening is to be connected to the terminal opposite that opening. Where more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the risk of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

## 29 Overcurrent Protection

### 29.1 General

29.1.1 Supplementary overcurrent devices are not required unless specifically stated as such in other parts of this Standard or to reduce the risk of electric shock, fire, or injury to persons.

### 29.2 Supplementary protectors

29.2.1 Supplementary protectors shall not be used for overcurrent protection of circuits defined as "branch circuits" as defined in Annex A, Ref. No. 1.

29.2.2 Supplementary protection devices shall be in accordance with Annex A, Ref. No. 41. Supplementary protection devices that are user replaceable shall be accessible from outside the enclosure, or shall be located behind a hinged cover.

29.2.3 Except as indicated in 29.2.4, a supplementary protection device shall not be connected in the grounded (neutral) side of the line.

29.2.4 Additional protection in the grounded side of the supply circuit is allowed when the protection simultaneously disconnects all grounded and ungrounded conductors of the supply circuit.

29.2.5 Where the device has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers may be used as the protection for each ungrounded conductor of a 3-wire single-phase circuit or for each ungrounded conductor of a 4-wire, 3-phase circuit, when no conductor involves a potential to ground in excess of 150 volts.

### 29.3 Thermal links

29.3.1 Non-resettable thermal links incorporated as overcurrent protection shall comply with the applicable requirements in Annex A, Ref. No 39.

### 29.4 Fuses

29.4.1 Fuses used for overcurrent protection shall be plug fuses or cartridge fuses. Plug fuses shall be Edison base or Type S fuses and shall comply with 29.4.2. Cartridge fuses shall be Class CC, G, H, J, K, RK1, RK5, or T, and shall comply with 29.4.3.

29.4.2 Plug fuses shall comply with Annex A, Ref. No. 42 and Annex A, Ref. No. 43. The fuseholder shall comply with Annex A, Ref. No. 44.

29.4.3 Cartridge fuses shall comply with Annex A, Ref. No 42, and additionally, the applicable part Standard based on fuse class. Fuseholders shall comply with Annex A, Ref. No 45, and additionally, the applicable part Standard based on fuse class.

29.4.4 For plug fuses and cartridge fuses, except as indicated in 29.4.5, a disconnecting means shall be provided on the supply side of each fuse. The disconnecting means shall be such that each individual circuit can be independently disconnected from the source of supply.

29.4.5 For service replaceable fuses, the disconnecting means can be the circuit breaker or fused disconnect switch in the building installation. If so used, no additional disconnecting means is necessary, provided that manufacturer's service instructions inform the service personnel to disconnect power to the unit prior to changing the fuse.

29.4.6 A device shall be constructed so that fuses will be readily accessible when the disconnecting means is opened so that the fuse may be replaced without the service personnel or user inadvertently contacting live parts.

29.4.7 If a Type S fuseholder, or Edison base fuseholder with or without a Type S adapter, is used, the line connection shall be made to the center contact.

29.4.8 A fuse and fuseholder shall have a voltage and current rating not less than those for the circuit in which they are connected. Plug fuses are not allowed in a circuit rated more than 125 volts or 125/250 volts, 3-wire.

29.4.9 Fuses shall be located in all ungrounded conductors.

29.4.10 A device shall be marked in accordance with 76.3.8 when it is provided with overcurrent protection consisting of an interchangeable fuse that is accessible to the user, whether the user is instructed to change the fuse or not.

## 29.5 Circuit breakers

29.5.1 Circuit breakers incorporated as overcurrent protection shall comply with Annex A, Ref. No. 46.

## 30 Capacitors



30.1 The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the unit during malfunction of the capacitor does not occur. See 30.3.

30.2 The materials and construction of a capacitor or its case within a unit shall be such that pressures capable of causing injury to persons do not develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 30.3.

30.3 Compliance with the requirements described in 30.1 and 30.2 shall be determined by the Electrolytic capacitor fault test, 52.8.

30.4 Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the unit. See 30.5 and 30.6.

30.5 With reference to the requirement in 30.4, a capacitor complying with the requirements for protected oil-filled capacitors in Annex A, Ref. No 47, is to be constructed to reduce the risk of expelling the dielectric medium.

30.6 With reference to 30.4, a unit having a capacitor other than that described in 30.5 shall be provided with a complete noncombustible bottom panel below the capacitor except as follows:

a) A ventilated, bottom-panel construction complying with either 7.9.3 or 7.9.4; or

b) A ventilated, bottom-panel construction complying with the Capacitor Fault test described in 52.5.1.

30.7 Except as noted in 30.8, a means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock or a risk of electrical energy – high current level. A risk of shock exists when the voltage across the capacitor exceeds the limits specified in

9.2.1. A risk of electrical energy – high current level – exists when the stored energy exceeds 20 joules as determined by the following equation:

$$J = 5 \times 10^{-7} CV^2$$

where:

*C* is in microfarads, and

*V* is in volts.

30.8 The requirement of 30.7 does not apply when:

a) A tool is required to remove a panel to reach the capacitor and the unit is marked as specified in 76.3.9;

b) The unit is marked in accordance with 76.3.10; and

c) The capacitor terminals and all parts connected to these terminals are insulated to reduce the risk of contact of these terminals and parts by qualified electrical maintenance personnel and a cautionary marking per 76.3.14 is provided.

30.9 Capacitors or filters connected across an input ac circuit shall comply with Annex A, Ref. Nos. 48 and 49.

## 31 Resistors

31.1 The assembly of a power resistor, such as a wire-wound type requiring a separate support, shall be reliable. The resistor shall be prevented from loosening or rotating by a means other than friction between surfaces.

31.2 An assembly employing lock washers complies with the requirement in 31.1.

## 32 Lampholders

32.1 A lampholder shall be constructed or installed so that uninsulated live parts, other than a screw shell, are capable of unintentionally contacting by persons removing or replacing the lamp during intended service.

32.2 A medium-base screw-shell lampholder shall not be used in a circuit involving a potential of more than 150 volts.

## 33 Printed Wiring Boards

33.1 Except as noted in 33.2, a printed-circuit board shall comply Annex A, Ref. No. 50, and shall be classed V-0, V-1, or V-2 in accordance with Annex A, Ref. No. 18.

33.2 A printed wiring board located outside an enclosure, such as in an external control circuit, and located in a LVLE circuit or a limited-energy circuit described in 2.24 and 2.22 respectively shall be classed as either minimum V-2, or HB.

33.3 A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.

33.4 Further evaluation is to be conducted for a barrier or a partition that is part of the unit assembly and that provides mechanical protection and electrical insulation of a component connected to the printed-circuit board.

## 34 Insulating Materials

34.1 An insulating material used for supporting live parts and a barrier material shall be moisture-resistant and not be adversely affected by the temperature and stresses to which it is subjected under conditions of use.

34.2 Insulating material is to be judged with respect to the application for which it is to be used. Materials such as mica, some molded compounds, and certain refractory materials are usually used for the sole support of live parts. When an investigation is required to determine whether a material is capable of being used, such investigation is to be conducted in accordance with Annex A, Ref. No. 12. Consideration is to be given to the material's mechanical strength, resistance to hot wire ignition, resistance to high-current-arc ignition, resistance to high-voltage-arc ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions; the degree to which the material is enclosed; and any other feature affecting the risk of fire, electric shock, electrical energy-high current levels, or injury to persons. All factors are to be taken into account with respect to conditions of actual service.

34.3 Ordinary vulcanized fibers used for insulating bushings, washers, separators, and barriers, shall not be the sole support for uninsulated live parts.

34.4 A sensor such as a current transformer, transducer, or similar device, shall be provided with insulation that has been evaluated for the maximum voltage and temperature involved in its application, while taking into account the presence of other circuits.



## 35 Adhesives

35.1 An adhesive that is relied upon to reduce a risk of fire, electric shock, or injury to persons shall comply with the requirements for adhesives in Annex A, Ref. No. 8.

35.2 The requirement in 35.1 also applies to an adhesive used to secure a conductive part, including a nameplate, that when loosened or dislodged:

a) Energizes an accessible non-current carrying metal part,

b) Makes a live part accessible,

c) Reduces spacings below the minimum usable values, or

d) Short-circuits live parts.

## 36 Protection of Service Personnel

36.1 The requirements in this section apply only to service personnel who find they must reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the unit is energized. For requirements covering accessibility of live parts for protection of users, refer to Protection of Users – Accessibility and User Servicing, Section 8.

36.2 Live parts shall be so arranged and covers so located as to reduce the risk of electric shock or electrical energy – high current levels while covers are being removed and replaced.

36.3 An uninsulated live part involving a risk of electric shock or electrical energy – high current levels and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, or similar action or performing mechanical service functions with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

36.4 Live parts involving a risk of electric shock or electrical energy – high current levels – located on the back side of a door shall be either guarded or insulated to reduce the risk of unintentional contact of the live parts by service personnel.

36.5 A component that requires examination, resetting adjustment, servicing, or maintenance while energized shall be so located and mounted with respect to other components and with respect to grounded metal parts that it is accessible for electrical service functions without subjecting the service person to the risk of electric shock, electrical energy- high current, or injury to persons by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring.

36.6 For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, 36.5 requires that protection be provided so that the risk of inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock is reduced, taking into account that misalignment of the tool with the adjustment means is capable of resulting where an adjustment is attempted. This protection is to be provided by locating the adjustment means away from uninsulated live parts or by a guard that reduces the risk of the tool contacting uninsulated live parts.

36.7 A live heat sink for a solid-state component, a live relay frame, or similar device and involving a risk of electrical shock or electrical energy – high current levels, which are capable of being mistaken for non-current carrying metal, shall be guarded to reduce the risk of unintentional contact by the serviceperson or be marked in accordance with 76.3.4.

36.8 Moving parts that are capable of causing injury to persons and that are required to be in motion during service operations not involving the moving parts shall be located or protected so that the risk of unintentional contact with the moving parts is reduced.

36.9 For products that can be serviced in the field, sufficient instruction, on or inside the equipment, shall be provided to verify that no hazardous voltage is present and exposed in the equipment compartment being accessed.

36.10 There shall be marking for each portion of a circuit with hazardous DC voltage on where to measure the presence of voltage. The marking shall be in accordance with 76.3.9.

36.11 An indicator of presence of hazardous DC voltage per 36.10 can be used. The indicator is to work with the supply in the open position.

## 37 Electronic Protection Circuits

37.1 When circuit analysis or test results indicate that single component failure affects the ability of an electronic or solid-state circuit to perform its back-up, limiting, or other function intended to reduce the risk of fire, electric shock, or injury to persons the circuit shall comply with Annex A, Ref. No. 37, including environmental and stress tests applicable to the intended usage of the end-product. When such circuits employ a microprocessor executing software to perform the safety-related function, the software shall comply with Annex A, Ref. No. 51.

37.2 When it is determined that environmental tests are required, the protection control is to be subjected to the following tests in accordance with the method described in Annex A, Ref. No. 37:

a) Transient Overvoltage Test

b) Ramp Voltage Test

c) Electromagnetic Susceptibility Tests

d) Electrostatic Discharge Test

e) Thermal Cycling Test

f) Humidity Test

g) Effects of Shipping and Storage Test

Before and after each test, the control is to be checked for normal operation.



37.3 The following test parameters are to be used in the investigation of the control covered by 37.1 for compliance with Annex A, Ref. No. 37:

a) Electrical supervision of critical components;

b) Audibility as a trouble indicator for an electrical supervision circuit;

c) A field strength of 3 volts per meter (0.91 volts per foot) is to be used for the Radiated EMI Test; and

d) Exposure Class H5 is to be used for the Humidity Test.

37.4 The following test parameters are to be used in the investigation of the circuit employing software covered by 37.1 for compliance with Annex A, Ref. No. 51:

a) The requirements for Software Class 1/Software Class B are to be applied; and

b) A failure in the software during its intended operation does not affect compliance under the following conditions:

1) There is no loss of protective function as specified by the manufacturer, or

2) The EV charging system equipment is de-energized such that there is no longer a risk.

## PROTECTION OF USERS AGAINST INJURY

### 38 General

38.1 Where the operation and maintenance of a unit by the user involves a risk of injury to persons, means shall be provided to reduce the risk.

38.2 For the purpose of the requirements described in 38.3 – 44.1, the words "injury to persons" are in reference to physical harm to persons other than the physiological effects of electric shock.

38.3 When judging a product with respect to the requirement in 38.1, reasonably foreseeable misuse of the unit shall be a factor.

38.4 A functional attachment that is made available or specified by the manufacturer for use with the basic unit shall be included in the evaluation of the unit. Unless the manufacturer specifies the use of two or more attachments at the same time, only one attachment at a time is to be evaluated with the unit.

38.5 Whether a guard, a release, an interlock, or similar device is required and whether such a device is to be used shall be determined from an investigation of the complete unit, its operating characteristics, and the risk of injury to persons resulting from a cause other than gross negligence. The investigation shall include evaluating the results of breakdown or malfunction of any component; not more than one component at a time, unless one event contributes to another. Where the investigation shows that breakdown or malfunction of a particular component results in a risk of injury to persons, that component shall be investigated for reliability.

38.6 Specific constructions, tests, markings, guards, and similar specifications are detailed for some common constructions. Specific features and products not covered herein are to be examined and tested to determine whether they are to be used for the purpose.

## 39 Sharp Edges

39.1 An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use. This requirement does not apply to a part or portion of a part that is required to be sharp in order to perform a working function.

## 40 Enclosures and Guards

40.1 Except as noted in 40.2, a pulley, a fan blade, a belt, a gear, or other moving part that is capable of causing injury to persons shall be enclosed or provided with other means to reduce the risk of unintentional contact therewith.

40.2 A part or portion of a part that is required to be exposed in order to perform the working function is not required to be enclosed and where required guarding shall be provided. See 40.5.

40.3 The degree of protection required by 40.1 depends upon the general construction and intended use of a unit.

40.4 A moving part that involves a risk of injury to persons shall comply with the requirements specified in Protection of Users – Accessibility and User Servicing, Section 8, and shall be evaluated with respect to:

a) The degree of exposure required to perform its intended function;

b) The sharpness of the moving part;

c) The risk of unintentional contact with the moving part;

d) The speed of the moving part; and

e) The risk that a part of the body is endangered or that clothing is capable of being entangled, resulting in a risk of injury to persons.

The above factors are to be evaluated with respect to both intended operation of the unit and reasonably foreseeable misuse.

40.5 Some guards are required to be self-restoring. Other features of guards that are to be evaluated include:

a) Removability without the use of a tool;

b) Removability for servicing;

c) Strength and rigidity;

d) Completeness; and

e) Creation of a risk of injury to persons, such as a pinch point, and the requirement for additional handling because of the increased need for servicing, such as for cleaning, unjamming, or similar service.

## 41 Strength of Materials

41.1 The material of a part, such as an enclosure, a frame, a guard, or similar part, the breakage of which results in a risk of injury to persons, shall have such properties as to meet the demand of expected use conditions.

41.2 The requirement in 41.1 applies to those portions of a part adjacent to moving parts that involve a risk of injury to persons.

41.3 A part as mentioned in 41.1 and 41.2 shall withstand the Impact test described in Section 68, without being affected to the extent that:

a) The performance of the unit is adversely affected so as to result in a risk of injury; or

b) Parts capable of causing injury to persons are exposed to unintentional contact.

A component such as a pilot lamp, lens, or control knob is not required to be subjected to the impact test.



41.4 Portable or hand held units, or parts of units that are hand held other than the vehicle connector, are to be subjected to the Drop Test, Section 69.

## 42 Stability

42.1 Under all conditions of servicing and intended use after installation, a fully assembled portable unit shall not become physically unstable to the degree that an injury to operators or service personnel results. A portable unit intended to be fastened in place complies with this requirement. See Stability Tests, Section 70.

## 43 Mounting Means

43.1 A mounting means for a fixed in place unit shall withstand the Static Load Test, Section 71 without permanent deformation, breakage, or cracking of the mounting supports.

## 44 Strength of Handles

44.1 A handle used to support or carry a unit shall comply with the Strength of Handles Test, Section 72.

## PERFORMANCE

## 45 General

45.1 A representative unit is to be subjected to the tests described in Sections 46 – 73. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 45.1. A test voltage of not less than 90 % of the values specified in Table 45.1 is acceptable when the unit delivers rated output power at the reduced test voltage.

**Table 45.1**
**Values of Test Voltages**

| Rated voltage | Test voltage |
|---|---|
| Less than 110 | Rated voltage[a] |
| 110 – 120 | 120 |
| 121 – 219 | Rated voltage[a] |
| 220 – 240 | 240 |
| 241 – 253 | Rated voltage[a] |
| 254 – 277 | 277 |
| 278 – 439 | Rated voltage[a] |
| 440 – 480 | 480 |
| 481 – 525 | Rated voltage[a] |
| 526 – 600 | 600 |
| 601 – 1500 | Rated voltage[a] |

[a] A unit marked with an operating voltage range shall comply with the requirements in Sections 46 – 73 while connected to a source of voltage adjusted to any value within the specified range.



45.2 A unit marked with one frequency rating is to be tested at that frequency. For a unit marked with a dual frequency rating such as 50/60 hertz or a frequency range such as 50 – 60 hertz, tests are to be conducted at any frequency covered by the marking except that Power Verification (Section 48), Temperature (Section 49), and Transformer Burnout Tests (52.2.1 – 52.2.4) are to be conducted at the lowest frequency.

## 46 Leakage Current Test

46.1 Except as indicated in 46.2 and 46.3, a cord-connected unit rated for a nominal 250-volt or less shall be tested in accordance with 46.4 – 46.10. Leakage current shall not be more than:

a) 0.5 MIU for a two-wire cord- and plug-connected unit,

b) 0.5 MIU for a three-wire (including grounding conductor) cord- and plug-connected portable unit, and

c) 0.75 MIU for a three-wire (including grounding conductor) cord- and plug-connected fastened in place appliance.

46.2 Conductive parts of a unit that complies with the following conditions and that have a leakage current greater than specified in (a), (b), or (c) of 46.1 shall have a leakage current from simultaneously accessible parts to the grounded supply conductor no greater than 3.5 MIU. The leakage current between simultaneously accessible parts shall not exceed 0.5 MIU.

a) The unit requires electromagnetic interference (EMI) suppression filtering for compliance with other requirements, such as Federal Communications Commission (FCC) Regulations;

b) The unit is equipped with a grounding type supply cord and plug;

c) There is a low probability that a path for available current through the body exists in the expected environment. When the available current flows to ground, this involves the probability that the user is grounded during the use of the unit;

d) There is a low probability that high leakage conductive parts are contacted during normal use of the unit; and

e) The probability of injury resulting from an involuntary reaction is small.

46.3 For a unit that upon loss-of grounding, dependably disconnects all sources that produce leakage current, the leakage current to ground shall not exceed 5 MIU with the grounding conductor open and with the loss-of-grounding circuit disabled. The leakage current between simultaneously accessible parts on the unit shall not be more than 5 MIU.

46.4 All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 46.1. Where surfaces are simultaneously accessible, they are to be tested:

a) Individually,

b) Collectively (connected together) with the combined current measured to ground, and

c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.

Surfaces are simultaneously accessible when they are capable of being touched by one or both hands of a person at the same time. Accessible parts within a 100 by 200 mm (4 by 8 inches) rectangle are simultaneously accessible to one hand. The rectangle shall be flexed or bent to closely conform to the surface of the device. Accessible parts that are capable of being touched at the same time by the ends of a string 1.8 m (6 ft) in length are simultaneously accessible to both hands. The grounding pin, blade, or contact of an attachment plug is an accessible part.



46.5 When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 100 by 200 mm (4 by 8 inches) in contact with the surface. Where the conductive surface has an area less than 100 by 200 mm (4 by 8 inches) the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface and is not to remain in place long enough to affect the temperature of the unit.

46.6 Typical measurement circuits for leakage current with the ground connection open are illustrated in Figure 46.1 and Figure 46.2. The measurement instrument is defined in Figure 46.3. The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

a) The measured ratio $V_1/I_1$ with sinusoidal voltages is to be as close as feasible to the ratio $V_1/I_1$ calculated with the resistance and capacitance values of the measurement instrument shown in Figure 46.3.

b) The measured ratio $V_3/I_1$ with sinusoidal voltages is to be as close as feasible to the ratio $V_3/I_1$ calculated with the resistance and capacitance values of the measurement instrument shown in Figure 46.3. $V_3$ is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts is converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1,000. The mathematic equivalent is to multiply the RMS voltage reading by 2.

**Figure 46.1**

**Leakage Current Measurement Circuit Used for Devices Intended for Connection to 120 V Circuits**

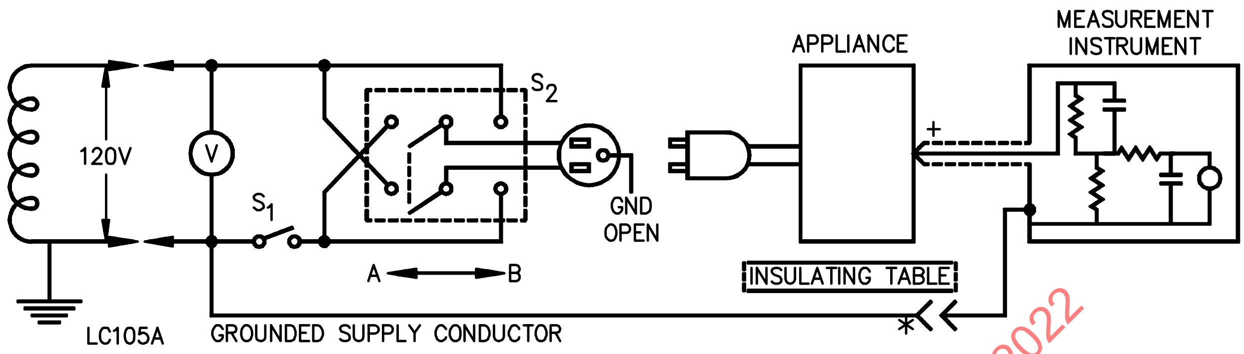
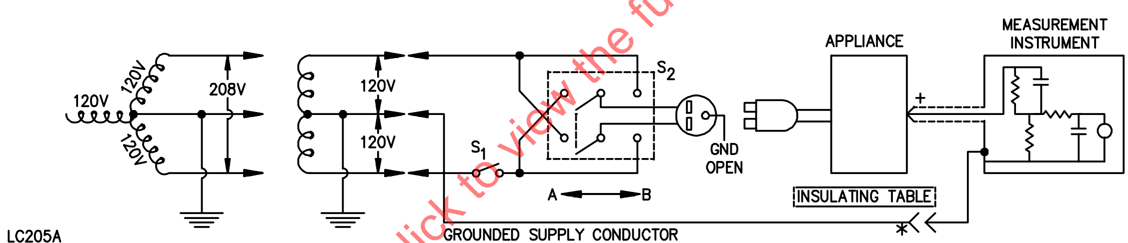



**Figure 46.2**

**Leakage Current Measurement Circuit Used for 120/208 Vac, 208 Vac or 120/240 Vac and 240 Vac Devices**




* Separated and used as clip when measuring currents from one part of the device to another.

+ Probe with shielded lead.

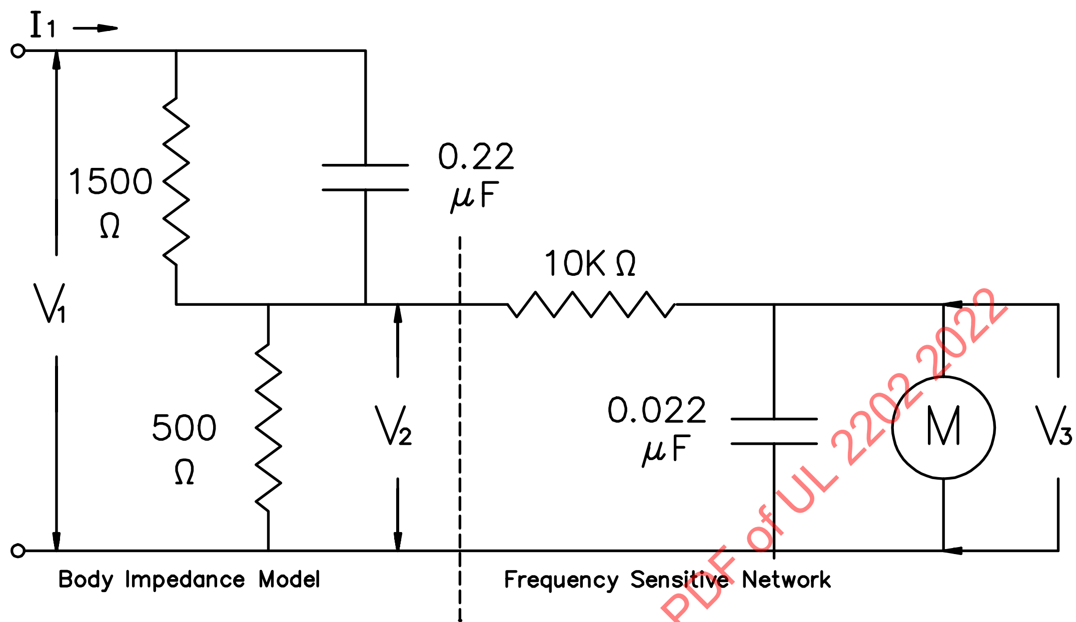
NOTES

1) All voltages shown in Figure 46.1 and Figure 46.2 are nominal.

2) When it is not feasible to isolate the device from ground, the supply circuit shall be isolated from ground. It is then also sometimes required to reverse the leads of the measurement instrument.

**Figure 46.3**

**Measurement Instrument for Reaction (Leakage) Current**




S3263A

Note – Detailed specifications and guidance for the calibration of this instrument are given in Annex A, Ref. No. 52.



46.7 Unless the measurement instrument is being used to measure leakage current from one part of a unit to another, it is to be connected between accessible parts and the identified conductor, if present, or the bonding conductor that has the least extraneous voltages introduced from other equipment operated on the same supply.

46.8 When the identified conductor is not required to be connected to the unit under test, then the instrument return lead is not prohibited from being connected to either the identified conductor or the bonding/grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.

46.9 A sample of a unit is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage.

The test sequence is to be as follows, with reference to Figure 46.1 and Figure 46.2

a) With switch S1 open, the unit is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2, and with the unit switching devices in all their normal operating positions.

b) Switch S1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the product switching devices in all their normal operating positions.

c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.

d) The leakage current is also to be monitored with switch S1 open while the unit is at operating temperature and while cooling.

46.10 A sample is to be subjected to the entire leakage current test, as specified in 46.9, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.

## 47 Leakage Current Test Following Humidity Conditioning

47.1 A cord-connected unit rated 250 volts or less shall comply with the requirements for leakage current in 46.1, following exposure to air having a relative humidity of 88 ±2 % at a temperature of 32 ±2 °C (90 ±4 °F).

47.2 To determine whether a unit complies with the requirement in 47.1, a sample of the unit is to be heated to a temperature just above 34 °C (93 °F) to reduce the risk of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 47.1. Immediately following the conditioning, the sample is to be removed from the humidity chamber and tested unenergized as described in 46.9(a). The sample is then to be energized and tested as described in 46.9 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

## 48 Power Verification Test

48.1 The input and output parameters of units shall be verified by measuring the input current at rated input voltage under conditions of maximum output current, and the maximum output current shall also be verified during this operation. The measured input current shall not be more than 110 % of its rated value and the maximum output current at its corresponding output voltage shall not exceed the manufacturer’s output rating.

48.2 During this test, the unit is connected to a source of power at its rated voltage. If the rating includes multiple voltage, such as 120/240 Vac, then the test is done at all voltages. If the rating includes a range of voltages, such as 230 – 240 Vac, then the test is done at the minimum and maximum voltages of the range. The unit is also connected to a load that is suitable for the current and voltage anticipated.

48.3 During this test, the unit shall be operated in accordance with the manufacturer’s instructions. The unit is connected as indicated in 48.2 and caused to operate at its condition of maximum output current as specified by the manufacturer. The input current and output current are measured and recorded. The recorded values shall be in compliance with 48.1.

## 49 Temperature Test

49.1 Under the conditions specified in 48.1, the unit shall not reach a temperature at any point high enough to cause a risk of fire, damage any material used, cause a protective device to operate, or exceed the temperature limits specified in Table 49.1. During this test, the ambient temperature is to be as specified in 49.11.

49.2 For a fixed in place unit, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the value determined by the requirement described in 14.1.1.4.

49.3 With reference to 49.1, a unit having voltage adjustment taps for intended use shall operate within the temperature limits at the setting representing the most severe loading condition as determined by an analysis of the circuit.

49.4 A unit intended for mounting or support in more than one position, or in a confined location, is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch thick trade-size soft-pine boards.

**Table 49.1**
**Temperature Limits**

| Materials and Components | °C | (°F) |
|---|---|---|
| COMPONENTS | | |
| 1. Capacitors: | | |
| a. Electrolytic types | 65[b] | (149)[b] |
| b. Other than electrolytic | 90[b] | (194)[b] |
| 2. Field wiring Terminals | 75[c] | (167)[c] |
| 3. Vulcanized fiber employed as electric insulation | 90 | (194) |
| 4. Plated bus bar | 90[d] | (194)[d] |
| 5. Unplated bus bar and a joint | 75[d] | (167)[d] |
| 6. Relays, solenoids, and similar devices | | |
| a. Class 105 coil insulation systems: | | |
| Thermocouple method | 90[a] | (194)[a] |
| Resistance method | 110 | (203) |
| b. Class 130 coil insulation systems: | | |
| Thermocouple method | 110[a] | (230)[a] |
| Resistance method | 120 | (248) |
| 7. Transformer insulation systems: | | |
| a. Class 105: | | |
| Thermocouple method | 90[a] | 194)[a] |
| Resistance method | 110 | (203) |
| b. Class 130: | | |
| Thermocouple method | 110[a] | (230)[a] |
| Resistance method | 120 | (248) |
| c. Class 155: | | |
| Thermocouple method | 135[a] | (275)[a] |
| Resistance method | 140 | (284) |
| d. Class 180: | | |
| Thermocouple method | 150[a] | (302)[a] |
| Resistance method | 160 | (320) |
| e. Class 200: | | |
| Thermocouple method | 165[a] | (329)[a] |
| Resistance method | 175 | (347) |
| f. Class 220: | | |
| Thermocouple method | 180[a] | (356)[a] |

**Table 49.1 Continued on Next Page**

## Table 49.1 Continued

| Materials and Components | °C | (°F) |
|---|---|---|
| Resistance method | 190 | (374) |
| 8. Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock | 150[e] | (302)[e] |
| 9. Wood and other combustible material | 90 | (194) |
| 10. Rubber- or thermoplastic-insulated wire and cord | 60[e,f] | (140)[e,f] |
| 11. Other types of insulated wires | g | g |
| 12. A surface upon which a portable unit is mounted in service, and surfaces that are adjacent to the unit when so mounted | 90 | (194) |
| 13. Any point on or within a terminal box or compartment of a fixed in place unit on which field-installed conductors rests | 60[c] | (140)[c] |
| 14. Thermoplastic sealing compound | h | h |
| 15. Selenium rectifier | 75[e,i] | (167) |
| 16. Power semiconductor | j | j |
| 17. Printed-wiring board | k | k |

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple is not prohibited from being 5 °C (9 °F) higher than that specified when the temperature of the coil as measured by the resistance method is not more than that specified.

[b] A capacitor that operates at a temperature of more than 65 °C (149 °F) for electrolytic and more than 90 °C (194 °F) for other types is not prohibited from being judged on the basis of its marked temperature limit.

[c] The temperature observed on the terminals and at points within a terminal box of a unit shall not attain a temperature higher than the temperature marking required in items p and o of 78.2.

[d] For a bus bar having a current density in accordance with 21.2.9, it is not required to measure the temperature since it has characteristics which result in temperatures not exceeding the indicated values.

[e] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with Annex A, Ref. No 53.

[f] A short length of rubber- or thermoplastic-insulated cord inside the unit is exposed to a temperature of more than 60 °C (140 °F) when supplementary insulation on each individual conductor is rated for the measured temperature and has dielectric properties in accordance with Annex A, Ref. Nos. 31 and 53.

[g] The temperature is not to exceed the temperature limit of the wire except as noted in note f.

[h] The sealing compound temperature limit is 15 °C (27 °F) less than the softening point of the compound as determined in accordance with Annex A, Ref. No 54.

[i] A temperature limit of 85°C (185°F) meets the intent of the requirement when the stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 150 °C (302 °F).

[j] For a power-switching semiconductor and similar components the temperature limit on the case is the maximum case temperature specified by the semiconductor manufacturer.

[k] For a printed wiring board, the temperature limit is the specified limit of the board.



49.5 Unless investigated and found to meet the intent of the requirement, see 10.4, a supporting means formed of rubber or neoprene material is to be removed prior to the test. Where the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the unit supported by the metal insert. At the request of the manufacturer, it is not prohibited to conduct the test without any means of support.

49.6 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of which the temperature is being measured. Usually, good thermal contact results from securely taping or cementing the thermocouple in place. Where a metal surface is involved, brazing or soldering the thermocouple to the metal is to be done when required for good thermal contact.

49.7 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method is an alternate method for a coil that is inaccessible for mounting thermocouples, such as a coil immersed in sealing compound, wrapped with thermal insulation, or wrapped with more than two layers of material such as cotton, paper, or rayon more than 0.8 mm (1/32 inch) thick.

49.8 The temperature of a winding is determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

$$T = \frac{R}{r}(\mathrm{k}+\mathrm{t}) - \mathrm{k}$$

in which:

*T* is the temperature of the winding in °C;

*R* is the resistance of the coil at the end of the test in ohms;

*r* is the resistance of the coil at the beginning of the test in ohms;

*t* is the room temperature in °C at the beginning of the test; and

*k* is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

The winding is to be at room temperature at the start of the test.

49.9 All temperature limit values in Table 49.1 are based on an ambient temperature of 40 °C (104 °F) for units intended to be installed in wet and damp locations and 25 °C (77 °F) for all other units. However, with correction of temperature measurements, tests conducted in other ambients as described in Table 49.2 are allowed.

**Table 49.2**
**Temperature Measurement Correction**

| Ambient temperature rating of unit | Test ambient temperature | Correction of observed temperature |
|---|---|---|
| 1. 25 °C (77 °F) | Range of 10 – 40 °C (50 – 104 °F) | a |
| 2. Range of 25 – 40 °C (77 – 104 °F) | Range of 20 – 40 °C (68 – 104 °F) | a |
| 3. Above 40 °C (104 °F) | Rated ambient<br>b | c |

[a] An observed temperature shall be corrected by addition (when the test ambient temperature is lower than the rated ambient temperature) or by subtraction (when the test ambient temperature is higher than the rated ambient temperature) of the difference between the rated ambient temperature and the test ambient temperature. The corrected temperature shall not exceed the temperature limit specified in Table 49.1.

[b] Allowable tolerances are: Minus – not less than 5 °C (9 °F) below rated ambient. Plus – not specified.

[c] When the test ambient temperature equals rated ambient, no correction is to be made, and an observed temperature shall not exceed the temperature limit specified in Table 49.1. When the test ambient temperature is other than rated ambient, correction is to be made as described in item 2 of note a.

49.10 When a unit is rated for an ambient temperature higher than 25 °C (77 °F), the rating shall be indicated in the instruction manual in accordance with 78.2(j).

49.11 Thermocouples are to consist of wires not larger than 24 AWG (0.21 mm$^2$) and not smaller than 30 AWG (0.05 mm$^2$). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ a temperature-indicating instrument with thermocouples consisting of 30 AWG iron and constantan wire. Such equipment is to be used whenever referee temperature measurements by thermocouples are required. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements for special thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in Annex A, Ref. No. 55.

49.12 A temperature is determined to be constant when three successive readings taken at intervals of 10 % of the previously elapsed duration of the test, but not less than 15 minutes, indicate no increase greater than 2 °C (4 °F).

49.13 During the temperature test, the temperature of a surface that is capable of being contacted by the user shall not be more than the values specified in Table 49.3. When the test is conducted at a room temperature of other than 25 °C (77 °F), the results are to be corrected to that temperature. For units intended for installation in wet and damp locations, the results are to be corrected to 40 °C (104 °F).

**Table 49.3**
**Maximum Surface Temperatures**

| Location | Composition of surface[a] | | | |
|---|---|---|---|---|
| | Metal | | Nonmetallic | |
| Handles or knobs that are grasped for lifting, carrying, or holding | 50 °C | (122 °F) | 60 °C | (140 °F) |
| Handles or knobs that are contacted but do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance | 60 °C | (140 °F) | 85 °C | (185 °F) |
| Surfaces subject to casual contact[b] | 70 °C | (158 °F) | 95 °C | (203 °F) |

[a] A handle, knob, or similar device made of a material other than metal that is plated or clad with metal having a thickness of 0.127 mm (0.005 inch) or less is judged as a nonmetallic part.

[b] See 49.14.



49.14 In reference to 49.13, a fixed in place unit that exceeds the limits in Table 49.3 is acceptable provided it meets all three of the following:

a) The risk of contact is reduced due to the installation of the product;

b) The unit is marked in accordance with 76.3.5; and

c) The unit is provided with instructions in accordance with 78.2(h).

## 50 Dielectric Voltage-Withstand Test

### 50.1 General

50.1.1 The test potential mentioned in 50.3.1 and 50.4.1 is to be obtained from any convenient source having a capacity of at least 500 volt-amperes. A lower capacity is not prohibited when a meter is located in the output circuit, and the test potential is maintained except in case of breakdown. The voltage of the source is to be continuously adjustable. Starting at zero, the applied potential is to be increased at a rate of 200 volts per second until the required test value is reached.

50.1.2 When a direct-current potential is used for an ac circuit, a test potential of 1.414 times the applicable rms value of alternating-current voltage specified in 50.3.1 and 50.4.1 is to be applied.

50.1.3 Printed-wiring assemblies and other electronic-circuit components that are damaged by application of the test potential or that short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. Testing for a representative subassembly is an alternative to testing an entire unit. Semiconductor devices in the unit are to be individually shunted before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

### 50.2 Maximum-voltage measurements

50.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand test potentials specified in 50.3.1 and 50.4.1 and determination of the minimum spacings specified in Spacings, Section 23, shall be determined in accordance with 50.2.2 and 50.2.3.

50.2.2 A connector or comparable part that is capable of being disconnected during intended operation is to be both connected and disconnected during the test so that the maximum voltage is obtained.

50.2.3 Where a complex voltage is present, the peak value of the voltage is to be measured and this value is to be used for calculation of the dielectric voltage-withstand potential and determination of the minimum spacings. For a sinusoidal or a direct current voltage, the rms or average values respectively is to be measured.



### 50.3 AC and DC power circuits

50.3.1 Except as noted in 50.3.2, the ac and dc power circuits of a unit shall withstand for 1 minute without breakdown the application of a 60 hertz sinusoidal potential with the unit at the maximum operating temperature:

a) One thousand volts plus twice the maximum rated voltage between

1) The primary circuit and non-current carrying metal parts,

2) The primary and secondary circuits, and

3) All secondary windings, including any ferro-resonant windings;

b) Five hundred volts between a secondary circuit operating at 50 volts or less and non-current carrying metal parts; 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit, including any ferro-resonant windings, operating at more than 50 volts and non-current carrying metal parts; and

c) One thousand volts plus the rated voltage of a capacitor between the terminals of a capacitor used for radio-interference elimination or arc suppression.

50.3.2 With reference to 50.3.1:

a) For a dc circuit, either an alternating-current or a direct-current potential is used. Where an alternating current potential is used, the potential is to be the value indicated above, divided by 1.414;

b) See 50.1.2; and

c) A dc circuit having a potential of 30 volts or less is not required to be tested.

50.3.3 With reference to 50.3.1, the test potential between ac power circuits and non-current carrying metal parts is to be based on the phase-to-ground voltage rating. The test potential for other points involving the ac power circuit is to be based on the highest operating voltage of the circuits involved.

### 50.4 Secondary circuits

50.4.1 Each secondary circuit other than a power circuit covered in 50.3.1 shall withstand for 1 minute without breakdown the application of a test potential between primary and secondary circuits, between secondary circuits and grounded metal with grounding connections, where present, disconnected, and between isolated secondary windings of transformers. The unit shall be at operating temperature during the test. The test potential shall be as indicated in Table 50.1.

**Table 50.1**
**Magnitude of Test Potential for Secondary Circuits**

| Maximum voltage in the circuit[a,b] | Test potential |
|---|---|
| 30 (42.4 peak), 60 dc, or less | No test |
| More than 30 (42.4 peak) but not more than 333.3 (471.3 peak) or more than 60 dc | Ten times maximum voltage in circuit (maximum of 1000 volts rms) |
| More than 333.3 (471.3 peak but not more than 1000 (1414 peak) | Three times maximum voltage in circuit |
| More than 1000 (1414 peak) | 1750 volts plus 1.25 times voltage in circuit |

[a] Where the peak voltage is greater than 120 % of 1.414 times the rms voltage, the circuit shall be tested as if the voltage were peak voltage divided by 1.414.

[b] Values are rms unless otherwise indicated.



### 50.5 Induced potential

50.5.1 When an isolating power transformer is tested in accordance with 52.2.2(d), the test described in 50.5.2 – 50.5.5 is to be conducted.

50.5.2 The primary winding of the transformer is to be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential is to be applied for 7200 cycles or for 60 seconds, whichever is less. A sinusoidal source is to be used, and the frequency of the service is to be in the range of 120 – 1000 hertz where required to prevent saturation of the core.

50.5.3 Primary- and secondary-circuit wiring connected to the transformer is to be disconnected for this test.

50.5.4 Testing a 3-phase transformer with a single phase voltage is not prohibited. The voltage mentioned in 50.5.2 is to be applied successively across each primary winding.

50.5.5 While in the heated condition obtained during the transformer overload test, the test voltage required in 50.5.2 is to be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit opened. The results meet the intent of the requirement when there is no dielectric breakdown.

## 51 Volt-Ampere Capacity Measurement

51.1 When it is required to determine volt-ampere capacity of a transformer winding for compliance with other requirements in this standard – see 2.22, 23.1.11 and 23.1.12(a) – the capacity is to be measured by replacing the intended load on that winding with a variable resistor that has been set to maximum resistance. A thermal protector or an overcurrent protective device, when provided, is to be shunted. A wattmeter is to be connected to measure power dissipated by the resistor. The assembly is to be energized with the test voltage specified in Table 45.1. The variable resistor is to be continuously adjusted to dissipate maximum power, and the power value is to be measured after 1 minute of operation or just prior to opening the winding, whichever occurs first. This value is the winding capacity. For a multi-secondary winding, one winding is to be loaded and tested at a time, that is, while measuring the output of a particular winding, other windings are to be open circuited.

## 52 Abnormal Tests

### 52.1 General

52.1.1 A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons – see 52.1.3 – when subjected to the tests specified in 52.1.2 – 52.8.2. Separate samples are to be used for conducting these tests.

52.1.2 Following each test, a dielectric voltage-withstand test specified in Section 50 is to be conducted. The potential is to be applied across the points indicated in 50.3.1. Conducting more than one abnormal test on a sample, and conducting the dielectric voltage-withstand after completion of all abnormal tests is not prohibited.



52.1.3 A risk of fire, electric shock, or injury to persons exists when:

a) Flame, burning oil, or molten metal is emitted from the enclosure of the unit as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper,

b) The insulation breaks down when tested in accordance with 52.1.2 or live parts are made accessible (see Protection of Users – Accessibility and User Servicing, Section 8),

c) Cracking, rupturing, or bursting of the battery case or cover, where such damage results in user contact with battery electrolyte, or

d) Explosion of the battery supply where such explosion results in a risk of injury to persons.

52.1.4 During these tests the unit is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 26 – 28 $m^2$/kg (14 – 15 yards per pound), and having, for any square inch, a count of 32 threads in one direction and 28 in the other direction. Units not having any bottom openings are not required to be placed on a softwood surface covered with tissue paper. When it is impractical to drape the entire unit, cheesecloth is required to be placed only over all ventilating openings.

52.1.5 For a unit having supporting feet made of rubber or neoprene material, the requirement in 49.5 shall apply.

52.1.6 The supply circuit is to have branch-circuit overcurrent protection, the size of which equals 125 % of the input current rating (20-ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the values specified in 45.1 and 45.2.

52.1.7 The enclosure of the unit is to be connected directly to ground during the test.

52.1.8 Except as noted in 52.1.9, each test is to be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:

a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices.

b) Opening of the intended branch-circuit overcurrent protection device described in 52.1.6 – see 52.1.10.

c) Opening of an internal fuse.

52.1.9 With reference to 52.1.8:

a) When the manually reset protector is a circuit breaker that complies with Annex A, Ref. No. 46, it is to be operated for 3 cycles using the minimum resetting time and not faster than 10 cycles of operation per minute; and

b) A manual reset protector that becomes inoperative in the open condition shall be operated between 10 cycles and 3 cycles.

52.1.10 With reference to 52.1.8(b), when the branch-circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 78.2(p).



## 52.2 Transformer burnout test

52.2.1 Except as noted in 52.2.2, an adjustable resistive load is to be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c) below. Opening of the intended branch-circuit overcurrent protection device described in 52.1.6 or an internal overcurrent protection device connected in the primary-winding circuit is an example of when this test is terminated.

a) For a transformer having a single isolated secondary winding, the load is to be adjusted to result in maximum volt-ampere output but not resulting in more than three times the maximum normal alternating current to flow in the primary winding.

b) For a transformer having multiple isolated secondary windings, each secondary winding is to be tested separately; that is, with the winding under test loaded with an alternating current equal to three times the rms value of the secondary current flowing through that winding during maximum normal operation of the unit and the other isolated windings, each loaded with an alternating current equal to the rms value of the secondary current flowing through their respective windings during maximum normal operation of the unit.

c) For an autotransformer, the conditions specified in (a) are to be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 52.1.

52.2.2 With reference to 52.2.1:

a) A transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current is to be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, where any are present.

b) A transformer employed in a switch-mode inverter or converter circuit shall be subjected to the transformer overload test described in 52.3.5 in lieu of the transformer burnout test.

c) Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the unit, having overcurrent protection described in Overcurrent Protection, Section 29, is not required to comply with this requirement.

d) A transformer that is protected by the intended branch-circuit protection device that is sized in accordance with the requirements in Overcurrent Protection, Section 29, and is provided in a unit marked in accordance with 78.2(p), is not required to comply with this requirement.

e) An isolating power transformer used for the transfer of either the input or output power of the unit and complying with Annex A, Ref. Nos. 5 and 6; or Annex A, Ref. No. 56, or shall be subjected to the transformer overload and induced potential tests described in 52.3 and 50.5, in lieu of the transformer burnout test.

f) A transformer subjected to the transformer overload and induced potential tests described in 50.5.1 – 50.5.5 and 52.3.1 – 52.3.4, in lieu of the transformer burnout test.

g) An isolating power transformer used for the transfer of either the input or output power of the unit complying with the requirements in either of the following standards:

1) Annex A, Ref. Nos. 5 and 6; or

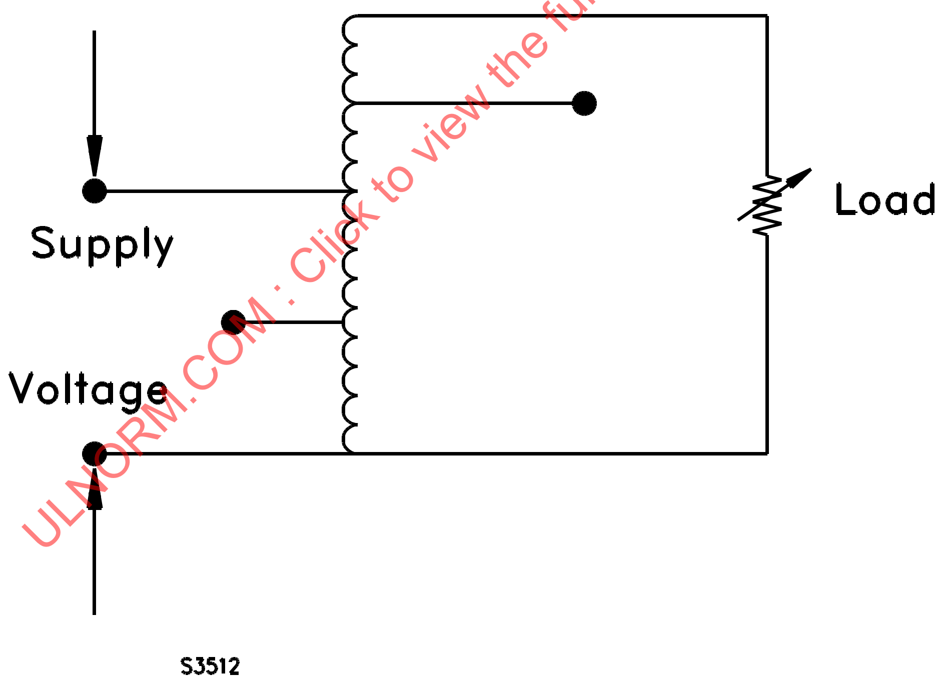
2) Annex A, Ref. No. 40.

h) A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the unit is not required to comply with this requirement.

52.2.3 A ferro-resonant transformer is to be tested in accordance with 52.2.1 with the secondary winding loaded to maximum input current. The transformer is to be operated continuously until ultimate conditions are observed.

**Figure 52.1**

**Autotransformer Burnout Test**




NOTE – See 52.2.1(c) for description of test.

52.2.4 During the tests described in 52.2.1 and 52.2.3, secondary-circuit protective devices that are external to the transformer are to be bypassed. Primary-circuit protective devices are to be left in the circuit.

### 52.3 Transformer overload test

52.3.1 When an isolating power transformer is to be tested in accordance with 52.2.2(f), the tests described in 52.3.2 – 52.3.4 are to be conducted. When a transformer employed in a switch-mode inverter or converter circuit is to be tested in accordance with 52.2.1(b), the test described in 52.3.5 is to be conducted.

52.3.2 A resistive load is to be connected directly to each transformer secondary winding and adjusted to a value so each secondary winding carries 50 % of rated load until temperatures of the transformer core become stabilized. The load is then to be increased to 200 % of the rated value; no further adjustment of the overload current is to be made. The duration of the overload is to be as specified in Table 52.1. The short circuit method as described in Annex A, Ref. No. 57 is one method used to obtain the 200 % of rated load current. Where the short-circuit test method is used, all secondary windings are to be shorted and the voltage applied to the primary windings is to be adjusted to result in rated current to flow in the secondary windings.

**Table 52.1**
**Overload Test Times**

| Insulation class | Overload time, minutes |
|---|---|
| 105 | 30 |
| 130 | 30 |
| 155 | 30 |
| 180 | 26 |
| 200 | 23 |
| 220 | 20 |

52.3.3 With reference to the requirement in 52.3.2, testing of a transformer rated more than 500 kilovolt-amperes is not required when the test has already been performed with results that meet the intent of the requirement on a smaller transformer rated not less than 500 kilovolt-amperes, when the smaller transformer has the same insulation system and same general construction as the larger transformer, and the temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer.

52.3.4 Within 1 hour following the overload test, the transformer shall perform as intended in a repeated dielectric voltage-withstand test except that the test value is to be at 65 % of value specified in Dielectric Voltage-Withstand Test, Section 50, and the induced potential test described in 50.5.1 – 50.5.5.

52.3.5 For a unit tested in accordance with 52.2.2 b) the power circuit supplied by the transformer is to be connected to a resistive load that draws maximum obtainable output power without causing operation of internal overcurrent protection devices or a protection circuit or resulting in opening of a circuit component such as a diode, resistor, sold state device, or similar device.

### 52.4 Short circuit test

52.4.1 The unit is to be tested as described in 52.4.2. The unit shall comply with the requirement in 52.1.1.

52.4.2 With reference to 52.4.1, fuses and other protective devices provided as part of the unit are to remain in the circuit. The output connections of the unit are to be short-circuited and the unit connected to a source of supply adjusted to its highest test voltage – see Table 45.1. The test is to be continued until the internal protection opens, constant temperatures are attained, or the transformer winding opens. When an automatically reset protector is provided, the test is to be continued for 7 hours. When a manually reset protector is provided the test is to be continued until the protector operates for 50 cycles.

### 52.5 Capacitor fault test

52.5.1 Where required by 30.6, a unit having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in Annex A, Ref. No. 47. These tests are to be conducted with the capacitors mounted in the unit enclosure as intended, and oil leakage from the capacitors passing through the enclosure, where present shall be extinguished – see 52.1.3(a).

### 52.6 Forced ventilation test

52.6.1 A unit having forced ventilation is to be operated with the rotor of a blower motor locked. For a unit having more than one blower motor, the test is to be conducted with the rotor of each blower motor locked, one at a time. When agreeable to all concerned, all fan motors in a unit having more than one fan motor shall be locked simultaneously.

52.6.2 A unit having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 %, then to be repeated under fully blocked condition. A single-fan unit with a filter is not required to be tested under the fully blocked condition.

### 52.7 Component short- and open-circuit test

52.7.1 A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:

a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded.

b) For electromagnetic radio frequency interference capacitors subjected to the dielectric voltage-withstand test across their terminals in accordance with 50.3.1, resistors, transformers, inductors, and optical isolators.

### 52.8 Electrolytic capacitor fault test

52.8.1 For a unit having dc electrolytic storage capacitors operating above 60 vdc, the fault test described in 52.8.2 shall be conducted. This requirement does not apply to a capacitor that complies with Annex A, Ref. No. 47. The capacitor shall have an available fault current rating of 10,000 amperes or a lower value where a circuit analysis indicates that because of a series impedance, the lower value is applicable.

52.8.2 With reference to the requirement in 52.8.1, a fault in one of the capacitors in the storage capacitor bank is to be simulated. This is to be accomplished by connecting the capacitor under test in reverse while the input ac supply to the unit is not energized. The unit is then to be energized and operated as in normal operation.

## 53 Flanged Bobbin Transformer Abnormal Test

53.1 Except as noted in 53.2, a flanged bobbin transformer required to be tested as provided in (c) of 27.2.4 – also see 27.2.7 – shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) – (c). A risk of fire or electric shock shall not result from:

a) Short-circuiting the secondary winding;

b) Loading the secondary winding to a current equal to maximum normal current plus X percent of the difference between the short-circuit current and the rated current – where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and

c) Loading the secondary winding to maximum normal current.

53.2 With reference to 53.1:

a) A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the unit – see 27.1.3 – is not required to be subjected to this test; and

b) A transformer complies with this requirement when it complies with the requirements in either of the following:

1) Annex A, Ref. Nos 5 and 6.

2) Annex A, Ref. No. 40.

53.3 The results of the test do not meet the intent of the requirement when the cheesecloth glows, or flames, is charred or a breakdown occurs when the test described in 53.5 is conducted.

53.4 Samples for the 15-day abnormal operation tests are to be prepared as follows:

a) The transformer is to be mounted either in the unit enclosure as intended under the conditions described in 52.1.4 or on a test bench with the cheesecloth mentioned in 52.1.4 draped over the transformer.

b) All secondary windings are to be loaded to rated current before the abnormal condition is introduced; and the loads, other than that connected to the winding to be overloaded, are not to be readjusted thereafter.

53.5 While still in a heated condition from the tests described in 53.1, a transformer shall withstand the dielectric voltage-withstand test applied between the primary winding and the secondary winding. The dielectric voltage-withstand-test potential is to be applied to the transformer 1 minute after completion of the abnormal-operation test.

53.6 The abnormal tests are to be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the unit connected in either the primary or secondary circuit, or in both. A protective device that is relied upon to open the circuit as a result of an abnormal test is to be one that has been investigated and found to meet the intent of the requirement.

53.7 For the purpose of these requirements, each secondary winding tap and each primary winding tap that is used to supply power to a load in the unit are the equivalent of a secondary winding.

53.8 For the sequence of tests described in 53.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For example, when the test described in 53.1(a) continues for 15 days, the tests described in 53.1 (b) and (c) are not required to be conducted.

53.9 To determine whether a transformer complies with the requirement in 53.1, three separate samples are to be subjected to each condition described in 53.1 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in

53.1 with the other windings loaded to rated current. The test conditions are to be as described in 53.10 – 53.14.

53.10 To determine the short-circuit current value for conducting the tests described in 53.1(b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, where provided by the manufacturer, is to be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.

53.11 For the loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 53.1 (a) – (c) is to be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens or 15 days have passed. In conducting the tests described in 53.1 (a) – (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, where required 1 minute after voltage is applied to the primary winding. For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.

53.12 When short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 53.1 (b) and (c) that continues for 15 days is to have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.

53.13 For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 53.1 (a) – (c) is to be discontinued when the protective device opens the circuit and the next test in the sequence is to be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.

53.14 When a protective device opens the circuit or a winding on any sample opens during the 15-day abnormal-operation tests while the samples are unattended, the variable resistor load on the other samples is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the samples are subjected to the dielectric voltage-withstand test described in 53.5 while in a heated condition. The next test in the sequence in 53.1 (b) and (c) that continues for 15 days is to be conducted.



## 54 Strain Relief Tests

### 54.1 General

54.1.1 The tests in 54.2 and 54.3 apply to the flexible cord connections, field wiring connections, and the EV cable connections.

54.1.2 Both the Strain Relief – Pull Test and the Strain Relief – Push Back Test are required for each cord or cable connection mentioned in 54.1.1. Field wiring connections are only required to be subjected to the Strain Relief – Pull Test.

54.1.3 All of the tests can be performed on one sample, but each test is to be performed individually.

54.1.4 The internal connections are to be disconnected or cut prior to the tests in 54.2 and 54.3.

### 54.2 Strain relief – pull test

54.2.1 The strain relief means provided for a flexible cord or EV cable connection, other than output cords of Class 2 Transformers, shall withstand a direct pull of 156 N (35 pounds) applied to the cord for one minute without displacement. The strain relief does not comply when at the point of disconnection of the conductors, there is such movement as to indicate that stress on the connections results.

54.2.2 The strain relief means provided for the output cord of a Class 2 transformer shall be tested as indicated in 54.2.1, except the weight shall be 89 N (20 pounds).

54.2.3 A wiring lead intended for field wiring connection shall be tested as indicated in 54.2.1, except in the case of a lead extending from the enclosure the weight is to be 89 N (20 pounds) and in the case of al lead within a wiring compartment, the weight is to be 44.5 N (10 pounds).

54.2.4 The weight is to be suspended from the cord, cable, or lead and supported by the unit so that the strain relief means is stressed from any angle of the unit.

### 54.3 Strain relief – push back test

54.3.1 The supply cord or EV cable shall be prevented from being pushed into the product through the cord entry hole where such displacement is likely to:

a) Subject the cord or cable to mechanical damage or to exposure to a temperature higher than that for which the cord or cable is rated;

b) Reduce spacings below the minimum intended values; or

c) Damage internal connectors or components.

54.3.2 The supply cord is to be held 25.4 mm (1 inch) from the point where the cord emerges from the unit and is then to be pushed back into the unit. The cord is to be pushed back into the unit in 1 inch increments until the cord buckles or the force to push the cord into the unit exceeds 26.7 N (6 pounds force). The supply cord or cable, within the unit, is to be manipulated to the worst-case position during the test to determine compliance with 54.3.1.

## 55 Flexing

55.1 With reference to 20.1.10, after wiring has been subjected to flexing as described in 55.2, the unit shall be subjected to the Dielectric Voltage-Withstand test in Section 50 and the wiring is to be examined for damage to determine where any conductors are broken or where individual strands have penetrated the insulation.

55.2 Wiring that is subjected to movement at times other than installation and servicing is to be tested by cycling the moving part through the maximum travel intended for the construction. The duration of the test is to be 500 cycles.

## 56 EV Cable Secureness Test

56.1 EV cables shall be subjected to the test outlined in 56.2 – 56.4. After this test, there shall be no axial displacement of the supply conductors, conductor insulation, or outer jacket of the EV cable from the assembled condition exceeding the maximum allowed displacement as specified in Table 56.1. In addition, there shall be no evidence of damage to the EV cable, the enclosure of live parts, the strain relief means, or the grounding path integrity.

56.2 The device shall be assembled as intended onto a 300 mm (12 inch), or longer, length of cable with its conductors positioned as if the conductors were to be connected to the terminals. Screws, nuts, or other hardware shall be tightened according to the manufacturer's instructions. The cable shall be cut at a right angle to its major axis but not stripped.

56.3 The cable clamp shall be held firmly in place. A force equivalent to the pressure of 1.034 $N/mm^2$ (150 $lb/in^2$) times the cross sectional area of the EV cable [rounded up to the nearest 22.2 N (5 lb) increment], but not less than 156 N (35 lbs), shall be applied gradually to the EV cable at a point not less than 150 mm (6 inches) from the cable grip in a direction perpendicular to the plane of the opening and in line with the cable. The force shall be applied and sustained for one minute.

56.4 A torque shall also be applied to the EV cable at a point 150 mm (6 inches) from the cable grip as specified in Table 56.1 for one minute in the direction least favorable to the clamp construction.

**Table 56.1**
**Cable Secureness Test Values**

| Device rating amperes | Torque | Maximum displacement |
|---|---|---|
| | N·m (ft-lb) | mm (inches) |
| 15 | 0.41 (0.3) | 2.38 (3/32) |
| 16 – 20 | 0.54 (0.4) | 2.38 (3/32) |
| 21 – 35 | 0.68 (0.5) | 2.38 (3/32) |
| 36 – 70 | 1.4 (1.0) | 2.38 (3/32) |
| 71 – 125 | 2.7 (2.0) | 2.38 (3/32) |
| 126 – 200 | 5.4 (4.0) | 2.38 (3/32) |
| 201 – 400 | 10.8 (8.0) | 4.76 (3/16) |
| 401 – 800 | 16.3 (12.0) | 4.76 (3/16) |



## 57 Grounding Tests

### 57.1 Grounding impedance test

57.1.1 In accordance with 19.9 where penetration of nonconductive coatings is not determinable by examination, a measurement of the grounding path resistance is to be made. The impedance at 60 hertz between the point of connection of the equipment-grounding means and the metal part that is required to be bonded to ground shall not be more than 0.1 ohm when measured in accordance with 57.1.2. The resistance of the equipment grounding conductor of a power supply cord shall not be included in the resistance measurement.

57.1.2 In the US and Mexico, compliance with 57.1.1 is to be determined by passing a current of 25 amperes derived from a 60 hertz source with a no-load voltage not exceeding 6 volts between the following points and measuring the voltage across these points: the equipment grounding connection and the metal part in question.

In Canada, equipment shall comply with the grounding impedance test of CSA C22.2 No.0.4.

### 57.2 Bonding/Grounding continuity test

57.2.1 The bonding/grounding path for charging system equipment provided with a permanently attached length of EV cable shall be continuous when required for bonding/grounding of the vehicle. Compliance is determined in accordance with the test in 57.2.2.

57.2.2 The bonding/grounding path from the main ground terminal of the charging system equipment to the ground pin at the vehicle connector shall be connected in series with an ac or dc source of voltage less than 30 V, and a means of indicating an unbroken circuit (e.g., an incandescent lamp, a bell, a buzzer). Operation of the indicator shall be evidence of continuity of the ground path under test.

## 58 Overcurrent Protection Calibration Test

58.1 A fuse, or circuit protective device, provided in the primary of a transformer for protection of the secondary circuit in accordance with 25.9 shall operate to open the circuit in not more than the time indicated in Table 58.1 when the transformer is delivering the specified secondary current.

**Table 58.1**
**Maximum Time to Open**

| Rated secondary potential, volts | Secondary test current, amperes | Maximum time for overcurrent protective device to open, minutes |
|---|---|---|
| 20 or less | 10 | 2 |
| 20 or less | 6.75 | 60[a] |
| Over 20 | $200/V_{max}$ | 2 |
| Over 20 | $135/V_{max}$ | 60[a] |

[a] After 15 minutes of operation, the current is to be readjusted to the value shown.



58.2 To determine when a fuse or circuit protective device complies with the requirement in 58.1, the transformer is to deliver the test current to a resistance load with the primary connected to a circuit as described in 45.1. During the 2-minute test, the load is to be adjusted continuously to maintain the required test current. During the 60-minute test, the load is to be adjusted once after 15 minutes of operation and the test is to be continued without further adjustment.

58.3 When the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding is to be tested as indicated in 58.1 or 58.2 with the remaining windings delivering rated load.

## 59 Strength of Terminal Insulating Base and Support Test

59.1 In accordance with the requirement in 14.1.2.8, an insulating base or support and the bus or strap upon which pressure wire connectors for field wiring are mounted shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 14.1.1.4, are torqued to 125 % of the value marked on the unit. The results meet the intent of the requirement when the base is not damaged as defined in 59.2. The test is not required for wire connectors that are part of a component such as a terminal block, circuit breaker, switch, or similar device.

59.2 With reference to 59.1, damage has occurred when the base insulating material cracks or rotates; bosses, recesses, or other means to prevent turning do not perform their intended function; straps or bus bars bend or twist; or members other than the wire connector move at electrical joints. Minor chipping or flaking of brittle insulating material is not prohibited when the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is not prohibited.

## 60 Bonding Conductor Connection Test

60.1 A bonding conductor that does not comply with the requirement in 19.11 is not prohibited when, using separate samples for each test, neither the bonding conductor nor the connection opens when:

a) Carrying currents equal to 135 and 200 % of the rating or setting of the intended branch-circuit overcurrent-protective device for the times specified in Table 60.1;

b) Three samples are subjected to a limited-short-circuit test using a test current as specified in Table 60.2 while connected in series with a nonrenewable fuse having a rating equal to the intended branch-circuit overcurrent-protective device; and

c) No damage occurs resulting in contact with live parts and no ignition occurs of surgical cotton located outside the enclosure. Surgical cotton is to be absorbent 100 % cotton.

When a fuse smaller than that indicated in (a) and (b) is employed in the unit for protection of the circuit to which the bonding conductor is connected, the magnitude of the test current and size of fuse used during the test is not prohibited from being based on the rating of the smaller fuse.



**Table 60.1**
**Duration of Overcurrent Test**

| Rating or setting of branch-circuit overcurrent protective device, amperes | Test time, minutes | |
|---|---|---|
| | 135 % of current | 200 % of current |
| 0 – 30 | 60 | 2 |
| 31 – 60 | 60 | 4 |
| 61 – 100 | 120 | 6 |
| 101 – 200 | 120 | 8 |

**Table 60.2**
**Circuit Capacity for Bonding Conductor Short-circuit Test**

| Rating of unit, volt-ampere | | Volts | Capacity of test circuit, amperes |
|---|---|---|---|
| Single phase | 3-phase | | |
| 0 – 1176 | 0 – 832 | 0 – 250 | 200 |
| 0 – 1176 | 0 – 832 | 251 – 1000 | 1000 |
| 1177 – 1920 | 833 – 1496 | 0 – 1000 | 1000 |
| 1921 – 4080 | 1497 – 3990 | 0 – 250 | 2000 |
| 4081 – 9600 | 3991 – 9145 | 0 – 250 | 3500 |
| 9601 or more | 9146 or more | 0 – 250 | 5000 |
| 1921 or more | 1497 or more | 251 – 1000 | 5000 |

60.2 The test circuit described in 60.1(b) is to have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in 45.1. The open-circuit voltage is to be 100 – 105 % of the closed-circuit voltage. Each test is to be performed on each of the three samples.

## 61 Glass Covered Openings Impact Test

61.1 With reference to 7.6.1(b), a glass covered opening shall withstand a 3.38 J (2-1/2 foot-pound) cracking or breaking to the extent that a piece is released or dropped from its normal position.

61.2 The impact specified in 61.1 is to be applied by means of a smooth, solid steel sphere 50.8 mm (2 inches) in diameter and having 535 g (1.18 pounds) mass. The sphere is to fall freely from rest through a vertical distance of 63.5 cm (25 inches).

## 62 Evaluation of Reduced Spacings on Printed-Wiring Boards

### 62.1 General

62.1.1 In accordance with 23.1.2(c), printed-wiring board traces of different potential having reduced spacings shall be judged by conducting a shorted trace test described in 62.2.1.

### 62.2 Shorted trace test

62.2.1 Printed-wiring board traces mentioned in 62.1.1 are to be short-circuited, one location at a time, and the test is to be conducted as described in 52.1.1 – 52.1.3, 52.1.5, 52.1.7, and 52.1.8. As a result of this test:

a) The overcurrent protection associated with the branch circuit to the unit shall not open; and

b) A wire or a printed-wiring board trace shall not open.

When the circuit is interrupted by opening of a component, the test is to be repeated twice using new components, as required. Opening of an internal overcurrent protective device is a test result that eliminates the need for the test being repeated.

## 63 Heat Sink Temperature Cycling Test

63.1 Where required by 21.3.1(b), a current-carrying, aluminum heat sink shall be subjected to the test described in 63.2 and 63.3.

63.2 Three samples of the heat sink/solid state component assemblies are to be subjected to this test. After completion of the 500th cycle described in 63.3, a temperature of the solid state component for each sample shall not be more than 15 °C (27 °F) higher than the temperature during the 24th cycle and neither temperature shall be more than the rating of the solid state component.

63.3 The samples are to be subjected to 500 cycles of current-on and current-off operations. During the current-on time, the samples are to be carrying maximum rated current. The duration of the current-on and current-off times shall be the length of time required to reach stable temperatures. Stable temperatures are obtained when three successive readings taken at not less than 10 minute intervals indicates no more than 2 °C (3.6 °F) variation between any two readings. Forced-air cooling is a way to reduce the current-off time with the concurrence of those concerned.



## 64 Tests for Permanence of Cord Tag

### 64.1 General

64.1.1 Except as noted in 64.1.2, in accordance with 76.2.3, the tests described in 64.3.1 shall be conducted on a power-supply-cord tag containing markings. Representative samples that have been subjected to these tests shall meet the following requirements:

a) The tag shall resist tearing for longer than 1.6 mm (1/16 inch) at any point;

b) The tag shall not separate from the power supply cord;

c) The tag shall not slip or move along the length of the power supply cord more than 12.7 mm (1/2 inch);

d) There shall be no permanent shrinkage, deformation, cracking, or any other condition that renders the marking on the tag illegible; and

e) Over lamination shall remain in place and not be torn or otherwise damaged. The printing shall remain legible.

64.1.2 A power-supply-cord tag complying with Annex A, Ref. No. 72, for the intended cord type and size and for the limited slippage rating, is not required to comply with this requirement.

### 64.2 Test conditions

64.2.1 Nine samples of the tag applied to the power-supply cord in the intended manner are to be tested. For adhesive applied tags, tests are to be conducted no sooner than 24 hours after application of the tag. The samples are to be conditioned as follows:

a) Three of the samples are to be tested as received.

b) Three samples are to be tested at the end of 30 minutes of conditioning at a room temperature of 23 ±2 °C (73.4 ±3.6 °F) and 50 ±5 % relative humidity, following conditioning in an air-circulating oven at 60 ±1 °C (140 ±1.8 °F) for 240 hours.

c) The remaining three samples are to be tested within 1 minute after exposure for 72 hours to a humidity of 85 ±5 % at 32 ±2 °C (89.6 ±3.6 °F).



### 64.3 Test method

64.3.1 Each sample is to consist of a length of power supply cord to which the tag has been applied. The power supply cord, with the attachment plug or connector pointing up, is to be held tautly in a vertical plane. A force of 22.2 N (5 pounds) is to be applied for 1 minute to the uppermost corner of the tag farthest from the power supply cord, within 6.4 mm (1/4 inch) of the vertical edge of the tag. The force is to be applied vertically downward in a direction parallel to the major axis of the cord. In determining compliance with 64.1.1(d), manipulation such as straightening of the tag by hand is used where applicable. To determine compliance with 64.1.1(e), each sample is to be scraped 10 times across printed areas and edges, with a force of 8.9 N (2 pounds), using the edge of a 2.0 mm (5/64 inch) thick steel blade held at a right angle to the test surface.

## 65 Tests on Transformer Insulating Materials

65.1 Where required by note (c) or (g) of Table 27.1, the transformer insulating material shall be subjected to the test described in 65.2.

65.2 The insulating material is to be placed between two opposing electrodes. The electrodes are to be cylindrical brass or stainless steel rods 6.4 mm (1/4 inch) in diameter with edges rounded to a 0.8 mm (1/32-inch) radius. The upper movable electrode is to weigh 50 ±2 grams to exert sufficient pressure on the specimen to provide good electrical contact. The test potential is to be increased to the test value and the maximum test potential is to be maintained for 1 second. The result complies when there is no dielectric breakdown.

## 66 Bus Bar Tests

66.1 An aluminum bus bar employing a coating mentioned in 21.2.1 (c) or a bus bar that has a clamped joint construction covered by 21.2.3 (b) and 21.2.4 (c), shall be subjected to the tests described in 66.2 – 66.4.

66.2 The temperature of the bus bar joint shall be measured during the temperature test described in Section 49 and comply with the maximum temperature specified in Table 49.1.

66.3 The temperature rise at the joint during the 500th cycle shall not be more than 15 °C (27 °F) higher than the temperature rise at the end of the 25th cycle.

66.4 The test sample is to consist of an assembly of bus bars connected together to form a series circuit. The bus bars are to be clamped together with the joint construction used in actual production. The number and size of the bus bar are to represent the maximum ampere rating and the maximum current density in which the joint construction is employed. More than one test is to be conducted when required to accomplish this. The length of each bus bar is to be 609 mm (2 feet). The bus bar is to be connected to a power supply by any means that does not affect the joint temperature. The power supply is to be adjusted to deliver a value of current that results in a temperature of 75 °C (135 °F) above room temperature at the joint. The assembly is then to be subjected to a 500-cycle test. At the end of the 24th cycle, the current is to be readjusted to bring the temperature of the joint to 75 °C (135 °F) above room temperature; and this current value is to be maintained for the remainder of the cycling test. At the end of the 25th and 500th cycles, the temperatures are to be recorded. The temperatures are to be measured on both sides of the joint as close as possible to the bolt or rivet. The cycling rate is to be 3 hours on and 1 hour off. The on period during which temperatures are recorded shall be what is required for the joint to attain thermal equilibrium. The length of the bus bar may be less than 609 mm (2 feet) with the concurrence of those concerned.

## 67 Harmonic Distortion Test

67.1 A unit rated for a harmonic factor (HF) or total harmonic distortion (THD) of the supply current is to be tested as described in 67.2 and 67.3. With the unit energized at the input voltage and frequency in accordance with 45.1 and 45.2, HF or THD shall not be more than 10 % over the manufacturer's rating for the unit when controlling the maximum intended battery load.

67.2 The supply for the test is to have a voltage distortion of less 0.5 %. Since the source (supply) voltage affects the magnitude of the harmonics, for measuring purposes, the supply impedance for cord-connected units rated 240 volts or less shall be 0.08 ohm or less and the supply impedance for other units shall not exceed a value that affects the results of the test.

67.3 The magnitude of the various harmonics of the supply frequency is to be recorded to the thirty-third (33) harmonic. The harmonic distortion factor is the ratio of the harmonic content to the rms value of the fundamental. The harmonic factor (HF) is to be calculated as follows:

$$HF = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{I_{\text{fundamental}}}$$

The total harmonic distortion (THD) is to be calculated as follows:

$$THD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots}}{\sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + \cdots}}$$

where

$I_1$ = 100 % at the fundamental frequency,

$I_2$ = magnitude, in percent of the fundamental, of the second harmonic

$I_3$ = magnitude, in percent of the fundamental, of the third harmonic

## 68 Impact Test

68.1 An enclosure or guard shall be subjected to this test. The enclosure or guard is to be subjected to an impact of 6.8 J (5 foot-pounds) on any surface that is exposed to a blow during normal use. This impact is to be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter and weighing 535 g (1.18 pounds), from a height of 1.29 m (51 inches) to produce the 6.8 J (5 foot-pound) impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 1.29 m (51 inches) to strike the surface.

68.2 The enclosure or guard is to be subjected to the impact test described in 68.1 with or without any attachment specified by the manufacturer so as to result in the most severe test.

68.3 When the part under test is made of polymeric material, the impact test is to be first conducted on a sample or samples in the as-received condition. The test is then to be repeated on a different sample or samples that have been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10 °C (18 °F) higher than the maximum operating temperature of the material, and not less than 70 °C (158 °F). While being conditioned, a part is to be supported in the same manner in which it is supported on the unit.

68.4 Upon being removed from the oven mentioned in 68.3 and before being subjected to the impact test, no samples shall show signs of cracking or other deleterious effects from the oven conditioning, and no sample shall be distorted so as to result in a risk of injury to persons.

68.5 After the impact test, any openings resulting from the test shall comply with the accessibility requirements described in Protection of Users – Accessibility and User Servicing, Section 8.



## 69 Drop Test

69.1 The test is to be performed on three samples of a portable or hand held unit, or portion of a hand held unit not including the vehicle connector, weighing less than 18 kg (40 lbs). The samples are to be at room temperature [nominal 25 °C (77 °F)].

69.2 With reference to 69.1, each sample is to be dropped three times from a height of 0.9 m (3 feet) to strike a concrete surface in the positions favorable to producing adverse results.

69.3 Immediately following the test, the unit is to be:

a) Subjected to the Dielectric Voltage Withstand Test of Section 50. The potentials shall be applied between the input/output circuits and bonded/grounded or non-current carrying metal parts;

b) Examined for exposure of live parts of internal wiring; and

c) Examined for reduction of spacings below the minimum specified in Spacings, Section 23.

## 70 Stability Tests

70.1 A unit is not to be energized during this test. The test is to be conducted under conditions favorable to causing the product to overturn. The following conditions are to be such as to result in the least stability:

a) Position of all doors, drawers, casters, and other movable or adjustable parts, including that of the supply cord resting on the surface supporting the unit;

b) Connection of or omission of any attachment made available by or specified by the manufacturer;

c) Provision of or omission of any normal load where the product is intended to contain a mechanical load; and

d) Direction in which the unit is tipped or the supporting surface is inclined.

70.2 With reference to 70.1 (a), where casters are used only to transport the unit and jacks are lowered after installation, then the jacks – not the casters – are to be used in the most unfavorable position for the test, consistent with reasonable leveling of the unit.

70.3 In conducting the stability test, the unit is to be:

a) Placed on a plane inclined at an angle of 10° from the horizontal, or

b) Tipped through an angle of 10° from an at rest position on a horizontal plane.

70.4 With reference to the requirement in 70.3(b), for a unit that is constructed so that, while being tipped through an angle of 10°, a part or surface of the unit not normally in contact with the horizontal supporting surface touches the supporting surface before the unit has been tipped through an angle of 10°, the tipping is to be continued until the surface or plane of the surface of the unit originally in contact with the horizontal supporting surface is at an angle of 10° from the horizontal supporting surface.

## 71 Static Load Test

71.1 When mounted as specified by the manufacturer, a power unit shall comply with the test specified in 71.2.

71.2 The supporting means of a power unit shall support a static load of four times the weight of the of the unit and not less than 9.1 kg (20 pounds):

a) Applied through the center of gravity of the power unit in the downward direction, or

b) Applied evenly over the horizontal plane of the unit.

## 72 Strength of Handles Test

72.1 A handle used to support or carry a unit shall withstand a load of four times the weight of the unit without damage to the handle, its securing means, or that portion of the enclosure to which the handle is attached.

72.2 To determine whether a unit complies with the requirement in 72.1, the load is to be uniformly applied over a 76 mm (3 inch) width at the center of the handle, without clamping. The load is to be started at zero and gradually increased so that the test value is attained in 5 to 10 seconds; the test value is to be maintained for 1 minute. When a unit has more than one handle and is not capable of being carried by one handle, the load is to be distributed between the handles. The distribution of the load is to be determined by measuring the percentage of the unit weight sustained by each handle with the unit in the normal carrying position. When the unit is furnished with more than one handle and is capable of being carried by only one handle, each handle is to withstand the total load.

## 73 Accelerated Aging Tests of Supporting Feet

73.1 Mounting feet depended upon for support – see 49.5 – made of neoprene or rubber compounds and solid polyvinyl chloride materials, except foamed materials, shall have physical properties as indicated in Table 73.1 before and after the conditioning indicated in Table 73.2.

**Table 73.1**
**Physical Properties for Supporting Feet**

| Physical property[a] | Neoprene or rubber compound | | Polyvinyl-chloride materials | |
|---|---|---|---|---|
| | Before conditioning | After condition ing | Before conditioning | After condition ing |
| Tensile Set Minimum set when 25.4 mm (1 inch) gage marks are stretched to 63.5 mm (2-1/2 inches), held for 2 minutes and measured 2 minutes after release. | 6.4 mm (1/4 inch) | – | Not Specified | |
| Elongation Minimum increase in distance between 25.4 mm (1 inch) gage marks at break. | 250 % [to 88.9 mm (3-1/2 inches)] | 65 % of original | 250 % [to 88.9 mm (3-1/2 inches)] | 75 % of original |
| Tensile Strength Minimum force at breaking point. | 5.86 MPa (850 psi) | 75 % of original | 8.27 MPa (1200 psi) | 90 % of original |

[a] To be determined using the test methods and apparatus described in Annex A, Ref. No. 58, except the method for tensile set is to be as specified in this table.

**Table 73.2**
**Conditioning Parameters**

| Minimum material temperature rise[a] °C | (°F) | Conditioning: Rubber or neoprene | Conditioning: Thermoplastic |
|---|---|---|---|
| 35 | (63) | Air oven aging for 70 hours at 100 °C (212 °F) | 7 days in an air-circulated oven at 87 °C (189 °F) |
| 50 | (90) | Air oven aging for 168 hours at 100 °C (212 °F) | 10 days in an air-circulated oven at 100 °C (212 °F) |
| 55 | (99) | 7 days in an air-circulated oven at 113 °C (235 °F) | |
| 65 | (117) | 10 days in an air-circulated oven at 121 °C (249.8 °F) | 7 days at 121 °C (249.8 °F) or 60 days at 97 °C (206 °F) in an air-circulated oven |
| 80 | (144) | 7 days in an air-circulated oven at 136 °C (276.8 °F) | |

[a] Measured during the Temperature Test, Section 49.



## MANUFACTURING AND PRODUCTION TESTS

### 74 Production-Line Dielectric Voltage-Withstand Test

74.1 As a routine production-line test, each unit shall withstand, without electrical breakdown, the application of an alternating-current potential at a frequency within the range of 40 – 70 hertz or a direct-current potential between the primary wiring, including connected components, and accessible non-current carrying metal parts that are capable of becoming energized and between primary wiring and accessible low-voltage – 42.4 volts peak, 60 volts, dc or less – metal parts, including terminals and connector contacts.

74.2 The test duration and potential shall be as described in either condition A or B of Table 74.1.

**Table 74.1**
**Production Test Condition**

| Unit voltage rating, volts | Condition A | | | Condition B | | |
|---|---|---|---|---|---|---|
| | Test potential v ac | Test potential v dc | Time, seconds | Test potential v ac | Test potential v dc | Time, seconds |
| Rated 250 or less | 1000 | 1400 | 60 | 1200 | 1700 | 1 |
| Rated more than 250 | 1000+2V[a] | 1400+2.8V[a] | 60 | 1200+2.4V[a] | 1700+3.4V[a] | 1 |

[a] Maximum marked voltage.

74.3 The test potential is to be gradually increased to the required value but the full value is to be applied for 1 second or 1 minute, as required.

74.4 The unit is to be at intended operating temperature, at room temperature, or at any intermediate temperature for the test.

74.5 The test is to be conducted when the unit is fully assembled. It is not intended that the unit be unwired, modified, or disassembled for the test except as follows:

a) Parts such as snap covers or friction-fit knobs that interfere with performance of the test are not required to be in place.

b) The test is to be performed before final assembly when the test represents that for the completed unit. Any component not included shall not affect the results with respect to determination of possible electric shock from miswiring, defective components, spacings, or similar defect.

c) Solid state components that are capable of being damaged by a secondary effect (induced voltage surge, excessive heating, or similar effect) of the test are to be short-circuited by means of a temporary electrical jumper, or the test is to be conducted without the component electrically connected, providing the wiring and terminal spacings are maintained. Additionally, transient voltage suppression devices other than capacitors connected from primary wiring to non-current carrying metal are to be disconnected during the test where required.

74.6 The test equipment shall have a means of indicating the test potential, an audible or visual indicator of electrical breakdown and, for automated or station type operations, either a manual-reset device to restore the equipment after electrical breakdown or an automatic-reject feature for any unit that does not comply. When an alternating-current test potential is applied, the test equipment shall include a transformer having a sinusoidal output.

74.7 When the rated output of the test equipment is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to indicate directly the applied test potential.

74.8 When the rated output of the test equipment is 500 volt-amperes or more, the test potential is to be indicated by a voltmeter in the primary circuit or in a tertiary-winding circuit; by a selector switch marked to indicate the test potential; or by a marking in a readily visible location to indicate the test potential in the case of equipment having a single test-potential output. When an indicating voltmeter is not used, the test equipment shall include a visual means (such as an indicator lamp) to indicate that the test voltage is present at the test-equipment output.

74.9 Test equipment other than that described in 74.6 – 74.8 are not prohibited from being used when found to accomplish the intended factory control.

74.10 For the test, either a specified number of control devices are to be closed or separate applications of the test potential are to be made so that all parts of the primary circuit are tested.

## 75 Production-Line Bonding/Grounding-Continuity Test

75.1 Each unit that has an input or output cord with a bonding/grounding conductor shall be tested, as a routine production-line test, to determine that bonding/grounding continuity is provided between the grounding blade or pin of the attachment plug and the accessible non-current carrying metal parts of the unit that are capable of becoming energized.

75.2 Only a single test is required when the accessible metal selected is conductively connected to all other accessible metal.

75.3 Any indicating device (an ohmmeter, a battery and buzzer combination, or similar device) is to be used to determine compliance with the grounding continuity requirement.

## MARKING

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



## 76 Details

### 76.1 General

76.1.1 Unless otherwise stated, all markings are required to be permanent, that is, either by being molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon investigation, is found to comply with Annex A, Ref. No. 59.

### 76.2 Content

76.2.1 Except as noted in 76.2.2, a unit shall be plainly and permanently marked where it is readily visible, after installation, with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the EV charging system equipment is identified;

b) A distinctive catalog number or the equivalent;

c) The electrical ratings specified in 6.1; and

d) The date or other dating period of manufacture not exceeding any three consecutive months.

76.2.2 With reference to 76.2.1:

a) The manufacturer's identification is not prohibited from being in a traceable code when the unit is identified by the brand or trademark owned by a private labeler.

b) The date of manufacture is not prohibited from being abbreviated, or being in a nationally accepted conventional code, or in a code affirmed by the manufacturer, when the code:

1) Does not repeat in less than 20 years, and

2) Does not require reference to the production records of the manufacturer to determine when the unit was manufactured.

76.2.3 Markings are not prohibited from being located on a tag that is attached to the power supply cord and complies with Annex A, Ref. No. 60. For tags that are not in compliance with these standards, the tag shall comply with the requirements in Tests for Permanence of Cord Tag, Section 64.

76.2.4 With reference to the requirement in 76.2.1(c), the symbols described in (a) and (b) are used for markings:

a) A circuit intended to be connected to an alternating-current supply shall be identified by markings indicating that the supply shall be alternating current. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 76.1 is an example for this marking. See 76.2.5.

b) The number of phases shall be indicated if the unit is designed for use on a polyphase circuit. The symbol illustrated in Figure 76.2 is an alternative for the word "phase." See 76.2.5.