UL 5085-1

STANDARD FOR SAFETY

Low Voltage Transformers – Part 1: General Requirements

UL Standard for Safety for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1

First Edition, Dated April 17, 2006

Summary of Topics

This revision of ANSI/UL 5085-1 dated June 2, 2022 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

As noted in the Commitment for Amendments statement located on the back side of the title page, UL and CSA are committed to updating this harmonized standard jointly. However, the revision pages dated June 2, 2022 will not be jointly issued by UL and CSA as these revision pages only address UL ANSI approval dates.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated March 25, 2022.

No Text on This Page

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First Edition

Underwriters Laboratories Inc.
UL 5085-1
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Low Voltage Transformers – Part 1: General Requirements

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Approved American National Standard

ANSI/UL 5085-1-2013 (R2022)

Commitment for Amendments

This standard is issued jointly by 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 CSA Group or UL at any time. Revisions to this standard will be made only after processing according to the standards development procedures of 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.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the First edition including revisions through June 2, 2022.

The most recent designation of ANSI/UL 5085-1 as a Reaffirmed American National Standard (ANS) occurred on May 24, 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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Preface

This is the harmonized CSA Group and UL standard for low voltage transformers. It is the first edition of CSA C22.2 No. 66.1 and the first edition of UL 5085-1. This harmonized standard has been jointly revised on December 6, 2013. For this purpose, CSA Group and UL are issuing revision pages dated December 6, 2013.

This harmonized standard was prepared by a Technical Harmonization Committee comprised of members from CSA Group, Underwriters Laboratories Inc. (UL), and representatives of the low voltage transformer manufacturing industry. The efforts and support of members of the Technical Harmonization Committee are gratefully acknowledged.

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

This standard was reviewed by the CSA Subcommittee on C22.2 No. 66, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

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 to be considered equivalent to, an IEC standard. This standard is published as an equivalent standard for 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

The Technical Harmonization Committee identified the following IEC Standard within the scope of this standard: IEC 61558-1 (1998-07), Safety of power transformers, power supply units, and similar - Part 1: General requirements.

The THC determined that the safe use of transformers and reactors is critically dependent on the electrical system in which they are intended to be installed. Significant investigation is required to assess safety and system compatibility issues that may lead to harmonization of traditional North American transformers and reactors with those presently addressed in the known IEC standards. The THC agreed such future investigation might be facilitated by completion of harmonization of North American standards for transformers and reactors.

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 literal interpretation 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.

Parts

The Standard for Low Voltage Transformers is divided into the following parts:

Part Number	Standard Title	Standard Number
1	General Requirements	CSA C22.2 No. 66.1/UL 5085-1
2	General Purpose Transformers	CSA C22.2 No. 66.2/UL 5085-2
3	Class 2 and Class 3 Transformers	CSA C22.2 No. 66.3/UL 5085-3

NOTES –

1. Part 1 covers the general requirements for transformer characteristics, marking, construction, and tests. Additional specific requirements are provided in the subsequent parts.

2. Part 2 and Part 3 supplement requirements and/or modify the corresponding clauses in Part 1 and should be applied together with Part 1. The numbered clauses in Part 2 and Part 3 correspond to the numbered clauses in Part 1.

PART 1: GENERAL REQUIREMENTS

1 Scope

1.1 These requirements cover the following types of transformers:

a) Air-cooled transformers and reactors for general use;

b) General purpose autotransformers;

c) Ferroresonant transformers;

d) Class 2 and Class 3 transformers (which are evaluated in accordance with Part 3);

e) Cord-connected transformers (which are evaluated in accordance with Part 2);

f) Transformers incorporating overcurrent or over-temperature protective devices, transient voltage surge protectors, or capacitors; and

g) Permanently-connected transformers.

1.2 These transformers are intended to be used in accordance with the National Electrical Code, ANSI/NFPA 70, or CSA C22.1, the Canadian Electrical Code, Part I. The Canadian Electrical Code defines low voltage as any voltage from 31 to 750 V inclusive and high voltage as any voltage above 750 V. The National Electrical Code, ANSI/NFPA 70, defines low voltage as any voltage up to 600 V, nominal. Therefore, low voltage transformers intended for use in Canada may be rated above 600 V up to 750 V. Low voltage transformers intended for use in the United States are rated up to 600 V. Where information in clauses and tables in this standard reference voltage ranges, the limit of 600 V applies in the United States, while the limit of 750 V applies in Canada.

1.3 The standard does not cover the following transformers:

a) Direct plug-in types;

b) Neon;

c) Liquid-immersed;

d) Variable voltage (Variac);

e) Low voltage landscape;

f) Swimming pool and spa:

g) Ignition;

h) High intensity lighting;

i) Toy;

j) Fluorescent lamp types;

k) Transformers for welders;

l) Distribution;

m) Transformers intended for use in the United States with a nominal primary rating of more than 600 V;

n) Transformers incorporating rectifying or waveshaping circuitry;

o) Transformers for use with radio- and television-type appliances;

p) Transformers intended for use in the United States having overvoltage taps rated over 660 V;

q) Autotransformers used in industrial control equipment, which are evaluated in accordance with the requirements of the Standard for Industrial Control Equipment, UL 508, or CSA C22.2 No. 14, Industrial Control Equipment; and

r) Other special types of transformers covered in requirements for other electrical devices or appliances.

1.4 Part 1, as well as Part 2 and Part 3, establish the characteristics, construction, operating conditions, markings, and test conditions for each type of transformer.

1.5 The requirements in this standard may be modified by requirements in an end product standard if a transformer is intended for use only as a component in other equipment.

2 Definitions

2.1 The following definitions apply in this standard:

2.1.1 CLASS 2 TRANSFORMER – A transformer that has a 30 V rms maximum secondary potential under any condition of loading.

Note: The impedance within an inherently-limited transformer limits the current output to a particular maximum value. Maximum power is limited by winding impedance (inherently limited) or by overcurrent protection (not-inherently limited). It may or may not be provided with a thermostat or other temperature sensitive device to limit its maximum temperature. A not-inherently limited Class 2 transformer is provided with overcurrent protection to limit the maximum power output.

2.1.2 CLASS 3 TRANSFORMER – A transformer that has a secondary potential over 30 V rms and less than 100 V for inherently-limited transformers, or less than 150 V for not-inherently limited transformers.

Advisory Note: *These transformers are intended for use only in the United States. See Annex D of Part 3.*

2.1.3 COMPOUND-FILLED TRANSFORMER – A transformer in which the windings or windings and core are enclosed with an insulating fluid or thermal compound that becomes solid and retains its hardness at intended operating temperatures and storage temperatures.

2.1.4 DRY-TYPE TRANSFORMER – A transformer in which the core and coils are in a gaseous or dry compound insulating material.

2.1.5 ENCAPSULATED COIL – A coil that is enclosed with an insulating fluid that becomes solid.

2.1.6 EXPOSED CORE TRANSFORMER – A transformer having an exposed magnetic core lamination.

2.1.7 INDUSTRIAL CONTROL TRANSFORMER – A transformer suitable for field installation and intended to operate within a 40°C (104°F) ambient temperature.

2.1.8 NONVENTILATED DRY-TYPE TRANSFORMER – A dry-type enclosed transformer which is constructed to provide no intentional circulation of external air through the transformer and is intended to operate at normal ambient room air pressure.

2.1.9 VENTILATED DRY-TYPE TRANSFORMER – A dry-type enclosed transformer constructed so that ambient air may circulate through the enclosure to cool the transformer core and windings.

2.1.10 WINDING – A continuous conductor made up of a number of turns magnetically coupled to a magnetic core, to which a voltage is either applied or induced.

Note: Two or more such conductors that are permanently factory connected to form intermediate voltage taps, current taps, or similar items are considered a single winding. The winding can consist of single or parallel-wound conductors.

3 General

3.1 Components

3.1.1 Except as indicated in Clause 3.1.2, a component of a product covered by this standard shall comply with the requirements for that component. See Annex B for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the CSA or UL standards as appropriate for the country where the product is to be used.

3.1.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

3.1.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.1.4 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.

3.1.5 For transformers intended for use in Canada the following applies: General requirements applicable to this standard are given in CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II.

3.2 Reference Publications

3.2.1 Products covered by this Standard shall comply with the reference installation codes and standards 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.

For undated references to standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this standard was approved. For dated references to standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the standard was approved. See the following information for a list of reference publications.

ANCE Standards

NMX-J-235/2–ANCE
Enclosures for Electrical Equipment, Environmental Considerations

CSA Standards

C22.1-02
Canadian Electrical Code, Part 1 (19th Edition)

CAN/CSA-C22.2 No. 0-M91 (R2001)
General Requirements – Canadian Electrical Code, Part II

C22.2 No. 0.1-M1985 (R2013)
General Requirements for Double-Insulated Equipment

C22.2 No. 0.15-01
Adhesive Labels

CAN/CSA-C22.2 No. 0.17-00 (R2004)
Evaluation of Properties of Polymeric Materials

C22.2 No. 14-95 (R2001)
Industrial Control Equipment

CAN/CSA-C22.2 No. 18-98 (R2003)
Outlet Boxes, Conduit Boxes, Fittings, and Associated Hardware

CAN/CSA-C22.2 No. 65-03
Wire Connectors

CAN/CSA-C22.2 No. 94-M91 (R2001)
Special Purpose Enclosures

CAN/CSA C22.2 No. 94.2
Enclosures for Electrical Equipment, Environmental Considerations

C22.2 No. 153-M1981 (R2003)
Quick-Connect Terminals

C22.2 No. 209-M1985 (R2004)
Thermal Cut-Offs

CAN/CSA-C22.2 No. 60065:03
Audio, Video and Similar Electronic Apparatus – Safety Requirements

CAN/CSA-C22.2 No. 60950-1-03
Information Technology Equipment – Safety – Part 1: General Requirements

UL Standards

UL 50
Enclosures for Electrical Equipment

UL 50E
Enclosures for Electrical Equipment, Environmental Considerations

UL 310
Electrical Quick-Connect Terminals

UL 486A-486B
Wire Connectors

UL 486E
Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors

UL 508
Industrial Control Equipment

UL 514C
Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers

UL 746B
Polymeric Materials – Long Term Property Evaluations

UL 746C
Polymeric Materials – Use in Electrical Equipment Evaluations

UL 969
Marking and Labeling Systems

UL 1446
Systems of Insulating Materials – General

UL 2097
Reference Standard for Double Insulation Systems for Use in Electronic Equipment

UL 2353
Single- and Multi-Layer Insulated Winding Wire

UL 60691
Thermal-Links – Requirements and Application Guide

ANSI/NFPA[1] Standards

ANSI/NFPA 70,
National Electrical Code

ASTM[2] Standards

A 90/A 90M
Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 653/A 653M
Standard Specification for Steel Sheet, Zinc-Coated, (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process,

D 396
Standard Specification for Fuel Oils

E230/E230M
Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

ANSI/IEEE[3] Standards

IEEE C57.12.91
Standard Test Code for Dry-Type Distribution and Power Transformers.

[1] American National Standards Institute/National Fire Protection Association.
[2] American Society for Testing and Materials.
[3] American National Standards Institute/Institute of Electrical and Electronics Engineers, Inc.

3.3 Units of Measurement

3.3.1 The values given in SI (metric) units shall be normative, except for AWG/kcmil conductor sizes. Any other values given shall be for information purposes only.

4 Construction

4.1 The requirements in Part 1 are general in nature and apply to all transformers where applicable. Part 1 covers the general requirements for transformer characteristics, marking, construction and tests. Additional requirements for various transformer types are detailed in Part 2 and Part 3. Part 2 and Part 3 supplement or modify the corresponding clauses in Part 1 and should be read together with Part 1. The numbering of clauses in Part 2 and Part 3 corresponds to the numbered clauses in Part 1.

5 Mechanical Assembly

5.1 A transformer shall be formed and assembled so that it is able to resist the abuses to which it is likely to be subjected. A risk of fire, electric shock, or injury to persons shall not result from a reduction of spacings, loosening or displacement of parts, or other serious defect.

5.2 An adhesive used in the assembly of the enclosure shall be investigated as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, or CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II, as applicable.

Note: Methods utilizing fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding, need not be investigated.

5.3 An unenclosed core and coil transformer shall be provided with mounting brackets, a mounting plate, or other suitable means for mounting.

6 Enclosures

6.1 General

6.1.1 Transformers shall have enclosures of noncombustible, moisture-absorption resistant material that encases all live parts. In addition to the overall enclosure, the requirements in Clauses 6.1.2 – 6.1.14 and Table 5 apply to those portions of an enclosure surrounding a terminal or wiring compartment.

Note 1: Component type transformers intended for installation in other equipment (e.g., open coil, open core types) do not require an enclosure.

Note 2: Industrial control transformers rated 5 kVA or less are not required to be equipped with an enclosure.

6.1.2 The thickness of a sheet metal enclosure shall comply with the following:

a) Table 2, Table 3, and Table 4 or

b) The requirements for the Compression test in Clause 24.2 for an enclosure with reinforcement similar to a supporting frame.

6.1.3 With regard to Clause 6.1.2, a supporting frame is an angled structure or channel, or folded rigid piece of sheet metal, that:

a) Is attached to the enclosure surface;

b) Has essentially the same outside dimensions as the enclosure surface; and

c) Has sufficient torsional rigidity to resist the bending moments that may be transmitted by the enclosure surface when the surface is deflected.

6.1.4 With regard to Clause 6.1.2, the following are considered construction types without a supporting frame:

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

b) A single sheet that is corrugated or ribbed;

c) An enclosure surface loosely attached to a frame, for example, with spring clips; and

d) An enclosure surface having an unsupported edge.

6.1.5 The thickness of sheet steel enclosure shall be determined by taking the numerical average of five micrometer readings equally spaced across the full width of the sheet as rolled.

6.1.6 The thickness of an enclosure constructed of nonferrous sheet metal shall provide strength and rigidity equal to that of a sheet steel enclosure described in Clause 6.1.2.

6.1.7 A cast iron enclosure shall not be less than 6.4 mm (0.25 in) thick at tapped holes for conduit. The minimum thickness may be less than that specified when the cast iron complies with the Compression test in Clause 24.2. However, the thickness shall not be less than 3.2 mm (0.125 in), excluding any coating.

6.1.8 When threads for the connection of conduit are tapped only part of the way through a hole in the enclosure, there shall not be less than 5 full threads in the metal. There shall be a smooth, well-rounded inlet hole to provide a passage similar to that provided by a standard conduit bushing.

6.1.9 A transformer intended to be supported by rigid metal conduit shall have conduit hubs with not less than 5 full threads or a similar supporting means that is strong so that the parts would comply with the requirements specified in the Pullout, Bending, and Twisting Tests in Clause 20.

6.1.10 A knockout for the connection of conduit to a transformer wiring compartment shall be constructed in accordance with Table 1.

6.1.11 Space shall be provided within a terminal or wiring compartment for a standard conduit bushing to be mounted on rigid metal conduit connected to the compartment.

6.1.12 Wires within an enclosure, compartment, or raceway shall be located or guarded to reduce the risk of contact with any sharp edge, burr, fin, or moving part that may cause damage to the conductor insulation.

6.1.13 Wiring space or other compartments provided for field wiring shall be free of any sharp edge, burr, fin, moving part, or sharp point of a sheet metal screw that would damage the conductor insulation or cause a cut-type injury.

6.1.14 An edge, projection, or corner of an enclosure, opening, frame, guard, knob, or handle of a device shall be smooth and rounded and shall not cause a cut-type injury when contacted during intended use or maintenance.

6.2 Nonmetallic enclosures

6.2.1 Polymeric Enclosures shall be rated minimum

a) 5VA when provided with a surface area larger than 25,800 mm^2 (40 in^2), or

b) 5VB when provided with all surface areas less than 25,800 mm^2,

and shall be evaluated in accordance with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, or CAN/CSA-C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials.

6.2.2 *Deleted*

6.2.3 Polymeric enclosures shall be subjected to the Polymeric enclosure impact test described in Clause 24.4.

6.3 Enclosures – specific environmental conditions

6.3.1 An enclosure intended for a specific environmental condition shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, UL 50, or CAN/CSA-C22.2 No. 94, Special Purpose Enclosures or the Standard for Enclosures for Electrical Equipment, Environmental Considerations, CAN/CSA C22.2 No. 94.2/NMX-J-235/2/UL 50E.

6.3.2 An enclosure of a transformer complying with the requirements for a Type 3R, when used with a field-added rain hood, may be shipped without the hood. However, a specialty transformer and the hood shall be marked as described in Clauses 17.3.2 – 17.3.4 of Part 2.

6.3.3 The mounting or securing means provided for the hood shall be external to the enclosure.

Note: Internal means may be provided if it is constructed to reduce the risk of water entering the enclosure.

6.4 Mounting

6.4.1 A transformer shall be provided with a secure mounting means. It shall be constructed so that there will be a spacing through air of not less than 6.4 mm (0.25 in) between the supporting surface and the enclosure when the device is mounted on a plane surface.

Note: A 6.4 mm spacing is not required between the supporting surface and the enclosure when the transformer is intended to be mounted on an outlet box cover or intended for mounting in a knockout of an outlet box or cabinet.

6.4.2 The means of securing a transformer to a wall shall be subjected to the Lifting or Mounting Means Test specified in Clause 37 of Part 2.

6.4.3 A transformer intended for mounting on an outlet box shall have an outlet box cover or similar item that achieves the same purpose.

6.4.4 When an outlet box cover is constructed of sheet steel, it shall have a thickness not less than 1.14 mm (0.045 in) when zinc coated, and 1.07 mm (0.042 in) when uncoated. When constructed of malleable iron, the cover shall have a wall thickness of not less than 2.4 mm (0.094 in). When constructed of another type of cast metal, the thickness shall not be less than 3.2 mm (0.125 in). Covers constructed of sheet aluminum, copper, or brass shall not be less than 1.47 mm (0.058 in) thick. The cover shall be resistant to corrosion on all surfaces.

6.4.5 When an outlet box cover is constructed of nonmetallic material, it shall:

a) Support a weight three times the weight of the transformer, as described in Clause 24.3.2.1, without cracking or crazing;

b) Withstand an impact of 7 J (5 ft·lbf) applied as described in Clause 24.3.3.1; and

c) Comply with the requirements for nonmetallic box covers in the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C, or CAN/CSA-C22.2 No. 18, Outlet Boxes, Conduit Boxes, Fittings, and Associated Hardware.

6.4.6 A transformer intended for mounting in place of a knockout in an outlet box, cabinet, or similar area shall be provided with mounting means that will restrain the transformer from being turned after it is mounted.

6.4.7 A transformer is considered to comply with the requirement in Clause 6.4.6 when the mounting means provides restraint against turning when the transformer is mounted in a box or cabinet wall having a minimum uncoated thickness of 1.35 mm (0.053 in).

6.4.8 When a nipple is provided on the primary side for connection to an outlet box, there shall not be fewer than three (3) complete engaging threads on the nipple.

6.5 Openings

6.5.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part, an opening in an enclosure, unless suitably baffled, shall comply with either Clause 6.5.2 or Clauses 6.5.3 and 6.5.4.

6.5.2 Openings shall prevent passage of a straight rod 12.7 mm (0.5 in) in diameter. When the distance between live parts and the enclosure is greater than 102 mm (4 in), openings shall be constructed so that they will prevent passage of a rod 19 mm (0.75 in) in diameter.

6.5.3 When inserted through an opening, the probe illustrated in Figure 1 shall not touch any uninsulated live parts (including film-coated wire) operating at a voltage of more than 42.4 V peak to any other part or to ground.

6.5.4 The probe illustrated in Figure 1 shall be inserted to any depth that the opening will permit, using an applied force not greater than 4.4 N (1 lb). The probe shall be applied in any possible configuration; and if necessary, the configuration shall be changed after insertion through the opening.

6.5.5 The diameter of the wires of a metal screen shall not be less than 1.3 mm (0.051 in) when the metal screen openings are 320 mm^2 (0.500 in^2) or less in area, and shall not be less than 2.06 mm (0.081 in) for larger screen openings.

6.5.6 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall be at least 1.07 mm (0.042 in) thick when uncoated and at least 1.14 mm (0.045 in) thick when zinc-coated for mesh openings or perforations 320 mm^2 (0.500 in^2) or less in area. They shall be at least 2.03 mm (0.080 in) thick when uncoated and at least 2.13 mm (0.084 in) thick when zinc-coated for larger openings.

6.5.7 A louver shall not be more than 305 mm (12 in) long.

6.5.8 The area of an opening covered by a louver, a perforated or an expanded-metal mesh panel that is thinner than the enclosure shall not exceed 0.129 m^2 (200 in^2).

6.6 Barriers for openings

6.6.1 A barrier that is not an integral part of the enclosure intended for enclosure openings shall comply with the requirements specified in Clauses 6.6.3 – 6.6.6.

6.6.2 Transformers shall be constructed so that molten or flaming particles cannot fall on the surface on or over which the transformer is mounted.

Note: This requirement does not apply to transformers intended for floor-mounting marked in accordance with Clause 17.2.3.

6.6.3 When a barrier is provided for compliance with Clause 6.6.2, it shall be located and situated as illustrated in Figure 2.

6.6.4 A sheet-metal barrier shall be at least 1.35 mm (0.053 in) thick when uncoated steel, 1.42 mm (0.056 in) thick when zinc-coated, or 1.91 mm (0.075 in) thick when aluminum.

Note: A metal barrier may be of thinner metal provided its strength and rigidity are not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness.

6.6.5 For bottom openings, a perforated metal barrier shall be constructed with a metal screen, or the equivalent, having 14 x 14 mesh and wire with a minimum diameter of 0.46 mm (0.018 in) or the perforated metal panel shall comply with the Hot, Flaming Oil Test in Clause 23 and Figure 2. A ventilated bottom panel not meeting these construction requirements shall also be subjected to this test.

6.6.6 A polymeric barrier shall comply with the applicable requirements of Nonmetallic enclosures in Clause 6.2. A polymeric barrier that is not an integral part of the enclosure shall be rated minimum V-2.

6.7 Covers

6.7.1 When doors and covers are provided for enclosures, they shall be hinged:

a) When they provide access to normal operating renewable fuses, thermal cutoffs, or other protective devices or

b) When opening covers for normal operation of the transformer are necessary.

6.7.2 When doors or covers provide access to protective devices, they shall shut closely against a minimum 6.3 mm (0.25 in) rabbet or shall have close-fitting flanges that overlap at least 12.7 mm (0.5 in). Any other construction affording equivalent protection shall be subject to investigation.

6.7.3 When they are provided to comply with Clause 6.7.1, hinged doors or covers shall not depend solely on screws or other similar means requiring the use of a tool to hold them closed. They shall be provided with a spring latch or catch unless the screws are captive. For doors or covers other than those required by Clause 6.7.1, a hasp, sliding latch, or other means may be used to hold them closed.

6.7.4 The cover of an enclosure shall be provided with means (such as screws) for firmly securing it in place. Friction alone shall not be used.

6.7.5 A cover that must be removed for the connection of circuit conductors shall not be provided with means for the connection of conduit or armored cable.

6.7.6 A transformer mounted on an outlet box cover and provided with secondary leads emanating from a flexible conduit connector may be used when the volt-ampere and secondary voltage ratings are not more than 100 VA and 30 V, respectively.

7 Corrosion Resistance

7.1 The internal and external surfaces of an enclosure of iron or steel (other than stainless steel) shall be corrosion resistant. Examples of corrosion resistance that comply with these requirements are galvanizing, plating, and enameling.

Note: An interior surface covered by a compound is not required to be additionally resistant to corrosion.

7.2 A Type 3R enclosure made of sheet steel (other than stainless steel) having a thickness of 3.05 mm (0.120 in) or more shall be made corrosion resistant by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel complying with the coating designation G60 or A60 in Weight [Mass] of Coating Requirements, Table 1 of ASTM A 653/A 653M, Standard Specification for Steel Sheet, Zinc-Coated, (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed), by the Hot-Dip Process, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the test method of ASTM A 90/A90M, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.

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 0.010 mm (0.00041 in) on each surface with a minimum thickness of 0.009 mm (0.00034 in). The thickness of the coating shall be established by a metallic coating thickness test as specified in the Standard for Enclosures for Electrical Equipment, UL 50, or CAN/CSA-C22.2 No. 94, Special Purpose Enclosures.

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on both surfaces after forming. The composition of the paint shall be evaluated to determine its suitability, or corrosion tests shall be conducted if these are considered necessary.

d) Any one of the means specified in Clause 7.3.

7.3 A Type 3R enclosure made of sheet steel (other than stainless steel) having a thickness of less than 3.05 mm (0.120 in) shall be made corrosion resistant by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel complying with the coating designation G90 in Weight [Mass] of Coating Requirements, Table 1 of ASTM A 653/A 653M, Standard Specification for Steel Sheet, Zinc-Coated, (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any

method. However, in case of question, the weight of the coating shall be established in accordance with the test method of ASTM A 90/A 90M, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.

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 0.015 mm (0.00061 in) on each surface with a minimum thickness of 0.014 mm (0.00054 in). The thickness of the coating shall be established by a metallic coating thickness test as specified in the Standard for Enclosures for Electrical Equipment, UL 50, or CAN/CSA-C22.2 No. 94, Special Purpose Enclosures. An annealed coating shall also comply with Clauses 7.6 and 7.7.

c) A cadmium coating not less than 0.025 mm (0.0010 in) thick on both surfaces. The thickness of coating shall be established by a metallic coating thickness test as specified in the Standard for Enclosures for Electrical Equipment, UL 50, or CAN/CSA-C22.2 No. 94, Special Purpose Enclosures.

d) A zinc coating complying with the requirements in Clause 7.2 (a) or (b) with one coat of outdoor paint as specified in Clause 7.2(c).

e) A cadmium coating not less than 0.0019 mm (0.000075 in) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.0013 mm (0.000051 in) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established by the metallic coating thickness test as specified in UL 50, or CAN/CSA-C22.2 No. 94. The paint shall be as specified in Clause 7.2(c).

7.4 With regard to Clauses 7.2 and 7.3, other finishes, including paints, special metallic finishes, and combinations of the two may be used when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) complying with Clauses 7.2(a) or 7.3(a), as applicable, indicate they provide equivalent protection. Among the factors taken into consideration when evaluating such coating systems are:

a) Exposure to salt spray,

b) Moist carbon dioxide-sulfur dioxide-air mixtures,

c) Moist hydrogen sulfide-air mixtures,

d) Ultraviolet light, and

e) Water.

7.5 An enclosure made of stainless steel, copper, brass, or aluminum shall not be required to be additionally corrosion resistant.

7.6 An annealed coating on sheet steel that is bent or similarly formed or extruded or rolled at edges of holes after annealing shall additionally be painted in the bent or formed area if the bending or forming process damages the zinc coating.

7.7 If flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification, the zinc coating is considered damaged. Simple sheared or cut edges and punched holes shall not be required to be additionally protected.

8 Connections

8.1 General

8.1.1 The requirements stated here pertain to all transformers unless otherwise indicated in Part 2 and Part 3.

8.1.2 A nominal 2.8-, 3.2-, 4.7-, 5.2-, or 6.4-mm (0.110-, 0.125-, 0.187-, 0.205-, or 0.250-in) wide quick-connect terminal shall comply with the requirements for the Standard for Electrical Quick-Connect Terminals, UL 310, or CSA C22.2 No. 153, Quick-Connect Terminals.

Other sizes of quick-connect terminals shall be investigated with regard to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rise. All tests shall be conducted in accordance with UL 310 or CSA C22.2 No. 153.

8.1.3 When a quick-connect terminal is provided, the maximum ampere rating of the coil shall be 5 A for a terminal tab with a nominal width of 3.2 mm (0.125 in) or less. The maximum ampere rating of the coil shall be 24 A for a terminal tab with a nominal width greater than 3.2 mm.

8.2 Wiring terminals

8.2.1 For these requirements, wiring terminals are those to which connections are made in the field when a transformer is installed. A terminal shall be a pressure terminal connector, a wire-binding screw, or a stud.

8.2.2 When a transformer is intended for mounting on an outlet box, wiring terminals that will be inside the box after the transformer is installed shall be located or recessed so that contact between the terminals and wires inside the box would be unlikely after the transformer is installed.

8.3 Wire-binding screws and studs

8.3.1 The thickness of a terminal plate for a wire-binding screw shall not be less than 0.76 mm (0.030 in). There shall not be less than 2 full threads in the metal for the binding screw.

8.3.2 A wire-binding screw or stud shall not be smaller than No. 8 (4.2 mm diameter) nor shall it have more than 1.26 threads per mm (32 threads per in). A No. 10 (4.8 mm) screw shall be used with conductors larger than 14 AWG (2.1 mm^2). For transformers intended for use in the United States, a No. 6 (3.5 mm) machine screw may be used where the factory-installed or intended field-installed conductor is not larger than 14 AWG.

8.3.3 A wire binding screw terminal design is one in which the conductor is intended to encircle the terminal screw at least 3/4 of one full turn without overlapping.

8.3.4 A wire binding screw shall thread into metal.

8.3.5 The terminal plate and the wire binding screw or stud and nut of a primary wiring terminal shall be of brass or similar nonferrous metal. A No. 10 (4.8 mm) or larger wire binding screw may be iron or steel if plated. A steel wire binding screw shall not be plated with copper or brass; however, a cadmium or zinc plating is acceptable.

8.3.6 Wire-binding screws or studs shall be provided with cupped washers, upturned lugs, or similar devices to retain the wires under the heads of screws or nuts.

8.3.7 A wire-binding screw shall be locked into position when replacement with a longer screw would create a risk of electric shock or fire.

8.4 Pressure terminal connectors

8.4.1 A pressure terminal connector, when intended to accommodate aluminum and copper conductors, shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, or CAN/CSA-C22.2 No. 65, Wire Connectors. The size and ampacity of the field-installed conductor shall be determined in accordance with Table 15.

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

8.4.3 When a pressure terminal connector is provided for field connection, it shall be sized to accept a conductor having an ampacity of at least 125 percent of the rated transformer full-load current that will flow through the field connector when the transformer is operating at full kVA at that terminal. For three-phase transformers, the line current is 0.577 of the ratio of the transformer three-phase VA rating to the line voltage.

Note: The wire connector may be sized for 100 percent of the rated transformer current only if the connector is mounted on a terminal pad as described in Clause 8.1.4 of Part 2 and is replaceable with a connector sized for 125 percent of the rated transformer output.

8.4.4 A pressure terminal connector shall be prevented from turning by a restraint such as a shoulder or boss. A lock washer alone shall not be used for this purpose.

Note: A means to prevent turning is not required when spacings are not less than those specified in Spacings and Insulation in Clause 11, with:

a) Connectors of opposite polarity turned 30 degrees toward each other; or

b) A connector turned 30 degrees toward any other opposite polarity live part or dead metal part.

8.5 Leads

8.5.1 A transformer lead shall have a voltage and temperature rating at least equal to that of the application. In a Class 120(E) or higher insulation system, a lead that is terminated under the outerwrap of the insulation shall be additionally investigated to determine its suitability for the application.

8.5.2 The connection between a lead and the winding or other part of the transformer shall be soldered, welded, or otherwise securely connected within the enclosure. A soldered joint shall be made mechanically secure before soldering.

8.5.3 When a lead is rigidly held in place without the use of solder or is intended to be retained in place by compound or other means so as not to be subjected to appreciable motion, additional mechanical security shall not be required.

8.5.4 Strain relief shall be provided so that stress on a lead, including a flexible cord, will not be transmitted to the connection inside the transformer. See Strain Relief in Clause 15.1.

8.5.5 A strain relief means shall not depend solely on adhesion between the conductor and an asphalt-type compound. When epoxy- and polyester-type compounds are used for strain relief, the construction shall comply with the strain relief tests specified in Strain Relief in Clause 15 of Part 2 and the Strain Relief Test in Clause 37 of Part 3.

8.5.6 The surface of an insulated lead intended for the connection of an equipment grounding conductor shall be green with or without one or more yellow stripes. No other lead shall be so identified.

8.5.7 Thermoplastic-insulated wire and flexible cord shall not be used for a transformer lead unless it has been investigated and determined to be acceptable for the application. The investigation is normally to consider the strain relief means used and the effects of the varnishing and compounding operations of the lead insulation.

8.5.8 Where a lead enters a metal enclosure, the hole shall be provided with insulating material or have smooth, well-rounded edges.

9 Internal Wiring

9.1 The internal wiring of a transformer shall be rated for the temperature, voltage, and other conditions of use to which it will be subjected.

9.2 A splice or connection shall be mechanically secure and shall provide electrical contact.

9.3 A splice shall be provided with insulation equivalent to that on the wires involved when necessary to maintain permanence of spacing between the splice and uninsulated live parts.

9.4 Aluminum conductors, insulated or uninsulated, used for internal interconnections between current-carrying parts shall be terminated at each end by a method that has been determined to be acceptable for the combination of metals at the connection points.

10 Grounding

10.1 All exposed dead metal parts shall be bonded together and to a grounding means provided for the connection of a grounding conductor when a transformer is:

a) Equipped with a wiring compartment;

b) Mounted on a nonmetallic outlet box cover; or

c) Intended for mounting on an outlet box provided with a nonmetallic cover.

The grounding means shall be a grounding screw, a threaded grounding stud, a grounding wire connector, or a grounding wire and shall be identified by the color green, with or without one or more yellow stripes, or by the designation "G," "GR," "GND," "Ground," or the equivalent. The symbol shown in Figure 3 may be used for this purpose.

When used alone, the symbol shall be defined in instructions provided with the transformer.

10.2 When a grounding screw is provided, it shall be No. 8-32 (4.2 mm diameter) or larger and shall have a head that is slotted, hexagonal, or both. When it threads into aluminum, the grounding screw shall be plated steel or stainless steel. When it threads into any other material, the grounding screw shall be plated steel, stainless steel, copper, or copper alloy. A grounding screw shall engage at least two full threads and shall be provided with upturned lugs or the equivalent to hold the conductor under the screw.

10.3 When a threaded grounding stud is provided, it shall be No. 8-32 (4.2 mm diameter) or larger. Studs shall be secured by threading, welding, brazing, or equivalent securement means. When it threads into aluminum, the grounding stud shall be plated steel or stainless steel. When it threads into any other material, the grounding stud shall be plated steel, stainless steel, copper, or copper alloy. A threaded

grounding stud shall be provided with a nut and cupped washer with upturned edges or the equivalent to hold the conductor under the nut head.

10.4 When a grounding wire connector is provided, it shall be a pressure wire connector sized to accept a minimum 14 AWG (2.1 mm^2) copper conductor.

10.5 When a grounding wire is provided, it shall be at least 14 AWG (2.1 mm^2) and shall be either bare, covered, or insulated solid or stranded copper. When covered or insulated, the covering or insulation shall be green with or without one or more yellow stripes, and no other lead shall be so identified. The grounding wire shall be not less than 152 mm (6 in) long. When the primary leads are larger than 14 AWG, the grounding wire shall be no smaller than the primary leads.

10.6 When a transformer is intended for connection to open wiring or concealed knob-and-tube wiring, a grounding means as described in Clause 10.1 shall be provided on the enclosure.

Note: In Canada, the Canadian Electrical Code, Part I, no longer permits concealed knob-and-tube wiring.

10.7 When a transformer intended for mounting on an outlet box is provided with a metal cover, all exposed dead metal parts shall be bonded to the cover.

10.8 When a transformer is intended for mounting in a knockout, all exposed dead metal parts shall be bonded to the mounting means. If there is no means for maintaining a bonding path between the transformer and the equipment grounding conductor when the transformer is installed in a nonmetallic box, the transformer shall be marked in accordance with Clause 17.2.2.

Note: An additional bonding means is not required on metal box covers or metallic nipples.

10.9 The grounding path, when ferrous, shall be resistant to corrosion by varnishing, painting, galvanizing, plating, or a similar means. A grounding connection may include a metal enclosure, or wires, or similar device completely within the enclosure. When a separate conductor is used, it shall not be secured by a removable fastener used for any purpose other than grounding, unless the conductor is unlikely to be omitted after removal and replacement of the fastener. The ends of the conductor shall be in metal-to-metal contact with the parts to be bonded.

10.10 A solder splice shall not be used in a wire intended for bonding purposes.

11 Spacings and Insulation

11.1 General

11.1.1 In addition to these requirements, see Spacings and Insulation in Clause 11 of Part 2 and Part 3.

11.1.2 The spacings at wiring terminals between uninsulated live parts of opposite polarity and between an uninsulated live part and a dead metal part that may be grounded when the transformer is installed shall not be less than those indicated in Table 6 – Table 9 for each respective case. To simulate operating conditions, the spacings at wiring terminals shall be measured with field-installed conductors in place on all terminals. For general purpose transformers, the wire size shall be the smallest size having an ampacity of at least 125 percent of the full-load current of the winding and sized in accordance with the requirements in Clause 11.1.2 of Part 2.

Note: These spacing requirements do not apply when insulation complying with Clause 11.4.1 is provided.

11.1.3 At points other than wiring terminals, spacings shall not be less than those indicated in Table 6 between:

a) Uninsulated live parts of opposite polarity;

b) An uninsulated live part and a dead metal part; and

c) Different windings.

Note 1: Spacings between adjacent windings and between windings and ground may be minimum 1.6 mm (0.063 in) for transformers rated 300 V or less and minimum 3.2 mm (0.125 in) for transformers rated over 300 V, where windings are reliably held in place by means such as varnishing or impregnation. (When spacings within a transformer coil are reliably maintained by means such as varnishing or impregnation, the spacings may be in accordance with Table 7 or Table 8 and the requirements in Clause 11.4.10 of Part 2.)

Note 2: These winding spacing requirements do not apply:

a) Between turns of the same winding.

b) Between different windings when the sum of the open circuit voltages of the windings is 30 V or less.

c) When insulation complying with Clause 11.4.1 is provided.

d) Between multi-filar windings designed for series or parallel connections.

Note 3: For transformer coils constructed on molded or rigid polymeric forms, these spacings do not apply between a crossover lead and the winding to which it is conductively connected when:

a) A molded in slot relief having a minimum depth dimension of twice that of the crossover wire diameter is provided and

b) A molded or otherwise fixed open slot is provided that allows the crossover conductor to be positioned away from the coil to which it is connected.

11.2 Insulating material for mounting of low voltage live parts

11.2.1 Material for the mounting of low voltage live parts shall be glass, porcelain, phenolic or cold-molded composition, or similar insulating material. Untreated fiber, rubber, wood, and hot-molded shellac or tar compositions shall not be used.

Note: This requirement does not apply to material used for separators, spacers, coil supports, and similar parts within a transformer enclosure.

11.2.2 A polymeric insulating material used as electrical insulation or for direct or indirect support of live parts shall provide the levels of performance specified in the requirements for direct and indirect support of live parts in the standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, or CAN/CSA-C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials.

Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as the sole support of uninsulated live parts.

11.3 Coil insulation

11.3.1 Coils shall be constructed to provide insulation between the various windings and between the windings and the core and the enclosure.

11.3.2 Coil insulation, unless inherently moisture-resistant, shall be treated to render it resistant to moisture.

11.3.3 Film-coated wire is not required to be additionally treated to reduce moisture absorption.

11.3.4 Coil insulating materials used in a transformer insulation system that is not rated Class 120(E) or higher shall have an electrical relative thermal index not less than 105°C (221°F), as determined by the

requirements in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, or CAN/CSA-C22.2 No. 0.17, Evaluation of Properties of Polymeric Materials.

Note 1: Electrical grade paper as described in Clause 11.4.1 is not required to have an electrical relative thermal index.

Note 2: Insulating materials used as insulation in areas other than between primary and secondary windings and the primary or secondary windings and core are not required to have an electrical relative thermal index.

Note 3: Magnet wire insulation is not required to have an electrical relative thermal index.

Note 4: Insulating materials used as insulation between the windings and core of a toroidal transformer are allowed to have an electrical thermal index less than 105°C when the core is not exposed.

11.3.5 When the temperature rise on a coil measured by the change of resistance method is above the limit for Class 105(A) insulation as specified in Tables 8 and 9 of Part 2 and Table 7 of Part 3, the following requirements apply:

a) For transformers intended for use in Canada, coil insulating materials shall comply with CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II, or the coil insulation system shall comply with the Standard for Systems of Insulating Materials – General, UL 1446. Additionally, the transformer shall be marked as indicated in Clause 17.2.5 to verify that the insulation system complies with the requirements in UL 1446.

b) For transformers intended for use in the United States, the coil insulation system shall comply with UL 1446. Additionally, the transformer shall be marked as indicated in Clause 17.2.5 to verify that the insulation system complies with the requirements in UL 1446.

11.4 Insulation used in lieu of spacings

11.4.1 Insulating material used in lieu of the spacing requirements shall:

a) Be rated for the application;

b) Comply with Table 10;

c) Be resistant to moisture;

d) Be securely held in place; and

e) Be of the same strength as electrical grade paper when exposed or otherwise likely to be subjected to mechanical damage.

Note: Insulating material used in lieu of spacings located between different windings; between any winding and the core; between any crossover lead and a metallic enclosure; or between any crossover lead and the core may be:

a) Electrical grade paper that has been waxed or otherwise treated to make it resistant to moisture absorption and that has a minimum total thickness of 0.30 mm (0.012 in), which may consist of more than one layer of paper;

b) A polymeric coil form of not less than 0.64 mm (0.025 in);

c) Material of any thickness mechanically and thermally equivalent with a minimum dielectric breakdown voltage of 2500 V applied as described in the Insulating Barriers Test in Clause 19; or

d) Triple-insulated magnet wire that complies with the requirements for wire insulation in the Standard for **Single- and Multi-Layer Insulated Winding Wire, UL 2353, or** *CAN/CSA-C22.2 No. 60950-1-03, Information Technology Equipment – Safety-Part 1: General Requirements*, **or** *CAN/CSA-C22.2 No. 60065:03, Audio, Video and Similar Electronic Apparatus – Safety Requirements.*

11.4.2 The coating on magnet wire shall not be relied upon as the sole insulating material specified in Clause 11.4.1.

Note 1: This requirement does not apply to triple-insulated magnet wire as noted in item (d) of the note in Clause 11.4.1.

Note 2: The coating on the magnet wire may be relied upon as the sole insulating material as specified in 11.4.1 for multifilar windings designed for series or parallel connection. Transformers provided with multifilar windings designed for series or parallel connection are to be subjected to the induced potential test described in Clause 25.1.

11.4.3 The layer of insulating material between an input winding and an output winding in a flanged, bobbin-wound transformer in which the windings are wound one on top of the other, shall have a continuous minimum 0.8 mm (0.031 in) bent-up edge against both of the bobbin end flanges.

Note: Margin tape may be used if spacings are reliably maintained.

11.4.4 Except as specified in Clauses 11.4.5, 11.4.6 and 11.5.1 of Part 3, insulation between the primary crossover leads (and between secondary crossover leads, where the secondary is greater than 30 V rms) and

a) The winding to which the leads are connected;

b) The adjacent winding;

c) The metallic enclosure; or

d) The core

shall be electrical grade paper at least 0.30 mm (0.012 in) thick or insulation as required by Clause 11.4.1 except that the insulation is not required when the spacing specified in Clause 11.1.3 is maintained.

11.4.5 Crossover insulation may be electrical grade paper with a minimum thickness of 0.05 mm (0.002 in) or equivalent, when:

a) A spacing of one-half of that specified in Table 6 is maintained or

b) The coil withstands the Induced potential test described in Clause 25.1.

11.4.6 The start lead, crossover lead, or start and crossover leads of magnet coils wound on molded bobbins incorporating a cavity slot or opening need not be further insulated if:

a) The subject windings withstand the induced potential described in Clause 29.2 of Part 2 and Clause 32.2 of Part 3 and

b) The start, crossover, or start and crossover leads are placed within the cavity slot or opening provided for that purpose.

11.4.7 Except as provided for in Table 10, insulation between the primary lead connections and the adjacent winding or shield and between secondary lead connections and the primary winding shall be one of the following:

a) Electrical grade paper that has a minimum thickness of 0.71 mm (0.028 in);

b) Other insulating material mechanically and thermally equivalent (except in thickness) to that in (a), with a dielectric breakdown voltage of not less than 5000 V as described in the Insulating Barriers Test in Clause 19.

11.4.8 Insulating material used in lieu of spacing requirements not covered in this part shall comply with applicable requirements in Spacings and Insulation in Clause 11 of Part 2 and of Part 3.

11.4.9 Encapsulants may be used to reduce spacings provided:

a) Minimum 0.8 mm (0.031 in) spacings shall be maintained prior to application of the encapsulant;

b) The area of reduced spacing, with the encapsulant applied, withstands the applicable Dielectric Voltage-Withstand Test described in Clause 32 of Part 3; and

c) The encapsulant temperature during the Temperature (Heating) Test in Clause 26 does not exceed 65°C rise (based on an assumed operating ambient rating of 25°C (45°F) or 90 °C (194°F)), when tested at an ambient rating of greater than 25°C.

When the encapsulant has been investigated and rated for a higher operating temperature, the temperatures shall not exceed the material temperature rating.

11.5 Double insulation

11.5.1 Units marked with the words, "Double Insulated", or with the symbol for double insulation (a square within a square), shall comply with the Reference Standard for Double Insulation Systems for Use in Electronic Equipment, UL 2097, or General Requirements for Double-Insulated Equipment, CSA C22.2 No. 0.1.

12 Switches, Protective Devices, and Wiring Devices

12.1 General

12.1.1 A switch or other wiring device shall be secured to its supporting surface by a method other than friction between surfaces to prevent it from turning or shifting in position when such motion may result in reduction of spacings to less than those required in this Standard.

12.2 Switches

12.2.1 An ON/OFF switch provided on transformers mounted on outlet boxes shall completely disconnect all ungrounded conductors from the load it controls when the device is in the OFF position.

12.3 Protective devices

12.3.1 Protective devices include fuses, over-temperature and overcurrent protectors, thermal protectors, eutectic material, and similar devices intended:

a) To interrupt the flow of current;

b) To limit the maximum temperature; or

c) To interrupt the flow of current and limit the maximum temperature

as a result of overload conditions.

12.3.2 Crossed or reduced cross-section conductors shall not be employed as a protective device. A nicked conductor is a form of reduced cross-section conductor.

12.3.3 Operation of a thermal cutoff in a transformer shall not cause a risk of fire or electric shock during intended use. A thermal cutoff shall comply with the requirements of the Standard for Thermal-Links – Requirements and Application Guide, UL 60691, or CSA C22.2 No. 209, Thermal Cut-Offs.

12.3.4 A manually reset type of protective device shall be constructed so that automatic tripping is not prevented by any setting or position of the reset mechanism.

13 Current-Carrying Parts

13.1 A current-carrying part shall be constructed of silver, copper, aluminum, alloys of these metals, or similar materials.

13.2 An aluminum current-carrying part shall be plated at each bolted joint with tin, silver, nickel, or cadmium, unless one or more internal connections are welded or for any connections to the part that are not welded, these are assembled using a oxide-inhibiting compound, or for a bus bar welded to an aluminum pad to which pressure terminal connectors are to be bolted, an oxide-inhibiting compound is provided along with instructions for its application.

13.3 Iron and steel shall not be used for a current-carrying part.

Note: A plated steel screw, nut, and stud may be used to secure a soldering lug, pressure wire connector, or bus bar. A No. 10 or larger plated steel wire-binding screw may be used at a terminal in connection with a nonferrous terminal plate.

13.4 Cadmium, zinc, tin, or silver shall be used to plate wire binding screws, nuts, and stud terminals. Copper and brass shall not be used for plating. Binding head screws, bolts, studs, nuts, and washers used for electrical connections shall be of nonferrous metal except that iron or steel may be used for No. 10 sizes or larger when:

a) These parts are protected with a plating of cadmium, zinc, or a similar material with a thickness of not less than 0.005 mm (0.0002 in) and

b) The conductor or terminal to be secured is clamped against a surface of nonferrous metal that will carry the greater part of the current.

The threading of binding head screws and machine screws, other than wiring terminal screws, into material other than metal shall be evaluated.

13.5 An uninsulated live part shall be secured to prevent its turning or shifting in position when such motion can result in the reduction of spacings below minimum required values.

13.6 Friction between surfaces shall not be used as means to prevent shifting or turning of a live part.

13.7 A spring washer of a type intended for use with an aluminum bus shall be used at one end of a bolt that secures current-carrying parts together if an aluminum part is included in the joint.

Note 1: A spring washer may be replaced with a split-ring lock washer and flat washer if each aluminum part in the joint has a tensile yield strength of at least 138 MPa (20,000 lb/in^2).

Note 2: A flat washer, a split-ring lock washer, or a bolt head that complies with Clause 13.9(b) may be used in place of a spring washer if aluminum bolts are used.

Note 3: A spring washer is not required for a type of fastener equivalent to that used for investigating a component wire connector in accordance with the Standard for Wire Connectors, UL 486A-486B or the Standard for Wire Connectors for Use with Aluminum and/or Copper Conductors, UL 486E, *or CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code Part II.*

Note 4: A spring washer is not required at a bolted contact of an aluminum alloy part used in the grounding circuit for an application such as the service grounding electrode, a neutral bonding conductor, or an equipment grounding conductor.

13.8 A spring washer as specified in Clause 13.7 (such as a Belleville washer or similar item) and illustrated in Figure 4 is a dished washer of stainless or hardened and tempered steel, having:

a) An outer diameter not less than 150 percent of the bolt diameter;

b) A thickness not less than one eighth of the bolt diameter; and

c) A dish not less than 3.5 percent of the bolt diameter.

13.9 A flat washer as specified in Note 2 of Clause 13.7 shall have:

a) A thickness at least one sixth the diameter of the rivet shank or bolt and

b) An outer diameter at least 150 percent of that of the rivet shank or bolt but not less than the outer diameter of the spring washer.

13.10 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 any polymeric insulation material to maintain the clamping force.

14 Cord-Connected Transformers

14.1 Cord-Connected Transformers shall comply with Cord Connected Transformers in Clause 14 of Part 2.

15 Strain Relief

15.1 Strain relief shall be investigated in accordance with Strain Relief in Clause 15 of Part 2 and the Strain Relief Test in Clause 37 of Part 3.

16 Bushings for Low Voltage Wiring

16.1 A bushing used in a transformer that may be exposed to moisture shall be constructed of:

a) Porcelain;

b) Cold-molded or phenolic composition; or

c) Other similar insulating material.

A bushing constructed of fiber shall be treated for moisture resistance; it shall comply with the Moisture Absorption Test in Clause 22.

16.2 When provided, an untreated fiber or rubber bushing shall be used only in a transformer intended for use indoors. Additionally, rubber bushings shall only be used for Class 2 circuits.

16.3 A fiber bushing shall have a wall thickness of not less than 1.2 mm (0.05 in) and shall be formed and secured in place so that it would not be adversely affected by conditions of moisture or intended use. A fiber plate not less than 0.8 mm (0.031 in) thick, with a punched hole, may be used instead of a bushing when the cord or wire is rigidly held in position.

16.4 A bushing shall be securely held in place.

16.5 An insulating bushing is not required at a point where a low-voltage wire or cord passes through:

a) A hole in an interior metal wall or barrier;

b) A hole in insulating material;

c) A conduit nipple or hub; or

d) An armored cable connector or the equivalent.

16.6 An insulating bushing is not required where a Type SV or heavier flexible cord enters the enclosure of a transformer.

17 Markings

17.1 General

Advisory Note: *In Canada, there are two official languages, English and French. Annex C provides French translations of the 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.*

17.1.1 A transformer shall have a plain legible marking that includes:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified;

b) The catalog number or the equivalent;

c) The electrical rating; and

d) The date of manufacture which may be abbreviated, or in an established or otherwise traceable code, or a code affirmed by the manufacturer. When a code is used, it shall enable the transformer to be identified as manufactured within a 3-month period.

Note: The manufacturer's identification may be in a traceable code when the transformer is identified by the brand or trademark owned by a private labeler.

17.1.2 When a manufacturer produces transformers of a particular type (for example, general purpose transformers) at more than one factory, each finished transformer shall have a distinctive marking to identify it as the product of that factory. The marking may be provided as part of a code.

17.1.3 A cautionary marking shall be prefixed by the word "CAUTION", "WARNING", or "DANGER" in letters not less than 3.2 mm (0.125 in) high. The remaining letters of such marking shall not be less than 1.6 mm (0.06 in) high.

17.1.4 For component transformers, only the manufacturer's name and catalog number are required to appear on the transformer.

17.1.5 A required marking shall be molded, die stamped, paint stenciled, stamped or etched on metal, or indelibly stamped on pressure sensitive labels secured by adhesive. Pressure sensitive labels secured by adhesive shall comply with the Standard for Marking and Labeling Systems, UL 969, or CSA C22.2 No. 0.15, Adhesive Labels.

17.1.6 *Deleted*

17.2 Miscellaneous

17.2.1 When more than one primary circuit wire connector is provided at a single connection point, each connector shall be identified as to the wire size or range of wire sizes for which it is appropriate.

17.2.2 In accordance with Clause 10.8, when there is no means for maintaining a bonding path between the transformer and the equipment bonding conductor, the transformer shall be marked "Install in Metal Box Only."

17.2.3 When required by Clause 6.6.2, transformers shall be marked with the following or equivalent wording: "CAUTION: When mounting on or over a combustible surface, a floor plate of at least 1.43 mm (0.056 in) galvanized or 1.6 mm (0.06 in) uncoated steel must be installed to extend at least 150 mm (5.9 in) beyond all sides of the transformer."

17.2.4 A transformer with primary field-wiring terminals intended for use with copper and aluminum conductors shall be marked "Use copper or aluminum wire." When field-wiring terminals are intended for aluminum wire only, the transformer shall be marked "Use aluminum wire only."

17.2.5 Transformers provided with an insulation system evaluated in accordance with the Standard for Systems of Insulating Materials – General, UL 1446, or intended for use in the United States, shall be marked with the following:

$$X\text{-}YZ$$

in which:

X is "ISC," the acronym for "Insulation System Class;"

Y is the rating of the insulation system (i.e., Class 130(B) insulation); and

Z is "US," the acronym for the country in which the transformer is intended to be used.

17.2.6 Transformers provided with an insulation system evaluated in accordance with CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II, or intended for use in Canada, shall be marked with the following:

$$X\text{-}YZ$$

in which:

X is "ISC," the acronym for "Insulation System Class;"

Y is the rating of the insulation system (i.e., Class 130(B) insulation); and

Z is "CAN," the acronym for the country in which the transformer is intended to be used.

17.2.7 Transformers provided with an insulation system evaluated in accordance with the Standard for Systems of Insulating Materials – General, UL 1446, and CAN/CSA-C22.2 No. 0, General Requirements – Canadian Electrical Code, Part II, or intended for use in the United States and Canada, shall be marked with the following:

$$X\text{-}Y$$

in which:

X is "ISC," the acronym for "Insulation System Class;" and

Y is the rating of the insulation system (i.e., Class 130(B) insulation)

18 Tests

18.1 The specifications and order for tests are noted in the subsequent parts of this standard.

18.2 Unless otherwise specified, all tests shall be conducted at the supply voltages specified in Table 12.

18.3 When marked, the primary input in amperes, volt amperes, or watts shall not exceed the marked rating by more than 10 percent when the transformer is operated from a supply circuit of the rated voltage or voltages and frequency as marked and delivering rated output voltage and current, volt amperes or watts into a resistive load. The primary input amperes shall not exceed the marked rating when the equipment is operated at a test voltage specified in Table 12.

18.4 The frequency of the circuit shall be the rated frequency of the transformer. When the transformer is rated for a range of frequencies (such as 50 – 60 Hz) or has a dual frequency (such as 50/60 Hz), tests shall be conducted at 60 Hz unless otherwise specified in this standard.

18.5 Results obtained from the tests described in Clauses 25 and 26 performed on transformers with aluminum windings can be used to represent transformers with copper windings. However, results of those tests conducted on transformers with copper windings cannot be used to represent transformers with aluminum windings.

18.6 With regards to Clause 18.2, when a transformer is provided with one or more primary voltage winding taps, the lowest rated full capacity tap shall be tested. The test voltage applied to this tap shall be as specified in Table 12. When the voltage is expressed as a range, the highest voltage of the range shall be used.

19 Insulating Barriers Test

19.1 This test shall be performed as noted in Clauses 11.4.1 and 11.4.7. The insulating material shall be placed between two opposing electrodes. The electrodes shall be cylindrical brass or stainless steel rods 6.4 mm (0.25 in) in diameter with edges rounded to a 0.8 mm (0.031 in) radius. The upper moveable electrode shall weigh 50 ±2 grams to exert sufficient pressure on the specimen and provide electrical contact. The test potential shall be increased to the test value and the maximum test potential shall be maintained for 1 second. There shall not be dielectric breakdown.

20 Pullout, Bending, and Twisting Tests

20.1 Conduit and fixture connections of a transformer constructed for support by rigid metal conduit shall be subjected to:

a) A pull of 890 N (200 lb);

b) A bending moment of 67.8 N·m (600 lbf-in); and

c) A torque of 67.8 N·m.

Each of the above tests shall be applied for 5 minutes on 3 separate samples. The connections shall not be pulled apart following this test.

20.2 When the pullout test is conducted, the transformer shall be supported by rigid metal conduit in the intended manner. Then, the transformer shall support a weight of 90.7 kg (200 lbs) or, if a fixture stud or similar fitting is provided, the weight shall be supported from rigid metal conduit or similar material threaded onto this fitting so that the stud and the conduit connection are tested simultaneously.

20.3 When the bending and twisting tests are conducted, the transformer shall be rigidly supported by a means other than the conduit fittings. In the bending test, the force shall be applied to the conduit at right angles to its axis. The lever arm shall be measured from the inner end of the threaded section, in a conduit-hub- or stud-type connection, to the point of application of the bending force.

20.4 In the torsion test, the torque shall be applied to the conduit in a direction tending to tighten the connection, and the lever arm shall be measured from the center of the conduit.

21 Bonding Conductor Test

21.1 A bonding conductor shall be subjected to the tests noted in Clauses 21.2 – 21.4 where appropriate. Neither the bonding conductor nor the connection shall open when:

a) Carrying currents equal to 135 and 200 percent of the rating or setting of the intended branch-circuit overcurrent-protective device for the times specified in Table 13; and

b) Three samples are subjected to a limited-short-circuit test using a test current as specified in Table 14 while connected in series with a nonrenewable fuse rated in accordance with Table 13.

Note: When a fuse that is smaller than that indicated in (a) and (b) is used in the unit for protection of the circuit to which the bonding conductor is connected, then the magnitude of the test current and size of fuse used during the test is to be based on the rating of the smaller fuse.

21.2 The test circuit described in Clause 21.1(b) shall have a power factor of 0.9 – 1.0 and a closed-circuit test voltage as specified in Table 12. The open-circuit voltage shall be 100 – 105 percent of the closed-circuit voltage.

21.3 With the bond at normal operating temperature, the current shall be applied from dead metal part intended for grounding to the grounding terminal means for the period specified in Table 13. The potential drop shall be measured between the grounded part and grounding terminal means at the end of this period.

21.4 Results comply when:

a) The measured potential drop does not exceed 4 V;

b) The bonding connection does not open; and

c) There is no evidence of melting of any metal bond nor heating or burning that would create a risk of fire or shock hazard.

22 Moisture Absorption Test

22.1 A sample of material required to be resistant to moisture shall not absorb more than 10 percent of the water by mass when:

a) Dried at 105 ±5°C (221 ±41°F) for 1 hour;

b) Immersed in water at 23 ±1°C (73.4 ±33.8°F) for 24 hours; and

c) Removed from the water with surface water wiped off.

23 Hot, Flaming Oil Test

23.1 Constructions, including a ventilated bottom panel, not meeting the requirements in Clause 6.6.4 shall be evaluated by conducting the tests described in Clauses 23.2 – 23.5.

23.2 Openings in a bottom panel shall be small in size, few in number, and arranged so that hot, flaming No. 2 fuel oil poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

23.3 A sample of the complete, finished bottom panel shall be supported in a horizontal position a short distance above a horizontal surface under a hood (or in another area that is ventilated but free from drafts). Bleached cheesecloth running 28 – 30 m^2/kg mass (14 – 15 yd^2/lb) and having, for any square inch, 32 threads in one direction and 28 in the other, shall be draped in one layer over a shallow, flat-bottomed pan. The pan shall be sized and shaped to cover completely the pattern of openings in the panel but not so large as to catch any of the oil that does not pass through the openings or runs over the edge of the panel. The pan shall be positioned with its center under the center of the pattern of openings in the panel. The center of the cheesecloth shall be 50.8 mm (2 in) below the openings.

Note: Use of a metal screen or wired-glass enclosure surrounding the test area is recommended to reduce the likelihood of splattering oil, causing injury to test personnel.

23.4 A small metal ladle no more than 63.5 mm (2.5 in) in diameter, with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, shall be partially filled with 10 cm^3 (0.61 in^3) of No. 2 fuel oil, which is a medium-volatile distillate having:

a) A minimum API gravity of 30 degrees,

b) A flash point of 43.3 – 87.7°C (110 – 190°F), and

c) An average calorific value of 38.2 MJ/L (136,900 Btu per gallon). See Standard Specification for Fuel Oils, ASTM D 396.

The ladle containing the oil shall be heated and the oil shall be ignited. The oil shall flame for 1 minute and then shall be poured at the approximate rate of, but not less than, 1 cm^3 (0.061 in^3) per second in a steady stream onto the center of the pattern of openings from a position 102 mm (4 in) above the openings. The oil shall not ignite the cheesecloth.

23.5 Five minutes after completion of the pouring of the oil, the cheesecloth shall be replaced with a clean piece and a second 10 cm^3 (0.61 in^3) of hot, flaming oil shall be poured from the ladle onto the openings. The cheesecloth shall again be observed to see if it ignites. Five minutes later, a third identical pouring shall be made. The cheesecloth shall not ignite during any three pourings.

24 Enclosure Tests

24.1 General

24.1.1 For additional enclosure requirements not referenced in this Clause, see Part 2 and Part 3.

24.2 Compression test

24.2.1 An outside force of 444 N (100 lbs) shall be directed toward the inside of the transformer on each of the five surfaces of the assembled transformer enclosure. (The transformer core and coil need not be installed in the enclosure during this test unless the core and coil are necessary to maintain the structural strength of the finished transformer.) The force shall be applied gradually 90 ±5 degrees to each of the thinner metal surfaces in any area that is most likely to cause the greatest deflection. The force shall be transmitted through a rod having a flat steel face with a 12.7 mm (0.5 in) square contact area at the transformer surface. There shall not be inward deflection greater than 12.7 mm.

24.3 Outlet box cover support and impact tests

24.3.1 General

24.3.1.1 When a transformer is provided with an endbell or a nonmetallic cover intended to cover an outlet box as described in Clause 6.7.2, the cover shall be subjected to the tests described in Clauses 24.3.2.1 and 24.3.3.1. There shall be no cracking or crazing of the cover. At the conclusion of the test, the cover shall withstand a potential of 2 V + 1000 V (applied as described in the Dielectric Voltage-Withstand Test in Clause 29 of Part 2 or Dielectric Voltage-Withstand Test in Clause 32 of Part 3) without dielectric breakdown. V is the test voltage specified in Table 12.

24.3.2 Support

24.3.2.1 One sample of the transformer and cover shall be mounted on an outlet box and subjected to application of a weight three times the weight of the transformer using both configurations shown in Figure 5.

24.3.3 Impact

24.3.3.1 Three samples of the transformer and cover (including end bells) shall be subjected to a single impact of 7 J (5 ft-lbs) with the transformer and cover mounted on an outlet box. The impact shall be produced as shown in Figure 6 by:

a) Dropping a steel sphere 51 mm (2 in) in diameter and weighing 0.535 kg (1.18 lbs) from a height of 1.3 m (51 in) or

b) Suspending the steel sphere from a cord and swinging it as a pendulum, dropping through a vertical distance of 1.3 m.

24.4 Polymeric enclosure impact test

24.4.1 When applicable, polymeric enclosures referenced in Clause 6.2.3 shall be subjected to the following tests specified in Clauses 24.4.2 – 24.4.4.

24.4.2 Three samples shall each be subjected to an impact on any surface that is exposed to a blow during normal use or during installation. For an enclosure with no side or face having a surface area exceeding 25,800 mm^2 (40 in^2), the impact shall be 6.78 N·m (5 ft/lbs). The impact shall be produced by dropping a steel sphere, 51 mm (2 in) in diameter with a mass of 0.53 kg (1.2 lb), from a height of 1300 mm (4.3 ft.). For an enclosure having any surface area of more than 25,800 mm^2, the impact shall be 13.56 N·m (10 ft/lbs). The steel sphere shall be dropped from a height of 2600 mm (8.5 ft). Tests are to be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F).

Note: At the manufacturer's discretion, one sample of the transformer may be submitted and subjected to three impacts where applicable.

24.4.3 Three samples shall each be cooled to 0°C (32°F) and maintained at that temperature for 3 hours Immediately following removal from the cold chamber, each sample shall be subjected to the appropriate impact described in Clause 24.4.2.

24.4.4 As a result of the tests described in Clauses 24.4.2 and 24.4.3, the impacts shall not:

a) Reduce spacings below the minimum required values;

b) Make any bare live parts or internal wiring accessible;

c) Have an undue adverse effect on the insulation; and

d) Produce any other condition that might increase a risk of shock or fire.

25 Induced Potential

25.1 While heated as indicated in the specific test condition noted in Induced Potential in Clause 29.2 of Part 2 or Induced Potential in Clause 32.2 of Part 3, a transformer shall be subjected to the application of an alternating potential between the terminals of one winding with the ends of all other windings of the transformer open. The potential shall be twice the rated voltage of the winding under test. The frequency of the applied potential shall be minimum twice the rated frequency of the transformer and shall be applied for 7200 cycles. There shall not be dielectric breakdown.

25.2 The test voltage noted in Clause 25.1 shall be started at one-quarter or less of the full value and increased to full value in not more than 15 seconds. After being held for the time specified, the voltage shall be reduced to one-quarter of the maximum value or less in the same manner within 5 seconds. The circuit shall then be opened.

26 Temperature (Heating) Test

26.1 Requirements relating to heating shall be based on an ambient air temperature of 25°C (77°F). When a temperature test is conducted at any ambient air temperature, the variation from 25°C shall be added to or subtracted from the observed temperature reading.

26.2 Temperatures shall be measured by means of thermocouples unless it is specifically stated that temperature determinations shall be made by the change-of-resistance method. A thermocouple-measured temperature is constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test (but at not less than 5 minute intervals), show no change. The junction of the thermocouple shall securely contact the point of the surface to be measured. The thermocouple shall consist of wires not larger than 24 AWG (0.21 mm^2).

Note: Where the thermocouple is used to measure temperatures of electrically live points, electrical insulation may have a maximum thickness of 0.71 mm (0.028 in) between the thermocouple and the live points.

26.3 When thermocouples are used to determine temperatures regarding the heating of electrical devices, it shall be standard practice to use thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer-type indicating instrument. Such equipment shall be used whenever referee temperature measurements are necessary. The thermocouple wire shall comply with the requirements for special thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in the *Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples,* ANSI/ASTM E230/E230M.

26.4 The temperature rise of a copper or aluminum winding shall be determined by the change-of-resistance method using the following formula (windings are to be at room temperature at the start of the test):

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

in which:

Δt is the temperature rise,

R is the resistance of the coil at the end of the test,

r is the resistance of the coil at the beginning of the test,

k is 234.5 for copper and 225.0 for aluminum,

t_1 is the room temperature in degrees C at the beginning of the test, and

t_2 is the room temperature in degrees C at the end of the test.

26.5 Short lengths of conductors may be exposed to temperature rises higher than those shown in the respective Temperature Test tables when supplementary heat-resisting insulation of adequate dielectric strength is used over the insulation to safeguard against deterioration.

TABLES

Table 1
Dimensions of conduit bushings and diameter of knockouts and widths of flat surrounding surfaces

(See Clause 6.1.10)

Trade size of conduit,		Bushings				Knockout diameter				Minimum width of flat surrounding surface,	
		Overall diameter,		Height,		Minimum,		Maximum,			
mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
16	0.50	25.4	1.00	9.5	0.38	21.82	0.859	23.01	0.906	3.3	0.13
21	0.75	31.4	1.23	10.7	0.42	27.79	1.094	28.98	1.141	4.1	0.16
27	1.00	40.5	1.59	13.1	0.52	34.52	1.359	35.71	1.406	5.1	0.20
35	1.25	49.2	1.94	14.3	0.56	43.66	1.719	44.86	1.766	6.9	0.27
41	1.50	56.0	2.20	15.1	0.59	50.01	1.969	51.21	2.016	7.9	0.31
53	2.00	68.7	2.70	15.9	0.625	62.31	2.453	63.50	2.500	9.1	0.36
63	2.50	81.8	3.22	19.1	0.75	75.01	2.953	76.20	3.000	7.6	0.30
78	3.00	98.4	3.88	20.6	0.81	90.88	3.578	92.08	3.625	8.4	0.33
91	3.50	112.7	4.44	23.8	0.94	104.0	4.094	105.6	4.156	8.6	0.34
103	4.00	126.2	4.97	25.4	1.00	117.1	4.609	118.7	4.672	9.7	0.38
129	5.00	158.0	6.22	30.2	1.19	144.5	5.688	146.1	5.750	12.2	0.48
155	6.00	183.4	7.22	31.8	1.25	172.2	6.781	173.8	6.844	14.2	0.56

Table 2
Minimum thickness of sheet metal for enclosures for transformers rated greater than 10 kVA

(See Clause 6.1.2)

Maximum dimensions of enclosure				Minimum average thickness of sheet metal							
				Steel[a]				Copper, brass, or aluminum			
Length or width		Area		Without supporting frame		With supporting frame[b] or equivalent reinforcement[c]		Without supporting frame		With supporting frame[b] or equivalent reinforcement[c]	
cm	(in)	cm^2	(in^2)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
7.6	3	38.7	6	0.51	0.02	0.51	0.02	0.58	0.023	0.58	0.023
20.3	8	194	30	0.66	0.026	0.51	0.02	0.91	0.036	0.74	0.029
30.5	12	581	90	0.81	0.032	0.51	0.02	1.14	0.045	0.74	0.029
45.7	18	871	135	1.07	0.042	0.81	0.032	1.47	0.058	1.14	0.045
61	24	2323	360	1.37	0.053	1.07	0.042	1.91	0.075	1.47	0.058
122	48	7742	1200	1.70	0.067	1.35	0.053	2.41	0.095	1.91	0.075
152	60	9677	1500	2.36	0.093	1.35	0.053	3.10	0.122	1.91	0.075
Over 152	Over 60	Over 9677	Over 1500	3.12	0.123	1.35	0.053	3.89	0.153	1.91	0.075

[a] Other metals may be used if they are tested in accordance with the Compression test in Clause 24.2.

[b] A supporting frame is described in Clause 6.1.3.

[c] As referenced in Clause 6.1.2, thinner metals may be used if they are tested in accordance with the Compression test in Clause 24.2.

Table 3
Minimum thickness of sheet steel for enclosures of carbon or stainless steel for transformers rated 10 kVA and less

(See Clause 6.1.2 and Table 4)

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness			
Maximum width,		Maximum length,		Maximum width,		Maximum length,		Uncoated[e],		Zinc-coated[f]	
cm	(in)[c]	cm	(in)[d]	cm	(in)[c]	cm	(in)[d]	mm	(in)	mm	(in)
10.20	4.02	Not limited		15.90	6.26	Not limited		0.51	0.020	0.58	0.023
12.10	4.76	14.60	5.75	17.10	6.73	21.00	8.27	–	–	–	–
15.20	5.98	Not limited		24.10	9.49	Not limited		0.66	0.026	0.74[g]	0.029
17.80	7.01	22.20	8.74	25.40	10.00	31.80	12.52	–	–	–	–
20.30	7.99	Not limited		30.50	12.01	Not limited		0.81	0.032	0.86	0.034
22.90	9.02	29.20	11.50	33.00	12.99	40.60	15.98	–	–	–	–
31.80	12.52	Not limited		49.50	19.49	Not limited		1.07	0.042	1.14	0.045
35.60	14.02	45.70	17.99	53.30	20.98	63.50	25.00	–	–	–	–
45.70	17.99	Not limited		68.60	27.01	Not limited		1.35	0.053	1.42	0.056
50.80	20.00	63.50	25.00	73.70	29.02	91.40	35.98	–	–	–	–
55.90	22.01	Not limited		83.80	32.99	Not limited		1.52	0.060	1.60	0.063
63.50	25.00	78.70	30.98	88.90	35.00	109.20	42.99	–	–	–	–
63.50	25.00	Not limited		99.10	39.02	Not limited		1.70	0.067	1.78	0.070
73.70	29.02	91.40	35.98	104.10	40.98	129.5	50.98	–	–	–	–

Table 3 Continued on Next Page

Table 3 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness			
Maximum width,		Maximum length,		Maximum width,		Maximum length,		Uncoated[e],		Zinc-coated[f]	
cm	(in)[c]	cm	(in)[d]	cm	(in)[c]	cm	(in)[d]	mm	(in)	mm	(in)
83.80	32.99	Not limited		129.50	50.98	Not limited		2.03	0.080	2.13	0.084
88.90	35.00	119.40	47.01	137.20	54.02	167.60	65.98	–	–	–	–
106.70	42.01	Not limited		162.60	64.02	Not limited		2.36	0.093	2.46	0.097
119.40	47.01	149.90	59.02	172.70	67.99	213.40	84.02	–	–	–	–
132.10	52.01	Not limited		203.20	80.00	Not limited		2.74	0.108	2.82	1.111
152.40	60.00	188.00	74.02	213.40	84.02	261.60	102.99	–	–	–	–
160.00	62.99	Not limited		246.40	97.01	Not limited		3.12	0.123	3.20	0.126

[a] Construction considered to be without supporting frame is specified in Clause 6.1.4.

[b] A supporting frame is specified in Clause 6.1.3.

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

[d] The maximum length is not limited only if the edge of the surface is flanged at least 12.7 mm (0.5 in) or fastened to adjacent surfaces not normally removed in use.

[e] Uncoated sheet steel not less than 0.51 mm (0.020 in) thick may be used at the flat and base portions of end bells.

[f] Zinc-coated both sides.

[g] As an alternative to the minimum thickness requirement of 0.74 mm (0.03 in), zinc-coated sheet steel enclosures shall be subjected to the impact test described in Clause 24.3.3.1.

Table 4
Minimum thickness of sheet metal for electrical enclosures of aluminum, copper, or brass for transformers rated 10 kVA and less

(See Clause 6.1.2)

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

Table 4 Continued on Next Page

Table 4 Continued

Without support frame[a]				With supporting frame or equivalent reinforcing[b]					
Maximum width,		Maximum length,		Maximum width,		Maximum length,		Minimum thickness,	
cm	(in)[c]	cm	(in)[d]	cm	(in)[c]	cm	(in)[d]	mm	(in)
132.1	52.0	Not limited		312.4	123.0	Not limited		–	–
152.4	60.0	188.0	74.0	330.2	130.0	406.4	160.0	3.89	0.153

[a] See Note a to Table 3.
[b] See Note b to Table 3.
[c] See Note c to Table 3.
[d] See Note d to Table 3.

Table 5
Minimum thickness of cast metal enclosures for transformers rated 1000 kVA and less

(See Clause 6.1.1)

Metal	Maximum area of any surface,		Maximum dimension,		Minimum thickness,	
	cm^2	(in^2)	mm	(in)	mm	(in)
Case	–	–	–	–	3.2	0.13
Die-cast	50	7.8	90	3.5	1.14	0.045
	Over 50 – 155	Over 7.8 – 24	Over 90 – 150	Over 3.5 – 5.9	1.60	0.063
	Over 155	Over 24	Over 150	Over 5.9	2.38	0.094

Table 6
Minimum spacings other than at wiring terminals

(See Clauses 11.1.2, 11.1.3, 11.4.5, 11.5.2 (Part 3), and D1.2.3 (Part 3, Annex D))

Potential involved[a], V	Through air,		Over surface[b],	
	mm	(in)	mm	(in)
0 – 50	1.6	0.06	1.6	0.06
51 – 150	3.2	0.125	6.4	0.25
151 – 300	6.4	0.25	9.5	0.37
301 – 600	9.5	0.37	12.7	0.5
For transformers intended for use in Canada:				
Over 600 – 750	9.5	0.37	12.7	0.5

NOTE – An isolated part of conductive material (such as a screw head or washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

[a] The potential involved shall include consideration of voltages obtained in elevated voltage use of winding or windings when the transformer is marked in accordance with Clause 17.5.2 of Part 2.

[b] Gaps less than 0.33 mm (0.013 in) shall be disregarded (bridged) in determining over surface spacings.

Table 7
Minimum spacings within a transformer rated 250 VA or less

(See Clauses 11.1.2 and 11.1.3)

Potential involved[a], V	Through air,		Over surface[b],	
	mm	(in)	mm	(in)
0 – 300	1.6	0.06	1.6	0.06
301 – 600	3.2	0.125	3.2	0.125
For transformers intended for use in Canada:				
Over 600 – 750	3.2	0.125	3.2	0.125

[a] The potential involved shall include consideration of voltages obtained in elevated voltage use of winding or windings if the transformer is marked in accordance with Clause 17.5.2 of Part 2.

[b] Gaps less than 0.33 mm (0.013 in) shall be disregarded (bridged) in determining over surface spacings.

Table 8
Minimum spacings within a transformer for transformers rated more than 250 VA

(See Clauses 11.1.2 and 11.1.3)

Potential involved[a], V	Through air,		Over surface[b],	
	mm	(in)	mm	(in)
0 – 50	1.6	0.06	1.6	0.06
51 – 300	3.2	0.125	3.2	0.125
301 – 600	6.4	0.25	6.4	0.25
For Canada only:				
Over 600 – 750	6.4	0.25	6.4	0.25

[a] The potential involved is to include consideration of voltages obtained in elevated voltage use of winding or windings if the transformer is marked in accordance with Clause 17.5.2 of Part 2.

[b] Gaps less than 0.33 mm (0.013 in) are to be disregarded (bridged) in determining over surface spacings.

Table 9
Spacings at field wiring terminals for general purpose transformers

(See Clause 11.1.2)

Potential involved[a], V	Minimum spacings between terminals of opposite polarity and between terminals and exposed non-current carrying metal parts (including enclosure and conduit fittings)			
	Through air,		Over surface[b],	
	mm	(in)	mm	(in)
0 – 50	3.2	0.125	6.4	0.25
Over 50 – 300	12.7	0.5	12.7	0.5
Over 300 – 600	25.4	1	25.4	1
For transformers intended for use in Canada:				
Over 600 – 750	25.4	1	25.4	1

NOTES –

1 Over surface and through air spacings may be reduced by 50 percent if projecting strands of wire are not likely to touch adjacent terminals.

Table 9 Continued on Next Page

Table 9 Continued

Potential involved[a], V	Minimum spacings between terminals of opposite polarity and between terminals and exposed non-current carrying metal parts (including enclosure and conduit fittings)			
	Through air,		Over surface[b],	
	mm	(in)	mm	(in)
2 Over surface and through air spacings may be reduced by not more than 50 percent in circuits protected by a fuse rated not more than 15 A at 150 V or less, 10 A at 151 – 300 V, or 5 A at 301 – 600 V, but not greater than one and a half times the ampacity of the circuit.				
3 Over surface and through air spacings for the secondary of transformers rated at 1.5 kVA or less may be reduced to 50 percent of the values.				
[a] The potential involved is to include consideration of voltages obtained in elevated voltage use of winding or windings if the transformer is marked in accordance with Clause 17.5.2 of Part 2.				
[b] Gaps less than 0.33 mm (0.013 in) are to be disregarded (bridged) in determining over surface spacings.				

Table 10
Insulation provided in lieu of spacings

(See Clauses 11.4.1 and 11.4.7)

Insulating material	Minimum thickness of insulating material,		Minimum portion of specified spacing[a]	Minimum dielectric breakdown voltage[b]	Circuit potential, V
	mm	(in)			
electrical grade paper	0.71	0.028	–	–	–
electrical grade paper	0.33	0.013	1/2	–	–
electrical grade paper	0.25	0.010	–	–	0 – 50
any	any		1/2	2500	–
any	any		–	5000	–
[a] Spacing required if no insulating material is provided.					
[b] Dielectric voltage withstand test shall be conducted in accordance with Dielectric Voltage-Withstand Test in Clause 29 of Part 2 or Dielectric Voltage-Withstand Test in Clause 32 of Part 3.					

Table 11
Location of required markings for low voltage transformers

(See Clauses 17.4.1 (Part 2) and 17.1.7 (Part 3))

Marking reference	Requirements	Location[a]	
		Enclosed	Open
General			
17.1.1(a), (b), and (c)	Manufacturer's name, trademark, or identifier, electrical ratings, catalog number or equivalent	A	B
17.1.1(d)	Date of manufacture	C	C
17.1.2	Factory marking/Identifier	A	B
17.2.2	Bonding path for transformers mounted on a knockout	–	C
17.2.3	Combustible surface marking	B	–
Wiring terminal markings			

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Table 11 Continued

Marking reference	Requirements	Location[a]	
		Enclosed	Open
17.2.1	Wire size or range of wire sizes for connectors	B	B
17.2.4	Terminal markings	B	B

[a] Required markings may be placed with an instruction manual or stuffer sheet when the transformer is such that space does not allow for markings.

For marking locations identified below, "A" is the highest order of location, and "D" is the lowest order of location. At the option of the manufacturer, a higher order of location category can be used.

A. Marking shall be visible after installation when the enclosure cover is on and the door is closed.

B. Marking shall be visible before installation:

1. When the enclosure cover is removed or the door is open;

2. When other devices are mounted nearby as intended; and

3. When devices are installed side-by-side with intended clearances.

C. Marking can be located anywhere on the device and is not required to be visible after installation.

D. Marking is on a wiring diagram or instructional manual shipped with the device.

Table 12
Values of test voltages

(See Clauses 18.2, 18.3, 18.6,21.2, 24.3.1.1, 26.6 (Part 2), 27.1 (Part 2), 35.6 (Part 2), 36.1 (Part 2), 18.6 (Part 3), 32.1.1 (Part 3), 34.1 (Part 3), D1.3.3 (Part 3, Annex D), Table 4 (Part 3) and Table D1.1 (Part 3, Annex D))

Rated primary voltage	Test voltage
Less than 110	Rated voltage[a]
110 – 120	120
Over 120 and less than 190	Rated voltage[a]
190 – 208	208
Over 208 and less than 220	Rated voltage[a]
220 – 240	240
Over 240 and less than 254	Rated voltage[a]
254 – 277	277
Over 277 and less than 440	Rated voltage[a]
440 – 480	480
Over 480 and less than 550	Rated voltage[a]
550 – 600	600
Over 600	Rated voltage[a]

[a] If the rated voltage is expressed as a range, the maximum voltage of the range shall be used.