UL 1815

STANDARD FOR SAFETY

Nonducted Heat Recovery Ventilators

UL Standard for Safety for Nonducted Heat Recovery Ventilators, UL 1815

Fifth Edition, Dated February 29, 2012

Summary of Topics

This revision of UL 1815 dated January 5, 2024 includes requirements for power supplies without grounding conductor, 8.1A, 30.3, and 30.3A.

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated November 22, 2023.

No Text on This Page

FEBRUARY 29, 2012
(Title Page Reprinted: January 5, 2024)

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UL 1815

Standard for Nonducted Heat Recovery Ventilators

First Edition – April, 1990
Second Edition – April, 1995
Third Edition – November, 2001
Fourth Edition – October, 2009

Fifth Edition

February 29, 2012

This UL Standard for Safety consists of the Fifth Edition including revisions through January 5, 2024.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover nonducted, stationary or fixed heat recovery ventilators for household, commercial, or industrial use and intended to be employed in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 These requirements cover heat recovery ventilators rated 600 volts or less.

1.3 These requirements cover heat recovery ventilators that may be mounted through a wall or ceiling, or in a window.

1.4 These requirements cover heat recovery ventilators that may employ short ducts intended to bring air to and from the equipment. These requirements do not cover heat recovery ventilators employing ducts intended to supply conditioned air for environmental heating and/or cooling or distribute air throughout a building; such units are judged under the requirements in the Standard for Ducted Heat Recovery Ventilators, UL 1812. These requirements do not preclude a preheater provided as part of the air exchange system.

2 Undated References

2.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Glossary

4.1 For the purpose of this standard the following definitions apply.

4.1.1 CAPACITOR, CLASS X – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor or RC unit would not lead to danger of electrical shock but could result in a risk of fire. Examples would be units connected phase to phase or phase to neutral.

Note 1: X1 capacitors are generally used in circuits of permanently connected appliances. However, if the appliance is provided with a separate surge protective device that limits the impulse voltage to £ 2.5KV, an X2 capacitor is permitted.

Note 2: X2 capacitors are generally used in circuits of cord-connected appliances.

4.1.2 CAPACITOR, CLASS Y – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock. Examples would be capacitors connected across the primary and secondary circuits where electrical isolation is required to prevent an electric shock or between hazardous live parts and accessible parts.

Note 1: Y1 capacitors are used in circuits where the prevention of electric shock is afforded solely by the isolation provided by the capacitor. Two Y2 capacitors connected in series is considered to provide the same level of protection as one Y1 capacitor.

Note 2: Y2 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≥ 150V and ≤ 300V.

Note 3: Y4 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≤ 150V.

4.2 CONTROL, AUTOMATIC – A control in which at least one aspect is non-manual.

4.3 CONTROL, AUXILIARY – A device or assembly of devices that provides a functional utility, is not relied upon as an operational or protective control, and therefore is not relied upon for safety. For example, an efficiency control not relied upon to reduce the risk of electric shock, fire, or injury to persons during normal or abnormal operation of the end product is considered an auxiliary control.

4.4 CONTROL, MANUAL – A device that requires direct human interaction to activate or rest the control.

4.5 CONTROL, OPERATING – A device or assembly of devices, the operation of which starts or regulates the end product during normal operation. For example, a thermostat, the failure of which a thermal cutout/limiter or another layer of protection would mitigate the potential hazard, is considered an operating control. Operating controls are also referred to as “regulating controls”.

4.6 CONTROL, PROTECTIVE – A device or assembly of devices, the operation of which is intended to reduce the risk of electric shock, fire or injury to persons during normal and reasonably anticipated abnormal operation of the appliance. For example, a thermal cutout/limiter, or any other control/circuit relied upon for normal and abnormal conditions, is considered a protective control. Protective controls are also referred to as “limiting controls” and “safety controls”.

4.7 CONTROL, TYPE 1 – The actuation of an automatic control for which the manufacturing deviation and the drift (tolerance before and after certain conditions) of its operating value, operating time, or operating sequence has not been declared and tested under this standard.

4.8 CONTROL, TYPE 2 – The actuation of an automatic control for which the manufacturing deviation and the drift (tolerance before and after certain conditions) of its operating value, operating time, or operating sequence have been declared and tested under this standard.

4.8.1 DANGEROUS MALFUNCTION – Unintended operation of the appliance that may impair safety. Operating Control functions whose failure would result in a Dangerous Malfunction would be considered Safety Critical Functions. See 4.15.3.

Note: Control functions whose failure might result in a Dangerous Malfunction would include:

a) Unexpected operation of the appliance where the operation would result in risk of electric shock, fire or mechanical risk of injury.

b) Unattended energization of a heating appliance where the user has placed flammable materials near the appliance based on the assumption the appliance would remain off.

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4.9 DUCT FAN – A straight-through ventilator provided with flanges for connection to a duct and which may be used with heated air.

4.9.1 ELECTRONIC DISCONNECTION – The de-energizing of the functional load of the appliance by an electronic device of a circuit with no air gap.

4.10 ENCLOSURE – That part of a unit which by itself or in conjunction with barriers reduces the risk of contacting all or any parts of the unit that may otherwise present a risk of electric shock or injury to persons and/or prevents propagation of flame initiated by electrical disturbances occurring within.

4.11 FIELD WIRING TERMINAL – A terminal to which a wire may be connected in the field, unless the wire and a means of making the connection – such as a pressure terminal connector, soldering lug, soldered loop, or crimped eyelet – that is factory assembled to the wire are provided as part of the heat recovery ventilator.

4.12 FUNCTIONAL PART – A part other than an enclosure or structural part that is necessary for the intended operation of a unit.

4.13 HEAT RECOVERY VENTILATOR – A product intended to remove air from a building, replace it with air outside the building and in the process transfer heat from the warmer to the colder air.

4.13.1 INTENTIONALLY WEAK PART – A part intended to rupture under conditions of abnormal operation to prevent the occurrence of a condition which could impair compliance with this standard.

4.13.2 LOW-POWER CIRCUIT – A circuit or parts of circuits farther from the supply source than a low-power point.

4.13.3 LOW-POWER POINT – A point closest to the supply source in an electronic circuit where the maximum available power to an external load at the end of 5 seconds does not exceed 15 watts.

4.14 MOTORS:

a) OPEN MOTOR – A motor having ventilating openings that permit passage of external cooling air over and around the windings of the motor.

b) TOTALLY ENCLOSED MOTOR – A motor that is enclosed so as to prevent the free exchange of air between the inside and outside of the case but not sufficiently enclosed to be termed airtight.

c) TOTALLY ENCLOSED FAN-COOLED MOTOR – A totally enclosed motor with external cooling by a fan or fans integral with the motor but external to the enclosing parts.

4.15 POWER VENTILATOR – A ventilator that consists of an impeller – which may be of the centrifugal, axial, or propeller type – and an integral driver. A power ventilator is:

a) Installed in a weather-resisting base intended to fit, usually by a curb, over a wall or roof opening, or

b) Provided with flanges for connection to a duct.

4.15.1 PROTECTIVE ELECTRONIC CIRCUIT (PEC) – An electronic circuit that prevents a hazardous situation under abnormal operating conditions. The function of a Protective Electronic Circuit would be considered a Safety Critical Function. See 4.15.4.

4.15.2 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist within a circuit unless the circuit meets one of the following criteria. The circuit shall be supplied by an isolating source such that:

a) The voltage does not exceed 30 V rms;

b) The voltage does not exceed 42.4 V peak;

c) The voltage does not exceed 60 V dc continuous; or

d) The voltage does not exceed 24.8 V peak for DC interrupted at a rate of 200 Hz or less with approximately 50 percent duty cycle.

e) When protective impedance is used, the current available through a 1500 ohm resistor between the part or parts and either pole of the supply source does not exceed 0.7 mA peak or 2 mA DC.

4.15.3 RISK OF FIRE – A risk of fire is considered to exist at any two points in a circuit where a power of more than 15 watts can be delivered into an external resistor connected between the two points.

4.15.4 SAFETY CRITICAL FUNCTION – Control, protection and monitoring functions which are being relied upon to reduce the risk of fire, electric shock or casualty hazards.

4.16 STRUCTURAL PART – A part used in such a manner that failure of the part may present a risk of electric shock or injury to persons.

4.17 USER SERVICING – Any form of servicing, such as routine cleaning, changing a filter or a heat exchange medium, and the like, that might be performed by personnel other than those trained to maintain the appliance.

CONSTRUCTION

5 General

5.1 An appliance shall employ materials that are acceptable for the particular use.

6 Component

6.1 A component of a product covered by this standard shall:

a) Comply with the requirements for that component;

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

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

d) Additionally comply with the applicable requirements of this end product standard; and

e) Not contain mercury.

Exception No. 1: A component of a product covered by this standard is not required to comply with a specific component requirement that:

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

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

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

Exception No. 2: A component complying with a UL component standard other than those cited in this standard is acceptable if:

a) The component also complies with the applicable component standard; or

b) The component standard:

1) Is compatible with the ampacity and overcurrent protection requirements in the National Electrical Code, NFPA 70, where appropriate;

2) Considers long-term thermal properties of polymeric insulating materials in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and

3) Any use limitations of the other component standard is identified and appropriately accommodated in the end use application. For example, a component used in a household application, but intended for industrial use and complying with the relevant component standard may assume user expertise not common in household applications.

6.2 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.

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

Exception: Where these other functions are not required for the application and not identified as part of markings, instructions, or packaging for the appliance, the additional component standard(s) need not be applied.

6.4 A component not anticipated by the requirements of this standard and that involves a potential risk of electric shock, fire, or personal injury, shall be additionally investigated in accordance with the applicable UL standard, and shall comply with 6.1 (b) – (d).

6.5 With regard to a component being additionally investigated, reference to construction and performance requirements in another UL end product standard is appropriate where that standard anticipates normal and abnormal use conditions consistent with the application of this standard.

7 Frame and Enclosure

7.1 General

7.1.1 An appliance shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected, without resulting in a risk of fire, electrical shock, or injury to persons due to total or partial collapse with a resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

7.1.2 A cast- or sheet-metal section of the enclosure shall not be thinner than the applicable value specified in Table 7.1.

Exception No. 1: A small area or surface that is curved or otherwise reinforced to provide equivalent mechanical strength need not comply with the specifications in the first column of thicknesses in Table 7.1.

Exception No. 2: A section of the enclosure made of uncoated or galvanized sheet steel or cast malleable iron may be thinner than the specifications in the first column of thicknesses in Table 7.1 if such factors as the following are considered acceptable:

a) Mechanical strength and impact resistance with regard to intended use and location of the appliance;

b) Resistance to corrosion;

c) Size and shape; and

d) Location on the appliance.

Table 7.1
Minimum acceptable thicknesses of enclosure metal

Metal	At small, flat, unreinforced surfaces and at surfaces of a shape or size to provide adequate mechanical strength, inch (mm)		At surfaces to which a wiring system is to be connected in the field, inch (mm)[a]		At large, unreinforced, flat surfaces, inch (mm)	
Die-cast metal	3/64	(1.2)	–		5/64	(2.0)
Cast malleable iron	1/16	(1.6)	–		3/32	(2.4)
Other cast metal	3/32	(2.4)	–		1/8	(3.2)
Uncoated sheet steel	0.026	(0.66)	0.032	(0.81)	0.026	(0.66)
Galvanized sheet steel	0.029	(0.74)	0.034	(0.86)	0.029	(0.74)
Nonferrous sheet metal	0.036	(0.91)	0.045	(1.14)	0.036	(0.91)

[a] A sheet-metal wall of thickness less than that specified is acceptable if it is not less than 0.026 inch (0.66 mm) and the area surrounding the knockout has a thickness not less than 0.053 inch (1.35 mm).

7.1.3 Among the factors to be considered when judging a nonmetallic enclosure, including one of polymeric material, or a magnesium enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Combustibility;

e) Resistance to arcing;

f) Resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use; and

g) For a polymeric enclosure, thermal aging.

7.1.4 For a polymeric enclosure all of the factors in 7.1.3 are considered with respect to aging. See Nonmetallic enclosure parts, Section 7.2; and Polymeric and Other Nonmetallic Materials, Section 34.

7.1.5 An overall enclosure for electrical components of an appliance intended for outdoor exposure shall have provision for drainage. See 20.1.1.12.

7.1.6 An appliance shall have provision for condensate drainage that shall be located below the lowest electrical part when installed as intended. The smallest dimension of the hole shall be at least 1/2 inch (12.7 mm).

7.2 Nonmetallic enclosure parts

7.2.1 Polymeric material or other material having a flame-spread rating greater than zero in accordance with the Standard for Tests for Surface Burning Characteristics of Building Materials, UL 723, shall not be employed as an enclosure or a skirt or other part of a venturi system of an appliance that is intended to be:

a) Permanently connected electrically and

b) Installed within a building structure so that the portion of the appliance enclosed within the wall is not visible to the user.

7.2.2 Unless otherwise specified in this end product standard, polymeric electrical insulating materials and enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.2.3 Metallized or painted polymeric parts or enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: This requirement is not applicable to exterior surfaces of polymeric enclosure materials or parts provided that the metallized coating or paint does not offer a continuous path for an internal flame to propagate externally.

7.2.4 A fan blade (air impeller) of polymeric material outside a motor shall not be located within 1 inch (25.4 mm) of an opening in the motor housing.

Exception: A fan blade may be within 1 inch of an opening in the motor housing if:

a) The material is classed as V-2, V-1, V-0, or V in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or

b) The material complies with the requirements for enclosure flammability using a 3/4-inch (19.1-mm) flame, in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, or

c) No motor opening within 1 inch of the blade has a dimension more than 17/64 inch (6.75 mm) or an area more than 0.055 square inch (35.5 mm^2), and no more than six such openings are provided, or

d) In a skeleton or open frame type motor,

1) The fan blade is of material classed HB or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94,

2) The coil is completely wrapped with insulation at least 1/32 inch (0.8 mm) thick, and

3) The space between the coil wrap and bobbin does not exceed 1/32 inch, or

e) The material has a hot wire ignition rating of at least 7 seconds as described in the Standard Test Method for Ignition of Materials by Hot Wire Sources, ASTM D3874, or

f) The fan employs a thermally protected motor to drive the blade and complies with the test requirements in the Blade Ignition Test, Section 55.

7.3 Accessibility of live parts

7.3.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from uninsulated live parts and film-coated wire, an opening in an enclosure of an appliance or in a motor shall be investigated as described in (a) or (b):

a) For an opening that has a minor dimension (see 7.3.5) less than 1 inch (25.4 mm), such a part and film-coated wire shall not be contacted by the probe illustrated in Figure 7.1.

b) For an opening that has a minor dimension of 1 inch or more, neither an uninsulated live part nor film-coated wire shall be within X inches of the perimeter of the opening or within the volume generated by projecting the perimeter X inches normal to its plane. X equals five times the minor dimension of the opening, but not less than 6-1/16 inches (154 mm). See Figure 7.2.

Exception: A motor need not comply with these requirements if it complies with the requirements in 7.3.2.

Figure 7.1

Articulate probe with web stop

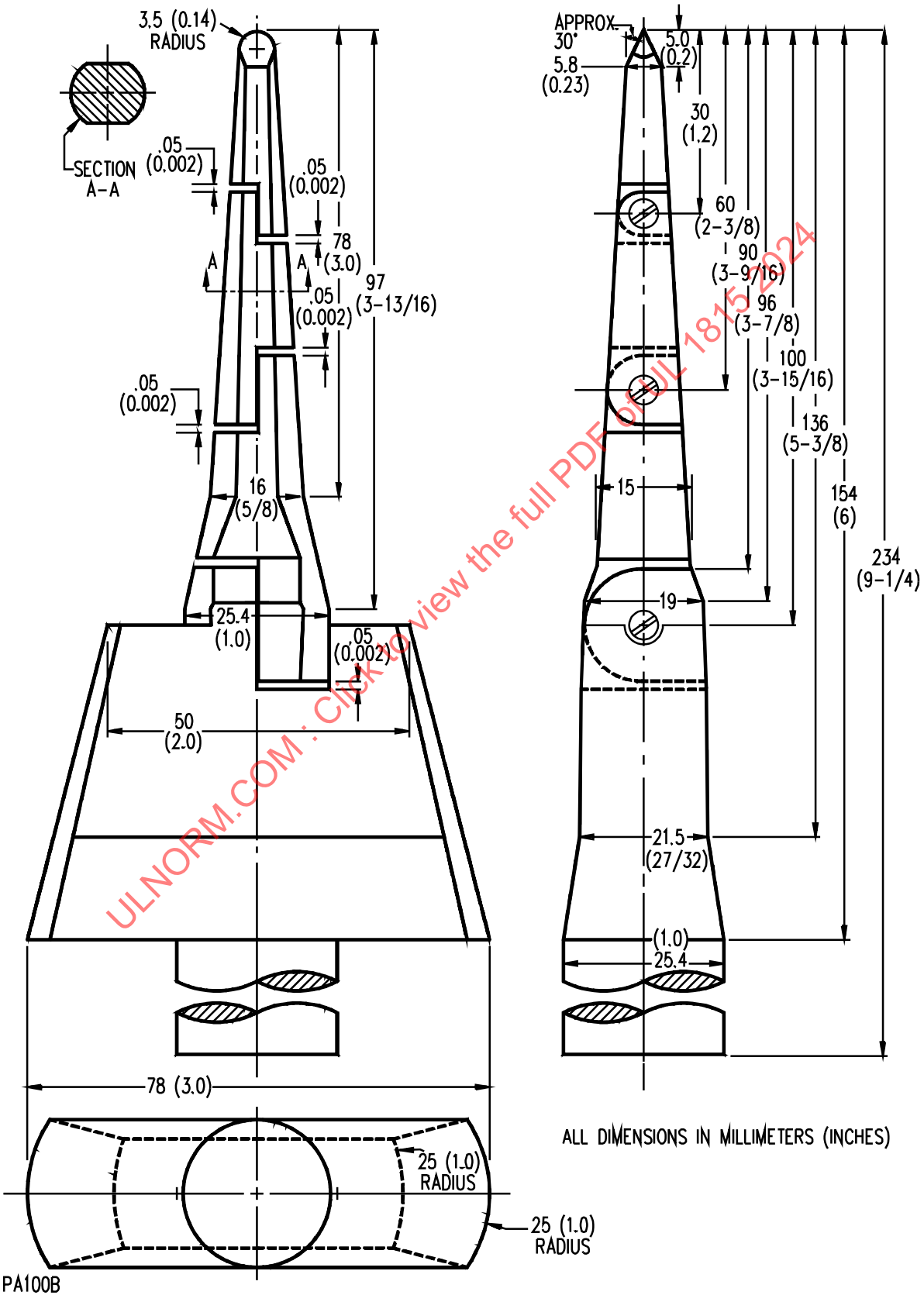
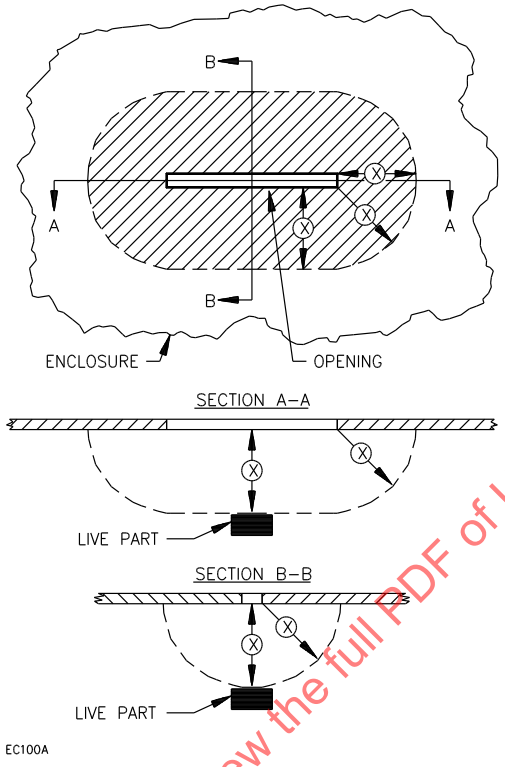


Figure 7.2

Opening in enclosure



7.3.2 With respect to a part or wire as mentioned in 7.3.1, in a motor as mentioned in the exception to 7.3.1:

a) An opening that has a minor dimension (see 7.3.5) less than 3/4 inch (19.1 mm) is acceptable if:

1) Film-coated wire cannot be contacted by the probe illustrated in Figure 7.4;

2) In a directly accessible motor (see 7.3.6), an uninsulated live part cannot be contacted by the probe illustrated in Figure 7.5; or

3) In an indirectly accessible motor (see 7.3.6), an uninsulated live part cannot be contacted by the probe illustrated in Figure 7.3.

b) An opening that has a minor dimension of 3/4 inch or more is acceptable if an uninsulated live part or film-coated wire is not within X inches of the perimeter of the opening or within the volume generated by projecting the perimeter X inches normal to its plane. X equals five times the minor dimension of the opening, but not less than 3-5/32 inches (80 mm) for contact with an uninsulated live part through an opening in the enclosure of a directly accessible motor and 4 inches (102 mm) for all other openings. See Figure 7.2.

Figure 7.3

Probe for uninsulated live parts

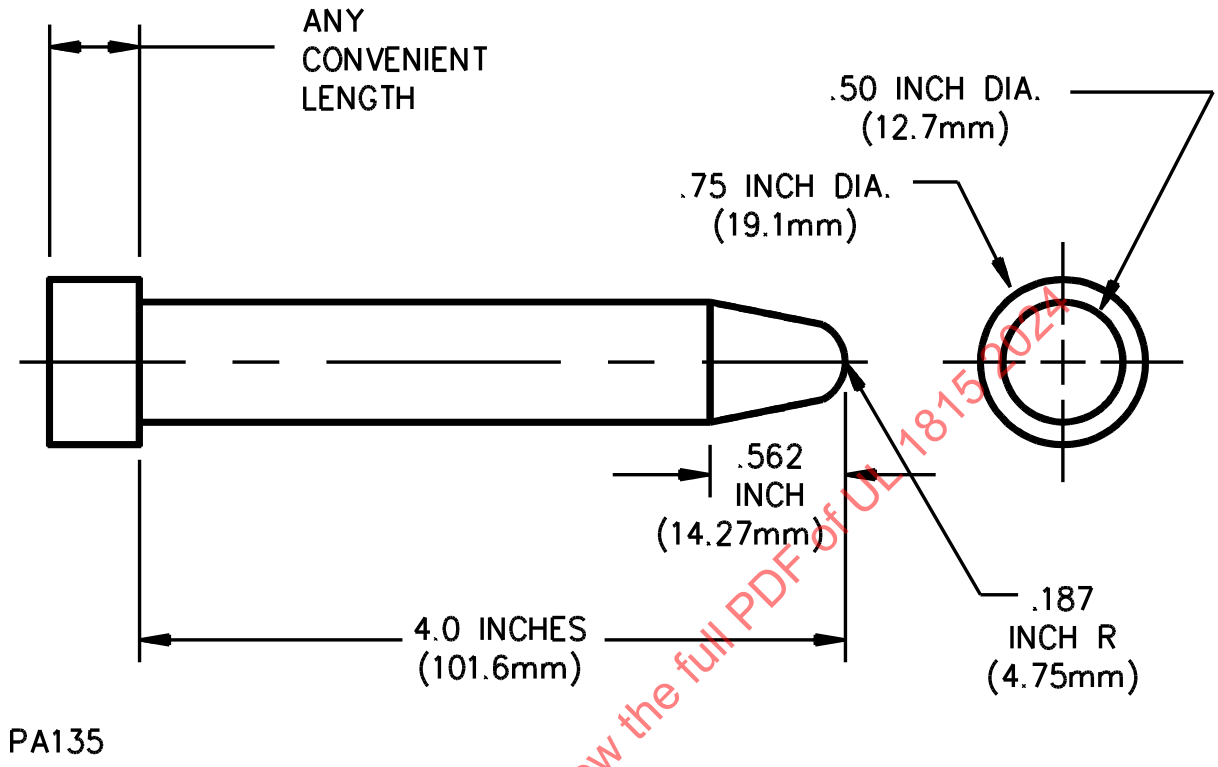


Figure 7.4

Probe for film-coated wire

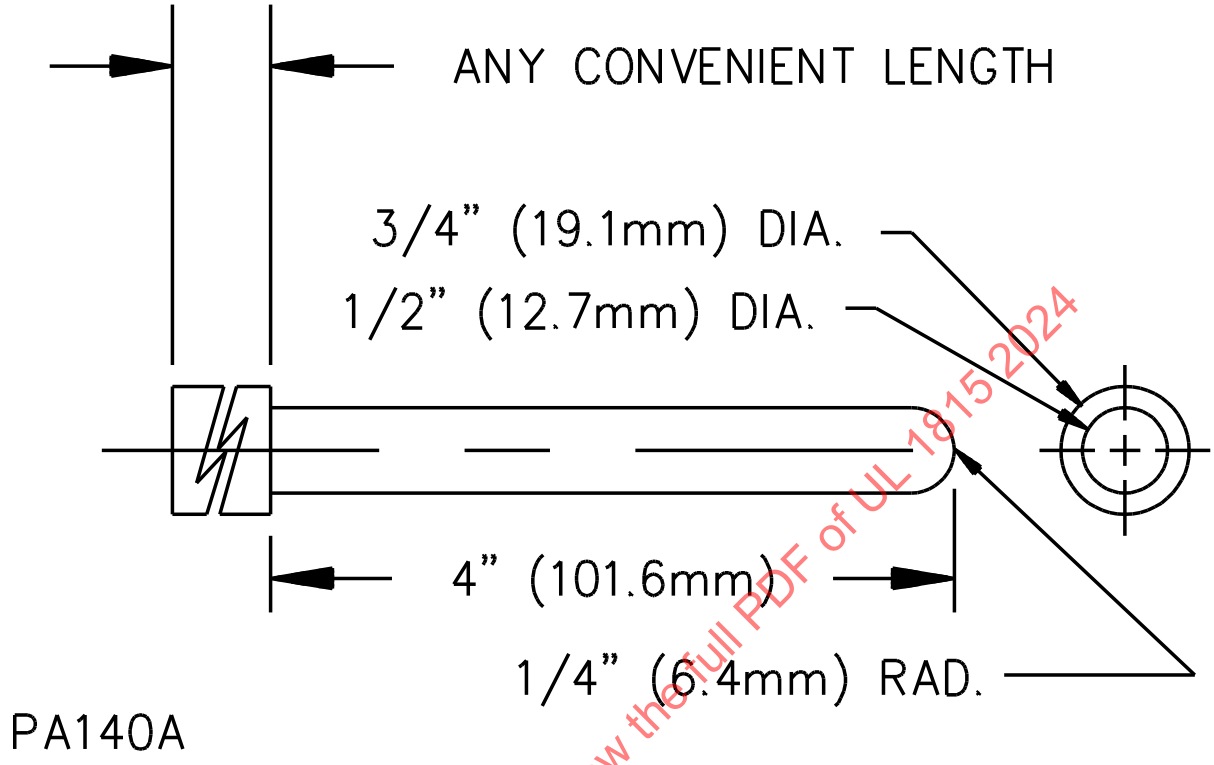
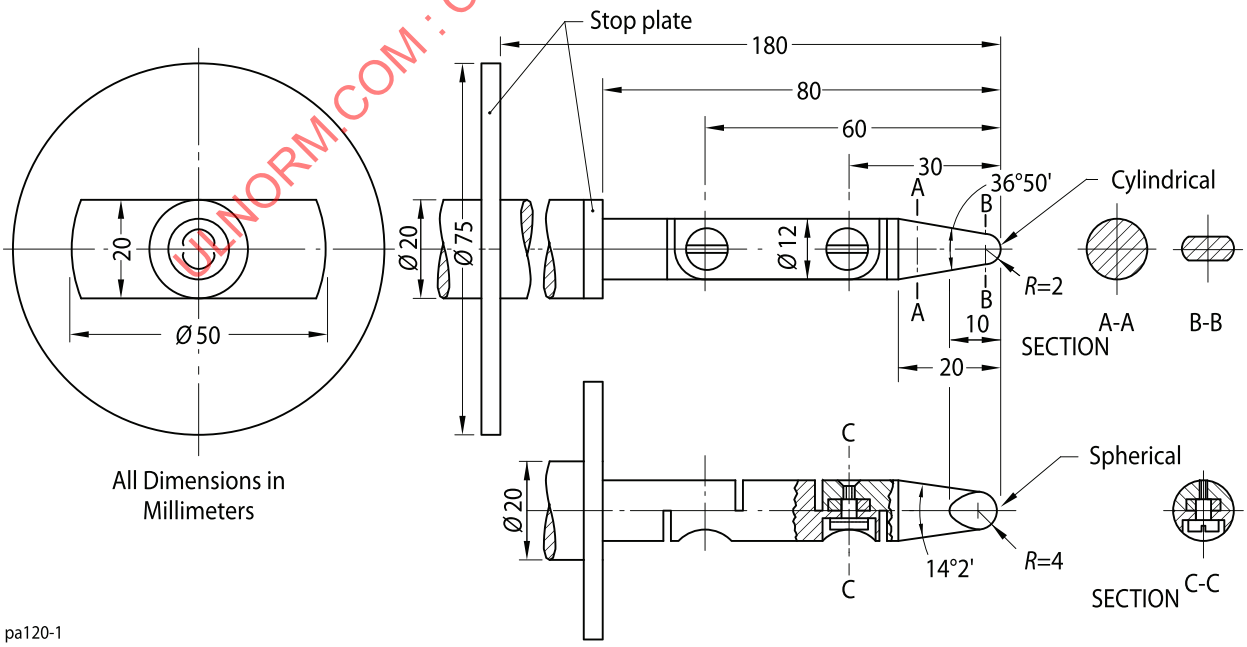


Figure 7.5

IEC articulate probe



7.3.3 The probes mentioned in 7.3.1 and 7.3.2 and illustrated in Figure 7.1 and Figure 7.3 – Figure 7.5 shall be applied to any depth that the opening will permit; and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the appliance or motor. The probes illustrated in Figure 7.1 and Figure 7.5 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

7.3.4 The probes mentioned in 7.3.1 and 7.3.2 and illustrated in Figure 7.1 and Figure 7.3 – Figure 7.5 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with the minimum force necessary to determine accessibility.

7.3.5 With reference to the requirements specified in 7.3.1 and 7.3.2, the minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that can be inserted through the opening perpendicular to the plane of the opening.

7.3.6 With reference to the requirements specified in 7.3.2, an indirectly accessible motor is a motor:

a) That is accessible only by removing a part of the outer enclosure, such as a guard or panel, that can be removed without using a tool, or

b) That is located at such a height above the floor or is otherwise guarded or enclosed so that it is unlikely to be contacted.

A directly accessible motor is a motor that can be contacted without removing any part, or that is located so as to be accessible to contact.

7.3.7 During the examination of a product to determine whether it complies with the requirements in 7.3.1 and 7.3.2, a part of the enclosure that may be removed without using a tool (to attach an accessory, to make an operating adjustment or for other reasons) is to be removed.

7.3.8 With reference to 7.3.7, a filter(s) or exchange medium intended to be removed is to be removed – even if it is necessary to use tools to do so – when the appliance is being examined with reference to exposure of uninsulated live parts.

7.3.9 With reference to the requirements specified in 7.3.1 and 7.3.2, insulated brush caps are not required to be additionally enclosed.

7.3.10 If a motor employs leads that terminate in an attachment plug that is intended to be plugged into a receptacle provided as part of the appliance, uninsulated live parts and film-coated wire shall be located or protected, as judged in accordance with 7.3.1 – 7.3.4, to reduce the risk of unintentional contact by persons with, or damage to such parts during any cleaning operation.

7.3.11 With reference to 7.3.10, a layer of tape, at least 1/32 inch (0.8 mm) thick, on a coil is considered to provide the required protection.

8 Attachment Plugs, Receptacles, Connectors, and Terminals

8.1 Attachment plugs, receptacles, appliance couplers, appliance inlets (motor attachment plugs), and appliance (flatiron) plugs, shall comply with the Standard for Attachment Plugs and Receptacles, UL 498.

Exception: Attachment plugs and appliance couplers integral to cord sets or power supply cords are covered under the requirements of Standard for Cord Sets and Power-Supply Cords, UL 817 and need not comply with Standard for Attachment Plugs and Receptacles, UL 498.

8.1A The attachment plug of the power supply cord of an appliance provided with a 15- or 20-ampere general-use convenience receptacle shall be of the 3-wire grounding type. The attachment plug of the power supply cord of all other appliances not required to be grounded shall be polarized or of the grounding type.

8.2 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 0.110, 0.125, 0.187, 0.205, and 0.250 inch (2.8, 3.2, 4.8, 5.2, and 6.3 mm), intended for internal wiring connections in appliances, or for the field termination of conductors to the appliance, shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310.

Exception: Other sizes of quick-connect terminals shall be investigated with respect to crimp pull out, insertion-withdrawal, temperature rise, and all tests shall be conducted in accordance with Standard for Electrical Quick-Connect Terminals, UL 310.

8.3 Single and multipole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory assembly to copper or copper alloy conductors, or for factory assembly to printed wiring boards, shall comply with the Standard for Component Connectors for Data, Signal, Control and Power Applications, UL 1977.

8.4 Wire connectors shall comply with the Standard for Wire Connectors, UL 486A-486B.

8.5 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

8.6 Equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors, shall comply with the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

8.7 Terminal blocks shall comply with the Standard for Terminal Blocks, UL 1059, and, if used for field wiring connection they shall be rated for field wiring.

8.8 Female devices (such as receptacles, appliance couplers, and connectors) that are intended, or that may be used, to interrupt current in the end product, shall be rated for current interruption of the specific type of load, when evaluated with its mating plug or connector.

9 Controls

9.1 General

9.1.1 Auxiliary controls shall be evaluated using the applicable requirements of this end product standard and the parameters in Controls – End Product Test Parameters, Section 37.

Exception: This requirement does not apply to circuits that comply with the requirements in Sections 37A – 37K.

9.1.2 Operating (regulating) controls shall be evaluated using the applicable component standard requirements specified in 9.2 – 9.4, and if applicable, the parameters in Controls – End Product Test Parameters, Section 37, unless otherwise specified in this end product standard.

Exception: This requirement does not apply to circuits that comply with the requirements in Sections 37A – 37K.

9.1.3 Operating controls that rely upon software for the normal operation of the end product where deviation or drift of the control may result in a risk of safety, such as a speed control unexpectedly changing its output, shall comply with the:

a) Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and Standard for Software in Programmable Components, UL 1998;

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; or

c) Circuits that comply with the requirements in Sections 37A – 37K.

9.1.4 Protective (limiting) controls shall be evaluated using the applicable component standard requirements specified in 9.2 – 9.4, and if applicable, the parameters in Controls – End Product Test Parameters, Section 37, unless otherwise specified in this end product standard.

Exception: This requirement does not apply to circuits that comply with the requirements in Sections 37A – 37K.

9.1.5 Solid-state protective controls that do not rely upon software as a protective component shall comply with the:

a) Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991;

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, except Clause H.11.12 (Controls using software); or

c) Circuits that comply with the requirements in Sections 37A – 37K.

9.1.6 Protective controls that rely upon software as a protective component shall comply with the:

a) Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and Standard for Software in Programmable Components, UL 1998;

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; or

c) Circuits that comply with the requirements in Sections 37A – 37K.

9.2 Electromechanical and electronic controls

9.2.1 A control, other than as specified in 9.3 – 9.4, shall comply with the:

a) Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1;

c) Standard for Programmable Controllers – Part 2: Equipment Requirements and Tests, UL 61131-2; or

d) Circuits that comply with the requirements in Sections 37A – 37K.

9.3 Motor and speed control

9.3.1 A control used to start, stop, regulate or control the speed of a motor shall comply with the:

a) *Deleted*

b) Standard for Industrial Control Equipment, UL 508;

c) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1;

d) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; or

e) Circuits that comply with the requirements in Sections 37A – 37K.

9.4 Temperature controls

9.4.1 A temperature control shall comply with the:

a) *Deleted*

b) Standard for Industrial Control Equipment, UL 508;

c) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9; or

d) Circuits that comply with the requirements in Sections 37A – 37K.

9.4.2 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control shall comply with the Standard for Thermistor-Type Devices, UL 1434.

9.4.3 A thermal cutoff shall comply with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

10 Light sources and associated components

10.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

Exception: Lampholders forming part of a luminaire that complies with the Standard for Luminaires, UL 1598, are considered to fulfill this requirement.

10.2 Lighting ballasts shall comply with the:

a) Standard for Fluorescent-Lamp Ballasts, UL 935; or

b) Standard for High-Intensity Discharge Lamp Ballasts, UL 1029.

Exception No. 1: Ballasts forming part of a luminaire that complies with the Standard for Luminaires, UL 1598, are considered to fulfill this requirement.

10.3 Light emitting diode (LED) light sources shall comply with the Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750.

11 Cords, Cables, and Internal Wiring

11.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power-Supply Cords, UL 817.

11.2 Flexible cords and cables shall comply with the Standard for Flexible Cords and Cables, UL 62.

11.3 Internal wiring composed of insulated conductors shall comply with the Standard for Appliance Wiring Material, UL 758.

Exception No. 1: Insulated conductors need not comply with the Standard for Appliance Wiring Material, UL 758, if they comply with the:

a) Standard for Thermoset-Insulated Wires and Cables, UL 44;

b) Standard for Thermoplastic-Insulated Wires and Cables, UL 83; or

c) Standard for Fixture Wire, UL 66.

Exception No. 2: Insulated conductors for specialty applications (e.g. data processing or communications) and located in a low-voltage circuit not involving the risk of fire or personal injury need not comply with the Standard for Appliance Wiring Material, UL 758.

12 Power Supplies

12.1 A Class 2 power supply shall comply with the:

a) Standard for Class 2 Power Units, UL 1310;

b) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, with an output marked "Class 2";

c) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, with an output that complies with the limited power source (LPS) requirements and is marked "LPS"; or

d) The requirements in Sections 37A – 37K.

12.2 A non-Class 2 power supply shall comply with the:

a) Standard for Power Units Other Than Class 2, UL 1012; or

b) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

13 Printed Wiring Boards

13.1 Printed-wiring boards, including the coatings, shall comply with the Standard for Printed-Wiring Boards, UL 796.

Exception No. 1: A printed-wiring board in a Class 2 nonsafety circuit is not required to comply with the bonding requirements in the Standard for Printed-Wiring Boards, UL 796, if the board is separated from parts of other circuits such that loosening of the bond between the foil conductor and the base material will not result in the foil conductors or components coming in contact with parts of other circuits of the control or of the end-use product.

Exception No. 2: Wiring boards that comply with the requirements in Sections 37A – 37K.

14 Supplemental Insulation, Insulating Bushings, and Assembly Aids

14.1 The requirements for supplemental insulation (e.g. tape, sleeving or tubing) are not specified unless the insulation or device is required to fulfill 22.14 or a performance requirement of this standard.

14.2 In accordance with 14.1, the supplemental insulation shall comply with the following:

a) Insulating tape shall comply with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510;

b) Sleeving shall comply with the Standard for Coated Electrical Sleeving, UL 1441;

c) Tubing shall comply with the Standard for Extruded Insulating Tubing, UL 224; and

d) Electrical insulation systems shall comply with the Standard for Systems of Insulating Materials – General, UL 1446.

14.3 Insulating bushings that comply with Components, Section 6, of this end product standard, and the Standard for Insulating Bushings, UL 635, are considered to fulfill the construction requirements of this Standard. Tests specified in this Standard (e.g. Strain Relief Test) may still need to be performed to confirm the combination of the insulating bushing and the supporting parts comply with the performance requirements.

15 Valves (Electrically Operated) and Solenoids

15.1 Electrically operated valves shall comply with the:

a) Standard for Electrically Operated Valves, UL 429;

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Electrically Operated Water Valves, Including Mechanical Requirements, UL 60730-2-8; or

c) Circuits that comply with the requirements in Sections 37A – 37K.

16 Transformers

16.1 General-purpose transformers shall comply with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2.

Exception No. 1: A transformer that is completely enclosed within the end product enclosure, and that meets the applicable construction and performance requirements of this end product standard meets the intent of this requirement.

Exception No. 2: A transformer that complies with the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411, and that is used in a circuit involving an audio or video component, meets the intent of this requirement.

16.2 Class 2 and Class 3 transformers shall comply with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

Exception No. 1: Transformers located in a low voltage circuit, and that do not involve a risk of fire or personal injury, need not comply with this requirement.

Exception No. 2: This requirement does not apply to transformers that comply with the requirements in Sections 37A – 37K.

17 Protection Against Corrosion

17.1 Metal shall be used in combinations that are galvanically compatible.

17.2 An iron or steel part shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

Exception: The following parts need not be protected against corrosion:

a) A shaft, bearing, lamination, or minor part, such as a washer, screw, and the like.

b) A cast-metal part that derives inherent protection by virtue of its thickness.

c) A part, such as a decorative grille, that is not required to form a part of an enclosure.

d) A part whose corrosion is not likely to result in a risk of fire, electric shock, or injury to persons.

17.3 Hinges and other attachments shall be resistant to corrosion.

17.4 A sheet steel enclosure shall be protected against corrosion as specified in Table 17.1.

Exception: An enclosure of a product not intended for outdoor exposure shall comply with the requirement in 17.2.

Table 17.1
Protection against corrosion

Enclosure use	Thickness of sheet steel and reference in standard for type of protection required	
	0.053 inch (1.35 mm) or more	Less than 0.053 inch
Outer enclosure protecting motors, wiring, or enclosed live parts	6.8 or 6.9	6.8
Outer enclosure that is the sole enclosure of live parts	6.8	
Outer enclosure that does not enclose electrical parts	6.8 or 6.9	6.8 or 6.9
Interior enclosure protecting live parts other than motors	6.8 or 6.9	6.8

17.5 Aluminum, brass, copper, or stainless steel may be used without additional protection against corrosion.

17.6 A nonmetallic enclosure intended to be used outdoors shall be judged on the basis of the effect of exposure to ultraviolet light and water.

17.7 An enclosure of cast iron at least 1/8 inch (3.2 mm) thick is considered to be protected by one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The acceptability of the paint may be determined by consideration of its composition or by corrosion tests if such tests are considered necessary.

17.8 To comply with Table 17.1, one of the following coatings shall be used:

a) Hot-dipped mill-galvanized sheet steel conforming with the Coating Designation G90 in Table I of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M.

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 0.00061 inch (0.015 mm) on each surface with a minimum thickness of 0.00054 inch (0.014 mm). The thickness of the coating shall be established by the metallic coating thickness test described in Section 51. An annealed coating shall also comply with 17.12.

c) A zinc coating conforming with 17.9 (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface applied after forming. The acceptability of the paint may be determined by consideration of its composition or by corrosion tests if such tests are considered necessary.

d) A cadmium coating not less than 0.001 inch (0.025 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the metallic-coating-thickness test as described in Section 51.

e) A cadmium coating not less than 0.00075 inch (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the metallic-coating-thickness test described in Section 51 and the paint shall be as specified in (c).

17.9 To comply with Table 17.1, one of the following coatings shall be used:

a) Hot-dipped mill-galvanized sheet steel conforming with the Coating Designation G60 or A60 in Table I of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M.

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 0.00041 inch (0.010 mm) on each surface with a minimum thickness at least 0.00034 inch (0.009 mm). The thickness of the coating shall be established by the metallic-coating-thickness test described in Section 51.

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The acceptability of the paint is to be determined by consideration of its composition or by corrosion tests if such tests are considered necessary.

17.10 With reference to 17.8 and 17.9, other finishes, including paints, metallic finishes, and combinations of the two may be accepted if comparative tests with galvanized sheet steel – without annealing, wiping or other surface treatment – conforming with 17.8(a) or 17.9(a), as applicable, indicate they provide equivalent protection. Among the factors that are to be taken into consideration when judging

the suitability of such coating systems are exposure to salt spray, moist carbon dioxide-sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light, and water.

17.11 If tests are required, test specimens of a finish as described in 17.7 or 17.10 or 17.8(c) or 17.9(c), are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and the like.

17.12 A hot-dipped mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that is not exposed to water during the water spray test need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

18 Protection Against Risk of Fire

18.1 The enclosure of an appliance shall prevent molten metal, burning insulation, flaming particles, and the like from falling onto flammable materials, including the surface upon which the appliance is supported if the appliance is:

a) Installed in a remote location;

b) Thermostatically or automatically controlled; or

c) Intended to be operated unattended.

18.2 The requirements in 18.1 will necessitate the use of a barrier or material having a zero flame spread rating when tested in accordance with the Standard for Tests for Surface Burning Characteristics of Building Materials, UL 723:

a) Under a motor unless:

1) The structural parts of the motor or of the appliance provide the equivalent of such a barrier, or

2) The protection provided with the motor is such that no burning insulation or molten material falls to the surface that supports the appliance or into the wiring compartment when the motor is energized under each of the following fault conditions:

i) Open main winding,

ii) Open auxiliary winding,

iii) Starting switch short-circuited, and

iv) Capacitor of a permanent-split, capacitor motor short-circuited and the rotor locked – the short-circuit is to be applied before the motor is energized, or

3) The motor is provided with a thermal motor protector that will prevent the temperature of the motor windings from exceeding 125 °C (257 °F) under the maximum load under which the motor will run without causing the protector to cycle and from exceeding 150 °C (302 °F) with the rotor of the motor locked, or

Exception: Direct drive fan motors need only be subjected to the locked rotor test.

4) The motor complies with the requirements for impedance-protected motors in the Standard for Overheating Protection for Motors, UL 2111, or the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and the Standard for Thermally Protected Motors, UL 1004-3, and the temperature of the motor winding does not exceed 150 °C during the first 72 hours of operation with the rotor of the motor locked.

b) Under wire, unless the wire

1) Is neoprene or thermoplastic insulated, such as wire marked VW-1, or

2) Has at least equivalent characteristics as determined in the flame tests specified in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

c) Under a switch, relay, solenoid, or the like unless:

1) A short circuit or overload in the component would not result in a risk of fire, or

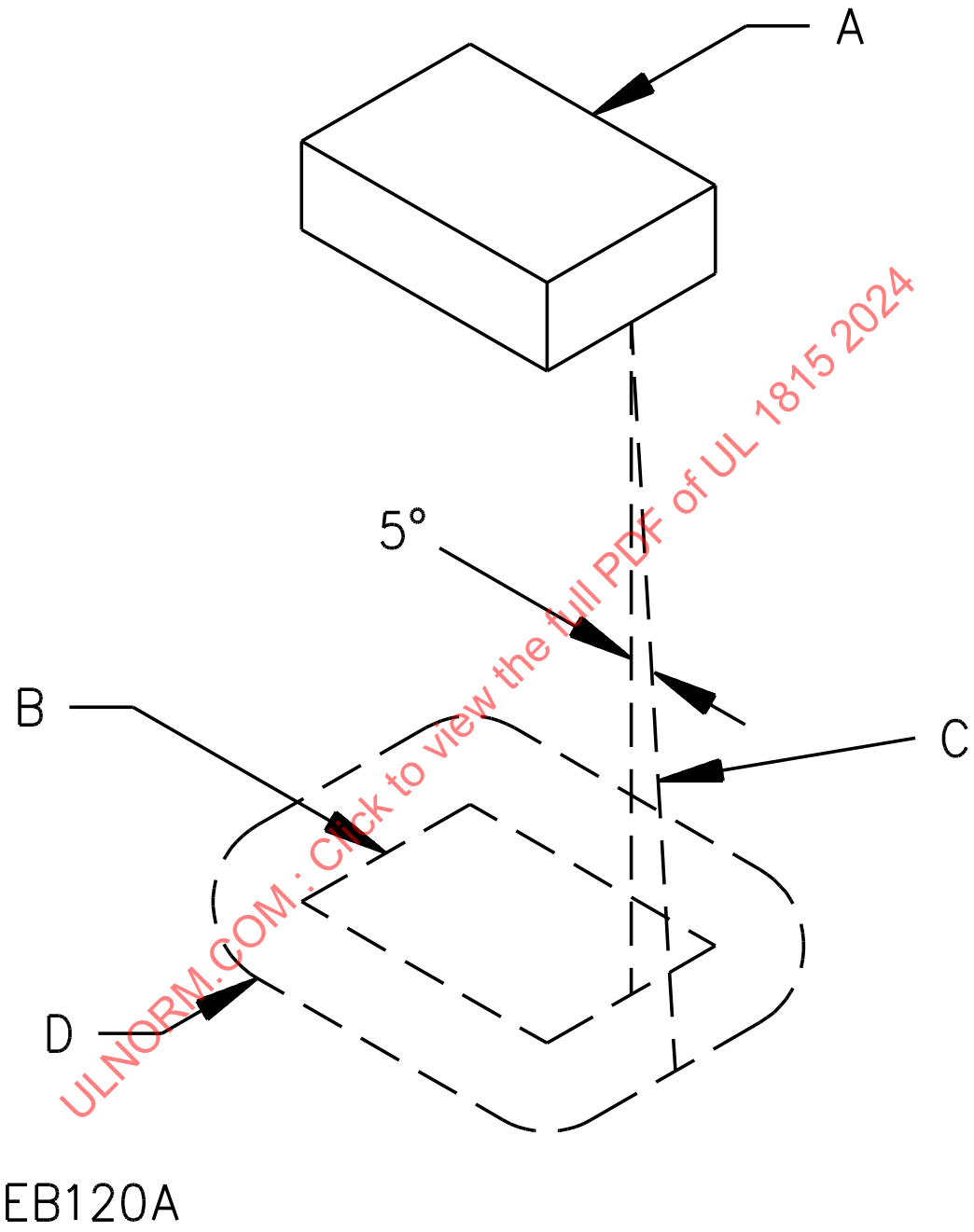
2) There are no openings in the enclosure through which molten metal, burning insulation, flaming particles, or the like can fall.

Exception: A terminal need not have a barrier.

18.3 The barrier specified in 18.2 shall be horizontal, shall be located as illustrated in Figure 18.1, and shall have an area in accordance with the illustration. Openings for drainage, ventilation, and the like, may be employed in the barrier provided such openings would not permit molten metal, burning insulation, or the like, to fall onto flammable material.

Figure 18.1

Barrier



A – Region to be shielded by barrier. This will consist of the entire component if it is not otherwise shielded and will consist of the unshielded portions of a component that is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line that traces out minimum area of barrier. The line is always (1) tangent to the component, (2) 5 degrees from the vertical, and (3) so oriented that the area traced out on a horizontal plane is maximum.

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

18.4 A ventilating opening provided in:

a) The enclosure of an appliance or

b) An externally mounted component of an appliance,

and that is intended to be recessed into a wall or false ceiling shall not vent into a concealed space where the spread of a fire might occur undetected.

19 Mechanical Assembly

19.1 An appliance shall be assembled so that its intended performance will not be impaired by the vibration of normal operation. Brush caps shall be tightly threaded or otherwise designed to prevent loosening.

19.2 A switch, a lampholder, an attachment-plug receptacle, a motor-attachment plug, or similar component shall be mounted securely, and shall be prevented from turning or shifting. See 19.3.

Exception No. 1: A switch need not be prevented from turning if the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated – a toggle switch is considered to be subject to such forces;

b) The means for mounting the switch makes it unlikely that operation of the switch will loosen it;

c) Spacings are not reduced below the minimum acceptable values if the switch is rotated; and

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

Exception No. 2: A lampholder of the type in which the lamp cannot be replaced, such as a neon pilot or indicator lamp in which the lamp is sealed in by a nonremovable jewel, need not be prevented from turning if rotation cannot reduce spacings below the minimum acceptable values.

19.3 The means for preventing turning, as required by 19.2, shall consist of more than friction between surfaces – for example, a toothed lock washer that provides spring take-up, applied as intended, is an acceptable means for preventing a small stem-mounted switch or other device having a single-hole mounting means from turning.

19.4 A household appliance shall be completely assembled when it is shipped from the factory, except that shipment partially disassembled to facilitate packaging or installation is acceptable if intended assembly can be readily accomplished without resulting in a risk of fire, electric shock, or injury to persons. If mismatching of components of an appliance shipped disassembled could result in a risk of fire, electric shock, or injury to persons, the parts shall be marked as specified in 72.1.5.

19.5 A commercial or industrial appliance shall be completely assembled when shipped from the factory.

Exception: A commercial or industrial appliance marked in accordance with 72.2.5 need not be completely assembled when shipped from the factory.

19.6 If a part is shipped disassembled from an appliance and if it is necessary to make field connections to that part:

a) The appliance shall be constructed so that it can be permanently connected to one of the wiring systems that would be acceptable for the appliance;

b) Wiring terminals or leads to which the field connections are to be made shall comply with the requirements for field-wiring terminals, including those for spacings;

c) The marking information required by 73.7 shall be provided; and

d) Means for mounting a disconnect switch assembly that is part of the appliance shall be provided.

19.7 A disconnect switch assembly that is shipped mounted on the appliance:

a) Shall be factory-wired to the remainder of the appliance; or

b) Shall comply with the requirements in 19.6 (a), (b), and (c) and those in 72.2.5.

19.8 Internal connections that must be made in the field in a cord-connected appliance that is shipped partially disassembled shall be made by plug and receptacle connections. Internal connections that must be made in the field in an appliance intended for permanent connection to the power supply and shipped partially disassembled shall be made in accordance with 20.1.1.1 and 20.1.1.6 or by plug and receptacle connection.

19.9 Unless the intended method of assembly is obvious, an appliance that is shipped from the factory partially disassembled shall be provided with clear and detailed assembly instructions.

19.10 An appliance that is shipped from the factory partially disassembled and is not marked in accordance with 72.1.5 shall be shipped in a single shipping container.

19.11 Uninsulated live parts of a thermostat provided with a welded stop shall not contact dead metal parts or parts of opposite polarity if breakage of the welded stop would permit the thermostat to rotate.

19.12 A mounting bracket necessary for installation shall be furnished. See 72.2.7.

Exception: For an appliance that is acceptable for use with any of a number of mounting brackets or assemblies provided separately, a bracket or assembly need not be provided if appropriate reference to such devices are included in the installation instructions.

20 Power Supply Connections

20.1 Permanently connected appliances

20.1.1 General

20.1.1.1 An appliance intended for permanent connection to the power supply shall be constructed so that it may be permanently connected electrically to one of the wiring systems that would be acceptable for the appliance in accordance with the National Electrical Code, ANSI/NFPA 70.

20.1.1.2 A knockout in a sheet-metal enclosure provided for connection of the appliance to a wiring system installed in accordance with the National Electrical Code, ANSI/NFPA 70, shall be securely attached and removable without deformation that would impair the intended performance of the enclosure.

20.1.1.3 A flat surface shall surround a knockout and shall be of sufficient area to permit the attachment of a length of standard rigid metallic conduit of a size corresponding to the size of the knockout. The flat area shall have a minimum diameter in accordance with Table 20.1.

Table 20.1
Dimensions associated with openings for conduit

Trade size of conduit, inches	Unthreaded openings				Threaded openings			
	Nominal knockout diameter, inches (mm)		Minimum diameter of flat surface at knockout, inches (mm)		Throat diameter, inches (mm)			
					Minimum		Maximum	
1/2	7/8	(22.2)	1.152	(29.26)	0.591	(15.01)	0.622	(15.80)
3/4	1-3/32	(27.8)	1.450	(36.83)	0.783	(19.89)	0.824	(20.93)
1	1-23/64	(34.5)	1.804	(45.82)	0.997	(25.32)	1.049	(26.64)
1-1/4	1-23/32	(43.7)	2.309	(58.65)	1.311	(33.3)	1.380	(35.05)

20.1.1.4 The diameter of a knockout shall accommodate conduit of the trade size for which the knockout is intended as specified in Table 20.1.

20.1.1.5 With reference to the requirement specified in 20.1.1.1, an appliance intended for permanent attachment to a building structure or a duct-connected appliance shall be provided with means for permanent electrical connection to the power supply.

Exception: An appliance need not be provided with a means for permanent electrical connection if it is provided with a power-supply cord that:

a) Is at least 18 inches (0.5 m) and not more than 10 feet (3 m) long,

b) Has three conductors, one being an equipment-grounding conductor,

c) Is Type S, SJ, SJO, SJT, SO, SP-3, SPT-3, or ST,

d) Is permanently attached to the appliance, and

e) Complies with the requirements in 20.2.1.2 and 20.2.2.1 – 20.2.2.5.

20.1.1.6 A field-wiring compartment in which power-supply connections are to be made shall be located so that the connections may be readily inspected after the appliance is installed as intended.

20.1.1.7 Accessibility of field installed wiring and inspection of splices is to be judged by:

a) A trial installation following any instructions provided by the manufacturer or

b) Using any wiring system permitted by the National Electrical Code, ANSI/NFPA 70, if no instructions are provided.

20.1.1.8 The minimum usable volume of an outlet box or terminal compartment in which field-installed wiring connections to the power supply are to be made shall be as specified in Table 20.2.

Exception: A motor containing an integral wiring compartment that complies with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, need not comply with this requirement.

Table 20.2
Minimum usable volume of terminal compartment

Size of field-installed conductors, AWG (mm^2)		Volume for each field-installed wire originating outside of the compartment and terminating inside the compartment[a]	
		Cubic inches	(cm^3)
14	(2.1)	2.00	(33)
12	(3.3)	2.25	(37)
10	(5.3)	2.50	(41)
8	(8.4)	3.00	(50)
6	(13.3)	5.00	(82)

[a] Including a grounding conductor.

20.1.1.9 An electrical component shall not be mounted on a part, such as the cover of a wiring-terminal compartment, that must be removed to permit field-wiring connections to be made or inspected.

20.1.1.10 A terminal compartment intended for the connection of a power-supply raceway that is mounted to the appliance shall be attached so as to be prevented from turning with respect thereto.

20.1.1.11 If the constructional features of an appliance permit field-wiring connections to be made in the motor terminal compartment, the compartment shall comply with the applicable requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

20.1.1.12 With reference to 7.1.5, a conduit opening in an outer enclosure for power-supply or external-control-circuit connection shall be threaded. The metal at a threaded opening for conduit shall not be less than 1/4 inch (6.4 mm) thick.

Exception No. 1: A conduit opening need not comply if it is on a duct fan that is not intended for outdoor exposure.

Exception No. 2: A conduit opening need not comply if it is located wholly below the lowest uninsulated live part within the enclosure or if its location prevents drainage into the enclosure.

20.1.1.13 An outer cover or panel that must be removed in order to inspect field-wiring connections to:

a) An appliance to be exposed to the weather or outside or

b) A wall-mounted appliance shall be constructed so that it may be removed with an ordinary tool, such as a screwdriver or pliers.

20.1.1.14 It shall not be necessary to dismount an electrical component or disconnect a duct to gain access to a wiring compartment to inspect field-wiring connections.

20.1.1.15 If threads for the connection of conduit in the exterior of the enclosure are tapped all the way through the hole in a wall of a box or if an equivalent construction is employed, there shall not be less than 3-1/2 nor more than five threads in the metal, and the construction shall be such that a conduit bushing can be properly attached. If threads for the connection of conduit are not tapped all the way through a hole in a wall of a box, conduit hub, or the like, there shall not be less than five full threads in the metal and there shall be a smooth, rounded inlet hole for the conductors that provides protection for the conductors equivalent to that provided by a standard conduit bushing. The opening shall have an internal diameter in accordance with Table 20.1.

20.1.1.16 A terminal compartment of a duct fan that is exposed to the main air stream shall not have any open holes.

20.1.1.17 The overall enclosure of an appliance to be exposed to the weather or outside or a wall-mounted appliance may serve as the compartment for field-wiring terminals if:

a) No part that requires service access – an oil hole, belt, or the like – is located in that compartment; and

b) The total area of openings in the enclosure is not more than 2-1/4 square inches (14.5 mm^2) and no slot is wider than 1/32 inch (0.8 mm).

20.1.2 Field-wiring terminals and leads

20.1.2.1 An appliance that is intended to be permanently connected electrically shall be provided with wiring terminals, including an equipment-grounding terminal, for the connection of conductors having an ampacity acceptable for the appliance; or the appliance shall be provided with pigtail leads not smaller than 18 AWG (0.82 mm^2) acceptable for such connection.

20.1.2.2 A field-wiring terminal shall be provided with a pressure terminal connector securely fastened in place – for example, firmly bolted or held by a screw.

Exception: A wire-binding screw may be employed at a wiring terminal intended for connection of a 8 AWG or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

20.1.2.3 A wiring terminal shall be prevented from turning or shifting in position.

20.1.2.4 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10.

Exception No. 1: A No. 8 screw may be used at a terminal intended only for the connection of a 14 AWG or smaller conductor.

Exception No. 2: A No. 6 screw may be used at a terminal provided with a 16 or 18 AWG pigtail conductor.

20.1.2.5 It should be noted that, 14 AWG is the smallest conductor that may be used for branch-circuit wiring, and thus is the smallest conductor that may be anticipated at a terminal for connection of a power-supply wire.

20.1.2.6 terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.25 mm) thick. There shall be two or more full threads in the metal, which may be extruded if necessary to provide the threads.

Exception: A plate not less than 0.030 inch (0.76 mm) thick is acceptable if the tapped threads have adequate strength.

20.1.2.7 Upturned lugs, a cupped washer, or the equivalent shall retain a conductor of the size specified in 20.1.2.1 under the head of a screw or washer.

20.1.2.8 The free length of a lead inside an outlet box or wiring compartment shall be 6 inches (152 mm) or more if the lead is intended for field connection to an external circuit.

Exception: A lead may be less than 6 inches long if it is evident that use of a longer lead might result in a risk of fire, electric shock, or injury to persons.

20.1.3 Identification

20.1.3.1 A permanently connected appliance rated 125 or 125/250 volts (3-wire) or less, and employing a lamp- or element-holder of the Edison screw-shell type, or a single-pole switch or overcurrent-protective device other than an automatic control without a marked off position shall have one terminal or lead identified for the connection of the grounded conductor of the supply circuit. The terminal or lead so identified shall be the one that is electrically connected to screw shells of a lamp- or element-holder, and shall not be connected to a single-pole switch or single-pole overcurrent-protective device, other than an automatic control without a marked off position.

20.1.3.2 With reference to 20.1.3.1, if leads from the motor or other component terminate in an attachment plug intended for insertion in a receptacle that is:

a) Provided as part of the appliance, and

b) Intended for connection of the branch-circuit power-supply conductors,

the plug and receptacle shall be polarized if a single-pole switch or an Edison-base lampholder is connected in the load side of these devices.

20.1.3.3 A terminal intended for connection of a grounded power-supply conductor shall be made of or plated with metal substantially white in color and shall be readily distinguishable from the other terminals; or identification of that terminal shall be clearly shown in some other manner, such as on an attached wiring diagram.

20.1.3.4 The surface of a lead intended for the connection of a grounded power-supply conductor shall have a white or gray color and shall be readily distinguishable from the other leads.

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

20.2 Cord-connected appliances

20.2.1 Cords and plugs

20.2.1.1 The length of cord external to the appliance shall be 5 – 10 feet (1.5 – 3.0 m) measured from the face of the attachment plug to the point of attachment to or entry into the enclosure.

20.2.1.2 A flexible cord shall be rated for use at a voltage not less than the rated voltage of the appliance, and shall have an ampacity not less than the current rating of the appliance.

20.2.1.3 An attachment plug shall be rated for the current and voltage ratings of the appliance. If an appliance can be adapted for use on two or more different values of voltage by field alteration of internal connections, the attachment plug shall be rated for the voltage for which the appliance is connected when shipped from the factory. See 72.1.3.

20.2.2 Strain relief

20.2.2.1 Strain relief shall be provided so that the mechanical stress on the flexible cord is not transmitted to terminals, splices, or internal wiring. See 56.1.

20.2.2.2 A metal strain-relief clamp or band is acceptable without supplementary protection on a Type SJ, SJO, SJT, SJTO, S, SO, ST, STO, SV, or SVO cord.

20.2.2.3 A strain-relief clamp or band of metal shall not be used on Type SP-2 or lighter rubber-insulated cord or on Type SPT-1, SPT-2, SVT, or SVTO cord unless such a cord is protected by varnished cloth tubing or the equivalent under the clamp, and the construction complies with the requirements specified in 56.4.

20.2.2.4 Means shall be provided to prevent the flexible cord from being pushed into the appliance enclosure through the cord-entry hole if such displacement might subject the cord to mechanical damage or to exposure to a temperature higher than that for which the cord is suitable, or might reduce spacings, such as to a metal strain-relief clamp, below the minimum acceptable values.

20.2.2.5 If a knot in a flexible cord serves as the strain relief, the surfaces that the knot may touch shall be free from projections, sharp edges, burrs, fins, or the like that may damage the conductors.

20.2.3 Bushings

20.2.3.1 A bushing or the equivalent shall be provided at a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case. The bushing shall be substantial, secured in place, and shall have a smooth, well-rounded surface against which the cord may bear. An insulating bushing shall be provided if:

a) The cord is Type S, SJ, SJO, SJT, SO, SP-3, SPT-3, ST, SP-1, or heavier cord,

b) The wall or barrier is of metal, and

c) The construction is such that the cord may be subjected to stress or motion.

Exception: For a cord hole in wood, porcelain, phenolic composition, or other acceptable nonconductive material, a smoothly rounded surface is considered to be the equivalent of a bushing.

20.2.3.2 Ceramic materials and some molded compositions are acceptable for insulating bushings.

20.2.3.3 Vulcanized fiber may be employed if the bushing is not less than 3/64 inch (1.2 mm) thick, and if formed and secured in place so that it will not be damaged by conditions of ordinary moisture.

20.2.3.4 A separate soft-rubber, neoprene, or polyvinyl chloride bushing may be employed in a fan or in the frame of a motor if the bushing is:

a) Not less than 3/64 inch (1.2 mm) thick.

b) Located so that it will not be exposed to oil, grease, oily vapor, or other substances that may deteriorate the compound employed.

20.2.3.5 A bushing of a material specified in 20.2.3.4 may be employed at any point in an appliance only if used in conjunction with a type of cord for which an insulating bushing is not required.

20.2.3.6 If a bushing of a material specified in 20.2.3.4 is used, the hole in which the bushing is mounted shall be smooth and free from sharp edges.

20.2.3.7 A bushing of the same material as, and molded integrally with the supply cord is acceptable on Type S, SJ, SJO, SJT, SO, SP-3, SPT-3, ST, SP-1, or heavier cord, if the built-up section is not less than 1/16 inch (1.6 mm) thick at the point where the cord passes through the enclosure.

20.2.3.8 An insulated metal grommet is acceptable in place of an insulating bushing, if the insulating material is not less than 1/32 inch (0.8 mm) thick and completely fills the space between the grommet and the metal in which it is mounted.

21 Live Parts

21.1 A current-carrying part shall be silver, copper, a copper alloy, or other material acceptable for the application.

21.2 Ordinary iron or steel, if provided with a suitable corrosion-resistant coating, may be used for a current-carrying part:

a) If acceptable in accordance with Glossary, Section 4, or

b) Within a motor or associated governor,

but the use of ordinary iron or steel for current-carrying parts elsewhere in the appliance is not acceptable.

21.3 An uninsulated live part shall be secured to the surface on which it is mounted, and supporting insulating materials shall be secured in place, so that the part will be prevented from turning or shifting in position if spacings would be reduced below the minimum values specified in Spacings, Section 32.

21.4 Friction between surfaces is not acceptable as a means to prevent shifting or turning of a live part, but a toothed lock washer with spring take-up, applied as intended, is acceptable.

22 Internal Wiring

22.1 The internal wiring and connections between parts of an appliance shall be adequately protected or enclosed.

Exception: A suitable length of flexible cord may be employed for external interconnection if flexibility is essential, and the flexible cord complies with 20.1.1.5 (a) – (e).

22.2 Internal wiring, consisting of individual insulated conductors either separate or in a harness, is considered to be acceptably protected if:

a) When judged as though it were film-coated wire, the wiring would be acceptable in accordance with 7.3.1, or

b) Even though it could be touched by the probe specified in 7.3.1, the wiring is secured so that it is not likely to be grasped or hooked in such manner that it or related electrical connections could be subjected to undue stress.

A grille, louver, or the like, regardless of how secured in place, is not to be removed when the exposure of internal wiring is being judged.

22.3 The internal wiring and connections of an appliance shall consist of components of a type or types that are acceptable for the particular application, when considered with respect to:

a) The temperature and voltage to which they are likely to be subjected,

b) Exposure to oil, grease, or moisture, and

c) To other conditions of service to which they are likely to be subjected.

22.4 Wiring shall be protected from sharp edges including male screw threads, burrs, moving parts, and other agents that may abrade the insulation on conductors or otherwise damage wires.

22.5 A flexible cord used for external interconnection as specified in 22.1 shall be provided with bushings and strain relief that comply with the strain relief requirements, Section 56.

22.6 Insulated conductors that pass through an opening in a sheet-metal wall that is not more than 0.042 inch (1.07 mm) thick shall be:

a) Securely held away from the edges of the opening;

b) Protected by a bushing, metal grommet, eyelet, or the equivalent; or

c) Protected by rolling the edge of the metal opening at least 120 degrees.

22.7 A nonmetallic bushing as mentioned in 22.6(b) shall:

a) Be securely held in place and

b) Have a wall thickness not less than 3/64 inch (1.2 mm).

22.8 The edges of an opening in sheet metal more than 0.042 inch (1.07 mm) thick shall be treated to prevent abrasion of the insulation by removal of burrs, fins, and sharp edges.

22.9 Insulated wires may be bunched and passed through a single opening in a metal wall within the enclosure.

22.10 All splices and connections shall be mechanically secured and shall provide reliable electrical contact.

22.11 A soldered connection shall be made mechanically secure before being soldered if breaking or loosening of the connection may result in a risk of fire, electric shock, or injury to persons.

22.12 With reference to 22.11, a lead is considered to be mechanically secure when one or more of the following are provided:

a) At least one full wrap around a terminal.

b) The lead is passed through an eyelet or opening.

c) The lead is twisted together with another conductor.

22.13 A splice shall be provided with adequate insulation equivalent to that on the wires involved if permanence of spacing between the splice and other metal parts may not be maintained.

22.14 Insulation consisting of two layers of friction tape, two layers of thermoplastic tape, or of one layer of friction tape wrapped over one layer of rubber tape, is acceptable on a splice if the voltage involved is less than 250 volts. In determining if splice insulation consisting of coated-fabric, thermoplastic, or other tubing is acceptable, consideration is to be given to such factors as dielectric properties, heat- and moisture-resistant characteristics, and the like. Thermoplastic tape wrapped over a sharp edge is not acceptable.

22.15 The means of connecting stranded internal wiring to a wire-binding screw shall be such that loose strands of wire will be prevented from contacting other live parts not always of the same polarity as the wire and from contacting dead metal parts. This may be accomplished by using pressure terminal connectors, crimped eyelets, soldering all strands of the wire together, or equivalent means.

22.16 Type SE, SJE, SJT, SJO, SJOO, SJTO, SJTOO, SO, SOO, ST, STO, STOO cord or internal wiring material of equivalent construction may be used in a wall-mounted appliance or an appliance to be exposed to the weather or outside, without protection other than that provided by the outer enclosure.

22.17 Internal wiring consisting of wire or cord other than that specified in 22.16 shall be enclosed in metal, such as conduit, metal-clad cable, or the like. The assembly shall be mechanically secure and shall provide an electrical bond between parts.

22.18 Internal wiring in a duct-type appliance shall not be exposed to the main air stream, and shall be installed in accordance with the requirements for wiring in ducts in the National Electrical Code, ANSI/NFPA 70.

22.19 Internal wiring of an appliance to be exposed to the weather or outside shall be of such type and assembled so as to reduce the risk of electric shock resulting from exposure to the weather or outside.

22.20 Internal wiring of an appliance to be exposed to the weather or outside shall be located so that it will not be immersed in water as a result of exposure to the weather or outside.

23 Heating Elements

23.1 In addition to the requirements specified in this standard, a sheathed heating element shall comply with the requirements in the Standard for Sheathed Heating Elements, UL 1030.

23.2 A heating element shall be supported in a substantial and acceptable manner.

23.3 An appliance in which the heating element is designed for operation only in an air stream shall be wired or controlled so that the element can be operated only when under the cooling effect of the stream. An appliance in which the cooling effect of the motion of a part is necessary to prevent excessive temperature shall be wired or controlled so that the heating element cannot be operated in the absence of such motion.

23.4 The marked voltage rating of a heating element shall not be less than the voltage rating of the circuit in which the heating element is connected.

Exception No. 1: A heating element having a marked voltage within an applicable range of voltages specified in 71.4 is acceptable if the voltage rating of the appliance is within that range.

Exception No. 2: The marked voltage of an element that is connected in series is to be compared with the applied voltage.

24 Insulating Material

24.1 Material for the mounting of uninsulated live parts shall be porcelain, phenolic composition, or other material acceptable for the particular application. Polymeric materials shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

24.2 Vulcanized fiber may be used for an insulating bushing, washer, separator, or barrier but not as the direct support for uninsulated live parts.

24.3 A molded part shall have adequate mechanical strength and rigidity to withstand the stresses of intended service. Brush caps shall be secured or located so as to be protected from mechanical damage that might occur during intended use.

25 Lampholders

25.1 An Edison-base lampholder of an appliance equipped with a polarized attachment plug shall be wired so that the screw shell will be connected to the terminal or lead that is intended to be connected to the grounded conductor of the power-supply circuit.

25.2 In addition to the requirements specified in this standard, lampholders with an edison-base shall comply with the requirements in the Standard for Lampholders, UL 496.

26 Receptacles

26.1 A 15- or 20-ampere attachment-plug receptacle intended for general use in an appliance provided with means for grounding – a permanently wired appliance or a cord-connected appliance with a grounding conductor in the cord – shall be of the grounding type. The grounding contact of the receptacle shall be electrically connected to dead metal that will be grounded when the appliance is in use.

27 Motors

27.1 General

27.1.1 A motor shall be acceptable for the particular application, and shall handle the maximum normal load of the appliance without resulting in a risk of fire, electric shock, or injury to persons.

27.1.2 A motor winding shall resist the absorption of moisture.

27.1.3 With reference to 27.1.2, film-coated wire and wire employing cotton over film coating are not required to be additionally treated to prevent absorption of moisture in an appliance not intended to be exposed to the weather or outside – see the Water Spray Test, Section 50. A treatment of the winding is usually necessary if the appliance is to comply with the requirements in Section 50.

27.1.4 A brush holder assembly shall be constructed so that when a brush is worn out – no longer capable of performing its function – the brush, spring, and other parts of the assembly are retained to the degree necessary to keep:

a) Accessible dead metal parts from becoming energized and

b) A live part from becoming accessible.

27.2 Protection

27.2.1 Motor-overload protection for the motor of an appliance shall consist of one of the following:

a) Thermal protection complying with the applicable requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1 and the Standard for Thermally Protected Motors, UL 1004-3.

b) Impedance protection complying with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1 and the Standard for Impedance Protected Motors, UL 1004-2.

c) Other protection that is shown by test to be equivalent to the protection mentioned in (a).

Exception No. 1: With reference to (a), if a fan blade or blower wheel is attached directly to the motor shaft and there is no other load, the motor need not comply with the running protection requirements of the

Standard for Rotating Electrical Machines – General Requirements, UL 1004-1 and the Standard for Thermally Protected Motors, UL 1004-3.

Exception No. 2: A commercial or industrial appliance that complies with 27.1.1.

Exception No. 3: This requirement does not apply to motor controls that comply with UL 1004-3 or with the requirements in Sections 37A – 37K.

27.2.2 If a multispeed motor is provided with protection in accordance with these requirements the protection shall accomplish the intended result at each setting of the speed-control device.

27.2.3 If a multispeed motor would not otherwise be provided with protection in accordance with these requirements, and if the protection with which the appliance would be provided upon installation would not function to protect the motor for one or more settings of the speed-control device, protection at each setting shall be provided as part of the appliance.

27.2.4 A motor in an appliance that is marked for use with a separate solid-state speed control in accordance with 72.1.17 and 72.1.18, and a motor in a residential appliance that is provided with an integral solid-state speed control, shall employ overload protection that complies with the tests described in the Abnormal Operation Test, Section 58.

27.2.5 Electronically protected motor circuits shall comply with the Standard for Tests for Safety-Related Controls Employing Solid State Devices, UL 991. When the electronic circuit is relying on software as a protective component, it shall comply with all of the requirements in the Standard for Software in Programmable Components, UL 1998. If software is relied upon to perform a safety function, it shall be considered software class 1.

Exception: Compliance with UL 991 and UL 1998 is not required for an electronically protected motor circuit if:

a) There is no risk of fire, electric shock or casualty noted during Abnormal testing with the motor electronic circuit rendered ineffective (open or short circuited),

b) It complies with the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, and the Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9. When the electronic circuit is relying on software as a protective component, it shall comply with all of the requirements in clause H.11.12 of UL 60730-1, if software is relied upon to perform a safety function, it shall be considered software class B, or

c) It is a power conversion controller incorporating overcurrent protection complying with the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1 and is rated or set to trip at not more than the 115 percent of the motor nameplate full-load current rating.

27.2.6 The requirements in Table 27.1 are among the factors to be used in evaluating the protective circuit.

Table 27.1
Application of UL 991 and UL 1998 or UL 60730-1 and UL 60730-2-9

	Application of UL 991 and UL 1998	Application of UL 60730-1, and UL 60730-2-9
1)	Conduct a failure-mode and effect analysis (FMEA) – for the protective circuit identified in 27.2.5.	Conduct a failure-mode and effect analysis (FMEA) – for the protective circuit identified in 27.2.5.
2)	A control becoming permanently inoperative and disconnecting power meets the criteria for electrical supervision of critical components and trouble indication.	A control becoming permanently inoperative and disconnecting power meets the criteria for electrical supervision of critical components and trouble indication.
3)	Assumed temperature ranges are as follows: a) Indoor Use: 0.0 ±2°C (32.0 ±3.6°F) and 40.0 ±2°C (104 ±3.6°F), b) Outdoor Use: -35.0 ±2°C (-31.0 ±3.6°F).	Assumed temperature ranges are as follows: a) Indoor Use: 0.0 ±2°C (32.0 ±3.6°F) and 40.0 ±2°C (104 ±3.6°F), b) Outdoor Use: -35.0 ±2°C (-31.0 ±3.6°F).
4)	Cycling test duration shall be 14 days.	Cycling test duration shall be 14 days.
5)	Endurance test duration shall be 100,000 cycles.	Endurance test duration shall be 100,000 cycles.
6)	Radio-frequency electromagnetic field immunity: a) Immunity to conducted disturbances – Test level 3 shall be used, b) Immunity to radiated electromagnetic fields – field strength of 3 V/m shall be used.	Radio-frequency electromagnetic field immunity: a) Immunity to conducted disturbances – Test level 3 shall be used, b) Immunity to radiated electromagnetic fields – field strength of 3 V/m shall be used.
7)	For exposure to humidity, the following conditions shall apply: a) Indoor Use: 21.1 to 26.7°C (70 to 80°F) and minimum 50 percent relative humidity, b) Outdoor Use: minimum 98 percent relative humidity.	For exposure to humidity, the following conditions shall apply: a) Indoor Use: 21.1 to 26.7°C (70 to 80°F) and minimum 50 percent relative humidity, b) Outdoor Use: minimum 98 percent relative humidity.
8)		Surge immunity test – Test with installation Class 3 used for other than outdoor use protective devices. Class 4 shall be used for protective devices intended for outdoor use.
9)	Electrical fast transient/burst immunity such that a test level 3 shall be used for all equipment other than outdoor use equipment. Test level 4 shall be used for outdoor use equipment.	Electrical fast transient/burst immunity such that a test level 3 shall be used for all equipment other than outdoor use equipment. Test level 4 shall be used for outdoor use equipment.
10)		Electrostatic Discharge Test with a Severity Level of 3 having Contact Discharge at 6 kV for accessible metal parts and air discharge at 8 kV for accessible parts of insulating material.

27.3 Commercial or industrial appliances

27.3.1 An appliance that is exposed to the weather or outside, or a wall-mounted appliance motor that is exposed to the main air stream shall be totally enclosed.

Exception: An appliance that is exposed to the weather or outside or a wall-mounted appliance that is marked in accordance with 72.2.6 may employ a motor of other than the totally enclosed type if the motor is provided with inherent overtemperature protection complying with the requirements for running and locked-rotor protection.

27.3.2 A duct-fan motor that is exposed to the main air stream shall be totally enclosed. See 22.18.

27.3.3 An appliance employing a motor that must be cooled by the main air stream to prevent overheating when operating continuously – an air-over motor – shall incorporate automatically reset inherent overtemperature protection.

28 Thermostats

28.1 A manually reset thermostat shall be located so that it can be reset:

a) From outside the appliance, or

b) After opening a hinged door or the equivalent that does not give access to uninsulated live parts.

Exception: If marked in accordance with 72.1.13.

28.2 The reset button of a manually reset thermostat shall be protected from mechanical abuse.

28.3 A thermostat with either a marked or an implied off position (see 28.5 and 28.6), while in the marked or implied off position:

a) Shall open all ungrounded conductors of the circuit; and

b) Shall either:

1) Be provided with a positive mechanical means such that the control cannot function automatically, or

2) Not reclose (remain open) when cooled to a temperature of minus 35°C (minus 31°F).

Exception No. 1: If unintentional energization of a product will not result in a risk of fire, electric shock, or injury to persons, the control need not comply with these requirements.

Exception No. 2: If unintentional energization of a product will not result in a risk of electric shock, but may result in a risk of fire or injury to persons, the control need only open a sufficient number of conductors to de-energize the circuit.

28.4 If a control as mentioned in 28.3 is used in combination with another control, the combination of controls may be used to comply with the requirements in 28.3.

28.5 A control as mentioned in 28.3 is considered to have an implied off position if:

a) The control is marked with a word or phrase, such as "cold" or "no heat," that conveys the same meaning as the word off; or

b) The control may be placed in an unmarked off position that is implied by the fact that there is a marked on position.

28.6 With reference to 28.5, a single-pole thermostat marked with "Lo-Normal-Hi," with a temperature scale such as "40 – 80 F," or with a numerical scale that does not include the numeral 0 such as "1 – 5" is not considered to have an implied off position.

29 Limiting Controls

29.1 A thermal cutoff shall be acceptably secured in place.

29.2 A thermal cutoff that is depended upon to reduce the risk of overheating of an appliance during abnormal operation shall comply with the requirements in the Standard for Themal-Links – Requirements and Application Guide, UL 60691, in addition to the requirements specified in this standard. The operation of a thermal cutoff shall not result in a risk of fire or electric shock as described in 59.3 and 59.4.

29.3 If malfunction of a combination temperature-regulating and -limiting control for a heating element could result in a risk of fire or electric shock – as described in 59.3 and 59.4 – due to overheating of the appliance, a back-up protective device shall be provided to limit temperature.

30 Grounding

30.1 Electrical continuity shall be provided between all exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any user-servicing operation and that can become energized and:

a) The equipment-grounding terminal or lead, and to the metal surrounding the knockout, hole, or bushing provided for field power-supply connection for an appliance intended for permanent electrical connection; or

b) The point of connection of the equipment-grounding conductor of the power-supply cord for an appliance equipped with a power-supply cord of the grounding type. See 30.3.

30.2 With reference to the requirement in 30.1, two pieces of enameled or painted sheet metal are not considered to be adequately bonded together unless measures are taken to penetrate the enamel or paint at points of bonding.

30.3 A power-supply cord of an appliance for use on a circuit operating at a potential of more than 150 volts to ground shall include an equipment-grounding conductor.

Exception: Appliances with no parts requiring electrical continuity in accordance with 30.1, and having no dead metal parts likely to become energized which are in contact with water, are not required to be provided with an equipment grounding conductor.

30.3A A cord-connected appliance provided with double insulation in accordance with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097, is not required to be provided with an equipment-grounding conductor. Also see 8.1A.

30.4 An equipment-grounding conductor of a flexible cord shall be:

a) Finished to show a green color with or without one or more yellow stripes;

b) Connected to the grounding member of an attachment plug of the grounding type; and

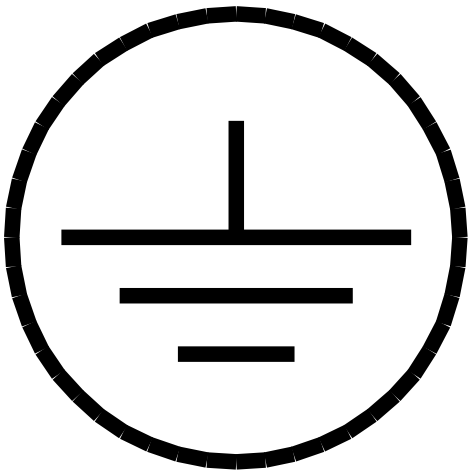
c) Connected to the dead metal parts mentioned in 30.1 by a screw or other acceptable means not likely to be removed during servicing. Solder alone is not acceptable for making this connection.

30.5 The screw mentioned in 30.4(c) shall be of corrosion-resistant metal, or shall be adequately protected against corrosion. A lock washer or equivalent means shall be employed to prevent the screw from becoming loosened by vibration. The screw shall have a green-colored head that is hexagonal, slotted, or both, and shall be located so that it is not likely to be removed during intended servicing of the appliance.

30.6 A pressure wire connector intended solely for the connection of an equipment-grounding conductor shall be identified by being colored green, marked "G," "GR," "Ground," "Grounding," by the symbol in Figure 30.1 or the like, or by a marking on a wiring diagram provided on the appliance. The pressure wire connector shall be located so that it is unlikely to be removed during intended servicing of the appliance.

Figure 30.1

Grounding symbol



30.7 Other than during an electrical fault, an equipment-grounding connection, a grounding conductor, an enclosure, a frame, a component-mounting panel, or any other part connected to earth ground shall not carry current.

30.8 An equipment-grounding terminal shall secure a conductor of a size acceptable for the application in accordance with the National Electrical Code, ANSI/NFPA 70.

30.9 A connector shall comply with the applicable requirements in the Standard for Wire Connectors, UL 486A-486B. A connector not covered by UL 486A-486B shall exhibit, upon investigation, performance equivalent to that specified in the standard.

31 Capacitors

31.1 A capacitor of a capacitor motor and a capacitor connected across the line – such as a capacitor for radio-interference elimination or power-factor correction – shall be housed within an enclosure or container that will protect the plates against mechanical damage and that will prevent emission of flame or molten material resulting from malfunction of the capacitor. The container shall be metal providing strength and protection not less than that of uncoated sheet steel having a thickness of 0.020 inch (0.51 mm). Sheet metal having a thickness less than 0.026 inch (0.66 mm) shall not be used.

Exception: The container of a capacitor may be of sheet metal thinner than 0.026 inch, or may be of acceptable material other than metal, if the capacitor is mounted in an enclosure that houses other parts of the appliance, and if such box, case, and the like is acceptable for the enclosure of live parts.

31.2 In addition to the requirements specified in this Standard, capacitors shall comply with the requirements in the Standard for Capacitors, UL 810.

31.3 Under both normal and abnormal conditions of use, a capacitor employing a liquid dielectric medium more combustible than askarel shall not result in a risk of fire or electric shock; and shall be constructed to reduce the risk of expelling the dielectric medium. See 32.1.7.

31.4 A capacitor complying with the requirements for protected oil-filled capacitors, Sections 17 – 20 of the requirements for the Standard for Capacitors, UL 810, is considered to be constructed to reduce the risk of expelling the dielectric medium.

32 Spacings

32.1 General

32.1.1 The spacings between field-wiring terminals of opposite polarity, and between a wiring terminal and any other uninsulated metal part (dead or alive) not of the same polarity, shall not be less than that specified in Table 32.1.

Exception No. 1: The spacing requirements in Table 32.1 do not apply to the inherent spacings of a component of an appliance, such as a switch. Such spacings are to comply with the requirements for the component in question.

Exception No. 2: Spacings on printed wiring board assemblies may comply with the requirements in 32.1.8 and Table 32.3.

Table 32.1
Minimum acceptable spacings at field-wiring terminals

Potential involved volts	Minimum spacings, inch (mm)					
	Between field-wiring terminals, through air or over surface		Between field-wiring terminals and other uninsulated metal parts not always of the same polarity[a]			
			Over surface		Through air	
250 or less	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)
More than 250	1/2	(12.7)[b]	1/2	(12.7)[b]	3/8	(9.5)

[a] Applies to the sum of the spacings involved where an isolated dead part is interposed.

[b] A spacing of not less than 3/8 inch (9.5 mm), through air and over surface, is acceptable at wiring terminals in a wiring compartment or terminal box if the compartment or box is integral with a motor.

32.1.2 Spacings, other than at field-wiring terminals, between uninsulated live parts of opposite polarity, and between an uninsulated live part and a dead metal part, shall not be less than the applicable value specified in Table 32.2. If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces, or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum acceptable spacing will be maintained.

Exception: The spacing requirements in Table 32.2 do not apply to the inherent spacings of a component of an appliance, such as a switch. Such spacings are to comply with the requirements for the component in question.

32.1.3 In the application of 32.1.2 and 49.1 and Table 32.2 to an appliance employing a motor not rated in horsepower, the appropriate table of the National Electrical Code, ANSI/NFPA 70, is to be used to determine the relationships between horsepower and full-load current for motors.

32.1.4 At terminal screws and studs to which connections may be made in the field by wire connectors, eyelets, or the like described in 4.11, spacings shall not be less than those specified in Table 32.2 with the connectors, eyelets, or the like, in such position that minimum spacings – opposite polarity and to dead metal – exist.

Table 32.2
Minimum acceptable spacings at other than field-wiring terminals

Potential involved, volts	Minimum spacings, inch (mm)							
	An appliance employing a motor having a diameter of 7 inches (180 mm) or less				An appliance employing a motor having a diameter of more than 7 inches (180 mm)[a]			
	Over surface		Through air		Over surface		Through air	
0 – 50	1/16	(1.6)	1/16	(1.6)	1/4[c]	(6.4)	1/8[c]	(3.2)
51 – 125	3/32[b]	(2.4)	3/32[b]	(2.4)	1/4[c]	(6.4)	1/8[c]	(3.2)
126 – 250	3/32	(2.4)	3/32	(2.4)	1/4[c]	(6.4)	1/4[c]	(6.4)
251 – 600	1/2[c]	(12.7)	3/8[c]	(9.5)	1/2[c]	(12.7)	3/8[c]	(9.5)

[a] This is the diameter, measured in the plane of the laminations, of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and the like, used solely for the motor mounting, cooling, assembly, or connection.

[b] For an appliance employing only motors rated 1/3 horsepower or less, these spacings may be not less than 1/16 inch.

[c] Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 inch over surface and through air between film-coated wire, rigidly supported and held in place on a coil and a dead metal part is acceptable.

Table 32.3
Minimum acceptable spacings on printed wiring board assemblies

Voltage available[c] (volts)	Energy available	Minimum spacings		Conformal coating
		inch	mm	
0 – 600	Unlimited	1/32	0.8	Section 64
0 – 50[b]	Unlimited	1/32	0.8	Section 64
0 – 30	Limited[a]	1/64	0.4	Section 64

NOTE – The minimum spacings are required between live parts of opposite polarity. Spacings between live parts and dead metal shall comply with Table 32.1.

[a] Low-voltage limited energy as described in 32.2.1.

[b] A coating is not required if the board assembly is in compliance with the exception to 32.1.8.

[c] For peak voltages and battery voltages multiply applicable rms voltage by 2.

32.1.5 A barrier or liner of vulcanized fiber or similar material employed in lieu of spacings shall be of material acceptable for the application and shall not be less than 1/32 inch (0.8 mm) thick.

Exception No. 1: A barrier or liner used in conjunction with not less than one-half the required spacing through air, may be not less than 1/64 inch (0.4 mm), provided that the barrier or liner is of acceptable insulating material, resistant to moisture, of adequate mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, secured in place, and located so that it will not be damaged by operation of the appliance in service – particularly arcing.

Exception No. 2: Insulating material having a thickness less than that specified may be used if, upon investigation, it is found to be acceptable for the particular application.

32.1.6 Motor spacings shall comply with the spacing requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

32.1.7 Electrical spacings for a capacitor employing a dielectric medium more combustible than askarel shall not be less than the sum of the following values:

a) 1/2 inch (12.7 mm) for capacitor expansion under fault conditions, and

b) An additional clearance of 1/16 inch (1.6 mm) for circuits not exceeding 300 volts and 1/8 inch (3.2 mm) for circuits of 301 – 600 volts.

32.1.8 Spacings on a printed wiring board assembly may be less than indicated in Table 32.2 provided a coating and spacings are utilized as specified in Table 32.3.

Exception: A coating is not required if the available rms voltage is 50 volts or less and the board is located in such a manner that it is not readily subject to contamination by dust or electrolyte.

32.2 Low-voltage, power-limited circuits

32.2.1 A low-voltage, limited-energy circuit is a circuit supplied from an isolated secondary winding of a transformer, if the open-circuit secondary voltage is 30 volts rms (42.4 volts peak) or less, and either:

a) The secondary short-circuit current is 8 amperes or less, after 1 minute, or

b) The volt-ampere output capacity of the secondary winding is 250 volt-amperes or less and an overcurrent protective device rated at not more than 3.2 amperes is connected in series with the secondary circuit.

A fixed series impedance in the secondary circuit may be used to limit the output of the transformer and, in such case, the secondary winding of the transformer and the fixed series impedance are to be judged as part of the line-voltage circuit. The maximum output capacity of the secondary circuit is to be determined as described in 32.2.4.

32.2.2 The overcurrent protective device specified in 32.2.1 shall:

a) Not be of the automatic reset type,

b) Be trip-free from the reclosing mechanism if of the manual reset type, and

c) Not be interchangeable with one of a larger current rating if it is a renewable device.

32.2.3 The maximum volt-ampere output capacity of the secondary winding is to be determined as follows. The primary winding of the transformer, at room temperature, is to be connected as intended in an appliance, and the secondary winding in question is to be connected to a variable-resistance load. If a fixed series impedance is relied upon to limit the output, that impedance is to be included in the circuit during the test. A multiple-winding transformer is to have one secondary winding tested with all the other secondary windings open-circuited, and is to be allowed to cool to room temperature again before another winding is tested. The primary winding is to be connected to a source of rated voltage. The load on the secondary is to be varied in approximately ten increments from open-circuit to short-circuit conditions in 2-1/2 minutes. For each step or increment in the resistance, the product of the output voltage and current are to be recorded, plotted, and drawn as a smooth curve. The peak value obtained from this graph shall not exceed 250 volt-amperes and, if two or more secondary windings supply interconnected circuits, the sum of the outputs of the windings in question shall not exceed 250 volt-amperes.

32.2.4 The maximum volt-amperes output capacity of the circuit is to be determined as follows. The circuit is to be connected as intended in the equipment and the circuit in question is to be connected to a variable-resistance load. If a fixed series impedance is relied upon to limit the output, that impedance is to be included in the circuit during the test. The load on the circuit is to be varied in approximately ten increments from open- to short-circuit conditions in 2-1/2 minutes. For each step or increment in the resistance, the product of the output voltage and current are to be recorded, plotted, and drawn as a smooth curve. The maximum value obtained from this graph shall not exceed 250 volt-amperes.

32A Clearance and Creepage Distances

32A.1 As an alternative approach to the spacing requirements specified in Spacings, Section 32, and other than as noted in 32A.3, clearances and creepage distances may be evaluated in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, as described in 32A.3.

32A.2 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section 32.

32A.3 In conducting evaluations in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, the following guidelines in Table 37.1– Table 37.3 shall be used.

33 Filters and Heat Transfer Media

33.1 Filters shall comply with the requirements for air filters in the Standard for Air Filter Units, UL 900.

33.2 Heat transfer media shall have a flame spread index not greater than 25 and its smoke developed index shall not be over 50 when tested in accordance with the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723.

Exception No. 1: Heat transfer media in units for residential installation only and marked in accordance with 72.1.19, shall have a flammability classification of 5V, V-0, V-1, V-2, HF-1, HF-2, HBF, or HB as indicated in Table 33.1 or have a flame-spread index not over 200 when tested in accordance with the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723.

Exception No. 2: Heat transfer media that complies with the test requirements for the Standard for Air Filter Units, UL 900. When the Flame-Exposure Test is conducted, only two samples of the media are required to be tested.

Exception No. 3: Heat transfer media in such quantities that their total exposed surface area within the compartment does not exceed 10 ft^2 (0.93 m^2) shall have a flame-spread index of not more than 25, or shall comply with the requirements of the vertical burning test for classifying materials 5V in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Table 33.1
Acceptable uses of materials based on flammability classifications

Degree of exposure to ignition source	Type of material					
	HB or HBF	HF-1	HF-2	V-2	V-0 or V-1	5V
Not Exposed	Yes	Yes	Yes	Yes	Yes	Yes
Exposed, but isolated as shown in Figure 33.1	No	No[c]	No[a,c]	Yes[a]	Yes	Yes
Exposed	No	No[b,c]	No[b,c]	No[b,c]	No[b,c]	Yes

NOTE - The flammability classifications are in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[a] May not be used in space A illustrated in Figure 33.1 if there are openings in the enclosure bottom in that space.

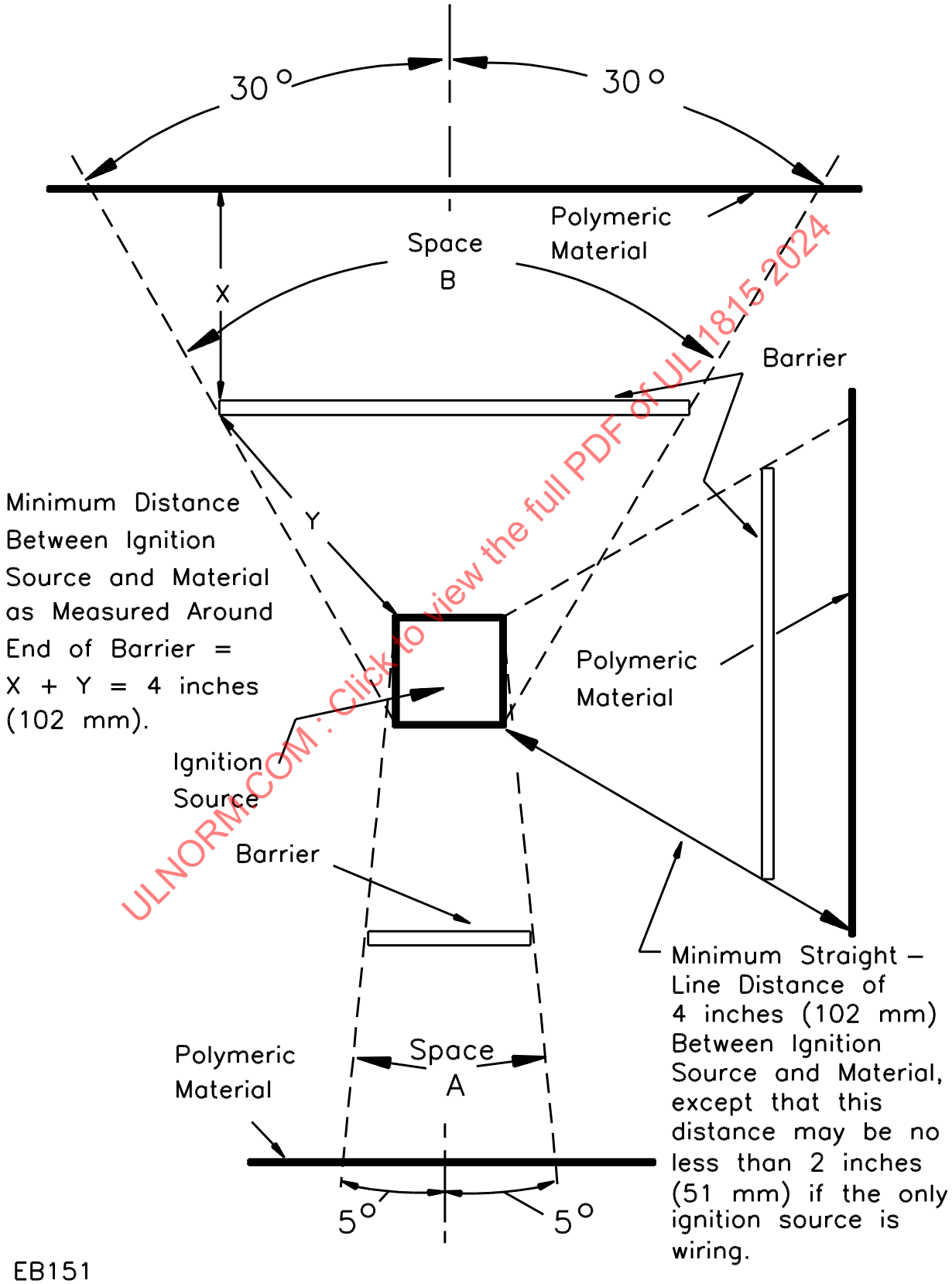
Table 33.1 Continued on Next Page

Table 33.1 Continued

Degree of exposure to ignition source	Type of material					
	HB or HBF	HF-1	HF-2	V-2	V-0 or V-1	5V
[b] Vertically oriented material, when laminated between two metal surfaces each no less than 0.010-inch (0.25 mm) thick, may have an exposed vertical surface no more than 3/8-inch (9.5-mm) wide. such as Type SO, ST, SPT-3, SJO, or SJT, or single or multiple conductor appliance wiring material having an insulation wall thickness not less than 1/16 inch (1.6 mm) for 18 or 16 AWG (0.82 or 1.3 mm^2) or 5/64 inch (2.0 mm) for 14 – 10 AWG (2.1 – 5.3 mm^2) and is rated for refrigeration or air conditioning use, it need not be so enclosed.						
[c] May be used if the only ignition sources are flexible cord such as Type SO, ST, SPT-3, SJO, or SJT or appliance wiring material such as single or multiple conductor appliance wiring material having an insulation wall thickness not less than 1/16 inch (1.6 mm) for 18 or 16 AWG (0.82 or 1.3 mm^2) or 5/64 inch (2.0 mm) for 14 – 10 AWG (2.1 – 5.3 mm^2) and is rated for refrigeration or air conditioning use, it need not be so enclosed.						

Figure 33.1

Exposure to ignition source



34 Polymeric and Other Nonmetallic Materials

34.1 General

34.1.1 This section specifies the construction requirements applicable to polymeric and other nonmetallic materials used in a unit. Details of the performance requirements are specified in Tests for Polymeric Materials, Section 67.

34.1.2 These requirements apply to a unit intended for indoor use only, having a maximum normal operating temperature on the material that does not exceed 100°C (212°F). See Temperature test, Section 47.

34.1.3 The acceptability of polymeric material for use in a unit shall be determined for each application. See Table 34.1 for properties to be evaluated depending on use of the material.

Table 34.1
Evaluation of properties of polymeric materials

Characteristics to be evaluated	Enclosures	Structural parts	Thermal and acoustical insulation	Functional parts
Flammability[a]				
Source of ignition				
External	Yes	Yes		
Internal	Yes	Yes	Yes	Yes
Heat deflection	Yes	Yes		Yes
Water absorption	Yes	Yes[b]		
Environmental exposure	Yes	Yes		
Air oven aging	Yes	Yes		
Tensile and flexural strength	Yes	Yes		
Izod or tensile impact strength	Yes	Yes		
Impact	Yes	Yes		
Volume resistivity	Yes[c]	Yes[c]	Yes[c]	Yes[c]

[a] A material having a flame-spread rating of no more than 25 when tested in accordance with the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723, is acceptable from a flammability standpoint.

[b] When applicable.

[c] When applicable, see 34.1.4.

34.1.4 For the purpose of evaluating electrical spacings between an uninsulated live part and a polymeric material, the material shall be treated as a metal part unless it complies with the requirements of the Volume resistivity test, 67.11.1 and 67.11.2.

34.1.5 Consideration shall be given to the possibility of external ignition of a nonmetallic outer enclosure and of a structural part.

34.2 Material classification

34.2.1 A polymeric material or other nonmetallic material used in a unit shall have flammability classification of 5V, V-0, V-1, V-2, HF-1, HF-2, HBF, or HB as indicated in Table 33.1.

34.3 Ignition sources

34.3.1 With reference to 34.4.3, Figure 33.1, and Table 33.1, possible ignition sources within the unit are considered to be wiring in a high-voltage circuit, and any other electrical component such as a switch, relay, transformer, or motor winding not completely enclosed in:

a) Metal not less than 0.010 inch (0.25 mm) thick, or

b) 5V polymeric material.

Exception: Wiring need not be isolated as indicated in 34.4.1 – 34.4.4 if it complies with the VW-1 flame test or the vertical flame test described in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

34.4 Material applications

34.4.1 Material employed for sole or partial support of live parts shall be classed 5V.

34.4.2 A barrier as illustrated in Figure 33.1 shall be of metal or of 5V material, and shall be mechanically secured in place.

34.4.3 The acceptability of an opening in a control compartment, other than that of minimum size for the passage of a control shaft or rod, shall be judged on the basis of the necessity for its existence. On any one surface, the minor dimension of an opening shall not exceed 3/8 inch (9.5 mm) and the maximum area shall not exceed 0.25 inch^2 (1.61 cm^2) except that this may be increased to a maximum of 1.00 inch^2 (6.45 cm^2) if a barrier of metal or 5V polymeric material is secured in place and interposed between ignition sources and combustible material. In any case, the maximum aggregate area of all openings in any one surface shall not exceed 1.0 inch^2 (6.45 cm^2).

34.4.4 With reference to 34.4.3, wiring in the control compartment is to be routed away from any openings that expose the wire to combustible materials. In judging the need for a barrier, consideration is to be given to grouped openings that have an aggregated area exceeding 0.25 inch^2 (1.61 cm^2).

35 Overload-Protective Devices

35.1 A protective device, the intended functioning of which requires replacement or resetting, shall be in a readily accessible location.

35.2 A protective device shall be inaccessible from outside the appliance without opening a door or cover.

Exception: The operating handle of a circuit breaker, the operating button of a manually operable motor protector, and similar parts may project outside the enclosure.

35.3 In addition to the requirements specified in this Standard, fuseholders shall comply with the requirements in the Standard for Fuseholders – Part 1: General Requirements, UL 4248-1 and

a) The Standard for Fuseholders – Part 4: Class CC, UL 4248-4;

b) The Standard for Fuseholders – Part 5: Class G, UL 4248-5;

c) The Standard for Fuseholders – Part 6: Class H, UL 4248-6;

d) The Standard for Fuseholders – Part 8: Class J, UL 4248-8;

e) The Standard for Fuseholders – Part 9: Class K, UL 4248-9;

f) The Standard for Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse, UL 4248-11;

g) The Standard for Fuseholders – Part 12: Class R, UL 4248-12; or

h) The Standard for Fuseholders – Part 15: Class T, UL 4248-15.

35.4 A fuseholder shall be constructed and installed so that no uninsulated live part other than the screw shell or clips will be exposed to contact by a person removing or replacing a fuse. The screw shell of a plug-type fuseholder shall be connected toward the load.

35.5 A door or cover of an enclosure shall be hinged or attached in an equivalent manner if it gives access to any overload-protective device, the intended functioning of which requires renewal, or if it is necessary to open the cover in connection with the intended operation of the protective device.

35.6 Means shall be provided for holding closed a door or cover over a fuseholder, and the door or cover shall fit tightly.

35.7 A thermal protective device shall not open the circuit during intended operation of the appliance.

35.8 In an automatic appliance, if breakdown of a capacitor that is not part of a permanent-split-capacitor motor or a part of a capacitor-start motor would result in a risk of fire or electric shock, thermal or overcurrent protection shall be provided in the appliance to prevent the establishment of such a condition.

35.9 In addition to the requirements specified in this Standard, supplemental fuses shall comply with the requirements in the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1 and the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14.

36 Switches, Including Motor Controllers

36.1 A switch or other control device shall:

a) Be acceptable for the application,

b) Have a current and voltage rating not less than that of the load that it controls, and

c) Be located within the confines of the frame or enclosure of the appliance or be additionally protected so as to reduce the likelihood of contact by external objects.

Exception: With reference to (c), the actuating part of a switch need not be located within the confines of the frame or enclosure.

36.2 With reference to the requirement in 36.1, the current rating of a switch that controls an inductive load, such as a transformer or a fluorescent-lamp ballast, shall not be less than twice the rated full-load current of the transformer or ballast, unless the switch is acceptable for the particular application.

36.3 A switch that controls a medium-base lampholder shall be acceptable for use with tungsten-filament lamps.

36.4 If an appliance provided with a power-supply cord and an attachment plug employs a motor rated more than 1/3 horsepower (250 W output), a motor controller – a device for starting and stopping the motor – shall be provided in the appliance.

36.5 An acceptable speed-control switch shall be provided with an appliance that employs a multispeed motor – a motor with a winding capable of various pole groupings.

36.6 A solid-state speed control shall comply with the applicable requirements in the supplement for solid-state fan speed controls in the requirements for Industrial Control Equipment, UL 508.

36.7 In addition to the requirements specified in this Standard, switches shall comply with the requirements in the:

a) Standard for Clock-Operated Switches, UL 917;

b) Standard for Enclosed and Dead-Front Switches, UL 98;

c) Standard for General-Use Snap Switches, UL 20;

d) Deleted

e) Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1.

36.8 In addition to the requirements specified in this Standard, Switchgear and Controlgear shall comply with the requirements in the:

a) Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1;

b) Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1; or

c) Standard for Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches, UL 60947-5-2.

37 Controls – End Product Test Parameters

37.1 General

37.1.1 Spacings of controls shall comply with the electrical spacing, or clearances and clearance distance requirements of the applicable control standard as determined in Controls, Section 9.

37.1.2 Where reference is made to declared deviation and drift, this indicates the manufacturer's declaration of the control's tolerance before and after certain conditioning tests.

37.2 Auxiliary controls

37.2.1 Auxiliary controls shall not introduce a risk of electric shock, fire, or personal injury.

37.2.2 Auxiliary controls shall comply with the requirements of this end product standard.

37.3 Operating controls (regulating controls)

37.3.1 The following test parameters shall be among the items considered when judging the acceptability of an operating control investigated using the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1. Appendix A provides more examples of controls intended to be used as operating controls:

a) Control Types 1 or 2;

b) Unless otherwise specified in this standard, manual and automatic controls shall be tested for 6,000 cycles with under maximum normal load conditions, and 50 cycles under overload conditions;

c) Installation class 2 per Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5;

d) For the applicable Overvoltage Category, see Table 37.1;

e) For the applicable Material Group, see Table 37.2; and

f) For the applicable Pollution Degree, see Table 37.3.

Table 37.1
Overvoltage categories

Appliance	Overvoltage category
Intended for fixed wiring connection	III
Portable and stationary cord-connected	II
Control located in low-voltage circuit	I
NOTE – Applicable to low-voltage circuits if a short circuit between the parts involved may result in operation of the controlled equipment that would increase the risk of fire or electric shock.	

Table 37.2
Material group

CTI PLC value of insulating materials	Material group
CTI ≥600 (PLC = 0)	I
CTI ≥ 400 < 600 (PLC = 1)	II
CTI ≥ 175 < 400 (PLC = 3)	IIIa
CTI ≥ 100 < 175 (PLC = 4)	IIIb
NOTE – PLC stands for Performance Level Category, and CTI stands for Comparative Tracking Index as specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.	

Table 37.3
Pollution degree

Appliance control microenvironment	Pollution degree
No pollution or only dry, nonconductive pollution. The pollution has no influence. Typically hermetically sealed or encapsulated controls without contaminating influences, or printed wiring boards with a protective coating can achieve this degree.	1
Normally, only nonconductive pollution. However, a temporary conductivity caused by condensation may be expected. Typically indoor appliances for use in household or commercial clean environments achieve this degree.	2
Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation that is expected. Typically controls located near and may be adversely affected by motors with graphite or graphite composite brushes, or outdoor use appliances achieve this degree.	3

37.4 Protective controls (limiting controls)

37.4.1 An electronic control that performs a protective function shall comply with the requirements in 9.1.4, while tested using the parameters in this section. Examples of protective controls are a control used to sense abnormal temperatures of components within the appliance; temperature protection of the motor due to locked rotor, running overload, loss of phase; or other function intended to reduce the risk of electric shock, fire, or injury to persons. During the evaluation of the protective control/circuit, the protective functions are verified under normal and single-fault conditions of the control/circuit.

37.4.2 The following test parameters shall be among the items considered when judging the acceptability of an electronic protective control investigated using the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1. Appendix A provides more examples of controls intended to be used as protective controls:

a) Failure-Mode and Effect Analysis (FMEA) or equivalent Risk Analysis method;

b) Power Supply Voltage Dips, Variation and Interruptions within a temperature range of 10°C (50° F) and the maximum ambient temperature determined by conducting the Temperature Test. See Temperature Test, Section 47;

c) Surge immunity test –installation class 3 shall be used;

d) Electrical fast transient/burst test, a test level 3 shall be used;

e) Electrostatic Discharge Test;

f) Radio-frequency electromagnetic field immunity:

1) Immunity to conducted disturbances – When applicable, test level 3 shall be used; and

2) Immunity to radiated electromagnetic fields; field strength of 3 V/m shall be used;

g) Thermal Cycling test of clause H.17.1.4.2 shall be conducted at ambient temperatures of 10 +2°C (50 +4°F) and the maximum ambient temperature determined by conducting the Temperature Test; The test shall be conducted for 14 days;

h) Overload shall be conducted based on the maximum declared ambient temperature (T_{max}) or as determined by conducting the Temperature Test;

i) If software is relied upon as part of the protective electronic control, it shall be evaluated as software class B;

j) Thermal Cycling test of clause H.17.1.4.2 shall be conducted at ambient temperatures of 10 +2°C (50 +4°F) and the maximum ambient temperature determined by conducting the Temperature Test. See Temperature Test, Section 47. The test shall be conducted for 14 days;

k) Overload shall be conducted based on the maximum declared ambient temperature (T_{max}) or as determined by conducting the Temperature Test; and

l) If software is relied upon as part of the protective electronic control, it shall be evaluated as software class B.

37.4.3 The test parameters and conditions used in the investigation of the circuit covered by 37.4.1 shall be as specified in the Standard for Test for Safety-Related Controls Employing Solid-State Devices, UL 991, using the following test parameters:

a) With regard to electrical supervision of critical components, for attended appliances, a motor operated system becoming permanently inoperative with respect to movement of an exposed

portion of the appliance meets the criteria for trouble indication. For unattended appliances, electrical supervision of critical components may not rely on trouble indication;

b) A field strength of 3 V per meter is to be used for the Radiated EMI Test;

c) The Composite Operational and Cycling Test is to be conducted for 14 days at temperature extremes of 0°C (32°F) and 70°C (158°F);

d) The Humidity Class is to be based on the appliance's intended end use and is to be used for the Humidity Test;

e) A vibration level of 5 g is to be used for the Vibration Test;

f) When a Computational Investigation is conducted, I_p shall not be greater than 6 failures/10^6 hours for the entire system. The Operational Test is to be conducted for 14 days;

g) When the Demonstrated Method Test is conducted, the multiplier for the test acceleration factor is to be 576.30 for intermittent use appliances, or 5763.00 for continuous use appliances. The test acceleration factor equation is to be based on a 25°C (77°F) use ambient;

h) The Endurance Test is to be conducted concurrently with the Operational Test. The control shall perform its intended function while being conditioned for 14 days in an ambient air temperature of 60°C (140°F), or 10°C (50°F) greater than the operating temperature of the control, whichever is higher. During the test, the control is to be operated in a manner representing normal use;

i) For the Electrical Fast Transient Burst Test, test level 1 is to be used;

j) Conduct a failure-mode and effect analysis (FMEA); and

k) If software is relied upon as part of the protective electronic control, it shall be evaluated as software class 1 in accordance with the Standard for Software in Programmable Components, UL 1998.

37.4.4 Unless otherwise specified in the Standard for Nonducted Heat Recovery Ventilators, UL 1815, protective controls shall be evaluated for 100,000 cycles for Type 2 devices, and 6,000 cycles for Type 1 devices, with rated current.

37.5 Controls using a temperature sensing device

37.5.1 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control, shall be tested using the following number of cycles when testing a sensing device in accordance with the endurance test:

a) For a device employed as a operating device – 6000 cycles,

b) For a device employed as a protective device – 100,000 cycles, or

c) For a device employed as a combination operating and protective device – 100,000 cycles.

UL 60335-1 BASED REQUIREMENTS FOR THE EVALUATION OF ELECTRONIC CIRCUITS

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37A General

37A.1 These requirements provide an alternate path for the investigation of electronic controls and other circuits used in appliances covered by this standard.

37A.2 Thermal motor protectors in direct contact with motor windings and intended for direct control of the motor supply are outside the scope of this Standard even if they incorporate one or more electronic components.

37A.3 The requirements in Sections 37A – 37K are intended to apply to the electronic circuit and how it is integrated in the appliance. The overall appliance construction, performance testing and marking requirements are applicable as specified in this standard except as cited in the following requirements.

37B Components

37B.1 Capacitors

37B.1.1 A capacitor connected between two line conductors in a primary circuit, or between one line conductor and the neutral conductor or between primary and accessible secondary circuits or between the primary circuit and protective earth (equipment grounding conductor connection) shall comply with one of the subclasses of the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14 and shall be used in accordance with its rating.

Note: Details for damp heat, steady state test can be found in 4.12 of Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains – Edition 4.1; Consolidated Reprint, IEC 60384-14.

37B.2 Isolation devices

37B.2.1 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this standard shall be constructed in accordance with the Standard for Optical Isolators, UL 1577, and shall be able to withstand for 1 minute, without breakdown, an ac dielectric voltage withstand potential of 2500 volts as specified in 35.1 between the input and output circuits.

37B.2.2 A power switching semiconductor device that is relied upon to provide isolation to ground shall be constructed in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential of 2500 volts as specified in 35.1 for 1 minute.

37B.2.3 A power switching semiconductor device that is relied upon to provide isolation between primary and secondary circuits or between other circuits shall be a device (such as a solid state motor controller) that complies with the Standard for Industrial Control Equipment, UL 508.

Exception: A power switching semiconductor device located within a component that has been separately evaluated to the requirements for that component is not required to be further evaluated, provided the component is used within its established ratings and limitations.

37B.2.4 A relay that is relied upon to provide isolation between primary and secondary circuits shall comply with the Standard for Industrial Control Equipment, UL 508.

37B.3 Printed-wiring boards

37B.3.1 Printed wiring boards shall comply with the Standard for Printed Wiring Boards, UL 796, and shall have a flammability rating and other characteristics as specified in this standard.

Exception: A printed circuit board solely in a Low-Power Circuit and whose failure would not constitute a risk of electric shock is not permitted to comply with UL 796.

37B.3.2 Any printed-wiring board that complies with the requirements for Direct Support in the Standard for Printed-Wiring Boards, UL 796, is considered to provide an insulating base with a Comparative Tracking Index (CTI) of minimum 100.

37B.4 Bridging components – switch mode power supplies

37B.4.1 Components connected between the primary and secondary circuits of an isolating device such as a switching transformer or between primary and secondary earth reference points shall be evaluated to provide the specified level of isolation for the application under normal and abnormal (single component fault) conditions.

37B.4.2 A capacitor connected between primary and accessible secondary circuits shall comply with Capacitors, 37B.1. This shall consist of a single Class Y1 capacitor or two Class Y2 capacitors connected in series.

37B.5 Switch mode power supply insulation system

37B.5.1 Insulation used within a transformer of switch mode power supply shall comply with the Standard for Systems of Insulating Materials – General, UL 1446, for the specified temperature class of the insulation system or the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

37C Identification of Safety Critical Circuit Functions

37C.1 General

37C.1.1 Electronic circuits or parts of circuits shall be analyzed to determine if the function of the control is necessary for compliance with this standard. A function is considered a Safety Critical Function (SCF) if failure (loss or malfunction) of its functionality would result in the risk of fire, electric shock, mechanical Risk of injury or a Dangerous Malfunction.

37C.1.2 Safety Critical Functions shall be identified as either Protective Electronic Circuits as detailed in 37C.2 or as those of operating circuits that mitigate Dangerous Malfunctions as detailed in 37C.3.

37C.1.3 In the evaluation of electronic circuits, all the contacts of relays or contactors that cycle during the Normal Temperature Test shall be simultaneously short-circuited.

37C.2 Protective electronic circuits

37C.2.1 An electrical component shall not be connected across the contacts of a Protective Electronic Circuit.

Exception: Electrical components may be connected across the contacts provided that any single component fault does not result in a loss of protective function.

37C.2.2 Protective Electronic Circuit functions are as specified in Appendix A.

37C.3 Operating circuits that mitigate a dangerous malfunction of the appliance

37C.3.1 The suitability of stand-by or electronic disconnect circuits shall be as specified in this standard.

37C.3.2 An electronic disconnection circuit whose failure could result in a Dangerous Malfunction shall have at least two components whose combined operation provides the load disconnection.

37C.3.3 Operating circuits whose functions are relied upon to mitigate Dangerous Malfunctions of the appliance are as specified in Appendix A.

37D Evaluation of the Different Types of Electronic Circuits

37D.1 All circuit functions mandated by this standard shall be validated. This includes operating functions not designated as Safety Critical Functions.

37D.2 All circuits shall be evaluated to determine the effects of electronic circuit faults.

37D.3 When the applicable component/hardware faults specified in 37H.10 are imposed one at a time they shall not result in:

a) The appliance presenting a risk of fire, electric shock or mechanical hazard; or

b) The loss of any Safety Critical Function either in that circuit or others.

37D.4 The risk of electrically generated fire from the faults of the Abnormal Operation and Fault Tests, Section 37H is considered to be mitigated in Low-Power Circuits.

37E Circuits that Provide Safety Critical Functions

37E.1 In addition to the requirements of the Evaluation of the Different Types of Electronic Circuits, Section 37D, circuits that provide Safety Critical Functions shall incorporate measures to control the fault/error conditions that would impair the safety functions.

37E.2 The evaluation of the programmable component shall be in accordance with Annex R of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1, Edition 5.

37E.3 Circuits that provide Safety Critical Functions that rely upon a programmable component for one or more of its safety functions shall be subjected to the test of the Programmable Component Reduced Supply Voltage Test, Section 37I, unless restarting at any point in the operating cycle after interruption of operation due to a supply voltage dip will not result in a hazard. The test is carried out after removal of all batteries and other components intended to maintain the programmable component supply voltage during mains supply voltage dips, interruptions and variations.

37E.4 Circuits that provide Safety Critical Functions shall maintain their required functions when subjected to the EMC related stresses specified in the Electromagnetic Compatibility (EMC) Requirements – Immunity, Section 37J.

37E.5 The tests of Electromagnetic Compatibility (EMC) Requirements – Immunity, Section 37J are carried out with surge protective devices disconnected, unless they incorporate spark gaps.

37F General Conditions for the Tests

37F.1 Details

37F.1.1 An electronic control shall be tested in the appliance under the Performance test conditions and order of tests specified in this standard.

Exception: Except as noted elsewhere in this Supplement, upon the agreement of the manufacturer and with due consideration of the relevant compliance criteria, an electronic control may be tested outside of the appliance.

37F.1.2 Cumulative stress resulting from successive tests on electronic circuits is to be avoided. It may be necessary to replace components or to use additional samples.

37F.1.3 User adjustable electronic controls shall be adjusted to their most unfavorable setting.

37F.2 Intentionally weak parts

37F.2.1 If a conductor of a printed circuit board or other component becomes open-circuited, the appliance is considered to have withstood the particular test, provided both of the following conditions are met:

a) The base material of the printed circuit board withstands the test of Needle-Flame Test (NFT) of Annex E of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1, and

b) Any loosened conductor does not reduce electrical spacings (clearances or creepage distances) between live parts and accessible metal parts below the values specified in this standard.

c) The same result is obtained when the test is run three times.

Exception: The base material of the printed-wiring board is not permitted to comply with the Needle-Flame Test of (a) if the base material has a flammability rating of V-0 and a CTI of minimum 100.

37F.3 Test results determined by overcurrent protection operation

37F.3.1 If compliance with these requirements under any of the fault conditions depends on the operation of an over-current device incorporated within the electronic control, the fuse and/or circuit breaker shall comply with the requirements for that component.

37F.3.2 If compliance with the requirements of this standard depends upon the operation of a miniature fuse-link complying with Miniature Fuses – Part 1 Definitions, IEC 60127-1 for miniature fuses and general requirements for miniature fuse-links, during any of the fault conditions specified in 37H.11, the test is repeated but with the miniature fuse-link replaced by an ammeter. If the current measured:

a) Does not exceed 2.1 times the rated current of the fuse-link, the circuit is not considered to be adequately protected and the test is carried out with the fuse-link short-circuited;

b) Is at least 2.75 times the rated current of the fuse-link, the circuit is considered to be adequately protected;

c) Is between 2.1 times and 2.75 times the rated current of the fuse-link, the fuse link is short-circuited and the test is carried out:

1) For the relevant period or for 30 minutes, whichever is the shorter, for quick acting fuselinks;

2) For the relevant period or for 2 minutes, whichever is the shorter, for time lag fuse-links.

37F.3.3 In case of doubt, the maximum resistance of the fuse-link has to be taken into account when determining the current.

37F.3.4 The verification whether the fuse-link acts as a protective device is based on the fusing characteristics specified in IEC 60127-1, which also gives the information necessary to calculate the maximum resistance of the fuse-link.

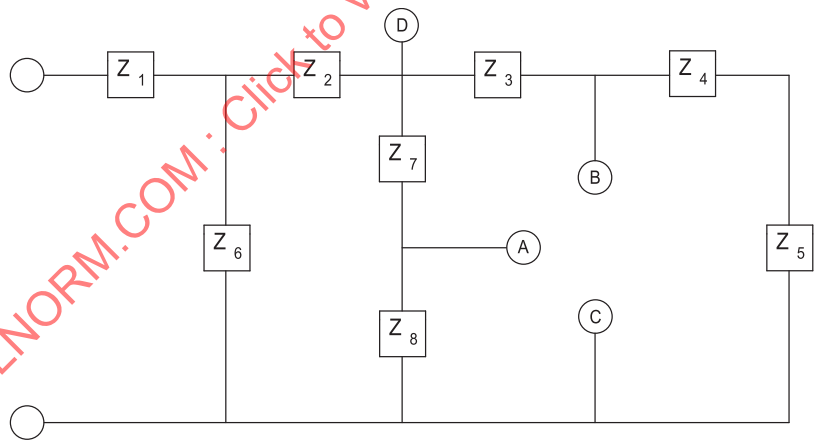
37F.3.5 Fuses other than as noted in 37F.3.2 are considered to be Intentionally Weak Parts in accordance with 37F.2.

37G Low-Power Circuits

37G.1 The appliance shall be supplied at rated voltage and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source. The resistance is then decreased until the power consumed by the resistor reaches a maximum. Points closest to the supply source at which the maximum power delivered to this resistor does not exceed 15 W at the end of 5 seconds are called Low-Power Points. The part of the circuit farther from the supply source than a low-power point is considered to be a Low-Power Circuit. See Figure 37G.1.

Figure 37G.1

Example of an electronic circuit with low-power points



37G.2 The measurements shall be made from only one pole of the supply source, preferably the one that gives the fewest low-power points.

37G.3 When determining the low-power points, measurements shall start with points close to the supply source.

37G.4 The power delivered to the variable resistor shall be measured by a wattmeter.

37G.5 If power is interrupted to parts of circuits by Intentionally Weak Parts, the test shall be repeated two more times to confirm a consistent result.

37H Abnormal Operation and Fault Tests

37H.1 Electronic controls shall be constructed so that the compliance criteria for risk of fire, electric shock and injury to persons as a result of abnormal operating conditions of the appliance specified in this standard are fulfilled.

37H.2 Unless otherwise specified, the tests are continued until a non-self-resetting thermal cutout operates or until steady conditions are established. If an intentionally weak part becomes permanently open-circuited, the relevant test is repeated on two additional samples.

37H.3 Unless otherwise specified, only one abnormal condition is simulated at any one time. If more than one of the tests is applicable to the same appliance, these tests are carried out consecutively after the appliance has cooled down to room temperature.

37H.4 Fault condition 37H.10 is applied to encapsulated and similar components if the circuit cannot be assessed by other methods.

37H.5 For application of the fault conditions, the appliance is operated under the conditions specified in the Normal Temperature Test, Section 47 of this standard.

37H.6 When any of the fault conditions are simulated, the duration of the test is until ultimate results are known but no longer than as specified for the Normal Temperature Test, Section 47 of this standard. In each case, the test is ended if a non-self-resetting interruption of the supply occurs within the appliance.

37H.7 If an electronic timer or programmer must operate to ensure compliance with the test before the maximum period under the conditions of the test is reached, it shall be additionally investigated as a Protective Electronic Circuit.

37H.8 The contacts of relays, contactors or other devices that cycle during the Normal Temperature Test, Section 47, shall be short-circuited.

37H.9 Unless otherwise specified, any electronic control that limits the temperature during the Normal Temperature Test, Section 47 of this standard is short-circuited for abnormal operation tests. If the appliance incorporates more than one control, they are short-circuited, or rendered inoperative, in turn.

37H.10 Electronic circuit faults as specified in (a) – (g) shall be considered. If considered necessary they shall be applied one at a time.

a) Short circuit of spacings if clearances or creepage distances are less than the required values;

b) Open circuit at the terminals of any component;

c) Short circuit of capacitors, unless they comply with Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14;

d) Short circuit of any two terminals of an electronic component, other than an integrated circuit. This fault condition is not applied between the two circuits of an optocoupler that complies with Standard for Optical Isolators, UL 1577;

e) Failure of triacs in the diode mode;

f) Failure of microprocessors and integrated circuits except components such as thyristors and triacs. All possible output signals are considered for faults occurring within the component. If it can

be shown that a particular output signal is unlikely to occur, then the relevant fault is not considered; and

g) Failure of an electronic power switching device in a partial turn-on mode with loss of gate (base) control.

Exception No. 1: Positive temperature coefficient thermistors are not short-circuited if they are used within the manufacturer's specification and comply with the Standard for Thermistor-Type Devices, UL 1434, or Annex J of the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1. However, PTC-S thermistors are short-circuited unless they comply with Clause 14.6 of the Standard for Audio, Video and Similar Electronic Apparatus – Safety Requirements, UL 60065.

Exception No. 2: Components in Low-Power Circuits whose failure also does not result in the loss of a Safety Critical Function.

37H.11 The fault conditions of 37H.10 (a) – (g) shall be applied, one at a time to the components on the supply side of the Low-Power Points determined in 37G.1. The control shall not become a Hazard of Itself.

37H.12 If the appliance incorporates a Protective Electronic Circuit which operates to ensure compliance with Clause 37.4.2, the relevant test is repeated with a single fault simulated in the PEC, as indicated in (a) to (f) of Clause 37.4.2

37H.13 Each Low-Power Point identified by the test of 37H.1 shall be individually tested. It shall be shorted or loaded to the maximum available between the point and the supply return used for the 15 watt determination. The control shall not become a Hazard of Itself.

37I Programmable Component Reduced Supply Voltage Test

37I.1 The appliance is supplied at rated voltage and operated under normal operation. After approximately 60 seconds, the power supply voltage is reduced to a level such that the appliance ceases to respond to user inputs, or parts controlled by the programmable component cease to operate, whichever occurs first. This value of supply voltage is recorded. The appliance is then supplied at rated voltage and operated under normal operation. The voltage is then reduced to a value of approximately 10 % less than the recorded voltage. It is held at this value for approximately 60 seconds and then increased to rated voltage. The rate of decrease and increase of the power supply voltage is to be approximately 10 V/s. The appliance shall continue to either operate normally from the same point in its operating cycle at which the voltage decrease occurred or a manual operation shall be required to restart it.

37I.2 This test may be performed on a control outside the appliance provided that the conditions of test appropriately represent the control environment within the appliance.

37J Electromagnetic Compatibility (EMC) Requirements – Immunity

37J.1 Protective Electronic Controls and control with functions necessary to prevent Dangerous Malfunctions shall continue to provide their desired safety function when subjected to the EMC related stresses specified in (a) – (g), applied one at a time.

a) The appliance is subjected to electrostatic discharges in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test, IEC 61000-4-2 test level 4 being applicable. Ten discharges having a positive polarity and ten discharges having a negative polarity are applied at each preselected point.

b) The appliance is subjected to radiated fields in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated,

radio-frequency, electromagnetic field immunity test, IEC 61000-4-3, test level 3 being applicable. The dwell time for each frequency is to be sufficient to observe a possible malfunction of the protective electronic circuit.

c) The appliance is subjected to fast transient bursts in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test, IEC 61000-4-4. Test level 3 is applicable for signal and control lines. Test level 4 is applicable for the power supply lines. The bursts are applied for 2 minutes with a positive polarity and for 2 minutes with a negative polarity.

d) The power supply terminals of the appliance are subjected to voltage surges in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5, five positive impulses and five negative impulses being applied at the selected points. Test level 3 is applicable for the line-to-line coupling mode, a generator having a source impedance of 2 Ω being used. Test level 4 is applicable for the line-to-earth coupling mode, a generator having a source impedance of 12 Ω being used. In addition:

i) Grounded heating element sheaths in grounded appliances are disconnected during this test.

ii) For appliances having surge arresters incorporating spark gaps, the test is repeated at a level that is 95 % of the flashover voltage.

e) The appliance is subjected to injected currents in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radiofrequency fields, IEC 61000-4-6, test level 3 being applicable. During the test, all frequencies between 0.15 MHz to 80 MHz are covered. The dwell time for each frequency is to be sufficient to observe a possible malfunction of the Protective Electronic Circuit.

f) The appliance is subjected to the class 3 voltage dips and interruptions in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests, IEC 61000-4-11. The values specified in Table 1 and Table 2 of IEC 61000-4-11, are applied at zero crossing of the supply voltage.

g) The appliance is subjected to mains signals in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signaling at a.c. power port, low frequency immunity tests, IEC 61000-4-13, test level class 2 being applicable.

37J.2 The tests are carried out with the appliance supplied at rated voltage, the device being set in the off position or in the stand-by mode.

37J.3 The tests of 37J.1 are carried out after the Protective Electronic Circuit has operated during the relevant abnormal operation tests of this standard. However, appliances that are attended during use are not subjected to the tests for electromagnetic phenomena.

37K Manufacturing and Production and Line Testing

37K.1 In addition to the regular production and manufacturing tests of this standard, the manufacturer shall verify the correct function of circuits that are considered to provide Safety Critical Functions.

PROTECTION AGAINST INJURY TO PERSONS

38 General

38.1 Sections 38 – 42 specify the requirements for construction and performance of appliances the operation of which may result in risk of injury to persons.

38.2 During examination of an appliance with respect to a risk of injury to persons, the general requirements for such features as materials, enclosures, guards, and the like, will be applied along with appropriate requirements for tests, construction, marking, guards, and the like, that apply to that type of appliance. Other than as specifically noted herein, specific features that are not contemplated by these requirements will be given consideration.

39 Accessories

39.1 Use of an accessory that may be furnished with an appliance shall not result in a risk of fire, electric shock, or injury to persons.

40 Switches and Controls

40.1 A device that automatically starts an appliance, such as a timer, or a temperature device, shall not be employed unless it can be demonstrated that automatic restarting will not result in a risk of injury to persons. See 72.1.10.

40.2 Automatic restarting of an appliance provided with an automatically reset thermally-actuated device, such as a room thermostat or a motor thermal protector, shall not result in a risk of injury to persons. See 72.1.10.

40.3 A control (thermostat or limiting) shall comply with the requirements in the:

a) Deleted

b) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; and Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

40.4 A motor control shall comply with the requirements in the:

a) Standard for Industrial Control Equipment, UL 508;

b) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1; or

c) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1 and Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

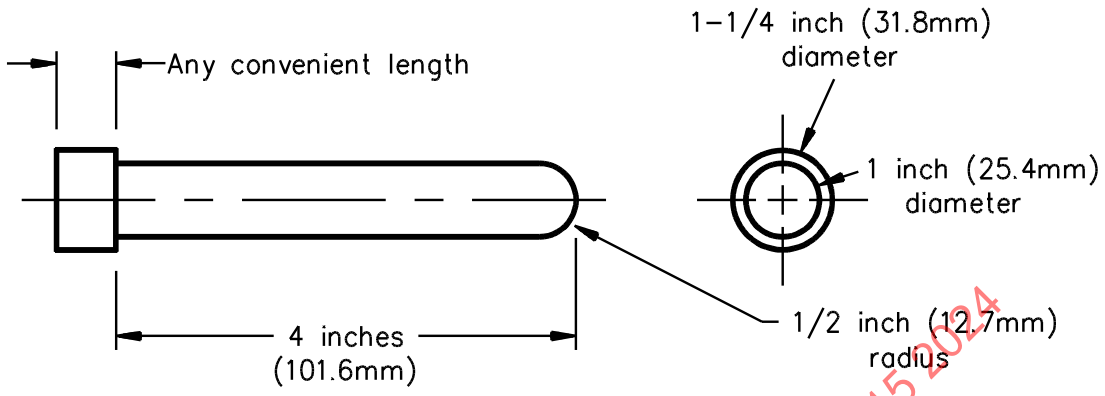
41 Enclosures and Guards

41.1 General

41.1.1 A fan shall be guarded or enclosed so that any moving parts, other than blades, that involve a risk of injury to persons cannot be contacted by the probe illustrated in Figure 41.1.

Figure 41.1

Probe for moving parts



41.1.2 Conventional designs of fan blades are considered acceptably guarded if:

a) The relationship between weight (W) in pounds, radius (r) in inches, and speed (N) in revolutions per minute is such that K in the equation:

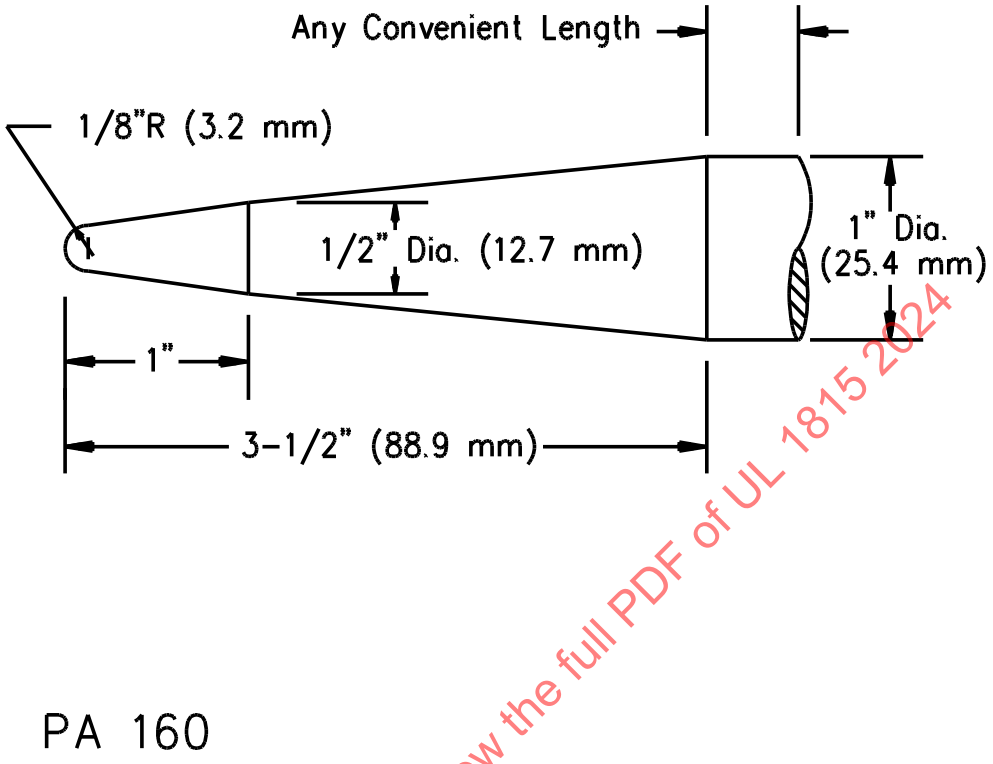
$$K = 6 \times 10^{-7}(Wr^2N^2)$$

is less than 100, and

b) The guarding is such that the probe illustrated in Figure 41.2 cannot touch the leading edge of the blade and hub when inserted as described in 41.1.3. For a reversible fan, both edges are considered leading edges.

Figure 41.2

Probe for fan blades



41.1.3 The portion of a blade of a fan or a blower wheel that can cause a risk of injury to persons shall be guarded so that the probe illustrated in Figure 41.2 cannot touch the part when inserted with a force of 1 pound (4.4 N) through any opening in the guard.

41.1.4 If a part used to comply with the requirement in 41.1.3 is made of a polymeric material, a sample is to be exposed for 7 hours to air at 70°C (158°F). While in the oven the part is to be assembled to the fan and the fan is to be in its intended operating position. After the sample has cooled to room temperature, the part is acceptable if the probe illustrated in Figure 41.2 cannot be made to touch a portion of a blade or blower wheel that can cause a risk of injury to persons when inserted through any opening in the guard.

41.1.5 A guard employed to comply with the requirement in 41.1.3 shall be attached to the fan in any of the following ways:

a) Permanently;

b) By means requiring the use of a tool or tools for removal; or

c) By means not requiring the use of a tool or tools for removal provided that:

1) Two separate motions, for example push and turn, or

2) A force of 5 pounds (22.2 N) is required to disengage the securing means.

41.1.6 The removal force specified in 41.1.5(c)(2) is to be measured after conditioning the holding means by removing and replacing the guard ten times in the intended manner.

41.1.7 An enclosure, a frame, a guard, a handle, or the like that is exposed to contact during intended operation shall not be sufficiently sharp to constitute a risk of injury to persons.

41.2 Impact test

41.2.1 A component, the malfunction of which might result in a risk of injury to persons and that is subject to impact, shall withstand the impact test described in 41.2.2 and 41.2.3.

41.2.2 An appliance is to be subjected to an impact of 1.5 foot-pounds (6.7 N) on any surface that is exposed to a blow during intended use. Only one impact is to be applied at a given point. The impact is to be produced by dropping a steel sphere, 2 inches (50.8 mm) in diameter and weighing approximately 1.18 pounds (0.5 kg), from a height of 15 inches (381 mm). For surfaces other than the top of an enclosure, the steel sphere is to be suspended by a cord and allowed to swing as a pendulum, dropping through a vertical distance of 15 inches. For the test on a freestanding appliance, the appliance is to stand in its intended operating position without restraint.

41.2.3 Following the impact test, the probe illustrated in Figure 41.2 is to be used to determine whether a portion of a blade or blower wheel that can cause risk of injury to persons is exposed.

41.2.4 The unobstructed distance to a moving part that involves a risk of injury to persons shall not be less than 1 inch (25.4 mm) for an opening on the outside of an appliance. If the unobstructed distance to such a part is 1 inch or more, the requirements of Table 41.1 apply.

Exception: A part may be less than 1 inch from the opening if it cannot be contacted by the probe illustrated in Figure 41.1.

Table 41.1
Distance from opening to part capable of causing injury to persons

Maximum diameter of opening, inches (mm)	Minimum acceptable distance to moving part, inches (mm)
Less than 1-1/2 (38.1)	1 (25.4)
1-1/2 to 3 (38.1 to 76.2)	4 (102)
Greater than 3 (76.2) but less than 4 (102)	6 (152)

41.3 Duct-connected appliances

41.3.1 A guard need not be provided on the discharge side of an appliance intended for connection to an outside duct.

42 Temperature

42.1 During the temperature test, the temperature rise on a surface of an appliance that may be contacted by the user with the appliance operating as intended shall not be more than the value specified in Table 42.1.

Table 42.1
Minimum acceptable temperature rise on surfaces subject to contact

Surface area	Degrees C	Degrees F
A. Handles or knobs that are grasped for lifting, carrying, or holding:		
Metallic	25	45
Nonmetallic	35	63
B. Handles or knobs that may be contacted but do not involve lifting, carrying, or holding when heated; and other surfaces that may be contacted during intended operation:		
Metallic	35	63
Nonmetallic	60	108
NOTE – Based on a 25°C (77°F) ambient temperature.		

PERFORMANCE

43 General

43.1 An appliance and any intended accessory shall not cause a risk of fire, electric shock, or injury to persons when installed in accordance with the instructions provided by the manufacturer and tested in accordance with the performance requirements of this standard.

44 Starting Current Test

44.1 When operated as described in 44.3, an appliance shall start and operate normally without:

a) Tripping an overload protector provided as part of the appliance; or

b) Opening the fuse, when connected to a circuit protected by a fuse as described in 44.2.

44.2 The fuse specified in 44.1(b) is to be other than a time-delay type. The current rating of the fuse is to be equal to the current rating of the supply circuit of the lowest rating to which the appliance is intended to be connected.

Exception: A time-delay fuse may be employed, provided that the appliance is marked in accordance with 72.1.7 and:

a) The construction of the appliance or the nature of its usage is such that it is likely to be used continually on the same branch circuit after installation – for example, a window heat recovery ventilator, an attic heat recovery ventilator, or the like; or

b) The appliance is of the household type that would normally be used on a 15- or 20-ampere branch circuit.

44.3 To determine whether an appliance complies with the requirements in 44.1, the appliance is to be connected to a power-supply circuit protected by a fuse as specified in 44.2 or in the exception to 44.2, whichever applies. The appliance is to be at room temperature at the beginning of the test. The appliance is to be started three times without tripping an overload protector provided as part of the unit, or opening the fuse protecting the supply circuit. Each start of the appliance is to be made under conditions representing the beginning of normal operation – the beginning of the normal operating cycle in the case of an automatic appliance. The motor of the appliance is to be allowed to come to full speed after each start, and to come to rest between successive starts.

45 Leakage Current Test

45.1 A cord-connected appliance rated for a nominal 240-volt or less supply shall be tested in accordance with 45.3 – 45.6. The leakage current shall not exceed:

a) 0.5 milliampere for an ungrounded 2-wire product,

b) 0.5 milliampere for a grounded, 3-wire, portable product, and

c) 0.75 milliampere for a grounded, 3-wire, product:

1) Employing a standard attachment plug rated 20 amperes or less and

2) Intended to be fastened in place or located in a dedicated space.

Exception: The leakage current shall be no more than 3.5 mA under the following conditions:

a) The product is rated 20 A or less,

b) The product requires electromagnetic field suppression filtering for compliance with EMI regulations; and

c) The product is equipped with a grounding-type power supply cord and plug.

45.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of an appliance and ground or other exposed conductive surfaces of an appliance.

45.3 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively where simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered acceptable for reducing the risk of electric shock as determined in accordance with 7.3.1 – 7.3.9. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounded conductor of the power-supply cord, the leakage current can be measured between the grounding conductor and the grounded supply conductor.

45.4 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using metal foil having an area of 10 by 20 centimeters in contact with the surface. If the surface has an area of less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the appliance.

45.5 The measurement circuit for leakage current is to be as illustrated in Figure 45.1. The measurement instrument is defined in (a) – (d). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of the voltage across the resistor or current through the resistor.

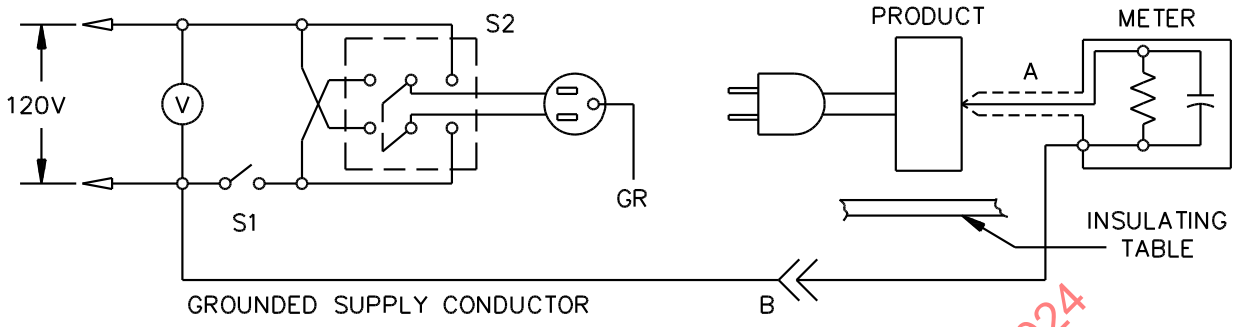
c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – equal to the ratio of the impedance of a

1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 milliampere, the measurement is not to have an error of more than 5 percent at 60 hertz.

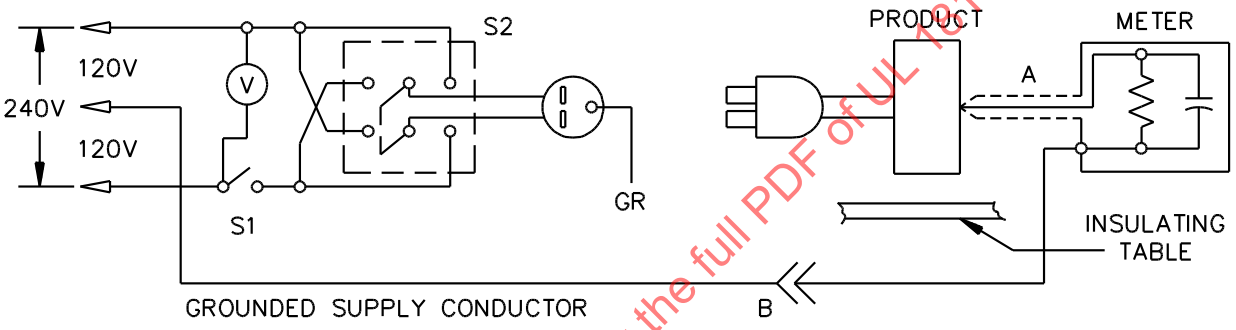
d) Unless the meter is being used to measure leakage from one part of an appliance to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

Figure 45.1

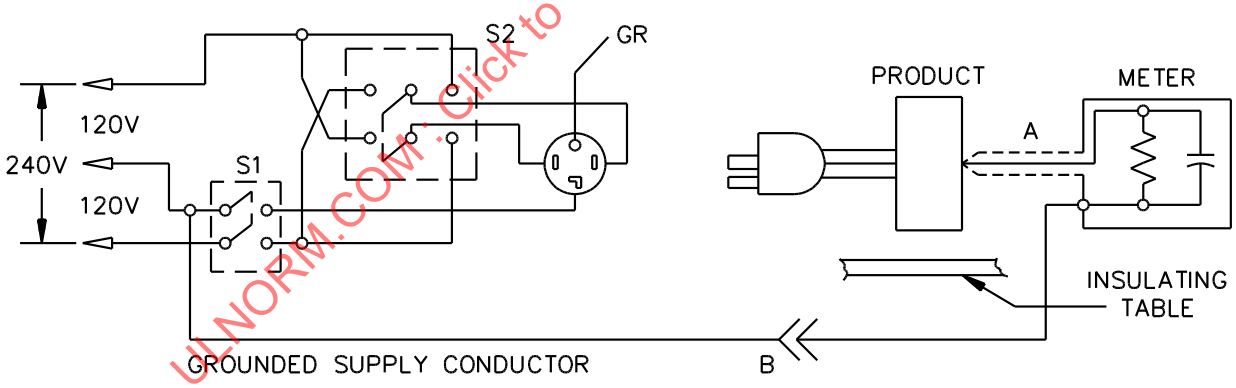
Leakage current measurement circuits



Product intended for connection to a 120–volt power supply, as illustrated above.



Product intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.



Product intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.

LC300J

NOTES:

A – Probe with shielded lead.

B – Separated and used as a clip when measuring current from one part of a product to another.

45.6 A sample of the appliance is to be tested for leakage current in the as-received condition, without prior energization except as may occur as part of the production-line testing, but with the grounding conductor, if any, open at the attachment plug. The supply voltage is to be adjusted to the applicable values specified in 47.1.6. The test sequence, with reference to the measuring circuit, Figure 45.1, is to be as follows:

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

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

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

45.7 Normally the complete leakage current test, as described in 45.6, is to be conducted without interruption for other tests. However, with the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

46 Input Test

46.1 The current input to an appliance shall be not more than 110 percent of the rated value when the appliance is operated under conditions of intended service, and when connected to a power-supply circuit of maximum rated voltage and rated frequency.

46.2 The test voltage for an appliance is to be as specified in Table 46.1.

Table 46.1
Values of test voltages

Rated voltage (volts)	Test voltage (volts)
100 – 120	120
121 – 190	Rated voltage
191 – 208	208
210 – 240	240
241 – 253	Rated voltage
254 – 277	277
278 – 439	Rated voltage
440 – 480	480
481 – 525	Rated voltage
550 – 600	600

46.3 The input is considered to be the maximum input measured while restricting the air-system inlet to not more than one-half the unrestricted cross-sectional area of the ventilator inlet.

47 Temperature Test

47.1 General

47.1.1 When tested as described in 47.1.3 – 47.1.17, an appliance shall not:

a) Attain a temperature at any point sufficiently high to result in a risk of fire,

b) Cause deterioration of any materials employed in the appliance, or

c) Exceed the temperature rises specified in Table 47.1.

Table 47.1
Maximum acceptable temperature rise

Materials and components	Degrees C	Degrees F
A. Motors		
1. Class A insulation systems on coil windings of an ac motor having a diameter of 7 inches (178 mm) or less (not including a universal motor)		
a. In an open motor		
Thermocouple or		
resistance method	75[a]	135[a]
b. In a totally enclosed motor		
Thermocouple or	80	144
resistance method		
2. Class A insulation systems on coil windings of an ac motor having a diameter of more than 7 inches (178 mm), of a dc motor and a universal motor, and on a reactor		
a. In an open motor		
Thermocouple method	65[a]	117[a]
Resistance method	75	135
b. In a totally enclosed motor		
Thermocouple method	70	126
Resistance method	80	144
3. Class B insulation systems on coil windings of an ac motor having a diameter of 7 inches (178 mm) or less (not including a universal motor) and on a vibrator coil		
a. In an open motor and on a vibrator coil		
Thermocouple or	95[a]	171[a]
resistance method		
b. In a totally enclosed motor		
Thermocouple or	100	180
resistance method		
4. Class B insulation systems on coil windings of an ac motor having a diameter of more than 7 inches (178 mm), and of a dc motor or a universal motor		
a. In an open motor		
Thermocouple method	85[a]	153[a]
Resistance method	95	171

Table 47.1 Continued on Next Page

Table 47.1 Continued

Materials and components	Degrees C	Degrees F
b. In a totally enclosed motor		
Thermocouple method	90	162
Resistance method	100	180
B. Other Electrical Components		
1. Relay, solenoid, and other coils with:		
a. Class 105 insulated winding		
Thermocouple method	65[a]	117[a]
Resistance method	85	153
b. Class 130 insulated winding		
Thermocouple method	85[a]	153[a]
Resistance method	105	189
2. Sealing compound	40°C (72°F) less than melting point	
3. Fuses	65	117
4. Capacitors	40[e]	72[e]
Electrolytic	40[e]	72[e]
Other types	65[f]	117[f]
5. Any point on or within a terminal box of a stationary appliance	65	117
C. Electrical Insulation		
1. Fiber employed as electrical insulation	65	117
2. Phenolic composition employed as electrical insulation or as a part of the deterioration of which would result in a risk of fire, electric shock, or injury to persons	125[b]	225[b]
3. Rubber- or thermoplastic-insulated wires and cords	35[b,c,d]	65[b,c,d]
4. Varnished-cloth insulation	60	108
D. General		
1. A surface upon which a stationary appliance may be mounted in service, and surfaces that may be adjacent to the appliance when so mounted	65	117
2. Wood and other combustible material	65	117

[a] On the surface of an insulated coil where the temperature is affected by an external source of heat, the temperature rise measured by a thermocouple may be higher than the specified maximum, if the temperature rise of the coil measured by the resistance method is not more than that specified in the table. The additional acceptable temperature rises above the values specified are:

Item	Temperature	
A.2.a	15°C	(27°F)
A.1.a	5°C	(9°F)
B.1.a	15°C	(27°F)
A.4.a	20°C	(36°F)
A.3.a	10°C	(18°F)
B.1.b	20°C	(36°F)

[b] The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has been investigated and found to have acceptable heat-resistant properties.

Table 47.1 Continued on Next Page

Table 47.1 Continued

Materials and components	Degrees C	Degrees F
[c] Rubber-insulated conductors within a Class A insulated motor and rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor may be subjected to a temperature rise of more than 35°C (63°F), provided that an acceptable braid is employed on the conductors of other than a flexible cord. This does not apply to thermoplastic-insulated wires or cords.		
[d] A short length of rubber- or thermoplastic-insulated flexible cord exposed to a temperature of more than 60°C (140°F), such as at terminals, is acceptable if supplementary heat-resistant insulation of acceptable dielectric strength is employed on the individual conductors of the cord to reduce the risk of deterioration of the conductor insulation, and if the strain-relief means does not depend upon that portion of the insulation subjected to the excessive temperature.		
[e] For an electrolytic capacitor that is integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure shall not be more than 65°C (11°F).		
[f] A capacitor that operates at a temperature rise of more than 65°C (117°F) may be judged on the basis of its marked temperature limit.		

47.1.2 A thermal cutoff shall not operate during the temperature test. See 35.7.

47.1.3 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except the change-in-resistance method may be used for a coil that is inaccessible for mounting of thermocouples, such as a coil:

a) Immersed in sealing compound,

b) Wrapped with thermal insulation, or

c) Wrapped with more than two layers of material such as cotton, paper, or rayon having a total thickness of more than 1/32 inch (0.8 mm).

In an alternating-current motor having a frame diameter of 7 inches (178 mm) or less, the thermocouple is to be mounted on the integrally-applied insulation of the windings.

47.1.4 If the change-in-resistance method is used, determination of the temperature rise of a winding is to be calculated by the following formula:

$$\Delta t = \frac{R_2}{R_1}(K + t_1) - (K + t_2)$$

in which:

Δt is the temperature rise in degrees C,

R_2 is the resistance of the coil in ohms at the end of the test,

R_1 is the resistance of the coil in ohms at the beginning of the test,

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

t_2 is the ambient temperature in degrees C at the end of the test, and

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

47.1.5 If necessary, the value of R at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after shutdown. A curve of the resistance values and the time is to be plotted and extrapolated to give the value of R at shutdown.

47.1.6 For the temperature test, the voltage of a direct-current supply circuit is to be 115 or 230 volts, and that of an alternating-current supply circuit is to be 120 or 240 volts, for an appliance having a nominal voltage rating of 115 or 230 volts. If the unit has a single frequency rating, the test is to be conducted at that frequency. An appliance rated 25 – 50 or 50 – 60 hertz is to be tested using a 60-hertz supply.

47.1.7 The appliance is to be operated under each condition of normal service. For a multispeed appliance, this includes operation at each speed and, for a reversible appliance, it includes operation in each direction of rotation. If a reversible appliance continues to rotate in the same direction, but at a slower speed, when the reversing switch is thrown, the requirement applies at the lower speed as well as at the normal speed. The test is to be continued until temperatures have become constant.

47.1.8 In addition to the conditions described in 47.1.7, an appliance that includes a solid-state speed control is to be operated under each of the following conditions:

a) At the speed and, if applicable, the rotation direction resulting in maximum motor temperatures. During this test the appliance is to be connected to the load side of a triac. The triac is to be provided with associated circuitry allowing it to be triggered during each half-cycle of the ac input to the appliance. Speed control is to be accomplished by varying the trigger points.

b) Connected and tested as described in (a) with a 2 volt dc offset potential applied to the ac input voltage by a suitable method. The 2 volt dc offset potential may be obtained by using a modified speed control having routing diodes and dual triggering circuits to allow independent adjustment of the positive and negative 1/2 cycle triac triggering points. The triggering points are to be adjusted so that a 2 volt dc bias is measured on the switched ac output waveform. The dc bias may be measured by a dc voltmeter having a frequency damped response in the range of 0 – 120 hertz.

c) With the appliance connected to an ac supply modified to produce half-wave output. The supply is to be switched from sinusoidal to half-wave output after the appliance is operating at maximum speed. This test is to be conducted in the rotation direction, if reversible, and speed control setting resulting in maximum motor temperatures. This test may be omitted if the motor shaft will not continue to rotate in a manner considered to be a possible normal condition after the supply is switched from full- to half-wave operation. If the motor shaft does not rotate or rotates in a manner not considered to be a possible normal mode of operation, the test of 47.1.9 shall also be conducted.

47.1.9 With respect to 47.1.8(c), the motor is to be tested with the supply modified to produce a half-wave output if any of the following conditions exist:

a) The fan motor shaft does not rotate,

b) The fan motor rotates in a manner not considered to be a possible normal mode of operation when tested with the half-wave supply as described in 47.1.8(c), or

c) The motor will not restart when operated from a half-wave source after the motor is de-energized.

47.1.10 During the test described in 47.1.9 the motor shall comply with the following:

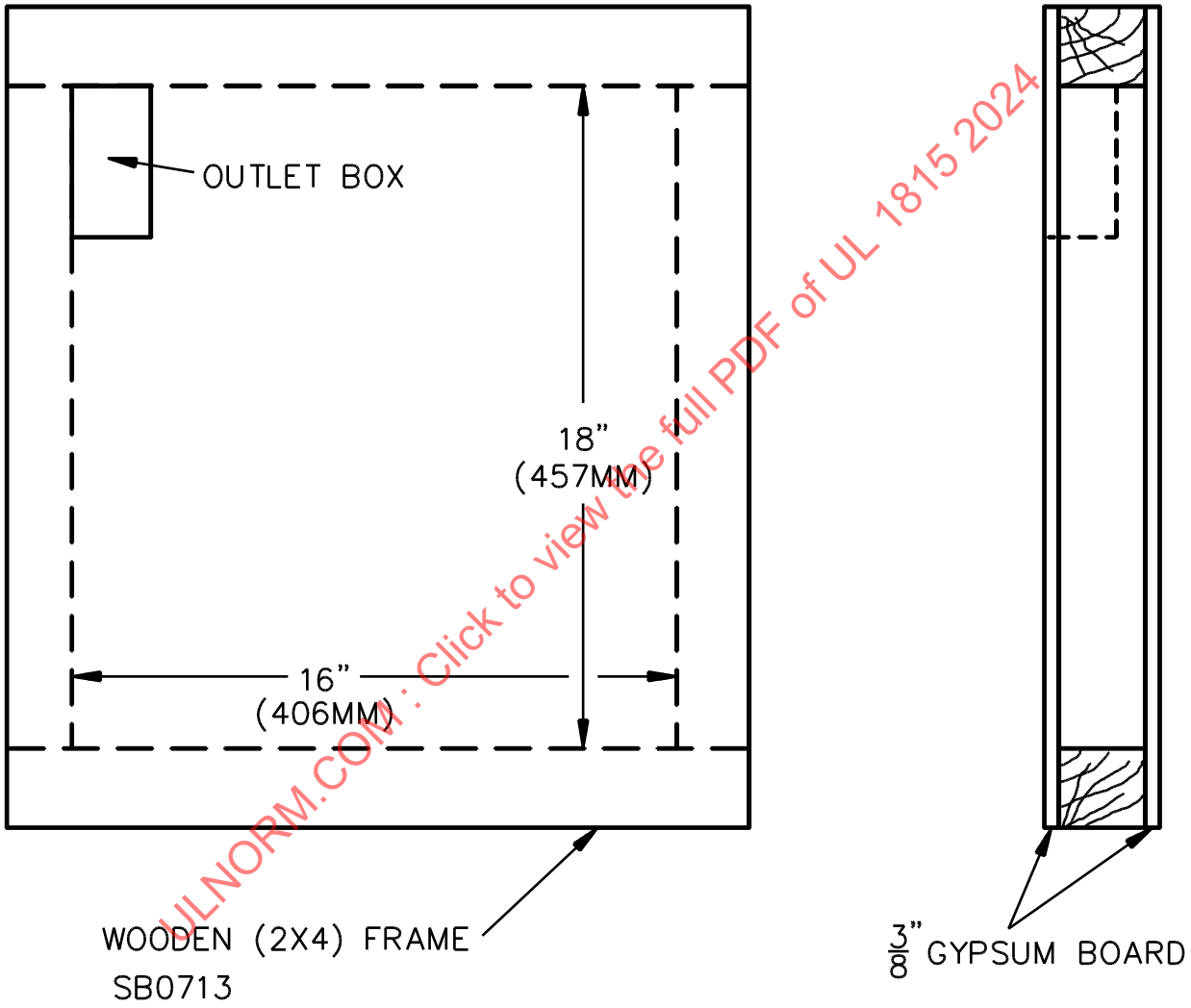
a) An impedance-protected motor shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and the Standard for Impedance Protected Motors, UL 1004-2, and

b) A thermally protected motor shall comply with Section 14, Locked Rotor Temperature Test requirements in the Standard for Overheating Protection for Motors, UL 2111, or the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and the Standard for Thermally Protected Motors, UL 1004-3.

47.1.11 For the temperature test, a separate controller – that is, a controller that is not a physical part of the appliance – that is intended for installation in a wall is to be mounted as follows. The controller is to be secured inside its own enclosure, if provided; otherwise it is to be installed inside the smallest standard flush-type outlet box that will accommodate it, and the box is to be mounted in a simulated wall section as illustrated in Figure 47.1.

Figure 47.1

Method of mounting outlet box



47.1.12 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2), except that a coil temperature may be determined by the change-of-resistance method under the conditions described in 47.1.3. Whenever referee temperature measurements by thermocouples are necessary, thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type instrument are to be used.

47.1.13 A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5-minute intervals, indicate no change.

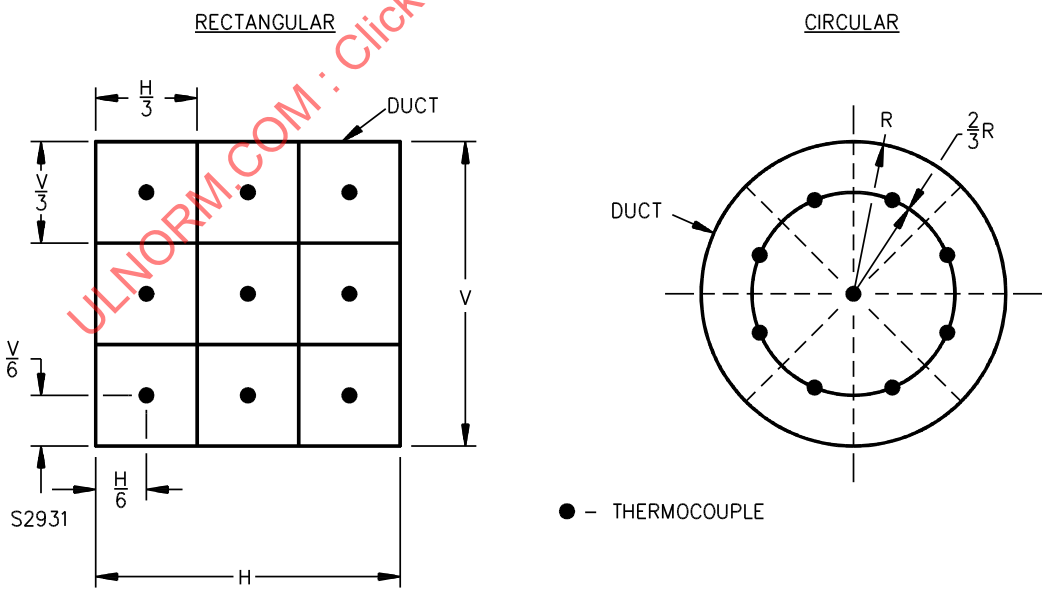
47.1.14 All values for temperature rises in Table 47.1 are based on an assumed ambient temperature of 25°C (77°F). However, tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F).

47.1.15 A duct appliance for moving heated air is to be tested with a heat source capable of supplying air heated to the temperature for which the appliance is intended to be used. The temperature at the duct appliance inlet is not to be less than the temperature for which the appliance is marked in accordance with 72.2.1.

47.1.16 With reference to the requirements in 47.1.15, the temperature at the inlet is to be determined by a thermocouple grid positioned in a plane perpendicular to the air flow and located 6 inches (150 mm) from the collar of the duct heat recovery ventilator. The grid is to be constructed of thermocouples of the same length connected in parallel. The duct is to be divided into equal areas and thermocouples are to be located as illustrated in Figure 47.2. The thermocouples are to be iron-constantan wire not larger than 24 AWG (0.21 mm^2).

Figure 47.2

Thermocouple location in test duct



Duct divided into nine equal areas as illustrated with a thermocouple located in center of each of the resulting nine areas.

Duct divided radially into eight equal areas with thermocouples located as illustrated in each of the eight areas and at the center of the duct.

47.1.17 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material being measured. In most cases, adequate thermal contact will result by securely taping or cementing the thermocouple in place; but if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

48 Undervoltage Test

48.1 Unless a thermally responsive inherent motor protector opens the circuit, the appliance shall start and operate continually under the conditions described in 46.3 that produce maximum motor loading, but with the voltage reduced to 85 percent of the rated voltage of the motor.

49 Dielectric Voltage-Withstand Test

49.1 An appliance shall withstand for 1 minute without breakdown the application of a DC potential or an AC 60-hertz potential between live parts and dead metal parts and between live parts of opposite polarity of a capacitor used for power-factor correction or for radio-interference elimination, with the appliance at the maximum operating temperature reached in intended use. The test potential is to be as shown in Table 49.1:

Table 49.1
Dielectric Voltage Withstand Voltages

Unit under test	Test potential V AC	Test potential V DC
Low-voltage circuit	500	700
Motors rated at not more than 1/2 horsepower (373 W output) and not more than 250 volts.	1000	1400
Secondary circuit of a transformer or autotransformer that operates at 250 volts or less	1000	1400
Secondary circuit of a transformer or autotransformer that operates at 251 – 600 volts	1000 + 2V[a]	1400 + 2.8V[a]
Other than noted in the previous lines	1000 + 2V[a]	1400 + 2.8V[a]
[a] Maximum marked voltage. See 32.1.3.		

49.2 To determine whether an appliance complies with the requirements in 49.1, it is to be tested using a 500-volt-ampere or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero to the required test value, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

50 Water Spray Test

50.1 Permanently connected appliance

50.1.1 When tested as described in 50.3 and 50.4, a permanently connected appliance intended for outdoor exposure shall:

a) Have an insulation resistance of 50,000 ohms or more between live parts and interconnected dead metal parts, and

b) Comply with the requirements for the Dielectric Voltage-Withstand Test, Section 49, both upon cessation of the water spray and 1/2 hour later. After exposure to the water spray and for an additional 1/2 hour there shall be no water:

1) At any point that may be contacted by a splice in field-installed wiring, and

2) On uninsulated live parts or on film-coated wire other than motor windings.

50.1.2 An appliance intended for outside exposure is to be mounted as in actual service, and is to be subjected to a water spray as described in 50.4.1 for 4 hours. The appliance is not to be operating, unless it is intended to draw air in rather than to expel it, or has louvers that open only when the motor is running. The insulation-resistance and dielectric voltage-withstand tests are to be conducted immediately upon conclusion of exposure to the water spray and are to be repeated 1/2 hour later.

50.2 Cord-connected appliances

50.2.1 When tested as described in 50.2.2, the leakage current of a cord-connected appliance shall not exceed:

a) 0.5 milliampere under the condition noted in 50.2.2(g), or

b) 2.5 milliamperes under the conditions noted in 50.2.2 (e) and (f).

Both upon cessation of the water spray and 1/2 hour later, the appliance shall comply with the requirements for the Dielectric voltage-Withstand Test, Section 49.

50.2.2 The test specified in 50.2.1 is to be as follows:

a) The appliance is to be mounted as intended with the switch in the on position. For a multispeed appliance the on position of the switch is to be the low-speed setting.

b) The leakage current is to be measured using the test methods and equipment described in 45.2 – 45.5, except that the circuit shown in Figure 50.1 is to be used. The leakage current is to be measured with switches S1 and S2 in all possible positions.

c) The appliance is to be turned off by opening switch S1 unless the appliance:

1) Is intended to draw air in rather than expel it or

2) Has louvers that open only when the appliance is operating.

d) The appliance is to be subjected to water spray for 4 hours in accordance with 50.3.1 and 50.4.1.

e) During exposure to the water spray, the leakage current is to be measured using both positions of switch S2. The leakage current shall not exceed 2.5 milliamperes.

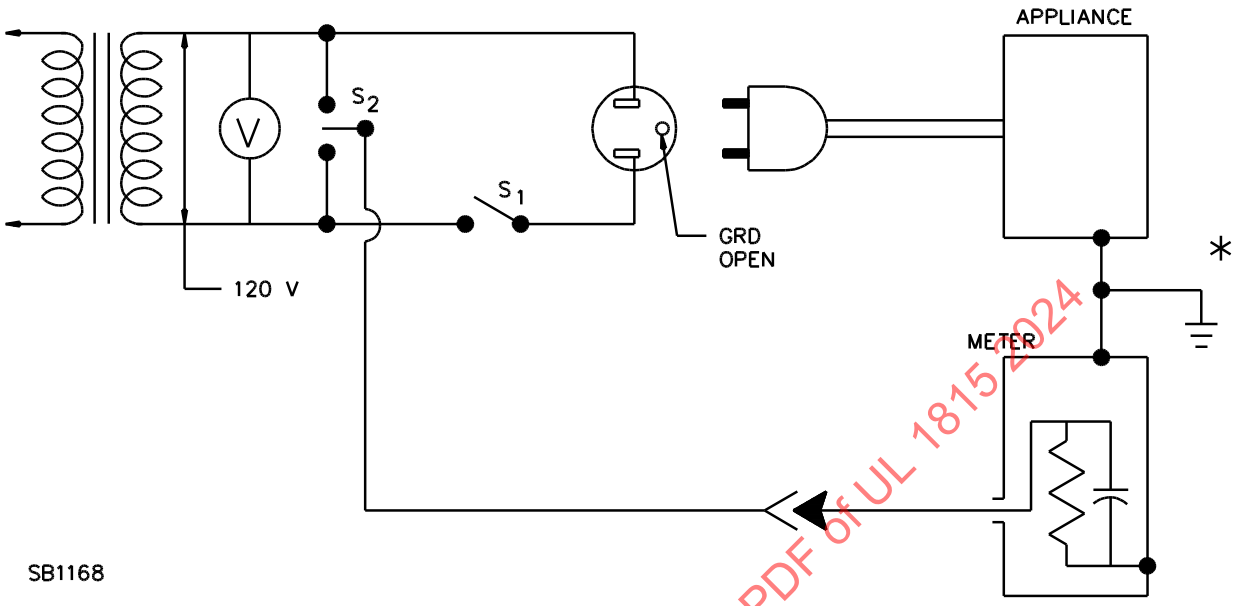
f) Immediately upon cessation of the water spray, the appliance is to be turned off by opening switch S1 unless it was in the open position during exposure to the water, and the leakage current is to be monitored for 30 minutes. The leakage current shall not exceed 2.5 milliamperes.

g) After the 30-minute monitoring period mentioned in (f), the leakage current is to be measured with switch S1 open, and in both positions of switch S2. The leakage current shall not exceed 0.5 milliampere.

h) Within 1 minute following the leakage current measurements, after the cessation of the water spray, and 1/2 hour later, the dielectric voltage-withstand test described in Section 49 is to be conducted except that the duration of the dielectric voltage-withstand test conducted within 1 minute after cessation of the water spray is to be 15 seconds.

Figure 50.1

Leakage current measurement circuit for water spray test



Before conducting leakage current measurement with this circuit, the appliance is to be disconnected from the receptacle, and it should be determined by closing S1, utilizing both positions of S2, and observing the leakage currents at the meter, that the stray leakage currents are negligible.

50.3 Water resistivity

50.3.1 The water to be used for the test is to have its resistivity adjusted, before the test is started, to 3500 ohm-centimeters ±5 percent when measured at 25°C (77°F). At the conclusion of the test, the resistivity of the water is to be not less than 3200 ohm-centimeters or more than 3800 ohm-centimeters at 25°C.

50.4 Test apparatus

50.4.1 The test apparatus is to consist of three water spray heads mounted in the piping shown in Figure 50.2. The spray heads are to be constructed in accordance with the details shown in Figure 50.3. The water pressure during the test is to be maintained at gauge pressure 5 psi (34.5 kPa) at each spray head. The distance between the center nozzle and the appliance is to be approximately 5 feet (1.5 m). The enclosure is to be brought into the focal area of the three spray heads in such a position and under such conditions as are most likely to result in entrance of water into the enclosure. The spray is to be directed at a 45-degree angle to the vertical toward the enclosure.