UL 867

STANDARD FOR SAFETY

Electrostatic Air Cleaners

UL Standard for Safety for Electrostatic Air Cleaners, UL 867

Fifth Edition, Dated August 4, 2011

Summary of Topics

This revision to ANSI/UL 867 August 16, 2021 is being issued to incorporate the following requirements:

> ***– Requirements for Battery Operated Air Cleaners; 1.1.1, 1.1.2, 4A.9.1, 6A.1, 6A.1.1, Section 33A and Section 51D***
>
> ***– UL 508C Withdrawal and Replacement with UL 61800-5-1; 13A.3***

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 19, 2021.

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UL 867

Standard for Electrostatic Air Cleaners

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Fifth Edition

August 4, 2011

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The most recent designation of ANSI/UL 867 as an American National Standard (ANSI) occurred on August 16, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 867 on June 11, 1992. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover electrostatic air cleaners rated at 600 volts or less, intended to remove dust and other particles from the air and intended for use in accordance with the National Electrical Code, ANSI/NFPA 70.

1.1.1 In reference to 1.1, these requirements may be used to evaluate products that are:

a) Powered entirely by a low-voltage supply source, such as those intended for connection to a Universal Serial Bus (USB) supply source; or

b) Provided with or intended for use with one or more rechargeable battery system(s) for portable appliances intended for household use only.

1.1.2 These requirements do not cover battery operated products other than portable appliances intended for household use only.

1.2 These requirements do not cover electrostatic air cleaners for use in hazardous locations or to clean atmospheres defined as hazardous by the National Electrical Code, ANSI/NFPA 70.

1.3 These requirements do not cover air cleaners intended to remove particles other than dust and other particles normally found in heating and ventilating systems.

1.4 Requirements for the installation of duct-type electrostatic air cleaners are included in the Standard for the Installation of Air Conditioning and Ventilating Systems, NFPA 90A; and the Standard for the Installation of Warm Air Heating and Air Conditioning Systems, NFPA 90B.

2 General

2.1 Components

2.1.1 *Deleted*

2.1.2 *Deleted*

2.1.3 *Deleted*

2.1.4 *Deleted*

2.1.5 No component shall contain liquid mercury.

2.2 Units of measurement

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

2.3 Undated references

2.3.1 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 Glossary

3.1 For the purposes of this standard the following definitions apply.

3.2 ACCESSIBLE PART – A part located so that it can be contacted by a person either directly or by means of a probe as specified in Accessibility of Uninsulated Live Parts and Moving Parts, Section 7.

3.3 AIR CLEANERS – An air cleaner is defined as one of the following:

a) Duct type – An air cleaner intended for installation in and at adjoining ducts, including the plenum, of heating, air conditioning, and ventilating systems. The air cleaner may not be provided with a fan, and the duct may provide part or all of the cabinet. This type of air cleaner may be either cord-and-plug connected or permanently connected to the electrical supply source.

b) Fixed type – An air cleaner intended to be:

1) Permanently connected to the electrical supply source;

2) Permanently mounted, such that tools are required for the product installation or removal; or,

3) Sized so that it is not easily moved from one place to another.

c) Portable type – A cord-and-plug-connected air cleaner that:

1) Can be easily moved from one place to another for use; and

2) Has no provision for permanent mounting. Tools are not required for the product installation or removal.

d) *Deleted*

e) *Deleted*

3.3.1 BARRIER, INSULATING – A partition for isolating parts of electrical circuits.

3.3.2 BARRIER, MECHANICAL – A partition for isolating ignition sources, moving parts or protection of wiring.

3.4 *Deleted*

3.4.0 CABINET – The part of the equipment that:

a) Provides physical protection to insulated wiring, enclosures, moving parts, motors, enclosed electrical parts, tubing or any other parts that may cause injury to persons; and,

b) Does not, by itself, enclose any high-voltage or line-voltage uninsulated live parts.

3.4.0.1 CAPACITOR, CLASS Y – Capacitor or resistor-capacitor unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock. (Examples would include 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.)

3.4.1 COMPONENT – A device or fabricated part of a product covered by the scope of a safety standard dedicated to that purpose. If incorporated in a product, a part that is otherwise typically field installed (e.g. luminaire) is considered to be a component. Unless otherwise specified, materials that compose a device

or fabricated part, such as aluminum or copper, are not considered components. Generally, components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under specific, limited conditions, such as certain temperatures not exceeding specified limits.

3.4.2 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 risk of electric shock, is considered an operating control and in this example could also be called a “regulating control”. Operating controls can also include other controlling devices such as switches, contactors, relays and similar devices. Appendix B specifies control functions that are not considered to result in a risk of fire, electric shock or injury to persons.

3.4.3 CONTROL, PROTECTIVE – A device or assembly of devices, the operation of which is intended to reduce the risk of fire, electric shock or injury to persons during normal and reasonably anticipated abnormal operation of the product. 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” or “safety controls” and are investigated under normal and single-fault conditions. Appendix B specifies control functions that are considered to result in a risk of fire, electric shock or injury to persons.

3.4.4 ELECTRONIC COMPONENT – A part in which electrical conduction is achieved principally by electrons moving through a vacuum, gas or semiconductor. A Metal Oxide Varistor (MOV) is considered to be an electronic component, but neon indicators are not.

3.4.5 ELECTRONIC DISCONNECTION – The de-energizing of a load within a product by an electronic device of a circuit. No electro-mechanical component having an air gap, such as a switch, contactor or relay is used to de-energize the load.

3.5 ELECTROSTATIC AIR CLEANER (AIR CLEANER) – A product intended to remove dust and other particles from the air. The complete product consists of an assembly of a power pack, controls, ionizer-collector cell, and other components.

3.5.1 ENCLOSURE – The part of the equipment that does one or more of the following:

a) Isolates ignition sources,

b) Renders inaccessible all or any part(s) of the equipment that may otherwise present a risk of electric shock, including uninsulated high- or line-voltage parts.

c) Retards propagation of flame initiated by electrical disturbances occurring within.

3.6 EXPOSED PART – A part that is subjected to handling in normal use without removing parts such as doors, covers, or other parts if removal requires the use of a tool.

3.6.1 FUNCTIONAL PART – A part other than an enclosure or cabinet used to maintain the intended relative physical position of fixed or moving parts, maintain the integrity of the structure or required for the intended operation of the product. A fan blade is an example of this type of part.

3.6.2 GROUNDING, FUNCTIONAL – Grounding of a point in a product which is necessary for a purpose other than safety.

3.7 HIGH-VOLTAGE CIRCUIT – A circuit involving a potential of more than 600 volts.

3.7.1 IGNITION SOURCE – Any high- or line-voltage electrical component not located within an enclosure. Wiring with VW-1 insulation is not considered an ignition source.

3.8 ISOLATED-LIMITED-ENERGY CIRCUIT – A circuit derived from an isolated-secondary winding of a transformer having a maximum capacity of 100 volt-amperes and an open-circuit-secondary voltage rating not exceeding 600 volts.

3.9 LINE-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 600 volts, and having characteristics in excess of those of a low-voltage or an isolated-limited-energy circuit.

3.10 LOW-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 30 volts rms and supplied by a primary battery, a Class 2 transformer, or by a combination of a transformer and fixed impedance that, as a unit, complies with all the performance requirements for a Class 2 transformer. A circuit derived from a line-voltage circuit by the connection of resistance in series with the supply circuit to limit the voltage and current is not considered to be a low-voltage or an isolated-secondary circuit.

3.11 *Deleted*

3.11.1 MOTOR CONTROLLER – Any device normally used to start and stop a motor, such as a switch, thermostat, pressure limiting control, or the like.

3.11.2 NONFUNCTIONAL PART – A part of the equipment that does not perform a specific function. Decorative trim is an example of this type of part.

3.12 PARTIALLY PROTECTED PART – A part that is exposed only during user servicing, with voltage and current limitations as specified in Partially Protected Parts, Section 37.

3.13 POWER SUPPLY – A unit consisting of a high-voltage transformer and other electrical component. The unit may also contain controls for the air cleaner.

3.13.1 PROTECTIVE ELECTRONIC CIRCUIT (PEC) – An electronic circuit that prevents a risk of fire, electric shock or injury to persons under abnormal operating conditions.

3.14 *Deleted*

3.14.1 SWITCH MODE POWER SUPPLY UNIT – Electronic device incorporating transformer(s) and electronic circuitry(ies), that converts electrical power into single or multiple power outputs by rapidly switching a solid-state device on and off. It may also isolate the input circuit from the output circuit and regulate and/or convert the output voltage and current. The device may consist of one or more individual units with identical or different waveforms and frequencies including dc output.

3.14.2 THERMISTOR – A thermally sensitive semiconductor resistor, which shows over at least part of its resistance/temperature characteristic a significant non-linear change in its electrical resistance with a change in temperature. A thermistor may be either of the positive temperature coefficient (PTC) type or of the negative temperature coefficient (NTC) type.

3.15 USER SERVICING – The replacing, cleaning, or adjusting of filters or adjustment of controls and the like intended to be done by the user.

3.16 VOLTAGE FOLDBACK – A circuit design feature intended to protect the power supply output transistors. When overcurrent is drawn by the load, the supply reduces the output voltage and current to within the safe power dissipation limit of the output transistors.

CONSTRUCTION

4 General

4.1 The construction of a product shall be such that all of the following conditions are met:

a) Normal use and user servicing do not result in a risk of electric shock, fire, or injury to persons.

b) The materials and component are used within their electrical, mechanical, and temperature limits.

c) The assembly protects the components and wiring from being displaced or damaged.

4A Components

4A.1 General

4A.1.1 A component of a product covered by this standard shall:

a) Comply with the requirements for that component as indicated in 4A.2 – 4A.10 or the individual component section;

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; and

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

Note – 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.

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; or

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 component standard other than those cited in 4A.2 – 4A.10 or the individual component section is acceptable if:

a) The component also complies with the applicable component standard of 4A.2 – 4A.10 or the individual component section; or

b) The component standard:

1) Is compatible with the ampacity and overcurrent protection requirements of the National Electrical Code, ANSI/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.

4A.1.2 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.

4A.1.3 A component not anticipated by the requirements of this standard, not specifically covered by the component standards of 4A.2 – 4A.10 or individual component sections 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 4A.1.1(b) – (d).

4A.1.4 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.

4A.2 Attachment plugs, receptacles, connectors and terminals

4A.2.1 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. See 4A.2.9.

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

4A.2.2 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 3.5, 3.2, 4.8, 5.2, and 6.3 mm (0.110, 0.125, 0.187, 0.205, and 0.250 in), 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 UL 310.

4A.2.3 Single and multipole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory connection and 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. See 4A.2.9.

4A.2.4 Wire connectors shall comply with the Standard for Wiring Connectors, UL 486A-486B.

4A.2.5 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

4A.2.6 Multi-pole splicing wire connectors that are intended to facilitate the connection of hard-wired utilization equipment to the branch-circuit conductors of buildings or that are intended for consumer connection within and between parts of electrical equipment, shall comply with the Standard for Multi-Pole Splicing Wire Connectors, UL 2459. See 4A.2.9.

4A.2.7 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.

4A.2.8 Terminal blocks shall comply with the Standard for Terminal Blocks, UL 1059, and, if applicable, be suitably rated for field wiring.

4A.2.9 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 suitably rated for current interruption of the specific type of load, when evaluated with its mating plug or connector. For example, an appliance coupler that can be used to interrupt the current of a motor load shall have a suitable horsepower rating when tested with its mating plug.

4A.3 Boxes and raceways

4A.3.1 Electrical boxes and the associated bushings and fittings, and raceways, of the types specified in Chapter 3 of the National Electrical Code, ANSI/NFPA 70 and that comply with the relevant UL standard (such as the Standard for Metallic Outlet Boxes, UL 514A, Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C, Standard for Cover Plates for Flush-Mounted Wiring Devices, UL 514D) and 4A.1 are considered to fulfill the requirements of this Standard.

4A.4 Cords, cables and internal wiring

4A.4.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817.

4A.4.2 Flexible cords and cables shall comply with the Standard for Flexible Cords and Cables, UL 62. Flexible cord and cables are considered to fulfill this requirement when preassembled in a cord set or power supply cord complying with the Standard for Cord Sets and Power Supply Cords, UL 817.

4A.4.3 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 UL 758 if they comply with one of the following:

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

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

c) Standard for Fixture Wire, UL 66; or

d) The appropriate UL standard(s) for other insulated conductor types specified in Chapter 3 (Wiring Methods and Materials) of the National Electrical Code, ANSI/NFPA 70.

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 UL 758.

4A.5 Cord reels

4A.5.1 A cord reel shall comply with the special-use cord reel requirements of the Standard for Cord Reels, UL 355.

4A.6 Ground-fault, arc-fault and leakage current detectors/interrupters

4A.6.1 Ground-fault circuit-interrupters (GFCI) for protection against electrical shock shall comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943. The following statement, or equivalent, shall be included as a marking near the GFCI, or as an instruction in the manual: " Press the TEST button (then RESET button) every month to assure proper operation."

4A.6.2 Appliance-leakage-current interrupters (ALCI) for protection against electrical shock shall comply with the Standard for Appliance-Leakage-Current Interrupters, UL 943B.

Note – An ALCI is not considered an acceptable substitute for a GFCI.

4A.6.3 Equipment ground-fault protective devices shall comply with the Standard for Ground-Fault Sensing and Relaying Equipment, UL 1053, and the applicable requirements of the Standard for Ground-Fault Circuit-Interrupters, UL 943.

4A.6.4 Arc-fault circuit-interrupters (AFCI) shall comply with the Standard for Arc-Fault Circuit-Interrupters, UL 1699.

4A.6.5 Leakage-current detector-interrupters (LCDI) and any shielded cord between the LCDI and appliance shall comply with the Standard for Arc-Fault Circuit-Interrupters, UL 1699.

4A.7 Light sources and associated components

4A.7.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

Exception: Lampholders forming part of a luminaire that complies with an appropriate UL luminaire standard are considered to fulfill this requirement.

4A.7.2 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 an appropriate UL luminaire standard are considered to fulfill this requirement.

Exception No. 2: Ballasts for other light sources shall comply with the appropriate UL standard(s).

4A.7.3 Light emitting diode (LED) light sources shall comply with the Standard for Light Emitting Diode (LED) Light Sources For Use In Lighting Products, UL 8750.

Exception No. 1: LED light sources forming part of a luminaire that complies with an appropriate UL luminaire standard are considered to fulfill this requirement.

Exception No. 2: Individual LED light sources mounted on printed wiring boards and intended for indicating purposes need not comply with UL 8750, but shall comply with the applicable requirements of this end product standard.

4A.8 Overcurrent protection

4A.8.1 *Deleted*

4A.8.2 *Deleted*

4A.8.3 *Deleted*

4A.8.4 *Deleted*

4A.8.5 *Deleted*

4A.9 Power supplies

4A.9.1 A power supply other than a high-voltage power supply shall comply with one of the following:

a) For a power supply providing a low-voltage circuit output:

1) Standard for Class 2 Power Units, UL 1310; or

2) Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, or Standard for Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements For Battery Chargers, UL 60335-2-29; with an output marked "Class 2", or that complies with the limited power source (LPS) requirements and is marked "LPS".

b) For a power supply providing a line-voltage circuit output:

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

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

c) For a switch mode power supply unit not complying with (a) or (b), the relevant requirements in this Standard, including the Switch Mode Power Supply Units – Overload Test, Section 49D, shall be applied.

4A.10 Supplemental insulation, insulating bushings and assembly aids

4A.10.1 The requirements for supplemental insulation (e.g. tape, sleeving or tubing) are not specified unless the insulation or device is required to fulfill a requirement of this standard. In such cases:

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.

4A.10.2 Insulating bushings that comply with Section 4A.1 of this end-product standard, and the Standard for Insulating Bushings, UL 635, are considered to fulfill the 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 part are suitable.

4A.11 Transformers

4A.11.1 General-purpose transformers shall:

a) 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; or

b) Be completely enclosed within the cabinet and comply with the insulation requirements in 4A.11.3 – 4A.11.7 as well as the construction and performance requirements of this standard as far as they reasonably apply; or,

c) Comply with the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411, if used in a circuit involving an audio or video component.

4A.11.2 Class 2 and Class 3 transformers shall:

a) 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; or,

b) Be entirely located within a low-voltage circuit that is not provided with a protective control.

4A.11.3 If a general purpose transformer has a Class 105 (A) insulation system, the transformer shall comply with:

a) The spacings requirements in Table 23.1; or

b) Except as specified in 4A.11.4, be provided with an insulation system consisting of a combination of magnet wire and be one or more of the following major component insulation materials:

1) Thermoset materials;

2) Those specified in Table 4A.1 at the specified minimum thickness;

3) Materials or a combination of materials, whether polymeric or not polymeric (treated cloth, for example), that are thinner or other than those specified in Table 4A.1, and used to isolate the windings from dead metal parts and:

i) Have a relative or generic thermal index for electrical properties of at least 221°F (105°C); and

ii) Be unfilled glass-reinforced nylon, polycarbonate, polybutylene terephthalate, polyethylene terephthalate, phenolic or acetal.

4) Other polymeric materials complying with the Thermal Aging Test, Section 46B.

Table 4A.1
Primary class A insulating materials and minimum thicknesses

Material	Minimum thickness	
	mm	(inches)
Vulcanized fiber	0.71	(0.028)
Polyethylene terephthalate film	0.18	(0.007)
Cambric	0.71	(0.028)
Treated cloth	0.71	(0.028)
Electrical grade paper	0.71	(0.028)
Mica	0.15	(0.006)
Aramid paper	0.25	(0.010)

4A.11.4 Insulating materials not complying with 4A.11.3(b) shall comply with 4A.11.5 and be used between a crossover lead and the:

a) Turns of the transformer winding to which the lead is connected;

b) Adjacent winding;

c) Metallic enclosure; or

d) Transformer core.

4A.11.5 The insulating materials referenced in 4A.11.4 shall:

a) Be electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness not less than 0.013 inch (0.33 mm); or

b) Be mechanically and thermally equivalent insulating material(s) to (a) and:

1) Have a dielectric breakdown strength of 2500 volts or more in the thickness used; or

2) Withstand the dielectric voltage-withstand test potential in 46.1.1(a) with the potential applied between the coil leads and with the coil lead cut at the point where it enters the inner layer; or

3) Withstand the induced-potential test in 46.3.

4A.11.6 Leads provided as part of a Class 105 (A) insulation system on a general purpose transformer shall be rated 194°F (90°C) minimum.

4A.11.7 The following shall comply with the Standard for Systems of Insulating Materials – General, UL 1446:

a) Materials used in an insulation system operating above Class 105 (A) temperatures; or

b) Insulation systems employing integral ground insulation.

4A.12 Button or coin cell batteries

4A.12.1 An appliance, or any accessory of the appliance such as a wireless control, intended for use with one or more single cell batteries, shall comply with 4A.12.2 if the batteries are sized with a maximum:

a) Diameter of 1.25 inch (32 mm); and

b) Height that is less than its diameter.

4A.12.2 An appliance for household use and provided with one or more batteries as specified in 4A.12.1 shall comply with the Standard for Products Incorporating Button or Coin Cell Batteries of Lithium Technologies, UL 4200A or be intended for one of the following:

a) Countertop use only;

b) Fixed installation and with the batteries located at a height not less than 4 feet (1.2 m) above the floor; or

c) Use where the batteries are not intended to be replaced and are not referenced in the appliance markings or in any instructions provided with the appliance.

4A.13 Information technology equipment

4A.13.1 Information technology equipment such as a printer, visual display unit, router, communication connectors/data ports or computer shall comply with the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1.

4A.14 Optical isolators and semiconductor devices

4A.14.1 An optical isolator shall comply with the Standard for Optical Isolators, UL 1577 if it is relied upon to provide isolation between:

a) Primary and secondary circuits;

b) Low-voltage safety circuits; or

c) Other high-voltage circuits.

4A.14.2 In addition to complying with 4A.14.1, an optical isolator relied upon to provide feedback between primary and secondary circuits of a switch mode power supply unit shall have a minimum isolation voltage of 1500V.

4A.14.3 A power switching semiconductor device that is relied upon to provide isolation to ground shall comply with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. If the switching semiconductor is used as part of a switch mode power supply unit, it shall have a minimum isolation voltage of 1500 V.

5 Accessories

5.1 An appliance having provision for the use of an electrical accessory intended to be attached in the field shall comply with the requirements in this standard, with or without the accessory installed.

5.2 Installation of an accessory by the user shall be by means of a locking type receptacle and plug-in connector.

5.3 When an accessory is to be installed by the user, the appliance shall comply with the requirements in Section 7, Accessibility of Uninsulated Live Parts and Moving Parts, during and after the installation of the accessory.

5.4 The installation of an accessory by service personnel shall be by means of receptacles, plug-in connectors, insulated wire connectors, or by connection to existing wiring terminals.

5.5 With reference to 5.4, an installation shall not require the cutting of wiring or the soldering of connections by the installer. Installations shall not require cutting, drilling, or welding in electrical enclosures and in other areas where such operations may damage electrical components and wiring within the cabinet or enclosure.

5.6 A means for strain relief shall be provided and comply with the strain relief test in Section 42, Strain Relief Test, at a force of 20 pounds (89 N), for the wiring in the accessory if there is a possibility of transmitting stress to the terminal connections during installation.

5.7 All terminals and wiring intended to be field connected shall be identified on the accessory, on the appliance if connections are made between the accessory and the appliance, and on the wiring diagram.

5.8 The intended installation of the accessory shall be indicated in the installation instructions included on or with the accessory. See 59.8.

5.9 As part of the investigation, an accessory is to be trial installed to determine that the installation is feasible, the instructions are detailed and correct, and the use of the accessory does not introduce a risk of electric shock, fire, or injury to persons.

5.10 An electrical accessory intended for field installation shall be marked in accordance with 57.9.

6 Frame, Cabinet and Enclosure

6.1 General

6.1.1 Electrical parts shall be provided within a cabinet or enclosure.

6.1.2 Other than as noted in 6.1.3, an air-inlet or an air-outlet opening of a duct-type product may be considered enclosed by the adjacent duct work if an insulated or an uninsulated live part accessible without the duct work installed is at an energy level equal to or below that of a partially-protected part as specified in Partially Protected Parts, Section 37.

6.1.3 An air-inlet or an air-outlet opening not always intended to be attached to duct work is not considered to be enclosed.

6.1.4 The cabinet, enclosure and parts of the cabinet or enclosure such as doors, covers, and the like, shall be provided with means for securing them in place.

6.1.5 An enclosure or cabinet shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it is likely to be subjected, without increasing its risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

6.1.6 A cast-metal or die-cast metal cabinet or enclosure shall be investigated to determine that it is equivalent to sheet metal.

6.1.7 *Deleted*

6.1.8 *Deleted*

6.1.9 Glass covering an observation opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts.

6.1.10 Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 0.055 inch (1.40 mm) thick. Glass for a larger opening, but not more than 144 square inches (929 cm^2) in area and having no dimensions greater than 12 inches (305 mm), shall not be less than 0.115 inch (2.92 mm) thick.

6.1.11 Glass used to cover an opening larger than 144 square inches (929 cm^2) shall be investigated to determine that it has the necessary mechanical strength and is otherwise suitable for the purpose.

6.1.12 Each gasket required to seal an enclosure against the entrance of rain and condensate shall be held in place by mechanical fasteners or adhesives except as indicated in 6.1.13, and shall:

a) Be neoprene, rubber, thermoplastic, polyvinyl chloride or other materials with equivalent properties that comply with Section 49C; or

b) Comply with the Standard for Gaskets and Seals, UL 157 if the gasket physical properties are equivalent to those specified in 49C.2 – 49C.10.

6.1.13 In reference to 6.1.12, gaskets which are not held in place by mechanical fasteners or adhesives but are intended to be retained in the correct position by some other means shall be prevented from displacement either:

a) Due to their location within the equipment, or

b) By the placement of other components in the enclosure so that if the equipment cover is removed, the gasket will be reengaged in the intended manner when the cover is replaced.

6.1.14 Adhesives required to secure gaskets shall comply with 49C.11.

6.1.15 Products intended for outdoor use shall comply with the Rain Test, Section 49B.

6.1.16 For products intended for installation within a concealed space of a building structure, an opening complying with Section 7, Accessibility of Uninsulated Live Parts and Moving Parts, but located on a part of the product concealed by the building structure shall not have any dimension exceeding 17/64 in. (6.75 mm) or a cross-sectional area exceeding 0.055 in^2 (35.5 mm^2) and there shall be no more than:

a) Four openings in the rear of the enclosure; and

b) Two openings in each of the other four sides of the enclosure.

6.2 High-voltage power supply

6.2.1 A high-voltage power supply shall:

a) Be housed within its own enclosure or comply with 49.4.1 – 49.4.3 if the power supply has uninsulated live parts; or

b) Be housed within the cabinet if the live parts of the power supply are insulated.

6.2.2 A power-supply enclosure shall be:

a) Uncoated sheet steel not less than 0.026 inch (0.66 mm) thick;

b) Zinc-coated sheet steel not less than 0.029 inch (0.74 mm) thick;

c) Copper, brass, or aluminum not less than 0.036 inch (0.91 mm) thick; or

d) A polymeric material complying with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

6.3 Fixed products

6.3.1 Other than as noted in 6.3.2, the thickness of a sheet-metal enclosure of a control panel, a duct door, or a similar component shall be as specified in Table 6.1 and Table 6.2.

Exception: Table 6.3 may be used for products that are only intended for ceiling mounting.

Table 6.1
Minimum thickness of carbon steel or stainless steel enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness for uncoated,		Minimum thickness for coated,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)	inch	(mm)
4.0	10.2	Not limited		6.25	15.9	Not limited		0.020[d]	0.51	0.023[d]	0.58
4.75	12.1	5.75	14.6	6.75	17.1	8.25	21.0				
6.0	15.2	Not limited		9.5	24.1	Not limited		0.026[d]	0.66	0.029[d]	0.74
7.0	17.8	8.75	22.2	10.0	25.4	12.5	31.8				
8.0	20.3	Not limited		12.0	30.5	Not limited		0.032	0.81	0.034	0.86
9.0	22.9	11.5	29.2	13.0	33.0	16.0	40.6				
12.5	31.8	Not limited		19.5	49.5	Not limited		0.042	1.07	0.045	1.14
14.0	35.6	18.0	45.7	21.0	53.3	25.0	63.5				
18.0	45.7	Not limited		27.0	68.6	Not limited		0.053	1.35	0.056	1.42
20.0	50.8	25.0	63.5	29.0	73.7	36.0	91.4				
22.0	55.9	Not limited		33.0	83.8	Not limited		0.060	1.52	0.063	1.60
25.0	63.5	31.0	78.7	35.0	88.9	43.0	109.2				
25.0	63.5	Not limited		39.0	99.1	Not limited		0.067	1.70	0.070	1.78
29.0	73.7	36.0	91.4	41.0	104.1	51.0	129.5				
33.0	83.8	Not limited		51.0	129.5	Not limited		0.080	2.03	0.084	2.13
38.0	96.5	47.0	119.4	54.0	137.2	66.0	167.6				
42.0	106.7	Not limited		64.0	162.6	Not limited		0.093	2.36	0.097	2.46
47.0	119.4	59.0	149.9	68.0	172.7	84.0	213.4				
52.0	132.1	Not limited		80.0	203.2	Not limited		0.108	2.74	0.111	2.82
60.0	152.4	74.0	188.0	84.0	213.4	103.0	261.6				
63.0	160.0	Not limited		97.0	246.4	Not limited		0.123	3.12	0.126	3.20
73.0	185.4	90.0	228.6	103.0	261.6	127.0	322.6				

[a] See 6.3.4 and 6.3.5.

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

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet metal for an enclosure intended for outdoor use – rainproof – shall not be less than 0.034 inch (0.86 mm) thick if zinc-coated and not less than 0.032 inch (0.81 mm) thick if uncoated.

Table 6.2
Thickness of sheet metal for enclosures of aluminum, copper, or brass

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

[a] See 6.3.4 and 6.3.5.

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

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use – rainproof – shall not be less than 0.029 inch (0.74 mm) thick.

Table 6.3
Thickness of sheet metal for an enclosure of a ceiling-mounted product or an ionizer-collector frame assembly

Maximum dimension,		Maximum area of any surface,		Minimum thickness,									
				Steel						Copper, brass, or aluminum			
				Without supporting frame				With supporting frame or equivalent reinforcing				With supporting frame or equivalent reinforcing,	
				Zinc coated,		Uncoated,		Zinc coated,		Uncoated,		Without supporting frame,	
inches	(mm)	feet^2	(m^2)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
60	1.5	10.42	0.97	0.034	0.86	0.032	0.81	0.029	0.74	0.026	0.66	0.045	0.66	0.036	0.91
90	2.3	Over 10.42	0.97	0.045	1.14	0.034	1.14	0.034	0.86	0.032	0.81	0.058	0.81	0.045	1.14
Greater than 90	2.3	Over 10.42	0.97	0.056	1.42	0.053	1.35	0.045	1.14	0.042	1.07	0.075	1.07	0.058	1.47

6.3.2 A sheet-metal wall to which a wiring system is to be connected in the field shall have a thickness of not less than:

a) 0.032 inch (0.81 mm) if uncoated steel,

b) 0.034 inch (0.86 mm) if galvanized steel, or

c) 0.045 inch (1.14 mm) if nonferrous.

6.3.2.1 Metallized or painted polymeric parts shall comply with Section 6A, Nonmetallic Parts.

6.3.3 Table 6.1 and Table 6.2 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

6.3.4 With reference to Table 6.1 – Table 6.3, a supporting frame is an angled structure, or channel, or a folded rigid section of sheet metal that is:

a) Rigidly attached to the enclosure surface,

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

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

6.3.5 Equivalent reinforcing may be accomplished by constructions that will produce a structure as rigid as one that is built with a frame of angles or channels. Construction types without a supporting frame include:

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

b) A single sheet that is corrugated or ribbed; or

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

6.3.6 The thickness of a sheet-steel enclosure of an ionizer-collector frame assembly shall be as specified in 6.3.2 and Table 6.3.

6.3.7 A duct-mounted product shall be provided with flanges that are acceptable for connection to a duct system on the air-inlet and air-outlet sides.

Exception: In place of flanges, holes may be provided in the sides of the ionizer-collector frame assembly for the attachment of flanges or equivalent means to mount the product to the duct system.

6.4 Portable products

6.4.1 A sheet-metal enclosure shall be evaluated with respect to its size, shape, thickness of metal, and its suitability for the application, considering the intended use of the complete air cleaner. The thickness of sheet steel shall not be less than 0.026 inch (0.66 mm) if uncoated or 0.030 inch (0.76 mm) if galvanized. Other sheet metal shall have a thickness not less than 0.036 inch (0.91 mm) except for small areas or for surfaces that are curved or otherwise reinforced.

6.4.2 A wooden cabinet or enclosure shall not be less than 1/2 inch (12.7 mm) thick.

6A Nonmetallic Parts

6A.1 Except as specified in 6A.3, all nonmetallic parts shall comply with Sections 6A – 6C and the tests for each respective nonmetallic part as described in Table 51A.1.

6A.1.1 Nonmetallic fasteners used as a part of:

a) An enclosure or cabinet for other than a battery-operated appliance shall comply with the Fastener Strength Test, Section 51B; or

b) An enclosure of a battery-operated appliance shall comply with the Non-Metallic Enclosure Fastener Test, Section 51D.

6A.2 In addition to the requirement in 6A.1, nonmetallic materials serving as electrical insulation or located within 1/8 in (3 mm) of:

a) Line-voltage uninsulated live parts shall comply with the Electrical Insulation section in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; or

b) High-voltage uninsulated live parts shall:

1) Comply with the High-Voltage Insulating Material Arcing Test, Section 51; or

2) Be used only with high-voltage uninsulated live parts that operate within the voltage and current limitations specified in the Partially Protected Parts Test, Section 37 if the product is rated 250 V or less.

6A.3 Nonmetallic parts not complying with 6A.1 shall be one of the following:

a) Air-cleaner filters that comply with Section 22, Filters;

b) A nonfunctional part having a total surface area of less than 1 ft^2 (0.093 m^2), located so it cannot propagate flame from one area to another or to other ignitable parts and does not connect a source of ignition to other ignitable parts; or

c) An insulating barrier of a size and location as specified in (b) and complying with 11.4.

6B Nonmetallic Materials

6B.1 Materials shall be classified with respect to flammability characteristics that are established by the tests specified in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

6B.2 Materials shall be assigned flammability ratings based on greatest to least resistance to flame and are identified as: 5VA, 5VB, V-0, V-1, V-2, HF-1, HF-2, HB, and HBF.

6B.3 In reference to 6B.2, the assigned flammability rating shall be appropriate for the material-use application in accordance with Table 51A.1.

6C Nonmetallic Material Ignition Sources Separation

6C.1 A nonmetallic part shall be positioned as shown in Figure 6C.1 if the part:

a) Has a flame rating of HB as determined in accordance with Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; or

b) Complies with either the Flammability – 12 mm Flame or the Flammability – 20 mm (3/4-Inch) Flame Test as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

6C.2 A nonmetallic part as specified in 6C.1 shall be separated from ignition sources by means of a mechanical barrier, extending at least to the boundary surface of the space whenever such parts are located:

a) Below an ignition source and within Space A;

b) Above an ignition source and within Space B; and

c) In the vertical plane relative to an ignition source and within Space C.

6C.3 The nonmetallic parts referenced by 6C.1 shall be located such that the distance between:

a) Line-voltage wiring not employing VW-1 insulation and the nonmetallic parts shall be a minimum of 2 inches (51 mm); and

b) Any other ignition source and the nonmetallic parts shall be a minimum of 4 inches (102 mm).

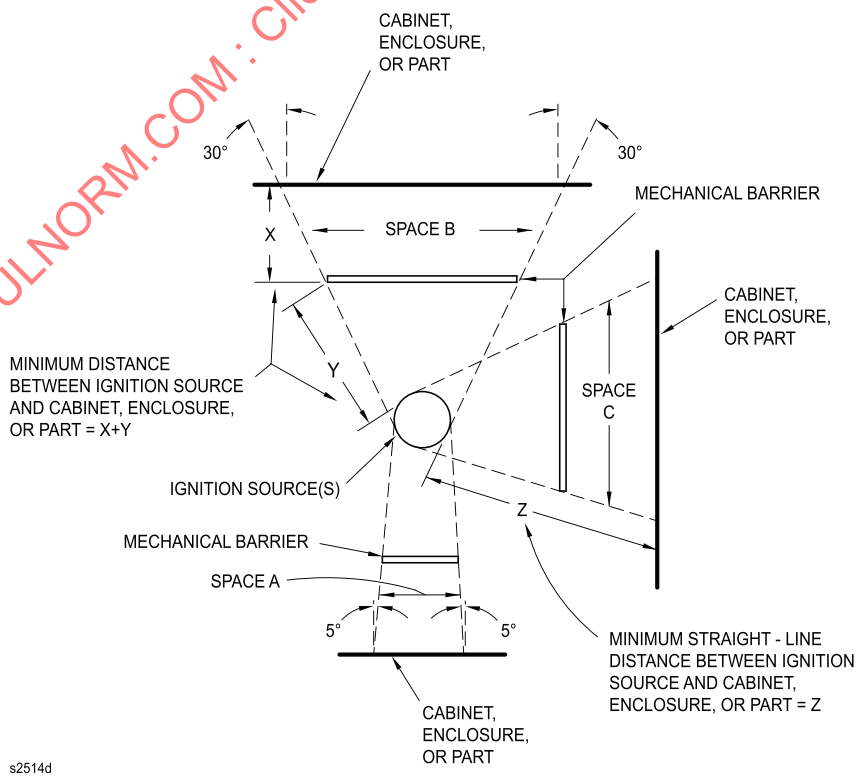
6C.4 With reference to 6C.3 and Figure 6C.1, the minimum distance for the nonmetallic materials located:

a) Above the ignition source shall be as shown in Distance X + Y; and

b) In the vertical plane relative to the ignition source shall be as shown in straight-line Distance Z.

Figure 6C.1

Separation of ignition sources from nonmetallic materials



7 Accessibility of Uninsulated Live Parts and Moving Parts

7.1 In reference to 7.5 and except as specified in 7.2, an opening in a cabinet or enclosure shall comply with the following to reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated (magnet) wire, or injury to persons from a moving part:

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

1) Figure 7.1; or

2) Figure 7.2, for those products intended only for ceiling mounting.

b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 7.1.

Figure 7.1

Articulate probe with web stop

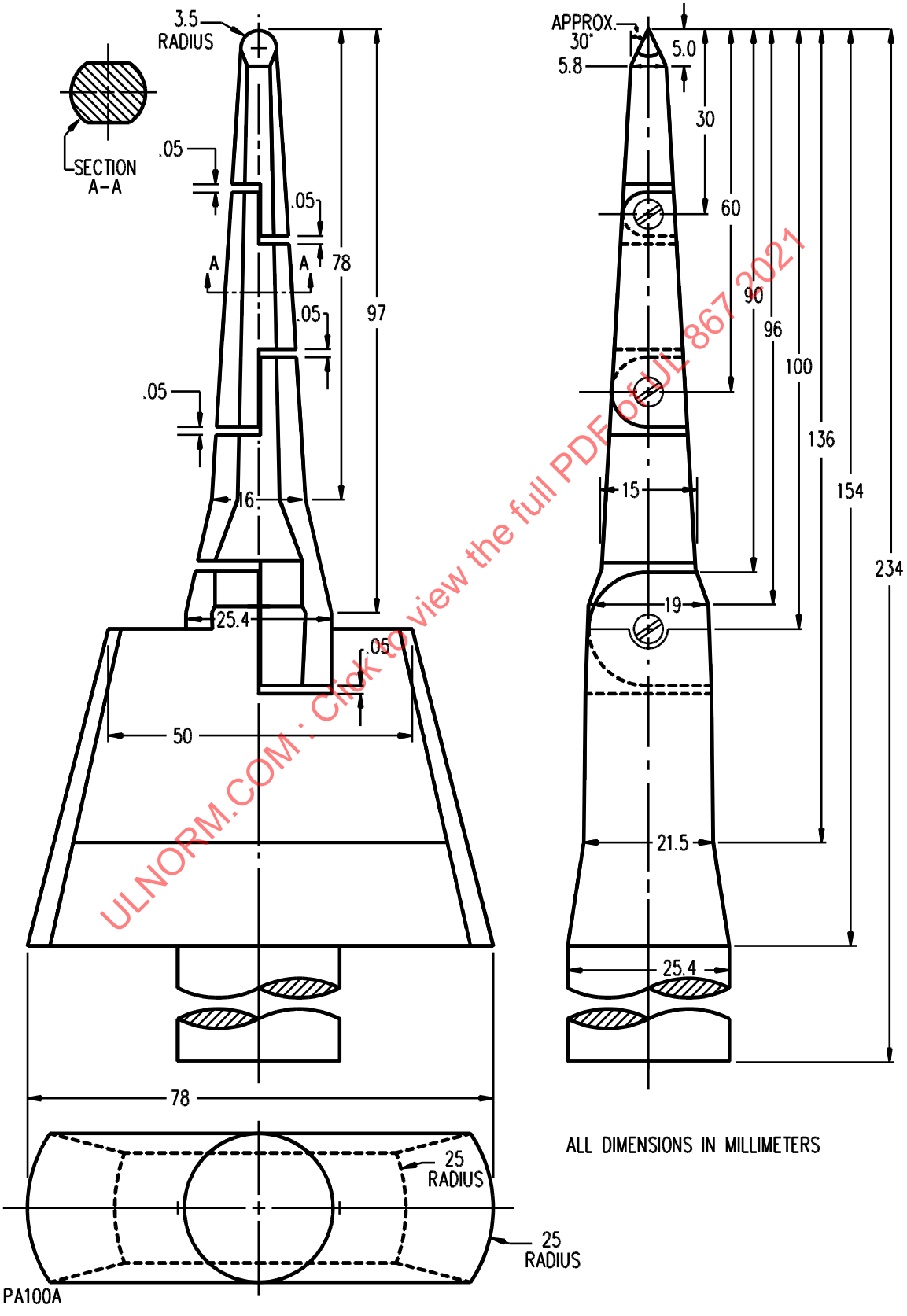


Figure 7.2

Probe for moving parts of a ceiling mounted air cleaner

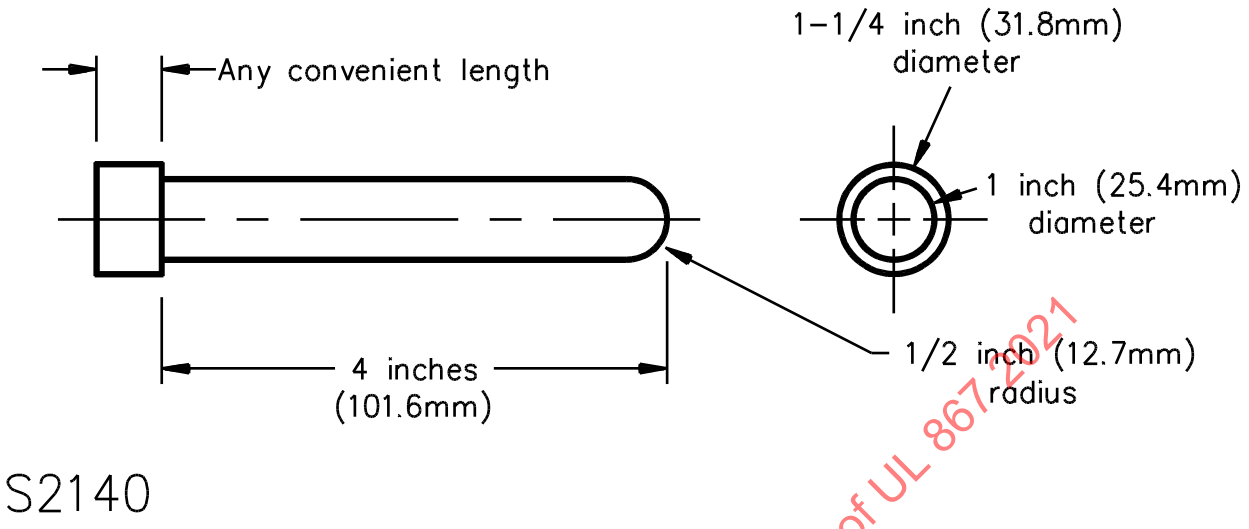


Table 7.1

Minimum distance from an opening to a part that may involve a risk of electric shock or injury to persons

Minor dimension of opening,[a,b]		Minimum distance from opening to part[b],	
inches	(mm)	inches	(mm)
3/4[c]	19.1	4-1/2	114.0
1[c]	25.4	6-1/2	165.0
1-1/4	31.8	7-1/2	190.0
1-1/2	38.1	12-1/2	318.0
1-7/8	47.6	15-1/2	394.0
2-1/8	54.0	17-1/2	444.0
See footnote d		30	762.0

[a] See 7.5.

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

[c] Any dimension less than 1 inch applies to a motor only.

[d] More than 2-1/8 inches, but not more than 6 inches (152.0 mm).

7.2 In reference to 7.1, an opening in an integral enclosure of a motor shall:

a) Have a minor dimension less than 3/4 inch (19.1 mm) if:

1) A moving part cannot be contacted by the probe illustrated in Figure 7.3.

2) Film-coated (magnet) wire cannot be contacted by the probe illustrated in Figure 7.4.

3) No uninsulated live part in a directly accessible motor, as described in 7.7, can be contacted by the probe illustrated in Figure 7.5.

4) No uninsulated live part in an indirectly accessible motor, as described in 7.6, can be contacted by the probe illustrated in Figure 7.3.

b) Be spaced not less than the distance specified in Table 7.1 from any wire or moving part if the opening has a minor dimension of 3/4 inch or more.

Figure 7.3

Probe for moving parts and uninsulated live parts

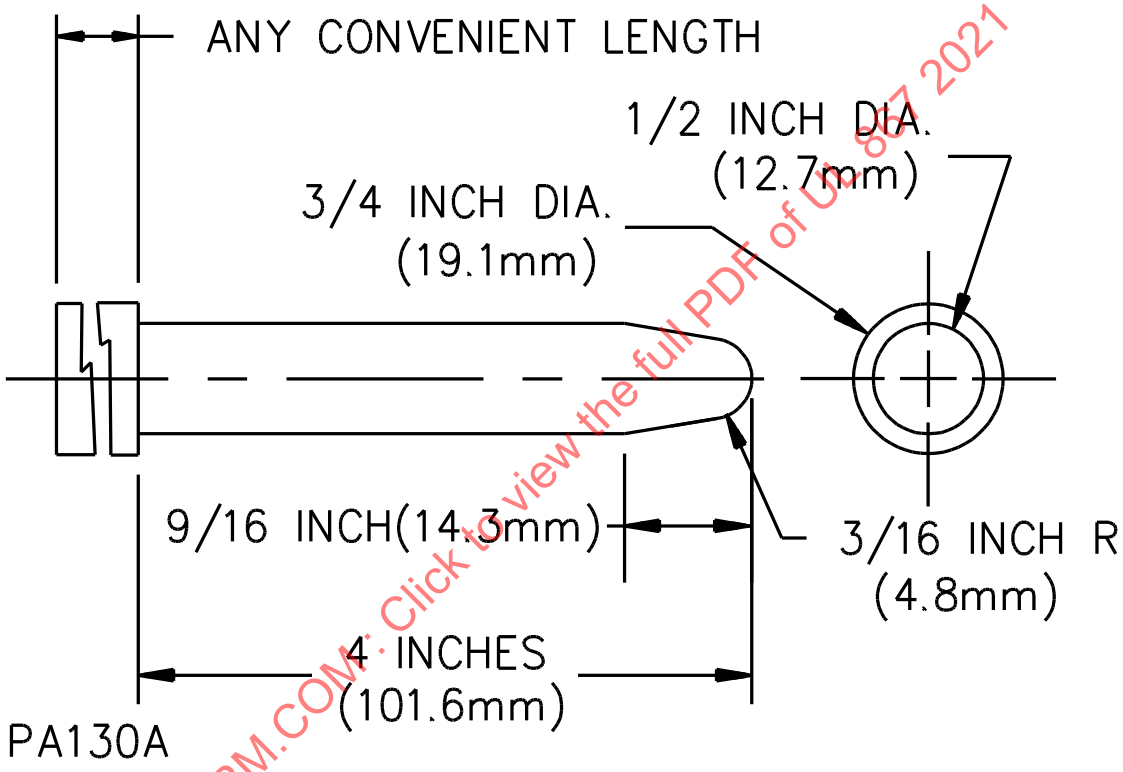


Figure 7.4

Probe for film-coated (magnet) wire

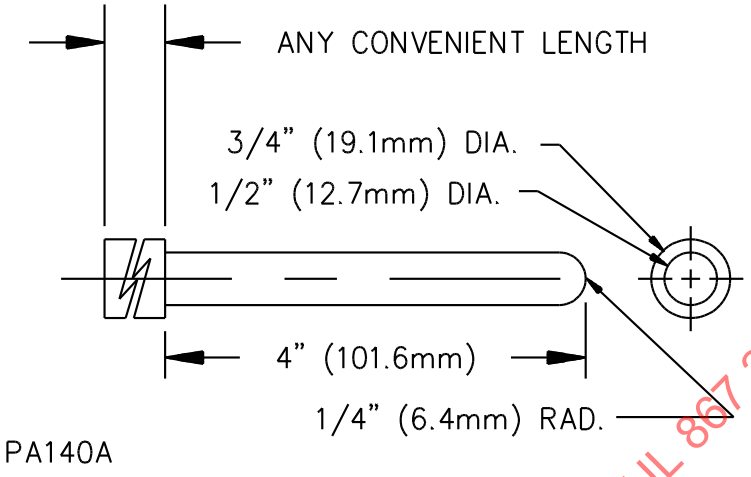
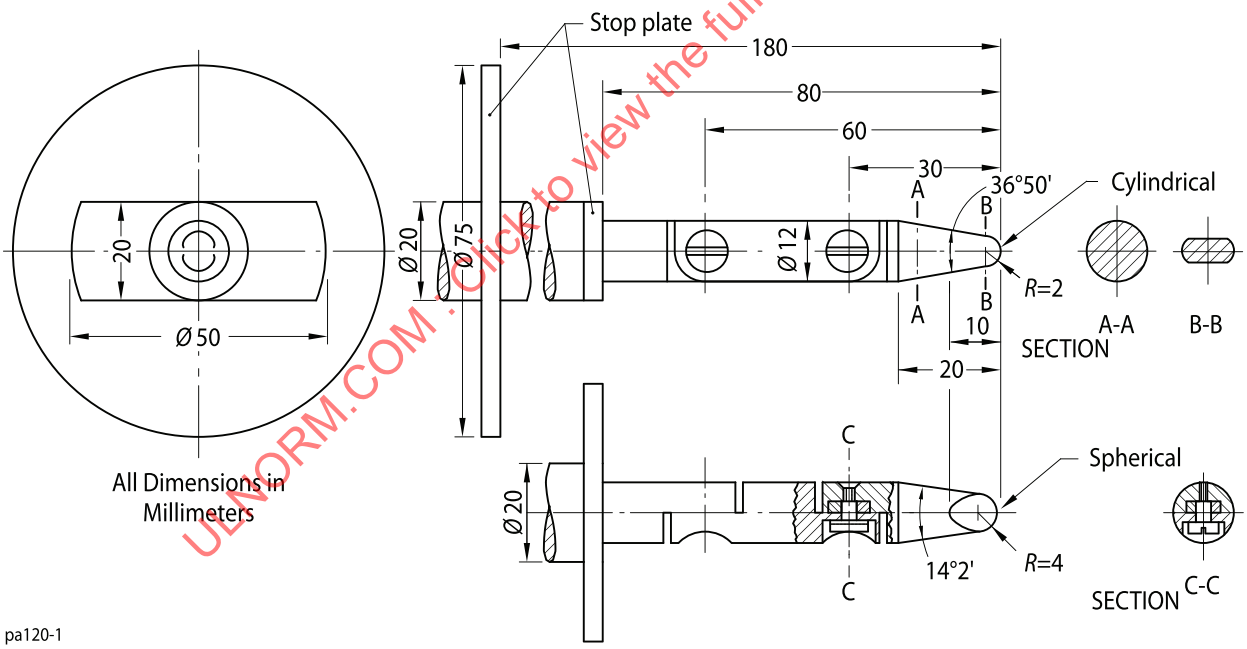


Figure 7.5

Articulate probe



7.3 The probes mentioned in 7.1 and 7.2 and illustrated in Figure 7.1 – Figure 7.5 shall be applied to any depth that the opening will permit. They shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure or cabinet. The probes illustrated in Figure 7.1 and Figure 7.5 shall be applied in any possible configuration. If necessary, the configuration shall be changed after insertion through the opening.

7.4 The probes mentioned in 7.3 and 7.5 are to be used as measuring instruments to evaluate the accessibility provided by an opening, and not as instruments to evaluate the strength of a material. They are to be applied with the minimum force necessary to determine accessibility.

7.5 With reference to the requirements in 7.1 and 7.2, 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.

7.6 With reference to the requirements in 7.2, an indirectly accessible motor is a motor that is:

a) Accessible only by opening or removing a part of the cabinet, such as a guard or panel, that can be opened or removed without using a tool; or

b) Located at such a height or is otherwise guarded or enclosed so that it is unlikely to be contacted.

7.7 A directly accessible motor is a motor that:

a) Can be contacted without opening or removing any part or

b) Is located so as to be accessible to contact.

7.8 During the examination of a product to determine whether it complies with the requirements in 7.1 or 7.2, a part of the cabinet or enclosure that may be opened or removed by the user without using a tool shall be opened or removed.

7.9 With reference to the requirements in 7.1 and 7.2, insulated brush caps are not required to be additionally enclosed.

7.10 If the opening or removal of a door, a cover, or any other component required for user servicing permits access to a part that is considered to present a risk of electric shock (see 37.1), the door, cover, or component shall be provided with an interlock switch as specified in 29.2.1 – 29.2.5 to de-energize the primary circuit of the high-voltage power supply.

7.11 Unless a mechanical means is provided to discharge to ground any residual charge existing in the high-voltage parts after the primary circuit is de-energized, a time-delay feature shall be provided so that live parts do not become accessible until residual charges decay as required in 47.1.

8 Mechanical Assembly

8.1 General

8.1.1 A product shall be assembled so that it will not be adversely affected by the vibration of normal operation.

8.1.2 Provision shall be made for mounting a product securely. Bolts, screws, or other parts used for mounting the product shall be independent of those used for securing components of the product to the frame, base, or panel.

8.1.3 The mounting assembly shall be capable of supporting four times the weight of the product for 1 minute.

Exception: A product that is intended to be mounted to a duct system need not comply with this requirement.

8.1.4 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.

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

a) The switch is of a plunger or other type that does not tend to rotate. A toggle switch is considered to be subjected to forces that turn the switch during its normal operation.

b) It is unlikely that the operation of the switch will loosen its mounting means.

c) Spacings are not reduced below the minimum values if the switch rotates.

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 for a neon pilot or indicator light in which the lamp is sealed by a nonremovable jewel, need not be prevented from turning if rotation cannot reduce the spacings below the minimum required values.

8.1.5 Means for preventing the turning mentioned in 8.1.4 is to consist of more than friction between surfaces. For instance, a properly applied lock washer can be used as a means to prevent a small stem-mounted switch or other device having a single-hole mounting means from turning.

8.1.6 If a vertically-mounted switch or circuit breaker is such that movement of the operating handle results in one position being above the other position, the upper position shall be the on position.

Exception: This requirement does not apply to horizontally- or rotationally-mounted switches, or switching devices with more than one on position, such as a double-throw or timer switch.

8.2 Assembly for shipping

8.2.1 A product shall be completely assembled when it is shipped from the factory.

Exception: A product may be shipped partially disassembled to facilitate packing or installation if the intended assembly can be accomplished readily without introduction of risk of fire, electric shock, or injury to persons.

8.2.2 If mismatching of components of a product that is shipped disassembled presents a risk of fire, electric shock, or injury to persons, the parts shall be marked as specified in 56.2. See also 8.2.4.

8.2.3 If a cord-connected product is shipped partially disassembled, internal connections that must be made in the field shall be made by plug and receptacle connections. If a product intended for permanent connection to the power supply is shipped partially disassembled, internal connections that must be made in the field shall be made in accordance with 12.1.1.1 – 12.1.5.5 or by plug and receptacle connections.

8.2.4 A product that is shipped from the factory partially disassembled shall be shipped in a single shipping container or marked in accordance with 57.2.

8.3 Mechanical barriers

8.3.1 A mechanical barrier shall be formed from one or more of the following:

a) Metal with at least the thickness specified in Table 6.1 or Table 6.2 as provided under the columns titled “With supporting frame or equivalent reinforcing” for the dimensions of the mechanical barrier;

b) A nonmetallic material of the necessary strength and rigidity and:

1) Rated 5VA; or

2) Evaluated to the 127 mm (5 inch) Flammability Test as described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C;

c) Any other material or construction determined to be equivalent to (a) – (b).

9 Live Parts

9.1 A current-carrying part shall have the necessary mechanical strength and ampacity, and shall be made of a metal that can be used for the application.

9.2 An uninsulated live part shall be secured to its supporting surface by a means other than friction between surfaces so that it will be prevented from turning or shifting in position if such motion may result in a reduction of spacings below the minimum required values. The construction of a contact assembly shall be such that the alignment of the contacts will be maintained.

10 Protection Against Corrosion

10.1 Products intended for indoor use

10.1.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other means that have been determined to be equivalent.

Exception No. 1: Small minor parts of iron or steel such as washers, screws, bolts, and the like that do not carry current.

Exception No. 2: Parts made of stainless steel are not required to be additionally protected against corrosion.

Exception No. 3: Bearings and other parts for which protection is impractical because of the function of the part.

10.1.2 The requirement in 10.1.1 applies to all parts of the framework, cabinet and enclosure; all iron and steel current-carrying parts, except resistors; all spring-door fasteners; and other parts upon which proper mechanical operation may depend.

10.1.3 Iron and steel used within a cabinet or enclosure that is intended to be washed down during normal maintenance of the product shall be protected against corrosion. A zinc coating that withstands, without a fixed deposit, three 1-minute dips in a standard copper sulphate solution, or some other equivalent coating shall be used. Painting or baked enamel is not considered to provide the required protection.

10.1.4 Bonderized steel parts provided with a primer coat and covered by a baked-alkyd-enamel finish are considered to comply with the requirements in 10.1.3.

10.2 Products intended for outdoor use

10.2.1 A sheet-steel cabinet or enclosure intended for outdoor use shall be protected against corrosion by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel complying to the coating Designation G90 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation.

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). An annealed coating shall comply with 10.2.2 and 10.2.3.

c) A zinc coating complying with (1) or (2) and with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on both surfaces. If necessary, the acceptability of the paint may be determined by evaluation of its composition or by corrosion tests.

1) Hot-dipped, mill-galvanized sheet steel complying with the coating Designation G60 or A60 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. An A60 (alloyed) coating shall also comply with 10.2.2 and 10.2.3.

2) 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 of 0.00034 inch (0.009 mm). An annealed coating shall also comply with 10.2.2 and 10.2.3.

d) A cadmium coating not less than 0.0010 inch (0.025 mm) thick on both surfaces.

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 paint shall be as described in (c).

f) Other finishes, including paints, metal finishes, or combinations of the two may be used when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) complying with (a), indicate they provide equivalent protection. Among the factors that are taken into consideration when judging such coating systems are exposure to salt spray, moist carbon dioxide-sulphur dioxide-air mixture, moist hydrogen sulphide-air mixtures, ultraviolet light, and water.

10.2.2 A hot-dipped, mill-galvanized A60-alloyed-coating or an annealed coating on sheet steel that is bent or similarly formed or extruded or rolled at the edge of a hole after annealing shall be additionally painted in the affected area if the process damages the zinc coating.

10.2.3 If flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25-power magnification, the zinc coating is considered to be damaged.

10.2.4 Simple sheared or cut edges and punched holes are not required to be additionally protected.

10.2.5 In reference to 10.2.1(a) and (c)(1), the weight of the zinc coating may be determined by any method that has been determined to be acceptable; 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.

10.2.6 In reference to 10.2.1(b), (c)(2), (d) and (e), the thickness of the cadmium or zinc coating shall be established by the Metallic Coating Thickness Test, Section 50.

11 Electrical Insulation

11.1 All circuits

11.1.1 A thermoplastic or epoxy potting compound shall be used within its temperature rating and shall be a minimum of 1/32 inch (0.8 mm) thick. Prior to potting, the parts shall be mechanically secure.

11.1.2 *Deleted*

11.1.3 *Deleted*

11.2 Primary circuits

11.2.1 A base for the support of a live part shall be glazed slate, porcelain, phenolic, cold-molded composition, or other material that has been evaluated for such use. It shall be able to withstand the most severe conditions likely to be met in service.

11.2.2 *Deleted*

11.2.3 Vulcanized fiber shall not be used for the sole support for uninsulated live parts of other than low-voltage circuits.

11.3 Secondary circuits

11.3.1 A base for the support of a high-voltage part shall be of glazed porcelain, mica, glass, or other insulating material that has been evaluated for the application. It shall be moisture resistant and constructed so that, considering the material used, it will withstand the most severe conditions likely to be met in service.

11.3.2 *Deleted*

11.3.3 Insulating materials other than those specified in 11.3.1 shall comply with 11.4 or with the High-Voltage Insulating Material Arcing Test, Section 51.

11.4 Insulating barriers

11.4.1 An insulating barrier shall:

a) Be constructed to withstand the most severe condition anticipated in service;

b) Comply with requirements for mechanical barriers in 8.3 if exposed or otherwise subjected to mechanical damage; and

c) Be reliably held in place.

11.4.2 Materials used for an insulating barrier:

a) Shall be of the material(s) and minimum thickness as specified in Table 11.1 for high, line or low-voltage circuits.

b) Shall be vulcanized fiber or varnished cloth not less than 1/32 inch (0.8 mm) thick for line or low-voltage circuits.

c) Shall be equivalent to those specified in (a) or (b) for each respective circuit.

d) Are not specified for low-voltage circuits that do not contain a protective control.

Table 11.1
Insulating barriers for high-voltage circuits

Materials	Minimum thickness, inch	(mm)
Phenolic composition[a]	1/32	0.8
Cold-molded composition[a]	3/32	2.4
Porcelain, unglazed[a,b]	1/8	3.2
Porcelain, glazed	1/8	3.2
Mica	1/32	0.8
Glass	1/8	3.2

[a] May be used only when tested as described in the High-Voltage Insulating Material Arcing Test, Section 51.

[b] Unglazed porcelain tubes may be used for insulated wires.

12 Supply Connections

12.1 Permanently-connected products

12.1.1 General

12.1.1.1 A product shall have provision for the connection of a wiring system.

12.1.1.2 A product shall be provided with wiring terminals or leads for the connection of conductors having an ampacity rated for the sum of the following:

a) The ampere rating of the power pack and

b) One hundred twenty-five percent of the full-load motor current.

12.1.1.3 It is assumed that a product will be connected with conductors having 60°C (140°F) insulation unless otherwise marked.

12.1.1.4 A lead that is intended to be spliced in the field to a branch-circuit conductor shall not be smaller than 18 AWG (0.82 mm^2) and the insulation, if rubber or thermoplastic, shall not be less than 1/32 inch (0.79 mm) thick.

12.1.1.5 A product intended for duct- or plenum-mounting shall be permanently connected to the electrical supply source unless constructed as specified in 12.2.1.2.

12.1.2 Wiring compartment

12.1.2.1 A terminal box or compartment for making power-supply connections in the field shall be of ample size to accommodate such connections and shall be located so that the connections can be readily inspected after the product is installed as intended.

12.1.2.2 If inspection indicates that the volume of a compartment may be insufficient to accommodate the intended wiring, a trial installation is to be made using wires of the size specified in 12.1.1.2 and conduit and fitting sized for the wire in accordance with the National Electrical Code, ANSI/NFPA 70.

12.1.2.3 Leads intended for connection to any external line-voltage circuit or to an external low-voltage circuit containing one or more protective controls shall be provided with strain relief if stress on the lead may be transmitted to terminals, splices, or internal wiring. Leads shall comply with 42.1 when subjected to a direct pull of 20 pounds-force (89 N).

12.1.3 Conduit connection means

12.1.3.1 A tapped hole for the attachment of threaded rigid conduit shall be provided with:

a) At least three full threads tapped all the way through the wall of an enclosure and located so that a bushing may be attached to the end of the conduit or

b) At least 3-1/2 full threads and a smooth, rounded inlet hole having a diameter approximately the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing.

12.1.3.2 A knockout in a sheet-metal enclosure shall be reliably secured but shall be capable of being removed without undue deformation of the enclosure.

12.1.3.3 A plate or plug used to close an unused conduit opening or other hole in the enclosure shall be securely mounted and shall have:

a) For an opening with a 1/4 inch (6.4 mm) or smaller maximum dimension, a thickness not less than 0.014 in (0.36 mm) for steel nor less than 0.019 inch (0.48 mm) for nonferrous metal.

b) For an opening with a maximum dimension greater than 1/4 inch, but not greater than 1-3/8 inches (34.9 mm), a thickness not less than 0.027 inch (0.69 mm) for steel nor less than 0.032 inch (0.81 mm) for nonferrous metal.

c) For an opening with a maximum dimension greater than 1-3/8 inches, a thickness equal to that required for the enclosure of the device or equal to that required for a standard knockout seal.

12.1.3.4 A flat surface shall be provided around all knockouts, and the location of the knockouts shall be such that the spacing between the installed conduit bushing and uninsulated live parts will not be less than the minimum values specified in Spacings, Section 23.

12.1.3.5 When measuring a spacing between an uninsulated live part and a bushing installed in the knockout referred to in 12.1.3.4, it is to be assumed that a bushing having the dimensions specified in Table 12.1 is in place in conjunction with a single locknut.

Table 12.1
Dimensions of bushings

Trade size of conduit, inches	Overall diameter, inches	Overall diameter, (mm)	Height, inches	Height, (mm)
1/2	1	25.4	3/8	9.5
3/4	1-15/64	31.4	27/64	10.7
1	1-19/32	40.5	33/64	13.1
1-1/4	1-15/16	49.2	9/16	14.3
1-1/2	2-13/64	56.0	19/32	15.1
2	2-45/64	68.5	5/8	15.9

Table 12.1 Continued on Next Page

Table 12.1 Continued

Trade size of conduit, inches	Overall diameter, inches	Overall diameter, (mm)	Height, inches	Height, (mm)
2-1/2	3-7/32	81.8	3/4	19.1
3	3-7/8	98.4	13/16	20.6
3-1/2	4-7/16	113.1	15/16	23.8
4	4-31/32	126.6	1	25.4
4-1/2	5-35/64	141.0	1-1/16	27.0
5	6-7/32	158.0	1-3/16	30.2
6	7-7/32	183.4	1-1/4	31.8

12.1.3.6 The opening or knockout intended for the attachment of a permanent wiring system shall be based on the product minimum supply circuit ampacity (MCA) and the required field-supplied wire size in accordance with Table 12.2.

Table 12.2
Field wiring knockout or opening dimension size[a,b,d]

Product minimum supply circuit ampacity (MCA) determined in 57.8.1	Required field-supplied wire size, AWG	Trade size of conduit, inches	Knockout or opening diameter size (range), in (mm)
Up to 15	14	1/2	0.86 – 0.90 (21.8 – 23.0)
15 – 20	12	1/2	0.86 – 0.90 (21.8 – 23.0)
20 – 30	10	1/2	0.86 – 0.90 (21.8 – 23.0)
30 – 40	8	1[c]	1.36 – 1.40 (34.5 – 35.7)[c]
40 – 55	6	1	1.36 – 1.40 (34.5 – 35.7)

[a] Based on copper field wiring conductors having insulation that does not exceed 140°F (60°C) within the product during the Temperature Test, Section 45.

[b] Applies to either a 3 or 4 wire field wiring connection having 1 or 2 ungrounded wires, a grounded (neutral) wire and a grounding (earth) wire.

[c] If only a 3 wire connection is used with a product having a MCA of 30 – 40, the knockout or opening diameter can be decreased to 1.09 – 1.14 in (27.8 – 29.0 mm).

[d] These values were determined based on 310.15, “Ampacities for Conductors Rated 0 – 2000 Volts” in the National Electrical Code, NFPA 70; the trade size of conduit table in the Standard for Heating and Cooling Equipment, UL 1995; and Annex D, “Knockout Dimensions”, in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

12.1.4 Terminal parts

12.1.4.1 A field-wiring terminal shall be provided with a pressure terminal connector, firmly bolted or held by a screw.

Exception: A wire-binding screw may be employed at a field-wiring terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

12.1.4.2 A wire-binding screw to which field-wiring connections are made shall not be smaller than No. 8 (4.2 mm diameter).

Exception: A No. 6 (3.5 mm diameter) screw may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor.

12.1.4.3 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick for a 14 AWG (2.1 mm^2) or smaller wire and not less than 0.050 inch (1.27 mm) thick for a wire larger than 14 AWG.

12.1.4.4 A terminal plate tapped for a wire-binding screw shall be provided with no fewer than two full threads in the metal. The metal may be extruded at the tapped hole for the binding screw to provide two full threads.

Exception: Two full threads are not required if fewer threads result in a secure connection in which the threads will not strip upon the application of a 20 pound-inch (2.26 N·m) tightening torque.

12.1.4.5 A wire-binding screw shall thread into metal.

12.1.5 Terminal identification

12.1.5.1 A permanently connected product rated 125 or 125/250 volts (three-wire) or less employing a screw-shell lampholder, a single-pole switch, or a single-pole 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.

12.1.5.2 A field-wiring terminal intended for the connection of a grounded supply conductor shall be identified by means of a metallic coating that is substantially white in color. It shall be readily distinguishable from the other terminals, or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as on a wiring diagram provided on the product. If wire leads are provided instead of terminals, the lead intended to be connected to the grounded supply conductor shall have a white or gray color and shall be readily distinguishable from the other leads.

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

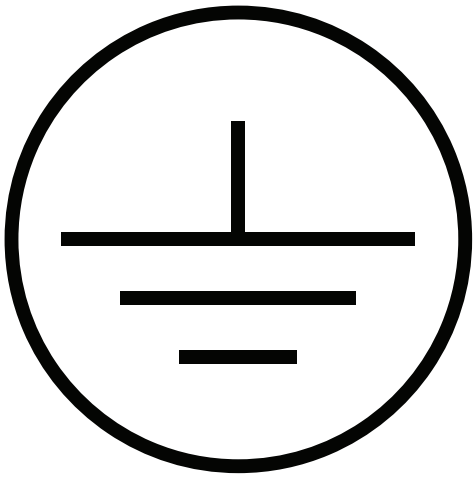
Exception: A conductor with insulation having a surface that is green or green with or without one or more yellow stripes may be used for internal wiring provided such wiring does not serve as a lead wire for connection to branch-circuit conductors.

12.1.5.4 A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green-colored head that is hexagonal, slotted, or both. It shall be located so that it is unlikely to be removed during normal servicing of the product.

12.1.5.5 A pressure wire connector intended for connection of an equipment-grounding conductor shall be plainly identified, such as by being marked "G," "GR," "Ground," "Grounding," the grounding symbol (from IEC 60417, Symbol 5019) as illustrated in Figure 12.1 or the like, or by a marking on a wiring diagram provided on the product. The pressure wire connector shall be located so that is unlikely to be removed during normal servicing of the product.

Figure 12.1

Grounding symbol



12.2 Cord-connected products

12.2.1 Cords and plugs

12.2.1.1 A cord-connected product, other than a duct- or plenum-mounted product, shall be provided with a flexible cord that is not less than 6 feet (1.83 m) nor more than 10 feet (3.05 m) long. The cord shall be provided with an attachment plug for connection to the supply circuit.

12.2.1.2 A duct- or plenum mounted product not complying with 12.1.1.5 shall comply with all of the following:

a) Be provided with a flexible supply cord which is:

1) A 3-conductor Type SJ or equivalent cord rated for at least 105°C (221°F);

2) Terminated in a grounding attachment plug; and

3) Not more than 6 feet (1.83 m) long;

b) Be packaged with a field-wiring compartment containing a single receptacle for plug connection of the product if the product is intended for installation on and obtain its power supply from a furnace; and

c) Be provided with installation instructions in accordance with 59.5.

d) *Deleted*

12.2.1.3 Except as specified in 12.2.1.3.1, a flexible cord shall include a grounding conductor and a grounding-type attachment plug. The grounding conductor shall be:

a) Green with or without one or more yellow stripes;

b) Connected to the grounding blade of a grounding attachment plug; and

c) Connected to the frame, cabinet or enclosure of the product by means of a screw not likely to be removed during ordinary servicing, or by other reliable means. Solder alone shall not be used to make this connection.

12.2.1.3.1 In reference to 12.2.1.3, a cord-connected product not having a grounding conductor shall be portable, rated less than 150 volts and:

a) Provided with a 2-blade polarized attachment plug; or,

b) Intended only for connection to a low-voltage supply source and be provided with a plug appropriate for the low-voltage source (such as a USB type connector).

12.2.1.4 *Deleted*

12.2.1.5 The flexible cord shall be Type SP-2, SPE-2, SPT-2, or of a type that has been evaluated for harder service.

12.2.1.6 The voltage rating of the cord and the attachment plug shall not be less than the rated voltage of the product.

12.2.1.7 The ampacity of the cord shall not be less than the current rating of the product. The current rating of the attachment plug shall not be less than 125 percent of the current rating of the product, except that a 20-ampere plug can be used for a product rated not more than 4,000 watts at 240 volts.

12.2.1.8 The flexible cord shall be attached permanently to the product, or may be in the form of a separate cord set as specified in 12.2.1.9.

12.2.1.9 If a separate cord set is provided for the product as specified in 12.2.1.8, the product shall not be provided with terminal pins that will accommodate a standard flatiron or appliance plug.

12.2.2 Strain relief

12.2.2.1 A product shall be provided with means to prevent stress on the power-supply cord from being transmitted to terminals, splices, or wiring within the product. The product shall comply with the Strain Relief Test, Section 42.

12.2.2.2 A metal strain-relief clamp or band (without auxiliary protection) may be used with a Type S, SE, SJ, SJE, SJO, SJT, SJTO, SO, ST, or STO cord. A metal strain-relief clamp or band may be used with Type SP-2 rubber-insulated cord and with Type SPT-2 cord only if auxiliary, nonconducting, mechanical protection is provided with the cord and the combination is determined acceptable by investigation.

12.2.2.3 Means shall be provided so that the flexible cord or supply leads cannot be pushed into the product through the cord-entry hole when such displacement results in:

a) Mechanical damage to the cord or leads;

b) Exposure of the cord or leads to a temperature higher than that for which it is rated; or

c) A reduction of spacings, such as to a metal strain-relief attachment, below the minimum required values.

To determine compliance with this criteria, the cord shall be subjected to the Pushback Relief Test, Section 43.

12.2.2.4 If a knot in a flexible cord serves as strain relief, any surface that the knot can touch shall be free from burrs, fins, projections, sharp edges, and the like that may abrade the cord.

12.2.3 Bushings

12.2.3.1 A bushing or the equivalent shall be provided at an opening in a cabinet, enclosure, partition or in a mechanical or insulating barrier through which a supply cord passes. The bushing or the equivalent shall be substantial, reliably secured in place, and shall have a smooth, rounded surface against which the cord may bear. If a cord other than Type S, SE, SJ, SJE, SJO, SJT, SJTO, SO, ST, or STO is employed and the cabinet, enclosure, partition or barrier is of metal, an insulating bushing shall be provided.

12.2.3.2 In general, ceramic materials and some molded compositions may be used for insulating bushings.

12.2.3.3 A separate neoprene or polyvinyl chloride bushing may be employed on a supply cord:

a) Anywhere in a product if it is used in conjunction with a type of cord for which an insulating bushing is not required or

b) Where the cord enters the frame of a motor or the enclosure of a capacitor that is physically attached to a motor if:

1) The bushing is not less than 3/64 inch (1.2 mm) thick and

2) The bushing is located so that it will not be exposed to oil, grease, oil vapor, or other substances that can have a deleterious effect on the compound employed.

12.2.3.4 The edges of the hole in which a neoprene or polyvinyl chloride bushing is used shall be free from burrs, fins, and the like that are capable of damaging the bushing.

12.2.3.5 A bushing of the same material as, and molded integrally with, the supply cord may be used with a Type SP-2 or heavier cord if the built-up section is not less than 3/64 inch (1.2 mm) thick at the point at which the cord passes through the enclosure.

12.2.3.6 An insulated metal grommet may be used in place of an insulating bushing if the insulating material used is not thinner than 1/32 inch (0.8 mm) and completely fills the space between the grommet and the metal in which the grommet is mounted.

12.3 Cord-connected conversion to permanently connected

12.3.1 A product intended to be field-converted shall be manufactured as a cord connected product and have provision for permanent connection of a wiring system. Before conversion, the cord-connected product shall comply with 12.2 and after conversion the product shall comply with 12.1. In addition, the product shall comply with 12.3.2 and all relevant parts of this Standard.

12.3.2 In reference to 12.3.1, after conversion of the product, the opening provided for the power supply cord shall either comply with the accessibility requirements in Section 7, Accessibility of Uninsulated Live Parts and Moving Parts, or be used as the opening for connection of the permanent wiring system.

13 Polarization

13.1 The screw shell of each lampholder shall be connected:

a) To the conductor or terminal intended to be connected to the grounded conductor of the supply circuit, for a permanently-connected product;

b) To the conductor of the supply cord intended to be connected to the grounded conductor of the supply circuit, for a cord-connected product; or

c) To the same supply conductor in the absence of a conductor or terminal intended to be connected to the grounded conductor of the supply circuit.

13.2 A fuseholder, a single-pole switch, an overcurrent-protective device, and an automatic control with a marked off position shall be connected to an ungrounded conductor of the supply circuit.

13.3 The screw shell of a plug-type fuseholder and the accessible contact of an extractor-type fuseholder shall be connected toward the load.

13A Switches and Controllers

13A.1 Except as specified in 13A.6 or 13A.8, a switch or other control device shall have a rating not less than that of the load that it controls. Items to consider in determining the device rating could include the voltage, current, power factor, control device ambient temperature and other similar parameters. Power factor requirements for each specific load type are specified in 46C.5.

13A.2 A switch or other control device, other than as specified in 13A.2.1, shall be located within the confines of the frame, cabinet or enclosure of the product or be additionally protected so as to reduce the likelihood of contact by external objects.

13A.2.1 In reference to 13A.2, if the actuating part of a switch or other control device is not located within the confines of the frame, cabinet or enclosure of the product:

a) Unintentional operation of the switch or other control device shall not result in a risk of injury to persons; or

b) The actuating part shall be guarded such as by recessing, ribs or barriers.

13A.2.2 A protective control shall be an integral part of the product and control the load either,

a) Directly; or

b) Indirectly through a switching device which is an integral part of the product and that complies with the endurance test requirements for protective controls in 13A.3 or 13A.3.1.

13A.3 A protective control shall comply with one of the following:

a) Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1 and the Standard for Automatic Electrical Controls – Part 2-6: Particular Requirements for Automatic Electrical Pressure Sensing Controls Including Mechanical Requirements, UL 60730-2-6. The endurance cycle requirements in Table AA.1DV of UL 60730-2-6 for cut-outs shall be applied.

b) 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. The endurance cycle requirements in Table CC.2 of UL 60730-2-9 for cut-outs shall be applied.

c) Standard for Industrial Control Equipment, UL 508.

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

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

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

g) Standard for Nonindustrial Photoelectric Switches for Lighting Control, UL 773A.

h) Standard for Solid-State Fan Speed Controls, UL 1917.

i) 13A.19 and the protective electronic circuits tests in Protective Circuit Tests, Section 49A.

13A.3.1 In reference to 13A.3 (c) – (i), the endurance cycle requirements in the Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9, Table CC.2 for cut-outs shall be applied to such controls.

13A.3.2 In reference to 13A.3 (a), (b), (e) and (i), when determining the acceptability of a protective control, the control pollution degree shall be as specified in 23.6.3 (a) – (e).

13A.3.3 If the protective control has a protective electronic circuit, the factors outlined in Table 13A.1 shall be considered.

Table 13A.1
Factors to be considered when evaluating protective electronic circuits

No.	FACTOR
1	Conducting failure-mode and effect analysis (FMEA) for the protective circuits and functions.
2	Electrical supervision of critical components resulting in the control becoming permanently inoperative and disconnecting power.
3	Temperature ranges as follows: **Indoor Equipment:** 32.0 ±3.6°F (0.0 ±2°C) and 104 ±3.6°F (40.0 ±2°C) **Outdoor Equipment:** -31.0 ±3.6°F (–35.0 ±2°C) and 104 ±3.6°F (40.0 ±2°C)
4	Cycling test duration: 14 days
5	Endurance test duration: 100,000 cycles
6	Radio-frequency electromagnetic field immunity: A. To conducted disturbances – test level 3 B. To radiated electromagnetic fields – Evaluate in accordance with 49A.3.4 and 49A.3.2
7	Humidity exposure: **Indoor Equipment:** 70 – 80°F (21.1 – 26.7°C) and minimum 50 percent relative humidity **Outdoor Equipment:** 70 – 80°F (21.1 – 26.7°C) and minimum 98 percent relative humidity
8	Electrical fast transient/burst immunity: **Outdoor Equipment:** test level 4 **Indoor Equipment:** test level 3
9	Surge immunity: **Outdoor Equipment:** installation Class 4 **Indoor Equipment:** installation Class 3
10	Electrostatic Discharge with a Severity Level of 3 having: A. Contact discharge at 6 kV to accessible metal parts, and;

Table 13A.1 Continued on Next Page

Table 13A.1 Continued

No.	FACTOR
	B. Air discharge at 8 kV to accessible parts of insulating material
11	Voltage Dips and Interruptions: Evaluate in accordance with 49A.3.8 and 49A.3.2
12	Harmonics and Interharmonics: Evaluate in accordance with 49A.3.9 and 49A.3.2.
13	Calibration (deviation and drift): Evaluate in accordance with 13A.3.6 for a temperature protective control or 13A.3.7 for a pressure protective control.

13A.3.4 Software which is a required part of a protective electronic circuit shall comply with one of the following:

a) The Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, as well as the specific applicable Part 2 and with the requirements for a Class B or C control function;

b) Annex R of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1 and be for a software Class B control function; or

c) Not create any risk of fire, electric shock, or injury to persons under abnormal conditions with the software rendered ineffective, e.g., use of independent redundant protective devices.

13A.3.5 In reference to 13A.3, a device providing motor overload protection shall comply with the requirements in Motors and Motor Overcurrent Protection, Section 20.

13A.3.6 The cutout calibration temperature of a heater protective (temperature-limiting) control shall be ±10°F (±6°C) of its maximum marked set-point temperature.

13A.3.7 The cutout calibration pressure of a pressure protective (limiting) control shall not exceed 105 percent of its maximum marked setting.

13A.3.8 The cutout calibration setting of ozone-monitoring circuitry in which the circuitry is relied upon to limit the ozone in accordance with 40.1.6 shall not permit the concentration of ozone to exceed the values specified in 40.1.2.

13A.3.9 Except as specified in 13A.13, an operating control, including of the electronic type, shall comply with:

a) One of the standards specified in 13A.3;

b) The requirements in this Standard as far as they reasonably apply; or,

c) One of the following standards:

1) Standard for Solid-State Controls for Appliances, UL 244A; or,

2) Standard for Clock-Operated Switches, UL 917.

13A.4 *Deleted*

13A.5 *Deleted*

13A.6 A switch that controls an inductive load, other than a motor, such as a transformer or a fluorescent-lamp ballast, shall have a current rating of not less than twice the rated full-load current of the transformer or ballast.

13A.7 A manually operated, line-connected, single pole switch for appliance on-off operation shall not be connected to the conductor of the power supply cord intended to be grounded.

13A.8 A switch used for controlling a tungsten-filament lamp load shall:

a) Be provided with a T or L rating at least equal to the tungsten-filament lamp load; or

b) Have an alternating-current rating at least six times, or a direct-current rating at least ten times greater than the tungsten-filament lamp load.

13A.9 *Deleted*

13A.10 A cord-connected product incorporating a motor rated more than 250 watts (1/3 horsepower) output shall be provided with a motor controller.

13A.11 A speed-control switch shall be provided as part of a product that employs a variable-speed or multispeed motor.

13A.12 *Deleted*

13A.13 An operating control not complying with 13A.3.9 shall:

a) Comply with 13A.14(a), if the control is electronic; and

b) Be powered entirely by no more than one low-voltage circuit; comply with the Limiting Impedance Test in UL 508; or comply with the low-power circuit requirement determined as specified in 19.11.1 of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1.

13A.14 An operating control that complies with 13A.3.9 shall also comply with all the following:

a) For electronic controls – Installation Class 2 for electromagnetic compatibility (EMC) shall be in accordance with the voltage surge testing in 49A.3.6 and comply with the results specified in 49A.3.2;

b) Category II shall be the overvoltage category;

c) Insulating materials shall have a minimum comparative tracking index (CTI) of 100 (Material Group III);

d) The applicable pollution degree shall be as specified in 23.6.3 (a) – (e); and

e) The operating control (limiter) endurance cycle requirements specified by either:

1) Table CC.2 of the Standard for Automatic Electrical Controls – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9, with the operating control (limiters) endurance cycle requirements being applied; or

2) Endurance Test – Switching Devices, Section 46C.

13A.15 If an operating control complying with 13A.3.9 indirectly controls the load through a switching device, the endurance cycle requirements in 13A.14(e) shall be applied to the switching device.

13A.16 Appendix B, Operating and Protective ("Safety Critical") Control Functions, shall be referenced to determine whether a control function is considered to result in a risk of fire, electrical shock or injury to persons.

13A.17 If a control can be used to reduce the risk of fire, electric shock or injury to persons under abnormal operating conditions of the product, but a redundant control (of similar or different design) operates to perform the identical function, the circuit shall be evaluated to determine which control will be relied upon as the protective control. The control determined to be the protective control shall comply with the protective control requirements in 13A.3. The control determined to be the operating control is not required to comply with the protective control requirements but shall comply with the operating control requirements in 13A.13 or with 13A.3.9 and 13A.14.

13A.18 A thermistor shall comply with Annex J of the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1 or the Standard for Thermistor-Type Devices, UL 1434. The calibration shall be as specified in 13A.3.6. If a thermistor is used:

a) To reduce the risk of fire, electric shock or injury to persons under abnormal operating conditions of the product, the minimum number of endurance cycles shall be 100,000.

b) In other sensing applications of the product, the minimum number of endurance cycles shall be 6,000.

13A.19 A protective control as referenced in 13A.3(i) and having a protective electronic circuit:

a) In which electronic disconnection of the circuit could fail, shall have at least two components whose combined operation provides the load disconnection;

b) Shall prevent a risk of fire, electric shock or injury to persons under the relevant fault conditions specified in 49A.2;

c) In which an overcurrent protective device opens during application of any of the fault conditions specified in 49A.2, shall utilize an overcurrent protective device complying with the requirements applicable to that component. The fault condition causing the overcurrent protective device to open shall be repeated and the overcurrent protective device shall again open the protective electronic circuit. If the overcurrent protective device complies with the Standard for Miniature Fuses: Part 1, Definitions for Miniature Fuses and General Requirements for Miniature Fuse-Links, IEC 60127-1, as well as an applicable Part 2, then the protective device shall additionally comply with the Fuse-Link Test in 49A.5;

d) In which a conductor of the printed wiring board becomes open-circuited during the fault conditions test in 49A.2, then:

1) The printed wiring board shall comply with the Needle-Flame Test in Annex E of Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1 or have a minimum flammability rating of V-0 when tested in accordance with the vertical flame test described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94;

2) Any loosened conductor shall not reduce spacings below the values specified in relevant 23.1, 23.3, 23.6; and

3) The specific test in which the printed wiring became open-circuited shall be repeated a second time. There shall be no risk of fire, electric shock or injury to persons and spacings shall not be reduced below the values specified in relevant 23.1, 23.3, 23.6;

e) Shall maintain its required functions when subjected to the EMC related stresses specified in the Electromagnetic Compatibility (EMC) Tests, 49A.3; and

f) That relies upon a programmable component for one or more of its safety functions shall be subjected to the Programmable Component Reduced Supply Voltage Test, Section 49A.4, unless restarting at any point in the operating cycle after interruption of operation due to a supply voltage dip will not result in a risk of fire, electric shock or injury to persons. The test shall be carried out after removal of all batteries and other components intended to maintain the programmable component supply voltage during supply source (mains) voltage dips, interruptions and variations.

13B Remotely Operated Electrostatic Air Cleaners

13B.1 Any function of a product enabled in response to external communication or data signals shall be considered when determining normal and abnormal conditions of the product.

13B.2 Except as specified in 13B.3, a manual control shall be provided on a product such that actuation of the control is required before the product can be operated in any mode that permits remote operation, external communication or receiving/sending data signals.

13B.3 In reference to 13B.2, a product not provided with a manual control for actuating remote operation, external communication or receiving/sending data signals shall be:

a) Capable of remote operation, external communication or receiving/sending data signals only within line-of-sight; or

b) Limited only to monitoring external communication or data signals.

13B.4 A product shall include a means to manually disconnect, disable or override any remote operation commands, external communication or data signals. If the product attachment plug and receptacle serve as the manual means to disconnect data signals or remote operation commands, the product shall comply with 59.9.

13B.5 A control that operates in response to remote operation commands, external communication or data signals shall not introduce an operating condition or state that could lead to a risk of fire, electric shock or injury to persons. In addition, such a control shall not:

a) Render inoperative any protective control or protective control function within the product;

b) Alter the order of control response such as by forcing a protective control to operate instead of another control that would normally be intended to respond;

c) Reset any protective manual reset feature;

d) Supersede the response of any protective control; or

e) Alter the response to or expected performance of:

1) User actuation of controls, movement of doors, covers, grills, filters or the like; or

2) User interaction with any parts of the product that could result in exposure of hazardous electrical parts, moving parts, hot parts or radiation.

13B.6 Compliance with 13B.5 shall be determined by one of the following:

a) Using methods appropriate for determining the performance and reliability of protective control functions in accordance with Section 13A, Switches and Controllers; or

b) Examining the product circuit diagram(s) to determine that a control which operates in response to remote operation commands, external communication or data signals operates wholly independent of the protective controls of the product and therefore is incapable of adversely affecting the operation of any protective controls.

14 Grounding

14.1 General

14.1.1 Each product shall be provided with a means for grounding unless the product complies with 12.2.1.3.1.

14.1.2 Except as specified in 14.1.2.1, if a grounding means is provided on a product, all exposed dead metal parts that are likely to become energized and all dead metal parts within the product that are exposed to contact during any user-servicing operation and that are likely to become energized shall be reliably connected to the grounding means.

14.1.2.1 An ungrounded high-voltage transformer core not complying with 14.1.2 shall comply with the dielectric voltage-withstand test specified in 46.2.1.

14.1.3 With reference to the requirement in 14.1.2, the following dead metal parts are not considered likely to become energized:

a) A small metal part (such as an adhesive-attached foil marking, a screw, a handle, or the like) that is:

1) On the exterior of the cabinet or enclosure and separated from all components by grounded metal or

2) Electrically isolated from all electrical components.

b) A panel or cover that is insulated from all electrical components by an insulating barrier complying with 11.4.

c) A panel or cover that does not enclose uninsulated live parts or is electrically isolated from other electrical components.

d) Cores and assembly screws of relays, solenoids, and the like.

14.1.4 Upon insertion of a removable part, the grounding connection shall be made before the electrical connection, and, upon removal, the grounding connection shall be broken after the electrical connection.

14.1.5 Functional grounding shall not be relied upon for equipment grounding or bonding.

14.2 Bonding

14.2.1 Unless the dead-metal parts described in 14.1.2 are bonded together by mechanical fasteners, a separate bonding conductor or strap shall be used for this purpose.

14.2.2 The bonding shall be by positive means, such as clamping, riveting, bolted or screwed connections, brazing, or welding. The bonding connection shall penetrate a nonconductive coating. Bonding around a resilient mounting shall not depend on the clamping action of rubber or similar material unless the construction has been shown by investigation to be acceptable for the purpose. This investigation may include such tests as overload, short-circuit, and aging.

14.2.3 The bonding conductor shall be of a material and size that has been evaluated for use as an electrical conductor. It shall be protected from corrosion unless inherently corrosion resistant. A bonding conductor or strap shall be installed so that it is protected from mechanical damage.

14.2.4 The size of an electrical conductor or strap employed to bond an electrical enclosure or motor frame shall be determined by the rating of the overcurrent-protective device of the branch circuit to which the product will be connected in accordance with the National Electrical Code, ANSI/NFPA 70.

Exception No. 1: A conductor smaller than that specified may be used if the bonding connection does not open when carrying current equal to twice the rating of the branch-circuit overcurrent device for 2 minutes.

Exception No. 2: A bonding connector to a motor need not be larger than the motor-circuit conductors.

14.2.5 If more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, if a motor may be individually protected by a branch-circuit overcurrent device smaller than the overcurrent devices protecting the overall product, the size of a bonding conductor for that motor is to be selected on the basis of the overcurrent device intended for the ground-fault protection of the motor.

14.3 Portable products

14.3.1 *Deleted*

15 Internal Wiring

15.1 General

15.1.1 Internal wiring and connections shall be protected or enclosed to reduce the likelihood of stress on the connections or damage to the insulation.

15.1.1.1 To prevent particles from falling out of the product, open coil windings, internal wiring and wiring connections shall be:

a) Located in a compartment such as a cabinet or enclosure which is provided with a complete base pan; or

b) Mounted or similarly positioned away from any openings in the bottom of the product.

15.1.2 A bare conductor, including coil leads, shall be supported so that at least the minimum required spacings will be maintained.

15.1.3 Each splice and connection shall be mechanically secure and shall be arranged so that stress on the connections and terminals does not result.

15.1.4 A splice shall be provided with insulation if permanence of spacing between the splice and other metal parts cannot be maintained.

15.1.5 A wireway shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like, that may abrade wire insulation.

15.1.6 An aluminum conductor, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or as motor winding, shall be terminated at each end by a method that has been evaluated for the combination of metals involved at the connection point.

15.1.7 If a wire-binding screw or a pressure wire connector is used as a terminating device for an aluminum conductor, it shall be for use with aluminum under the conditions involved (for example, temperature, heat cycling, and vibration).

15.1.8 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises. All tests shall be conducted in accordance with UL 310.

15.1.9 Wiring routed to a hinged door, cover or other parts which may subject the wiring to movement shall comply with (a) – (g) if such movement is likely to cause a risk of fire, electric shock or injury to persons.

a) Stranded conductors shall be used;

b) The arrangement shall prevent undue twisting or stressing of conductors as a result of the movement;

c) The wiring shall be routed or protected to reduce the risk of damage of the insulation;

d) Type S or SJ wiring shall be used if the wiring is exposed to a user or service person;

e) Wires shall be tied together to form a bundle;

f) Strain relief shall be provided so that stress will not be transmitted to terminals or splices. The Strain Relief Test in Section 42, using a force of 20 pounds (89 N), shall be conducted; and

g) The wiring shall comply with the Wiring Endurance Test, Section 51C.

15.2 Primary circuits

15.2.1 The internal wiring of a product shall consist of general-use wire or appliance-wiring material that has been determined to be acceptable for the application, when considered with respect to the temperature, voltage, and condition of service to which the wiring is likely to be subjected.

15.2.2 Regarding 15.2.1, wiring material of one or more of the types specified in Table 15.1 having insulation thickness not less than that specified in Table 15.1 may be used for internal wiring.

Exception: Wiring material having insulation thinner than specified in Table 15.1 may be used if the insulation, when considered with respect to the temperature, voltage, and conditions of service, is considered equivalent to the thickness specified in Table 15.1.

Table 15.1
Appliance-wiring materials

Type of insulation	Nominal thickness of insulation, inch (mm)[a]							
	600-volt applications				300-volt applications			
	With an impregnated-braid cover,		Without a braid cover,		With an impregnated-braid cover,		Without a braid cover,	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
Thermoplastic	–	–	1/32	0.8	–	–	1/32[b]	0.8[b]
Rubber	1/32	0.8	–	–	1/64	0.4	1/32	0.8

Table 15.1 Continued on Next Page

Table 15.1 Continued

Type of insulation	Nominal thickness of insulation, inch (mm)[a]							
	600-volt applications				300-volt applications			
	With an impregnated-braid cover, plus cover thickness		Without a braid cover,		With an impregnated-braid cover, plus cover thickness		Without a braid cover,	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
Neoprene	–	–	3/64	1.2	1/64	0.4	1/32	0.8
Silicone rubber	1/32	0.8	1/32[c]	0.8[c]	1/64	0.4	1/32[c]	0.8[c]

[a] The minimum thickness is 0.028 inch (0.71 mm) for 1/32-inch- (0.8-mm-) thick insulation; the minimum thickness is 0.013 inch (0.33 mm) for 1/64-inch- (0.4-mm-) thick insulation.

[b] A minimum of 1/64 inch (0.4 mm) thick only for short, moving leads in a small device, if such leads make no more than casual contact with parts of opposite polarity and with grounded parts.

[c] Only if routed away from live parts of opposite polarity and protected from mechanical damage both during installation of field wiring and while in operation, unless material has the necessary resistance to mechanical damage.

15.2.3 Holes in a sheet-metal wall through which insulated wires pass shall be provided with a bushing.

Exception: Smooth-edged holes in walls thicker than 0.042 inch (1.07 mm), need not comply with this requirement.

15.3 High-voltage circuits

15.3.1 Internal secondary wiring shall be general-use high-voltage wire or wiring material rated for the application. The voltage rating of the wire shall not be less than the maximum peak voltage measured between the wire and any other part.

15.3.2 A hole in a metal partition through which an ungrounded lead or ungrounded terminal passes shall have smooth, well-rounded edges or shall be provided with a bushing. If the bushing deforms the wire insulation, the bushing shall be subjected to the High-Voltage Insulating Arcing Test, Section 51.

15.3.3 A bushing of glazed porcelain, steatite, or that which has been determined to be the equivalent may be used for secondary leads and terminals.

15.3.4 A bushing of phenolic composition may be used if the voltage involved is less than 1000 volts.

15.3.5 Bushings other than those specified in 15.3.3 and 15.3.4 may be used based on results of the High-Voltage Insulating Materials Arcing Test, Section 51.

16 Capacitors

16.1 *Deleted*

16.2 *Deleted*

16.3 Except as specified in 16.8, a motor start or run capacitor shall comply with the construction requirements in the Standard for Capacitors, UL 810.

16.4 A capacitor, mounted in an application not intended to be totally enclosed, shall be housed within a cabinet that protects the capacitor against mechanical damage and prevents the emission of flame or molten material resulting from malfunction or breakdown of the capacitor. The cabinet shall comply with the requirements in Section 6, Frame, Cabinet and Enclosure.

16.5 *Deleted*

16.6 A capacitor other than a motor start or run capacitor that is connected across-the-line or line to ground in other than a high-voltage circuit shall comply with one of the following:

a) The Dielectric Voltage Withstand Test, Insulation Resistance Test, and Endurance Test in the Standard for Electromagnetic Interference Filters, UL 1283;

b) The Temperature Test, Table 45.1, (B)(1)(b) and either the Dielectric Voltage Withstand Test in Section 46 or in the Standard for Electromagnetic Interference Filters, UL 1283; or

c) 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. Capacitor specifications shall be as follows:

1) Operating voltage – Not less than 110 percent of the product rated voltage.

2) For capacitors connected across the line (phase-to-phase) – Subclass X1 (≤ 4.0 kV) or X2 (≤ 2.5 kV) for impulse voltage (based on minimum Overvoltage Category of II).

3) For capacitors connected from line to ground – Subclass Y1 or Y2 for any product having a rated voltage not exceeding 500 volts; or as an alternate, subclass Y4 if a product has a rated voltage not exceeding 150 volts.

4) Upper category temperature – Based on the maximum capacitor surface temperature measured during the Temperature Test in Section 45, but not less than 185ºF (85ºC).

5) Lower category temperature – Based on the minimum surface temperature for which the capacitor has been designed to operate when installed within a product as intended, but not greater than 14ºF (-10ºC).

6) Duration of the damp-heat steady-state test – Not less than 21 days.

7) Passive flammability category B or C. As an alternate, a polymeric capacitor case shall have a V-0 flame rating as described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

16.7 *Deleted*

16.8 In reference to 16.3, motor start or run capacitor that does not comply with UL 810 shall:

a) Be housed within an enclosure or container that will reduce the risk of mechanical damage to the plates and the emission of flame or molten material resulting from breakdown of the capacitor;

b) Be provided with a metal capacitor container providing the strength and protection not less than that of uncoated steel having a thickness of 0.020 inch (0.51 mm); and

c) Be constructed to reduce the likelihood of expelling the dielectric medium under both normal and abnormal conditions of use.

16.9 In reference to 16.6, a capacitor shall consist of a single Class Y1 capacitor or two Class Y2 capacitors connected in series if it is connected between:

a) Two line conductors in a primary circuit;

b) One line conductor and the neutral conductor;

c) Primary and accessible secondary circuits; or

d) The primary circuit and protective earth (equipment grounding conductor connection).

17 Coil Windings

17.1 Windings of a motor, relay, transformer, and the like shall resist the absorption of moisture.

17.2 With regard to the requirement in 17.1, film-coated (magnet) wire is not required to be additionally treated to resist absorption of moisture, but fiber slot liners, cloth coil wrap, and similar moisture-absorptive materials shall be impregnated or otherwise treated to resist moisture absorption.

18 Printed-Wiring Boards

18.1 A printed-wiring board shall comply with the Standard for Printed-Wiring Boards, UL 796, including direct support criteria and shall be classed V-0, V-1, or V-2 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A printed-wiring board in a Class 2 nonsafety circuit is not required to comply with the bonding requirements in 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.

18.2 A resistor, a capacitor, an inductor, or other part that is mounted on a printed-wiring board to form a printed-circuit assembly shall:

a) Be secured so that it cannot be displaced by a force likely to be exerted on it during assembly, intended operation, or servicing; or

b) Be provided with a mechanical barrier or equivalent partition as part of the product to provide mechanical protection.

18.3 *Deleted*

19 Overcurrent Protection

19.1 A fuse and a fuseholder shall have voltage and current ratings that are for use in the circuit in which they are connected. A fuseholder shall be suitable for use with a cartridge fuse.

Exception: A plug fuse may be used in a circuit rated 125 volts or 125/250 volts, 3-wire, or less.

19.2 Fuses shall comply with the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; and the applicable UL 248 Part 2 (e.g. UL 248-5). Defined use fuses that comply with UL 248-1 and another appropriate UL standard for the fuse are considered to fulfill this requirement.

19.3 Fuseholders shall comply with the Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and the applicable Part 2 (e.g. UL 4248-9).

19.4 Circuit breakers shall comply with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception: Circuit breakers used in telecommunications circuitry that comply with the Standard for Circuit Breakers For Use in Communications Equipment, UL 489A, need not comply with UL 489.

19.5 Circuit breakers having integral ground fault circuit interrupter capability for protection against electrical shock shall additionally comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943.

19.6 Supplementary protectors shall comply with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077.

19.7 Fusing resistors shall comply with the Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television-Type Appliances, UL 1412.

19A General Purpose Transformer – Insulation Systems

19A.1 *Deleted*

19A.2 *Deleted*

Table 19A.1
Primary class A insulating materials and minimum thicknesses

Table 19A.1 relocated as Table 4A.1

19A.3 *Deleted*

19A.4 *Deleted*

19A.5 *Deleted*

20 Motors and Motor Overcurrent Protection

20.1 A motor shall be evaluated for the application and shall be capable of driving the maximum normal load of the product without introducing a risk of fire, electric shock, or injury to persons.

20.2 A brush-holder assembly shall be constructed so that when the brush is no longer capable of performing its function, the brush, spring, and other parts of the assembly are retained to the degree necessary not to cause:

a) Accessible dead metal parts to become energized and

b) Live parts to become accessible.

20.3 Each motor shall be provided with at least one of the following:

a) Thermal protection complying with the applicable requirements in the Standard for Thermally Protected Motors, UL 1004-3.

b) Impedance protection complying with the applicable requirements in the Standard for Motor-Operated Appliances, UL 73, when the motor is tested as used in the product under locked-rotor conditions.

c) Impedance protection complying with the Standard for Impedance Protected Motors, UL 1004-2.

d) Electronic protection complying with either the Standard for Electronically Protected Motors, UL 1004-7 or with the requirements in Section 13A, Switches and Controllers, applying to protective electronic circuits.

e) Other protection that is shown by tests to be equivalent to the protection mentioned in (a) – (d).

20.3.1 In reference to 20.3 (a) and (d), a motor that moves air by means of a fan that is not integrally attached, keyed, or otherwise fixed to the motor shaft shall be evaluated for running heating protection.

20.4 Motor-overload protection provided for a product not required to have such protection shall:

a) Comply with the requirements in 20.3.

b) Be shown by test not to result in a risk of fire, electric shock, or injury to persons.

20.5 Openings in a motor shall be arranged to prevent particles from falling out of the motor onto flammable material within or under the product.

21 Washing

21.1 A duct-type product provided with fixed means for washing the ionizer-collector frame assembly shall comply with the following:

a) The circuitry of a product having provision for automatic or manual washing means shall be interlocked so that the power pack will be de-energized while the system is being washed.

b) The primary circuit of a product shall be interlocked so that the blower-fan motor is de-energized while the system is being washed.

21.2 A duct-type product having fixed means for automatically or manually applying adhesive to the ionizer-collector frame assembly shall have the circuitry interlocked so that the power pack and blower-fan motor are de-energized while adhesive is being applied.

22 Filters

22.1 An air-cleaner filter together with any other materials, such as adhesives, mounting devices or other similar parts utilized as an integral part of the air filter and intended for use on a duct-type air cleaner shall comply with the Standard for Air Filter Units, UL 900.

22.2 An air-cleaner filter intended for use in a fixed-type product shall comply with 22.1 or with:

a) The separation of ignition sources from nonmetallic materials requirements as shown in Figure 6C.1; or

b) Table 51A.1 applying the flammability requirements for functional parts, if the filter is within 2 in. (50.8 mm) of but not underneath an ignition source.

22.2.1 An air-cleaner filter intended for use in a portable product shall comply with 22.1 or 22.2 or be located more than 2 in. (50.8 mm) away from and not underneath any ignition source.

22.3 An air-cleaner filter that is electrically charged by the product shall be tested as described in the Unenclosed High-Voltage Power Supply Test in 49.4.

23 Spacings

23.1 General

23.1.1 All uninsulated live parts connected to different line- or low-voltage circuits shall be spaced from one another as though they were parts of opposite polarity and shall be evaluated on the basis of the highest voltage involved.

23.1.2 The spacing at a field-wiring terminal is to be measured with wire of the size appropriate for the rating connected to the terminal as in actual service.

23.1.3 Wiring terminals are considered to be terminals to which connections are made in the field.

23.1.4 The spacings in a component device, such as a snap switch, a lampholder, a motor, and the like supplied as part of an air cleaner shall not be less than the minimum spacings required for the component device or the spacings specified in Table 23.1, whichever are smaller.

Table 23.1
Spacings in line-voltage circuits

Location involved	Voltage, AC	Minimum spacings			
		Through air,		Over surface,	
		inch	(mm)	inch	(mm)
Between field-wiring terminals of opposite polarity	0 – 150	1/4	(6.4)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
	301 – 600	3/8	(9.5)	1/2	(12.7)
Between uninsulated live parts of opposite polarity or between an uninsulated live part and a grounded part other than the cabinet or enclosure[a]	0 – 50	1/16	(1.6)	1/16	(1.6)[b]
	51 – 150	1/8	(3.2)	1/4	(6.4)[b]
	151 – 300	1/4	(6.4)	3/8	(9.5)[b]
	301 – 600	3/8	(9.5)	1/2	(12.7)
Between an uninsulated live part and the walls of the metal cabinet or enclosure, or other accessible dead metal part, including fittings for conduit or armored cable[c]	0 – 600	1/2	(12.7)	1/2	(12.7)

[a] In a portable product using a fractional horsepower motor rated 300 volts or less, the spacing through air or over surface may be 3/32 inch (2.4 mm) minimum; and if the motor rating does not exceed either 1/3 horsepower (250 watts output) or 150 volts, the spacings may be 1/16 inch minimum.

[b] For printed-wiring boards, see 23.3.1.

[c] A metal piece attached to the cabinet or enclosure is considered to be a part of the cabinet or enclosure if deformation of the cabinet or enclosure is likely to reduce spacings between the metal piece and uninsulated live parts.

23.1.5 Regarding spacing requirements, film-coated (magnet) wire is considered to be an uninsulated live part.

23.2 Low voltage and isolated-limited-energy circuits

23.2.1 Spacings between components of low-voltage and isolated-limited-energy circuits are not specified.

23.3 Line-voltage circuits

23.3.1 The spacings in a line-voltage circuit shall comply with one of the following:

a) Table 23.1;

b) For parts that are potted in an insulating compound, the through-air and over-surface spacings before potting shall be a minimum of 1/32 inch (0.8 mm). The insulating potting compound shall comply with the Material Property Considerations section in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

c) For a printed-wiring board:

1) The over-surface spacings shall not be less than 1/32 inch (0.8 mm) if the circuits are coated with a conformal coating complying with 23.3.1.1; or

2) The over-surface spacings other than to ground, between different circuits and at field wiring terminals are unspecified if:

i) The spacings comply with the Evaluation of Reduced Spacings on Printed-Wiring Boards, Section 48;

ii) The printed-wiring board has a flammability classification of V-0, in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and

iii) The printed wiring board is constructed from a base material having a minimum Comparative Tracking Index (CTI) Performance Level Category (PLC) rating of 2 in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

23.3.1.1 In reference to 23.3.1(c)(1) and 23.4.3(c), the conformal coating shall comply with the Conformal Coatings section in UL 746E, Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards.

23.3.2 *Deleted*

23.3.3 *Deleted*

23.3.4 *Deleted*

23.3.5 *Deleted*

23.4 High-voltage circuits

23.4.1 Spacings in high-voltage circuits shall comply with 23.4.2, 23.4.3, 23.4.4 or 23.4.5.

Table 23.2
Spacings for high-voltage parts

Voltage involved	Minimum spacings through air and over surfaces					
	Between uninsulated high-voltage parts				Between insulated high-voltage parts in the powerpack and filter cell,[a,b]	
	Power pack,		Filter cell,[a]			
	inches	(mm)	inches	(mm)	inches	(mm)
601 – 3000	3/4	(19.0)	1	(25.4)	1/2	(12.7)
3001 – 5000	1	(25.4)	1	(25.4)	1/2	(12.7)
5001 – 10,000	1-1/8	(28.6)	1	(25.4)	3/4	(19.0)
10,001 – 15,000	1-1/2	(38.1)	1	(25.4)	1	(25.4)
15,001 – 20,000	1-3/4	(44.5)	1-1/4	(31.8)	1-1/4	(31.8)
20,001 – 25,000	2	(50.8)	1-1/2	(38.1)	1-1/2	(38.1)

[a] Spacings within the active filter area may be less to permit proper functioning of the filter.

[b] This column also specifies the minimum through-air and over-surface spacings between insulated or uninsulated high-voltage parts and line-voltage, low-voltage or dead metal parts.

23.4.2 Spacings between the following parts shall comply with Table 23.2:

a) Insulated or uninsulated high-voltage parts and other insulated or uninsulated high-voltage parts of opposite polarity or different high-voltage circuits.

b) Insulated or uninsulated high-voltage parts and insulated or uninsulated line-voltage or low-voltage parts.

c) Insulated or uninsulated high-voltage parts and dead metal parts.

23.4.3 Insulated or uninsulated high-voltage parts shall comply with one of the following:

a) Be potted in an insulating compound such that the through-air and over-surface spacings before potting are a minimum of 1/32 inch (0.8 mm). The insulating potting compound shall comply with the High-Voltage Insulating Material Arcing Test, Section 51;

b) Be provided with an insulating barrier complying with Section 11.4;

c) Be provided with a conformal coating complying with 23.3.1.1; or

d) Be located on a printed wiring board:

1) In which the spacings comply with the Evaluation of Reduced Spacings on Printed-Wiring Boards, Section 48;

2) Having a flammability classification of V-0, in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and

3) Constructed from a base material having a minimum Comparative Tracking Index (CTI) Performance Level Category (PLC) rating of 1 in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

23.4.4 The spacings between insulated or uninsulated high-voltage parts and dead metal, other than the cabinet or enclosure, are not specified if:

a) The high-voltage power supply complies with 49.1.1 following the High-Voltage Spacings Short Circuit Test in 49.3.1; or,

b) Insulation on the high-voltage part complies with the High-Voltage Insulating Material Arcing Test, Section 51.

23.4.5 The spacings between high-voltage parts of opposite polarity or between high-voltage parts and dead metal parts, other than the cabinet or enclosure, are not specified if:

a) The parts have current levels complying with the Partially Protected Parts Test, Section 37; and

b) The insulating materials withstand the potentials specified in the Dielectric Voltage-Withstand Test, Section 46.

23.4.6 If a high-voltage circuit terminal is provided with an insulating cap, the spacing to the live part of the terminal shall be measured through the crevice where the surface of the cap abuts the remainder of the insulator.

23.5 Insulating barriers

23.5.1 *Deleted*

Table 23.3
Insulating barriers for high-voltage circuits

Table 23.3 relocated as Table 11.1

23.6 Alternate spacings – clearances and creepage distances

23.6.1 Except as specified in 23.6.2, the spacings requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are applicable as an alternative to the specified spacings requirements in the following:

a) Line-voltage circuits, 23.1 and 23.3; and

b) Low voltage and isolated-limited-energy circuits, 23.2.

23.6.2 The spacings requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840 shall not be used for spacings between field wiring terminals or between uninsulated live parts and a metal cabinet or enclosure.

23.6.3 (a) – (g) shall be considered when evaluating a product to the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840:

a) Hermetically sealed or encapsulated enclosures are identified as pollution degree 1.

b) Coated printed wiring boards are identified as pollution degree 1 if they comply with one of the following:

1) Printed wiring board coating performance test of UL 840; or

2) Conformal coating requirements as outlined in the Standard for Polymeric Materials–Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

c) Any areas not in contact with the airstream within an indoor use product are identified as pollution degree 2 unless they comply with (a) or (b).

d) Any areas in contact with the airstream within an indoor use product are identified as pollution degree 3 unless they comply with (a) or (b).

e) All areas of an outdoor use product are identified as pollution degree 3 unless they comply with (a) or (b).

f) Category II is the overvoltage category.

g) Printed wiring boards are considered as having a minimum comparative tracking index (CTI) of 100 unless further investigated for a higher CTI index.

23.6.4 Clearance B (Controlled Overvoltage) clearances as specified in Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840 shall be achieved by providing an overvoltage device or system as an integral part of the product.

24 Separation of Circuits

24.1 General

24.1.1 Unless provided with insulation rated for the highest voltage involved, factory-installed insulated conductors of different circuits shall be spaced as specified in Table 23.2, or separated by insulating or mechanical barriers. In any case, the conductors shall be segregated (see 24.1.2) from uninsulated live parts of a different circuit.

24.1.2 Segregation of insulated conductors may be accomplished by clamping, routing, or means that have been determined to be equivalent to maintain separation from insulated or uninsulated live parts of a different circuit.

24.1.3 *Deleted*

24.2 Class 2 circuits

24.2.1 The output of a transformer supplying a Class 2, low-voltage circuit and provided as a part of the equipment shall not be interconnected with the output of another such transformer. Each transformer shall be treated as a separate circuit, with each having its own separate wiring compartment. The output of each circuit shall be marked to warn that the separation shall be maintained.

Exception: The output of two or more transformers supplying a Class 2, low-voltage circuit provided as part of the equipment may be interconnected if the voltage and current measurements at the output terminals are within the values for a single Class 2, 30-volt, or less, transformer.

24.3 Permanently-connected products

24.3.1 Except as specified in 24.3.1.1, the product shall be constructed so that a field-installed conductor of any circuit shall be segregated or separated by barriers from:

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

b) Uninsulated live parts of any other circuit of the device; and

c) Field-installed conductors connected to any other circuit.

24.3.1.1 In reference to 24.3.1, if field-installed conductors contact low-voltage wiring terminals, any short-circuiting to such terminals that could occur shall not result in a risk of fire or electric shock.

24.3.2 In reference to 24.3.1, if field-installed conductors are segregated from other field-installed or factory-installed conductors and from uninsulated live parts of the product connected to different circuits, openings in the enclosure for the various conductors shall be located so that a minimum separation of 1/4 inch (6.4 mm) can be maintained between the field-installed conductors and any other field or factory-installed conductors or uninsulated live parts.

24.3.3 It is to be assumed, for the purpose of determining compliance with 24.3.1, that the conductors entering each opening of the enclosure will be connected to the terminals opposite the opening if:

a) The number of openings in the enclosure does not exceed the minimum required for the proper wiring of the device and

b) Each opening is located opposite a set of terminals.

Exception: More than the minimum number of openings may be provided if the following items have been investigated:

a) The possibility of conductors entering other points that are not opposite the terminals to which they are intended to be connected and

b) The possibility of contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit.

24.3.4 To determine if a product complies with the requirement in 24.3.1, it is to be wired as it would be in service. A reasonable amount of slack is to be left in each conductor, within the enclosure, and no more than average care is to be exercised in stowing this slack into the wiring compartment.

PROTECTION AGAINST INJURY TO PERSONS

25 General

25.1 A cabinet, an enclosure, an opening, a frame, a guard, a knob, a handle, or the like shall not be sufficiently sharp to cause a risk of injury to persons in normal maintenance or use.

25.2 If the breakage or damage of a part such as a cabinet, an enclosure, a frame, a guard, or the like may result in a risk of injury to persons, the part shall comply with the Impact Test, Section 28.

25.3 The requirements in 25.2 apply to those portions of a part adjacent to a moving part or an exposed live part considered to present a risk of injury to persons.

26 Rotating Parts

26.1 A rotating member shall be constructed and made of materials having the necessary strength to reduce the likelihood of breakage or its release, or loosening of a part that could cause injury to persons.

26.2 A rotating part shall be assembled:

a) So that the direction of rotation tends to tighten the means that holds the rotating part in place or

b) Using a keyed nut or a nut locked in place with a pin or other positive means.

27 Enclosures and Guards

27.1 Each moving part that can cause injury to persons shall be enclosed or guarded.

Exception: A moving part that can cause injury to persons that is necessarily exposed to perform the work function need not be enclosed or guarded. See 27.2.

27.2 Among the factors to be considered in evaluating the acceptability of an exposed moving part are:

a) Degree of exposure necessary to perform its intended function,

b) Sharpness of the moving part,

c) Likelihood of unintentional contact therewith,

d) Speed of the moving part, and

e) Likelihood that a part of the body would be endangered or that clothing would be entangled by the moving part.

These factors are to be considered with respect to both intended operation of the product and its reasonably foreseeable misuses.

28 Impact Test

28.1 A part as mentioned in 25.2 shall withstand the impact test described in 28.2, 28.3 and 28.5 to the extent that:

a) A moving part involving a risk of injury to persons or an exposed live part cannot be contacted by the probes illustrated in Figure 7.2 or Figure 7.3 for ceiling mounted appliances and

b) The appliance complies with the Dielectric Voltage-Withstand Test, Section 46.

28.2 A smooth steel sphere, 2 inches (51 mm) in diameter and weighing approximately 1.18 pounds (535 g), is to fall vertically from rest through a distance of 51 inches (1.3 m) to strike the part being tested. For a part not able to be struck from above by the free-falling sphere, the sphere is to be suspended by a cord and swung as a pendulum through a vertical distance of 51 inches. A guard for an air cleaner that is intended to be ceiling-mounted is to be subjected to an impact of 1.5 foot-pounds (6.7 N). The sphere is to be dropped from a height of 15 inches (381 mm) or is to be swung as a pendulum dropping through a vertical distance of 15 inches.

28.3 If nonmetallic material is used for a part as mentioned in 25.2, the impact test is to be performed on a sample in the as-received condition. The test is then to be repeated on another sample that has cooled to room temperature after being conditioned for 7 hours in an air oven at uniform temperature not less than 10°C (18°F) higher than the maximum operating temperature of the material measured under intended operating conditions, but not less than 70°C (158°F).

28.4 Upon removal from the oven mentioned in

28.3 and before being subjected to the impact test, the samples shall not show checking, cracking or other deleterious effects from the oven conditioning. Also, the samples shall not show distortion sufficient to impair the intended operation of the product.

28.5 A nonmetallic part used in accordance with 25.2 and intended for outdoor use shall additionally be cooled to a temperature of minus 35 ±2°C (minus 31 ±4°F) and maintained at this temperature for 3 hours. While the unit is still cold, the samples shall be subjected to the impact tests described in 28.1 and 28.2.

29 Interlocks

29.1 Switches

29.1.1 *Deleted*

29.1.2 *Deleted*

29.2 Interlocks

29.2.1 A moving part that could cause injury to a person is considered to be guarded if protected by a cover with an interlock that complies with one of the following conditions:

a) The part stops moving within 3 seconds after the cover is opened or

b) The interlock prevents the cover from being opened until the part stops moving.

29.2.2 Operation of an interlock in normal use shall not inconvenience the operator so as to encourage deliberate defeat of the interlock.

29.2.3 An interlock shall be located so that unintentional operation is unlikely. The interlock shall not be readily defeatable without damaging the product, or without making wiring connections or alterations.

29.2.4 An interlock that is required to reduce a risk of electric shock or injury to persons shall:

a) Withstand 100,000 cycles of operation controlling a load not less than that controlled in the air cleaner, and shall function normally upon completion of the test; or,

b) Comply with the protective control requirements in Section 13A, Switches and Controllers.

29.2.5 An interlock that is required to reduce the risk of electric shock shall open:

a) All supply conductors; or;

b) The ungrounded conductors if the unit is permanently connected to the electrical supply source.

30 Electronic Circuits

30.1 Ozone monitoring circuitry shall not be user-defeatable or user-adjustable.

31 Stability

31.1 A portable product shall not overturn when tipped through an angle of 10 degrees from the horizontal as described in 31.2.

31.2 The product is not to be energized during the test mentioned in 31.1. The test is to be conducted under conditions most likely to cause the product to overturn. The following conditions of the test are to result in the least stability:

a) The position of all doors, drawers, casters, and other movable or adjustable parts, including that of a supply cord, if any, resting on the surface supporting the air cleaner;

b) Connection of or omission of any attachment made available by or recommended by the manufacturer; and

c) Direction in which the product is tipped.

32 Collector Handle Securement Test

32.1 A handle used to remove air cleaner collector cells shall:

a) Withstand a force of four times the weight of the cell without breakage of the handle, its securing means, or that portion of the cabinet to which the handle is attached; or

b) Be used only on collector cells provided as part of a portable household product.

32.2 To determine if a handle complies with the requirements in 32.1, the force is to be started at zero and gradually increased so that the force specified in 32.1 is attained in 5 to 10 seconds and maintained for 1 minute. When the handle is 76.2 mm (3 inches) or more in width, the force is to be uniformly distributed over a 76.2 mm width at the center of the handle without clamping. When the width is less than 76.2 mm, the force is to be distributed over the entire handle. When more than one handle is furnished on a cell and the cell cannot be lifted by only one handle, the force is to be distributed between the handles. The distribution of forces is to be determined by measuring the percentage of the cell weight sustained by each handle with the cell in the intended lifting position. When a cell is furnished with more than one handle and can be carried by only one handle, each handle is to sustain the total force.

33 External Surface Temperatures

33.1 During the Temperature Test, Section 45, the temperature of a surface that may be contacted by the user shall not exceed the value specified in Table 33.1. If the test is to be conducted at a room temperature other than 25°C (77°F), the results are to be corrected to that temperature.

Table 33.1
Maximum surface temperatures

Type of surface	Composition of surface[a]	
	Metallic	Nonmetallic
Handle or knob that is grasped for lifting, carrying or holding	50°C (122°F)	60°C (140°F)
Handle or knob that is contacted but does not involve lifting, carrying, or holding and other surfaces subject to contact in operation and user maintenance	60°C (140°F)	85°C (185°F)

[a] A handle, knob, or the like made of a material other than metal, that is plated or clad with metal having a thickness of 0.005 inch (0.13 mm) or less is to be evaluated as a nonmetallic part.

33A Battery Operated Air Cleaners

33A.1 General

33A.1.1 Battery operated portable air cleaners intended for household use only shall comply with the applicable requirements (see Section 4, 4A.1 – 4A.4, 4A.2, 4A.4 – 4A.12, 4A.14, 5, 6.1 – 6.2, 6.4, 6A – 6C, 7, 8, 9, 10, 11, 13A, 13B, 15, 17, 18, 19.1 – 19.3, 19.6 – 19.7, 20.1 – 20.2, 22, 23.4, 24.1 – 24.2, 25, 26, 27, 28, 30, 32, 37, 38, 39, 40, 45.1, 45.5.1, 46, 46A, 46B, 47, 48, 49, 49A – 49C, 50, 51, 51A – 51C, 52, 56.9, 57 – 59) in this Standard and the requirements in this Section. The requirements in this Section

supplement and, in some cases, modify the general requirements in this Standard. These requirements apply only to those air cleaners provided with or intended for use with rechargeable batteries but do not apply to button or coin cell batteries as specified in 4A.12.

33A.1.2 These requirements do not cover appliances with user replaceable battery cells, see 3.9 of the Standard for General Requirements for Battery-Powered Appliances, UL 2595. Replaceable batteries shall be in the form of a battery pack per UL 2595.

33A.1.3 The battery system shall comply with the requirements of the Standard for General Requirements for Battery-Powered Appliances, UL 2595.

33A.1.4 The indents of Annex D of the Standard for General Requirements for Battery-Powered Appliances, UL 2595, as shown in Table 33A.1.

Table 33A.1
UL 2595 Indents

Indent	UL 2595 reference	Instructions
Indent A	4	These requirements supplement the requirements of UL 867
Indent B	3.26	Only air cleaners intended for outdoor use assume the user may be wet during use.
Indent C	4.1, 4.2	Appliances for use and marked “Use Indoors” are considered Low Temperature (LT = 0°C) Appliances for use outdoors are considered Extra-Low Temperature (ELT = -35°C)
Indent D	9.2	Refer to UL 2595
Indent E	9.4	UL 2595 test conditions shall consider operating modes, including air filter, fan operating speeds, emitters/ionizers, UV lamps, or other special features, whichever is more severe temperature, for the battery system. The air intake is restricted to any level between 0-50 percent of overall air intake area, whichever results in maximum input current. See 45.1.1 and 45.5.1 of UL 867.
Indent F	11.1.3	UL 2595 test conditions shall consider highest and lowest speed, whichever is more severe, for the battery system. Additional test conditions shall consider restricted air inlet, blocked air outlet and overvoltage condition using low voltage supply source at 1.3 times of rated voltage and minimum 8 amperes. See 49.6 and 49.7 of UL 867.
Indent G	Table 11.1	UL 2595 test conditions shall consider highest and lowest speed, whichever is more severe, for the battery system. The additional or alternative Safety Critical Functions (SCFs) are specified in Table 33A.2. If the safety of the electronic control circuit has been evaluated in accordance with the functional safety requirements in UL 2595, then the safety of the electronic circuit complies with the requirements in this Standard.
Indent H	15.3	For indoor products, the drop height of 15.2(a) shall be 3 ft (914 mm) on the hard wood floor. For outdoor products, the drop height of 15.2(a) shall be 3 ft (914 mm) on concrete.
Indent I	18.5	Not applicable – Refer to UL 867.
Indent J	22.1	Not applicable except for 22.4 – 22.6 – Refer to UL 867. For protective impedance of high voltage circuit, refer to 22.4 – 22.6 in this standard for evaluation.

Table 33A.1 Continued on Next Page

Table 33A.1 Continued

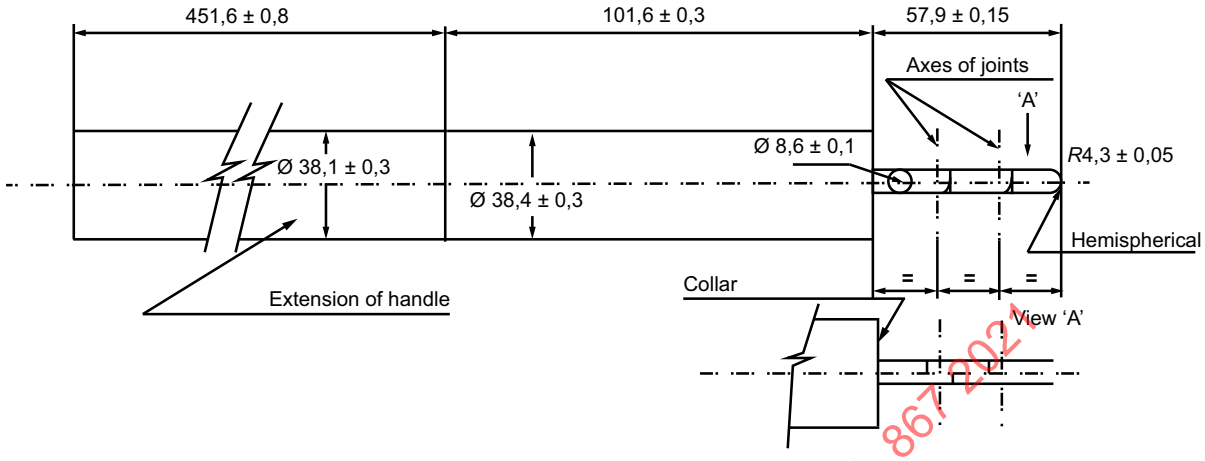
Indent	UL 2595 reference	Instructions
Indent K	8.4	Additionally, probes employed in the end-product standard to evaluate accessibility for risk of electric shock and injury are to be applied to the end product, but not to detachable or separable battery pack. Detachable or separable battery packs shall be additionally tested as the following: Test probe 18 of IEC 61032 in Figure 33A.1 is applied with a force not exceeding 0.22 lbf (1 N), the battery pack being in every possible position, except that battery packs normally used on the floor and having a mass exceeding 40 kg (88 lbs) are not tilted. The test probe is applied through openings to any depth that the probe will permit and is rotated or angled before, during and after insertion to any position. If the opening does not allow the entry of the probe, the force on the probe in the straight position is increased to 2.2 lbf (10 N). If the probe then enters the opening, the test is repeated with the probe in the angled position. During the tests, the battery pack shall be fully assembled as in normal use without any parts removed.
Indent L	20.1	a) Refer to Table 20.1 for voltage within 250 V. *Exception: Smaller creepage distances in the appliance are permitted in accordance with spacings for equivalent AC voltages specified in UL 867. These smaller creepage distances do not apply to detachable or separable battery packs.* b) For voltage above 250 V, refer to spacings, Section 23 of UL 867.

Table 33A.2
Additional safety-critical functions for battery-operated appliances

Type and Purpose of SCF	Minimum Performance Level (PL)
Operates motors, solenoids or similar components used to retain doors or panels in the closed position if the doors or panels provide protection of:	
a) uninsulated live parts, film-coated wire or moving parts capable of causing injury in accordance with Section 7; or	b
b) moving parts capable of causing injury in accordance with Section 27; or	b
c) thermally hot parts in accordance with Sections 33 and 45.	a
Prevents motor overload (over-temperature or overcurrent) as required by Sections 20.	b
Ozone-monitoring circuitry in which the circuitry is relied upon to limit the ozone in accordance with 40.1.6.	b
Prevents automatic restarting after operation of a protective circuit which de-energizes the product (or part of the product) where there is a risk of injury due to moving parts.	b
Regulates motor speed and is combined with a motor overload or motor protective control.	b
Limits temperatures within the product during abnormal conditions or under conditions not intended for the normal operation of the product in accordance with Section 49.	b
Limits pressure in a vessel.	c

Figure 33A.1

Probe 18 of IEC 61032



su4180

Dimensions in millimetres

– Finger: metal material

– Handle: insulating material

The extension of the handle represents the arm of the child.

The handle is provided with an extension 451.6 mm long, and the probe should be applied with or without this extension, whichever is the more onerous condition.

Both joints shall permit movement in the same plane and the same direction through an angle of 90°.

PERFORMANCE

34 General

34.1 The performance of the product shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Sections 35 – 51. The tests shall be performed in the order presented (or as close as is practical). A sample employed for the Leakage-Current Test, Section 35, shall be tested for leakage current prior to being used for other tests.

34.2 Unless otherwise indicated, the tests are to be conducted at rated frequency and at the voltage specified in Table 34.1.

Table 34.1
Voltages for tests

Voltage rating of product	Test potential, volts
110 – 120	120
220 – 240	240
254 – 277	277
440 – 480	480
550 – 600	600

35 Leakage Current Test

35.1 General

35.1.1 All exposed conductive surfaces of cord-connected products 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 if simultaneously accessible and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by a cabinet or enclosure that reduces the risk of electric shock, as described in Accessibility of Uninsulated Live Parts and Moving Parts, Section 7. 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.

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

35.1.3 If the product has a direct-current rating, measurements are to be made with the product connected in turn to each side of a 3-wire, direct-current supply circuit.

35.2 Normal use

35.2.1 For a product rated 250 volts or less, the leakage current at any accessible part shall not be more than 0.5 milliampere when tested in accordance with 35.2.2 – 35.2.4 if the open-circuit potential between the accessible part and earth ground or any other accessible part is more than:

a) 42.4 volts peak for an indoor product or where wet contact is not likely to occur and

b) 21.1 volts peak for an outdoor product and where wet contact is likely to occur.

35.2.2 The measurement circuit for the leakage-current test is to be as illustrated in Figure 35.1. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need

only indicate the same numerical value for the particular measurement as would the defined instrument. The meter used need not have all of the attributes of the defined instrument.

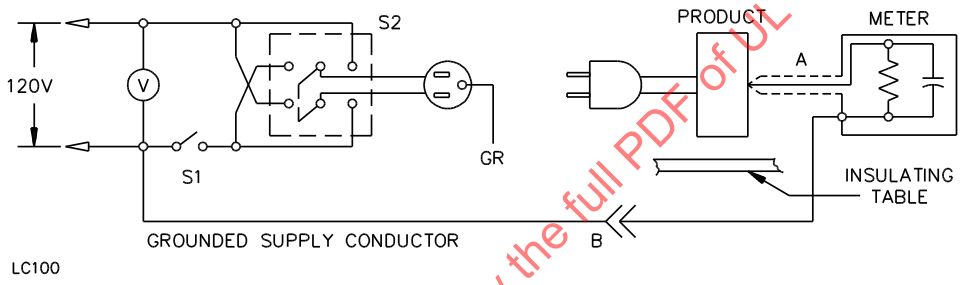
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

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

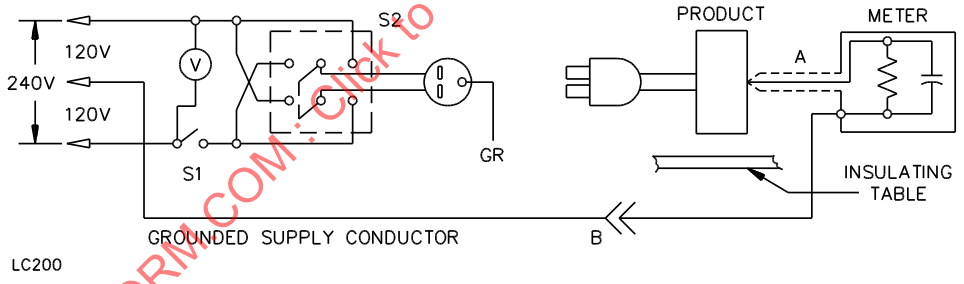
c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 milliampere, the measurement is to have an error of not more than 5 percent at 60 hertz.

Figure 35.1

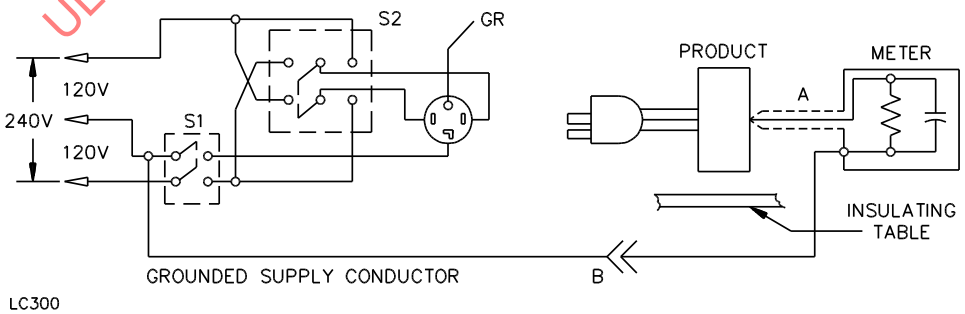
Leakage current measurement circuit



Product intended for connection to a 120-volt power supply



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.

A – Probe with shielded lead.

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

35.2.3 Unless it is being used to measure leakage from one part of a product to another, the meter is to be connected between an accessible part and the grounded supply conductor.

35.2.4 A sample of the product is to be tested for leakage current first in the as-received condition with all switches and thermostats closed. The grounding conductor, if any, is to be open at the attachment plug. The as-received condition is without prior energization except for what may occur as part of the production-line testing. The supply voltage is to be 120 or 240 volts, as applicable. The test sequence, with reference to the measuring circuit in Figure 35.1, is to be as follows:

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

b) Switch S1 is then to be closed, energizing the product. Within five seconds, the leakage current is to be measured using both positions of switch S2, and with the switching devices of the product in 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 described in the Temperature Test, Section 45.

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

36 Leakage Current Following Humidity Conditioning

36.1 A product shall comply with the requirements for leakage current in 35.2.1, following exposure for 48 hours to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).

36.2 To determine whether a product complies with the requirement in 36.2, a sample of the product is to be heated to a temperature just above 34°C (93°F) to reduce the likelihood of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and conditioned for 48 hours under the conditions specified in 36.1. Following the conditioning, the sample is to be tested unenergized as described in 35.2.4(a). The sample is then to be energized and tested as described in 35.2.4 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

37 Partially Protected Parts

37.1 The following requirement applies to a product rated 250 volts or less. The continuous current flow through a 500-ohm resistor connected between any part exposed only during user servicing and earth ground or any other accessible part shall not be more than the applicable value specified in Table 37.1. However, this value only applies if the open-circuit potential between the part and earth ground or any other accessible part is more than:

a) 42.4 volts peak for an indoor product or where wet contact is not likely to occur,

b) 21.2 volts peak for an outdoor product and where wet contact is likely to occur.

See 35.1.1 – 35.1.3.

Table 37.1
Partially protected part available current

Frequency, hertz[a,b]	Maximum current, milliamperes peak
0 – 100	7.1
500	9.4
1000	11.0
2000	14.1
3000	17.3
4000	19.6
5000	22.0
6000	25.1
7000 or more	27.5

[a] Linear interpolation between adjacent values may be used to determine the maximum current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

[b] For a composite current (combination of a continuous direct current and alternating current) the frequency is based on the alternating current of the combination waveform. The composite waveform is not to exceed 27.5 milliamperes.

37.2 The measurements of the available current of partially protected parts are to be made under the following conditions:

a) With any operating control, or adjustable control that is considered subject to user operation, in all possible positions of contact.

b) Either with or without cells, separable connectors, and similar devices in place.

c) For each loading condition specified in 38.2.

d) A secondary or resonating winding shunted by a capacitance is to be tested with and without the capacitance.

e) Each output terminal in turn is to be loaded to ground with wire-wound resistors, or a triode vacuum tube, varying from open circuit to short circuit in order to simulate loading conditions. Resistors, capacitors, diodes, and other solid-state components are in turn to be short-circuited or open-circuited.

Exception No. 1: A current-limiting resistor within the power supply that does not exceed 70°C (126°F) during the normal temperature test specified in the Temperature Test, Section 45, is not to be short- or open-circuited.

Exception No. 2: The available current need not be measured if a circuit protector, such as a fuse or circuit breaker, opens the circuit within 1 second of energization of the unit.

38 Input Test

38.1 The current or volt-ampere input to the product under any normal operating condition shall not exceed 110 percent of the marked rating.

38.2 To determine whether the power pack complies with the requirement in 38.1, the current and power input is to be measured while the equipment is operated at the secondary voltage and current settings that result in maximum input for each of the following conditions, when applicable to the unit:

a) Variable resistance connected from positive to negative output terminal and adjusted from open to short circuit.

b) Variable resistance connected from positive output terminal to ground, negative terminal open-circuited, resistance varied from open to short circuit.

c) As specified in (b) except negative terminal short-circuited to ground.

d) Variable resistance connected from negative output terminal to ground, positive terminal open-circuited, resistance varied from open to short circuit.

e) As specified in (d) except positive terminal short-circuited to ground.

38.3 A product intended for connection to a low-voltage supply source (such as by a USB type connector) shall be connected to a supply circuit using a test voltage that is 16.7 percent higher than the product rated voltage and capable of supplying a minimum 8 amperes at that test voltage. The product shall comply with 38.1.

39 Output Test

39.1 When the high-voltage circuit is delivering its rated load, the secondary-output voltage shall not be greater than 110 percent of the rated value.

39.2 The secondary-output voltage under all conditions of operation up to and including open-circuit shall be determined. The values obtained shall be used in determining the spacings required and the voltages to be employed during the Dielectric Voltage-Withstand Test, Section 46.

40 Ozone Test

40.1 General

40.1.1 Two samples of the product shall be supplied for testing. The test described in 40.2 – 40.4 shall be conducted on:

a) One sample, if the measured maximum ozone concentration is less than 0.030 parts per million; or

b) A second sample, if the measured maximum ozone level from the first sample tested is 0.030 ppm or more.

40.1.2 When tested as described in 40.2 – 40.4, a portable air cleaning product for household use shall not produce a concentration of ozone that exceeds:

a) 0.050 parts per million (ppm) by volume; or

b) 0.100 ppm by volume if the average of any five consecutive one minute average measurements are less than 0.050 ppm.

40.1.3 A product shall be tested in accordance with 40.2 – 40.4 under the most severe conditions for generating the maximum amount of ozone, taking into account all intended operating modes of the product. These conditions shall include the following:

a) High fan speed;

b) Low fan speed; and,

c) Any other operating conditions that could include, but are not limited to: fan(s) inoperative, emitters(s)/ionizer(s) on, UV lamps on or other special features activated or inactivated.

40.1.4 In reference to 40.1.3, the testing in 40.2 – 40.4 shall include the product operating with:

a) Only one operating mode occurring at a time if the product is intended to operate in this manner; or

b) Multiple operating modes occurring simultaneously if simultaneous operation of the product in different modes is intended and testing the product in multiple operating modes represents the most severe condition(s) for maximizing ozone emission.

c) All air filter(s) removed unless an interlock switch causes ozone production to stop if the air filter(s) are removed, as specified in 40.1.5.

40.1.5 In reference to 40.1.4(c), for a product having an interlock switch causing ozone production to decrease or stop if an air filter is removed:

a) The testing in 40.2 – 40.4 shall be conducted with the interlock switch bypassed; or

b) The interlock switch shall comply with Section 29, Interlocks, and the operating instructions of the product shall specify the intended filter(s), including replacement filters, in accordance with 59.10.

40.1.6 If ozone-monitoring circuitry is provided as part of the product, the test described in 40.2 – 40.4 shall be conducted with the circuitry bypassed unless the circuitry complies with the protective control requirements in Section 13A, Switches and Controllers.

40.2 Chamber specifications

40.2.1 The test is to be conducted in a chamber having a volume of 950 – 1100 cubic feet (26.9 – 31.1 m^3) with a minimum side dimension of 8 feet (2.4 m) and a maximum height dimension of 10 feet (3.0 m) without openings. The test chamber walls, ceiling, and floor are to be surface treated (polished) stainless steel or other nonporous and non-reactive material. The suitability of chamber materials shall be validated by the half-life procedure of 40.2.3.

40.2.2 The following test chamber criteria shall be met:

a) The test chamber shall be sufficiently airtight to avoid uncontrolled air exchange. The chamber is considered sufficiently airtight if at least one of the following requirements is fulfilled:

1) the air leakage is less than 0.5 percent of the chamber volume per minute at an overpressure of 1000 Pa;

2) the air leakage is less than 5 percent of the supply airflow rate when investigated per the Airtightness – Pressurization or Tracer Gas Method of the Standard Practice for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products, ASTM D6670, static condition, at a pressure differential of 10 PA.

b) The test chamber shall have proper mixing verified via the mixing procedure of the Standard Practice for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products, ASTM D6670, Sections titled Air Distribution in the Chamber and Air-Mixing in a Chamber, and shall not create local airflow across the surface of the product under test exceeding 0.1 m/s.

c) The test chamber supply air system shall be equipped with sufficient carbon and HEPA media to remove particles, reactive VOCs, and ozone.

40.2.3 Performance of the test chamber shall be verified prior to each test and after any modification or cleaning through:

a) Determination of the chamber ozone half-life at 0 forced air changes,

b) Calculation of the chamber deposition velocity under these conditions using the equation defined in 40.2.4,

c) Calculation of the air exchange rate necessary to maintain an overall chamber ozone removal rate (Napparent) value of 1.33 using the equation defined in 40.2.5,

d) Verification of the chamber ozone half-life of 31 ±2 minutes under the air exchange rate calculated in c), and if necessary, adjustment of the air exchange rate to achieve an ozone half-life of 31 ±2 minutes, repeating the verification as needed after adjustment of the air exchange rate.

The chamber ozone half-life is determined using an initial steady state concentration of 0.100 to 0.200 ppm ozone. For the purpose of this measurement, steady state is defined as a fluctuation not greater than ± 10 percent or 0.0020 ppm, whichever is greater, during a fifteen minute period.

Exception: If the chamber has initially demonstrated compliance with the requirements of steps a) through d), and with step d) in three or more consecutive tests over a two-day minimum time frame, only step d) need be repeated immediately prior to the testing of each model. However, steps a) through d) and three or more consecutive step d) tests shall be repeated, at a minimum, bi-annually or after any chamber modification or maintenance activities.

40.2.4 The chamber deposition velocity (Vd) is defined by the following equation:

$$Vd = \left[\left(\frac{Ln \frac{C(t)}{C(0)}}{-t_{1/2}} \right) - AER \right] * \left(\frac{4}{A / V} \right)$$

in which:

Vd = Deposition Velocity (m/h)

C(t) = Ending Ozone Concentration

C(0) = Initial Ozone Concentration

$t_{1/2}$ *= Chamber Half-Life (h)*

AER = Air Exchange Rate (1/h) = 0

A/V = Chamber Surface Area to Volume Ration (m^2/m^3)

40.2.5 The air exchange rate necessary to maintain an overall chamber ozone removal rate (Napparent) value of 1.33 is defined by the following equation:

$$AER = Napp - Vd * A / V$$

in which:

AER = Air Exchange Rate (1/h)

Napp = Napparent (1/h) = 1.33

Vd = Deposition Velocity (m/h) = Value determined in 40.2.3 and 40.2.4

A/V = Surface Area to Volume Ratio (m^2/m^3)

The chamber air exchange rate is defined as the ratio of the volume of clean air brought into the chamber per hour to the unloaded chamber volume.

40.3 Equipment specifications

40.3.1 Ozone analysis equipment shall meet the following criteria:

a) Ranges of 0.02, 0.04, 0.1, 0.2, and 0.4 mg/m^3 on the full scale (or have auto ranging capability);

b) The capability to detect 4 $\mu g/m^3$ or lower concentration;

c) A precision of ± 2 percent from the mean value in the 0 mg/m^3 to 0.2 mg/m^3 range (i.e. 2 $\mu g/m^3$ or 1 percent on the full scale);

d) A sampling rate of not less often than once every 60 seconds;

e) A sampling line of minimum length, not to exceed 13 feet (4 m), made of a flexible material that is inert, such as PTFE.

To prevent impact on the test, the ozone analysis equipment shall be placed outside of the chamber.

40.4 Test method

40.4.1 Prior to testing, the location of the peak ozone emission on a product shall be determined in accordance with 40.4.1.1 – 40.4.1.6.

40.4.1.1 The product shall be located in accordance with 40.4.4 and:

a) Within the test chamber specified in 40.2; or,

b) In an area where the local airflow across the surface of the product is not greater than 4 inches/s (0.1 m/s) and which has minimum dimensions of 10 feet (3 m) per side and not less than 8 feet (2.4 m) high.

40.4.1.2 The air stream discharge area shall be determined by measuring the air stream in a plane parallel to and 2 inches (50.8 mm) from the surface of the product air discharge grille. Each ozone sampling point shall be along this plane.

40.4.1.3 The location and number of ozone sampling points for a product shall be determined based on the discharge area of the air stream as follows:

a) One ozone sampling point shall be allotted for and be directly in line with each ozone generating source.

b) One ozone sampling point shall be located in the geometric center of the air stream discharge area with additional ozone sampling points provided based on the overall area of the air stream discharge of the product as follows:

1) For an air stream discharge area less than 16 in^2 (103 cm^2) – minimum of 4 sampling points.

2) For an air stream discharge area equal to or greater than 16 in^2 (103 cm^2) – minimum of 8 sampling points.

40.4.1.4 For the sampling points specified in 40.4.1.3 (b)(1) and (2), the air stream discharge shall be divided into equal sized zones so that the number of ozone sampling points equals the number of zones. The ozone sampling point shall be located in the geometric center of each zone.

40.4.1.5 The product shall be subjected to a 48 hour run-in period. Run-in and determining the location of peak ozone emission shall be conducted with the room at a controlled temperature in the range of 77 ±9°F (25 ±5°C) and a supply of filtered air.

40.4.1.6 At the completion of the run-in period, the location of peak ozone emission shall be determined by measuring the emission of ozone at each sampling point for a minimum of 2 minutes. The ozone sampling device shall point directly into the air stream. Ozone values shall be allowed to stabilize between measurements.

40.4.1.7 The tests in 40.4.2 – 40.4.6 shall be conducted on a product to determine compliance with 40.1.2.

40.4.2 During the test, the test chamber is to be maintained at a temperature of 25 ±2°C (77 ±4°F) and a relative humidity of 50 ±5 percent.

40.4.3 Prior to the start of each test, the ozone background level is to be measured with the product off. The background level shall be subtracted from the maximum measurement during the test. With respect to determining background level, the following measurement criteria shall be applied:

a) The ozone background measurement shall not exceed 0.005 ppm at steady state. Measurements above this value may interfere with emissions determinations.

b) Background measurements within the chamber shall be taken immediately prior to testing of the product.

For the purpose of this measurement, steady state is defined as a fluctuation not greater than ± 10 percent or 0.0020 ppm, whichever is greater, during a fifteen minute period.

40.4.4 The product is to be located in the center of the test chamber floor and

a) 30 inches (762 mm) above the floor for table-mounted products.

b) on the floor for floor mounted or supported products.

c) attached to the ceiling or other horizontal non-reactive surface at a minimum height of 30 inches for ceiling-mounted products.

d) attached to a non-reactive vertical surface at a minimum height of 30 inches for wall-mounted products.

40.4.5 A single ozone monitor sampling tube is to be positioned with the sample tube opening located 2 inches (50 mm) from the air outlet of the product and at the sampling point that provides the peak ozone emission as determined by 40.4.1 – 40.4.1.6. The sample tube is to point directly into the air stream.

40.4.6 To determine the concentration of ozone, the ozone emission is to be monitored for not less than:

a) 24 hours; or

b) 8 hours if the measured ozone concentration when plotted against time between the 7th and 8th hour of monitoring has:

1) A negative or zero slope and fluctuation not greater than ±10 percent or 2 parts per billion (ppb) around the mean, whichever is greater;

2) A positive slope with the mean ozone concentration of less than 20 ppb and fluctuation not greater than ±2 ppb around the mean; or,

3) A positive slope with the mean ozone concentration greater than or equal to 20 ppb and less than 38 ppb and with a normalized slope (slope divided by hourly mean) that is less than or equal to 0.0153 ppb/hr per mean ppb, and fluctuation not greater than ±10 percent around the mean.

40.4.7 *Deleted*

Figure 40.1

Filter Test Iterations Flow Chart

Figure deleted

40.4.8 *Deleted*

40.4.9 *Deleted*

40.4.10 *Deleted*

40.4.11 *Deleted*

41 Peak Ozone Emission Location Determination

Section 41 deleted

42 Strain Relief Test

42.1 For a product tested in accordance with 42.1.1 – 42.5, there shall be no movement of the cord or wiring leads to indicate that stress would be transmitted to internal connections or wiring.

42.1.1 If a strain relief is connected to or integral with a nonmetallic part, one complete sample of the nonmetallic part is to be placed in a full draft circulating air oven maintained at least 18ºF (10ºC) higher than the maximum temperature of the nonmetallic part as measured during the Temperature Test, Section 45, but not less than 158ºF (70ºC). The nonmetallic part is to remain in the oven for 7 hours. After its careful removal from the oven and return to room temperature, the nonmetallic part is to be subjected to the test in 42.2 and comply with 42.1.

42.2 The cord-connections inside the product are to be disconnected. A strain relief means for a power supply cord is to be subjected to a direct pull of 35 pounds-force (156 N). The force may be generated by suspending a 35 pound (15.9 kg) weight on the cord of the product.

42.3 A strain relief means for wiring leads intended for connection of field-installed supply conductors as specified in 12.1.2.3 or power supply conductors of an internally-mounted accessory as specified in 5.6 are to be subjected to a direct pull of 20 pounds-force (89 N). The force may be generated by suspending a 20 pound (9.1 kg) weight on the wiring leads.

42.4 The force specified in 42.2 or 42.3 shall be applied so that the strain relief is stressed from any angle permitted by the construction of the product.

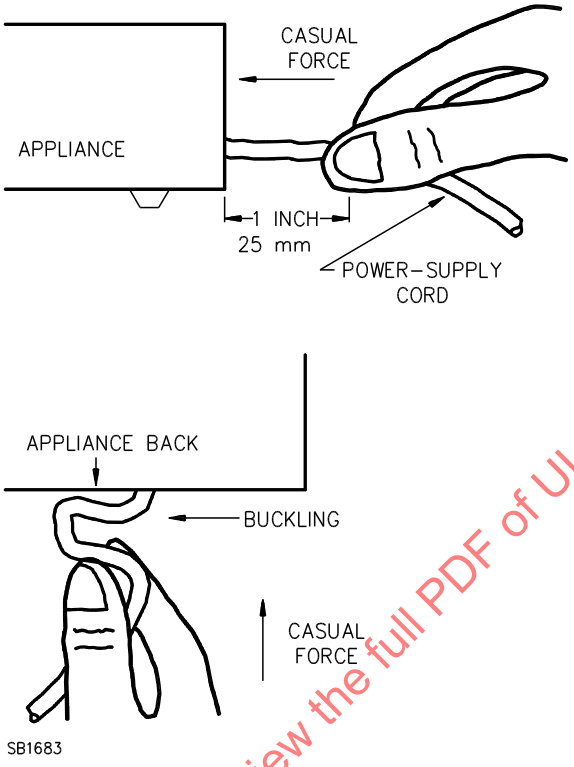
42.5 The force shall be applied for not less than 1 minute.

43 Pushback Relief Test

43.1 To determine compliance with 12.2.2.3, a product is to be tested as follows. The supply cord (or leads) is to be held 1 inch (25.4 mm) from the point where the cord emerges from the product. Then, the cord is to be pushed back with casual force as shown in Figure 43.1. The force is to be applied until the cord buckles, but in no case is the force to exceed 6 pounds-force (26.7 N).

Figure 43.1

Supply cord or lead push-back/strain relief evaluation



44 Grounding Resistance Test

44.1 The resistance of the grounding path between the equipment-grounding means and any other metal part required to be grounded (see 14.1.2) shall not be more than 0.1 ohm when measured in accordance with 44.2.

44.2 The resistance may be determined by any convenient method, such as an ohmmeter. If the current capacity of the grounding path is questionable, either a direct or alternating current equal to 200 percent of the maximum current that is available is to be passed from the equipment-grounding means to the metal part in question. The resulting drop in potential is to be measured between these two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes that passes between the two points.

45 Temperature Test

45.1 A product is to be tested under the conditions of load as described in 45.2 – 45.5.1. During the test:

a) The temperature at any point shall not be sufficiently high to constitute a risk of fire or to adversely affect any materials used in the product,

b) The temperature at specific points shall not exceed those specified in Table 33.1 and Table 45.1,

c) A motor-protective device shall not operate, and

d) A resistor shall neither burn out nor otherwise be adversely affected.

Table 45.1
Maximum temperatures

Materials and components	°C	(°F)
A. MOTORS		
1. Class A insulation systems on coil windings of an A-C motor having a frame diameter of 7 inches (178 mm) or less, not including a universal motor:[a,b]		
a. In an open motor:		
Thermocouple or resistance method	100	(212)
b. In a totally enclosed motor:		
Thermocouple or resistance method	105	(221)
2. Class A insulation systems on coil windings of a D-C motor and of a universal motor:[a]		
a. In an open motor:		
Thermocouple method	90	(194)
Resistance method	100	(212)
b. In a totally enclosed motor:		
Thermocouple method	95	(203)
Resistance method	105	(221)
3. Class B insulation systems on coil windings of an A-C motor having a frame diameter of 7 inches or less, not including a universal motor:[a,b]		
a. In an open motor and on vibrator coils:		
Thermocouple or resistance method	120	(248)
b. In a totally enclosed motor:		
Thermocouple or resistance method	125	(257)
4. Class insulation systems on coil windings of a D-C motor and of a universal motor:[a]		
a. In an open motor:		
Thermocouple method	110	(230)
Resistance method	120	(248)
b. In a totally enclosed motor:		
Thermocouple method	115	(239)
Resistance method	125	(257)
B. COMPONENTS		
1. Capacitors		
a. Electrolytic[c]	56	(149)
b. Other types[d]	90	(194)
2. Solid and built-up contacts, bus bars, and connecting bars	90	(194)
3. Field-wiring terminals[e]	75	(167)
4. Fuses	90	(194)
5. Knife-switch blades and contact jaws	55	(131)
6. Potting compound	15	(27)
	less than melting point	
7. Relay, solenoid, and coils (except motor coil windings and transformers) with:		
a. Class 105 insulation systems:		
Thermocouple method	90	(194)

Table 45.1 Continued on Next Page

Table 45.1 Continued

Materials and components	°C	(°F)
Resistance method	100	(212)
b. Class 130 insulation systems:		
Thermocouple method	110	(230)
Resistance method	120	(248)
8. Resistors[f]	–	–
9. Transformers		
a. Class 105 insulation systems:		
Thermocouple method	90	(194)
Resistance method	100	(212)
b. Class 130 insulation systems:		
Thermocouple method	110	(230)
Resistance method	120	(248)
10. Selenium rectifier[g,h]	75	(167)
11. Silicon rectifier[g]	100	(212)
C. CONDUCTORS		
1. Rubber or thermoplastic insulated wire and cold[g,i]	60	(140)
D. ELECTRICAL INSULATION – GENERAL		
1. Fiber used as electrical insulation	90	(194)
2. Phenolic composition used as electrical insulation or as a part the deterioration of which could result in a risk of fire or electric shock[g]	150	(302)
3. Varnished-cloth insulation	85	(185)
E. OTHER SURFACES		
1. A surface upon which a product may be placed or mounted in service, and surfaces that may be adjacent to the product when it is so placed or mounted	90	(194)
2. Any point on or within a terminal box or wiring compartment of a fixed product in which power-supply conductors are to be connected	60	(140)
3. Wood or other combustible material	90	(194)

NOTE – The values in Table 45.1 are based on an ambient temperature of 25°C (77°F). However, a test may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). Each observed temperature shall satisfy the following formula:

$$T_1 + (K - T_A) \geq T_L$$

in which:

T_1 is the observed temperature of the material or component,

K is 25 when temperatures are measured in degrees Celsius and 77 when measured in degrees Fahrenheit,

T_A is the ambient room temperature, and

T_L is the maximum required temperature.

If the ambient temperature is not 25°C, and the corrected temperature or the observed temperature exceeds the value in Table 45.1, the test may be repeated at an ambient temperature closer to 25°C.

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by a thermocouple may be more than the specified maximum by the amount in the following table if the temperature of the coil, measured by the resistance method, is not more than that specified:

Reference in Table 41.1	Additional temperature, °C	(°F)
Part A, item 1	5	(9)
Part A, items 2 and 4	15	(27)

Table 45.1 Continued on Next Page

Table 45.1 Continued

Materials and components	°C	(°F)
[b] The diameter of a motor is the frame diameter, measured in the plane of the lamination, of the circle circumscribing the stator frame, excluding lugs, fins, boxes, and the like, used solely for motor mounting, cooling, assembly, or connection.		
[c] For an electrolytic capacitor that is physically integral with or physically attached to a motor, the temperature or insulating material integral with the capacitor enclosure shall not be greater than 90°C (194°F).		
[d] A capacitor that operates at a temperature of more than 90° (194°F) may be evaluated on the basis of its marked temperature limit.		
[e] The temperature on a wiring terminal or lug is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.		
[f] See 37.2.		
[g] The limitations do not apply to materials or compounds that have been investigated and determined to be acceptable for use at higher temperatures.		
[h] A temperature of 85°C (185°F) complies if a stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 150°C (302°F).		
[i] Rubber-insulated conductors within a motor having a Class A insulation system, rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor may be subjected to a temperature greater than 60°C (140°F) if a braid is used on the conductor of other than a flexible cord. This does not apply to thermoplastic-insulated wires or cords.		

45.1.1 A product shall be operated under the most severe condition for generating the maximum temperatures, taking into account all intended operating modes of the product. Example operating modes include, but are not limited to: original and/or any alternate air filter(s) in place, air filter removed, fans operating at different speeds (e.g., high, medium, low), fans inoperative, emitters/ionizers on or off, UV lamps on or off or other special feature activated or inactivated.

45.1.2 For a product having an interlock switch to prevent operation if an air filter is removed:

a) The testing in 45.2 – 45.13 shall be conducted with the interlock switch bypassed; or,

b) The interlock switch shall comply with Section 29, Interlocks, and the operating instructions of the product shall indicate the intended filter(s), including replacement filters, as specified in 59.10.

45.2 Maximum load is to be any load from open circuit to short circuit to simulate actual loading conditions and to produce each of the following:

a) Maximum output current,

b) Maximum input current, and

c) Maximum input power.

The test is also to be conducted under short-circuit and open-circuit conditions. The load is to be applied to each output of the power pack to produce the specified maximum conditions.

45.3 With reference to 45.2, maximum conditions may be obtained by connecting the power-pack output to the maximum number of filter cells for which it is intended. As an alternative an ionizer output terminal, if employed, may be connected to a resistive load, and the collector output may be connected to a capacitive load.

45.4 To determine whether a product complies with the requirements in 45.1 – 45.3, it is to be connected to a supply of rated voltage and operated continuously until constant temperatures have been reached.

Exception: If a component obviously is not intended for continuous operation, the temperature test may be conducted to take into consideration the probable intermittent or short time operation of the component.

45.5 A product that is rated for use at more than one voltage or for a range of voltages, and contains a tapped transformer or other means of being adapted to different supply voltages, is to be tested at the most unfavorable combination of supply voltage and internal adjustment.

Exception: The product may be tested while connected in accordance with the manufacturer's instructions if all three of the following conditions are met:

a) A clear, permanent marking is provided adjacent to the cord or supply compartment to warn the user that internal adjustments must be made when the appliance is installed or moved.

b) Detailed instructions clearly showing the adjustments that must be made for various voltages are permanently attached to the appliance. These instructions may be on the outside or on the inside of the overall enclosure where visible at the point at which adjustments for supply voltages must be made.

c) The adjusting means provided for different voltages complies with the requirements for wiring terminals in 12.1.4.1 – 12.1.4.5.

45.5.1 A product powered entirely by a low-voltage supply source (such as by a USB type connector) shall be operated normally except with the air intake area restricted to any level between 0-50 percent of the overall air intake area so that the input current to the product is maximized.

45.6 Thermal equilibrium is considered to exist only if three successive readings indicate no change when taken at the conclusion of each of three consecutive, equal intervals of time where the duration of the interval is the longer of the following:

a) 5 minutes or

b) 10 percent of the total test time elapsed previous to the start of the first interval.

45.7 Rubber and other materials likely to deteriorate are to be removed from feet and other supports of the product if absence of the material may result in higher temperatures.

45.8 Ordinarily, temperatures are to be measured by thermocouples applied to the hottest accessible parts, except that motor-coil temperatures may be determined by the resistance method if the coil is inaccessible for mounting thermocouples.

45.9 The thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to comply to the requirements specified in the "Tolerances on Initial Values of EMF versus Temperature" tables in the Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples, ANSI/ASTM E230.

45.10 Whenever referee temperature measurements are necessary in connection with the heating of electrical equipment, thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer type of indicating instrument are to be employed.

45.11 A thermocouple junction and adjacent thermocouple lead wire are to be securely held in thermal contact with the surface of the material that is being measured. In most cases, thermal contact will result from securely taping or cementing the thermocouple in place. However, if a metal surface is involved, bracing or soldering the thermocouple to the metal may be necessary.

45.12 For the thermocouple-measured temperature of a coil in a motor the thermocouple:

a) Is to be applied to the magnet wire;

b) Is to be separated from the magnet wire by not more than the insulation on the conductor itself; or

c) May be separated from the conductor by not more than the insulation on the conductor itself and the normal coil wrap.

Exception: This requirement does not apply to a 7-inch (178 mm) diameter or smaller frame A-C motor as described in Table 45.1, part A, items 1 and 3.

45.13 In using the resistance method, the windings are to be at room temperature at the start of the test. The temperature of a winding is to be calculated using the following:

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

in which:

T_c is the temperature of the coil at the end of the test in degrees C;

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

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

k is 234.5 for copper, and 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other grades must be determined; and

t is the room temperature at the beginning of the test in degrees C.

46 Dielectric Voltage-Withstand Test

46.1 General

46.1.1 A product shall withstand without breakdown for 1 minute the application of a test potential at any frequency between 40 and 70 hertz for ac circuits or a test potential as specified in Table 53.1, Condition A for dc circuits, as follows:

a) Twice the maximum voltage rating of the line-voltage circuit plus 1000 volts applied between the line-voltage primary circuit and exposed or grounded dead metal.

b) 125 percent of the maximum measured or rated high-voltage circuit, whichever is higher, applied between:

1) High-voltage circuits and line-voltage circuits unless the product complies with 46.1.1.1; and

2) High-voltage circuit windings and resonating windings unless the product complies with 46.1.1.2.

c) 150 percent of the maximum measured or rated high-voltage circuit applied between:

1) High-voltage circuits and line-voltage circuits; and

2) High-voltage circuits and dead metal parts.

46.1.1.1 If the test specified in 46.1.1(b)(1) is not conducted, then any point of a high-voltage circuit winding shall be grounded.

46.1.1.2 If the test specified in 46.1.1(b)(2) is not conducted, then the resonating winding and the high-voltage circuit windings shall be common.

46.1.2 With reference to the test in 46.1.1(c) the frequency may be adjusted higher if needed, and:

a) For any high-voltage transformer not having a grounded secondary winding, the test shall be:

1) Conducted with only the grounded (neutral) side of the line-voltage circuit connected to dead metal parts; and then

2) Conducted with only the ungrounded (line) side of the line-voltage circuit connected to dead metal parts.

b) For any high-voltage transformer having a grounded secondary winding, neither the grounded (neutral) side nor the ungrounded (line) side of the line-voltage circuit shall be connected to any dead metal parts.

46.1.3 Each component of a product that is subjected to dc potentials during normal operation of the equipment shall withstand without breakdown for 1 minute, the application of a dc potential of 150 percent of the rated or measured dc voltage, whichever is greater, between that component and grounded metal. The values to be used in this test shall be based on the voltages measured in the Output Test, Section 39. The value used shall be the highest voltage existing at that component under any condition of operation.

46.1.4 The ionizer and collector cells are to be removed during the test described in 46.1.3.

46.1.5 If the application of a d-c potential of 150 percent of the measured dc voltage of one point causes the rated dc potential of another point to be more than 150 percent of the maximum voltage at these points, other places in the circuit may be grounded to prevent the excessive voltage condition from occurring.

46.1.6 Each meter provided with a product is to be disconnected from the circuit when the product is subjected to the dielectric voltage-withstand tests described in 46.1.1 – 46.1.5. Each meter is then to be separately subjected to the dielectric voltage-withstand tests in 46.1.1 and 46.1.3.

46.1.6.1 A product employing a low-voltage circuit or entirely powered by a low-voltage circuit shall be capable of withstanding, for 1 minute, without breakdown, the following test potential applied between low-voltage live parts of opposite polarity and between low-voltage live parts and dead metal parts. The test potential shall be one of the following:

a) An ac potential of 500 V at any frequency between 40 and 70 Hz;

b) A dc potential of 700 V; or

c) A dc potential of 500V if the product is intended to be connected only to a USB supply source.

46.1.6.2 With reference to 46.1.6.1, the test between low-voltage parts of opposite polarity shall be conducted on magnet coil windings of the transformer after breaking the inner coil lead where it enters the layer.

46.1.7 In determining whether a product complies with the requirements in 46.1.1 – 46.1.6.1, the potential is to be applied by a 500 volt-ampere or larger transformer with a regulated output voltage. The potential is to be increased from zero until the required test level is reached, and is to be held at that level

for 1 minute. The increase in the applied potential is to be at a rapid and substantially uniform rate such that the potential is consistent with the value correctly indicated by a voltmeter.

46.2 High-voltage transformer core

46.2.1 An ungrounded high-voltage transformer core can be used if it withstands a dielectric voltage-withstand test of four times the maximum secondary voltage applied from the core to the primary and secondary windings connected together. The potential is to be applied for 1 minute. See the Exception to 14.1.2.

46.3 Induced potential

46.3.1 Three samples of a magnet coil winding as described in 4A.11.5(b)(3) are to be subjected to this test. While in a heated condition from operation as described in the Temperature Test, Section 45, the primary winding of each transformer shall withstand without breakdown an alternating potential of twice the rated voltage of the winding.

46.3.2 The potential is to be:

a) Applied for 7200 cycles if the test potential frequency is 120 hertz or more and

b) 60 seconds if the frequency is less than 120 hertz.

A higher test frequency may be necessary so the core is not saturated. The test voltage is to be started at one-quarter or less of the full value and increased to full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced within 5 seconds to one-quarter or less of the maximum value and the circuit is to be opened.

46.3.3 With reference to 46.3.1, a transformer may be conditioned in an oven to obtain the temperature reached in the Temperature Test, Section 45, before conducting the induced-potential test.

46A General Purpose Transformers

46A.1 General

46A.1.1 In addition to the end-product Temperature Test and Dielectric Voltage-Withstand Test, a general purpose transformer shall also be subjected to the tests of 46A.2 – 46A.4.

46A.2 Voltage measurement test

46A.2.1 For purposes of comparison with voltages measured as described in the Overload Test of Section 46A.3, each secondary open-circuit voltage shall be measured with the primary connected to a test voltage and frequency supply source as indicated in Section 38, Input Test.

46A.3 Overload test

46A.3.1 A transformer shall be subjected to the test conditions described in 46A.3.2. The stabilized surface or core temperature recorded on the transformer during the second 50 percent load operation shall not be more than 5°C (9°F) greater than the stabilized core temperature obtained during the initial 50-percent of load operation. The open-circuit output voltage determined following the final 50 percent load operation shall be within 2 percent of the output voltage measured during the Voltage Measurement Test in 46A.2. As an option, a protective device, if provided, may be bypassed when conducting this test.

46A.3.2 The transformer shall be operated as described in the Temperature Test in Section 45, except that the load shall be 50 percent of the rated value, until the core, or surface temperatures if encapsulated, stabilize. After stabilization, the load shall be adjusted until 200 percent of rated secondary current is reached. After 2 minutes of operation, the load shall be readjusted, if necessary, to restore the current to 200 percent, but no further adjustment is to be made thereafter. The duration of this overload shall be 30 minutes. The load is then to be restored to the original 50 percent of rated value. It shall be held at that value until the core temperature again stabilizes or until the temperature drops to within 5°C (9°F) of the original stabilized 50-percent load-current temperature (whichever occurs first). This temperature value shall be compared with the original 50-percent load stabilized condition, as specified in 46A.3.1. Then, the secondary load shall be removed. With the primary energized, the secondary voltage(s) shall be measured and compared with the original output voltage measurements.

46A.3.3 When the core of the transformer is not accessible for direct temperature measurement (due to the transformer construction or reasons such as encapsulation or filling with electrical insulating material), the surface of the transformer enclosure shall be used. The portion of the enclosure surface used to measure this temperature shall be the hottest spot occurring in the 100-percent load heating test.

46A.3.4 A protective device, when provided, shall be bypassed when the device opens while the load is adjusted after the surface temperatures have stabilized.

46A.4 Repeated dielectric voltage-withstand test

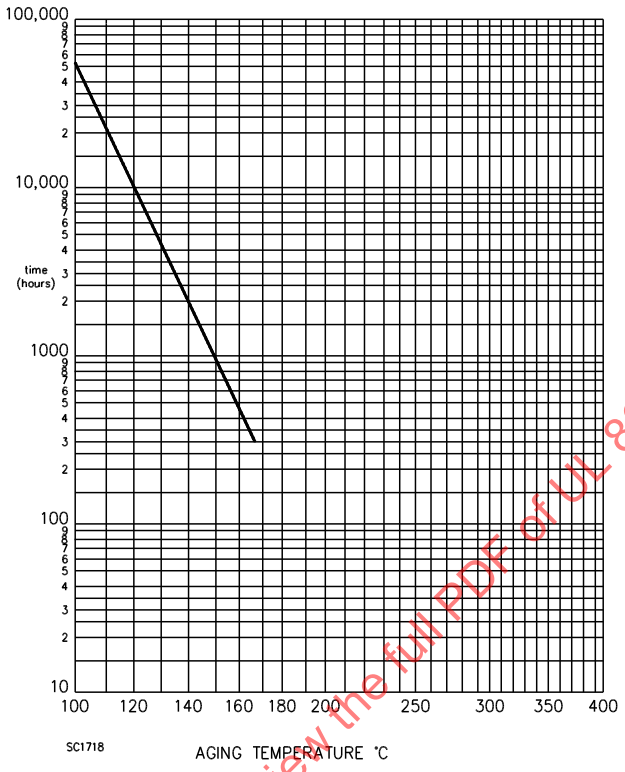
46A.4.1 Following the Overload Test in Section 46A.3, the transformer shall be subjected to a repeated dielectric voltage-withstand test. The test potential shall be 65 percent of the value originally specified. After this test, the transformer shall perform as intended.

46B Thermal Aging Test

46B.1 A polymeric material employed in a Class 105 (A) insulation system in accordance with 4A.11.3(b)(4) is to be aged for the amount of time corresponding to an aging temperature that appears on the Class 105 (A) system response shown in Figure 46B.1. The insulation system is to cool to room temperature and the applicable dielectric voltage-withstand requirements specified in Section 46 are to be applied between metal parts that are isolated from each other by the material under consideration.

Figure 46B.1

Class 105 (A) system response



46C Endurance Test – Switching Devices

46C.1 This test applies to switches or other similar operating controls as specified in 13A.14(e)(2).

46C.2 A switching device in a product shall perform acceptably when tested as follows for endurance. There shall be no electrical or mechanical failure nor undue burning, pitting or welding of contacts, or striking of an arc to dead metal parts.

46C.3 The tests on switching devices shall be conducted by:

a) Operating the switching device mechanisms within the product in accordance with 46C.4 and 46C.5 except using the normal switching device loads of the product; or,

b) Cycling the switching devices individually or collectively while controlling the loads specified in 46C.5.

46C.4 If the test in 46C.3(a) is conducted, the:

a) Enclosure of the product shall be connected through a 30 ampere cartridge fuse to the electrical test circuit pole considered least likely to strike (arc) to ground;

b) Switching device shall be mounted as intended in service; and,

c) Test cycling shall be as specified in 46C.5 unless a slower rate is required by the design of the product. A faster rate may be used if agreeable to all concerned.

46C.5 A switching device shall be subjected to an endurance test at the ambient temperature for which it is intended. The endurance test shall consist of making and breaking the connected load for 6000 cycles of operation, with 1 second ON and 9 seconds OFF. The voltage shall be as specified in 34.2.

a) Noninductive load(s) – 100 percent of the total connected load current. The power factor shall be 1.0.

b) One or more motors together with one or more other loads – 100 percent of the locked-rotor current of the largest motor plus 100 percent of the full load current of all other motors and/or other loads. The power factor shall be 0.4 – 0.5.

c) One or more inductive loads, such as a transformer or ballast, with or without other noninductive or pilot duty loads – 100 percent of the total inductive and other noninductive/pilot duty loads. The power factor shall be 0.7 – 0.8.

d) One or more pilot duty loads, such as coils within a relay or electric valve – 100 percent of the total connected pilot duty loads. The power factor shall not exceed 0.35.

46C.6 At the conclusion of the test in 46C.3, each switching device shall be subjected to the Dielectric Voltage-Withstand Test, Section 46.

47 Stored Energy Test

47.1 The voltage across a capacitance at the time the capacitance is accessible during user servicing, 5 seconds or more after the power supply to the appliance has been interrupted by the removal of an interlocked cover, or the like, shall not exceed the applicable value specified in Table 47.1.

Table 47.1
Stored energy

Capacitance, microfarads	Maximum potential across capacitance, prior to discharge, volts[a]
0.0030	40,000
0.0037	35,000
0.0047	30,000
0.0062	25,000
0.0087	20,000
0.014	15,000
0.025	10,000
0.074	5,000
0.89	1,000
1.04	900
1.25	800
1.54	700
1.95	600
2.59	500
3.65	400
3.97	380
4.34	360
4.79	340

Table 47.1 Continued on Next Page

Table 47.1 Continued

Capacitance, microfarads	Maximum potential across capacitance, prior to discharge, volts[a]
5.27	320
5.86	300
6.57	280
7.43	260
8.49	240
9.81	220
11.5	200
13.7	180
16.8	160
21.0	140
27.4	120
37.5	100
45.0	90
55.2	80
69.9	70
91.8	60
127.0	50
154.0	45
172.0	42.4
191.0	40
327.0	30
464.0	25
642.0	21.2

[a] Linear interpolation between adjacent values in the tables is to be used to determine the maximum required voltages corresponding to capacitance not specified in the table.

48 Evaluation of Reduced Spacings on Printed-Wiring Boards

48.1 General

48.1.1 Printed-wiring board traces of different potentials in the same circuit having reduced spacings and required to be tested in accordance with 23.3.1(c)(2)(i) or 23.4.3(d)(1) shall be evaluated by conducting the shorted trace test described in 48.2.1 – 48.2.4.

48.2 Shorted trace test

48.2.1 Printed-wiring board traces mentioned in 48.1.1 are to be tested as described in 48.2.2 – 48.2.4. As a result of the testing:

a) The overcurrent protection associated with the branch circuit to the unit shall not open,

b) The ground circuit fuse shall not open,

c) A wire or a printed-wiring board trace shall not open, and

d) The device shall emit no flame or molten metal.

48.2.2 Following each shorted trace test, the device is to be subjected to the Dielectric Voltage-Withstand Test, Section 46.

48.2.3 Each location of reduced spacings between the traces on the printed-wiring board is to be tested separately. The traces at each location are to be short-circuited by connecting them together with a conductor having an ampacity high enough not to affect the test results prior to energizing the air cleaner. Exposed dead metal parts of the air cleaner are to be connected to ground through a 3-ampere nontime-delay fuse. The air cleaner is to be connected in series with a nontime-delay fuse of the maximum current rating that can be accommodated by the fuseholder of a branch circuit to which the air cleaner could be connected. The air cleaner is to be energized as in normal use.

48.2.4 Each test is to be continued until further changes, as a result of the test condition, are not likely. If the circuit is interrupted by the opening of a component, the test is to be repeated twice using new components as necessary.

49 Abnormal Operation Test

49.1 General

49.1.1 A product shall not cause a risk of fire or electric shock when operated under abnormal conditions that may occur during use. During the tests specified in 49.2.1 – 49.7.1:

a) The cheesecloth mentioned in 49.1.2 shall not glow or flame;

b) The tissue paper mentioned in 49.1.2 shall not glow or flame;

c) The fuse in the ground circuit shall not open; and

d) A permanent path shall not result between live parts and exposed metal, as determined by a repeat of the Leakage-Current Test, Section 35.

49.1.2 During the abnormal operation test, the product is to be connected in series with a nontime-delay fuse of the maximum current rating that can be accommodated by the fuseholder of a branch circuit to which the product could be connected. The product complies with the test if the branch-circuit fuse opens before any risk of fire or electric shock is evident. If an automatically reset protector functions in the air cleaner, the test is to be continued for 7 hours. If a manual reset protector functions, the test is to be continued until the protector operates for 10 cycles using the minimum resetting time, but not at a rate faster than 10 cycles of operation per minute. The protector is to be operational upon completion of the test. Only one abnormal condition is to be simulated at a time. Abnormal operation tests are to be conducted with the product supported in its normal operating position. A portable product is to be placed on a pine board covered with white tissue paper. All products are to be covered with cheesecloth as described in 49.1.6, arranged so that the cloth is close to any openings in the cabinet or enclosure. Exposed dead metal parts are to be connected to ground through a 3-ampere nontime-delay fuse.

49.1.3 Parts that may be removed during user servicing may be removed if they are not:

a) Necessary for the functioning of the product,

b) Exposed to view during operation, and

c) Held captive.

49.1.4 The tests specified in 49.2.1 – 49.4.3 are first to be conducted with a resistive load connected to the output terminals so that three times the full-rated current will be drawn from the secondary winding. The test is to be repeated with the transformer secondary winding or windings shorted.

49.1.5 As a risk of fire or electric shock resulting from the abnormal operation tests will usually manifest itself within 1 hour, the tests are ordinarily to be limited to 1 hour. If at the end of 1 hour it appears possible

that risk of fire or electric shock will eventually result, the test is to be continued until ultimate results are obtained (usually not more than 7 hours).

49.1.6 The cheesecloth mentioned in 49.1.2 is to be untreated cotton cloth 36 inches (0.9 m) wide, running 14 – 15 yards per pound (28 – 30 m/kg). Tests involving cheesecloth are to be conducted in a room free of drafts.

49.2 High-voltage supply

49.2.1 A power supply with an output that exceeds the limits in Partially Protected Parts, Section 37, is to be tested with the controls adjusted for maximum output voltage and current under each of the following conditions:

a) With the ionizer output terminal, if employed, shorted to ground.

b) With the collector terminal shorted to ground.

c) With any ungrounded end of the secondary winding of the high-voltage transformer core. For a transformer having a completely insulated center-tapped winding, one-half of the secondary winding is to be shorted in lieu of connection to the core.

Exception: For a transformer having an untapped, completely insulated secondary winding, the test in (c) may be omitted.

49.3 High-voltage spacings short circuit

49.3.1 The spacings referenced in 23.4.4(a) are to be short-circuited in turn.

49.4 Unenclosed high-voltage power supply

49.4.1 A product having a high-voltage power supply not enclosed within its own enclosure as described in 6.2.1(a), or a product employing a filter that is electrically charged by the product, shall comply with the requirements in 49.4.2 – 49.4.3 without formation of a heavy carbonizing, low resistive path, or ignition of the material under test.

Heavy carbonizing is judged by application of a dielectric voltage-withstand potential between the two points, where the arc of 49.4.2 is applied, as required by Section 46 but not less than 1000 volts, 60 hertz for 1 minute.

49.4.2 An arc is to be established between parts that have a potential difference greater than 2500 volts peak or across the surface of a filter that is electrically charged by the appliance, using a conductive probe. Materials located between the parts are to be located in the path of the arc. The test is to be continued for 15 minutes unless the glowing or flaming occurs in a shorter time. Three samples are to be tested.

49.4.3 All secondary windings (including the resonant winding of the transformer, if provided) are to be short-circuited at the same time. If the circuit is interrupted by the opening of a component, the test is to be conducted a total of three times using new components when necessary.

49.5 Component short- and open-circuit test

49.5.1 Each high-voltage output is to be loaded as indicated in 45.3. Each component, such as a capacitor, a diode, a solid state device, or the like, connected in the line-voltage circuit is to be short-circuited and then open-circuited one component at a time.

49.6 Stalled rotor, restricted air inlet and blocked air outlet

49.6.1 These tests are applicable to a product if a risk of fire or electric shock is likely to occur due to shrinkage, warping or other deformation of any nonmetallic materials that may be heated under the conditions specified in (a) – (c). For each condition, the product is to be operated as specified in 49.1 and only one condition is to be applied at a time. At the conclusion of each condition, the product shall comply with 49.1.1.

a) For products with a motor, the rotor of the motor is to be locked.

b) Products having air inlet openings shall have the openings restricted by draping a single layer of cheesecloth over the product such that all air inlets are covered. The cheesecloth is to be the type as specified in 49.1.6.

c) Products having air outlet openings shall have all air outlet openings blocked.

49.7 Low-voltage powered product overvoltage test

49.7.1 A product intended to be powered entirely by a low-voltage supply source (such as by a USB type connector) shall be connected to a supply circuit at an overvoltage condition using a test voltage that is 30 percent higher than the product rated voltage and capable of supplying a minimum 8 amperes at that test voltage. The product shall be operated as specified in 49.1. At the conclusion of the test, the product shall comply with 49.1.1.

49A Protective Electronic Circuit Tests

49A.1 General

49A.1.1 The tests in 49A.2 – 49A.5 are applicable to products provided with a protective electronic circuit and intended to comply with 13A.3(i).

49A.1.2 User adjustable controls shall be adjusted to their most unfavorable setting.

49A.2 Fault conditions abnormal test

49A.2.1 Following the application of the operational fault conditions in accordance with 49A.2.2 – 49A.2.5, there shall be no risk of fire, electric shock or injury to persons. Electrical live parts or moving parts shall not be exposed. The product shall comply with the Dielectric Voltage Withstand Test in Section 46.

49A.2.2 In accordance with 13A.19(b), a product provided with a protective electronic circuit intended to comply with 13A.3(i) shall be operated as specified in the Temperature Test, Section 45 except the room ambient shall be maintained at 70 – 80°F (21.1 – 26.7°C). The product protective electronic circuit shall then be subjected to any one of the following relevant operational fault conditions, each consecutively applied one at a time:

a) Open circuit at the terminals of any component;

b) Short circuit of capacitors, unless they comply with 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;

c) Short circuit of any two terminals of an electronic component, including a metal oxide varistor (MOV). For the test applicable to an integrated circuit, see (e);