UL 873

STANDARD FOR SAFETY

Temperature-Indicating and -Regulating Equipment

UL Standard for Safety for Temperature-Indicating and -Regulating Equipment, UL 873

Twelfth Edition, Dated November 16, 2007

Summary of Topics

The revision dated February 6, 2015 is being issued to adopt the following proposal:

1. Revising the multiple disconnect caution marking text height requirement in 74.2.

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. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The new requirements are substantially in accordance with Proposal(s) on this subject dated November 5, 2014.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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The Department of Defense (DoD) has adopted UL 873 on January 17, 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 http://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover electrical equipment for control of air-conditioning, heating, cooking, refrigeration, and humidity, rated 600 volts or less, to be used in ordinary locations in accordance with the National Electrical Code, NFPA 70.

1.2 These requirements cover general-use equipment for field-installation and controls intended to be factory installed on or in certain appliances as safety, limiting, or operating controls. These controls respond directly or indirectly to changes in temperature, humidity, or pressure to effect control of equipment or appliance operation. Devices covered by these requirements include:

a) Refrigeration Controllers – Humidistats for factory installation on or in refrigeration equipment; pressure, temperature, pneumatic pressure, motor, timer, bimetallic-heater, magnetically-operated controls, and the like, and combinations thereof in control panels with or without transformers. See 1.4.

b) Industrial Operating Controls – Temperature controllers for industrial, farm, and boiler room applications; snow melting controls; return-duct humidistats; humidity controllers; pneumatic pressure regulators; transformer (low-voltage secondary) relays; pneumatic pressure, bimetallic-heater, motor, timer, and magnetically operated sequence switches; stoker controls; indicating and recording controls; and motor operators for actuating air dampers. These requirements do not cover output connected apparatus such as dampers, linkages, or valves.

c) Residential Operating Controls – Room thermostats, room humidistats, and other operating controls for residential heating and cooling appliances.

d) Controls for Factory Installation on or in Appliances –

1) Controls as mentioned in (a) – (c) but specifically intended for use on, in, or as a part of the end-use equipment.

2) Electric water-heater controls intended to regulate or limit water temperature.

3) Other controls including door-interlock thermostats for self-cleaning ovens; baseboard heater temperature-limiting controls; humidifier controls; fan thermostats; and temperature-regulating and -limiting thermostats for electric heating equipment such as clothes dryers, air heaters, household and commercial cooking appliances, beauty-parlor equipment, steam and dry bath heaters, and ranges (controlling oven or surface elements).

1.3 Certain safety controls, and safety control circuits on operating controls, are investigated under the requirements in this standard, insofar as they apply, and also under the applicable requirements for limit controls.

1.4 The following devices are among those considered to be refrigeration controllers:

a) A control that either directly or indirectly controls the starting and stopping of a compressor motor of refrigeration or air-conditioning equipment because of variations in temperature, pressure, refrigerant level, or the like.

b) A pressure limiting device and a defrost temperature-limiting device for refrigeration or air-conditioning equipment.

c) An auxiliary device, such as a defrost timing control, a defrost temperature regulating control, a start winding relay for a compressor motor, a control or defrost or heat pump change-over, fan or pump motor, vane or load capacity regulator, or a similar device that primarily serves refrigeration or air-conditioning equipment.

d) A control panel that, incorporates one or more of the functions described in (a) – (c) for programming refrigeration or air-conditioning equipment.

1.5 A wall-mounted room thermostat not intended for mounting in or on refrigeration or air-conditioning equipment is investigated as a thermostat and not as a refrigeration controller.

1.6 Industrial temperature-indicating and -regulating controls include controls that are intended, among other applications, for installation in or on industrial apparatus, or for boiler or furnace room, farm, outdoor, and comparable locations that may not always be clean and dry.

1.7 A residential control is one intended for indoor comfort control use in clean, dry, nonindustrial environments, such as dwellings, offices, and stores.

1.8 A humidistat is investigated in the same manner as a thermostat.

1.9 Requirements for controls intended to be factory installed on or in appliances may include requirements appropriate for the end-use appliance. The spacing requirements for several such controls are specified in Table 32.1.

1.10 These requirements do not cover primary safety or limit controls for gas, oil, or electric-fired central-heating furnaces or boilers; duct heaters; oil or gas burners; or stokers; nor do they cover controls for oil pumps and oil level regulators; boiler-feed or low-water cut-offs; or furnace fan or boiler circulators.

1.11 These requirements do not cover low-voltage thermostats, damper controls or similar devices intended for connection only to a low-voltage circuit of limited power supplied by a primary battery or by a Class 2 transformer. An assembly consisting of a line-voltage transformer with a low-voltage secondary incorporated as an integral part of a control, such as a thermostat or a damper control, is considered to be within the scope of these requirements. See 6.1.

1.12 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

2 Glossary

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

2.2 CLASS 2 TRANSFORMER – A stepdown transformer of the low-secondary-voltage type (30 volts or less) rated for use with Class 2 remote-control circuits, low-energy power circuits, and signal circuits (including bell or buzzer circuits and the like) in accordance with the National Electrical Code, ANSI/ NFPA 70-1993. Unless such a transformer is of the energy-limiting type having sufficient winding impedance to limit the current output to a specified maximum value, it is required to be provided with a fuse or other overcurrent-protective device rated for the application.

2.3 EQUIVALENT SELF-HEATING THERMAL PROTECTOR – A SHTP that is identified as being equivalent with another SHTP and is intended to be used in a lighting fixture interchangeably with the other SHTP without adversely affecting the compliance of the lighting fixture with the requirements for the fixture.

2.4 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 1000 volts.

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

2.6 LOW-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 30 volts and supplied by a primary battery, by a standard Class 2 transformer, or by a combination of a transformer and a 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 connecting resistance in series with the supply circuit as a means of limiting the voltage and current is not considered to be a low-voltage circuit.

2.7 PORTABLE EQUIPMENT – Cord and plug connected equipment that is capable of being carried or moved about.

2.8 SELF-HEATING THERMAL PROTECTOR (SHTP) – A thermal protective device consisting of a temperature sensitive switching element and a load voltage heater within a common housing. When mounted on a non-Type IC recessed fixture, the SHTP is intended to cycle under field related abnormal heating conditions.

2.9 STATIONARY EQUIPMENT – Cord and plug connected equipment that is intended to be fastened in place, or located in a dedicated space.

2.10 THERMAL PROTECTOR – A thermal protective device consisting of a temperature sensitive switching element with or without a series heater within a common housing.

2.11 COMPONENT – A device or fabricated part of the control equipment covered by the scope of the safety standard dedicated to the purpose. When incorporated in the ultimate use equipment, a product otherwise typically field installed (e.g. luminaire) is considered to be a component. Unless otherwise specified, materials that compose part of a device or a fabricated part of a device, such as thermoplastic or copper, are not considered components.

2.11 added January 6, 2012

2.12 CONTROL, OPERATING – A device or assembly of devices, the operation of which starts or regulates the end product during normal operation. For example, a thermostat, the failure of which a thermal cutout/limiter or another layer of protection would mitigate the potential hazard, is considered an operating control.

2.12 added January 6, 2012

2.13 CONTROL, SAFETY OR PROTECTIVE – A device or assembly of devices, the operation of which is intended to reduce the risk of electric shock, fire or injury to persons during normal and reasonably anticipated abnormal operation of the appliance. For example, a thermal cutout/limiter, or any other control/circuit relied upon for normal and abnormal conditions, is considered a safety or protective control.

2.13 added January 6, 2012

3 Units of Measurement

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

4 Components

4.1 *deleted January 6, 2012.*

4.2 *deleted January 6, 2012.*

4.3 *deleted January 6, 2012.*

4.4 *deleted January 6, 2012.*

5 References

5.1 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.

CONSTRUCTION

5A Components

5A added January 6, 2012

5A.1 General

5A.1.1 A component of a product covered by this standard shall:

a) Comply with the requirements for that component as indicated in this standard;

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

c) Be used within its established use limitations; and

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

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 evaluated 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 this standard is acceptable if:

a) The component also complies with the applicable component standard as cited in this standard; or

b) The component standard:

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

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

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

5A.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 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.

5A.1.3 A component not anticipated by the requirements of this standard, not specifically covered by the component standards as cited in this standard, and that involves a potential risk of electric shock, fire, or personal injury, shall be additionally investigated in accordance with the applicable standard, and shall comply with items (b) – (d) of 5A.1.1.

5A.1.4 With regard to a component being additionally evaluated, reference to construction and performance requirements in another end product standard is appropriate where that standard anticipates normal and abnormal use conditions consistent with the application of UL 873.

5A.1.5 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.

5A.2 Attachment plugs, receptacles, connectors, and terminals

5A.2.1 Attachment plugs and receptacles shall comply with the Standard for Attachment Plugs and Receptacles, UL 498.

5A.2.2 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 2.8, 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.

5A.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 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.

5A.2.4 Wire connectors shall comply with the Standard for Wire Connectors, UL 486A-486B.

5A.2.5 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

5A.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 shall comply with the Standard for Insulated Multi-Pole Splicing Wire Connectors, UL 2459. See 5A.2.9.

5A.2.6 revised February 6, 2015

5A.2.7 Equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors, shall comply with Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

5A.2.8 Terminal blocks shall comply with the Standard for Terminal Blocks, UL 1059, and, if applicable, be suitably rated for field wiring.

Exception: A fabricated part performing the function of a terminal block need not comply with UL 1059 if the part complies with the requirements of Section 15, Insulating Material, Section 16, Supply Connections, Section 17, Current-Carrying Parts, and Section 32, Spacings. Sections 21, Low-Voltage External Wiring Requirements, and 22, Grounding, provide additional options as exceptions.

5A.2.9 Female devices (such as receptacles 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.

5A.2.10 Bonding devices, ground clamps, grounding and bonding bushings and locknuts, and similar equipment, shall comply with the Standard for Grounding and Bonding Equipment, UL 467.

5A.3 Batteries

5A.3.1 A lithium ion (Li-On) single cell battery shall comply with the requirements for secondary lithium cells in the Standard for Lithium Batteries, UL 1642. A lithium ion muiltiple cell battery, and a lithium ion battery pack, shall comply with the applicable requirements for secondary lithium cells or battery packs in the Standard for Household and Commercial Batteries, UL 2054.

5A.3.2 Rechargeable nickel cadmium (Ni-Cad) cells and battery packs shall comply with the applicable construction and performance requirements of this standard.

5A.3.3 Rechargeable nickel metal-hydride (Ni-MH) battery cells and packs shall comply with the construction and performance requirements of this standard, or the applicable requirements for secondary cells or battery packs in the Standard for Household and Commercial Batteries, UL 2054.

5A.4 Electrical boxes and raceways

5A.4.1 Electrical boxes and the associated bushings and fittings, and raceways, of the types specified in Chapter 3 of the National Electrical Code, NFPA 70 and that comply with one of the following standards:

a) Standard for Metallic Outlet Boxes, UL 514A,

b) Standard for Conduit, Tubing, and Cable Fittings, UL 514B,

c) Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C, or

d) Standard for Cover Plates for Flush-Mounted Wiring Devices, UL 514D.

5A.5 Capacitors, filters and surge protective devices

5A.5.1 Capacitors

5A.5.1.1 A capacitor located in the line voltage circuit shall 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 or the Standard for Capacitors, UL 810.

5A.5.1.1 revised February 6, 2015

5A.5.2 Filters

5A.5.2.1 Electromagnetic interference filters with integral enclosures shall comply with the Standard for Electromagnetic Interference Filters, UL 1283.

5A.5.3 Surge Protective Devices

5A.5.3.1 Surge Protective Devices (SPDs), including air gaps and metal oxide varistors (MOVs), shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449. Paragraphs 5A.5.3.2 through 5A.5.3.6 are applicable . Referenced ratings are per UL 1449.

Exception: These requirements do not apply to SPDs located in a Class 2 circuit unless the circuit is performing a safety function.

5A.5.3.2 Type 1, 2, or 3 SPDs and Type 1, 2 or 3 Component Assemblies SPDs shall:

a) Maintain a Maximum Continuous Operating Voltage (MCOV) rating equal to or greater than working voltage of the circuit connected, and

b) Maintain the appropriate Type Rating for the application in accordance with Table 5A.1.

Table 5A.1
Type 1, 2, or 3 Ratings

Application	Type Rating
Line side of service equipment	1
Load side of service equipment or feeder circuit applications	1 or 2
Branch circuit or control circuit applications	1 or 2 or 3

5A.5.3.3 Type 4 or Type 5 discrete component SPDs and Type 4 component assemblies shall have a Maximum Continuous Operating Voltage (MCOV) rating equal to or greater than the phase-to-phase (line-to-line) voltage of the system supply.

Exception: If the Type 4 or 5 discrete component SPDs and Type 4 component assemblies have been subjected to all the Current Tests in accordance with UL 1449, during its investigation, the MCOV may have a rating equal to or greater than the working voltage of the circuit connected.

5A.5.3.4 Type 4 or 5 discrete component SPDs and Type 4 Component Assemblies shall be rated in accordance with (a), (b) or (c):

a) A Type 4 discrete component SPD rated for use in Type 1 - 3 applications may be used in applications indicated in Table 5A.1, or

b) A Type 4 discrete component SPD rated for use in Type 1 - 3 applications or ″other″ rated applications shall have an Operating Duty Cycle Voltage (V_p) and Peak Current (A_p) in accordance with Table 5A.2, based on the working voltage of the circuit connected, or

Exception: For SPDs used in other than across-the-line applications such as in a non-isolated electronic circuit, the additional circuit impedance in series with the SPD can be considered when determining the required SPD ratings. The A_p rating of the SPD may be less than that defined Table 5A.2 provided the A_p rating is equal to or is greater than the surge current parameters

determine by a calculation that accounts for fixed series impedance inherent in the circuit. [The calculated A_p would be equal to V_p divided by the combined known impedance inherent in the circuit plus 2 ohms, which is the anticipated source impedance].

c) A Type 5 discrete component SPD or Type 4 component assemblies shall be rated with a Nominal Discharge Current, NDC (I_n) in accordance with Table 5A.2, based on the working voltage of the circuit connected.

Exception: For SPDs used in other than across-the-line applications such as in a non-isolated electronic circuit, the additional circuit impedance in series with the SPD can be considered when determining the required SPD ratings. The $I_n$of the SPD may be less than that defined Table 5A.2 provided the I_n rating is equal to or is greater than the surge current parameters determine by a calculation that accounts for fixed series impedance inherent in the circuit. [The calculated I_n would be equal to V_p divided by the combined known impedance inherent in the circuit plus 2 ohms, which is the anticipated source impedance].

Table 5A.2
Type 4 or 5 SPD Ratings

SPD Circuit Phase-to-Ground Voltage, Vac[a] by Overvoltage Category [b]				Ratings of Type 4 or 5 SPDs	
				Minimum Operating Duty Cycle Peak Voltage (kV_p)(1.2 x 50 µs)	Operating Duty Cycle Peak Current or Minimum Nominal Discharge Current, NDC (I_n) A
I	II	III	IV		
50	-	-	-	0.33	165
100	50	-	-	0.50	250
150	100	50	-	0.80	400
300	150	100	50	1.5	750
600	300	150	100	2.5	1250
-	600	300	150	4.0	2000
-	-	600	300	6.0	3000

[a] For ungrounded systems or systems with one phase grounded, the phase-to-ground voltage is considered to be the same as the phase-to-phase voltage for the purposes of using this table.

[b] Typical examples of categories for products are given below.

Category IV - Primary Supply Circuit Level. Overhead lines and cable systems including distribution and its associated overcurrent protective equipment (equipment installed at the service entrance).

Category III - Distribution Circuit Level. Fixed wiring and associated equipment (not electrical loads) connected to the primary supply level, Category IV.

Category II - Load Circuit Level. Appliances and portable equipment and the like connected to the distribution level, Category III.

Category I - Signal Circuit Level. Special equipment or parts of equipment such as low-voltage electronic logic systems, remote controls, signaling and power limited (per NEC Article 725) circuits connected to the load level, Category II.

5A.5.3.5 Electronic safety controls shall, in addition to the requirements noted in 5A.5.3.2 and 5A.5.3.3, be subjected to a subsequent transient overvoltage test sequence in the end-use equipment application as defined by the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, with the SPD installed as intended. To minimize testing of the end-use equipment involving multiple

alternate SPDs sources or types, the SPD with the highest Measured Limited Voltage rating or Voltage Protective Rating, as applicable, shall be tested in the transient overvoltage test sequence. The highest rated SPD can represent multiple alternate SPDs sources or types.

Exception: If the electronic safety control complies with the transient overvoltage test sequence when tested with the SPD removed, the SPD need only comply with 5A.5.3.2 and 5A.5.3.3.

5A.5.3.6 SPDs are not permitted to be used between line / mains / non-Class 2 circuits and Class 2 circuits.

5A.6 Thermistors and thermal links

5A.6.1 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control shall comply with the Standard for Thermistor-Type Devices, UL 1434.

5A.6.2 A thermal link (thermal cutoff) shall comply with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

5A.6.2 revised February 6, 2015

5A.7 Cords and cables

5A.7.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817.

5A.7.2 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 UL 817.

5A.8 Gaskets and seals

5A.8.1 Gaskets and seals shall comply with the Standard for Gaskets and Seals, UL 157.

Exception: Gaskets and seals, and the securing adhesive, that comply with the requirements of Section 54, Accelerated Aging Tests on Gaskets, Sealing Compounds, and Adhesives, are considered to fulfill this requirement.

5A.9 Ground-fault, arc-fault, and leakage current detectors/interrupters

5A.9.1 Ground-fault circuit-interrupters (GFCI) for protection against electrical shock shall comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943, including any end-use equipment marking or instruction manual statement requirements.

5A.9.2 Appliance-leakage-current interrupters (ALCI) for protection against electrical shock shall comply with the Standard for Appliance-Leakage-Current Interrupters, UL 943B. An ALCI is not considered an acceptable substitute for a GFCI when a GFCI is required by the National Electrical Code, NFPA 70.

5A.9.3 Equipment ground-fault protective devices shall comply with the Standard for Ground-Fault Sensing and Relaying Equipment, UL 1053, and applicable requirements of the Standard for Ground-Fault Circuit-Interrupters, UL 943.

5A.9.4 Arc-fault circuit-interrupters (AFCI) shall comply with the Standard for Arc-Fault Circuit-Interrupters, UL 1699.

5A.9.5 Leakage-current detector-interrupters (LCDI) and any shielded cord between the LCDI and appliance shall comply with Standard for Arc-Fault Circuit-Interrupters, UL 1699.

5A.10 Heaters and heating elements

5A.10.1 Electric resistance heating elements shall comply with the construction requirements of:

a) The Standard for Electric Heating Appliances, UL 499; or

b) The Standard for Sheathed Heating Elements, UL 1030.

Exception: Heating wire (e.g. rope heater) that complies with the Standard for Appliance Wiring Material, UL 758, and the requirements of this end product standard are considered to fulfill this requirement.

5A.10.2 Thermistor-type heaters (e.g. PTC and NTC heaters) shall comply with the Standard for Thermistor-Type Devices, UL 1434.

5A.11 Insulation systems

5A.11.1 Materials used in an insulation system that operates above Class 105 (A) temperatures shall comply with the Standard for Systems of Insulating Materials – General, UL 1446.

5A.11.2 All insulation systems employing integral ground insulation shall comply with the requirements specified in the Standard for Systems of Insulating Materials – General, UL 1446.

5A.12 Light sources and associated components

5A.12.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

Exception: Lampholders forming part of a luminaire that complies with the applicable luminaire standard are considered to comply with this requirement.

5A.12.2 Lighting ballasts shall comply with:

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

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

Exception No. 1: Ballasts forming part of a luminaire that complies with the applicable luminaire standard are considered to comply with this requirement.

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

5A.12.3 Light emitting diode (LED) light sources shall comply with the Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750.

Exception No. 1: LED light sources forming part of a luminaire that complies with the applicable luminaire standard are considered to comply with this requirement.

Exception No. 2: Individual LED light sources mounted on printed wiring boards and intended for indicating purposes need not comply with Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750, but shall comply with the applicable requirements of this end product standard.

5A.12.3 revised February 6, 2015

5A.13 Marking and labeling systems

5A.13.1 A marking and labeling system shall comply with Standard for Marking and Labeling Systems, UL 969, under the specified environmental conditions.

Exception: A marking or labeling system that complies with Section 60, Permanence of Marking Test, of this standard is considered to fulfill the requirement.

5A.14 Overcurrent protection

5A.14.1 Fuses shall comply with the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1, and the applicable Part 2 (e.g. UL 248-5). Defined use fuses that comply with UL 248-1 and another appropriate standard for the fuse are considered to comply with this requirement.

5A.14.2 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.

5A.14.3 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.

5A.14.4 Supplementary protectors shall comply with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077.

5A.14.5 Fusing resistors shall comply with the Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television-Type Appliances, UL 1412.

5A.15 Power supplies

5A.15.1 A Class 2 power supply shall comply with one of the following:

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

b) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, with an output marked “Class 2”, or that complies with the limited power source (LPS) requirements and is marked “LPS”; or

c) The requirements in Section 36, Class 2 Power Sources and Circuits, and Section 68, Class 2 Power Sources and Circuits, and applicable Class 2 power source and circuit tests in Section 63, Class 2 Power Sources and Circuit Tests.

5A.15.1 revised February 6, 2015

5A.15.2 A non-Class 2 power supply shall comply with one of the following:

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

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

5A.15.2 revised February 6, 2015

5A.16 Printed wiring boards

5A.16.1 Printed wiring boards, including the coatings, shall comply with the Standard for Printed-Wiring Boards, UL 796.

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.

5A.17 Power switching semiconductors, optical isolators, and electronic components

5A.17.1 A power switching semiconductor device that is relied upon to provide isolation to ground shall comply with the Standard of Safety for Electrically Isolated Semiconductor Devices, UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted applying the criteria of Section 47 of this standard.

5A.17.2 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this end product standard shall comply with the Standard for Safety for Optical Isolators, UL 1577. The dielectric voltage withstand tests required by UL 1577 shall be conducted applying the criteria of Section 47 of this standard.

5A.17.3 Where an electronic component is determined to be a critical component, the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, including environmental stress tests appropriate to the intended usage of the end-product and its follow-up program, shall be applied.

5A.17.4 A critical component is a component that performs one or more safety-related or protective functions whose failure results in a condition such as the risk of fire, electric shock, or injury to persons, in the end product application.

5A.17.5 A critical component may also be identified using a failure-mode and effect analysis (FMEA) in accordance with the Failure-Mode and Effect Analysis (FMEA) of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. Other equivalent failure mode techniques such as FMEDA or FTA may be used.

5A.17.6 Electronic safety/protective (limiting) type controls shall comply with the requirements in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. Some examples of electronic safety/protective type controls which include protective functions are temperature limiting controls, safety controls, water heater controls, refrigeration motor-compresor variable speed drive controls providing protective/safety functions, etc.

Exception: Controls complying with Annex H requirements in the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1 are considered to be in compliance withUL 991 requirements.

5A.17.7 The test levels for the required environmental stress tests of UL 991, Sections 11 through 22, shall be as specified in the end-use equipment standard. When the end-use standard does not specify the test levels, the following identified test levels shall apply for the referenced tests:

a) Power supply voltage dips and short interruption – Per Section 11, UL 991;

b) Transient overvoltage – Per Table 12.2, UL 991;

c) Voltage (Ramp) variation - Per Table 13.1, UL 991;

d) Electromagnetic susceptibility –

1) Conducted Disturbances – Test Level 3,

2) Radiated Disturbances – Field Strength 3 V/m ;

e) Electrostatic discharge – Per Section 15, UL 991;

f) Composite operational and cycling test – Per Section 16, UL 991;

g) Test for effects of shipping and storage - Per Section 17, UL 991;

h) Humidity – Per Table 19.1, UL 991;

i) Dust – Per Section 20, UL 991. Applicable only for protective controls with an optical element, the obscuring of which would result in a loss of protective function;

j) Vibration – Class C;

k) Jarring - Per Section 22, UL 991.

5A.17.8 The composite operational and cycling test represents the thermal cycling test and the overvoltage and undervoltage test in UL 991.

5A.17.9 The computational investigation of critical components in UL 991 is conducted to determine the overall control system failure rate, λ_p, of the control system by appropriately combining the failure rates of all critical components. The end-use equipment standard shall specify the overall control system failure rate, λ_p. and the time and test ambient temperature for the Operational Test. When the end-use standard does not specify a control system failure rate, λ_p shall be 0 failures/10^6 hours for the entire control system. If the end-use standard does not specify a period of time and test ambient temperature for the Operational Test, the test shall be conducted for 14 days at the ambient temperature specified in UL 991.

5A.17.10 When there are critical components identified in the control system and the failure rate is not specified in the end-use standard, the demonstrated test method in UL 991 is required to be applied. The multiplier for the test acceleration factor for nonindustrial applications is to be 576.30 for intermittent end-use equipment, or 5763.00 for continuous end-use equipment. The multiplier for the test acceleration factor for industrial applications is to be 869.80 for intermittent end-use equipment, or 9698.00 for continuous end-use equipment. The test acceleration factor equation is to be based on the end-use equipment rated ambient.

5A.18 Supplemental insulation, insulating bushings, and assembly aids

5A.18.1 The requirements for supplemental insulation (e.g. tape, sleeving or tubing) shall comply with the following:

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

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

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

5A.18.2 Wire positioning devices shall comply with Sections 15, Insulating Materials, and 35, Separation of Circuits. A device that complies with the Standard for Positioning Devices, UL 1565, is considered to comply with this requirement.

5A.18.3 Insulating bushings that comply with 5A.1 and the Standard for Insulating Bushings, UL 635, are considered to comply with the requirements of this Standard. Tests specified in this standard (e.g. Strain Relief Test) shall be performed, as required, to confirm the combination of the insulating bushing and the supporting parts are suitable.

5A.19 Transformers

5A.19.1 General-purpose transformers shall comply with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2.

Exception: A transformer that meets the applicable construction and performance requirements of Section 64, Isolated-Limited Secondary and Non-Class 2 Circuit Tests, meets the intent of this requirement.

5A.19.1 revised February 6, 2015

5A.19.2 Class 2 and Class 3 transformers shall comply with the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

Exception: A Class 2 and Class 3 transformer that meets the applicable construction and performance requirements of Section 36, Class 2 Power Sources and Circuits, and Section 68, Class 2 Power Sources and Circuits, and applicable Class 2 power source and circuit tests in Section 63, Class 2 Power Sources and Circuit Tests.

5A.19.2 revised February 6, 2015

5A.20 Valves (electrically operated) and solenoids

5A.20.1 Electrically operated valves shall comply with the:

a) Standard for Electrically Operated Valves, UL 429; or

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

5A.20.2 Solenoids shall comply with the applicable construction and performance requirements of this standard.

6 General

6.1 A temperature-indicating or -regulating device or system that falls within the scope of 1.11, but has a maximum secondary potential of more than 30 volts or a maximum secondary output more than that specified for a standard Class 2 transformer under any service condition or load shall be investigated under conditions of intended service to determine whether it is acceptable for the intended application.

6.2 *deleted January 6, 2012.*

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7 Frame and Enclosure

7.1 General

7.1.1 Temperature-indicating and -regulating equipment shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected, without increasing the 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.

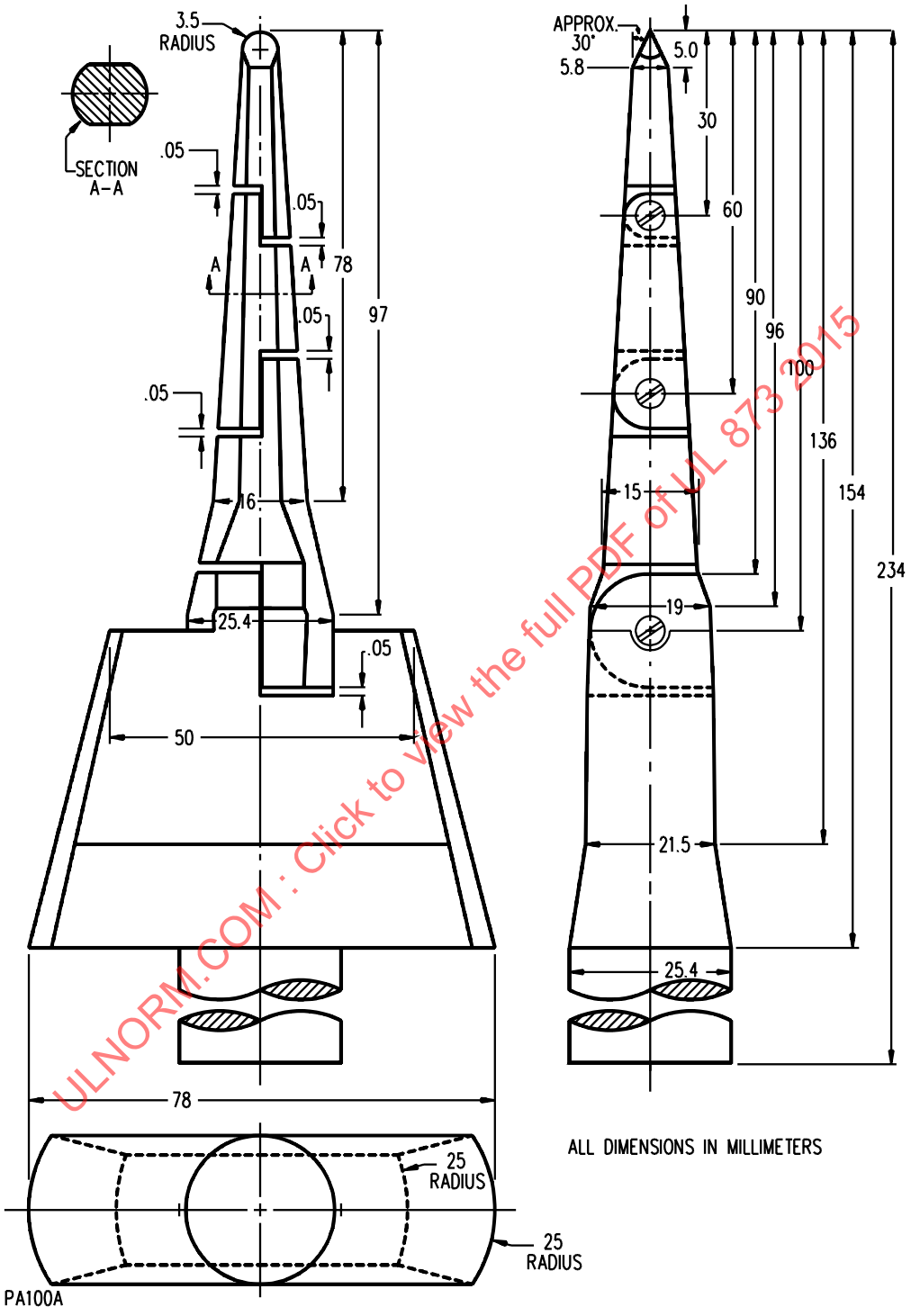
7.2 Accessibility of live parts

7.2.1 Electrical parts of a device, other than a supply cord or low-voltage terminals, shall be located or enclosed to reduce the risk of unintentional contact with an uninsulated live part. Additionally, electrical parts shall be located or enclosed so that protection against unintentional contact or shorting of live parts that could result in a malfunction of the controlled equipment is provided. For the purpose of these requirements, film-coated wire is considered to be an uninsulated live part.

Exception: An enclosure is not required for a device intended for assembly as part of another device.

7.2.2 An opening in an enclosure of a control is acceptable if an accessibility probe as illustrated in Figure 7.1, when inserted into the opening, cannot be made to touch any part that involves a risk of electric shock to the end-user or service personnel. However, in no case shall the opening be large enough to permit the entrance of a 1 inch (25.4 mm) diameter rod.

Figure 7.1
Accessibility probe



Note: All length dimensions in millimeters

7.2.3 The accessibility probe shall be articulated into any configuration and shall be rotated or angled to any position before, during, or after insertion into the opening, and the penetration shall be to any depth allowed by the opening size, including minimal depth combined with maximum articulation.

7.2.4 If any part of the enclosure must be opened or removed as part of normal operation, regular adjustment, or regular or required maintenance (set point adjustment, timer or time of day clock adjustment, battery replacement, and the like) with or without the use of tools, or can be opened or removed without the use of tools, the accessibility probe is to be applied without the part in place.

7.3 Covers

7.3.1 An enclosure and a part of an enclosure such as a door, cover, or tank, shall be provided with means for firmly securing it in place.

7.3.2 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part removed to install field wiring or for operation of the equipment. Sheet-metal screws may thread into sheet-metal nuts that are permanently mounted and protected against corrosion, and machine screws and self-tapping machine screws may thread directly into sheet-metal walls. See 19.12.

7.3.3 Sheet-metal screws mounting internal components that are not removed for installation or operation may thread directly into metal.

7.3.4 An enclosure cover shall be hinged if it gives access to fuses, thermal cutouts, or any other overload-protective device, the functioning of which requires renewal, or if it is necessary to open the cover in connection with intended operation of the device.

7.3.5 A door or cover giving access to a fuse or thermal cutout in other than a low-voltage circuit shall shut closely against a 1/4-inch rabbet or the equivalent, have turned flanges for the full length of four edges, or have angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the walls of the box proper and shall overlap the edges of the box not less than 1/2 inch (12.7 mm). A construction that affords equivalent protection or a combination of flange and rabbet is acceptable.

7.3.6 A strip used to provide a rabbet and an angle strip fastened to the edges of a door shall be secured at not less than two points, not more than 1-1/2 inches (38.1 mm) from each end of each strip and at points between these end fastenings not more than 6 inches (152 mm) apart.

7.3.7 A hinged cover shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed, but shall be provided with a spring latch or catch.

Exception: A cover that is hinged but is not required to be hinged for holding the cover may be held closed by a clasp, a sliding latch, or other means.

7.3.8 A snap-on cover that gives access to bare live parts and that does not require a tool for removal shall withstand the tests described in Snap-On Covers Test, Section 58.

7.3.9 The continuity of a bonding means for a snap-on or fastener-attached cover shall comply with the requirements in Bonding of Internal Parts, Section 22.

7.4 Transformers

7.4.1 A transformer shall be housed within its own enclosure, within the main enclosure of temperature-indicating and -regulating equipment, or within a combination of the two.

7.4.2 A sheet-steel transformer enclosure shall have a thickness of not less than 0.026 inch (0.66 mm) if uncoated and not less than 0.029 inch (0.74 mm) if galvanized.

Exception: Sheet steel having a thickness of not less than 0.020 inch (0.51 mm) if uncoated and not less than 0.023 inch (0.58 mm) if galvanized may be used for a drawn end bell having maximum dimensions of 2-1/4 inches (57.2 mm) on the flat portion and 1-1/2 inches (38.1 mm) at the base of the drawn portion.

7.4.3 A cast-metal transformer enclosure shall comply with the requirements in 7.5.1. A transformer enclosure of other material shall have strength and rigidity, and otherwise be rated for the purpose.

7.5 Cast metal

7.5.1 A cast-metal enclosure shall be at least 1/8 inch (3.2 mm) thick at every point, more than 1/8 inch thick at reinforcing ribs and door edges, and not less than 1/4 inch (6.4 mm) thick at tapped holes for conduit.

Exception: Other than at plain or threaded conduit holes, die-cast metal may be:

a) Not less than 3/32 inch (2.4 mm) thick for an area greater than 24 square inches (154.8 cm^2) or having dimensions more than 6 inches (152 mm).

b) Not less than 1/16 inch (1.6 mm) thick for an area of 24 square inches or less and having no dimensions more than 6 inches. The area limitation may be obtained by the provision of reinforcing ribs subdividing a larger area.

c) Not less than 0.035 inch (0.89 mm) thick if the enclosure will not be used as a splice box and if the voltage rating of the complete device is such that the voltage between any two conductors is 250 volts or less, and is limited to direct current or single-phase alternating current.

d) Not less than 0.028 inch (0.71 mm) thick if the enclosure houses only low-voltage circuits.

7.6 Sheet metal

7.6.1 Other than at points where a wiring system is to be connected, the thickness of a sheet-metal enclosure shall not be less than that specified in Tables 7.1 and 7.2.

Exception: A room thermostat shall be as specified in 7.9.3.

7.6.2 At points at which a wiring system is to be connected, uncoated steel shall not be less than 0.032 inch (0.81 mm) thick, zinc-coated steel shall not be less than 0.034 inch (0.86 mm) thick, and nonferrous metal shall not be less than 0.045 inch (1.14 mm) thick.

7.6.3 Tables 7.1 and 7.2 are based on a uniform deflection of the enclosure surface for a given load concentrated at the center of the surface regardless of metal thickness.

7.6.4 With reference to Tables 7.1 and 7.2, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface, and that has sufficient torsional rigidity to resist the bending moments that may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

a) Single sheet with single formed flanges – formed edges,

b) A single sheet that is corrugated or ribbed,

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

Table 7.1
Minimum thickness of sheet metal for enclosures– carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness, inch (mm)			
Maximum width[b],		Maximum length[c],		Maximum width[b],		Maximum length,					
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Uncoated		Metal coated	
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)				

Table 7.1 Continued on Next Page

Table 7.1 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness, inch (mm)			
Maximum width[b], Inches	(cm)	Maximum length[c], Inches	(cm)	Maximum width[b], Inches	(cm)	Maximum length, Inches	(cm)	Uncoated		Metal coated	
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 7.6.4.

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

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

[d] Sheet steel for an enclosure intended for outdoor use – raintight or 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 7.2
Minimum acceptable thickness of sheet metal for enclosures – aluminum, copper, or brass

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

[a] See 7.6.4.

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

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

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

7.7 Polymeric

7.7.1 A polymeric enclosure or enclosure part shall have mechanical strength and durability and be formed so that operating parts will be protected against damage, and shall resist the abuses likely to be encountered during installation and intended use and service.

7.7.2 An enclosure or enclosure part shall protect persons against a risk of electric shock. The enclosure material shall not create or contribute to a risk of fire, electric shock, or injury to persons.

7.7.3 Among the factors that are to be taken into consideration when investigating the acceptability of a polymeric enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture absorption;

d) Resistance to combustion and to ignition from electrical sources;

e) Dielectric properties, insulation resistance, and resistance to arc tracking; and

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

7.7.4 A material shall not display a loss of the properties specified in 7.7.3 beyond the minimum acceptable level as a result of aging.

7.7.5 The tests for determining compliance of a polymeric enclosure used with equipment covered by this standard are described in Polymeric Materials Tests, Section 62.

Exception: The cover of a wall-mounted room thermostat need not comply with the requirements in Polymeric Materials Tests, Section 62, but will be subjected to an appropriate investigation.

7.7.6 The polymeric enclosure material shall be rated for the normal operating temperature encountered in service and have a temperature rating at least equal to the normal operating temperature as determined by the temperature test described in Temperature Test, Section 40.

7.7.7 If continuity of a grounding system relies on dimensional integrity of a nonmetallic material, the dimensional stability of the material shall be considered in addition to the factors mentioned in 7.7.3.

7.7.8 A part, such as a dial or nameplate, that is a part of an enclosure shall be metal or other material as specified for the enclosure in 7.5.1 – 7.7.6.

7.7.9 A nonmetallic part such as a reset knob, lever, or button that protrudes through a hole in the enclosure that is not larger than the area of a 7/8-inch (22.2-mm) diameter circle shall be made of a material classified as V-0, V-1, or V-2 in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

7.7.10 A nonmetallic part that protrudes through a hole larger than the area of a 7/8-inch (22.2-mm) diameter circle shall be made of a material that complies with the requirements in 7.7.1, 7.7.2, and 7.7.8. See 7.10.5.

7.7.11 A nonmetallic cover that gives access to bare live parts shall comply with the requirements in 7.3.8 and Snap-On Covers Test, Section 58 and there shall be no exposure of live parts.

7.7.12 A cover attached by screws shall comply with the requirements in 7.3.8 with the screws tightened, and with the screws loosened one full turn.

7.8 Windows

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

7.8.2 Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick, and glass for a larger opening, but not more than 144 square inches (929 cm^2) in area and having no dimension greater than 12 inches (305 mm), shall not be less than 1/8 inch (3.2 mm) thick. Glass that covers a larger area shall not be less than 1/8 inch thick and shall conform to one of the following:

a) The glass shall be of a nonshattering or tempered type that, when broken, shall conform to the performance specifications in the Safety Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-1984; or

b) Shall withstand a 2-1/2 foot-pound (2.41 J) impact from a 2-inch (50.8-mm) diameter, 1.18 pound (535 g) steel sphere without cracking or breaking to the extent that a piece is released or dropped from its intended position.

7.8.3 A transparent material other than glass employed as a covering over an opening in an enclosure shall be investigated to determine if it has adequate mechanical strength and is otherwise acceptable for the purpose.

7.9 Room thermostats

7.9.1 A room thermostat intended for assembly on a flush-mounted box shall be provided with a box of sheet steel not less than 0.053 inch (1.35 mm) thick – 0.056 inch (1.42 mm) if zinc coated; or with a cast-metal box not less than 1/8 inch (3.2 mm) thick.

Exception: A room thermostat need not be furnished with a box if means for mounting on a standard outlet box – minimum inside width 1-13/16 inches (56.0 mm), minimum inside length 2-27/32 inches (72.2 mm) is provided and if, when so mounted on the intended box and when the full displacements and tolerances permitted by the mounting means are considered, at least the minimum required spacings are provided.

7.9.2 Zinc-base die-cast metal shall not be used for a flush box.

7.9.3 A residential room-thermostat cover having no dimension greater than 6 inches (152 mm) and having no surface greater than 18 square inches (116.1 cm^2) may be not less than 0.020 inch (0.51 mm) thick uncoated steel, 0.023 inch (0.58 mm) zinc-coated steel, 0.023 inch nonferrous metal, or 0.035 inch (0.89 mm) die-cast metal.

Exception No. 1: A 0.016-inch (0.41-mm) thick uncoated steel, 0.019-inch (0.48-mm) zinc-coated steel, 0.018-inch (0.46-mm) nonferrous metal, or 0.032-inch (0.81-mm) die-cast metal may be employed if there are no live parts exposed when the thermostat cover is removed.

Exception No. 2: The thickness of a cover that is decorative only is not specified; the mounting plate and mechanism shall comply with the enclosure requirements with the cover removed.

7.9.4 The enclosure of a room thermostat is to be formed so that its shape and means of support provide adequate mechanical strength.

7.10 Openings

7.10.1 An opening shall not be provided in an enclosure that houses a fuse or any portion of a circuit breaker other than the operating handle, unless the construction affords containment of electrical fault disturbances equivalent to that provided by an enclosure complying with the requirements in 7.3.5 – 7.3.7.

7.10.2 The following requirements apply to openings other than those provided in the enclosure of a room thermostat:

a) An opening shall not be provided in a compartment or part of an enclosure that contains field-wiring splices in a line-voltage circuit.

b) No openings shall be located in the mounting surface of an enclosure.

Exception: The following openings may be located in the mounting surface of an enclosure:

1) A mounting opening;

2) A maximum of four openings provided for the escape of air or paint during a painting process. The maximum dimension of such an opening shall not exceed 1/8 inch (3.2 mm); or

3) A maximum of four unused holes provided for mounting of internal components. The maximum dimension of such an opening shall not exceed 3/16 inch (4.8 mm).

c) If the bottom surface is not the mounting surface, an opening may be provided in the bottom surface of an enclosure if the opening does not permit materials to fall directly out from the interior of the unit. See Figure 7.2 for an example of a construction that may be used.

d) The shortest distance between an opening and the bottom of an enclosure or a wall-mounting surface shall be at least one-quarter of the enclosure height or depth, respectively, or 1 inch (25.4 mm), whichever is less.

e) There shall be no emission of flame or molten material, or manifestation of risk of fire, during normal or abnormal tests on the control, such as transformer burnout and burnout of a relay or solenoid with blocked armature.

f) Unless the construction of a device provided with forced ventilation is such that there is no direct path between live parts and the outlet opening, burnout tests in addition to those mentioned in (e) shall be conducted to determine that there is no emission of flame or molten material through that opening.

g) Air from an opening, either forced or otherwise, shall not be directed into a duct or into a concealed space in a building, against the mounting surface, and so that a disturbance would be propagated to other equipment.

h) No more than four holes for mounting an enclosure having a maximum dimension of 18 inches (457 mm); six holes for an enclosure with a maximum dimension of more than 18 inches, but less than 48 inches (1.2 m); eight holes for an enclosure with a maximum dimension of 48 inches or more. Four of the holes for mounting an enclosure with a maximum dimension of 12 inches (305 mm) may be keyhole slots having the configuration illustrated in Figure 7.3. The dimensions shown in Figure 7.3 may vary if the area is equivalent. Four of the holes for mounting a larger enclosure may be keyhole slots, the dimensions of which are not specified, and which shall be investigated with regard to the enclosure dimensions and configuration.

Figure 7.2
Bottom surface openings of enclosures

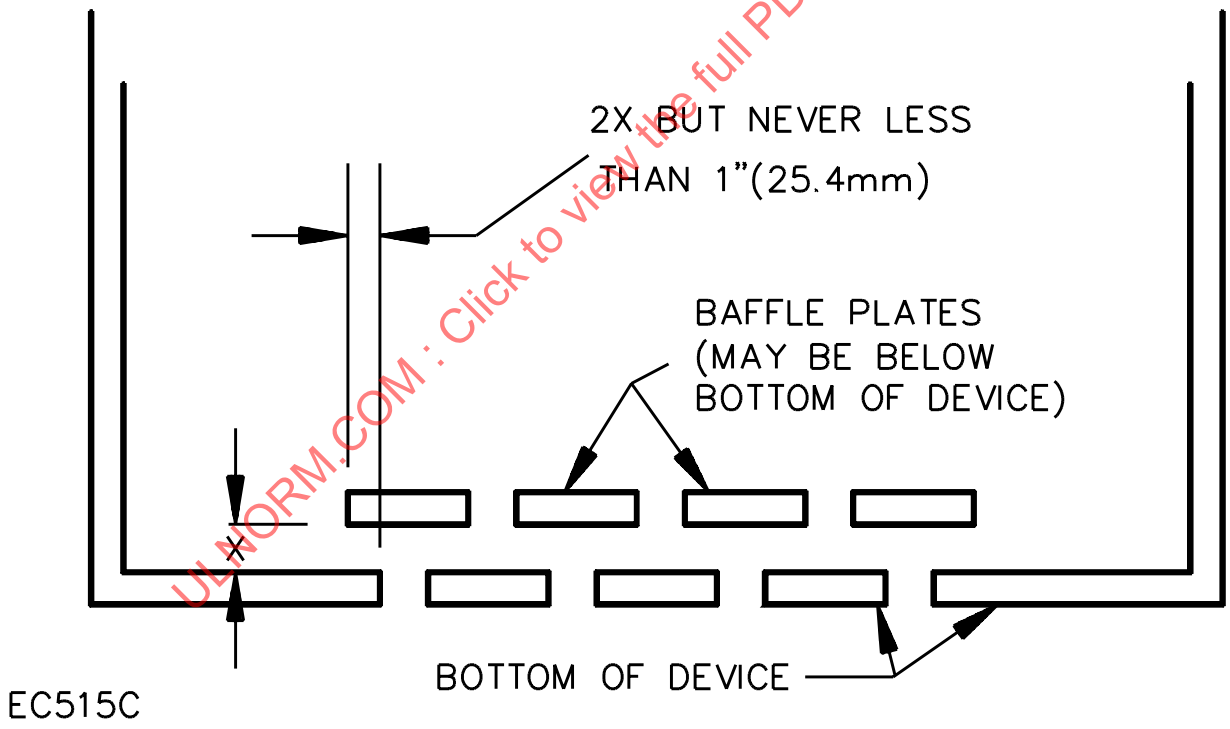
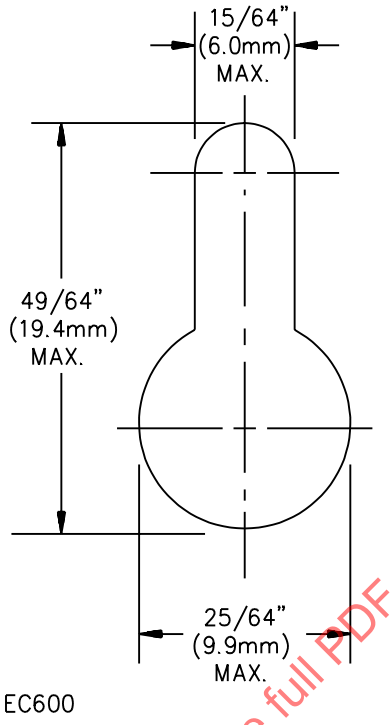


Figure 7.3
Keyhole slot



7.10.3 A room thermostat rated more than 300 volts, with the outer cover on or removed, shall comply with the requirements in 7.2.2.

7.10.4 An opening, such as a perforated hole, a louver, or an opening protected by wire screening, expanded metal, or a perforated cover, in the enclosure of a room thermostat the rating of which includes a value of 300 volts or less shall not permit passage of a 17/64-inch (6.7-mm) diameter rod.

Exception No. 1: If the distance between an uninsulated live part and the edge of an opening is 2-1/2 inches (63.5 mm) or more, the opening may permit passage of a 17/64-inch diameter rod but shall not permit passage of a 33/64-inch (13.1-mm) diameter rod.

Exception No. 2: If other means, such as an internal barrier or arrangement of parts provides equivalent protection, the maximum size of an individual opening in an enclosure is not specified.

7.10.5 The smaller dimension – width– of an opening in an enclosure around a dial, adjusting knob, lever, handle, pointer, or the like shall not be more than 1/8 inch (3.2 mm) for any setting or position of the dial, knob, or other members.

7.10.6 A plate or plug for an unused conduit opening or other hole in an enclosure shall have a thickness not less than 0.014 inch (0.36 mm) for steel or 0.019 inch (0.48 mm) for nonferrous metal for a hole having a 1/4-inch (6.4-mm) maximum dimension and 0.027-inch (0.69-mm) steel or 0.032-inch (0.81-mm) nonferrous metal for a hole having a 1-3/8-inch (34.9-mm) maximum dimension. A closure for a larger hole shall have a thickness equal to that required for the enclosure of the device or a standard knockout seal shall be used. Such a plate or plug shall be securely mounted.

7.11 Screens and expanded metal

7.11.1 The wires of a screen shall not be less than 16 AWG for screen openings 1/2 square inch (3.2 cm^2) or less in area, and shall not be less than 12 AWG for larger screen openings.

7.11.2 Perforated sheet steel, and sheet steel employed for expanded metal mesh, shall not be less than 0.042 inch (106.7 mm) thick – 0.045 inch (114.3 mm) if zinc coated – for mesh openings or perforations 1/2 square inch (3.2 cm^2) or less in area and shall not be less than 0.080 inch (203.2 mm) thick – 0.084 inch (213.3 mm) if zinc coated – for larger openings.

Exception: Expanded metal mesh that complies with the requirements in 7.11.3 may be used.

7.11.3 In a small device where the indentation of a guard or enclosure will not alter the clearance between uninsulated, movable, current-carrying parts and grounded metal, so as to adversely affect performance or reduce spacings below the minimum acceptable values specified in Table 33.1, 0.020-inch (0.51-mm) expanded metal mesh – 0.023-inch (0.58-mm) if zinc coated – may be employed, provided the exposed mesh on any one side or surface of the device so protected has an area of not more than 72 square inches (464.5 cm^2) and has no dimension greater than 12 inches (305 mm) or the width of an opening so protected is not greater than 3-1/2 inches (88.9 mm).

7.12 Wiring openings

7.12.1 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or if an equivalent construction is used, there shall be no less than three threads in the metal, and the construction of the control shall be such that a conduit bushing can be attached as intended.

7.12.2 If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors that affords protection to the conductors equivalent to that provided by a standard conduit bushing and that has an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

7.12.3 In an enclosure threaded for support by rigid conduit at least five full threads shall be provided for engaging the conduit.

7.12.4 A conduit hub or nipple attached to the enclosure of a pressure switch or similar equipment by swaging, staking, or similar means shall withstand, without pulling apart, a direct pull of 200 pounds (890 N), a bending moment of 600 pound-inches (67.8 N·m), and a torque of 600 pound-inches, each applied in turn for 5 minutes.

7.12.5 For the pullout test, the equipment is to be supported by a rigid conduit in the intended manner and is to support a weight of 200 pounds (90.8 kg).

7.12.6 For the bending and torsion tests, the equipment is to be rigidly supported by means other than the conduit fittings.

7.12.7 In the bending test, the force is to be applied to the conduit at right angles to its axis, and the lever arm is to be measured from the wall of the enclosure in which the hub or stud is located to the point of application of the bending force.

7.12.8 In the torsion test, the force is to be applied to the conduit in a direction tending to tighten the connection, and the lever arm is to be measured from the center of the conduit.

7.12.9 With reference to 7.12.5 – 7.12.8, some distortion of the enclosure under test may result. The test may be discontinued when noticeable distortion occurs.

7.12.10 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and the like that are supplied as a part of an enclosure shall comply with the requirements in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

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

7.12.12 A knockout shall be provided with a flat surrounding surface adequate for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in a spacing between uninsulated live parts and the bushing less than that required by this standard.

7.12.13 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum required in this standard shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a full-scale drawing provided with the device may be used to limit such a location.

7.12.14 In measuring a spacing between an uninsulated live part and a bushing installed in the knockout referred to in 7.12.12 and 7.12.13, it is to be assumed that a bushing having the dimensions in Table 7.3 is in place, and that a single locknut is installed on the outside of the enclosure.

Table 7.3
Dimensions of bushings

Trade size of conduit, inches	Overall diameter,		Height,	
	inches	(mm)	inches	(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	(68.7)	5/8	(15.9)
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	(112.7)	15/16	(23.8)
4	4-31/32	(126.2)	1	(25.4)
4-1/2	5-35/64	(140.9)	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)

7.12.15 No wire other than wires leading to a part mounted on a door or cover shall be brought out through the door or cover.

7.13 Raintight and rainproof enclosures

7.13.1 When subjected to the Rain Test, Section 56, an enclosure designated as:

a) Raintight shall restrict rain from entering the enclosure.

b) Rainproof shall restrict rain from interfering with the successful operation of the apparatus used within the enclosure.

7.13.2 A raintight or rainproof enclosure shall be marked as specified in 69.7.

7.13.3 A gasket employed to make an enclosure raintight or rainproof shall be tested as specified in Accelerated Aging Tests on Gaskets, Sealing Compounds, and Adhesives, Section 54.

7.13.4 A raintight or rainproof enclosure shall be provided with external means for mounting.

Exception: A rainproof enclosure may be provided with internal means for mounting if the mounting means is intended to restrict water from entering the enclosure.

7.13.5 An opening for conduit in a raintight enclosure, other than in the bottom of the enclosure shall be threaded.

7.13.6 An opening for conduit in a rainproof enclosure shall be threaded unless located wholly below the lowest terminal lug or other live part within the enclosure. There shall be provision for drainage of the enclosure if a knockout or unthreaded hole is provided other than in the bottom.

8 Mounting

8.1 Provision shall be made for mounting a device securely in position. Bolts, screws, or other parts used for mounting a device shall be independent of those used to secure components of the device to the frame, base, or panel.

8.2 A control switch, a lampholder, an attachment-plug receptacle, or a plug connector provided as a part of a device shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

8.3 A properly applied lock washer may be used as a means to restrict a control switch from turning.

9 Parts Containing Liquid Metal

9.1 A part of a control intended for use with cooking or other food-handling appliances that contains mercury and the parts of any control that contain sodium-potassium shall be constructed of metal that:

a) Has a tensile yield strength at a temperature of 120 percent of the maximum normal use Fahrenheit temperature equal to at least four times the hoop stress or other stress on the part at that temperature.

b) Is known not to be susceptible to corrosion-stress-cracking when exposed to the contained liquid metals and external agents, or is subjected to appropriate tests.

10 Adjustment Stop

10.1 A part of a control that is user operated and that limits the degree of rotation or length of movement of an adjustment– hereinafter referred to as the adjustment stop – shall be constructed so that it withstands the usage encountered in its intended operation as determined by the applicable tests in Strength of Adjustment Stop Test, Section 61.

10.2 If it is intended that the end-product incorporate the means to limit the movement of the adjustment stop as described in 10.1, the requirements are to be applied to the end-product and not to the control, however:

a) If an extended handle or the like is intended to be added on the appliance, the adjustment stop for the control shall have the strength necessary to prevent both damage and a change in calibration during shipping and handling.

b) If a control has no adjustment stop and is intended to be assembled into an appliance plug or other mechanism, the adjusting means shall be provided with a temporary seal to reduce the likelihood of damage or a change in calibration prior to final assembly.

c) The adjustment stop is to be tested as specified in Strength of Adjustment Stop Test, Section 61, except that the torque or force applied to the adjusting means need not be greater than 1 pound-inch (0.1 N·m) or 1 pound (4.5 N).

11 Operating Mechanism

11.1 A temperature-indicating or -regulating device shall be assembled so that it will not be adversely affected by the vibration of normal operation.

11.2 Screws and nuts that attach operating parts to movable members shall be upset or otherwise locked to reduce the likelihood of loosening under the conditions of actual use.

11.3 An operating mechanism shall not subject manually operated switch parts to undue stress.

11.4 The position of an operating handle shall be marked if necessary as a guide for proper operation.

11.5 A control that is intended for factory installation on an appliance and that has or is intended to have a marked off position or an implied off position – see 11.7 – 11.9 – shall:

a) Open all ungrounded conductors of the circuit when the adjusting means is in the off position; and

b) Be restricted from functioning automatically when in the off position either by a positive mechanical means or as specified in 11.10.

Exception No. 1: If unintentional energization of the appliance in which the control is intended to be used will not result in a risk of fire or electric shock – for example, a range oven having no live parts exposed to the user – the control need not comply with this requirement.

Exception No. 2: For a control intended for use in conjunction with another control, the requirement can be met by the combination of the two controls.

Exception No. 3: If energization of the appliance in which the control is intended to be used will not result in a risk of electric shock during operation or cleaning, or the like, but may result in a risk of fire or injury to persons if unintentionally energized – for example, a hot plate – the control need only open a sufficient number of conductors to de-energize the circuit.

11.6 A capillary-type control if specified for use in the end-product – for example, certain temperature-regulating controls for commercial cooking appliances – is to comply with the requirements specified in 11.5 with the capillary tube normal and cut, in separate tests.

11.7 A thermostat or a thermostatically controlled switching device intended for direct control of indoor electric space-heating equipment that is to be permanently connected electrically shall disconnect all ungrounded conductors of the supply circuit when:

a) The actuating member is placed in a marked off position, or

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

11.8 A device that is marked with a phrase such as ″no heat″ or ″cold″ that conveys the same meaning as the word ″off″ shall also comply with the requirement in 11.7.

11.9 A single-pole thermostat marked ″Lo – Normal – High″ or having a temperature scale such as 40 – 80 or a numerical scale such as 1 – 5 (not including the numeral 0) is not considered to have an off position as defined in 11.7.

11.10 A thermostat or thermostatically controlled switching device intended for direct control of indoor, electric-space-heating equipment that is to be permanently connected electrically that has a marked off position, or an unmarked off position that is implied by the fact that there is a marked on position shall not function as a thermostat (shall not respond to temperature changes) while the actuating member is in the off position.

11.11 A thermostat that does not reclose (remains open) when cooled to a temperature of minus 35°C (minus 31°F) is acceptable with respect to the requirement in 11.10.

11.12 A combined manual switch and thermostat intended for direct control of indoor electric space-heating equipment that is to be permanently connected electrically shall disconnect all ungrounded conductors of the supply circuit regardless of temperature, and shall be constructed so that the circuit cannot be energized automatically after the device has been manually placed in the off position.

11.13 A device involving electronic control circuits shall be investigated under conditions of actual service to determine if it complies with all applicable requirements and is otherwise acceptable for its intended application.

11.14 A marked off position shall have an air-gap construction.

Exception: A solid-state device may be employed but shall be subjected to an appropriate investigation to determine equivalent protection.

11.15 A component, such as a resistor, capacitor, diode, and the like, shall not be connected across the contacts of a safety control or a protective or limiting device.

Exception: A component may be connected across the contacts if investigated and found to be acceptable in the end product.

11.16 A water-heater temperature-limiting control shall be a manually reset control.

Exception: A temperature-limiting control for a marine-type storage-tank water heater may be a single-operation device. See Single-Operation Devices, Section 81.

11.17 A water-heater temperature-limiting control shall have no operating part in common with a water-heater temperature-regulating control, but a common mounting bracket or a common enclosure may be employed for both controls.

11.18 A temperature-regulating thermostat or control for a household electric storage tank water heater shall be set before leaving the factory to a control position corresponding to a temperature no higher than 60°C (140°F). This setting may be approximate, for a marking on the control that reads ″Low-Medium-High″ or the equivalent.

11.19 A combination thermostat/GFCI intended for control of in-floor electric heating elements in bathrooms and similar locations shall:

a) Have load switching devices (i.e. relays) that are dedicated to each circuit; the relays that are used to terminate the GFCI circuit shall not operate in reaction to the thermostat functionality, or

b) Have a feedback circuit that reliably verifies the correct operation of the entire GFCI circuit, including the load switching devices, during the user initiated GFCI test sequence – see also 5.15, Supervisory Circuit, of the fourth edition of the Standard for Ground-Fault Circuit-Interrupters, UL 943. The results of the test shall be made known to the user by means of an audible or visual indication. Units that are unable to acceptably complete the test shall permanently de-energize the load controlling switching devices; thereby, rendering the outputs incapable of delivering power to the load as described in item (b) of 5.15.5 of UL 943.

Added 11.19 effective January 6, 2012

11.20 Correct operation in 11.19 refers to the GFCI's ability to disconnect all ungrounded poles of the load circuit in response to the test operation. The reliability of the feedback (supervisory) circuit, if electronic, shall be ensured through an evaluation of the circuit to the relevant requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. Software used with the feedback circuit shall be evaluated to the Standard for Software in Programmable Components, UL 1998.

Added 11.20 effective January 6, 2012

12 Reset Mechanism – Limiting Control

12.1 A control shall not reset or be resettable manually or otherwise so that operation of the controlled appliance can be resumed until after a safe operating condition is restored. For example, pressure or temperature returned to a value at or below the control set point.

12.2 A control that is intended to be reset manually shall not reset automatically as a result of changes in environmental temperature at temperatures at or above minus 35°C (minus 31°F) for a regular limiting control or a marine-type storage-tank water heater temperature-limiting control, and above 0°C (32°F) for a non-marine storage-tank water heater temperature-limiting control.

Exception: This requirement does not apply if it is not required for the end-use product.

12.3 A manually reset device shall be trip-free; that is, the automatic tripping shall be independent of the manipulation or position of the reset button, handle, lever, or the like. The verification of the reset mechanism operation of an electro-mechanical limiting control shall be performed on the same sample, following the Overload and Endurance tests of sections 45 and 46.

12.3 revised January 6, 2012

12.4 A manually reset device of a control may provide one or another of the following kinds of reset function:

a) For a control designated ″Manually Reset 1″ or ″M1″, the control shall automatically reset to the closed position after normal operating conditions have been restored, if the reset means is held in the reset position. The operating tolerances specified in Calibration-Verification Test, Section 44, shall not be exceeded if the reset means is held in the reset or on position.

b) For a control designated ″Manually Reset 2″ or ″M2″, the control shall not function as an automatically reset device if the reset means is held in the reset or on position.

12.5 The means for resetting a control with a manual reset shall be external to the control enclosure.

Exception: If the control enclosure complies with the requirements for protection as specified in Protection of Users and Service Personnel, Section 23, and Protection Against Injury to Persons, Section 24, the means for resetting need not be external.

12.6 A manually reset mechanism shall not subject the operating mechanism or means of support to stress.

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13 Means for Calibration

13.1 The following controls shall comply with the requirements in 13.2 – 13.8:

a) A water-heater control;

b) A refrigeration pressure-limiting device;

c) An appliance temperature-limiting control including some regulating controls if limiting-control features are specified in the end-product standard;

d) A time-delay or thermal relay that responds to a limiting control;

e) A range oven-door-lock control;

f) A clean-temperature control for a self-cleaning range oven; and

g) A hot tub/spa water temperature control.

13.2 A means provided for factory calibration shall be factory-secured to restrict unintentional shifting after calibration.

13.3 A means for calibration that is accessible or apparent shall be modified, guarded, or sealed by a means such as soldering to effectively restrict manipulation by hand or an ordinary tool subsequent to factory calibration.

13.4 With reference to 13.3, a calibration means that is not considered to be accessible or apparent is a means that does not show, is not exposed to manipulation by a conventional tool, or is not readily displaced. Complete concealment of a conventional tool-engaging means in a screw, such as a slot, recessed head, or the like, by the use of solder, brazing material, or cement rated for the purpose is adequate to restrict manipulation if the calibration means cannot be changed readily by gripping with a conventional tool and engagement or manipulation is restricted at all other locations.

13.5 Enamel and other polymeric materials used to secure or seal the means of calibration at the factory are rated only for exposure to temperatures of 121°C (250°F) or less, unless they have been subjected to thermal aging tests and have been found acceptable for use at higher temperatures.

13.6 An adjustable control shall comply with the requirements in 13.2 and 13.3 with respect to the maximum temperature, pressure, or similar setting.

13.7 A temperature or pressure adjustment means, including a trim screw or the equivalent, shall be provided with a stop to restrict manipulation beyond a setting, or concealed or sealed, and in either case, factory-secured as required by 13.2.

13.8 Performance tests such as the calibration-verification tests, are to be conducted on samples having the highest setting permitted by the adjustment means, including a trim screw or the equivalent.

14 Protection Against Corrosion

14.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

Exception No. 1: Bearings, thermal elements, or the like need not be protected if such protection is impracticable.

Exception No. 2: Small minor parts of iron or steel such as washers, screws, bolts, and the like that do not carry current need not be protected if corrosion of such unprotected parts would not be likely to result in a risk of fire, electric shock, or injury to persons.

Exception No. 3: Parts made of stainless steel, properly polished or treated if necessary need not be protected.

14.2 The requirement in 14.1 applies to all enclosing cases whether of sheet steel or cast iron, and to all springs and other parts upon which proper mechanical operation may depend.

14.3 An enclosure designated either raintight or rainproof shall be protected against corrosion in accordance with the requirements in 14.4 – 14.18.

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

14.5 A hinge or other attachment shall be resistant to corrosion.

14.6 These requirements do not contemplate corrosion that might be caused by exposure to the earth or other corrosive agents.

14.7 The requirements specified in 14.8 – 14.18 do not apply to a part, such as a decorative grille, that is not a required part of an enclosure.

14.8 A nonmetallic enclosure is to be investigated on the basis of the effect of exposure to ultraviolet light and water.

14.9 A metallic enclosure shall be protected against corrosion as specified in 14.10 – 14.18. See 7.5.1 – 7.6.4 for the required enclosure thickness.

14.10 Copper, bronze, brass containing not less than 80 percent copper, or stainless steel may be used without additional protection against corrosion. Aluminum – sheet, extrusion, or casting– die-cast zinc, or other metal shall be of a grade or alloy having resistance to atmospheric corrosion, equivalent to that specified for sheet steel of the required thickness or shall be subjected to appropriate tests, or shall be additionally protected against corrosion.

14.11 An enclosure of cast iron or malleable iron at least 1/8 inch (3.2 mm) thick shall be protected against corrosion by a 0.00015-inch (0.0130-mm) thick coating of zinc, cadmium, or the equivalent on the outside surface and a visible coating of such metal on the inside surface, or one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface.

14.12 Unless acceptability of the paint can be determined by consideration of its composition, corrosion tests are required.

14.13 An enclosure of sheet steel having a thickness less than 0.126 inch (3.20 mm) if zinc-coated or 0.123 inch (3.12 mm) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 14.16.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81(1991).

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 (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 55. An annealed coating shall also comply with 14.18.

c) A zinc coating conforming with 14.14 (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint applied after forming on each surface. The acceptability of the paint is to be determined by consideration of its composition or by corrosion tests.

d) A cadmium coating not less than 0.001 inch (0.03 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the Metallic Coating Thickness Test, Section 55.

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the Metallic Coating Thickness Test, Section 55, and the paint shall be as specified in (c).

14.14 An enclosure of sheet steel 0.126 inch (3.20 mm) thick if zinc-coated or 0.123 inch (3.12 mm) thick if uncoated or heavier shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to give equivalent protection as described in 14.16.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement in this ASTM designation. The weight of zinc coating may be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81(1991).

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0076 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 55.

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

d) Any one of the means specified in 14.13.

14.15 The requirements specified in 14.14 also apply to sheet steel 0.056 inch (1.42 mm) thick if zinc-coated or 0.053 inch (1.35 mm) thick if uncoated or heavier for an enclosure to be mounted within and protected from direct exposure to weather by the enclosure of other equipment, such as an air conditioner. Such an enclosure is not to be marked rainproof or raintight.

14.16 With reference to 14.13 – 14.15, other finishes, including paints, metallic finishes and combinations of the two may be accepted when comparative tests with galvanized sheet steel – without annealing, wiping or other surface treatment – conforming with 14.13(a) or 14.14(a), as applicable, indicate they provide equivalent protection. Among the factors that are to be taken into consideration when judging the acceptability of such coating systems are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, and ultraviolet light and water.

14.17 Test specimens of a finish as described in 14.14 or 14.16, 14.13(c), or 14.14(c), if the paint is tested, are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and the like.

14.18 A hot-dipped mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that water does not enter during the Rain Test, Section 56, need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

15 Insulating Material

15.1 A base for the support of a live part shall be of strong, noncombustible, moisture-resistant, insulating material.

15.2 A material other than slate, porcelain, phenolic or cold-molded composition, or one that is rated for the support of live parts shall be investigated under conditions of intended service to determine if it has the necessary electrical and mechanical properties and is otherwise rated for the application.

15.3 A base shall be constructed so that, considering the material used, it will withstand the most severe condition likely to be met in service.

15.4 Insulating material, including a barrier between parts of opposite polarity and material that may be subjected to the influence of an arc formed by opening a switch, shall be rated for the application.

15.5 Vulcanized fiber may be used for an insulating bushing, a washer, a separator, or a barrier, but not for the sole support of an uninsulated live part of other than a low-voltage circuit.

15.6 Unless otherwise specified in Section 7.7, polymeric electrical insulating materials and polymeric enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. The materials shall have the appropriate flammability class required by UL 746C based on the equipment intended use. The material flammability class is determined by tests in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

15.6 added January 6, 2012

15.7 Metallized or painted polymeric parts or enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. This requirement is not applicable to exterior surfaces of polymeric enclosure materials or parts provided that the metallized coating or paint does not offer a continuous path for an internal flame to propagate externally.

15.7 added January 6, 2012

16 Supply Connections

16.1 General

16.1.1 Connections to wiring terminals of equipment that is to be permanently connected electrically and supply connections are connections that are made in the field when the equipment is installed.

16.1.2 Wires within an enclosure, compartment, raceway, or the like shall be routed or protected so that damage to conductor insulation cannot result from contact with a rough, sharp, or moving part.

16.2 Equipment permanently connected electrically

16.2.1 General

16.2.1.1 Wiring terminals or leads shall be provided and shall be rated for the connection of conductors having an ampacity not less than the largest of the following ratings that are applicable:

a) One hundred twenty-five percent of the ampere rating of electric heating equipment for pools, hot tubs/spas, and space-heating equipment;

b) One hundred twenty-five percent of the full-load motor-current rating in accordance with 67.4 and 67.5. See Table 45.3 or 45.4 for the ampere rating corresponding to the horsepower rating;

c) For a combination load, 125 percent of the full-load motor current of the largest motor, plus 125 percent of the ampere rating of an electric space-heating equipment load that is to be permanently connected electrically, plus 125 percent of the continuous duty load, plus 100 percent of the sum of the current ratings of all other loads;

d) For direct-current-motors intended to be operated from a rectified single-phase power supply unless marked in accordance with 70.10;

1) One hundred ninety percent if a half-wave rectifier is used, or

2) One hundred fifty percent if a full-wave rectifier is used; or

e) The ampere rating of the equipment, for a load not specified in (a), (b), (c), and (d);

f) One hundred twenty-five percent of a continuous duty load.

16.2.1.2 With reference to 16.2.1.1, it is assumed that 75°C (167°F) conductors will be employed for currents of more than 100 amperes.

16.2.1.3 A field-wiring terminal marked to indicate that it is rated for use with a copper, a copper-clad aluminum, or an aluminum power supply conductor shall comply with the requirement in 16.2.1.1 for a wire of each metal for which it is marked.

16.2.1.4 A terminal box or compartment on equipment that is to be permanently connected electrically shall be located so that the wire connections therein will be accessible for inspection, without disturbing the line-voltage or safety-circuit wiring after the equipment is installed in the intended manner.

Exception: Wire connections to equipment intended to be mounted on an outlet box may be accessible upon removal of the equipment from the box.

16.2.1.5 The free lead length of a field-wiring lead shall not be less than 6 inches (152 mm); insulation on the conductor shall comply with the requirements in 19.1 – 19.5.

16.2.1.6 A field-wiring lead, other than a lead for connection of a Class 2 circuit, shall not be more than two standard wire sizes smaller than the copper conductor to which it will be connected, and shall not be smaller than 18 AWG (0.82 mm^2) – for example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm^2) field-provided conductor. See Table 16.1.

Exception No. 1: A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it will be connected, but not smaller than 18 AWG, if more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the following conditions:

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

b) The factory-provided leads are bunched or otherwise arranged to restrict stress on an individual lead; and

c) The equipment is marked in accordance with 70.9.

Exception No. 2: A single 18 AWG field-wiring lead may be connected to a 12 AWG field-provided conductor.

Table 16.1
Field-wiring lead size

Field-wiring lead wire size determination by 16.2.1.1, AWG	Required size of internal lead for field-wiring, AWG
14 or 12	18
12	16
10	14
8	12
6	10
4	8
3	6
2	4
1	3
1/0	2
2/0	1
3/0	1/0
4/0	2/0
250 kcmil	3/0

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16.2.1.7 A lead provided for connection to an external line-voltage circuit shall not be connected to a wire-binding screw or pressure terminal connector located in the same compartment as the splice unless the screw or connector is rendered unusable for field-wiring connection or the lead is insulated at the unconnected end, and a marking on the equipment clearly indicates the intended use of the lead.

16.2.1.8 The free end of a field-wiring lead that will not be used in every installation – such as a tap for a multivoltage transformer or one free lead for a single-pole, double-throw switch – shall be insulated. For a grounding lead, see 21.4.10.

16.2.1.9 For power-circuit connections, equipment that is to be permanently connected electrically shall have provision for the connection of a wiring system.

16.2.1.10 A device that is rated for use with a fitting for only one type of wiring system shall be supplied with such a fitting.

16.2.1.11 An opening for the entry of a conductor or conductors of a circuit of limited power and voltage shall be provided with an insulating bushing. The bushing may be mounted in place in the opening or may be within the enclosure so that it may be properly mounted when the device is installed.

16.2.1.12 The opening mentioned in 16.2.1.11 may be used for accommodating armored cable or conduit.

16.2.1.13 A bushing of rubber or rubber-like material provided in accordance with 16.2.1.11 shall be 1/8 inch (3.2 mm) or more thick, except that it may be not less than 3/64 inch (1.2 mm) thick if the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it will not be exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or the like that might damage the bushing.

16.2.2 Terminals

16.2.2.1 Terminal parts by which supply connections are made shall be such as to provide reliable connections even under hard usage.

16.2.2.2 Soldering lugs or solderless (pressure) wire connectors shall be used. A solderless (pressure) connector intended for connection of a 14 AWG or smaller copper conductor shall comply with the torque test specified in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors, UL 486E, with a tightening torque of not less than 7 pound-inches (0.8 N·m).

Exception: For a 10 AWG or smaller wire, the parts to which wiring connections are made may consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

16.2.2.3 A wire-binding screw employed at a wiring terminal shall not be smaller than No. 8.

Exception: A No. 6 screw may be used for the connection of one 14, 16, or 18 AWG conductor.

16.2.2.4 Other than as noted in 16.2.2.5, 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 or smaller wire, and not less than 0.050 inch (1.27 mm) thick for a wire larger than 14 AWG. There shall not be less than two full threads in the metal.

16.2.2.5 A low-voltage transformer may have terminal plates 0.030 inch (0.76 mm) thick for either primary or secondary connections.

16.2.2.6 A terminal plate formed from stock having the minimum required thickness specified in 16.2.2.1 – 16.2.2.4 may have the metal extruded at a tapped hole for a binding screw so as to provide two full threads.

Exception: Two full threads are not required if fewer threads make a connection in which the threads do not strip when it is subjected to a 20 inch-pound (2.3 N) tightening torque.

16.2.2.7 A wire-binding screw shall not thread into material other than metal.

16.2.2.8 In order to polarize the wiring of equipment that is to be permanently connected electrically and is intended to be connected to more than one wire of a supply circuit rated at 125 volts or 125/250 volts or less and employing an Edison screw-shell lampholder or a single-pole switch or overcurrent-protective device other than an automatic control, one terminal or lead shall be identified for connection to the grounded conductor of the supply circuit. A terminal or lead identified for connection to the grounded supply conductor shall be electrically connected to screw shells of lampholders, and shall not be connected to a single-pole switch or a single-pole overcurrent-protective device.

16.2.3 Outlet-box-mounted devices

16.2.3.1 Wiring terminals and other live parts and sharp-edged grounded or dead metal parts of a device intended for mounting on an outlet box or similar enclosure shall be located or protected so that they will not be forced against wiring in the box during installation.

16.2.3.2 With reference to the requirements in 16.2.3.1, back wiring terminals may be employed if they are recessed or are protected by close-fitting barriers of insulating material or the equivalent that will restrict contact with wiring installed in the box.

16.2.3.3 Terminals that do not project into a box beyond the plane of the front edge of the box may be used.

16.2.3.4 With reference to 16.2.3.2, guards provided alongside terminals and extending at least 1/4 inch (6.4 mm) beyond the terminals before wiring, with a corresponding guard between double-pole switching mechanisms, may be used.

16.2.3.5 To determine whether a construction other than that described in 16.2.3.4 restricts wiring in the box from being forced against live parts or sharp edges, a trial installation using only ordinary care is to be made on an appropriately sized outlet box, employing both copper and aluminum Type TW wire having ampacities in accordance with the rating of the device. The wire is to extend 6 inches (152 mm) inside the box from its point of entrance into the box.

16.3 Cord and plug connected portable equipment

16.3.1 Portable equipment shall be provided with a length of flexible cord and an attachment plug for connection to the supply circuit. The type of cord shall be rated for the application, and the rating of the plug and the ampacity of the cord shall be as specified in 16.2.1.1.

16.4 Stationary equipment

16.4.1 General

16.4.1.1 In determining the acceptability of a cord and plug connection for equipment that is intended to be fastened in place or located in a dedicated space, the decision is to include consideration of:

a) Whether:

1) The cord connection of the equipment facilitates frequent interchange,

2) Reduction of the transmission of noise or vibration is accomplished, or

3) The fastening means or mechanical connections are intended to permit removal for maintenance and repair, and

b) Whether the equipment is to be connected at the end of the run.

16.4.1.2 The cord on stationary equipment shall be Type SJ or equivalent hard-service cord, not more than 3 feet (914 mm) long, directly connected to the equipment and terminated in an attachment plug. The rating of the plug and the ampacity of the cord shall be as specified in 16.2.1.1.

16.4.2 Strain relief

16.4.2.1 Strain relief shall be provided so that mechanical stress on a flexible supply cord will not be transmitted to terminals, splices, or interior wiring.

16.4.2.2 A strain-relief device shall be subjected to the test described in Strain-Relief Test, Section 53.

16.4.2.3 Surfaces against which a knot in a flexible cord that serves as strain relief may bear or which it may contact shall be free from projections, sharp edges, burrs, fins, and the like, that may abrade the insulation on conductors.

16.4.3 Bushings

16.4.3.1 Where a flexible cord passes or is intended to pass through an opening in a wall, barrier, or enclosing case, there shall be a bushing rated for the application or the equivalent that is reliably secured in place, and has a smooth surface against which the cord may bear. An insulating bushing shall be provided for a cord lighter than Type SJ that passes through a wall or barrier of metal if the construction is such that the cord may be subjected to stress or motion.

16.4.3.2 A cord hole with a smooth surface through wood, porcelain, phenolic composition, or other nonconductive material rated for the application is considered to be the equivalent of a bushing.

16.4.3.3 Ceramic materials and some molded compositions may be used for insulating bushings; but a separate bushing of wood or so-called hot-molded shellac and tar composition may not be used.

16.4.3.4 A fiber bushing shall not be less than 3/64 inch (1.2 mm) thick, shall be formed and secured in place so that it will not be adversely affected by conditions of ordinary moisture, and shall not be employed where it will be subjected to a temperature higher than 90°C (194°F) under normal operating conditions.

16.4.3.5 A soft-rubber bushing shall not be less than 3/64 inch (1.2 mm) thick and shall be located so that it will not be exposed to oil, grease, oily vapor, or other substances having a deleterious effect on rubber. Such a bushing may be used only in the frame of a motor or for a cord connected to a supply circuit of limited voltage and power. A hole in metal in which a soft-rubber bushing is employed shall be free from sharp edges, burrs, projections, and the like, that would be likely to cut into the rubber.

16.4.3.6 Insulating material in an insulated metal grommet employed in lieu of an insulating bushing shall not be less than 1/32 inch (0.8 mm) thick and shall completely fill the space between the grommet and the metal in which it is mounted.

16.4.4 Polarity

16.4.4.1 The attachment plug of a cord-connected product shall be of the polarized type if the product is not provided with a grounding type attachment plug – see 21.1.1.

16.4.4.2 The blade of the attachment plug identified for connection to the grounded supply conductor shall not be electrically connected to a single-pole switching device, intended for product on-off operation, but shall be connected electrically to the screw-shell of an Edison-base lampholder and to the identified terminal of a receptacle.

17 Current-Carrying Parts

17.1 A current-carrying part shall have the necessary mechanical strength and ampacity for the service, and shall be of metal that is rated for the application.

17.2 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a means other than friction between surfaces so that it will be restricted from turning or shifting in position if such motion may result in reduction of spacings to less than those required by this standard. The security of contact assemblies shall provide continued alignment of contacts.

17.3 A lock washer properly applied may be used at a terminal or connection stud.

18 Switches

18.1 A switch provided as part of a product intended to be connected to a power-supply circuit having a potential to ground of more than 150 volts shall be rated for the maximum potential to ground of the circuit.

18.2 A nominal 208-volt, single or 3-phase or a 120/240 volt, single-phase product is considered to involve a potential to ground of less than 150 volts. A 2-wire, single-phase or a 3-wire, 3-phase product with a rating in the range from 220 – 250 volts is considered to involve a potential to ground in excess of 150 volts.

Exception: A product marked in accordance with 74.10 or 74.11 need not comply with this requirement.

18.3 Switches shall comply with one of the following and, as applicable, the overload and endurance test cycle level requirements in this standard:

a) The Standard for Special-Use Switches, UL 1054;

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

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

d) The Standard for Nonindustrial Photoelectric Switches for Lighting Control, UL 773A; or

e) The requirements of this standard applicable to switches when evaluated as an integral switching part of the control.

18.3 added January 6, 2012

18.4 A clock-operated switch, in which the switching contacts are actuated by a clock-work, by a gear-train, by electrically-wound spring motors, by electric clock-type motors, or by equivalent arrangements shall comply with one of the following:

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

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

18.4 added January 6, 2012

18.5 A timer or time switch, incorporating electronic timing circuits or switching circuits, with or without separable contacts, shall comply with:

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

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

18.5 added January 6, 2012

19 Internal Wiring

19.1 Internal wiring shall consist of insulated conductors, including conductors covered with insulating tubing or with noncarbonizable beads, having adequate ampacity for the service.

19.2 A 18 or 16 AWG (0.82 or 1.3 mm^2) rubber-covered wire in other than a low-voltage circuit as described in 2.6 shall be at least Type RFH-1 with impregnated braid, for a potential of 300 volts or less; and shall be at least Type RFH-2 with impregnated braid and shall be rated for the application for a potential of 301 – 600 volts.

19.3 A 14 AWG (2.1 mm^2) or larger conductor shall be Type TW, RH, or RHW wire.

19.4 Other types of conductors that have been found to be acceptable may also be employed; Type TF wire may be used wherever Type RFH-1 or RFH-2 wire may be used.

19.5 If necessitated by temperatures, Type SF-1 fixture wire may be used for a potential of 300 volts or less; and Type V, AVA, or AVB wire or Type SF-2 fixture wire may be used for a potential of 600 volts or less.

19.6 If the use of a short length of insulated conductor is not feasible – for example, a short coil lead or the like– electrical insulating tubing may be employed.

19.7 Tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, and shall not contact sharp edges, projections, or corners. Tubing may be used in dry or damp locations but may not be used in wet locations.

19.8 The wall thickness of electrical insulating tubing shall comply with the requirements for such tubing, except that the thickness at any point for the smaller sizes of polyvinyl chloride tubing shall not be less than 0.017 inch (0.43 mm). Insulating tubing of other types shall have a wall thickness not less than that providing mechanical strength, dielectric properties, heat- and moisture-resistant characteristics, and the like, at least equal to those of 0.017-inch-thick polyvinyl chloride tubing.

19.9 Internal wiring and connections between parts shall be protected or enclosed.

19.10 Rubber-insulated conductors shall not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber.

19.11 A wireway shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like, which may abrade insulation on conductors.

19.12 Mounting screws and nuts shall be made or located so that sharp edges will not damage wiring. A screw shall have a flat or blunt end. The end of a screw shall have no burrs, fins or sharp edges that might abrade wire insulation, and shall not project more than 3/16 inch (4.8 mm) into a wireway.

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

19.14 A bushing used over other than smooth, rounded surfaces of a hole through which wires pass shall be of material that has mechanical and heat-resistant properties rated for the application – such as porcelain, phenolic, fiber at least 3/64 inch (1.2 mm) thick, or smooth, rounded metal. A soft-rubber bushing or the like shall not be used for other than low-voltage wiring – see 16.2.1.13 – unless the material has been evaluated and found to be acceptable.

19.15 Insulated wires that are entirely enclosed within metal walls may be bunched and passed through a single opening.

19.16 A bare conductor or a conductor insulated with noncarbonizable beads shall be enclosed. A bare conductor within an enclosure shall be supported so that the required spacings will be maintained.

19.17 A short length of rubber-insulated flexible cord may be exposed to a temperature in excess of the normal maximum allowable temperature for the compound involved in a location such as at a terminal if supplementary heat-resistant insulation of acceptable dielectric properties is employed on individual conductors of the cord to prevent deterioration of the rubber. In any case, rubber insulation shall be of a type normally available that has a temperature limit as close as possible to or higher than the temperature involved.

19.18 A joint or connection shall be mechanically secure and shall provide reliable electrical contact without stress on a connection or a terminal.

19.19 A soldered connection shall be made mechanically secure before being soldered.

Exception: A connection for which:

a) A soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used;

b) A hand-soldered lead passed through a hole in a printed wiring board and bent 90 degrees to the board to make contact with the conductor before soldering;

c) Soldering on a printed wiring board is done by a machine process in which the soldering time and solder temperature are automatically controlled – bending over of leads is not required; or

d) The lead wire is strapped in place, or the equivalent, adjacent to the soldered connection so as to hold the lead end in place.

19.20 A joint shall be provided with insulation equivalent to that on the wires involved if permanence of spacing between the joint and uninsulated live parts of opposite polarity or grounded dead metal parts may not be maintained.

19.21 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch 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 pullout, engagement-disengagement forces of the connector and tab, and temperature rise; all tests shall be conducted in accordance with UL 310.

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

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

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

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

c) The Standard for Fixture Wire, UL 66; or

d) The applicable standard(s) for other insulated conductor types specified in Chapter 3 (Wiring Methods and Materials) of the National Electrical Code, 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 Standard for Appliance Wiring Material, UL 758.

19.22 added January 6, 2012

20 Low-Voltage External Wiring Requirements

20.1 A cable external to the equipment and supplied by the manufacturer for connection in a low-voltage Class 2 circuit shall be rated for the intended application as specified in Article 725 of the National Electrical Code, ANSI/NFPA 70-1993.

21 Grounding

21.1 General

21.1.1 There shall be provision for grounding all dead metal parts of the following controls that are exposed or that are likely to be touched by a person during normal operation or adjustment and that are likely to become energized through electrical fault.

a) A stationary control or a control that is to be permanently connected electrically.

b) A cord-connected control for a room air conditioner or dehumidifier, for outdoor or industrial equipment, or for equipment that is required to be grounded.

c) A portable control for use on a circuit involving a potential of more than 150 volts to ground.

d) A control provided with a grounding means, whether required or not.

21.1.2 A motor or motor operator shall be provided with means for the attachment of an equipment-grounding conductor termination for wire-to-wire or fixed-terminal connections. The means for such connections may be located either inside or outside the motor terminal housing.

Exception No. 1: The grounding means need not be provided if grounding is not required by 21.1.1.

Exception No. 2: The grounding means need not be provided on a motor that is to be installed as part of factory-wired equipment and that has its dead metal parts bonded to the grounding terminal of the overall equipment. See Bonding of Internal Parts, Section 22.

21.1.3 To determine whether a part is likely to become energized, such factors as construction, the proximity of wiring, a dielectric voltage-withstand test after the overload and endurance tests, and burnout tests are to be evaluated.

21.1.4 All dead metal parts of a room thermostat rated more than 300 volts that are exposed to contact, with or without the outer cover in place, shall be in electrical connection with the point of connection of the grounding means.

21.1.5 Any device that is intended to be installed into a device box shall be provided with one of the following means for connection to an equipment grounding lead:

a) A grounding lead that is bare or that is a green insulated wire with or without one or more yellow stripes; or

b) A grounding terminal identified as specified in 21.4.

21.2 Grounding means

21.2.1 An equipment-grounding terminal or lead grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection.

21.2.2 A grounding connection shall reliably penetrate a nonconductive coating, such as paint or vitreous enamel.

21.2.3 A grounding point shall be located so that it is unlikely that the grounding means will be removed during normal servicing.

21.2.4 The following are acceptable means for grounding equipment that is to be permanently connected electrically:

a) An equipment-grounding terminal or lead in:

1) A room thermostat,

2) A control intended for use in a residence,

3) A device intended to be connected to a nonmetallic-enclosed wiring system, for example, a nonmetallic-sheathed cable, or

4) A device intended to be grounded by an isolated ground and intended to be connected to a metal-enclosed wiring system.

b) A knockout or equivalent opening in a metal enclosure of a nonresidential control intended to be connected to a metal-enclosed wiring system.

c) An equipment-grounding terminal or lead installed on a device that is intended to be mounted on an outlet box.

Exception: If the device is marked in accordance with 70.11(a), the equipment-grounding terminal or lead need not be provided on the device as shipped. If marked in accordance with 70.11(b), the grounding means may be in the form of a kit.

21.3 Equipment permanently connected electrically

21.3.1 A device employing field-wiring leads in flexible metal conduit, where flexing of the conduit is required for adjustment or movement after installation, shall have an equipment-grounding conductor of the size specified in 22.2.8 installed in the flexible conduit.

21.4 Terminals and leads

21.4.1 A wire-binding screw intended to connect an equipment-grounding conductor shall have a green-colored head that is hexagonal, slotted, or both.

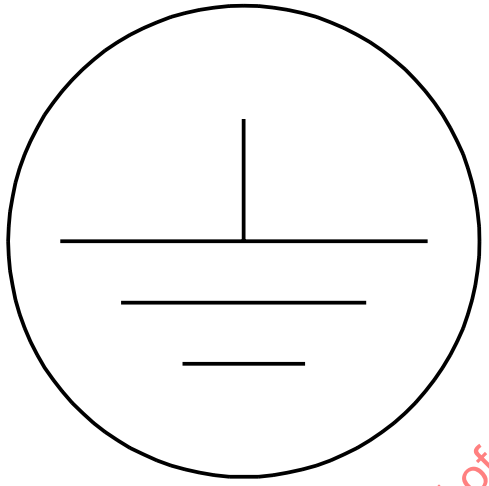
21.4.2 A pressure wire connector intended to connect an equipment-grounding conductor shall be plainly identified, by:

1) Being marked ″G,″ ″GR,″ ″GND,″ ″Ground,″ or ″Grounding;″

2) The symbol in Figure 21.1, or

3) Marking as in (1) or (2) above on a wiring diagram on the control.

Figure 21.1
Grounding Symbol



GND1

21.4.3 A wire-binding screw or pressure wire connector intended to connect an equipment-grounding conductor shall be located so that it is unlikely to be removed during normal servicing.

21.4.4 A terminal for connection of an equipment-grounding conductor shall be capable of securing a conductor of the necessary size and shall be constructed as specified in 16.2.1.3 – 16.2.2.4.

21.4.5 A grounding terminal for a 10 AWG (5.3 mm^2) or smaller wire may be a threaded stud welded to the enclosure or equivalent. Such a terminal shall be of suitable material, for example, it shall be plated if of steel; and shall also comply with 21.4.1 – 21.4.4 and 16.1.1 – 16.2.2.4.

21.4.6 A soldering lug, a push-in (screwless) connector, or a quick-connect or similar friction-fit connector, shall not be used for a grounding terminal.

21.4.7 A lead intended for connection to an equipment-grounding conductor shall be of the size specified in 22.2.8, and shall have a free length of 6 inches (152 mm) or more.

21.4.8 The surface of an insulated lead intended solely to connect an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead visible in a field wiring compartment to the installer shall be so identified.

21.4.9 The color coding requirement specified in 21.4.8 does not apply to a low-voltage nonsafety circuit under the following conditions:

a) Leads or wiring to low-voltage terminals are remote from the location where the line-voltage connections are made, and connectors and live parts are segregated in accordance with Section 35, or

b) Leads or low-voltage terminals are specifically marked with the intended use, such as ″Thermostat,″ so that reference to a wiring diagram is not necessary.

21.4.10 The free end of an equipment-grounding conductor shall be insulated – for example, shall have the end folded back and taped to the lead – unless the conductor is located so that it cannot contact live parts in the event that the conductor is not used in the field.

21.4.11 The following are acceptable means for grounding stationary, pendant, and portable equipment:

a) For pendant, cord-connected equipment – a terminal for bonding the grounding conductor of a multiple-conductor cord to the enclosure, and

b) For portable or stationary equipment – a multiple-conductor cord with a grounding conductor to the frame or enclosure of the equipment. The line fitting of such a cord, shall have a fixed contacting member for the grounding conductor.

21.4.12 The surface of an insulated grounding conductor of a flexible cord shall be green with or without one or more yellow stripes and no other lead shall be so identified.

21.4.13 The grounding conductor of a power-supply cord shall be attached to the grounding blade of an attachment plug and shall be connected within the frame or enclosure by means of a screw not likely to be removed during servicing not involving the power-supply cord. A grounding conductor shall be arranged so that an external pull on a power-supply cord will not transmit stress to the grounding connection on a frame or enclosure before line-voltage connections are broken.

21.4.14 Circuitry shall be arranged so that an equipment-grounding connection or conductor, an enclosure, a frame, a component mounting panel, and earth ground do not carry current except in the event of an electrical fault.

Exception: A single-point reference ground may be employed in a low-voltage or isolated-limited-energy-secondary circuit. An enclosure, frame, or panel, including bolted joints, may carry the current of a low-voltage circuit. Such current shall not be carried by a field-equipment grounding means, a metallic raceway or other power-supply grounding means, or earth ground in either case.

21.4.15 The grounded-circuit conductor shall not be grounded at or in conjunction with temperature-indicating and -regulating equipment.

22 Bonding of Internal Parts

22.1 General

22.1.1 Equipment required to be grounded or grounded if not required as specified in 21.1.1 and 21.1.4, and an exposed noncurrent-carrying metal part that is likely to become energized through electrical fault – see 21.1.3 – shall be reliably bonded to the point of connection of the field-equipment grounding means.

22.1.2 A guard, baffle, or cover that can be removed without a tool is to be removed when determining whether a part is exposed to contact by the user. A part that can be contacted by a 3/8-inch (9.5-mm) diameter rod having a hemispherical end inserted through an opening in a permanently attached guard or baffle for a distance of 4 inches (102 mm) is considered exposed for the purposes of grounding.

22.1.3 Uninsulated metal parts such as cabinets, electrical enclosures and covers, motor frames and mounting brackets, controller mounting frames and brackets, capacitors, other electrical components, interconnecting tubing and piping, valves, and plumbing accessories, shall be electrically bonded together if they may be contacted by a user or serviceperson. See 22.1.5 – 22.1.7 and 22.1.9 for parts to which this requirement does not apply.

22.1.4 Operations and adjustments that subject parts to contact by a user include actions taken at the time of installation and during normal use, such as seasonal adjustments, relamping, replacing fuses, resetting overload devices, and oiling motors. These procedures and those specified in Protection of Users and Service Personnel, Section 23 subject parts to contact by a serviceperson.

22.1.5 A part on the back side of a component mounting panel and a part located so as to require major disassembly by using tools are not considered to be exposed to the user; such parts are not considered to be exposed to a serviceperson unless it is likely that servicing will be performed while the equipment is energized after disassembly.

22.1.6 A metal part, such as an adhesive-attached metal-foil marking, a screw, or a handle that is located on the outside of an enclosure or cabinet and isolated from electrical components and wiring by grounded metal parts so that it is not likely to become energized, or separated from wiring and spaced from uninsulated live parts as if it were a grounded part, need not comply with the requirement in 22.1.1.

22.1.7 The requirement in 22.1.1 does not apply to a small internal assembly screw, or other small fastener, such as a rivet, a handle for a pull-out disconnect switch, or a magnet or armature of a relay or contactor.

22.1.8 Uninsulated live parts and wiring shall be held away from moving parts, such as relay and contactor magnets and armatures, by clamping, routing, or equivalent means that will provide permanent separation.

22.1.9 A metal panel or cover need not comply with the requirement in 22.1.1 if:

a) The panel or cover is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant material not less than 1/32 inch (0.8 mm) thick and reliably secured in place;

b) The panel or cover does not enclose uninsulated live parts, and wiring is positively separated from the panel or cover so that it is not likely to become energized; or

c) The panel or cover is isolated from live parts and wiring by grounded or bonded interposing metal so that the interposing metal would be subject to an electrical fault before the isolated metal part in question.

22.1.10 If a component such as a compartment temperature-control thermostat or a defrost timer is likely to be separated from its normal grounding means after installation in an end-use appliance for purposes of testing or adjustment while the equipment is energized, it shall be provided with a bonding terminal or with a bonding conductor so that it is not necessary to remove it from the component for such service.

22.2 Construction and connection

22.2.1 Parts shall be bonded by metal-to-metal contact or by a separate bonding jumper in accordance with 22.2.2 – 22.2.9.

22.2.2 A separate bonding conductor shall be copper, a copper alloy, or other material acceptable for use as an electrical conductor.

22.2.3 A ferrous metal part in a grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

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

22.2.5 The ends of a bonding conductor shall be in metal-to-metal contact with the parts to be bonded.

22.2.6 A splice shall not be employed in a wire used for bonding purposes.

22.2.7 An internal connection for bonding internal parts to an enclosure for grounding, but not for a field-installed grounding conductor or for the grounding wire in a supply cord, may employ a quick-connect terminal if:

a) The connector is not likely to be displaced,

b) The terminal has the dimensions specified in Table 22.1, and

c) The component is limited to use on a circuit having a branch-circuit protective device as specified in Table 22.1.

Table 22.1
Quick-connect terminals for grounding internal parts

Nominal size of terminal, inch			Rating of branch-circuit protective device, amperes
Width	Thickness	Length	
0.187	0.020	1/4	20 or less
0.187	0.032	1/4	20 or less
0.205	0.032	1/4	20 or less
0.250	0.032	5/16	60 or less

22.2.8 A separate component-bonding conductor shall not be smaller than:

a) That specified in Table 22.2,

b) The conductor supplying the motor or component, whichever is the smaller, or

c) The bonding conductor shall comply with the performance requirements in Bonding Conductor Tests, Section 59.

Table 22.2
Bonding conductor size

Rating or setting of automatic overcurrent device in circuit ahead of equipment, conduit, and the like, not exceeding, amperes	Size of bonding conductor[a]			
	Copper wire, AWG	Aluminum wire, AWG	Rigid conduit or pipe, inches	Electrical metallic tubing, inches
20[b]	12	10	1/2	1/2
30	10	8	1/2	1/2
40	10	8	1/2	1/2
60	10	8	1/2	1/2
100	8	6	1/2	1/2
200	6	4	1/2	1
400	3	1	3/4	1-1/4
600	1	2/0	3/4	1-1/4
800	1/0	3/0	1	2
1000	2/0	4/0	1	2
1200	3/0	250 kcmil	1	2

[a] Or equivalent cross-sectional area.
[b] For a cord-connected device, the grounding wire in the cord may be the same size as the current-carrying conductors.

22.2.9 If more than one size of branch-circuit overcurrent protective 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 is individually protected by a branch-circuit overcurrent device smaller than other overcurrent devices used with the equipment, a bonding conductor for that motor is to be sized on the basis of the overcurrent device intended for ground-fault protection of the motor.

23 Protection of Users and Service Personnel

23.1 General

23.1.1 The requirements in this section do not apply to live parts in low-voltage circuits.

23.1.2 Live parts shall be arranged and covers located so that persons are not likely to be exposed to a risk of electric shock while removing and replacing a cover.

23.1.3 Live parts shall be:

a) Recessed at least 1/8 inch (3.2 mm) from the plane of the front of the fixed portion of an enclosure;

b) Recessed at least 1/8 inch from the front edge of a wiring compartment, in the case of a device mounted to the face of a wiring compartment; or

c) Provided with equivalent protection by projections or guards.

23.1.4 To determine whether live parts recessed or protected in accordance with 23.1.3 comply with the requirement in 23.1.2, the cover is to be removed and replaced; contact of either a person or a conductive cover with a live part is unacceptable.

23.1.5 Unless a cover complies with the requirements for hinged covers in 7.3.4 and 7.3.7, and unless all live parts are protected as specified in 23.1.7, a handle, a knob, or other manual operating means shall be arranged so that it can be operated from outside the control enclosure. The position of such an operating means shall be marked, if necessary, as a guide for proper operation.

23.1.6 A device that involves manual operations that may be performed by a user only at the time of installation, during a servicing procedure, or seasonally, need not comply with 23.1.5 if it complies with the requirements in 23.1.7, 23.2.2, 23.2.5, 23.3.2, and 23.3.3. The requirements in Bonding of Internal Parts, Section 22 apply in any case.

23.1.7 An uninsulated live part or moving part capable of causing injury to persons shall be located, guarded, or enclosed so as to reduce the likelihood of contact of such part by a person while changing a lamp or fuse, lubricating a motor, adjusting a control, or during other normal operations, including those performed only at the time of installation, during a servicing procedure, or seasonally.

23.1.8 A live heat sink for a solid-state component, a live relay frame, and the like shall comply with 23.1.7, 23.2.2, and 23.3.2, and unless the equipment is marked in accordance with 74.4, shall also be guarded to reduce the risk of contact by persons, regardless of the location of the parts.

Exception: If the part is considered exposed to contact by a user as provided in 23.1.10 and 23.1.11, it need not comply.

23.1.9 With reference to 23.1.7, the size, shape, material, and color give a heat sink or relay-frame the appearance of a dead metal part. Other live parts that can be mistaken for dead metal parts are to be investigated similarly.

23.1.10 A guard, baffle, or cover that can be removed without a tool is to be removed when determining whether a part is exposed to contact by a user. A part that can be contacted by a 3/8-inch (9.5-mm) diameter rod having a hemispherical end inserted through an opening in a permanently attached guard or baffle for a distance of 4 inches (102 mm) is considered to be exposed for the purpose of protecting persons.

23.1.11 A part on the back side of a component mounting panel or located so that major disassembly by using a tool is necessary to expose it is not considered to be exposed to a user; such a part is not considered to be exposed to a service person unless it is likely that servicing will be performed while the part is energized after disassembly.

23.1.12 If a marking or an operating instruction refers a user to a hole or opening in an enclosure through which a tool is to be inserted for adjustment or a similar purpose, it shall not be possible to contact an uninsulated live part through a hole or opening with a 1/16-inch (1.6-mm) diameter rod.

23.1.13 A live adjustment means shall not be accessible for user operation.

23.1.14 A live service adjustment shall be insulated from contact by persons or metal tools, or shall be provided with a fixed cover that cannot be removed with an ordinary tool.

Exception: A factory only adjustment that is obviously a live part need not be so guarded.

23.2 Mechanical servicing

23.2.1 The requirements specified in 23.2.2 are intended to provide a reasonable degree of protection to a serviceperson performing a mechanical function on energized equipment. Such a service function does not in itself cause exposure to live parts or moving parts capable of causing injury to persons but it is commonly necessary to perform the function with the equipment energized.

23.2.2 An uninsulated live part or a moving part capable of causing injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by a serviceperson adjusting or resetting a control, or performing a mechanical service function that may have to be performed with equipment energized.

23.2.3 Mechanical service functions that may have to be performed with equipment energized include operating a valve or connecting a fitting that may be necessary during charging or adjusting a pneumatic system; adjusting a water control, or expansion valve; adjusting the setting of a temperature or pressure control with or without marked dial settings; resetting a control trip mechanism; operating a manual switch; adjusting an air-flow damper or lubricating a motor. A control that has the set point sealed at the factory as described in 13.1 – 13.4 and that does not have marking or instructions for adjustment, is not considered to be adjustable.

23.2.4 The requirements in 23.2.2 do not apply to a mechanical service function that is not normally performed with equipment energized, such as opening a drain plug, adjusting or replacing a drive belt or replacing a refrigerant-containing component.

23.2.5 An adjustable or resettable electrical control or manual-switching device may be located or oriented with respect to uninsulated live parts so that manipulation of the mechanism for adjustment, resetting, or operation can be accomplished in the normal direction of access if uninsulated live parts are not located in front – in the direction of access – of the mechanism, and are not located near any side or behind the mechanism, unless guarded.

23.2.6 The requirements in 23.2.2 – 23.2.5 do not apply to bare live parts in a 30-volt or less limited-energy circuit.

23.3 Electrical servicing

23.3.1 The requirements in 23.3.2 specify the location of certain electrical components within an overall assembly so that the necessary space is provided for working on the components while the equipment is energized.

23.3.2 An electrical component that may need to be examined, adjusted, serviced, or maintained while the equipment is energized shall be located and mounted with respect to other components and with respect to grounded metal parts so that it is accessible for electrical servicing without subjecting a serviceperson to a risk of electric shock or to a risk of injury by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring.

23.3.3 Compliance with the requirement in 23.3.2 may be obtained by mounting control components in an assembly so that unimpeded access to each component is provided through an access cover or panel in the outer cabinet, if provided, and the cover of the control assembly enclosure.

23.3.4 Electrical components to which 23.3.2 and 23.3.3 apply include fuses; adjustable or resettable overload relays; manual or magnetic motor controllers; magnetically operated relays; adjustable or resettable pressure or temperature controllers; manual switching devices; clock timers; incremental-voltage tap, and motor-speed tap terminals for variable-speed motors. Such components in a limited-energy circuit of 30 volts or less shall comply with the requirements in 23.3.2 in their relation to bare live parts in a circuit of greater energy level and to moving parts capable of causing injury to persons.

23.3.5 A totally enclosed current or potential-type start relay for a single-phase motor is not required to be accessible in accordance with 23.3.2 and 23.3.3.

23.3.6 The following are not considered to be uninsulated live parts: coils of controllers, relays and solenoids, and transformer windings, if the coils and windings are provided with acceptable insulating overwraps at least 1/32 inch (0.8 mm) thick, or the equivalent, in accordance with 32.2.13; enclosed motor windings; terminals and splices with acceptable insulation; and insulated wire.

23.3.7 A device having exposed Class 2 outputs that:

a) May be contacted during normal operation or servicing, and

b) Have clearances between the Class 2 circuit and an overvoltage protected line-voltage circuit that have been evaluated in accordance with Clearance B requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, shall be provided with a mechanism to indicate the failure of the overvoltage protective device or system. For example, the provision of a detection circuit that would indicate a transient voltage surge suppressor is no longer functional due to the absorption of an excessive amount of energy.

24 Protection Against Injury to Persons

24.1 Scope

24.1.1 The requirements in 24.2.1 – 24.6.8 apply to equipment the normal operation of which may involve a risk of injury to persons.

24.1.2 There are risks of injury to persons inherent in some equipment that, if completely eliminated, would defeat the utility of the equipment. The requirements in this section are intended to minimize such risks, while retaining the normal function of the equipment.

24.2 Sharp corners and edges

24.2.1 A part subject to contact during normal operation and user servicing shall be free of sharp corners and edges.

24.3 Moving parts

24.3.1 A hinged or pivoted panel or cover shall be positioned or arranged so that it is not subject to falling or swinging due to gravity or normal vibration in such manner as to cause injury to persons by the panel or cover, by other moving parts capable of causing injury or by uninsulated live parts. See 23.2.2 – 23.3.4.

24.3.2 The rotor of a motor, a pulley, a belt, gears, a chain, a fan, or other moving part that could cause injury to persons shall be enclosed or guarded to reduce the risk of unintentional contact with the moving part.

24.3.3 Among the factors to be considered in investigating the acceptability of an exposed moving part are:

a) The degree of exposure,

b) The sharpness of the moving part,

c) The likelihood of unintentional contact with it,

d) The speed of the moving part, and

e) The likelihood that fingers, arms, or clothing would be endangered by the moving part.

24.3.4 Unless it complies with the requirement in 58.1, a guard or enclosure for a moving part capable of causing injury to persons shall be secured to the equipment so that it cannot be removed without using a tool.

24.4 Temperature

24.4.1 During the Temperature Test, Section 40, the maximum temperature of a handle, a lever, a button, or a knob that is contacted by a user during normal operation shall not exceed 60°C (140°F) for a metal surface or 85°C (185°F) for a nonmetallic surface.

24.4.2 With reference to the requirement in 24.4.1, a nonmetallic handle, lever, button, knob, or the like that is plated or clad with metal 0.005 inch (0.13 mm) thick or less is to be investigated as a nonmetallic part.

24.4.3 The maximum temperatures specified in 24.4.1 do not apply to equipment intended specifically for use in an ambient temperature exceeding 85°C (185°F).

24.5 Mounting devices

24.5.1 A device weighing more than 5 pounds (2.3 kg) and relying on a mounting means other than its own enclosure, if malfunction of the mounting means will result in a risk of injury to persons, shall withstand for 1 minute, without dislocation of the mounting means or evidence of damage, a force equal to three times the weight of the device but not less than 20 pounds (9.1 kg) applied as described in 24.5.2.

24.5.2 With the device mounted in accordance with the manufacturer's instructions, force is to be applied through the approximate center of gravity of the device. The force is to be increased gradually to reach the required value in 5 – 10 seconds and is to be maintained at that value for 1 minute.

24.6 Strength of parts

24.6.1 A device that is actuated by an external source of pressure and that employs a bourdon tube, a flexible metal bellows, a diaphragm, or the like rated 300 psig (2069 kPa) or more and not contained within an enclosure, shall withstand for 1 minute without bursting a hydraulic pressure equal to four times the maximum rated operating pressure of the device.

24.6.2 To determine whether a part complies with the requirement in 24.6.1, a sample is to be subjected to a hydrostatic pressure test. The sample is to be filled with water to exclude air and is to be connected to a hydraulic pump. The pressure is to be raised gradually to the required test pressure. Except as indicated in 24.6.3 – 24.6.7, the sample is to withstand the test pressure for 1 minute without leakage or rupture.

24.6.3 Leakage at a gasket or fitting during the hydrostatic pressure test is acceptable unless it occurs at a pressure 50 percent or less of the required test pressure.

24.6.4 If leakage occurs during the test, the test is to be continued to four times the maximum rated operating pressure of the device, test equipment permitting. If the leakage is due to external fittings, modifications may be made to permit completion of the test.

24.6.5 A bourdon tube, a flexible-metal bellows, a diaphragm, or the like that is contained within an enclosure shall comply with the requirement in 24.6.1 or shall:

a) Withstand for 1 minute without visible leakage a hydraulic pressure in accordance with the second column of Table 24.1; and

b) Except as indicated in 24.6.7, withstand a hydraulic pressure for 1 minute equal to four times the maximum rated operating pressure of the device without rupture that may present a risk of injury to persons.

Table 24.1
Test pressures for devices with enclosures

Marked maximum operating-pressure rating	Test pressure for (a) of	
	24.6.5	24.6.7
300 – 2000 psig (2069 – 137,900 kPa)	Two times maximum rated operating pressure	Three times maximum rated operating pressure

24.6.6 With reference to 24.6.5(b), a bourdon tube, diaphragm, or bellows may split if no part is released outside the enclosure; a joint or a gasket may leak with acceptable results if the required pressure value is reached and maintained for 1 minute; a leaking gasket or flexible member may be replaced by a heavier disc to permit the required pressure value to be reached.

24.6.7 With reference to 24.6.6, if leakage becomes excessive so that the four times pressure cannot reasonably be reached – that is, if the part functions as if it has a ruptured disc – the part is acceptable if:

a) A pressure in accordance with the third column in Table 24.1 is reached;

b) No part capable of causing injury to persons is released outside the enclosure; and

c) It can be demonstrated by test – which may be at a low pressure – or otherwise, that the outer enclosure can either relieve a pressure equal to the maximum rated operating pressure of the device without rupture that presents a risk of injury to persons, or can withstand a pressure equal to the maximum rated operating pressure.

24.6.8 A pressure vessel, an air filter, a piston operator, or similar device shall withstand hydrostatic-strength tests consistent with the intended use unless it is certified by the National Board of Boiler and Pressure Vessel Inspectors and bears an ASME Code inspection symbol other than the UM symbol.

25 Capacitors

25.1 A capacitor shall employ such materials and shall be constructed so that it will not constitute a risk of fire. It shall not be adversely affected by the temperatures it reaches under the most severe conditions of normal use. A paper capacitor shall be impregnated or enclosed to exclude moisture. An electrolytic capacitor and a capacitor intended for connection directly across the line shall be rated for the application.

26 Fuseholders

26.1 A fuseholder shall be of either the cartridge-enclosed or plug-fuse type. Plug fuses are limited to use with equipment rated not more than 125 or 125/250 volts.

26.2 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).

26.2 revised February 6, 2015

27 Receptacles

27.1 A receptacle provided on equipment that is grounded as required by 21.1.1 shall be of the grounding type. Receptacles on other equipment shall be of the polarized type.

28 Protection of Control-Circuits

28.1 Conductors

28.1.1 A conductor of a control circuit that is connected to the load side of a branch-circuit short-circuit protective device – common control – shall be provided with overcurrent protection in accordance with Table 28.1 by a protective device located within the controller. See 28.1.2.

Exception No. 1: If the rating of the intended branch-circuit short-circuit protective device is not more than the applicable value specified in Table 28.2, additional protection is not required provided the controller is marked in accordance with 69.15.

Exception No. 2: The protection and marking required do not apply to:

a) A control circuit conductor that is not smaller than the main circuit conductors;

b) A limited-energy control circuit, such as a Class 2 circuit;

c) A short, direct lead, generally 12 inches (305 mm) long or less, such as transformer leads or a printed-wiring assembly having no connection external to the controller; and

d) Short, direct leads from contacts of a thermostat, pressure-operated switch, or the like for connection within the enclosure to field wiring that will be protected by a remote protective device. See 16.2.1.6.

Exception No. 3: The protection requirements do not apply to a lead, a strap, or a bus that withstands the applicable short-circuit test in accordance with the requirements in Short Circuit Test, Section 50. The controller shall be marked as specified in 69.16.

Exception No. 4: A control-circuit conductor, supplied from the secondary of a single-phase transformer that is connected so that only a 2-wire (single voltage) secondary is used, may be protected by an overcurrent device(s) located on the primary side of the transformer if the rating of the device does not exceed the applicable value specified in Table 28.2 multiplied by the ratio of secondary-to-primary rated transformer voltage.

Table 28.1
Overcurrent protection

Control-circuit wire size, AWG	Control-circuit wire size, (mm^2)	Maximum rating of protective device, amperes
22	(0.32)	3
20	(0.52)	5
18	(0.82)	7
16	(1.3)	10
14	(2.1)	20
12	(3.3)	25

Table 28.2
Control circuit short-circuit protection

Control-circuit wire size, AWG	Control-circuit wire size, (mm^2)	Maximum rating of protective device, amperes	
		Circuit does not leave enclosure	Circuit leaves enclosure
22	(0.32)	12	3
20	(0.52)	20	5
18	(0.82)	25	7
16	(1.3)	40	10
14	(2.1)	100	45
12	(3.3)	120	60

28.1.2 The protective device required by 28.1.1 shall be either a supplementary or a branch-circuit overcurrent-protective device. A fuse shall be factory installed in a supplementary fuseholder, but may be omitted if a branch-circuit-type fuseholder is provided. The controller shall be marked in accordance with 69.17. If the controller has a rating of more than 50 horsepower (37 kW output), only a branch-circuit overcurrent-protective device rated for the available fault current involved shall be used. If a fuse is used, it shall be Class CC, G, J, K, R, or T, and the fuseholder shall be appropriate for the fuse used. See also 50.3.1.

28.1.3 Internal conductors of a control circuit that are connected to a remote source of supply – not a common control – shall be provided with overcurrent protection in accordance with Table 28.1 or the controller shall be marked in accordance with 69.18. The internal conductors shall not be smaller than 20 AWG (0.52 mm^2).

Exception No. 1: These requirements do not apply to a limited-energy control circuit, such as a Class 2 circuit.

Exception No. 2: These requirements do not apply to a short, direct lead, generally 12 inches (305 mm) long or less, such as transformer leads or a printed-wiring board assembly.

Exception No. 3: These requirements do not apply to short, direct leads from contacts of a thermostat, pressure-operated switch, or the like for connection within the enclosure to field wiring that will be protected by a remote protective device.

Exception No. 4: These requirements do not apply to a lead, a strap, or a bus that withstands the applicable short-circuit test in accordance with the requirements in Short Circuit Test, Section 50. The controller shall be marked as specified in 69.16.

Exception No. 5: A control-circuit conductor, supplied from the secondary of a single-phase transformer that is connected so that only a 2-wire (single voltage) secondary is used, may be protected by an overcurrent device located on the primary side of the transformer if the rating of the device does not exceed the applicable value specified in Table 28.2 multiplied by the ratio of secondary-to-primary rated transformer voltage.

28.2 Transformers

28.2.1 Protection of a transformer is considered to be protection of the coil windings, and is distinct from protection of inherent or connected conductors in the primary or secondary.

28.2.2 A control circuit transformer shall be provided with one or more of the following types of overcurrent protection:

a) An overcurrent device located in the primary circuit that is rated or set as indicated in Table 28.3;

b) Secondary circuit protection rated or set at not more than 125 percent of the rated secondary current of the transformer if the primary feeder circuit has protection rated or set at not more than 250 percent of the rated primary current of the transformer;

Exception: If the rated secondary current of the transformer is 2 amperes or more, the current rating of the secondary overcurrent device may be as indicated in line 2 or 3 of Table 28.3, as applicable.

c) Coordinated thermal overload protection arranged to interrupt the primary circuit if the primary circuit overcurrent device is rated or set to open at a current of not more than:

1) For a transformer having not more than 6 percent impedance, six times the rated current of the transformer; or

2) For a transformer having more than 6 but not more than 10 percent impedance, four times the rated current of the transformer.

Exception No. 1: Overcurrent protection need not be provided if the primary feeder circuit overcurrent device provides the required protection of primary and secondary circuit conductors and windings.

Exception No. 2: Overcurrent protection of the windings or secondary circuit wiring need not be provided if the transformer is rated less than 50 volt-amperes and is an integral part of the controller of a Class 2 or Class 3 type that complies with the requirements for such devices. See 28.1.1 or 28.1.3 for primary circuit conductor protection.

Exception No. 3: Overcurrent protection of the primary winding need not be provided for a Class 1 power-limited transformer that complies with the National Electrical Code, ANSI/NFPA 70-1993. See 28.1.1 or 28.1.3 for primary and secondary circuit conductor protection.

Table 28.3
Maximum rating of overcurrent device

Current, amperes	Maximum rating, percent of transformer primary current rating
Less than 2	500
More than 2 and less than 9	167
9 or more	125[a]
[a] If 125 percent of the rated primary current does not correspond to a standard rating of fuse or nonadjustable circuit breaker, the next higher standard rating of protective device may be used. For the purpose of this requirement, the standard ampere ratings for fuses and inverse time circuit breakers are considered 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, and 150.	

29 Short-Circuit, Ground-Fault, Overload, and Thermal Protection

29.1 Motor overload relays, thermal protectors for motors, and impedance-protected motors are to be examined and tested in accordance with the requirements for such devices.

29.2 Equipment having a rating of more than 50 horsepower (37 kW output) shall be tested in accordance with 50.3.1. See 69.22.

29.3 Controls intended for use in fixed outdoor electric deicing and snow-melting equipment that incorporate equipment ground-fault protective devices (EGFPD) in its design, shall comply with the relevant requirements of this standard and also the referenced requirements of the Standard for Ground-Fault Sensing and Relaying Equipment, UL 1053. Also see 38.10.

29.3 added January 6, 2012

29.4 The EGFPD circuit of an ice and snow-melting equipment control shall comply with section 38.10.1. If the control is not provided with an alarm or test means to indicate an inoperative EGFPD condition, the EGFPD function of the control shall be evaluated as a protective function in accordance with the relevant requirements of this standard, and the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. If software is relied upon as part of the electronic control, it shall be evaluated in accordance with the Standard for Software in Programmable Components, UL 1998, as Software Class 1.

29.4 revised February 6, 2015

29.5 An ice and snow melting equipment control may be provided with a common switching device to control normal operation and provide EGFPD functionality. The control shall be marked in accordance with 69.27.

29.5 added January 6, 2012

30 Mercury-Tube Switches

30.1 A mercury-tube switch shall be rated for the application. It shall be firmly supported, reliably mounted, and housed in an acceptable enclosure. Wire leads shall be as short as possible and shall terminate in eyelets or the equivalent, or in soldered connections at terminal plates on the supporting base, or shall be fastened so that no stress will result. See also 47.1.9 and 47.1.10.

31 Coil Windings

31.1 Coil windings of a motor, relay, or transformer, shall resist the absorption of moisture.

31.2 Materials used in an insulation system that operates above Class 105 (A) temperatures shall comply with the magnet wire requirements in the Standard for Systems of Insulating Materials – General, UL 1446.

31.2 added January 6, 2012

31.3 All insulation systems employing integral ground insulation shall comply with the requirements specified in the Standard for Systems of Insulating Materials – General, UL 1446.

31.3 added January 6, 2012

32 Spacings

32.1 General

32.1.1 A live screwhead or nut on the underside of a base shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and covered with a waterproof, insulating, sealing compound that will not melt at a temperature 15°C (27°F) higher than the normal operating temperature of the device, but not less than 65°C (149°F).

Exception: If such a part is staked, upset, or otherwise reliably restricted from loosening, it need not be recessed, and may be insulated from the mounting surface by material other than sealing compound or by the provision of spacings through air and over surface as required in this standard.

32.1.2 A spacing at a wiring terminal is to be measured with appropriate wires connected to the terminals as in intended service.

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32.1.3 For the purpose of these requirements, the voltage and volt-ampere ratings are those recorded with the equipment connected to a supply circuit as specified in Table 38.1.

32.1.4 Uninsulated live parts connected to different circuits shall be spaced from each other as if they were parts of opposite polarity, in accordance with the requirement in 32.2.1, and shall be investigated on the basis of the highest voltage involved.

32.2 Line-voltage circuits

32.2.1 Other than as indicated in 32.2.2, 32.2.8, 32.2.11, 32.2.12, 32.3.1, 32.3.2, and as provided in Alternate Spacings – Clearances and Creepage Distances, Section 33, spacings shall not be less than those specified in Table 32.1. Greater spacings shall be provided in an enclosure that because of its size, shape, or the material used, is not sufficiently rigid to maintain the minimum spacings.

32.2.2 The spacings specified for a 0 – 300 volt potential in columns B, C, and D of Table 32.1 are applicable to equipment or circuits rated not more than 15 amperes at 51 – 150 volts, and 10 amperes at 151 – 300 volts. The spacings specified for a 301 – 600 volts potential in column B of Table 32.1 are applicable to equipment or circuits rated not more than 5 amperes at 301 – 600 volts.

Table 32.1
Minimum spacings, inch (mm)

		Maximum rating of 600 volts, unlimited volt-amperes			Maximum rating of 600 volts, 2000 volt-amperes		Maximum rating of 300 volts, 2000 volt-amperes		Maximum rating of 600 volts, unlimited volt-amperes			
									Controls for installation on or in appliances			
		A			B		C	D	E		F	
		General[a,l]			Industrial operating controls[m,n]		Residential operating controls[m,o]	Refrigeration and safety controls[l,m,p]	Water heater and hot tub/spa controls[q]		Other controls[r,s]	
Potential involved, volts		0 - 150	151 - 300	301 - 600[b]	0 - 300	301 - 600	0 - 300	0 - 300	0 - 300	301 - 600	0 - 300	301 - 600
Between any unisulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded dead metal part other than the enclosure, or an exposed dead metal part that is insulated[c]	Through air or oil	1/8[d,e] (3.2)	1/4[e] (6.4)	3/8[e] (9.5)	1/16[d,e] (1.6)	3/16[d,e] (4.8)	1/16[d]	1/8[d,e]	1/8[d,e,f]	1/4[e]	1/16 d,e,f,g	1/4 e,g
	Over surface	1/4[e]	3/8[e]	1/2[e] (12.7)	1,8[d,e]	3/8[e]	1/16[d,e]	1/4[e]	1/4[e,f]	1/4[e]	1/16 c,d,e, f,g,h	1/4 e,g

Table 32.1 Continued on Next Page

Table 32.1 Continued

		Maximum rating of 600 volts, unlimited volt-amperes			Maximum rating of 600 volts, 2000 volt-amperes		Maximum rating of 300 volts, 2000 volt-amperes		Maximum rating of 600 volts, unlimited volt-amperes			
									Controls for installation on or in appliances			
		A			B		C	D	E		F	
		General[a,l]			Industrial operating controls[m,n]		Residential operating controls[m,o]	Refrigeration and safety controls[l,m,p]	Water heater and hot tub/spa controls[q]		Other controls[r,s]	
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable[i,j]	Shortest distance	1/2[k]	1/2[k]	1/2	1/4	1/2	1/4	1/4	1/4	1/4	1/4	1/4

[a] A control rated 50 volts or less that is not a safety control may have the spacings in column C, 0 – 300 volts. A production control dielectric voltage-withstand test is not required.

[b] For refrigeration and safety controls that are self-actuated, alternating-current, pilot-duty contact devices – which may have a manually reset means and which have an external adjusting knob or handle, but not an operating one for such as on, off, constant, start, and the like – rated not more than 125 volt-amperes, 301 – 600 volts, and responding to changes in temperature, pressure, humidity, liquid level, and the like, the spacings may be those specified under column A, 151– 300 volts, in which case a representative sample of the device selected annually is to show acceptable results when subjected to the applicable overload and dielectric voltage-withstand tests. Operating controls of this rating are covered by column B.

[c] In a safety control, a water-heater or hot tub/spa temperature-limiting control, and the like, the spacing between wiring terminals, regardless of polarity, and the spacing between a wiring terminal and a grounded dead metal part – including the enclosure – shall not be less than 1/4 inch.

[d] The spacing between wiring terminals of opposite polarity and between a wiring terminal and a grounded or an exposed dead metal part shall not be less than 1/4 inch if short-circuiting or grounding of such terminals may result from projecting strands of wire.

[e] In a water-heater or hot tub/spa temperature-limiting control, a baseboard-heater temperature-limiting control, and a safety control, the spacing between same polarity live parts on opposite sides of a switching mechanism, except at contact point, shall not be less than 1/32 inch (0.8 mm) through air and 1/16 inch over surface.

[f] At closed-in points only, such as the screw-and-washer construction of an insulated terminal in metal, the spacing may be not less than 3/64 inch (1.2 mm).

[g] In a control, other than a water-heater or hot tub/spa temperature-limiting control and a baseboard-heater temperature-limiting control, intended for installation on or in an appliance, the spacings between same polarity live parts on opposite sides of a switching mechanism, except at contacted points, shall not be less than 1/32 inch through air and 3/64 inch over surface.

[h] For a device with a 1/16 inch over-surface spacing, all electrical parts of the device are to be subjected to regular production control dielectric voltage-withstand tests. The applied test potential shall be as specified in 47.1.1 – 47.1.6, with an additional 20-percent voltage applied if the test time is 1 second instead of 1 minute.

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

[j] Spacing to a metal enclosure does not apply to the housing or frame of a device intended for installation within an end-product enclosure.

[k] For a household room thermostat rated 300 volts or less and intended for outlet box mounting, through air spacings between an uninsulated live part and the top, bottom, and side walls of the box may be not less than 1/4 inch. Over-surface spacings between those parts may be 1/4 inch in such a thermostat rated 0 – 150 volts and 3/8 inch in one rated 151 – 300 volts.

Table 32.1 Continued on Next Page

Table 32.1 Continued

	Maximum rating of 600 volts, unlimited volt-amperes	Maximum rating of 600 volts, 2000 volt-amperes	Maximum rating of 300 volts, 2000 volt-amperes		Maximum rating of 600 volts, unlimited volt-amperes	
					Controls for installation on or in appliances	
	A	B	C	D	E	F
	General[a,l]	Industrial operating controls[m,n]	Residential operating controls[m,o]	Refrigeration and safety controls[l,m,p]	Water heater and hot tub/spa controls[q]	Other controls[r,s]

[l]

1) Other than as noted in (3), an auxiliary control for refrigeration or air-conditioning equipment that complies with the rating requirements in columns B and D of Table 32.1 and 32.2.2 at a rating of 600 volts or less may have the spacings specified in column B:

2) Controls that may be judged under column B include those for a fan, pump, or vane motor, resistance heater; timer; valve; solenoid; compressor-motor-start winding, and the like [see 1.4(c)];

3) Controls that are not to be judged under column B include compressor-motor control [see 1.4(a)]; a temperature, pressure, or other limiting control [1.4(b)]; or a control that is subject to condensation or defrost water as may occur within a refrigerated compartment of a refrigerator or freezer or on the outside of an air-conditioning plenum or duct.

[m] See 32.2.2.

[n] Includes controls for boiler and furnace rooms, farms, outdoor use, and the like.

[o] Includes room thermostats.

[p] Includes interlock thermostats for self-cleaning oven doors.

[q] Includes water-heater temperature-limiting controls.

[r] Includes controls for clothes dryers, ranges, air heaters, household and commercial cooking appliances, steam and dry bath heaters, fans, beauty-parlor equipment, office appliances, temperature limiting controls for baseboard heaters, and the like.

[s] Excluding limiting controls for boilers, central furnaces, duct heaters, refrigeration equipment, heat pump duct heaters, and the like.

32.2.3 With reference to the requirement in 32.2.2, the spacings applicable to a device of the type described also apply to that device when controlling more than one load if the total load connected to the line at one time does not exceed 2 horsepower (1492 W output), or have a current rating greater than 30 amperes at 51 – 150 volts, 20 amperes at 151 – 300 volts, or 10 amperes at 301 – 600 volts.

32.2.4 To determine the rating of a device as referenced in columns B, C, and D of Table 32.1 and 32.2.2, the input rating of the device is to be added to the rating of the equipment that the device is intended to control. The sum of the inputs to and the switch ratings of the device is the rating. This applies to a device that does not contain a number of individual components as mentioned in 32.2.6 and also to individual components investigated in accordance with 32.2.6.

32.2.5 The volt-ampere equivalent of a horsepower rating is the product of the voltage and the full-load current as specified in Tables 45.3 and 45.4 and for a polyphase device, the appropriate numerical multiplier.

32.2.6 In multicomponent equipment, spacings from one component to another, and from a component to the enclosure and to other uninsulated dead metal parts, excluding the component mounting surface, are based on the maximum voltage and total volt-ampere rating of the complete equipment; not on the individual component ratings. Spacings inherent in an individual component such as a relay or a temperature controller, including spacings from a live part to a mounting surface other than the enclosure, are to be investigated on the basis of the volt-amperes used and controlled by the individual component.

32.2.7 For a multipole, a double-throw, or a sequencing device or the like, the volt-ampere rating is the maximum sum of the power consumption of the device and the simultaneously controlled load.

32.2.8 Other than as noted in 32.2.9, spacings inherent in a component such as a snap switch, a lampholder, a motor, or a clock motor are investigated under the requirements for the component. Spacings from such a component to another component and to the enclosure, and spacings at wiring terminals shall comply with the requirements in 32.2.1 and Table 32.1.

32.2.9 Spacings in a wiring device, such as a snap switch that is a part of a safety-control circuit, a water-heater temperature-limiting control, a baseboard-heater temperature-limiting control, or the like, shall comply with the requirements in 32.2.1 and Table 32.1.

32.2.10 Spacings at a fuse and fuseholder are to be measured with a fuse that has maximum standard dimensions for the rating in place and shall not be less than those specified in column A of Table 32.1.

32.2.11 An insulating barrier or liner that is used to provide spacings, including spacings in conjunction with the required over surface spacings, shall not be less than 0.028 inch (0.71 mm) thick. A barrier or liner that is used in conjunction with a spacing through air or oil not less than one-half the required spacing may be less than 0.028 inch but not less than 0.013 inch (0.33 mm) thick, if the barrier or liner is an acceptable insulating material resistant to moisture and has the necessary mechanical strength if exposed or otherwise likely to be subject to mechanical damage, reliably held in place, and located so that it will not be adversely affected by operation of the equipment in service – particularly arcing.

Exception: An insulating barrier may be thinner than specified, as specified in 32.2.13.

32.2.12 An insulating barrier or liner used as the sole separation between live parts and grounded parts or between live parts of opposite polarity shall be material that is rated for mounting uninsulated live parts and is not less than 0.028 inch (0.71 mm) thick. Otherwise, a barrier shall be used in conjunction with at least a 1/32-inch (0.8-mm) air spacing.

Exception: An insulating barrier may be thinner than specified as provided in 32.2.13.

32.2.13 Insulating material having a thickness less than that specified in 32.2.11 and 32.2.12 may be used if, upon investigation, it is found to be acceptable for the application, and is equivalent in all respects to materials of the thicknesses specified in 32.2.11.

32.2.14 Mica used in lieu of the through-air spacing required in Table 32.1, may be less than 1/32 inch (0.8 mm) thick but not less than 1/64 inch (0.4 mm) thick if the mica is tightly held in place by the parts involved.

32.2.15 Film-coated wire is considered to be an uninsulated live part in determining the spacing requirements in this standard.

32.3 Magnet coil windings

32.3.1 Insulation required in place of spacings between a magnet-coil winding and other uninsulated live parts or grounded dead metal parts may differ in type and thickness from that required by 32.2.11. The type and thickness of crossover-lead insulation and insulation under coil terminals secured to the coil winding may be less than that specified in 32.2.12 if:

a) The insulation is at least 0.013 inch (0.33 mm) thick; or

b) The coil withstands the dielectric voltage-withstand test specified in either (1) or (2):

1) Application of the test potential in accordance with 47.1.1 – 47.1.6 between coil-end leads after breaking the inner coil lead where it enters the layer, or an equivalent opposite polarity test; or

2) Application of the induced potential tests described in 47.2.1 – 47.3.2.

32.3.2 A slot in a molded bobbin for guiding the crossover- or start-lead – unspliced at the windings – of a magnet-coil is to be filled with an insulating material unless the slot provides a graduated spacing to the winding, increasing to the end turns, and the magnet-coil winding withstands the induced potential tests in 47.2.1 – 47.3.2.

32.4 Low-voltage circuits

32.4.1 Safety controls

32.4.1.1 If a short circuit between the parts in a safety control may result in operation of the controlled device likely to result in a risk of fire, electric shock, or injury to persons spacings shall be as specified in 32.4.1.2 – 32.4.1.4, or as described in Alternate Spacings – Clearances and Creepage Distances, Section 33.

32.4.1.2 Spacing between an uninsulated live part and the wall of a metal enclosure, including fittings for connection of conduit or armored cable, shall not be less than 1/8 inch (3.2 mm). A greater spacing may be required if an enclosure is not sufficiently rigid to maintain the required spacing because of its size, shape, or the material used.

32.4.1.3 Spacing between wiring terminals, regardless of polarity, and between a wiring terminal and a dead metal part – including an enclosure – that may be grounded when the device is installed shall not be less than 1/4 inch (6.4 mm).

32.4.1.4 Spacing between uninsulated live parts, regardless of polarity, and between an uninsulated live part and a dead metal part, other than the enclosure, that may be grounded when the device is installed shall not be less than 1/32 inch (0.8 mm), if the construction of the parts is such that spacings will be permanently maintained.

32.4.2 Other than safety controls

32.4.2.1 Other than as noted in 32.4.1.1 – 32.4.1.4, spacing between uninsulated live parts of opposite polarity and between such parts and dead metal that may be grounded in service is not specified for a low-voltage circuit.

32.5 Isolated limited secondary circuits

32.5.1 Safety controls

32.5.1.1 If short-circuiting of parts in a safety control circuit of an isolated-limited-secondary circuit will not result in unsafe operation of the controlled device, the spacings shall not be less than that specified in Table 32.2 or as provided in Alternate Spacings – Clearances and Creepage Distances, Section 33.

Table 32.2
Minimum spacing in safety circuits in isolated-limited-secondary circuits

Spacing between uninsulated live parts and		Potential involved (volts)			
		0 – 600		601 – 1000	
		Inch	mm	Inch	mm
A. Exposed isolated (insulated) dead metal part	Through air	1/8	3.2	1/4	6.4
	Over surface	1/4	6.4	3/8	9.5
B. Grounded dead metal part other than the enclosure	Through air	1/16	1.6	3/16	4.8
	Over surface	1/16	1.6	3/16	4.8
C. Uninsulated live part of opposite polarity	Through air	1/16	1.6	3/16	4.8
	Over surface	1/16	1.6	3/16	4.8
D. Wall of metallic enclosure	Through air	1/4	6.4	1/2	12.7
	Over surface	1/4	6.4	1/2	12.7

32.5.2 Other than safety controls

32.5.2.1 Spacing between uninsulated live parts of opposite polarity and between such parts and dead metal that may be grounded in service is not specified for an isolated-limited-secondary circuit. The spacing is based on acceptable performance of applicable dielectric voltage-withstand and abnormal operation tests.

33 Alternate Spacings – Clearances and Creepage Distances

33.1 As an alternative to the specified spacing requirements of Spacings, Section 32, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. The spacing requirements in UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be considered and may modify those characteristics specified in 33.2 – 33.5.

33.2 When applying specific requirements in UL 840, it is anticipated that the degree of pollution expected or controlled will be as indicated in Table 33.1.

Table 33.1
Degrees of pollution

Equipment	Pollution degree
Hermetically sealed or encapsulated equipment or printed wiring boards with a protective coating[a].	1
Equipment for ordinary locations and indoor use, such as residential controls, commercial controls for use in a clean environment, nonsafety controls for insulation on or in appliances.	2
All safety or limit controls, equipment for indoor use, and equipment influenced by surrounding environment, such as industrial controls, refrigeration controls, and water heater controls.	3
[a] Tested in accordance with the protective coating test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.	

33.3 When applying specific requirements in UL 840, it is anticipated that the equipment will be identified by overvoltage categories as indicated in Table 33.2.

Table 33.2
Overvoltage categories

Equipment	Overvoltage category
Intended for fixed wiring connection	III
Portable and stationary cord-connected	II
Power-limited and safety a low voltage	I
[a] Applicable to low-voltage circuits if a short circuit between the parts involved may result in operation of the controlled equipment that would increase the likelihood of a risk of fire or electric shock.	

33.4 In order to evaluate clearances where the levels of overvoltage are controlled, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product. The equipment shall be evaluated for the rated impulse withstand voltage specified in UL 840.

33.5 Printed wiring boards constructed of Types XXXP, XXXPC, G-10, FR-2, FR-3, FR-4, FR-5, CEM-1, CEM-3, GPO-2, or GPO-3 industrial laminates in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, are considered to have a minimum comparative tracking index of 100 without further investigation.

34 Wiring Space

34.1 Ample space shall be provided within an enclosure for the distribution of wires and cables required for the proper wiring of the product.

34.2 The wire-bending space within the enclosure of a controller shall be in accordance with Table 34.1. Bending space is to be measured in a straight line from the end of the lug, connector, or terminal to the wall or barrier, in the direction the wire leaves the terminal.

Table 34.1
Minimum wire-bending space at terminals of enclosed controllers

Conductor size, AWG or kcmil (mm^2)		Bending space, inches (mm)			
		Wires per terminal			
		1		2	
14 – 10	(2.1 – 5.3)	Not Specified		–	
8 – 6	(8.4 – 13.3)	1-1/2	(38.1)	–	
4 – 3	(21.2 – 26.7)	2	(50.8)	–	
2	(33.6)	2-1/2	(63.5)	–	
1	(42.4)	3	(76.2)	–	
1/0	(53.5)	5	(127)	5	(127)
2/0	(67.4)	6	(152)	6	(152)
3/0 – 4/0	(85.0 – 107.2)	7	(178)	7	(178)
250	(127)	8	(203)	8	(203)
300	(152)	10	(254)	10	(254)
350 – 500	(177 – 253)	12	(305)	12	(305)
600 – 700	(304 – 355)	14	(356)	16	(406)
750 – 900	(380 – 456)	18	(457)	19	(483)
Note – If provision for three or more wires per terminal exists, the minimum wire-bending space shall be in accordance with the National Electrical Code, ANSI/NFPA 70-1993.					

34.3 Any supplementary terminal supplied with the controller shall be of a type identified by the manufacturer for use with the product, and shall not reduce the minimum wire-bending space.

35 Separation of Circuits

35.1 Separation between different internal wiring circuits (factory-installed conductors)

35.1.1 Insulated conductors shall be segregated or separated by barriers from each other.

Exception: Conductors provided with insulation rated for the highest voltage involved are not required to be segregated or separated.

35.1.2 Insulated conductors shall be segregated or separated by barriers from uninsulated live parts connected to different circuits.

35.1.3 Segregation accomplished by clamping, routing, or equivalent means that provides a minimum permanent 1/4-inch (6.4-mm) separation between applicable conductors complies with 35.1.1 and 35.1.2.

35.2 Separation between different field wiring circuits (field-installed conductors)

35.2.1 The equipment shall be constructed so that field-installed conductors of any circuit are segregated – see 35.4 – or separated by barriers – see 35.5 – from field-installed conductors connected to any other circuit. Table 35.1 summarizes the requirements.

Exception No. 1: Segregation or separation is not required between conductors of different Class 2 circuits.

Exception No. 2: Segregation or separation is not required between conductors of different Class 3 circuits if each circuit is wired with CL3, CL3R or CL3P or equivalent conductors.

Exception No. 3: Segregation or separation is not required between conductors of Class 2 and Class 3 circuits provided that both circuits are insulated for the maximum voltage of either circuit – see 69.23.

Exception No. 4: Segregation or separation is not required when both circuits are other than Class 2 or Class 3 provided that the Class 1, Electric Light or Power circuits are wired with conductors rated for the maximum voltage of either circuit.

Exception No. 5: Segregation or separation is not required between conductors of a limited energy (Class 2 or Class 3) circuit and a non-limited energy (Class 1, Electric Light or Power) circuit provided that:

a) The limited energy conductors are intermingled in order to accommodate the connection of the limited energy circuit to the equipment,

b) The non-limited energy circuit is 150 V_{ac} or less to ground, and

c) The product is marked to indicate that the limited energy circuit is to be wired with Types CL3, CL3R, CL3P, or the equivalent conductors as shown in Table 35.2. See 69.23.

Exception No. 6: Segregation or separation is not required between conductors of a limited energy (Class 2 or Class 3) circuit and a non-limited energy (Class 1, Electric Light or Power) circuit provided that:

a) The limited energy conductors are intermingled in order to accommodate the connection of the limited energy circuit to the equipment,

b) The non-limited energy circuit is 150 V_{ac} or less to ground, and

c) The product is marked to indicate that the limited energy circuit is to be wired with conductors suitable for Class 1, Electric Light or Power circuits. See 69.24.

Table 35.1
Segregation or Separation between Field-Installed Conductors

Circuit type		Applicable paragraph	Comments
Circuit 1	Circuit 2		
Non-limited Energy	Non-limited Energy	Exception 4 to 35.2.1	Segregation or Separation is not required
Non-limited Energy	Class 2	Exceptions 5 and 6 to 35.2.1	Markings needed requiring higher voltage insulation on Class 2 field-installed conductors
Non-limited Energy	Class 3	Exceptions 5 and 6 to 35.2.1	Markings needed requiring higher voltage insulation on Class 3 field-installed conductors
Class 2	Class 2	Exception 1 to 35.2.1	Segregation or Separation is not required
Class 3	Class 2	Exception 3 to 35.2.1	Markings needed requiring higher voltage insulation on field-installed conductors
Class 3	Class 3	Exception 2 to 35.2.1	Segregation or Separation is not required if provided with CL3, CL3P, CL3R, or equivalent conductors

Table 35.2
Cable Substitutes for Type CL3, CL3P, AND CL3R Cables

Cable type	Cable substitutes
CL3	CL3P, CL3R, CM, CMG, CMP, CMR, FPL, FPLP, FPLR and PLTC
CL3P	CMP and FPLP
CL3R	CL3P, CMP, CMR, FPLP and FPLR

35.3 Separation between field wiring circuits (field-installed conductors) and internal wiring circuits (factory-installed conductors)

35.3.1 Separation between field-installed conductors and factory-installed conductors shall be as described in 35.2. Table 35.3 summarizes the requirements.

Exception No. 1: Factory-installed conductors that can intermingle with field-installed conductors shall be provided with insulation rated for the highest voltage of either circuit.

Exception No. 2: In addition to the requirements in 35.2, equipment that permits field-installed conductors to intermingle with factory-installed conductors shall be marked to indicate that the field-installed conductors are to be provided with insulation rated for the highest voltage of either circuit. See 69.23, 69.24, and 69.26.

Table 35.3
Segregation or Separation between Factory-Installed and Field-Installed Conductors

Circuit type		Applicable paragraph	Comments
Factory-installed conductors	Field-installed conductors		
Non-limited Energy	Non-limited Energy	Exception 4 to 35.2.1; Exceptions 1 and 2 to 35.3.1	Both conductors need to be rated for the highest voltage involved
Non-limited Energy	Class 2	Exceptions 5 and 6 to 35.2.1	Markings needed requiring higher voltage insulation on field-installed conductors
Non-limited Energy	Class 3	Exceptions 5 and 6 to 35.2.1	Markings needed requiring higher voltage insulation on field-installed conductors
Class 2	Non-limited Energy	Exception 1 to 35.3.1	Factory-installed conductors need insulation rated for the highest voltage involved
Class 2	Class 2	Exception 1 to 35.2.1	Segregation or separation is not required
Class 2	Class 3	Exception 1 to 35.3.1	Factory-installed conductors need insulation rated for the highest voltage involved
Class 3	Non-limited Energy	Exception 1 to 35.3.1	Factory-installed conductors need insulation rated for the highest voltage involved.
Class 3	Class 2	Exception 3 to 35.2.1; Exception 2 to 35.3.1	Markings needed requiring higher voltage insulation on field-installed conductors
Class 3	Class 3	Exception 2 to 35.2.1	Segregation or Separation is not required if provided with CL3, CL3P, CL3R, or equivalent conductors

35.3.2 Insulated field-installed conductors shall be segregated or separated by barriers from uninsulated live parts connected to a different circuit.

Exception No. 1: Insulated non-limited energy field-installed conductors are not prohibited from contacting wiring terminals of different non-limited energy circuits.

Exception No. 2: Field-installed conductors of a limited energy circuit are not prohibited from contacting terminals of a different limited energy circuit provided that the short-circuiting of the terminals does not result in a risk of fire, electric shock, or injury to persons.

35.4 Segregation methods

35.4.1 Segregation accomplished by clamping, routing, or equivalent means that provides a minimum permanent 1/4-inch (6.4-mm) separation between applicable conductors complies with 35.2.1 and 35.3.1.

35.4.2 When field-installed conductors are segregated in accordance with 35.4.1, the segregation of the conductors complies with 35.4.1 when the segregation is from each other, from uninsulated live parts and from factory-installed conductors by locating openings in an enclosure for the various conductors – with respect to the terminals or other uninsulated live parts – so that a minimum permanent 1/4-inch (6.4-mm) separation is provided.

35.4.3 With reference to 35.4.2, if the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the equipment, and if each opening is located opposite a set of terminals, a conductor entering an opening shall be connected to the terminal opposite that opening. If more than the minimum number of openings are provided, the effect of a conductor entering an opening other than the one opposite the terminal to which the conductor is intended to be connected and the likelihood of the conductor contacting insulated conductors or uninsulated live parts connected to a different circuit is to be investigated.

35.4.4 To determine if the equipment complies with 35.4.1, 35.4.2, and 35.4.3, the equipment is to be wired as intended for service with:

a) Six to twelve inches of slack left in each conductor, and

b) No more than average care exercised in stowing the slack into the wiring compartment.

35.5 Separation methods

35.5.1 With respect to 35.2.1 and 35.3.1, if the intended uses of the equipment is such that in some applications a barrier is required while in some other applications no barrier is required, a removable barrier or one having openings for the passage of conductors is not prohibited. Instructions for the use of such a barrier shall be a permanent part of the equipment. Complete instructions in conjunction with a wiring diagram is not prohibited from being used in lieu of a barrier if, upon investigation, the combination is determined to comply with these requirements.

35.5.2 Conductors from a non-limited energy (Class 1, Electric Light or Power) field-installed circuit and from a limited energy (Class 2 or Class 3) field-installed circuit that are routed through a single opening in an enclosure of permanently connected equipment complies with the intent of 35.2.1 if the limited energy conductors are separated from the non-limited energy conductors by a continuous and firmly fixed nonconductor such as flexible tubing. Tubing that complies with the Standard for Extruded Insulating Tubing, UL 224, is acceptable. The voltage rating of the tubing shall not be less than the maximum voltage rating of the non-limited energy conductors. The tubing shall be provided as part of an installation kit with the equipment. See 69.25.

36 Class 2 Power Sources and Circuits

36.1 General

36.1.1 The term power source denotes a primary battery, a Class 2 transformer, or a combination of a transformer and power limiting components. See 36.5.1.

36.1.2 The voltage, current, and power limitations specified in 63.3.1 and 63.4.2 normally apply to Class 2 circuits that extend beyond the equipment. These values, however, may be used to limit the energy level of a circuit within the equipment.

36.1.3 These requirements, including those relating to installations where wet contact is likely to occur, do not cover immersion.

36.2 Interconnections

36.2.1 Other than as noted in 36.2.2 and in the Exceptions to 36.4.2, the output of a transformer or power source supplying a Class 2 circuit and provided as a part of the equipment shall not be interconnected with the output of another power source. See 75.6.

36.2.2 With reference to 36.2.1, the output of two or more such transformers or power sources may be interconnected if the voltage and current measurements at the output terminals are within the values for a single Class 2 power source.

36.2.3 The outputs of two or more transformers or power sources, all of which are investigated as Class 2 in accordance with the requirement in 2.6 and that are not interconnected, are to be considered as separate circuits. If the wiring terminals or leads for two or more Class 2 circuits are located in the same wiring compartment, the compartment shall be such that room is provided for intended wiring without crowding, and such that stowed wiring of one circuit will not be forced against terminals or live parts of another circuit. See 75.7.

36.3 Circuits

36.3.1 There shall be no electrical connection between the primary and secondary windings of a transformer, or between a primary or secondary circuit and any exposed or grounded part including the enclosure.

Exception: A single-point reference ground may be employed in a secondary circuit. An enclosure, frame, or panel, including bolted joints, may carry the current of a circuit. Such current shall not be carried by a field-equipment grounding means, a metallic raceway or other power-supply grounding means, or earth ground.

36.4 Transformers

36.4.1 A transformer coil shall be provided with insulation between the various windings, and between the windings and the core and the enclosure.

36.4.2 A Class 2 transformer shall have only one secondary winding, that shall be insulated from the primary winding. A winding having intermediate taps is considered to be a single winding.

Exception No. 1: Two or more secondary windings may be considered as a single winding. Interposing insulation between the secondary windings is not required if, when interconnected, the windings are in compliance with the performance requirements for a single-winding transformer.

Exception No. 2: A transformer of the inherently limiting type marked in accordance with 74.9 may have two secondary windings that, when interconnected, are not in compliance with the performance requirements for a single-secondary winding construction.

Exception No. 3: A transformer intended only for use in other equipment may have more than one secondary winding if isolation of all circuits can be maintained.

36.5 Power limiting components

36.5.1 A power limiting component – resistor, positive temperature coefficient resistor, diode, or the like – employed to limit the output of a power source to within the required current or power levels, or otherwise relied upon to comply with the performance requirements in Class 2 Power Sources and Circuit Tests, Section 63, shall have permanence and stability so as not to decrease its limiting capabilities. Among the factors considered when investigating the acceptability of a power limiting component are:

a) Effect of operating temperature,

b) Electrical stress level,

c) Effect of transient surges,

d) Resistance to moisture,

e) Endurance,

f) Temperature change shock, and

g) If appropriate, thermal runaway.

36.6 Overcurrent protection components

36.6.1 Overcurrent protection components include fuses, overtemperature and overcurrent protectors, thermal protectors, components employing eutectic materials, and similar components intended to interrupt the flow of current as a result of overload.

36.6.2 Overcurrent protection provided with a not-inherently limited power source shall be a one-time or manual-reset protector. An automatic reset device may be employed in addition to the required one-time or manual-reset protector.

36.6.3 If a replaceable overcurrent protection component, such as a fuse, is provided in a not-inherently limited power source, it shall not be interchangeable with a component having a higher current rating.

36.6.4 Spacings between parts of the same polarity specified in notes (e) and (g) to Table 32.1, 32.4.1.4, and 32.5.1.1 do not apply to the protective component(s) of a Class 2 power source.

37 Barriers

37.1 A barrier used to provide separation between the wiring of different circuits shall be of metal or of acceptable insulating material having the necessary mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, and shall be reliably held in place. Unclosed openings in a barrier for the passage of conductors shall not be larger than 1/4 inch (6.4 mm) in diameter and shall not exceed in number, on the basis of one opening per conductor, the number of wires that will need to pass through the barrier. The closure for any other opening shall have a smooth surface wherever an insulated wire may contact it and the area of any such opening, with the closure removed, shall not be larger than required for the passage of the necessary wires. See 19.13.

37.2 A barrier used to provide separation between the field wiring of one circuit and the wiring or uninsulated live parts of another shall be spaced not more than 1/16 inch (1.6 mm) from the enclosure walls and from interior mechanisms and component-mounting panels, or the like that serve to provide segregated compartments.

37.3 A metal barrier used to provide segregation shall have the necessary strength and rigidity, and shall be at least the thickness specified under the column in Table 7.1 titled ″With supporting frame or equivalent reinforcing,″ for the dimensions of the barrier. A barrier of insulating material shall be of such thickness and be supported so that its deformation cannot be readily accomplished so as to defeat its purpose, but in any case, the thickness shall not be less than 0.028 inch (0.71 mm). A barrier between uninsulated live parts connected to different circuits, and a barrier between uninsulated live parts of one circuit and the wiring of another circuit shall also comply with the requirements in 32.2.11 and 32.2.12.

PERFORMANCE

38 General

38.1 Samples

38.1.1 Unless otherwise indicated, a representative commercial sample is to be subjected to the tests described in the performance section. The order of tests, as far as applicable, is to be as specified in Table 38.1 and, unless otherwise specified, the various tests are to be conducted at rated frequency and at the voltage specified in the Table 38.1.

Table 38.1
Values of voltage for tests

Table 38.1 revised July 27, 2012

Test	Voltage rating of product and corresponding test potential, volts[a]					Number of section that applies
	110 – 120	220 – 240	254 – 277	440 – 480	550 – 600	
Power Input	120	240	277	480	600	39
Temperature	120	240	277	480	600	40
Operation	–	–	–	–	–	43
Overvoltage, a-c or d-c	132	264	305	528	660	–
Undervoltage, a-c	102	204	235	408	510	–
Undervoltage, d-c	96	192	222	384	480	–
Calibration verification	b	b	b	b	b	44
Overload	120	240	277	480	600	45
Endurance	120	240	277	480	600	46
Dielectric voltage withstand	c	c	c	c	c	47
Volt-ampere capacity	120	240	277	480	600	48
Burnout	120	240	277	480	600	49
Short circuit	120	240	277	480	600	50

[a] If the rating of the device does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage, except that for the operation test, the test voltages are to be as specified in Operation Test, Section 43.

[b] Any convenient test voltage.

[c] As described in text.

38.1.2 An alternating-current product that does not have a frequency rating is to be tested on a circuit having a frequency of 60 hertz, except that a circuit having a lower frequency may be employed with the concurrence of those concerned.

38.1.3 A multiple-pole, a sequencing, a double-throw, or a double-pole, single-throw (normally open, normally closed – sometimes called double-pole, opposite-throw) control and the like shall be tested with a load on each pole. The loads on a double-pole or multiple-pole control shall be connected so that opposite polarity on the poles results unless a same polarity rating is assigned to the control.

38.1.4 A product that must be mounted in a definite position in order to function properly is to be tested in that position and shall be marked in accordance with 69.5.

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38.2 Electric heat thermostat

38.2.1 A wall-mounted room thermostat intended for direct control of electric space-heating equipment that is to be permanently connected electrically shall be subjected to the applicable tests described in the performance section, except that two samples shall be subjected to the tests specified in Table 38.2 in the order specified.

Table 38.2
Sequence of tests for wall-mounted room thermostats intended for direct control of electric space-heating equipment that is to be permanently connected electrically

Tests	Paragraph number that applies	
	Sample 1	Sample 2
Overload	45.1	45.1
Endurance	46.1	46.2[a]
Added endurance	–	46.3
Dielectric voltage withstand	47.1.1	47.1.1
Added dielectric voltage withstand	47.1.2	–

[a] No examination of contacts for burning or pitting.

38.2.2 A room thermostat intended for permanent installation that includes an ampere rating other than one associated with a pilot duty or with a motor rating is to be tested in accordance with the requirements that apply to a wall-mounted room thermostat intended for direct control of electric space-heating equipment that is to be permanently connected electrically.

38.3 Controller

38.3.1 For a motor controller tested with the motor or motors with which it is to be used, the values of stalled-rotor current and full-load running current employed in the overload and endurance tests need not be the values specified in Tables 45.1 – 45.4.

38.3.2 For a combustion control intended to control a transformer as well as a motor, the test load is to include as large a transformer as is likely to be used in the field, unless the control has a transformer rating.

38.4 Baseboard heater controls

38.4.1 If intended for use with a baseboard heater, the contacts of a safety control or of a temperature-limiting control that is actuated by a change in pressure of a fluid confined in a self-contained bulb or capillary tube shall assume the open position upon loss of the fluid charge.

38.5 Relays

38.5.1 A time-delay relay or thermal relay– a contact device, generally normally open, operated by a bimetal-heater or hot wire, and the like – that responds to a temperature- or pressure-limiting control or other calibrated control is to be tested as specified in (a) – (f). A magnetic relay is to be subjected to these tests, except the calibration verification test is to be waived. See Table 38.3 for specific test conditions for electric range controls.

a) Heating test at rated ambient air temperature – Temperature Test, Section 40.

b) Initial calibration – Time-Calibration Verification Test, Section 57 – allowable tolerance time, ±10 percent or ±5 seconds, whichever is greater.

c) Overload and endurance at rated ambient air temperature – Overload Test, Section 45 and Endurance Test, Section 46. Number of cycles in accordance with Table 38.3 or Table 46.1.

d) Dielectric voltage withstand – Dielectric voltage-Withstand Test, Section 47.

e) Recalibration – Time-Calibration Verification Test, Section 57. Allowable drift time, ±10 percent or ±5 seconds.

f) Also see Means for Calibration, Section 13, Details, Section 65, and Calibration Setting, Section 71.

Exception: Wider tolerances than specified in (b) and (e) may be used for a control investigated in the end-use application and found to be acceptable.

Table 38.3
Electric range-control test conditions

Test No.	Control function[a]	Test sequence	Test description	Test temperature[b]	
				Switch head	Bulb
Sample 1					
1[c,d,e]	All	Elevated-temperature heating	Temperature Test, Section 40, temperature rise; Table 40.1 and its note c and 40.3	Cook	25°F (14°C) below cutout
2[e,f]	All	Heating	Temperature Test, Section 40, temperature rise; Table 40.1 and its note c	Room	Room
Sample 2-1 and 2-2					

Table 38.3 Continued on Next Page

Table 38.3 Continued

Test No.	Control function[a]	Test sequence	Test description	Test temperature[b]	
				Switch head	Bulb
3	C,D,L	Calibration verification	44.3– 44.7 or 38.5.1 and Time-Calibration Verification Test, Section 57	Room	Cutout
Sample 2-1					
4[e,g]	B,D	Aging	250 hours in test oven; rated electrical load	Clean	25°F (14°C) below cutout
5[d,g]	B,D	Overload	50 cycles; Overload Test, Section 45	Clean	Cutout
6-1[n] 6-2[n]	B[o],D	Endurance	B: 100,000 cycles, Endurance Test, Section 46	Cook	Cutout
			D: 100,000 cycles[p] Endurance Test, Section 46	Actuation or cook	Cutout
Sample 2-2					
7[e,g,h]	C,L[m]	Aging	250 hours in test oven; rated electrical load	Clean	25°F (14°C) below cutout
8[g]	C,L[m]	Overload	50 cycles; Overload Test, Section 45	Clean	Cutout
9[g,n]	C,L[m]	Endurance I	2000 cycles, except manually reset to be 1000 with load, and 1000 no load; Endurance Test, Section 46	Clean	Cutout
10-1[n]	C[o]	Endurance II	C: 98,000 cycles; Endurance Test, Section 46	Cook	Cutout
10-2	L[m]		L: 98,000 cycles with load Endurance Test, Section 46; except manually reset to be run 4000 no load	Cook	Cutout
Samples 2-1 and 2-2					
11	All	Dielectric	Dielectric voltage-Withstand Test, Section 47	Warm from endurance	
12	C,D,L	Recalibration verification	44.3 – 44.7 or 38.5.1 and 44.3	Room	Cutout
Sample 3 – Bulb Excursion					
13[i,j]	B,D,L	Calibration verification	44.3 – 44.7	Room	Cutout

Table 38.3 Continued on Next Page

Table 38.3 Continued

Test No.	Control function[a]	Test sequence	Test description	Test temperature[b]	
				Switch head	Bulb
14[i,j,k]	B,D,L	Bulb excursion	250 cycles – 1/2 hour at 1000°F (538°C), 1/2 hour at 104°F (40°C) nominal; no load	Room	Cycling –104 – 1000°F (40 – 538°C)
15[i,j]	B,D,L	Recalibration verification	44.3 – 44.7	Room	Cutout
Sample 4 – S,SN					
16[e,g]	S,SN	Aging	250 hours in test oven; not energized	Clean	25°F (14°C) below cutout
17[d,g]	S,SN	Overload	50 cycles; Overload Test, Section 45	Clean	Cutout
18-1[n]	SN[o]	Endurance	100,000 cycles; Endurance Test, Section 46	Cook	Cutout
18-2[n]	S	Endurance	100,000 cycles; automatic at highest cycling temperature setting; Endurance Test, Section 46	Cook	–
19	S,SN	Dielectric withstand	Dielectric voltage-Withstand Test, Section 47	Warm from endurance	
Sample 5 – S (automatic contacts tested manually)					
20	S	Aging	250 hours in test oven, not energized	Clean	–
21[g]	S	Overload	50 cycles; Overload Test, Section 45	Clean	–
22[g,n]	S	Endurance	10,000 cycles; Endurance Test, Section 46, manual, off to mid-temperature setting to off	Cook	–
23	S	Dielectric withstand	Dielectric Voltage-Withstand Test, Section 47	Warm from endurance	
Sample 6 – Manual contacts[i]					
24[i]	I	Aging	250 hours in test oven; rated electrical load	Clean	–
25[g]	S,SN	Aging	250 hours in test oven; not energized	Clean	–
26[g]	All	Overload	50 cycles; Overload Test, Section 45	Clean	–
27[g,i,n]	B,C,L	Endurance I – M	2000 cycles; Endurance Test, Section 46, manual	Clean	–
28[i,n]	B,C,L	Endurance II – M	4000 cycles; Endurance Test, Section 46, manual	Cook	–

Table 38.3 Continued on Next Page

Table 38.3 Continued

Test No.	Control function[a]	Test sequence	Test description	Test temperature[b]	
				Switch head	Bulb
29-1[i,n]	D[p], S,SN	Endurance	6000 cycles; Endurance Test, Section 46, manual	Cook	–
29-2[i,n]	D[p]	Endurance	6,000 cycles; Section 46, manual	Actuation or cook	
30	All	Dielectric withstand	Dielectric voltage-Withstand Test, Section 47	Warm from endurance	

[a] A thermal or magnetic relay – see 38.5.1 – or a thermal cycling switch or other control not specifically mentioned is to be tested for the conditions of the control or control function with which it is employed.

Control Function Code:

B – Bake/broil or other oven cooking or temperature-regulating control.

C – Cleaning temperature oven control.

D – Door interlock for oven.

L – Limiting temperature control. Test conditions may vary if the setting is for Type B, C, S or SN usage.

S – Surface element control, bimetal heater or hot-wire type, or the like.

SN – Surface element control other than Type S.

[b] For devices used on electric ranges, see 38.6.6. For other applications, test temperatures are to be in accordance with the ratings.

[c] See 38.8.1 and 38.8.2 for a range control switch body other than Type L. These paragraphs are not applicable to a limiting control or to other than a range control.

[d] For an interlock that is mechanically operated only, materials are assumed to operate at ambient temperature. The overload test is not applicable.

[e] A surface-element control is to be tested as specified. The elevated-temperature heating test for an oven control is to be conducted with the bulb heated to the maximum rated normal-use oven temperature, such as bake/broil or 25°F (14°C) below cutout, if the control is calibrated to open at the maximum normal-use oven temperature. See Exception No. 2 to 38.6.1.

[f] Test 2 may be waived if results of Test 1 indicate that the results of Test 2 will be acceptable.

[g] For a control not intended for use with a self-cleaning oven, the clean test temperature specified is to be the cook temperature. Aging test is to be omitted.

[h] Aging may be conducted after Endurance I or I – M for 250 hours minus the time elapsed during Endurance I or I – M, or, if the assigned clean and cook switch head temperatures are the same, aging may be omitted if the total time elapsed during Endurance I and Endurance II is at least 250 hours.

[i] See 44.3 – 44.4 for tolerances for a control used as an oven-door interlock or for a temperature-limiting function. For bake/broil, other cooking control, or where calibration change will not cause unsafe operation of the appliance, calibration verification may be waived or tolerances are not specified. After the bulb excursion test, the control is to be operable without damage to the switch or mechanism.

[j] The test for nonself-cleaning oven controls is to be waived.

[k] Test cycle may vary provided the bulb is stabilized at each temperature if agreeable to those concerned. Heat shock greater than normal use is not contemplated.

[l] Manual contacts on a Type B, C, D, or L oven control that operate during the self-cleaning cycle, or that terminate the cycle, are to be subjected to Tests 24, 26 – 28, and 30 in sequence except as noted in note h. Manual contacts on controls that are not switched during the self-cleaning cycle are to be subjected either to Test 24 if the contacts carry current during the self-cleaning cycle or to Test 25 if the contacts do not carry current during the self-cleaning cycle, and then to Test 26, 29, and 30 in sequence.

[m] A temperature-limiting control shall not function during normal appliance operation.

[n] The endurance test is to be conducted as follows:

Number of endurance cycles	Maximum cycle rates, cycles per minute	
	First portion of test	Last portion of test

Table 38.3 Continued on Next Page

Table 38.3 Continued

Test No.	Control function[a]	Test sequence	Test description	Test temperature[b]	
				Switch head	Bulb
With load	Without load	Number of cycles	Cycles per minute	Number of cycles	Cycles per minute
1000	5000	1000	1	5000	6
6000 (automatic)	–	6000	1	–	–
6000 (manual)	–	6000	6	–	–
10,000	–	10,000	6	–	–
30,000	–	24,000	6	6000	1
100,000	–	75,000	6	25,000	1

Magnetic, manual, motor-operated switches, and the like and switches that snap with lost motion and do not creep may be tested at a rate of 6 cycles per minute for all controls, the test is to be conducted with 50 ±20 percent on time. A temperature- or pressure-operated control is to be tested using a slow rate of change.

For endurance tests consisting of two parts [such as tests 9 and 10 (Endurance Tests I and II)], the number of endurance cycles is to be the sum of the cycles required for each part. For example, the number of endurance cycles for tests 9 and 10 is to be 100,000 cycles (the sum of 2000 and 98,000 cycles). When no current is used, the switch may be operated at any convenient speed.

[o] If the control is intended to be used in conjunction with a temperature-limiting control, the endurance test need only be 30,000 cycles of operation.

[p] See 38.6.7 and 38.6.8.

38.6 Electric range controls

38.6.1 A control for an electric range, including a separate surface cooking unit or a wall-mounted oven, intended for mounting where exposed to elevated temperatures shall be subjected to the temperature, overload and endurance tests while mounted in an oven maintained at the assigned ambient air temperature, with the temperature sensor operated at maximum rated set-point temperature of the control, and under other temperature conditions that represent rated service conditions, such as mounted on a heated surface, with a heated pressure connection, bimetal heater, or the like. For specific test conditions see 38.6.5 – 38.6.11.

Exception No. 1: Temperature tests are usually waived for a control intended to be entirely located in the air to be controlled as it is assumed that the entire control will be at the temperature of the surrounding air. The overload and endurance tests are to be conducted with the control entirely within the test oven in air at the maximum set-point temperature.

Exception No. 2: For a control with a long capillary tube or similar semiremote sensor where heat transfer to the switch head will not be significant, the temperature test may be conducted with the sensor at room temperature.

38.6.2 A pressure- or mechanically-operated control or one that is intended for a mechanical load shall be subjected to maximum rated stress during the test.

38.6.3 Tests are to be conducted with maximum rated temperatures, pressures, mechanical loads, electrical loads, and the like, that are consistent with maximum normal service conditions imposed simultaneously on the device. For a device that has different sets of ratings, such as different ampere ratings at different ambient-air-temperature ratings, separate tests are to be conducted. For a line of devices of the same construction that have different temperature or pressure settings, tests at the highest rated settings are usually considered representative. Separate tests are to be conducted on devices having different constructions.

38.6.4 Tests on a control for combination use shall be conducted to cover conditions of each use; separate samples may be used for each set of tests. See 38.9.2. More samples than specified are to be tested if needed for additional ratings, or the like.

38.6.5 A control intended for mounting in an electric range, including a separate wall-mounted oven and a surface cooking unit, shall be tested under the conditions specified in Table 38.3. Wherever calibration-verification tests are specified, except for bulb excursion alone, see Details, Section 65 (manufacturing calibration-verification and dielectric voltage-withstand tests), Calibration Setting, Section 71 (temperature marking), and Means for Calibration, Section 13 (fixing of setting). Refer to 11.13 and 6.2 for electronic components or circuits.

38.6.6 In Table 38.3, ″cook″ corresponds to the control compartment ambient temperature during cooking, ″clean″ corresponds to the control compartment temperature during self-cleaning, and ″actuation″ corresponds to the maximum compartment temperature when the device is actuated to lock, latch, unlock or unlatch the door of a self-cleaning oven (the actuation temperature is typically lower than the self-clean temperature and may or may not be higher than the cook temperature.) These temperatures are as specified by the manufacturer. The 1000°F temperature corresponds to the typical oven temperature during self-cleaning; higher or lower temperatures may be used at the manufacturer's request. Either ″cook″ or ″actuation″ temperatures, or both may be specified at the manufacturer's option.

38.6.7 Mechanical parts and electro-mechanical parts of an oven door latch or lock mechanism that do not switch current, such as linkages, springs, levers, solenoids, motors and the like, and that operate only during self-cleaning operation shall withstand 6,000 cycles of operation at normal load at the temperature specified in Table 38.3. Parts that operate during cooking or other appliance operating modes, such as bi-metal devices, shall withstand 100,000 cycles of operation at normal load at the temperature specified in Table 38.3.

38.6.8 Oven door lock thermostats and switching components of an oven door latch or lock system that cycle electrically (make or break current) during self-cleaning operation and that carry current or cycle without electrical load during cooking or other operating modes shall withstand 6,000 cycles of operation at normal electrical load, plus an additional 94,000 cycles at no load. Oven door lock thermostats and switching components that may cycle electrically one or more times during cooking or other appliance operating modes, shall withstand 100,000 cycles of operation at normal electrical load.

38.6.9 An automatic cycling control is to be tested as specified in Table 38.3. See 65.1.4. An automatic cycling control is a contact device, usually normally closed, that cycles automatically due to a bimetal heater, hot-wire mechanism, or the like, being controlled by the contacts that also control the load; the cycling rate is fixed, or variable on a manually adjustable or infinite switch.

38.6.10 A time-delay relay or a thermal relay that responds to another control is to be tested as specified in Table 38.3. This type relay is a contact device, usually normally open, operated by a bimetal heater, hot-wire mechanism, or the like. A magnetic relay is to be subjected to these tests, except the calibration-verification test is to be omitted.

38.6.11 These requirements do not necessarily apply to controls for commercial ranges.

38.7 Auxiliary electric range controls

38.7.1 For the controls in (a) – (d), the function of which will be bypassed during certain tests of the end-use appliance, the endurance test described in Endurance Test, Section 46 is to consist of 6000 cycles of operation:

a) A thermostat that detects a hot surface of a glass/ceramic cooking surface to control an indicating lamp;

b) A thermostat that limits the temperature of a glass/ceramic cooking surface, but does not function during the normal cooking operation;

c) A thermostat that controls a cooling fan for a control compartment; and

d) An auxiliary control that does not control cooking or cleaning temperatures, and that is not depended upon to reduce the risk of unsafe temperatures.

38.7.2 A calibration-verification test is not required for the controls described in 38.7.1 (a) – (d).

38.8 Conditioning at elevated temperature – household range control switch body

38.8.1 If, when tested at the cook temperature-ambient – see 38.6.6 – the insulating switch body of a range control, including a separate surface cooking unit or a wall-mounted oven control, and other than a temperature-limiting control, exceeds the allowable temperature rise in Table 40.1 as adjusted in accordance with 40.3, the switch body shall be tested as follows:

a) Three complete samples of the control are to be conditioned for 1000 hours in an oven without the control energized. The temperature of the oven is to be determined from the formula:

$$t_2 = 1.02 (t_1 + 288) - 273$$

in which:

t_2 is the oven temperature in degrees C and

t_1 is the measured temperature of the insulating body in degrees C; or

b) If the excess temperature is localized– for example, due to a bimetal heater – three samples of the complete control are to be conditioned for 1000 hours in an oven maintained at the cook temperature – see 38.6.6 – with the heater energized at 110 percent rated voltage or 110 percent rated current for a series type. Noncycling contacts are to be forced closed or bypassed if necessary, to attain the most severe temperatures.

Exception: Insulating materials that have been investigated and found to be acceptable for the required temperature.

38.8.2 Following the conditioning described in 38.8.1, the controls are to be examined and then subjected to a 50-cycle overload test, a 1000-cycle endurance test, and a dielectric voltage-withstand test. These tests may be conducted at room ambient air temperature. There shall be no undue deterioration of the insulation or electrical or mechanical breakdown of the control.

38.9 Temperature-limiting controls for electric ranges

38.9.1 An automatically or manually reset control that is intended to limit temperatures of an electric range, including a separate wall-mounted oven or a surface cooking unit, shall comply with the requirements for a temperature-limiting control as specified in this standard. Wherever calibration-verification tests are specified, except bulb excursion alone, see Details, Section 65 (production line calibration-verification and dielectric voltage-withstand tests), Calibration Setting, Section 71 (temperature marking), and Means for Calibration, Section 13 (fixing of setting). Tests are as specified in Table 38.3. Refer to 11.13 and 6.2 for electronic components or circuits. For tests on an oven door interlock used in lieu of a temperature-limiting control on a nonself-cleaning oven and for one used on a self-cleaning oven, see Table 38.3.

38.9.2 An electric range temperature-limiting control, or combination limiting control and relay, shall have no operating part in common with a temperature-regulating control. A common mounting bracket or a common enclosure may be employed for both controls.

Exception No. 1: An oven-door interlock may use common parts with a temperature-limiting control.

Exception No. 2: An oven-door interlock, a temperature-limiting control or combination limiting control and relay may have common parts with a control compartment cooling fan control if malfunction of the fan control will not affect operation of the oven-door interlock or temperature-limiting feature. Tests on such a combination control are to include 100,000 cycles thermal-mechanical endurance on all parts and verification of operation with the fan contact not functioning.

Exception No. 3: For a self-cleaning oven, an oven cooking or cleaning temperature control may use common parts with an oven door interlock but not with a temperature-limiting control. A single control may combine all three functions. Tests on such a control are to include 100,000 cycles of thermal-mechanical endurance on all parts.

38.10 Ice and Snow-Melting Equipment Controls

38.10 added January 6, 2012

38.10.1 In addition to the applicable performance requirements of this standard, a EGFPD operation of an ice and snow-melting equipment control shall be subjected to the following tests of Standard for Ground-Fault Sensing and Relaying Equipment, UL 1053:

a) Calibration Test sequence of Section 21. Devices with adjustable fault current setpoints, the calibration sequence is conducted at the minimum and maximum values of the range.

b) Current Withstand Test of Section 27. This test is conducted at the short circuit values specified in Table 50.2 of this standard.

c) The Calibration Test of Section 21 shall be repeated after the Current Withstand Test at room ambient.

d) The Dielectric Voltage-Withstand Test of Section 25 shall be conducted after each test as, and

e) The Component Failures Test of Section 26.

39 Power Input

39.1 The power input to a temperature-indicating or -regulating device shall not exceed the marked rating of the device by more than 10 percent when it is operated under the conditions of normal use and with the device connected to a supply circuit as specified in Table 38.1.

40 Temperature Test

40.1 Temperature-indicating and -regulating equipment, when tested as described in this section, shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to damage any materials employed in the equipment, or to exceed the temperature rises specified in Table 40.1.

40.2 All values for temperature rises specified in Table 40.1 apply to equipment intended for use at ambient temperatures normally prevailing in occupiable spaces, which usually are not higher than 25°C (77°F) but may occasionally be as high as 40°C (104°F) for brief periods. Tests of equipment for service with such ambient temperatures may be conducted – without correction – at any ambient temperature in the range of 10 – 40°C (50 – 104°F).

Table 40.1
Maximum temperature rises

Material and components		C°	F°
1.	Knife-switch blades and contact jaws	30	54
2.	Points on or within a terminal box or compartment including wiring on which conductors to be connected to the control may rest[a]	35	63
3.	Laminated-contacts[b]	50	90
4.	Terminals[a]	50	90
5.	Class 90 insulation system[c]		
	Thermocouple method	50	90
	Resistance method	60	108
6.	Class 2 transformer enclosure – see 2.2, 2.6, 7.4.1, and 7.4.2	60	108
7.	Varnished cloth insulation	60	108
8.	Solid contacts, busses, and connecting bars[d]	65	117
9.	Fuses[e]	65	117
10.	Fiber employed as electrical insulation	65	117
11.	Wood or other combustible material	65	117
12.	Power transformer enclosure	65	117
13.	Class A insulation systems on coil windings[f]		
	A. In an open motor		
	Thermocouple method	65	117
	Resistance method	75	135
	B. In a totally enclosed motor		
	Thermocouple method	70	126
	Resistance method	80	144
14.	Class 105 insulation systems on coil windings other than in a motor[c,f]		
	Thermocouple method	65	117
	Resistance method	85	153

Table 40.1 Continued on Next Page

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Table 40.1 Continued

Material and components		C°	F°
15.	Class 130 insulation systems[c,f]		
	Thermocouple method	85	153
	Resistance method	95	171
16.	Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock[g]	125	225
17.	Rubber- or thermoplastic-installed wire and cord except those mentioned in item 18[g]	35	63
18.	Types RFH, FFH, and RH wires[g]	50	90
19.	Other types of insulated wires[h]	–	–
20.	Sealing compounds[i]	–	–
21.	Capacitors[j]	–	–

[a] The temperature rise observed on the terminals and at points within a terminal box and a control for use with other than a residential appliance that is rated for continuous use above 25°C (77°F) may exceed the values specified but may not attain a temperature higher than 90°C (194°F). See 72.1 – 72.3.

[b] Multilayered, metallurgically bonded contacts are not considered to be laminated. See item 8.

[c] See 40.9.

[d] If contacts of any metal and their supporting blades, busses, and connecting bars attain a temperature greater than 90°C (194°F) where a high ambient temperature or other external temperature prevails, or where affected by a bimetal-heater or other heat source in the assembly, the control shall perform acceptably when subjected to overload and endurance tests conducted at the high temperatures involved, except that contacts of silver or a silver alloy that do not attain a temperature higher than 100°C (212°F) need not be subjected to overload and endurance tests conducted at the high temperature.

[e] A fuse that has been investigated and found acceptable for use at a higher temperature may be used at that temperature.

[f] Temperature rise measured by a thermocouple at a point on the surface of a coil, at which the temperature is affected by an external source of heat, may be 15°C (27°F) higher than that specified, provided that the temperature rise by the resistance method is not more than that specified.

[g] The limitation on phenolic composition and on rubber and thermoplastic insulation does not apply to compounds that have been investigated and found to be acceptable for higher temperature.

[h] For standard insulated conductors other than those mentioned in items 16 and 17, reference to the National Electrical Code, ANSI/NFPA 70-1993; and the maximum allowable temperature, corrected to a 25°C (77°F) assumed ambient temperature, is not to exceed the marked temperature limit of the wire in question, except as noted in 40.3.

[i] The maximum acceptable temperature, corrected to a 25°C (77°F) assumed ambient temperature, of a sealing compound is 15°C (27°F) less than the melting-point temperature of the compound.

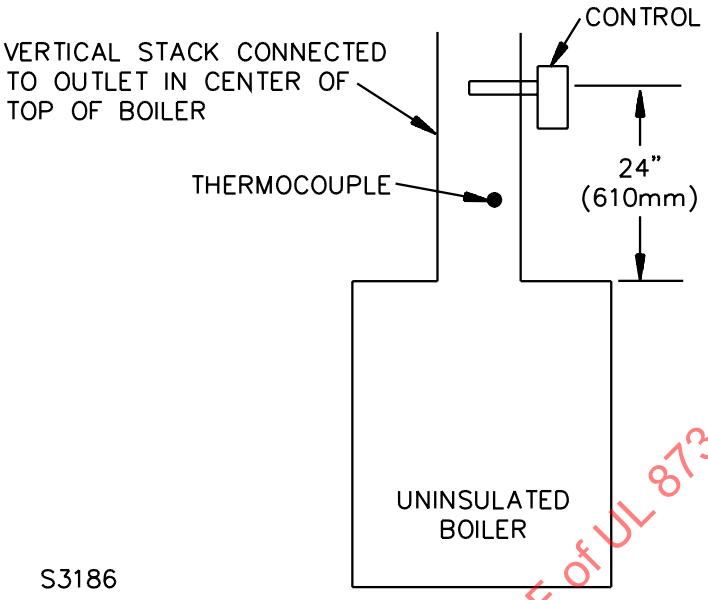
[j] For a capacitor, the maximum allowable temperature rise is the marked temperature limit of the capacitor minus an assumed ambient temperature of 25°C (77°F).

40.3 Equipment intended specifically for use with a prevailing ambient temperature constantly more than 25°C (77°F) is to be tested at such higher ambient temperature, and the allowable temperature rises specified in Table 40.1 are to be reduced by the amount of the difference between the higher ambient temperature and 25°C (77°F).

40.4 A low-potential supply source may be used for conducting temperature tests on parts other than coils or transformer windings. Unless otherwise noted, the tests on all parts are to be conducted simultaneously, as the heating of one part may affect the heating of another part.

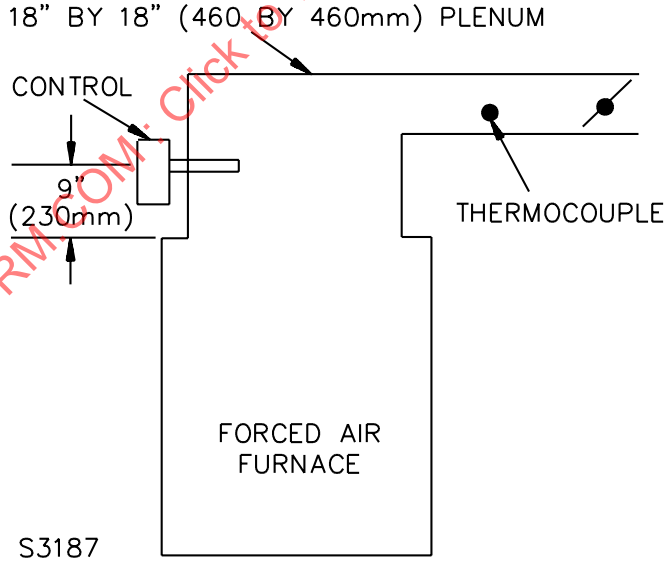
40.5 A control that is intended to be mounted in a chimney or vent connector, duct, plenum, or the like, is to be so mounted above an operating appliance using the mounting bracket regularly supplied with the control with the element inserted as far as permitted by any stop or flange so that service conditions will be approximated. The ambient temperature surrounding the control outside the chimney or vent connector, duct, or plenum is to be the highest temperature in which the control is intended to operate. Typical required test conditions are illustrated in Figures 40.1 and 40.2.

Figure 40.1
Typical test setup for a chimney- or vent connector-mounted control



Boiler operation is to be adjusted so that the thermocouple senses a flue-gas temperature of 538°C (1000°F).

Figure 40.2
Typical test setup for a plenum-mounted control



Furnace operation is to be adjusted so that the thermocouple senses an air temperature equal to the maximum setting temperature of the control.

40.6 If equipment is obviously not intended for continuous operation, such as some types of damper controls, the heating test may be conducted so that the probable intermittent or short-time operation of the equipment is considered.

40.7 If stalling of a motor on a timer, motor operator, damper control or the like is part of the normal operation of a device while connected to a supply circuit as specified in Table 38.1, the temperature rise shall not exceed the limits specified in Table 40.1 with the motor stalled.

40.8 If stalling of a motor as described in 40.7 is not part of the normal operation, the values specified in Table 40.1 do not apply; but the motor shall have acceptable impedance, thermal, or overload protection.

40.9 Other than at coils, temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2). See 40.13.

40.10 When thermocouples are used to determine temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer-type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

40.11 The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to conform with 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/E230M.

40.11 revised February 6, 2015

40.12 A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5-minute intervals, indicate no change.

40.13 The preferred method of measuring temperatures on coils is the thermocouple method, but temperature measurements by either the thermocouple or resistance method are acceptable, except that the thermocouple method is not to be used for a temperature measurement at a point where supplementary heat insulation is employed.

40.14 To determine if a device complies with the requirements in this section, it is to be operated under normal conditions, except as otherwise noted. The potential of the supply circuit is to be as specified in Table 38.1.

41 Leakage Current Test

41.1 The leakage current of a cord-connected product rated for a nominal 250-volt or less supply when tested in accordance with 41.3 – 41.7 shall not be more than:

a) 0.5 milliampere for an ungrounded 2-wire portable, stationary, or fixed product;

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

c) 0.75 milliampere for a grounded 3-wire stationary or fixed product employing a standard attachment plug rated 20 amperes or less.

41.1 revised July 27, 2012

41.2 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 surfaces of the product.

41.3 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively, if simultaneously accessible, and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered acceptable for reducing a risk of electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor and the grounded supply conductor. If exposed dead metal parts of the product are connected to the neutral supply conductor, this connection is to be open during the test.

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

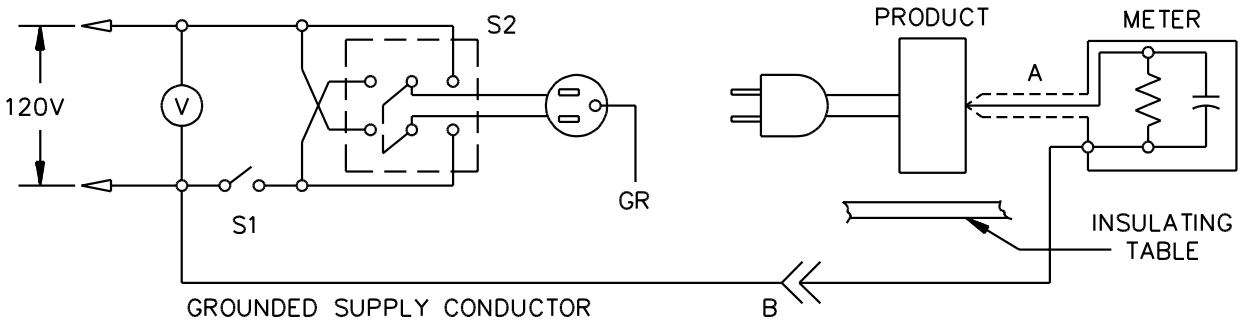
41.5 The measurement circuit for leakage current is to be as illustrated in Figure 41.1. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

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

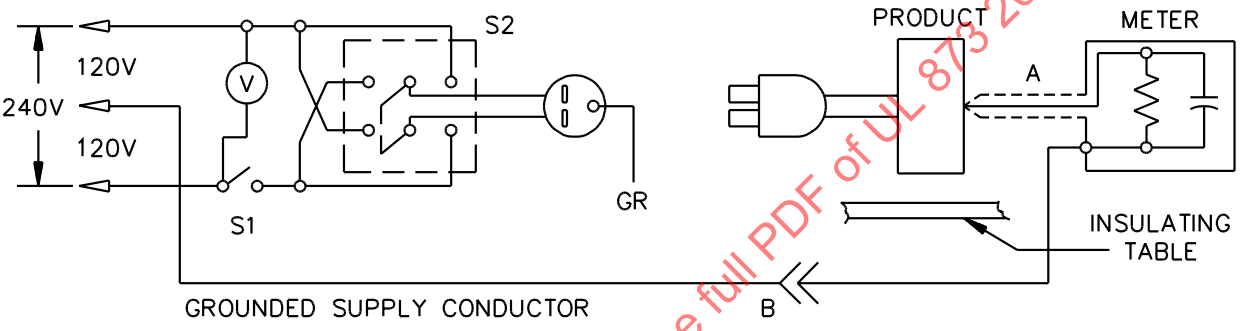
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

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 impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 or 0.75 milliampere, the measurement is to have an error of not more than 5 percent of 60 hertz.

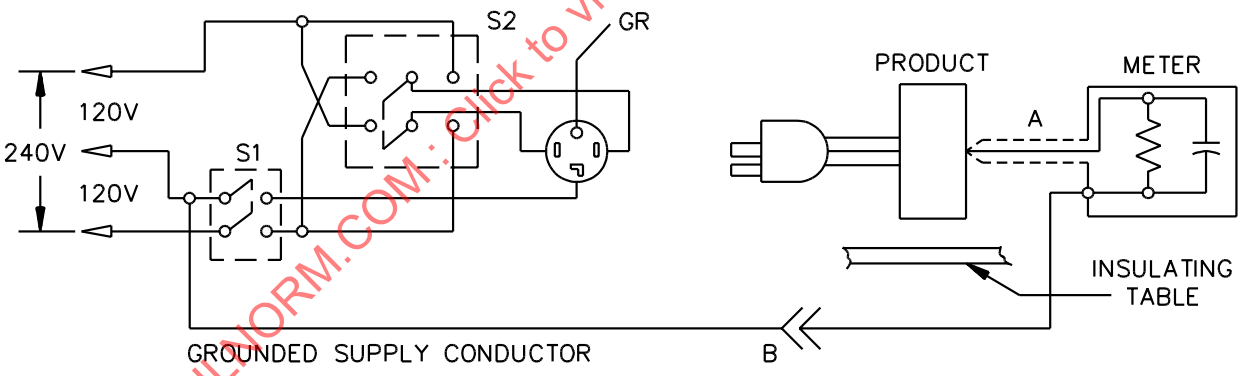
Figure 41.1
Leakage current measurement circuit



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



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



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

LC300J

NOTES –

A – Probe with shielded lead.

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

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

41.7 A sample of the product is to be tested for leakage current starting with the as-received condition – the as-received condition being without prior energization, except as may occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage. The test sequence, with reference to the measurement circuit – Figure 41.1 – is to be as follows:

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

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

c) 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 considered to be obtained by operation as in the normal temperature test.

41.8 Normally the complete leakage current test, as specified in 41.7, is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current test may be interrupted for the purpose of conducting other nondestructive tests.

42 Leakage Current Following Humidity Conditioning Test

42.1 A product shall comply with the requirements for leakage current in Leakage Current Test, Section 41, 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).

42.2 To determine whether a product complies with the requirement in 42.1, 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 42.1. Following the conditioning, the sample is to be tested unenergized as described in 41.5(a). The sample is then to be energized and tested as described in 41.5 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

43 Operation Test

43.1 An electromagnet for use on direct current shall withstand a voltage 10 percent more than its rated voltage continuously without damage to the operating coil and shall operate successfully at 20 percent less than its rated voltage. If a device has a voltage rating within one of the ranges specified in Table 38.1, that test voltage is to be used.

43.2 An electromagnet for use on alternating current shall withstand a voltage 10 percent more than its rated voltage continuously without damage to the operating coil and shall operate successfully at 15 percent less than its rated voltage. If a device has a voltage rating within one of the ranges specified in Table 38.1, the test voltage is to be used.

43.3 For operation at maximum voltage, the contactor coil is to be subjected to the overvoltage potential until a constant temperature is reached and tested immediately for closing at the normal line voltage.

43.4 For operation at minimum voltage, the contactor coil is to be subjected to the normal line voltage until a constant temperature is reached and tested immediately for closing at the minimum voltage.

43.5 If an electromagnet is energized through a transformer, rectifier, transformer and rectifier, or other component, the voltage adjustments are to be made at the transformer primary or input terminals, using the test values as specified for alternating current or direct current, as appropriate.

43.6 The test is to be conducted on samples, and using test conditions, that represent the most severe application involved in the use of the device. Examples are:

a) Enclosed instead of open,

b) At elevated ambient temperature,

c) The impedance of upstream components, such as described in 43.5, and

d) Location near or with other heat producing components.

44 Calibration-Verification Test

44.1 For a water-heater control or a hot tub/spa water temperature control tested at the ambient-air temperature or temperatures consistent with its intended use and for which it is to be rated, the cutout temperature shall:

a) Be ±5°F (±3°C) of the set-point temperature for a water-heater temperature-limiting control, and a hot tub/spa temperature-regulating and -limiting control;

b) Be ±7°F (±4°C) of the maximum temperature set point for a water heater temperature-regulating control having a maximum temperature setting of more than 170°F (77°C). A water heater temperature-regulating control with a maximum temperature set point of 170°F or less is not to be subjected to calibration-verification tests except as indicated in (c);

c) Be ±5°F of the factory temperature setting for a water heater temperature-regulating control with a maximum temperature set-point of 170°F or less. The factory temperature setting shall be no higher than 140°F (60°C). The test shall be performed on test samples set at the maximum 140°F or less; and

d) Not vary from the as-received temperature, following the endurance test, by more than 5 percent of the Fahrenheit set-point temperature, or by more than 10°F (6°C), whichever is the greater, for either control mentioned in (a), (b), and (c).

44.2 For an electric-baseboard-heater temperature-limiting control tested at ambient-air temperature or temperatures consistent with its intended use, the cutout temperature shall:

a) Be ±15°F (±8°C) of its marked set-point temperature; and

b) Not rise above the as received temperature following the endurance test by more than 2 percent of the rated Fahrenheit temperature.

44.3 For a control other than those covered by 44.1 and 44.2, the cutout temperature of a temperature-limiting control, when tested at ambient-air temperature or temperatures consistent with its intended use shall:

a) Be ±10°F (±6°C) of its maximum marked set-point temperature up to a 300°F (149°C) rating, 4 percent of its maximum set-point Fahrenheit temperature up to 400°F (204°C), and 5 percent above 400°F; and

b) Not vary from the as-received cutout temperature following the endurance test by which ever is greater:

1) More than 5 percent of the maximum set-point Fahrenheit temperature, or

2) More than 10°F.

Exception: Downward drift in cutout temperature may exceed the value specified in (b)(1) – but not more than 20 percent of the maximum set-point Fahrenheit temperature – if such performance does not contribute to a risk of fire, electric shock, or injury to persons. See 44.4.

44.4 Among the factors taken into consideration when investigating the downward-drift tolerance mentioned in Exception to 44.3 are:

a) The possibility of user tampering,

b) Overlapping performance with a temperature-regulating control, and

c) Other similar conditions that might result in a risk of fire, electric shock, or injury to persons.

44.5 The calibration-verification tests on a temperature-responsive control are to be performed on representative production samples that have been produced and calibrated within the same tolerances permitted in factory production. The set-point temperature of the sample is to be the maximum for which the device is intended. The tests are to be performed in a manner that will provide a true and measurable sensing-element temperature.

44.6 Other than as noted in 44.8, a temperature-responsive control is to be mounted in an air oven having forced circulation of at least 100 feet (30.5 m) per minute, and designed so as to nullify the effects of radiation. Thermocouples are to be attached to the sensing element, on an adjacent identical element, or located in air adjacent to the element. Indication of cutout is to be obtained by a low-energy circuit of such value as to not provide a current assist, and the cutout temperature is to be determined as the average of two trials.

44.7 Prior to calibration verification, uniform temperatures of all parts of a control are to be maintained by holding the temperature approximately 20°F (11°C) below the set point until conditions of equilibrium have been established. The temperature is then to be raised at a rate of not more than 1.0°F (0.5°C) per minute until the control functions.

44.8 A temperature-responsive control of the immersion-element type shall be tested with the element inserted in a circulating-water system. The conditions of test shall accomplish the performance contemplated in 44.1 – 44.7.

44.9 A refrigeration-controller pressure-limiting device shall function as intended at a pressure not exceeding 105 percent of its maximum marked setting – see 71.2. After being subjected to the endurance test, the cutout pressure shall not increase from the cutout pressure initially determined by more than 5 percent of the marked setting.

44.10 For the tests, a refrigeration-controller pressure-limiting device is to be connected to a source of hydrostatic pressure that can be accurately controlled and measured. Pressures are to be increased or decreased during the test at a maximum rate of 1/2 psi (3.5 kPa) per minute.

45 Overload Test

45.1 An ampere-rated switching device not intended for controlling a motor shall perform acceptably when subjected to an overload test consisting of making and breaking for 50 cycles of operation, at a rate of 6 cycles per minute, a current of 150 percent of the rated value, at the voltage specified in Table 38.1. There shall be no electrical or mechanical breakdown or malfunction of the device, nor undue burning, pitting, or welding of the contacts.

45.2 Other than as noted in 45.6 and 45.7, a switching device intended for full-voltage motor starting shall perform acceptably when subjected to a locked-rotor test consisting of making and breaking for 50 cycles of operation, at a rate of 6 cycles per minute, a current as described in 45.3 and Table 45.1, at the voltage specified in Table 38.1. There shall be no electrical or mechanical breakdown or malfunction of the device, nor undue burning, pitting, or welding of the contacts.

Table 45.1
Method of determining currents for overload tests

Device rated in	Motor type	Current in amperes for overload test described in paragraph indicated	
		Locked-rotor, 45.2, 45.6, and 45.7	150-percent-current, 45.6, and 45.7
Horsepower	Single Phase or DC Motors	A-C: Six times the full-load current specified in Table 45.4	A-C: 1.5 times the full-load current specified in Table 45.4
		D-C: Ten times the full-load current specified in Table 45.3	D-C: 1.5 times the full-load current specified in Table 45.3
Horsepower	Class A 3 Phase Motor	A-C: Six times the full-load current specified in Table 45.4	A-C: 1.5 times the full-load current specified in Table 45.4
Horsepower	Class B, C, and D 3 Phase Motors	A-C: See Table 45.2	A-C: 1.5 times the full-load current specified in Table 45.4
Full-load and locked-rotor amperes	All	Rated locked rotor amperes	1.5 times rated full-load amperes

Table 45.2
Locked-rotor motor currents corresponding to various a-c horsepower ratings

HP	110 – 120 V	220 – 240 V	440 – 480 V	550 – 600 V
	Motor designations	Motor designations	Motor designations	Motor designations
	B, C, D	B, C, D	B, C, D	B, C, D
1/2	40	20	10	8
3/4	50	25	12.5	10
1	60	30	15	12
1-1/2	80	40	20	16
2	100	50	25	20
3		64	32	25.6
5		92	46	36.8
7-1/2		127	63.5	50.8
10		162	81	64.8
15		232	116	93
20		290	145	116
25		365	183	146
30		435	218	174
40		580	290	232
50		725	363	290
60		870	435	348
75		1085	543	434
100		1450	725	580
125		1815	908	726
150		2170	1085	868
200		2900	1450	1160
250			1825	1460
300			2200	1760
350			2550	2040
400			2900	2320
450			3250	2600

Table 45.2 Continued on Next Page

Table 45.2 Continued

HP	110 – 120 V	220 – 240 V	440 – 480 V	550 – 600 V
	Motor designations	Motor designations	Motor designations	Motor designations
	B, C, D	B, C, D	B, C, D	B, C, D
500			3625	2900

45.3 The current of the overload tests mentioned in 45.2, 45.6, and 45.7 is to be as specified in Table 45.1.

45.4 A contact device designed for pilot duty shall perform acceptably when subjected to an overload test consisting of 50 operations, making and breaking a circuit of rated frequency and 110 percent of the voltage specified in Table 38.1, at intervals of 10 seconds, with the contacts closed for approximately 1 second each cycle. The load shall consist of an electromagnet representative of the magnet-coil load that the device is intended to control – the normal current is to be determined from the voltage and volt-ampere rating of the device. The test coils shall be those described in 46.5. The test shall be conducted with the contactor free to operate, for example, not blocked in either the open or closed position. There shall be no electrical or mechanical breakdown or malfunction of the device nor undue burning, pitting, or welding of the contacts.

45.5 A device that has been investigated and found to be acceptable for controlling an alternating-current motor is acceptable for alternating-current pilot duty without additional overload or endurance tests if:

a) During the locked-rotor motor-controller test, the contacts were caused to make and break, for 50 cycles of operation at a rate of 6 cycles per minute, a current having a value as specified in the second column of Table 45.1 at a power factor of 0.5 or less; and

b) The pilot-duty inrush current at the same voltage is not more than 67 percent of the rated locked-rotor motor current of the device, or the locked-rotor current corresponding to the horsepower rating, depending on the basis on which the device is rated.

45.6 A switch that is not intended primarily to make and break motor current under locked-rotor conditions, but that has a manual adjusting or regulating means that may cause it to be so used, shall comply with the requirements in 45.2 for locked-rotor test.

Exception: For a switch intended for operation on direct current, the number of operations shall be five, conducted at intervals of 30 seconds, and the device shall also comply with the requirements in 45.7 pertaining to the 150-percent-overload test.

45.7 A switch that may make a motor circuit under locked-rotor conditions, but that will never be required to break the circuit under such conditions, shall perform acceptably when subjected to an overload test consisting of 50 cycles of making and breaking, at a rate of 6 cycles per minute, a current as specified in the fourth column of Table 45.1. For an alternating-current device, the voltage of the test circuit shall have the value specified in Table 38.1. For a direct-current device it shall be 50 percent of that value. The switch shall also be subjected to the locked-rotor test described in 45.2, except that it is to make – not break – the circuit only. There shall be no electrical or mechanical malfunction of the device, nor undue burning, pitting, or welding of the contacts. A safety control that is subjected to the test of making – but not breaking – locked-rotor current shall open the circuit under no-load conditions without more than a 20 percent change in its calibration.

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45.8 The test cycle is to be 1 second on and 9 seconds off, if the design of the device permits the test to be so conducted.

45.9 If an ampere-rated device has the same ampere rating at more than one voltage, a test at the highest voltage is considered to be representative of tests at the lower voltages, but if the device has a higher ampere rating at the lower voltage than at the higher ones, tests are to be conducted at the highest and lowest voltages.

45.10 If a horsepower-rated device has more than one voltage rating, the overload test or tests are to cover the conditions of maximum voltage, power, and current.

45.11 Other than as noted in 45.4 and 46.6, a current-interrupting device for use on direct current shall be tested with a noninductive resistance load. A current-interrupting device for use on alternating current shall be tested with an inductive load, except that a thermostat intended for controlling a noninductive load, such as a range, water heater, clothes dryer, or the like, shall be tested with a noninductive resistance load.

45.12 The power factor of an inductive load shall be 0.75 – 0.80, except that it shall be 0.40 – 0.50 for a load simulating locked-rotor conditions in a motor, and shall not be more than 0.35 for a pilot-duty load.

45.13 Tables 45.3 and 45.4 give full-load currents corresponding to motor horsepower ratings, and are to be used in determining loads for the various tests specified for horsepower-rated equipment.

Table 45.3
Full-load motor-running currents in amperes corresponding to various d-c horsepower ratings

Horsepower	(W output)	90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
1/10	(75)	–	2.0	–	1.0	–	–
1/8	(93)	–	2.2	–	1.1	–	–
1/6	(124)	–	2.4	–	1.2	–	–
1/4[a]	(187)	4.0	3.1	2.0	1.6	–	–
1/3	(249)	5.2	4.1	2.6	2.0	–	–
1/2	(373)	6.8	5.4	3.4	2.7	–	–
3/4	(560)	9.6	7.6	4.8	3.8	–	1.6
1	(746)	12.2	9.5	6.1	4.7	–	2.0
1-1/2	(1120)	–	13.2	8.3	6.6	–	2.7
2	(1490)	–	17.0	10.8	8.5	–	3.6
3	(2240)	–	25.0	16.0	12.2	–	5.2
5	(3730)	–	40.0	27.0	20.0	–	8.3
7-1/2	(5600)	–	58.0	–	29.0	13.6	12.2
10	(7460)	–	76.0	–	38.0	18.0	16.0
15	(11.2 kW)	–	110.0	–	55.0	27.0	24.0
20	(14.9 kW)	–	148.0	–	72.0	34.0	31.0
25	(18.7 kW)	–	184.0	–	89.0	43.0	38.0
30	(22.4 kW)	–	220.0	–	106.0	51.0	46.0
40	(29.8 kW)	–	292.0	–	140.0	67.0	61.0

Table 45.3 Continued on Next Page

Table 45.3 Continued

Horsepower	(W output)	90 volts	110 – 120 volts	180 volts	220 – 240 volts	500 volts	550 – 600 volts
50	(37.3 kW)	–	360.0	–	173.0	83.0	75.0
60	(44.8 kW)	–	–	–	206.0	99.0	90.0
75	(60.0 kW)	–	–	–	255.0	123.0	111.0
100	(74.6 kW)	–	–	–	341.0	164.0	148.0
125	(93.3 kW)	–	–	–	425.0	205.0	185.0
150	(112 kW)	–	–	–	506.0	246.0	222.0
200	(149 kW)	–	–	–	675.0	330.0	294.0

[a] The full-load current for a 1/4-horsepower, 32-volt direct current motor is 8.6 amperes.

Table 45.4
Full-load motor-running currents in amperes corresponding to various a-c horsepower ratings

Horsepower[a]	(W Output)	110 – 120 volts		220 – 240 volts[a]		440 – 480 volts		550 – 600 volts	
		Single-phase	3-phase	Single-phase	3-phase	Single-phase	3-phase	Single-phase	3-phase
1/10	(75)	3.0	–	1.5	–	–	–	–	–
1/8	(93)	3.8	–	1.9	–	–	–	–	–
1/6	(124)	4.4	–	2.2	–	–	–	–	–
1/4	(187)	5.8	–	2.9	–	–	–	–	–
1/3	(249)	7.2	–	3.6	–	–	–	–	–
1/2	(373)	9.8	4.4	4.9	2.2	2.5	1.1	2.0	0.9
3/4	(560)	13.8	6.4	6.9	3.2	3.5	1.6	2.8	1.3
1	(746)	16.0	8.4	8.0	4.2	4.0	2.1	3.2	1.7
1-1/2	(1120)	20.0	12.0	10.0	6.0	5.0	3.0	4.0	2.4
2	(1490)	24.0	13.6	12.0	6.8	6.0	3.4	4.8	2.7
3	(2240)	34.0	19.2	17.0	9.6	8.5	4.8	6.8	3.9
5	(3730)	56.0	30.4	28.0	15.2	14.0	7.6	11.2	6.1
7-1/2	(5600)	80.0	44.0	40.0	22.0	21.0	11.0	16.0	9.0
10	(7460)	100.0	56.0	50.0	28.0	26.0	14.0	20.0	11.0
15	(11.2 kW)	135.0	84.0	68.0	42.0	34.0	21.0	27.0	17.0
20	(14.9 kW)	–	108.0	88.0	54.0	44.0	27.0	35.0	22.0
25	(18.7 kW)	–	136.0	110.0	68.0	55.0	34.0	44.0	27.0
30	(22.4 kW)	–	160.0	136.0	80.0	68.0	40.0	54.0	32.0
40	(29.8 kW)	–	208.0	176.0	104.0	88.0	52.0	70.0	41.0
50	(37.3 kW)	–	260.0	216.0	130.0	108.0	65.0	86.0	52.0
60	(44.8 kW)	–	–	–	154.0	–	77.0	–	62.0
75	(46.0 kW)	–	–	–	192.0	–	96.0	–	77.0
100	(74.6 kW)	–	–	–	248.0	–	124.0	–	99.0
125	(93.3 kW)	–	–	–	–	–	156.0	–	125.0
150	(111.9 kW)	–	–	–	–	–	180.0	–	144.0

Table 45.4 Continued on Next Page

Table 45.4 Continued

Horsepower[a]	(W Output)	110 – 120 volts		220 – 240 volts[a]		440 – 480 volts		550 – 600 volts	
		Single-phase	3-phase	Single-phase	3-phase	Single-phase	3-phase	Single-phase	3-phase
200	(149.2 kW)	–	–	–	–	–	240.0	–	192.0

[a] To obtain full-load currents for 200 and 208 volt motors, increase the corresponding 220 – 240 volt currents by 15 and 10 percent, respectively, for single- and 3-phase motors. To obtain full-load currents for 265- and 277-volt motors, decrease the corresponding 220 – 240-volt currents by 13 and 17 percent, respectively. The 265- and 277-volt ratings are applicable for equipment rated 2 horsepower or less, single-phase only.

45.14 Current-interrupting tests shall be conducted at the voltage specified in Table 38.1.

Exception: For a direct-current device, current-interrupting tests shall be conducted at 50 percent of the voltage specified in Table 38.1 in accordance with 45.7 and 46.1.

45.15 A circuit in which the closed-circuit voltage is 100 – 110 percent of the test potential specified in Table 38.1 may be used for the tests mentioned in 45.14.

Exception: For a device rated more than 25 horsepower (18.7 kW) or more than 100 amperes, the open-circuit voltage is to be 110 percent of the value specified in Table 38.1, or as much above that value as the closed circuit voltage is below it, whichever is less.

45.16 Alternating-current interrupting tests are to be conducted on a circuit having a frequency of 60 hertz. Tests at 25 – 60 hertz may, however, be considered to be representative.

45.17 A 2-pole or 4-pole device is to be tested on a single-phase or direct-current circuit. In a 4-pole device, adjacent poles are to be used, one pole being the nearest the enclosure. If the pole spacing varies, an additional test is to be conducted between the poles with the smallest spacing, to cover use on 2-phase interconnected systems.

45.18 A 3-pole device for polyphase use shall be tested on a 3-phase circuit. A 3-pole device for use on a direct-current or single-phase system with a grounded neutral shall be tested with rated voltage applied to the outside poles and with the middle pole electrically connected to the line and to the midpoint of a balanced load.

45.19 For a device that is intended for connection to a grounded-neutral system and is marked as specified in 74.10 or 74.11, the enclosure shall be connected during the test through a 3-ampere cartridge fuse to the grounded conductor of the circuit. For any other system, the enclosure is to be connected through such a fuse to the live pole least likely to arc to ground.

46 Endurance Test

46.1 A switch shall perform acceptably when operated manually, by means of a machine, or by automatic means for the number of cycles specified in Table 46.1, and at the rate specified unless the design of the device requires a longer time to complete a cycle of operation. If an electrical load is involved, and except as otherwise noted, a switch shall make and break its rated current at the voltage specified in Table 38.1. Switch contacts for control of a motor are to be tested with full-load motor current; if the switch is rated in horsepower instead of full-load motor current, the latter value is to be determined from Table 45.3 or 45.4, whichever is applicable. If the switch contacts control a direct-current motor, and the switch normally will make but not break the motor circuit under locked-rotor conditions, the potential of the test circuit is to be 50 percent of the value specified in Table 38.1. There shall be no electrical or mechanical breakdown of the device, nor undue burning, pitting, or welding of the contacts.

Table 46.1
Number of cycles for endurance test

Types of devices	Number of cycles of operation[a]					
	With current	Without current	First	Maximum cycles per minute	Last	Maximum cycles per minute
Safety controls including refrigeration pressure-limiting controls, defrost temperature-limiting controls, and electric-baseboard-heater temperature-limiting controls, and hot tub/spa controls	100,000	–	75,000	6	25,000	1[b]
Refrigeration controls	30,000	–	24,000	6	6,000	1[b]
Water-heater thermostats	30,000	–	30,000	1[b]	–	–
Range controls	[c]	–	[c]	[c]	[c]	[c]
Fan control for central electric air-heating equipment	30,000	–	24,000	6	6,000	1[b]
Manually operated switch	6,000	–	6,000	6	–	–
Protective switches not normally required to make and break a circuit, such as manually reset safety controls, high-pressure and high-temperature cutouts used in addition to the regular operating control, and the like, but not including automatically-reset controls	1,000	5,000	1,000	1[b]	5,000	[d]

Table 46.1 Continued on Next Page

Table 46.1 Continued

Types of devices	Number of cycles of operation[a]					
	With current	Without current	First	Maximum cycles per minute	Last	Maximum cycles per minute
Disconnect switches, such as a manual motor-circuit switch that is incorporated in a device with a motor controller	1,000	5,000	1,000	6	5,000	[d]
Motor controllers and ampere-rated devices not mentioned above, such as thermostats, humidistats, and timing mechanisms[e]	6,000	–	6,000	1[b]	–	–
Appliance controls	6,000[f]	–	6,000	1[b]	–	–
	30,000	–	24,000	6	6,000	1[b]
	100,000	–	75,000	6	25,000	1[b]

[a] Magnetic, manual and motor-operated switches, or the like, and switches that snap with lost motion and do not creep, may be tested at the rate of 6 cycles per minute.

[b] For all controls, the test is to be conducted with 50 ± 20 percent on time. A temperature-or pressure-operated control is to be so tested, using a slow rate of change.

[c] For range controls, refer to 38.6.1 – 38.9.2 and Table 38.3.

[d] When no current is used, the switch may be operated at any convenient speed.

[e] See 38.2 for wall-mounted room thermostats for direct control of fixed electric space heating.

[f] Number of operations are determined by requirements of an appliance.

46.2 Two samples of a wall-mounted room thermostat intended for direct control of electric space-heating equipment that is to be permanently connected electrically (designated SAMPLE 1 and SAMPLE 2) are to be subjected to an endurance test consisting of 6000 cycles of operation at the rate of not more than 1 cycle per minute and at 110 percent of both the rated current and the voltage specified in Table 38.1. The on time is to be 50 ±20 percent, and operation is to be by thermal means. There shall be no electrical or mechanical breakdown of either thermostat, and there shall be no undue burning or pitting of the contacts of SAMPLE 1. See 46.3.

46.3 SAMPLE 2 is to be subjected to an additional 30,000 cycles of operation under the conditions described in 46.2, except that the rated current and the test voltage specified in Table 38.1 is to be used. The test may be discontinued if the thermostat becomes inoperative due to the contacts not opening or closing. There shall be no indication of a risk of fire or electric shock.

46.4 The conditions for the endurance test are to be as described in 45.9 – 45.19.

46.5 A contact device designated for pilot duty is to perform acceptably when operated for the number of cycles specified in Table 46.1, making and breaking a circuit of rated frequency and at the voltage specified in Table 38.1. Unless the design of the device requires a longer time to complete a cycle of operation, the rate of operation for the test is to be as follows:

a) For a manually operable device, the first 1000 cycles are to be at the rate of 1 cycle per second – except that the first ten or 12 operations are to be made as rapidly as possible – and the remaining cycles are to be at the rate of 6 cycles per minute, with the device closed for approximately 1 second each cycle; and

b) For a self-actuated device the cycle rate is to be as specified in Table 46.1.

46.6 The load is to consist of an electromagnet representative of the magnet-coil load that the device is intended to control. The normal current is to be determined from the voltage and volt-ampere rating of the device. The test current is to be the normal current; and for an alternating-current device, the power factor is to be 0.35 or less and the inrush current is to be ten times the normal current, unless marked in accordance with 69.11. The test is to be conducted with the contactor free to operate, that is, not blocked either open or closed. There shall be no electrical or mechanical breakdown of the device nor undue pitting or burning of contacts.

46.7 If a device requiring an endurance test of 100,000 cycles has two or more electrical ratings – for example, different currents at different voltages – it may be tested for not less than 25,000 cycles at each rating, but the total number of cycles on any one sample is not to be more than 100,000. At least one sample is to be tested for 100,000 operations.

46.8 If equipment requiring an endurance test of 30,000 cycles has two or more electrical ratings, it may be tested for not less than 7,500 cycles at each rating, but the total number of cycles on any one sample is not to be more than 30,000. At least one sample is to be tested for 30,000 operations.

46.9 With reference to 46.7 and 46.8, the endurance testing can only be divided to accommodate multiple electrical ratings if all three of the following conditions are met:

a) Each electrical rating is of the same load type – for example, each rating is a resistive rating;

b) Each rating is of the same frequency – for example, each rating is at a frequency of 60 Hz; and

c) The power – VA – of each rating is not less than 75 % of the VA associated with the highest powered load.

47 Dielectric Voltage-Withstand Test

47.1 General

47.1.1 Equipment shall withstand for 1 minute, without breakdown, the application of an alternating potential of 1000 volts plus twice maximum rated voltage:

a) Between line-voltage live parts and grounded or exposed metal parts or the enclosure with the contacts open and closed;

b) Between line-voltage live parts of opposite polarity with contacts closed; and

c) Between live parts and line- and low-voltage circuits, line-voltage and isolated-limited-power secondary circuits, and different line-voltage circuits.

47.1.2 A wall-mounted room thermostat intended for direct control of electric space-heating equipment that is to be permanently connected electrically (designated SAMPLE 1) shall withstand for 1 minute, without breakdown, the application of an alternating potential of 900 volts between the line and load terminals. Supplementary insulation may be placed between the thermostat contacts during this test. There shall be no breakdown either through or across the insulating material supporting the contact and terminal assemblies.

47.1.3 A device employing a low-voltage circuit shall withstand for 1 minute, without breakdown, the application of an alternating potential of 500 volts applied between low-voltage live parts of opposite polarity with contacts closed, and between low-voltage live parts and the enclosure and grounded dead metal parts.

47.1.4 The opposite polarity dielectric voltage-withstand test may be omitted for a portion of a low-voltage, nonsafety circuit that is beyond any fixed impedance.

47.1.5 A transformer, shall withstand for 1 minute, without breakdown, the application of an alternating potential of 1000 volts plus twice the maximum rated primary voltage, at rated frequency, between primary and secondary windings and between the primary winding and the core or enclosure.

47.1.6 A power transformer shall withstand for 1 minute, without breakdown, the application of an alternating potential of 1000 volts plus twice the maximum rated primary or secondary voltage, at rated frequency, between primary and secondary windings, and shall withstand under the same conditions the application of an alternating potential of 1000 volts plus twice the rated voltage of each winding, at rated frequency, between each winding and the core or enclosure, except that the test between primary and secondary windings is omitted for an autotransformer.

47.1.7 A device employing a barrier or liner to insulate an exposed dead metal part shall withstand a dielectric voltage-withstand test as described in 47.1.1 between live parts and the exposed dead metal part. See Table 32.1.

47.1.8 If a device involves a meter or meters, such instruments shall be disconnected from the circuit and the complete device subjected to a dielectric voltage-withstand test as described in 47.1.1 – 47.1.7. The meter or meters shall then be tested separately in accordance with the tests outlined in 47.1.1 – 47.1.3 – whichever is applicable – except that an ammeter in a line-voltage circuit shall be tested at 1000 volts.

47.1.9 After the conditioning specified in 47.1.11, the insulation on a flexible pigtail lead for a line-voltage circuit or for a low-voltage safety-control circuit where breakdown will cause unsafe operation shall withstand for 1 minute, without breakdown:

a) When dry, an alternating potential of 1000 volts plus twice maximum rated voltage, and

b) After exposure to moist air, an alternating potential of rated voltage plus 500 volts.

47.1.10 A flexible pigtail lead for low-voltage circuits other than specified in 47.1.9 shall comply with the requirement in 47.1.3.

47.1.11 A lead that is to be tested dry is to be conditioned for 24 hours in a desiccator with dry calcium chloride, and a lead that is to be tested after exposure to moist air is to be conditioned for 24 hours in air having a relative humidity of 85 ±5 percent at a temperature of 32 ±2°C (90 ±4°F).

47.1.12 To determine if a lead complies with the requirement in 47.1.9, the straight conductor is to be employed as one electrode and a 1-inch-wide metal-foil wrap, located away from the ends of the sample, is to be the other electrode. The foil is to be located at three different positions or on three separate test samples.

47.1.13 To determine whether a device complies with the requirements in 47.1.1 – 47.1.12, the device is to be tested using a 500 volt-ampere or larger capacity transformer the output voltage of which is essentially sinusoidal and can be varied. The applied 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 substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter.

47.2 Induced potential

47.2.1 Each of three separate magnet-coil-winding samples shall withstand without breakdown the test mentioned in 32.3.1(b)(2) after constant temperatures have been reached as the result of operation under the conditions specified in Temperature Test, Section 40. While still heated, the coil winding shall be subjected to an alternating potential of twice the rated voltage at any suitable frequency – typically 120 hertz or higher – for 7200 electrical cycles or for 60 seconds, whichever is less. The required test voltage is to be attained by starting at one-quarter or less of the full value and increasing to the 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.

47.3 Induced potential repeated

47.3.1 While heated following operation at 110 percent of rated voltage as specified in Operation Test, Section 43, each of three samples shall withstand without breakdown a repeated induced potential test at 65 percent of the potential applied in accordance with 47.2.1.

47.3.2 If the temperature that a coil winding reaches in the tests described in 47.2.1 and 47.3.1 is known, an oven may be set at the required temperature and used to condition the sample to that temperature before conducting the test.

47A Abnormal Operation Test

47A added August 15, 2013

47A.1 General

47A.1.1 The abnormal conditions described in this section shall be imposed and maintained until ultimate results are obtained.

47A.2 Abnormal Switching Test

47A.2.1 Controls incorporating electronic circuitry to trigger the control's output switching device at specific phase angles near zero degrees in order to achieve switching of higher capacity loads, shall be subjected to this abnormal switching test. This test is applicable when:

a) Loads and circuits are only non-safety, and

b) Switching device components are used beyond their evaluated ratings. These evaluated ratings of switching devices are typically determined without electronic triggering techniques, such as zero cross switching.

47A.2.2 Two test samples shall be prepared and connected as follows:

a) The driver circuit to the switching device is to be removed or modified to allow random switching.

b) A ground arc fault indicating fuse is connected to accessible dead metal of the control. This fuse shall be 3-ampere maximum, non-time delay type fuse rated not less than the working voltage.

c) The control is to be supported on a tissue paper covered softwood surface, and is to be covered with a double layer of cheesecloth conforming to the outline of the control. The cheesecloth is in accordance with 63.1.2.

d) The rated supply circuit is connected through a branch circuit protection device sized according to installation requirements.

e) The control is connected to its rated electrical load.

47A.2.3 The prepared test samples shall be operated in accordance with the Endurance Test, Section 46, including the number of operating cycles and on/off periods, using random switching. The test samples shall be operated until either the required number of endurance test cycles are achieved or until ultimate results are demonstrated for 1h stabilized duration.

47A.2.4 Immediately after each abnormal switching test, each control shall be subjected to the Dielectric Withstand Test, 47.1.

47A.2.5 The control shall either operate as intended in accordance with the endurance test specifications, or demonstrate an end-of-life fail safe condition with no evidence of an imminent electrical shock, fire or injury to persons hazard. There shall be no:

a) Opening of the ground arc fault detection fuse,

b) Burning of the cheesecloth,

c) Opening of the branch circuit protection device, and

d) Breakdown during the post-abnormal switching dielectric withstand testing.

48 Volt-Ampere Capacity Test

48.1 An isolated limited-secondary circuit shall have a continuous-use capacity of 100 volt-amperes or less when energized from a circuit of rated frequency at the voltage specified in Table 38.1.

48.2 A single-wound secondary transformer is to attain a temperature rise on the enclosure, core, or coil of at least 50°C (90°F) when the secondary is loaded to the maximum output attainable or 100 volt-amperes, whichever is less.

48.3 Each secondary winding of a multisecondary transformer is to be loaded in turn with a variable resistor. Starting with a cold transformer for each part of the test, the load resistance is to be decreased from open-circuit to short-circuit in such a manner that the elapsed time is between 1-1/2 and 2-1/2 minutes. Depending upon the open-circuit voltage of the winding, the maximum outputs attained by this method are to be as follows:

a) 350 volt-amperes for 0 – 15 volts;

b) 250 volt-amperes for 15.1 – 30 volts; and

c) 200 volt-amperes for 30.1 – 1000 volts.

49 Burnout Test

49.1 A continuous-duty resistor shall not burn out or be adversely affected by carrying the full normal current on any step continuously. A resistor intended for intermittent use shall carry its rated current on any step for as long a time as the apparatus that it controls will permit.

49.2 A power transformer, other than a transformer supplying a low-voltage, electronic, or isolated-limited-secondary circuit is to be operated as described in 49.3. There shall be no damage to the enclosure or emission of flame or molten metal.

49.3 The device is to be operated continuously at the voltage and frequency specified in Table 38.1 and 38.1.2, with the enclosure grounded. The load connected to the output terminals is to be a resistance of such value that three times full rated current will be drawn from the secondary winding of the device, and operation is to be continued until constant temperatures are indicated on the enclosure or until burnout occurs.

49.4 A circuit on which a transformer is tested is to be protected by fuses rated at least ten times the primary current rating of the transformer, and opening of the fuses is acceptable. The test is to be conducted with the output terminals short-circuited, if such a condition results in less than three times full-rated current being drawn from the secondary. If other means of limiting the load to less than three times normal is inherent in or provided as part of the product, these features are to be given consideration and the burnout test conducted at the maximum load permitted by the limiting features.

49.5 A transformer supplying an isolated-limited-secondary circuit or an electronic circuit that is not Class 2 is to be tested in accordance with 49.2 – 49.4, except all secondary windings are to be short-circuited. See 63.1.4.

49.6 A transformer or power source supplying a Class 2 circuit is to be tested as specified in 63.12.1 – 63.12.7.

50 Short Circuit Test

50.1 Mercury-tube switch

50.1.1 Equipment employing a mercury-tube switch intended for connection to a line-voltage circuit shall perform acceptably when tested in series with a standard, nonrenewable cartridge fuse on a direct-current circuit of the voltage specified in Table 38.1, except that alternating current with a noninductive load may be employed if the product is intended for use on alternating current only. The fuse rating and capacity of the test circuit is to be as specified in Table 50.1.

Table 50.1
Mercury switch short-circuit test conditions

Volts	Maximum rating	Circuit current, amperes	Minimum fuse rating at least equal to switch amperes rating, or the nearest standard fuse[a] not exceeding four times motor full-load ampere rating but not less than:		
			0 – 125 volts	126 – 250 volts	251 – 600 volts
0 – 250	2000 volt-ampere	1000	20	15	–
0 – 250	30 ampere	3500	30	30	–
0 – 250	60 ampere	3500	60	60	–
0 – 250	Over 60 ampere	5000	[b]	[b]	–
251 – 600	Unlimited	5000	–	–	30

[a] For the purpose of this test, standard ampere ratings for fuses are 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, and 1200.

[b] Fuse size as specified in heading.

50.1.2 There shall be no ignition of the cotton or insulation on circuit conductors, nor emission of flame or molten metal– mercury excepted – from the enclosure housing the switch. Wiring attached to the product, except tube leads, shall not be damaged.

50.1.3 The enclosure and any other exposed metal are to be grounded, and cotton is to be placed around all openings in the enclosure. Successive operations are to be conducted by alternatively closing the short circuit on the mercury-tube switch and closing the mercury-tube switch on the short circuit by means of a switching device.

50.1.4 To determine if a mercury-tube switch complies with the requirements in 50.1.1 – 50.1.3, each of three samples is to be operated three times with sufficient time between successive operations on any one sample to permit cooling to room temperature, unless the switch is damaged so as to open the circuit permanently before the specified number of operations is conducted. The switch need not be operative after the tests.

50.2 Conductor

50.2.1 If required – see Exception No. 3 to 28.1.1 – there shall be no damage to any conductor, its insulation, or termination as a result of the short-circuit test described in 50.2.2 – 50.2.5.

50.2.2 Three sets of samples are to be subjected to the test. Each set is to consist of a group of two conductors; and one conductor – a total of nine conductors. The conductors are to be of the type, size, length, or the like used in the equipment with terminations as used in the equipment at each end. For each sample the conductor or conductors are to be routed within a length of conduit, if so used in the equipment, or they are to be placed on a metal plate.

50.2.3 The conduit or metal plate is to be connected to the unfused pole of the supply circuit. For the tests on one set, the two conductors are to be connected to the power supply and the terminals at the load end are to be connected together. For the tests on the other set, the conductor is to be connected across the supply circuit.

50.2.4 The test circuit is to be a 2-wire circuit having a power factor of 0.9 – 1.0, and available current as specified in Table 50.2, at the voltage specified in Table 38.1. The open-circuit voltage of the test circuit is to be 100 – 105 percent of the specified voltage. A nonrenewable fuse that will not open in less than 12 seconds when carrying twice its rated current is to be connected to 1 pole of the supply circuit.

Table 50.2
Circuit capacity for conductor short-circuit test

Combined rating of device			Horsepower (W)	Volts	Circuit capacity in amperes
Volt-amperes, single-phase	Volt-amperes, 3-phase	Volt-amperes, direct-current			
0 – 1176	0 – 832	0 – 648	1/2 maximum (373)	0 – 250	200
0 – 1176	0 – 832	0 – 648	1/2 maximum (373)	251 – 600	1000
1177 – 1920	833 – 1496	649 – 1140	over 1/2 (373) to 1 maximum (746)	0 – 600	1000
1921 – 4080	1497 – 3990	1141 – 3000	1 (746) to 3 (2200)	0 – 250	2000
4081 – 9600	3991 – 9145	3001 – 6960	3 (2200) to 7-1/2 (5600)	0 – 250	3500
9601 or more	9146 or more	6961 or more	Over 7-1/2 (5600)	0 – 250	5000
1921 or more	1497 or more	1141 or more	Above 1 (746)	251 – 600	5000

50.2.5 The fuse is to have a current rating equal to that of the branch-circuit overcurrent-protective device to which the equipment will be connected, but not less than 20 amperes.

50.3 Equipment for motor control

50.3.1 Equipment having a rating of more than 50 horsepower (37 kW output) or one or more motor overload relays shall comply with the applicable short-circuit test requirements in the Standard for Industrial Control Equipment, UL 508.

51 Parts Containing Liquid Metal Test

51.1 Parts of a control intended for use with cooking or other food-handling appliances that contain mercury, and parts of any control that contain sodium, potassium, or both shall withstand for 1 minute, without leakage or rupture, a hydraulic pressure equal to five times the maximum operating pressure.

51.2 The hydraulic pressure is to be increased until rupture occurs. The rupture shall occur at the bellows or diaphragm or other part that will be within the switch body or control enclosure; and for a control intended for use with cooking or other food-handling appliances, outside of the food-containing space. See 51.4.

51.3 Parts of a control intended for use with cooking or other food-handling appliances that contain mercury, and the parts of any control that contain sodium, potassium, or both shall:

a) Not leak or rupture when heated to 120 percent of the maximum load Fahrenheit temperature, and

b) Comply with the requirements in 51.4 when the bellows or diaphragm is deliberately punctured with a sharp pointed metal rod.

51.4 Mercury escaping due to the deliberate rupture by overpressure or deliberate puncture of a bellows or diaphragm shall not enter an oven or food handling compartment, or contact food handling hardware, or the like. It shall be contained in the switch body or control enclosure or be expelled outside the oven or compartment. Sodium, potassium, or both shall be contained in the switch body or control enclosure. There shall be no resulting risk of fire.

52 Two-Step Operation Surface-Unit Controls Test

52.1 General

52.1.1 A surface-unit control intended for use on a range or a counter-mounted cooking unit and required to have a minimum of two operations or the equivalent shall comply with the requirements in this section. Only one operation shall be required to turn such a control off. New samples are to be used for the tests in this section.

52.2 Push- and pull-and-turn controls

52.2.1 A rotary switch having a push-and-turn or a pull-and-turn operating sequence shall comply with the following:

a) The in-line force required to push or pull the shaft shall be at least 2 pounds (8.9 N), and the travel from the normal rest position to the turn position shall be at least 1/32 inch (0.8 mm).

b) A 30-pound (134-N) in-line push or pull force on the adjusting shaft shall not damage the switch.

c) For a control intended for use only with a knob having a grip diameter or length of 2 inches (50.8 mm) or less:

1) A means provided to restrict rotation of the shaft and closing of the contacts without prior push or pull operation shall not be defeated or damaged when a torque of 30 pound-inches (3.4 N·m) is applied to the shaft – that is, the control shall remain a two-operation type.

Exception: A stop that is defeated when a torque of at least 15 pound-inches (1.7 N·m) is applied to the shaft may be used if:

i) The contacts remain open and cannot be closed in this or subsequent operations of the control; or

ii) The stop or detent is not broken but is overridden to close the contacts; and in subsequent operation, requires both push-and-turn or the pull-and-turn to close the contacts.

2) There shall not be bridging or grounding of live parts or other risk of fire or electric shock if the stop or detent of the control is broken or damaged when a torque of 30 pound-inches or more as specified in (c)(1) or 15 pound-inches or more as specified in the Exception to (c)(1), whichever is appropriate, or a greater torque, is applied. A torque greater than 50 pound-inches (5.7 N·m) is not used for this test.

3) The torque required to open the contacts shall not be more than 4 pound-inches (0.5 N·m).

d) A control intended for use with a knob having a grip diameter or length of more than 2 inches (50.8 mm) shall comply with the requirements in (c)(1), (2), and (3) at a value of torque increased proportionally to the grip diameter or length of the knob from those specified.

e) A control other than as mentioned in (f) shall comply with the requirements in (a), (b), and (c) following an endurance test consisting of 6000 cycles of operation. A new sample is to be pushed or pulled and turned in one direction to the high heat position then turned back to the off position. If the construction is different in the other direction of rotation, a second endurance test is to be conducted on a new sample operated in the other direction.

f) A control as described in the Exception (ii) to (c)(1) shall comply with the requirements in (e) except that the actuator is to be turned for the first 1000 cycles of operation without first pushing or pulling.

52.3 Other types of controls

52.3.1 A surface-unit control of other than a push- or pull-and-turn control shall be tested as appropriate for its construction to demonstrate that it has strength and reliability at least equivalent to that required for a push- or pull-and-turn control.

53 Strain-Relief Test

53.1 A strain-relief device shall comply with the requirement in 53.2.

53.2 A strain-relief device shall withstand without damage to the cord or conductors and without displacement a direct pull of 35 pounds (156 N) applied to the cord for 1 minute. Supply connections within the equipment are to be disconnected from terminals or splices during the test.

54 Accelerated Aging Tests on Gaskets, Sealing Compounds, and Adhesives

54.1 The requirements specified in 54.2 – 54.6 apply to gaskets and sealing compounds employed to make an enclosure raintight or rainproof as determined in accordance with the requirements in Rain Test, Section 56. The requirements specified in 54.7 apply to adhesives required to secure such gaskets to an enclosure or cover.

54.2 Neoprene or rubber compounds, except foamed materials, used for gaskets to seal an enclosure, shall have physical properties as specified in Table 54.1 before and after accelerated aging under the conditions specified in Table 54.2.

Table 54.1
Physical properties for gaskets

	Neoprene or rubber compound		Polyvinyl chloride materials	
	Before test	After test	Before test	After test
Recovery – Maximum set when 1-inch (25.4-mm) gage marks are stretched to 2-1/2 inches (63.5 mm) held for 2 minutes and measured 2 minutes after release	1/4 inch (6.4 mm)	–	Not specified	
Elongation – Minimum increase in distance between 1-inch gage marks at break	250 percent, 1 – 3-1/2 inches (25.4 – 88.9 mm)	65 percent of original	250 percent, 1 – 3-1/2 inches	75 percent of original
Tensile Strength – Minimum force at breaking point	850 psi (5.9 MPa)	75 percent of original	1200 psi (8.3 MPa)	90 percent of original

Table 54.2
Accelerated aging conditions

Measured temperature rise		Material	Test program
°C	°F		
35	63	Rubber or neoprene	Air oven aging for 70 hours at 100.0°C ± 2.0°C (212.0°C ± 3.6°F)
35	63	Thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 87.0 ± 1.0°C (188.6 ± 1.8°F)
50	90	Rubber or neoprene	Air oven aging for 168 hours at 100.0°C ± 2.0°C (212.0°F ± 3.6°F)
50	90	Thermoplastic	Aged in full-draft, air-circulating oven for 240 hours at 100.0 ± 1.0°C (212.0 ± 1.0°F)
55	99	Rubber, neoprene or thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 113.0 ± 1.0°C (235.4 ± 1.8°F)
65	117	Rubber or neoprene	Aged in full-draft, air-circulating oven for 240 hours at 121.0 ± 1.0°C (249.8 ± 1.8°F)
65	117	Thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 121.0 ± 1.0°C (249.8 ± 1.8°F) for 1440 hours at 97.0 ± 1.0°C (206.6 ± 1.8°F)
80	144	Rubber, neoprene or thermoplastic	Aged in full-draft, air-circulating oven for 168 hours at 136.0 ± 1.0°C (276.8 ± 1.8°F)

54.3 Foamed neoprene or rubber compounds used for gaskets to seal an enclosure are to be subjected to accelerated aging under the conditions specified in Table 54.2. The compounds shall not harden or otherwise deteriorate to a degree that will affect their sealing properties.

54.4 Thermoplastic materials used for gaskets to seal an enclosure shall be subjected to accelerated aging under the conditions specified in Table 54.2. Thermoplastic material shall not deform or melt, or otherwise deteriorate to a degree that will affect its sealing properties. Solid polyvinyl-chloride gasket material shall have physical properties as specified in Table 54.1 before and after the accelerated aging.

54.5 Tensile strength and elongation are to be determined using the test methods and apparatus described in Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension, ASTM D412.

54.6 A sealing compound shall be applied to the surface it is intended to seal. For a temperature rise not exceeding 35°C (63°F), a representative sample of the surface with the sealing compound applied shall be conditioned for 7 days in an air oven at 87°C (189°F). The sealing compound shall not melt, become brittle or otherwise deteriorate to a degree that will affect its sealing properties as determined by comparing the conditioned sample to an unconditioned sample.

54.7 If gaskets are secured by adhesives, samples of the gasket, adhesive and mounting surface shall be exposed for 72 hours to each of the following conditions, for a temperature rise not exceeding 35°C (63°F):

a) 100°C (212°F),

b) Immersion in distilled water, and

c) Minus 10°C (14°F).

54.8 The force required to peel the gasket from its mounting surface after exposure shall not be less than 75 percent of the value determined on as-received samples.

54.9 The temperature rises mentioned in this section correspond to the maximum temperature rise measured on the gasket during the temperature test. Materials other than those mentioned in this section shall be nonabsorptive and they, and any materials having higher temperature rises, shall provide equivalent resistance to aging and temperatures.

55 Metallic Coating Thickness Test

55.1 The method of determining the thickness of a zinc or cadmium coating by the metallic-coating-thickness test is described in 55.2 – 55.9.

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

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

55.4 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at an ambient temperature of 21.1 – 32.2°C (70 – 90°F).

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

55.6 The sample to be tested is to be supported from 0.7 – 1 inch (17.8 – 25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 degrees from horizontal material.

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

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

55.9 To calculate the thickness of the coating being tested, select from Table 55.1 the thickness factor appropriate from the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as noted in 55.7.

Table 55.1
Thickness of coatings

Temperature, degrees F (C)		Thickness factors 0.00001 inch (0.00025 mm) per second	
		Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

56 Rain Test

56.1 Raintight or rainproof equipment shall be exposed to a water spray as described in 56.2 – 56.5. The exposure shall not result in:

a) Entrance of water into a raintight enclosure, or

b) Entrance of water above the lowest live part or wetting of live parts in a rainproof enclosure.

Exception: Water may enter a rainproof enclosure above live parts if the design is such that no water is visible on live parts, insulating materials, or mechanism parts and no water has entered any space above live parts within the enclosure in which wiring may be present under any proper installation conditions.

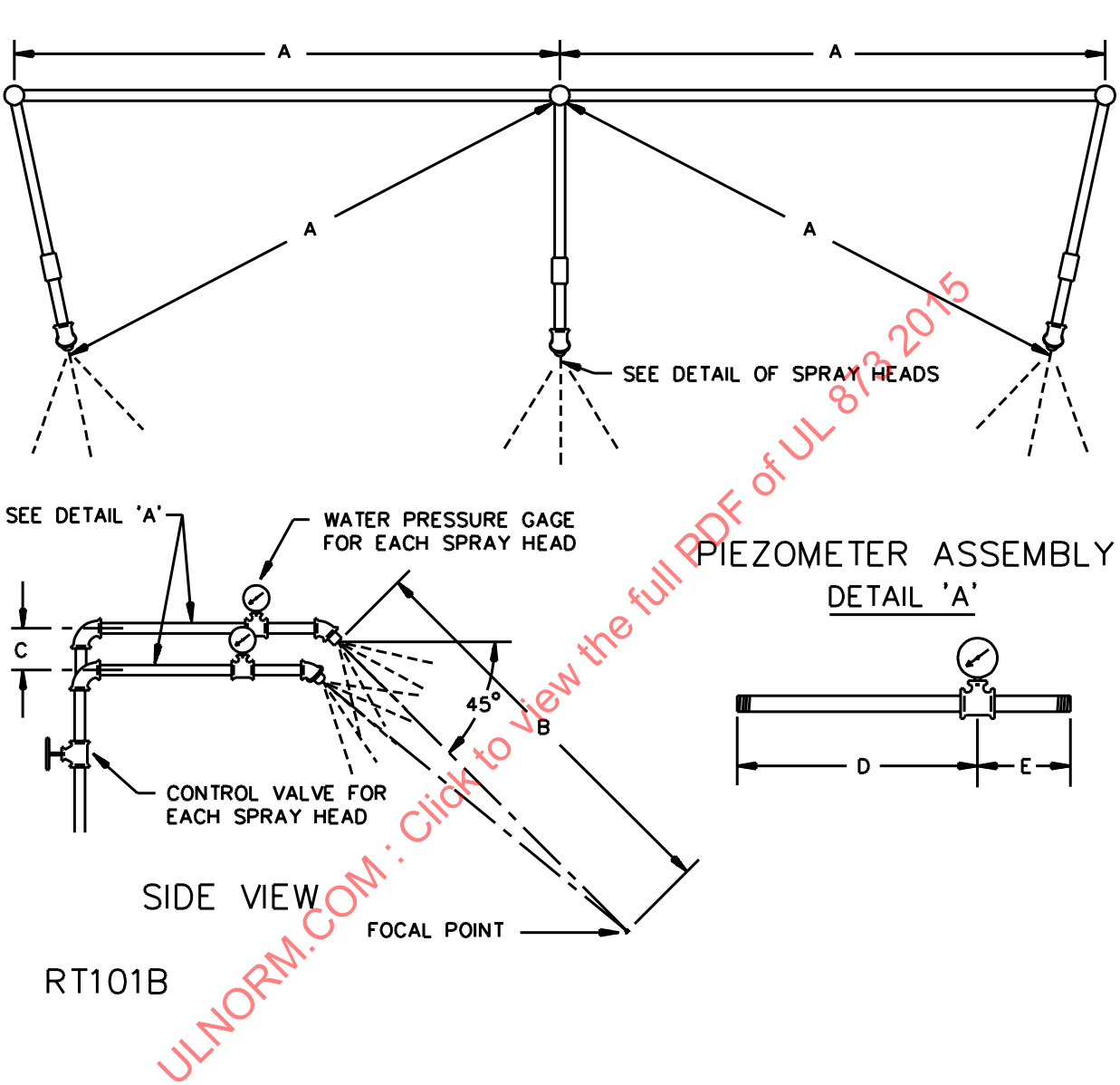
56.2 A raintight or rainproof enclosure is to be attached to a vertical clapboard surface as in intended service. Unspecified lengths of conduit are to be attached with normal torque and without a pipe thread compound. At each unthreaded wiring opening, a locknut and bushing are to be used. The unattached end of each conduit is to be covered to prevent entry of water during the test. Openings intended for the entry of a conductor or conductors for Class 2 wiring in a low-voltage circuit are not to be sealed, and openings in the enclosure bottom need not be closed.

56.3 The device is to be operated so that it is tested under the normal conditions judged most likely to cause the entrance of water. It may be necessary to operate the unit under various modes of operation and in different mounting or operating handle positions, if applicable, or to energize the unit if more adverse conditions could result. Each exposure is to be for 1 hour. If more than one exposure is required, the equipment is to be reconditioned, if necessary, prior to the second and each subsequent exposure so that the results of the test will not be adversely affected by prior exposures.

56.4 At the conclusion of each test, the outside of the enclosure is to be wiped dry. The enclosure is then to be opened for inspection.

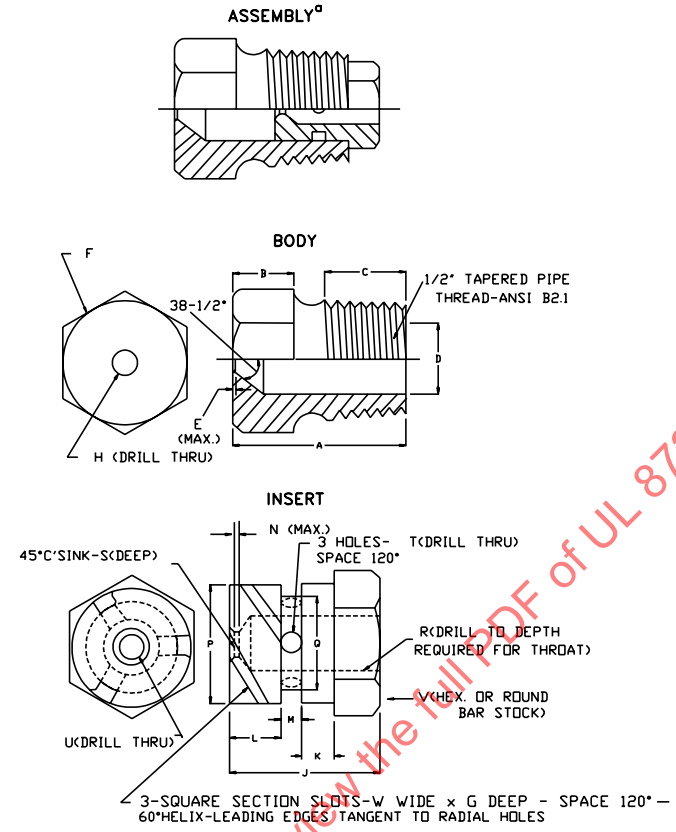
56.5 The water spray apparatus is to consist of three spray heads mounted in a water supply pipe rack as illustrated in Figure 56.1. Spray heads are to be constructed in accordance with Figure 56.2. The water pressure for all tests is to be maintained at 5 psi (34.5 kPa) at each spray head. The distance between the center nozzle and the unit is to be approximately 3 feet (0.9 m). The unit is to be brought into the focal area of the three spray heads in such position and under such conditions that the greatest quantity of water will enter the unit. The spray is to be directed at an angle of 45 degrees to the vertical toward the device.

Figure 56.1
Spray-head pipe rack



Item	inch	mm
A	28	710
B	55	1400
C	2-1/4	55
D	9	230
E	3	75

Figure 56.2
Spray head



Item	inch	mm	Item	inch	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	0.575	14.61
C	9/16	14.0		0.576	14.63
D	0.578	14.68	Q	0.453	11.51
	0.580	14.73		0.454	11.53
E	1/64	0.40	R	1/4	6.35
F	[c]	[c]	S	1/32	0.80
G	.06	1.52	T	(No. 35)[b]	2.79
H	(No. 9)[b]	5.0	U	(No. 40)[b]	2.49
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

[a] Molded nylon Rain-Test Spray Heads are available from Underwriters Laboratories, Inc.

[b] ANSI B94.11 Drill Size – Twist Drills, Straight Shank and Taper Shank Combined Drills, and Countersinks, ANSI 94.11M-1979(R1987).

[c] Optional– To serve as wrench grip.

57 Time-Calibration Verification Test

57.1 General

57.1.1 A time-delay or thermal relay that responds to a temperature-limiting control or other control requiring a calibration-verification test – see 38.5.1 or Table 38.3 – is to be subjected to the following tests in the order presented.

a) Initial time-calibration-verification Test I.

b) Initial time-calibration-verification Test II at different ambient air temperatures and voltages.

c) Endurance.

d) Time-calibration-verification after endurance.

57.2 Bimetal-heater design

57.2.1 A bimetal-heater, hot-wire, or similar device shall be time calibrated as specified in this section.

57.3 Initial time-calibration-verification Test I

57.3.1 The operating times determined in the initial time-calibration-verification tests shall be within the tolerances allowed for the device function. See Table 38.3.

57.3.2 Initial time-calibration-verification tests shall be conducted on separate samples having the shortest, average, and longest rated time settings, and on samples of different assigned production-time tolerances, to represent the intended variations in a line of devices. One test is to be conducted on each sample; or, at the manufacturer's request, the time setting is to be recorded as the average of three tests.

57.3.3 For the time-to-close calibration-verification test, the device is to remain at room temperature with the bimetal heater de-energized, until conditions have stabilized. The actuating heater is then to be energized at rated voltage, and the time for each load circuit to close is to be determined and recorded. The current through the load circuit is to be a value sufficient for detection purposes.

57.3.4 Room temperature is to be nominally 25°C (77°F), except that if the timing is severely affected by ambient air temperature, the manufacturer's specified ambient air temperature range is to be used.

57.3.5 For the time-to-open calibration-verification test, the device is to be at room temperature as noted in 57.3.3 and 57.3.4 with the actuating heater energized at rated voltage and:

a) Maximum rated current through all load-circuit contacts, or

b) A detection current through the load contacts if current does not affect timing.

57.3.6 When thermal equilibrium is attained, the actuating heater is to be de-energized, and the time for each load circuit to open is to be determined and recorded.

57.4 Initial time-calibration-verification Test II

57.4.1 Additional initial time-calibration-verification tests shall be conducted using the method described in 57.3.3 – 57.3.6 except that the test conditions shall be:

a) Rated actuating heater voltage and an ambient air temperature of 0°C (32°F);

b) Rated actuating heater voltage and an ambient air temperature equal to the maximum rating, but not less than 66°C (151°F);

c) Eighty-five percent of rated actuating heater voltage and room temperature; and

d) One hundred-ten percent of rated actuating heater voltage and room temperature.

57.4.2 The results are to be considered when investigating the control in the end-use equipment.

57.5 Endurance

57.5.1 An endurance test, preceded by an overload test as described in Overload Test, Section 45, shall be conducted on one sample having the highest heating effect from the actuating heater, at maximum current and at maximum rated ambient temperature.

57.5.2 The actuating heater is to be cycled using rated ambient temperature and rated voltage. The number of cycles is to be as specified for the device function, see Table 38.3. The test is to be conducted at a maximum rate of 1 cycle per minute or as specified in note a to Table 46.1. Only one pole of a multistage device is to be loaded, unless loading of the other poles contributes to timing differences. Additional overload and endurance tests are to be conducted on separate samples for additional ratings. The samples need not be calibrated, unless such ratings contribute to timing differences.

57.6 Time-verification and dielectric voltage-withstand tests after endurance

57.6.1 The sample subjected to the endurance test shall be recalibrated using the method specified for the Initial Time-Calibration-Verification Test I. The test results are to be judged by the requirements for the device function, see Table 38.3. The dielectric voltage-withstand test is then to be conducted in accordance with the Dielectric voltage-Withstand Test, Section 47.

57.7 Other designs

57.7.1 A limiting-type time-delay relay of a design not contemplated by these requirements shall be tested in a manner appropriate for its design to obtain the results contemplated by 44.3 – 44.10 or 57.3.2 – 57.6.1.

58 Snap-On Covers Test

58.1 A snap-on cover that gives access to live parts or film-coated wire and that does not have a tool-operated fastener shall have no apparent means of removal; such as an extending tab, and shall withstand the following tests:

a) A cover that can be released from securement with one hand by a squeezing force shall, when subjected to this test, either not be released, or when the cover is partially released, the opening between cover and case shall not permit the probe illustrated in Figure 7.1 to touch live parts or film-coated wire, require a subsequent operation to remove the cover, and comply with the tests described in (b) and (c) in the partially-released position. A squeezing force of 14 pounds (62.3 N) or less is to be applied at any two points, the distance between which shall not exceed 5 inches (127.0 mm), as measured by a tape stretched tightly over that portion of the surface of the cover that would be encompassed by the palm of the hand. The test shall be performed before and after ten removal and replacement operations.

b) A cover shall, when subjected to this test, either not become disengaged, or when the cover is partially released, the opening between cover and case shall not permit the probe illustrated in Figure 7.1 to touch live parts or film-coated wire, require a subsequent operation to remove the cover or enlarge the opening, and comply with the tests described in (a) and (c) in the partially removed position. A direct pull of 14 pounds is to be applied. The cover is to be pried at any two convenient points in one test and at any point in a separate test. The test is to be performed before and after ten removal and replacement operations.

c) A cover shall withstand an impact force of 1 foot-pound (1.35 J) applied to accessible faces of the cover – one blow per face – without being displaced, and there shall be no damage to internal parts or malfunction of the control as a result of this test. A steel ball approximately 2 inches (50.8 mm) in diameter and weighing approximately 1.18 pounds (535 g) is to be used to apply the impact.

59 Bonding Conductor Tests

59.1 Overcurrent

59.1.1 A bonding conductor that does not comply with the requirement in 22.2.8 is acceptable if:

a) The bonding conductor does not open when carrying for the time specified in Table 59.1, a current that equals twice the branch-circuit overcurrent-device rating – see 59.1.3 – but not less than 40 amperes; and

b) None of three samples of the bonding conductor, selected at random, opens during a limited short-circuit test with a current as specified in Table 50.2 when in series with a fuse as described in 59.1.2 and 59.1.3.

Table 59.1
Duration of current-flow, bonding-conductor test

Overcurrent-device rating, amperes	Minimum duration of current flow, minutes
30 or less	2
31 – 60	4
61 – 100	6

59.1.2 The circuit for the test described in 59.1.1(b) is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified in Table 50.2, at the voltage specified in Table 38.1. The open-circuit voltage of the test circuit is to be 100 – 105 percent of the specified voltage. The circuit is to be connected through a nonrenewable fuse that does not open in less than 12 seconds when carrying twice its rated current. One test is to be performed on each of three samples of the bonding conductor subject to the test.

59.1.3 The fuse mentioned in 59.1.1 is to have a current rating equal to that of the branch-circuit overcurrent-device to which the equipment will be connected, but not less than 20 amperes.

59.2 Resistance

59.2.1 The resistance between two parts connected by a bonding conductor shall not be more than 0.1 ohm.

59.2.2 The resistance is to be kept as low as possible in the event that a control is subject to a 0.1 ohm resistance requirement in end-use equipment.

59.2.3 Whether equipment complies with the requirements in 59.2.1 may be determined by any suitable instrument. If the results are unacceptable, an alternating current of at least 20 amperes from a power supply of not more than 12 volts is to be passed from the point of connection of the equipment grounding means to the metal part in the grounding circuit, and the resulting drop in potential is to be measured between the two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes passing between the two points. The grounding conductor of a power-supply cord is not to be included in this measurement.

60 Permanence of Marking Test

60.1 General

60.1.1 Unless known to be acceptable for the application, a pressure sensitive label that is required to be permanent shall be tested as described in 60.1.2.

60.1.2 After being subjected to the conditions described in 60.1.3 and 60.2 – 60.6, a pressure-sensitive label or a label secured by cement or adhesive is considered to be permanent if immediately following removal from each test medium and after being exposed to room temperature for 24 hours:

a) Each sample demonstrates good adhesion and the edges are not curled;

b) The label resists defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1/16 inch (1.6 mm) thick, held at right angles to the test panel; and

c) The printing is legible and is not defaced by rubbing with thumb or finger pressure.

60.1.3 Labels intended for indoor residential equipment may be subjected to the humidity test specified in 60.6.1 in place of the immersion test specified in 60.3.1.

60.2 Oven-aging

60.2.1 Three samples of the label applied to test surfaces as in the intended application are to be conditioned for 240 hours in an air oven maintained at the temperature specified in Table 60.1.

Table 60.1
Oven-aging test temperature

Maximum temperature during normal temperature test of surface to which applied		Oven temperature	
°C	°F	°C	°F
60 or less	140 or less	87	189
80 or less	176 or less	105	221
100 or less	212 or less	121	250
125 or less	257 or less	150	302
150 or less	302 or less	180	356
Over 150	302	a	

[a] A label that is applied to a surface attaining a temperature greater than 150°C (302°F), during the normal temperature test, is to be oven-aged at a temperature representative of the temperatures attained by the appliance during normal and abnormal operation.

60.3 Immersion

60.3.1 Three samples of the label applied to test surfaces as in the intended application are to be conditioned for 24 hours in a controlled atmosphere maintained at 23 ±2°C (73 ±4°F) with a relative humidity of 50 ±5 percent. The samples are then to be immersed for 48 hours in water at a temperature of 21 ±2°C (70±4°F).

60.4 Standard-atmosphere

60.4.1 Three samples of the label applied to test surfaces as in the intended application are to be conditioned for 72 hours in a controlled atmosphere maintained at 23 ±2°C (73 ±4°F) with a relative humidity of 50 ±5 percent.

60.5 Unusual condition exposure

60.5.1 If a label is exposed to unusual conditions in service, three samples of the label applied to test surfaces as in the intended application are to be conditioned for 24 hours in a controlled atmosphere maintained at 23 ±2°C (73 ±4°F) with a relative humidity of 50 ±5 percent. The samples are then to be immersed for 48 hours in a solution representative of service use maintained at the temperature the solution would attain in service, but not less than 23 ±2°C (73 ±4°F).

60.6 Humidity

60.6.1 Three samples of the test panels are to be suspended in a humidity cabinet at 32 ±2°C (90 ±4°F) with an 85 ±5 percent relative humidity for 72 hours.

61 Strength of Adjustment Stop Test

61.1 An adjustment stop of a control shall not be damaged so as to cause a reduction of spacings, too high a temperature setting, or other condition that may result in a risk of fire, electric shock, or injury to persons when subjected for 15 seconds to the tests described in 61.3 – 61.8.

61.2 As a result of the tests specified in this section:

a) If a change in setpoint is a factor, a calibration-verification test as specified in Calibration-Verification Test, Section 44, is to be conducted before and after the strength test. The setpoint after the test shall not differ from the as-received value more than the amount specified in Section 44;

b) Spacings shall not be reduced to a value less than those specified in Spacings, Section 32; and

c) The marked off position, if any, shall comply with the requirements in 11.5 – 11.12.

61.3 Breakage of the adjustment is acceptable if the requirements in 61.2 are met and the adjustment stop withstands one-half the specified test value.

61.4 For a control that is operated by a push, pull, slide, toggle, or lever adjustment, a force is to be applied to the free end of the adjustment in line with the intended movement in each direction of operation. The force is to be 20 pounds (89 N) for a commercial or industrial control and 10 pounds (45 N) for a household product control. A separate sample is to be used for each test.

61.5 A control adjustment operated as described in 61.4 and intended for use with an extended operator, handle, or lever is to be tested with the in-line force applied to the free end of an extension representing the intended end-use application.

61.6 For a control that is operated by a rotary adjustment intended for use with a knob having a grip diameter or grip length of 1 inch (25.4 mm) or less, a torque is to be applied to the shaft in each direction of intended operation. The torque is to be 9 pound-inches (1.0 N·m) for a commercial or industrial control and 7 pound-inches (0.8 N·m) for a household product control. A separate sample is to be used for each test.

61.7 A control that is operated by a rotary adjustment intended for use with a knob having a grip diameter or grip length of more than 1 inch (25.4 mm) is to be subjected to a torque that is proportionally greater than that specified in 61.6, based on the larger grip diameter or grip length of the knob used. The value for the torque to be used is to be determined by the formula:

$$T = \frac{D_1}{D} K$$

in which:

T is the test torque in pound-inches (N·m),

D_1 is the grip diameter or grip length, as applicable, in inches (m),

D is 1 inch (0.025 m),

k is 9 pound-inches (1.0 N·m) for a commercial or industrial control, or 7 pound-inches (0.8 N·m) for a household control.

61.8 If a lever arm is intended to be attached to a rotary-control shaft, the assembly is to be tested as described in 61.4 with the force applied to the free end of the lever.

61.9 If an adjustment means is not provided with a control, the manufacturer is to assign a maximum dimension for the knob, lever, toggle, or the like to be used with the control, and this dimension is to be used for determining the torque value.

62 Polymeric Materials Tests

62.1 General

62.1.1 An assumed ambient temperature of 40°C (104°F) is to be used in determining the required temperature rating of the polymeric enclosure.

62.1.2 An enclosure of polymeric material shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

62.1.3 An enclosure of polymeric material, shall comply with the applicable requirements in Table 62.1.

Table 62.1
Tests related to the use of polymeric materials for enclosures

Part 1 – Conditions of use		**1**	**2**	**3**	**4**
Material is used as the indirect support of live parts. The material is used to support electrical components that contain live parts, for example, switches, relays, terminal blocks, and the like		No	No	Yes	Yes
Part 2 – Equipment description					
Equipment is intended for indoor use Equipment is intended for outdoor use		Yes No	No Yes	Yes No	No Yes
Part 3 – Applicable requirements					
Tests	**Paragraphs**				
1. Conduit connection	62.2.1.1 – 62.3.	X	X	X	X

[a] Reference is to be made to Part 1 and Part 2 to find the column that matches the combination of conditions of use for the polymeric material and the equipment under consideration. The ″X″ appearing in that column in Part 3 designates the applicable requirements.

62.2 Conduit connections

62.2.1 General

62.2.1.1 A polymeric enclosure intended for connection to a rigid conduit system shall withstand, without pulling apart, or damage such as cracking and breaking, the pullout test, torque test, and bending test described in 62.2.2.1 – 62.2.4.2.

Exception: The torque test does not apply to an enclosure that is not provided with a preassembled hub and that has instructions stating that the hub is to be connected to the conduit before being connected to the enclosure.

62.2.2 Pullout

62.2.2.1 The enclosure is to be suspended by a length of rigid conduit installed in one wall of the enclosure and a direct pull of 200 pounds (90.8 kg) is to be applied for 5 minutes to a length of conduit installed in the opposite wall.

62.2.3 Torque

62.2.3.1 The enclosure is to be securely mounted as intended in service. A torque is to be applied to a length of installed conduit in a direction tending to tighten the connection. The tightening torque for rigid conduit threaded into the opening in the enclosure is to be 800 pound-inches (90.4 N·m) for 3/4-inch and smaller trade sizes, 1000 pound-inches (113 N·m) for 1-, 1-1/4-, and 1-1/2-inch trade sizes, and 1600 pound-inches (181 N·m) for 2-inch and larger trade sizes. The lever arm is to be measured from the center of the conduit.

Exception: An end-of-line enclosure – an enclosure that is intended to be connected at the end of a run of conduit and has only one 3/4-inch maximum trade size opening for the connection of conduit – need only be subjected to a tightening torque of 200 pound-inches (22.6 N·m).

62.2.4 Bending

62.2.4.1 A length of conduit – at least 1 foot (305 mm) long – of the proper size is to be installed in the center of the largest unreinforced surface, or in a hub or an opening if provided as part of the enclosure. The enclosure is to be securely mounted as intended in service, but positioned so that the installed conduit extends in a horizontal plane. The weight necessary to produce the desired bending moment when suspended from the end of the conduit is to be determined from the formula:

$$W = \frac{M - 0.5\,CL}{L}$$

in which:

W is the weight, in pounds, to be hung at the end of the conduit;

L is the length of the conduit, in inches, from the wall of the enclosure to the point at which the weight is suspended;

C is the weight of the conduit, in pounds; and

M is the bending moment required in pound-inches.

62.2.4.2 The bending moment for the test described in 62.2.4.1 is to be as specified in Table 62.2. If the enclosure surface may be installed in either a vertical or horizontal plane, the vertical bending moment value is to be used.

Exception: For an end-of-line enclosure – see the Exception to 62.2.3.1 – the bending moment need only be 150 pound-inches (16.9 N·m).

Table 62.2
Bending moment

Normal mounting plane of enclosure surface	Conduit size, inches	Bending moment, pound-inches (N·m)			
		Metallic conduit		Nonmetallic conduit	
Horizontal	All	300	(33.9)	300	(33.9)
Vertical	1/2 – 3/4	300	(33.9)	300	(33.9)
	1 – up	600	(67.8)	300	(33.9)
Note – The test may be terminated prior to attaining the values specified if the deflection of the conduit exceeds 10 inches (254 mm) for a 10 foot (3.1 m) length of conduit.					

62.3 Knockouts

62.3.1 If knockouts are incorporated in an enclosure made of polymeric material, they shall remain in place when subjected to a force of 20 pounds (89 N) applied at right angles by means of a mandrel with a 1/4-inch (6.4-mm) diameter flat end. The mandrel shall be applied at the point most likely to cause movement of the knockout.

63 Class 2 Power Sources and Circuit Tests

63.1 General

63.1.1 For Class 2 power sources and circuits, the tests described in this section, the sequence of conducting the tests and the number of samples for each test is specified in Table 63.1. A sample may be used for more than one test if it is not damaged in a previous test. If a test results in damage to the power source, additional samples may be necessary to complete the test series. Unless otherwise specified, each test is to be conducted at the supply voltage specified in Table 63.2.

Table 63.1
Test sequence and number of samples

Test sequence	Paragraph reference	Test	Number of samples[a]
1	63.3.1	Open-circuit secondary voltage	3
2	63.4.1 – 63.6.2	Output circuit and power	3
3	63.7.1 – 63.7.3	Calibration of overcurrent-protective devices	3
4	63.8.1 – 63.8.3	Rated secondary output	3
5	63.9.1	Rated output heating	1
6	63.10.1	Dielectric voltage withstand	1
7	63.11.1 – 63.11.3	Component breakdown	1 or more
8	63.12.1 – 63.12.7	Overload heating	1 or more
9	63.13.1	Repeat dielectric voltage withstand	1 or more
10	63.14.1 – 63.14.2	Overload of overcurrent- or overtemperature-protective devices	3
11	63.15.1 – 63.15.2	Endurance of automatic reset overtemperature-protective devices	3

[a] The same samples are to be used for these tests in the sequence indicated; however, if any nonreplaceable protective device opens or a coil burns open as permitted in 63.4.2 – 63.8.1 and 63.12.2 – 63.13.1, additional samples are to be used for the remaining tests. These additional samples need not be subjected to the preceding tests.

Table 63.2
Values of test voltage

Rated primary voltage	Test voltage
120 or less	120[a,b]
121 – 219	Rated voltage[a]
220 – 240	240
241 – 253	Rated voltage[a]
254 – 277	277
278 – 439	Rated voltage[a]
440 – 480	480
451 – 549	Rated voltage[a]
550 – 600	600

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

[b] If a transformer is rated less than 110 volts and is not intended for use on a 110 – 120 volt circuit, the transformer shall be marked as indicated in 69.4 and the test voltage is to be the rated voltage.

63.1.2 For the output current and power test, calibration of overcurrent protective devices test, overload heating test, overload of overcurrent- or overtemperature-protective devices test, and endurance of automatic reset overtemperature protective devices test specified in this section, all exposed dead metal parts of the power source are to be connected to the live pole least likely to strike ground through a 3-ampere non-time delay type fuse. The power source is to be connected to a circuit having 20-ampere branch-circuit protection. The power source is to be supported on a tissue paper covered softwood surface, and is to be covered with a double layer of cheesecloth conforming to the outline of the power source. The cheesecloth is to be bleached untreated cotton cloth running 14 – 15 square yards per pound (26 – 28m^2/kg) and for any square inch a count of 32 threads in one direction and 28 in the other direction (for any square centimeter, 13 threads in one direction and 11 in the other direction).

63.1.3 During the tests mentioned in 63.1.2, a risk of fire or electric shock is considered to exist if any of the following occur:

a) Opening of branch-circuit protection;

b) Opening of grounding fuse;

c) Charring of cheesecloth;

d) Emission of flame or molten material from the transformer enclosure;

e) Development of any opening in the enclosure that exposes live parts at a potential of more than that specified in Table 63.3 to any other part or to ground;

f) Noncompliance with the repeat dielectric voltage-withstand test in 63.13.1;

g) Exceeding the applicable values in Tables 63.3 and 63.4; or

h) Rise of the temperature on the enclosure exceeding 60°C (108°F).

Exception: The temperature rise on the enclosure during the test may be greater than 60°C but not greater than 125°C (225°F), if the transformer open-circuits without the emission of flame or molten material and without other evidence of risk of fire, electric shock, or injury to persons, in less than 1 hour after the primary winding is energized.

63.1.4 If a portion of an isolated-limited-secondary or electronic circuit is connected to low-voltage field-wiring terminals, one set of samples is to be subjected to the shorted-secondary test described in 49.5 and a second set of samples is to be tested as specified in this section, but with the load applied at the equipment output terminals. The energy level at the equipment output terminals, the temperatures measured, and opening of the overcurrent protective device shall comply with the requirements for a Class 2 power source.

Table 63.3
Maximum voltage

Alternating voltage, direct voltage, and combinations thereof, where the change in instantaneous voltage for a duration equal to 5 percent of the period of the fundamental frequency of the waveform is:[a]	Row	Instantaneous voltage polarity	Fundamental frequency, (f_o) hertz		Peak volts	
			More than but	Less than	Wet contact likely to occur[b]	
					No	Yes
Column 1		2	3		4	5
For any duration, greater than:	A	does not reverse	0	3	60	30
			3	4	55	27.5
			4	5	50	25
			5	6	45	22.5
			6	7	40	20
			7	8	35	17.5
			8	9	30	15
			9	10	25	12.5
A. 20 volts where wet contact is not likely to occur, or			10	200	24.8	12.4
			200	300	26	13
			300	400	28	14
B. 10 volts for locations where wet contact is likely to occur			400	500	31	15.5
			500	600	34	17
			600	700	37	18.5
			700	800	41	20.5
			800	900	46	23
			900	1000	51	25.5
			1000	1400	56	28
			1400		60	30
	B	reverses	Values to be determined by an investigation			
For all durations, not more than:	C	does not reverse	Any		60	30
A. 20 volts where wet contact is not likely to occur, and B. 10 volts for locations where wet contact is likely to occur	D	reverses	Any		60 V peak and 84.8 V[c] peak-to-peak	30 V peak and 42.4 V[d] peak-to-peak

NOTES

1 The peak output voltage is to be measured with the input voltage applied in accordance with Table 38.1.

2 The allowable voltage is not specified for the possible nonrepetitive transient wave during initial manual turn-on or turn-off of the power source or equipment.

[a] The change in instantaneous voltage at 5 percent of the period of the fundamental frequency of the waveform is to be determined by taking any 18-degree segment along the waveform and determining the change in instantaneous voltage in that segment. See Figure 63.1

Table 63.3 Continued on Next Page

Table 63.3 Continued

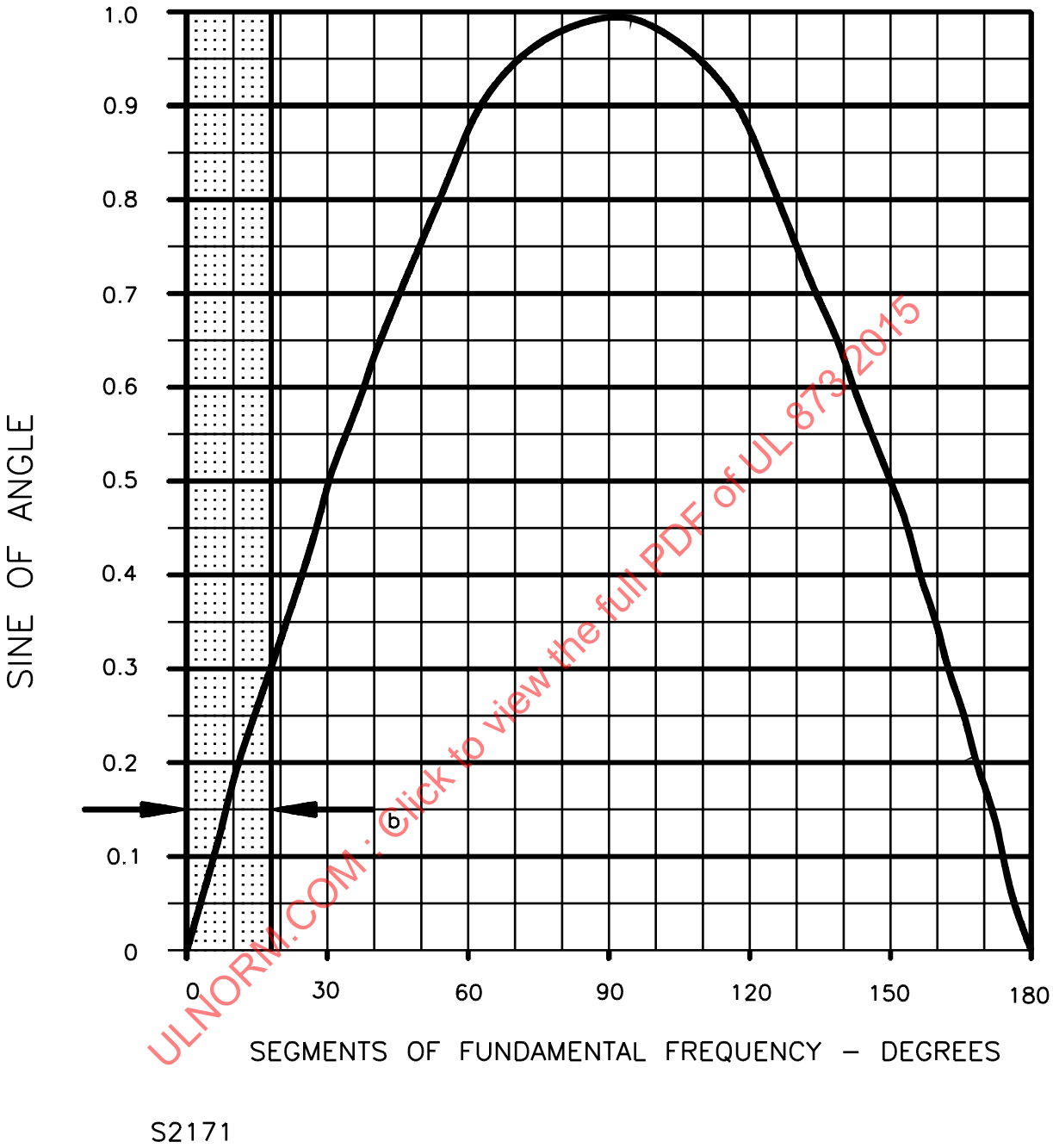
Alternating voltage, direct voltage, and combinations thereof, where the change in instantaneous voltage for a duration equal to 5 percent of the period of the fundamental frequency of the waveform is:[a]	Row	Instantaneous voltage polarity	Fundamental frequency, (f_o) hertz		Peak volts	
			More than but	Less than	Wet contact likely to occur[b]	
					No	Yes
Column 1		2	3		4	5

[b] Wet contact likely to occur applies to parts of outdoor equipment, such as automatic lawn sprinkling systems, and indoor equipment, such as controls for bathroom plumbing equipment.

[c] For a sinusoidal wave, 84.8 volts peak-to-peak equals 30 volts rms.

[d] For a sinusoidal wave, 42.4 volts peak-to-peak equals 15 volts rms.

Figure 63.1
Sine wave[a,c]



[a] Values of the sine for angles from 0° to 180°

[b] Eighteen-degree segment if started at zero.

[c] The 18-degree segment may be measured anywhere along the wave, and is to include any angle from 0° to 360°.

Table 63.4
Current and power limitations

Circuit characteristics	Inherently limited power source – overcurrent protection not required			Not inherently limited power source – overcurrent protection required		
Circuit voltage (volts)	0 – 20	Over 20 but not more than 30	Over 30 – 60 V[d]	0 – 15	Over 15 but not more than 20	Over 20 but not more than 60
Power limitation (volt-amperes)[a]	–	–	–	350	250	250
Current limitation (amperes)[b,c]	8	8	$150/V_{max}$	$1000/V_{max}$	$1000/V_{max}$	$1000/V_{max}$
Maximum overcurrent protection (amperes)	–	–	–	5	5	$100/V_{max}$
Power source nameplate ratings						
Power (watts or volts-amperes)[c]	$5 \times V_{max}$	100	100	$5 \times V_{max}$	$5 \times V_{max}$	100
Current (amperes)[c]	5	$100/V_{max}$	$100/V_{max}$	5	5	$100/V_{max}$

NOTES

1 In all cases the applied primary voltage is to be as indicated in Table 63.2.

2 Root-mean-square value for voltage and current.

[a] Maximum volt-ampere output after 1 minute of operation regardless of load, and overcurrent protection, if used, bypassed. When current-limiting impedance evaluated for the purpose is used, the current-limiting impedance shall not be bypassed.

[b] Maximum output current after 1 minute of operation under any noncapacitive load, including short circuit, and with overcurrent protection, if provided, bypassed. When current-limiting impedance evaluated for the purpose is used, maximum output current after 5 seconds of operation with current-limiting impedance not bypassed.

[c] V_{max} is the maximum output voltage (rms) with rated input voltage applied.

[d] This column pertains only to waveforms which do not reverse in polarity. See Figure 63.4.

63.2 Ambient air temperature

63.2.1 The tests described in this section are to be conducted in an ambient air temperature within the range of 21 – 30°C (70 – 86°F), except that the rated output heated test – with or without standard fuses, but without other forms of overcurrent and overtemperature protectors – may be conducted in an ambient temperature of 10 – 40°C (50 – 104°F).

63.3 Open-circuit secondary voltage

63.3.1 The open-circuit voltage between any two secondary output terminals of a power source shall not be more than the value specified in column 5 of Table 63.3 for the indicated frequency, with or without any combination of interconnected secondary terminals when the primary is energized in accordance with the voltage specified in 63.1.1.

Exception No. 1: The open-circuit voltage between multiple sets of secondary output terminals may exceed the values in column 5 for the indicated frequencies when secondary terminals are interconnected, if the following conditions are met:

a) The open-circuit voltage between any two terminals is not more than the values in column 5 for the indicated frequency when no connections are made between secondary terminals, and

b) The power source is marked in accordance with the interconnection of limitations in 74.9.

Exception No. 2: The open-circuit voltage between any two secondary output terminals with or without any combination of interconnected secondary terminals may be more than the values in column 5, but not more than the values in column 4 for the indicated frequencies if the product is marked for not wet contact use in accordance with 75.8.

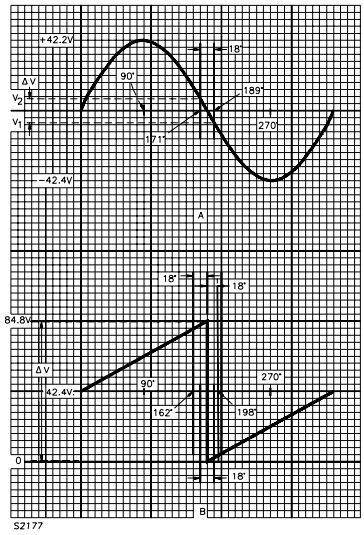
Exception No. 3: The open-circuit voltage between multiple sets of secondary output terminals may exceed the values in column 4 for the indicated frequencies when the secondary terminals are interconnected, if the following conditions are met:

a) The open-circuit voltage between any two output terminals is not more than the values in column 4 for the indicated frequency when no connections are made between secondary terminals, and

b) The power source is marked with both the interconnection limitations specified in 74.9 and the wet-contact limitations specified in 75.8.

63.3.2 With regard to Table 63.3, the change in instantaneous voltage for all durations equal to 5 percent (360 degrees $\times$ 0.05 = 18 degrees) of the period of the fundamental frequency (f_0) of the waveform is determined in the manner shown in Figure 63.2. The 18 degree time interval is to be located anywhere along the horizontal axis that the greatest voltage change takes place. For a sine wave, this occurs when the 18 degree time interval is centered about a zero-crossing point. For a saw-tooth wave, this occurs for any 18 degree interval which includes the retrace interval. For other waveforms, the interval may not include a zero-crossing point. Each 18 degree segment must be examined to locate the interval of greatest voltage change.

Figure 63.2
Eighteen-degree segments of common waveforms



NOTES:

For waveform A the maximum change in instantaneous voltage for 5 percent of the fundamental frequency period is determined as follows:

$$\Delta V = V_2 - V_1$$

$$= (42.4)\ (\sin 171) - (42.4)\ (\sin 189)$$

$$= (42.4)\ (0.156) - (42.4)\ (\textit{minus}\ 0.156)$$

$$= 6.63 + 6.63$$

$$\Delta V = 13.26\ \textit{volts}$$

For waveform B, the maximum change in instantaneous voltage for 5 percent of the fundamental frequency period is determined as follows:

$$\Delta V = V_2 - V_1$$

$$= 84.8 - 0$$

$$\Delta V = 84.4\ \textit{volts}$$

This is an unacceptable waveform because the voltage change exceeds the 60 volt limit listed in column 4 of Table 63.3, where the waveform does not reverse in polarity.

63.3.3 Whether or not the instantaneous voltage reverses in polarity is determined as shown in Figure 63.4.

63.3.4 Figure 63.5 shows examples of acceptable waveforms where the instantaneous voltage does not reverse in polarity and the change in instantaneous voltage is more than 20 volts if wet contact is not likely and more than 10 volts if wet contact is likely. The maximum acceptable voltage is a function of the fundamental frequency (f_o) of the waveforms as shown in Table 63.3. The maximum acceptable voltage for locations where wet contact is likely is half that allowed for locations where wet contact is not likely.

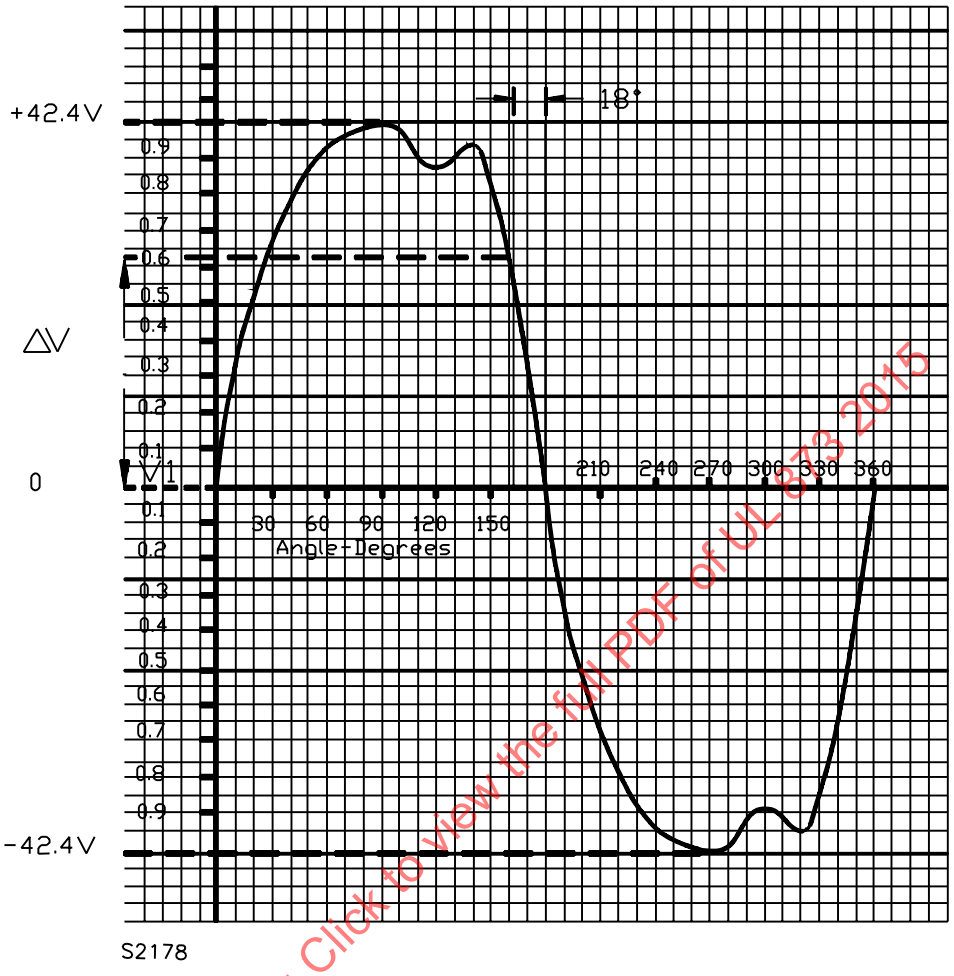
63.3.5 Figure 63.6 shows examples of acceptable waveforms where the instantaneous voltage does not reverse in polarity and the change in instantaneous voltage is not more than 20 volts if wet contact is not likely and not more than 10 volts if wet contact is likely. The maximum acceptable voltage is 60 volts peak if wet contact is not likely and 30 volts peak if wet contact is likely.

63.3.6 Figure 63.7 shows examples of acceptable waveforms where the instantaneous voltage reverses in polarity and the instantaneous voltage is not more than 20 volts if wet contact is not likely and not more than 10 volts if wet contact is likely. The maximum voltage allowed is 60 volts peak and 84.8 volts peak-to-peak if wet contact is not likely and 30 volts peak and 42.4 volts peak-to-peak if wet contact is likely.

63.4 Maximum current of inherently limited power source

63.4.1 The effective value (rms value of the periodically time-varying voltage or current) is to be used in the calculations for current and power.

Figure 63.3
Eighteen-degree segment of irregular waveform



NOTE:

For the nonsinusoidal waveform shown, the maximum change in instantaneous voltage for 5 percent of the fundamental frequency period is determined as follows:

$$\Delta V = V_1 - V_2$$

$$= 0.62 \times 42.4 - 0 \text{ (}\textit{taken graphically}\text{)}$$

$$= 26.3$$

Because the voltage change exceeds 20 and the waveform does reverse polarity, an investigation would be required to determine if the waveform is acceptable as indicated in row B of Table 63.3.

If the change in instantaneous voltage was not more than 20 volts, see row D of Table 63.3.

Figure 63.4
Polarity determination

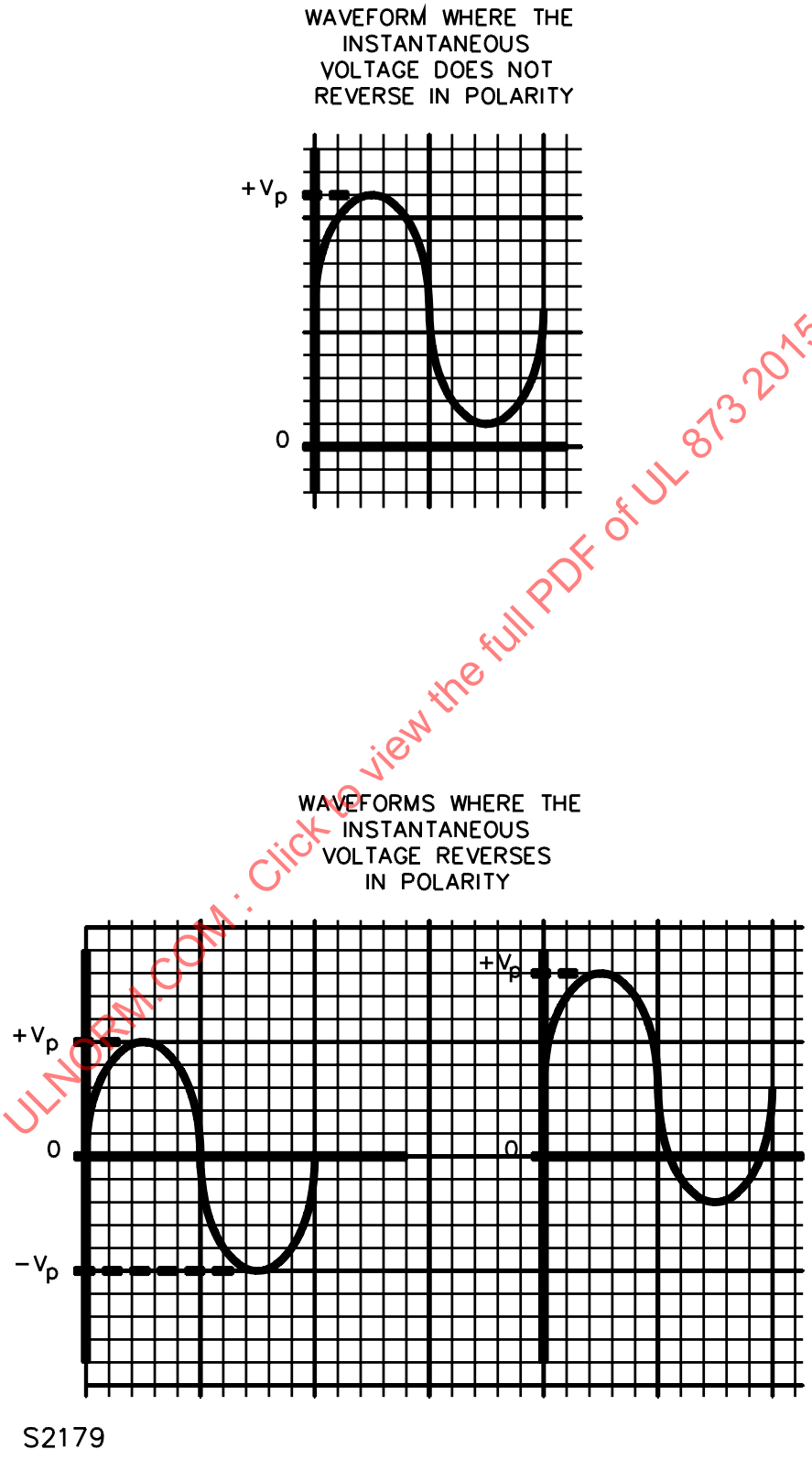
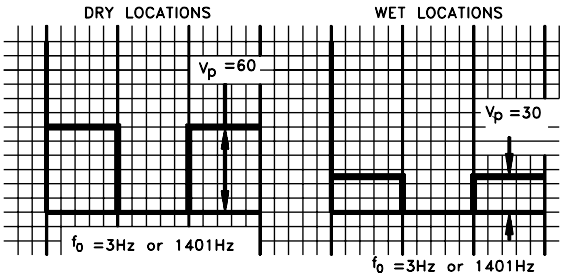


Figure 63.5
Waveforms of same polarity with large ΔV



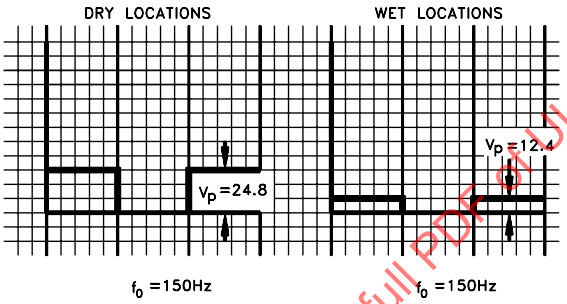


Figure 63.6
Waveforms of same polarity with small ΔV

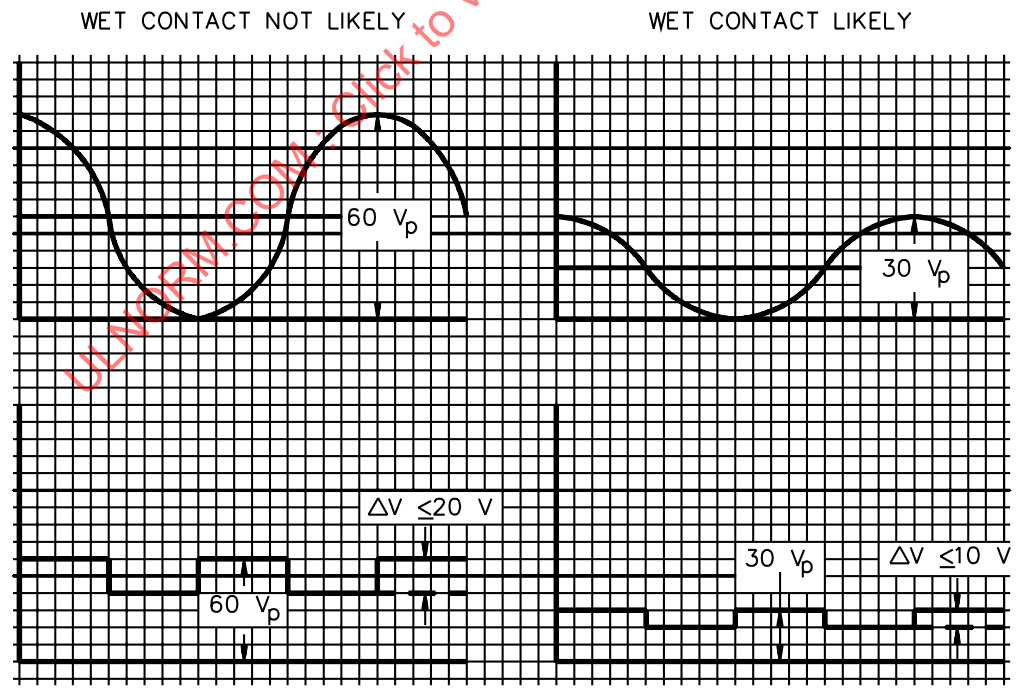
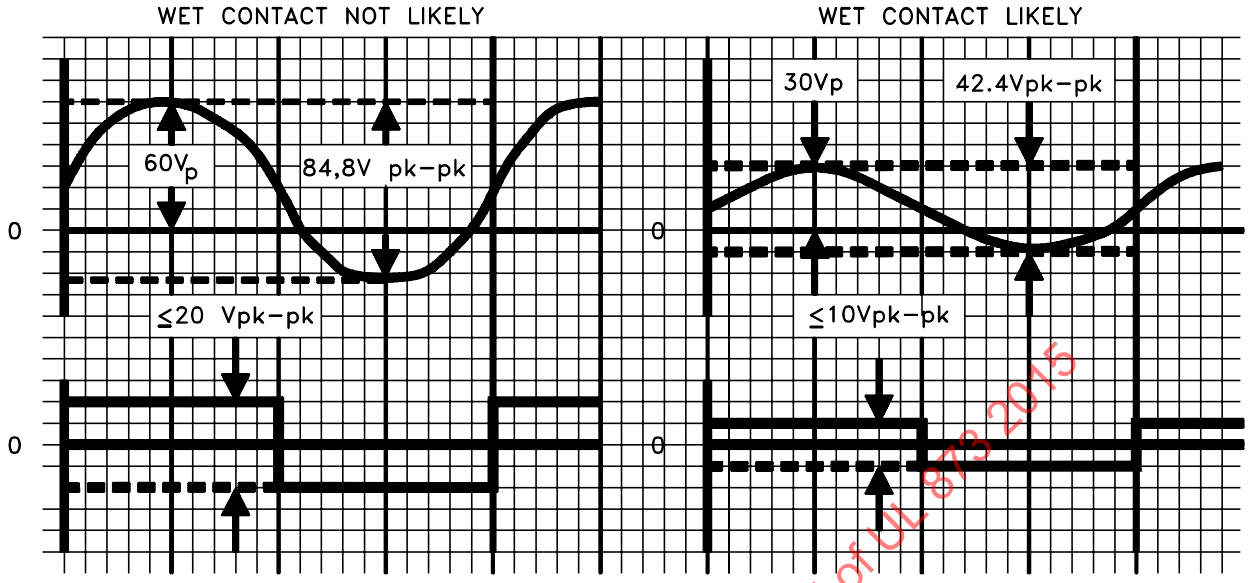
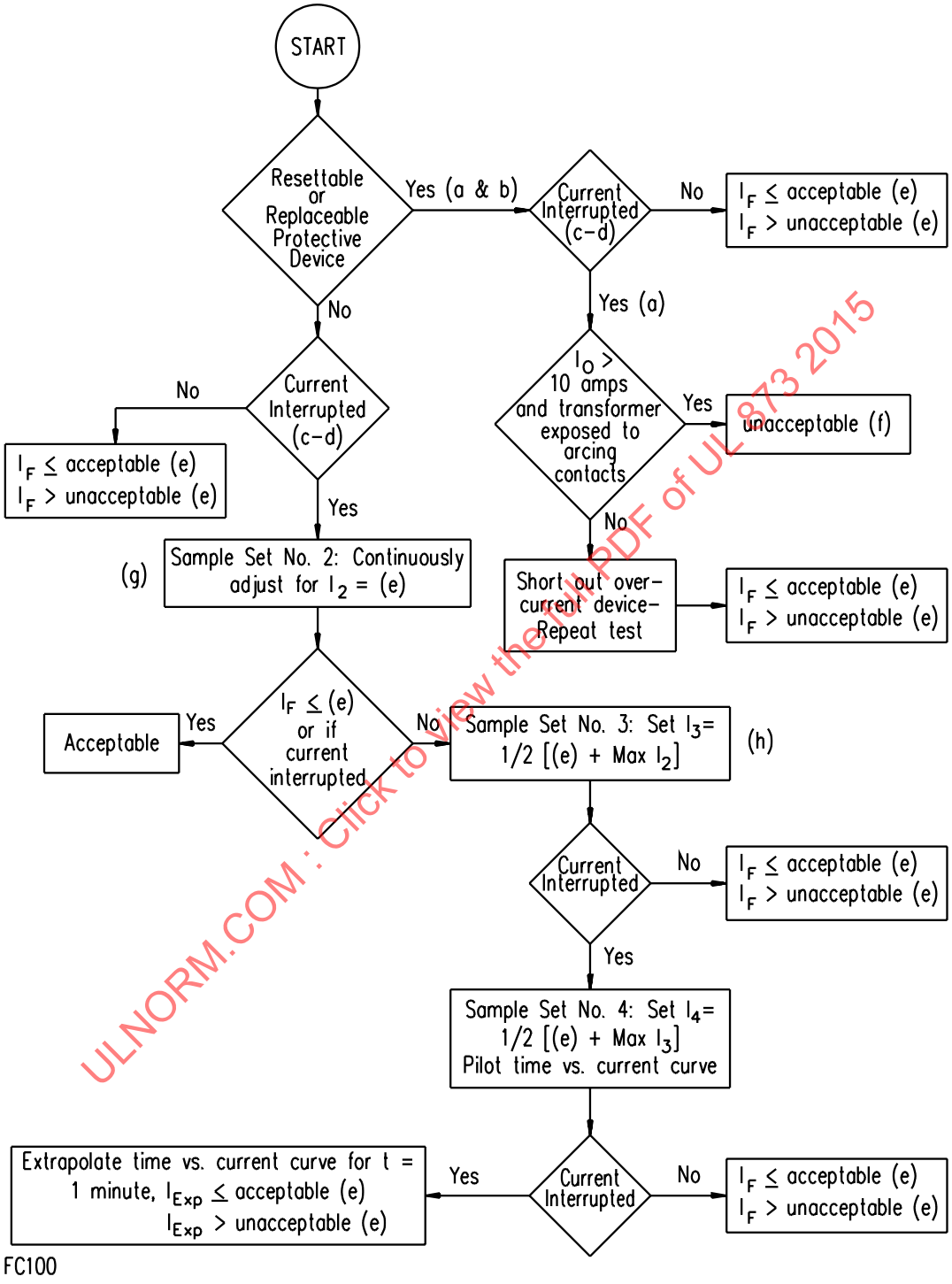


Figure 63.7
Waveforms with polarity reversal



63.4.2 The output current of a power source intended to be inherently power limited shall be tested as described in 63.4.3 – 63.4.9. See the flow chart in Figure 63.8. The results are acceptable if after 1 minute of operation the current does not exceed the values specified in Table 63.4 for inherently limited power sources.

Figure 63.8
Test flow chart



(Continued)

Figure 63.8 (Cont'd)

I_O = Current at opening
I_F = Current at 1 minute
I_2 = Current in Sample of Set No. 2
I_3 = Current in Sample of Set No. 3
I_4 = Current in Sample of Set No. 4
I_{Exp} = Extrapolated current at 1 minute
a = 63.4.6
b = 63.5.1
c = 63.4.1
d = 63.4.4
e = Table 63.4
f = 63.4.5
g = 63.4.7
h = 63.4.8

63.4.3 Unless the power source is marked in accordance with 74.9, multiple secondary windings or output terminals, if any, are to be interconnected to produce maximum current. Under the conditions described in 63.1.1 – 63.1.4 and 63.4.5, a resistance load is to be determined that produces the largest initial value of current (including short circuit). The secondary winding(s) is to be loaded with this value of resistance, and the power source is to be energized as described in 63.1.1 – 63.1.4 while at room temperature.

63.4.4 The impedance of the short circuit measuring circuit in the secondary is not to be more than 0.03 ohms. If the secondary winding of a transformer is provided with leads or a flexible cord, 1 foot (305 mm) of each lead or the cord is to be included in the short circuit.

63.4.5 If operation of a protective device exposes the power source to the effects of arcing contacts, the value of current at such operation shall not exceed 10 amperes.

63.4.6 If during this test the current is interrupted by a resettable or replaceable protective device, the test is to be repeated with the protective device shorted.

63.4.7 If the current is interrupted by a nonresettable, nonreplaceable protector or by coil burnout, other samples are to be tested by attempting to continuously adjust the resistance load to hold the current for 1 minute just above the value specified in Table 63.4.

63.4.8 If the current described in 63.4.7 exceeds the value specified in Table 63.4 after 1 minute of operation, a third sample is to be tested with the resistance load adjusted to provide an initial current midway between the maximum initial obtainable value and the value specified in Table 63.4. The value of resistance is not to be further adjusted during the test. The results are not acceptable if after 1 minute of such operation the output current exceeds the applicable values in Table 63.4.

63.4.9 If the current in the test described in 63.4.8 again results in the current being interrupted, another sample is to be tested as described in 63.4.8 with the initial current adjusted to midway between the initial current recorded during the test in 63.4.8 and the value specified in Table 63.4. During this test, a recording of current versus time is to be obtained. If the current is again interrupted before 1 minute of operation, the recorded curve of current versus time is to be extrapolated to 1 minute by a smooth curve that is judged to best match the measured data. The results are acceptable if the extrapolated value of current, after 1 minute, does not exceed the applicable values in Table 63.4.

63.5 Maximum current of not inherently limited power source

63.5.1 If the power source is not an inherently limited power source, it shall be tested as described in 63.4.2 – 63.4.9. The results are not acceptable if the maximum current exceeds the applicable values in Table 63.4 for not inherently limited power sources.

63.6 Maximum power of not inherently limited power source

63.6.1 The maximum obtainable power output shall not exceed the applicable value in Table 63.4.

63.6.2 Protective devices are to be shorted out during this test. Unless marked in accordance with 74.9, multiple secondary windings, if any, are to be interconnected to produce maximum power output. The maximum output power is to be determined by simultaneous voltage and current measurements with the variable resistance connected to the output terminations. Starting with the device at room temperature, the measurements are to be made within 2-1/2 minutes.

63.7 Calibration of overcurrent-protective devices

63.7.1 A one-time or manually-resettable overcurrent-protective device, provided as part of a not inherently limited Class 2 power source, shall operate to open the circuit in not more than the time indicated in Table 63.5 when the power source is delivering the specified secondary current. The protective device may be located in either the primary or secondary circuit. The results are acceptable if there is no emission of flame or molten metal from the power source enclosure and no other evidence of a risk of fire or electric shock as described in 63.1.2 and 63.1.3.

Table 63.5
Maximum acceptable time to open

Rated secondary potential, volts	Secondary test current, amperes	Maximum time for overcurrent protective device to open, minutes
20 or less	10	2
20 or less	6.75	60
21 and over	$200/V_{max}$	2
21 and over	$135/V_{max}$	60

63.7.2 To determine if an overcurrent-protective device complies with the requirement in 63.7.1, the power source is to be allowed to deliver the test current to a resistive load, with the primary connected to a circuit as described in 63.1.1 – 63.1.4 and 63.2.1.

63.7.3 If there is more than one secondary or if the secondary winding has accessible taps, sufficient tests shall be conducted to determine that for any winding or partial winding, the protective device will open within the applicable time specified in Table 63.5.

63.8 Rated secondary output

63.8.1 A power source marked with a secondary current rating shall be capable of delivering its rated full load secondary current continuously. If not marked with a secondary current rating, a power source shall be capable of delivering its marked secondary volt-ampere rating continuously.

63.8.2 To determine whether a power source complies with the requirement in 63.8.1, a power source is to be tested with a variable resistor and an ammeter connected to the secondary or output terminals, and the primary connected to a circuit in accordance with 63.1.1 – 63.1.4 and 63.2.1. The resistor is to be adjusted until the rated full-load secondary current or power is drawn. The power source is to be mounted so that the primary terminals or leads are on top. After 15 minutes of operation, the load is to be readjusted, if necessary, to return the current or power to the full load value. The circuit is to be energized for 1 hour without further adjustment. The results are acceptable if, at the end of the 1 hour period, the output current or power is not less than 90 percent of the rated value, and the overtemperature or overcurrent protective device does not open.

63.8.3 With reference to 63.8.2, if a power source has two secondary windings, both windings are to be operated simultaneously, with each secondary winding independently loaded.

63.9 Rated output heating

63.9.1 The test described in 63.8.1 – 63.8.3 is to be continued without further adjustment until temperatures become constant. The temperature rise shall not exceed the applicable values specified in Table 40.1.

63.10 Dielectric voltage withstand

63.10.1 A power source shall be subjected for 1 minute to the application of a 60 hertz essentially sinusoidal potential with the unit at the maximum operating temperature reached in the rated output heating test described in 63.9.1. The results are acceptable if there is no dielectric breakdown. The applied potential is to be:

a) As described in Dielectric voltage-Withstand Test, Section 47;

b) For a Class 2 power source, 2500 volts between the primary and secondary circuits;

c) One thousand volts plus two times the sum of the secondary voltages between the secondary windings unless considered as a single winding as described in the Exception No. 1 to 36.4.2; and

d) Five hundred volts between a secondary circuit and accessible dead metal parts.

63.11 Component breakdown

63.11.1 Components in the equipment shall be subjected to the test described in 63.11.2 and 63.11.3. There shall be no emission of flame or molten metal or a risk of fire or electric shock as described in 63.1.2 and 63.1.3 while operating as in the rated output heating test.

63.11.2 The components in the equipment, such as diodes, resistors, transistors, capacitors, and the like, are to be shorted or opened, one at a time. The equipment is to be energized and operated continuously as described in 63.1.1 – 63.1.4 and 63.2.1 until ultimate conditions are observed, including opening of a thermal cutoff or a similar device, for 7 hours if temperatures stabilize or cycling of an automatically reset protector occurs, or for 50 cycles of resetting a manually reset protector. During this test the grounding means, if provided, is to be connected directly to ground.

63.11.3 The test shall be followed by a dielectric voltage-withstand test, as required by 63.13.1.

Exception: The dielectric voltage-withstand test need not be conducted on a component that has been evaluated in accordance with 36.5.1.

63.12 Overload heating

63.12.1 A transformer shall be subjected to the overload heating tests described in 63.12.3 – 63.12.7, under the conditions specified in 63.1.1 – 63.1.4 and 63.2.1. A protective device that is relied upon to open the circuit as a result of the test is to be one that has been investigated and found to be acceptable for this purpose. If the same insulating system is used in a group of transformer models, only those models having the maximum volt-ampere rating, the minimum volt-ampere rating, and an intermediate volt-ampere rating need be tested.

63.12.2 The results are acceptable if:

a) The temperature rise of the coils by the resistance method at the end of 7 hours is not more than 105°C for coils having Class 105 insulation or 135°C for coils having Class 130 insulation,

Exception: The temperature rise may exceed these values if the test is continued on three samples for 15 days. If the test is interrupted by a protector or a burnout, additional samples are to be tested with the other conditions described in Table 63.6 and 63.12.3 – 63.12.7.

b) There is no emission of flame or molten metal from the transformer enclosure, and

c) There is no other evidence of risk of fire or electric shock as described in 63.1.2 and 63.1.3 (a) – (g) and, with the output terminals shorted, 63.1.3(h).

Table 63.6
Test loading conditions

Condition	Secondary winding load
A	Load used for final sample in tests described in 63.4.2 – 63.5.1
B	Rectifier to cause half wave rectified short circuit
C[a]	I_R +0.75 (I_A − I_R)
D[a]	50
E[a]	25
F[a]	20
G[a]	15
H[a]	10
I[a]	5

Note:

I_A = Current at end of 1 minute obtained on final sample of the output current test.

I_R = Rated current.

[a]For conditions (C-1), rated current (18R) plus indicated percent of difference between A (I A) and rated current.

63.12.3 One sample of a transformer is to be operated for 7 hours under each condition described in items A – I as shown in Table 63.6.

63.12.4 For the sequence of tests described in items A – I of Table 63.6, if a test for a particular condition continues for 7 hours without a coil or a protective device opening, the remaining tests need not be conducted. If a coil or protective device opens during a particular 7-hour test, the test is to be discontinued and the next test in sequence is to be conducted, until a test condition continues for 7 hours. All samples used for the tests are to be subjected to the evaluation criteria described in 63.12.2 while in the heated condition.

63.12.5 For the purpose of these requirements, each secondary winding tap other than a center tap, and each primary winding tap intended to supply power to a load, is considered to be the equivalent of a secondary winding.

63.12.6 If a power source is equipped with more than one set of output terminals or secondary windings, each of the secondary windings or sets of terminals is to be loaded for each condition specified in Table 63.6 with the other windings or set of terminals loaded to rated current. The secondary windings or output terminals are to be loaded to rated current before the abnormal condition is introduced; and the loads other than the one connected to the circuit to be overloaded, are not to be readjusted thereafter.

63.12.7 For the loading conditions, a variable resistor is to be connected across the secondary winding. The tests described in items A – H of Table 63.6 are to be continued for 7 hours unless a winding of the power source or a protective device opens in a shorter time. In conducting the tests described in items C – H of Table 63.6, the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 minute after application of voltage to the primary winding.

63.13 Repeat dielectric voltage withstand

63.13.1 Following the overload-heating test, a power source shall comply with the requirements of the dielectric voltage-withstand test described in 63.1.2.

Exception: The voltage between primary and secondary need not exceed 1000 volts plus twice the primary test voltages specified in Table 63.2.

63.14 Overload of overcurrent- or overtemperature-protective devices

63.14.1 A protective device for a not inherently limited power source, other than a fuse, thermal cutoff, or a device as covered in 63.15.1 and 63.15.2, provided as a part of a power source, shall make and break the circuit for a total of 50 cycles of operation with the power source connected and loaded in accordance with 63.4.2, 63.4.3, and 63.5.1. The results are acceptable if there is no emission of flame or molten material from the power source enclosure, or other evidence of a risk of fire or electric shock as described in 63.1.2 and 63.1.3, and the overcurrent protective device is operable at the end of the test.

63.14.2 In the test of a manual-reset device, the device is to be reset as soon as possible after opening; however, if the device will not reset within 1 hour after opening in any cycle, the test is to be stopped and the device considered inoperable.

63.15 Endurance of automatic-reset overtemperature-protective devices

63.15.1 An automatic-reset overtemperature-protective device on an inherently limited power source shall be subjected to an endurance test by connecting it to a source as specified in 63.1.1 – 63.1.4 and 63.2.1 with the secondary loaded as described in 63.4.2 – 63.6.1 to produce the maximum possible current through the automatic reset device. The power source is then to be allowed to operate for 15 days. The results are acceptable if:

a) There is no emission of flame or molten material from the power source enclosure,

b) There is no other evidence of a risk of fire or electric shock as described in 63.1.2 and 63.1.3, and

c) The protective device remains operable.

Exception: If maximum possible current results in interruption of an overcurrent-protective device, the power source is to be tested starting with a load that causes a current of 110 percent of the overcurrent device rating. The load current is to be increased or decreased, as necessary, in increments of 2 percent until a current is reached at which the overcurrent device does not open.

63.15.2 A supplementary automatic-reset protector used in addition to the protector specified in 36.6.2 for a not inherently limited power source shall also comply with the requirement in 63.15.1.