UL 353

Underwriters Laboratories Inc.

Standard for Safety

Limit Controls

UL Standard for Safety for Limit Controls, UL 353

Fifth Edition, Dated September 23, 1994

Summary of Topics

These revisions to UL 353 are being issued to revise the requirements covering surge protective devices in Section 3A.

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/revised requirements are substantially in accordance with Proposal(s) on this subject dated August 26, 2011.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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UL 353

Standard for Limit Controls

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Second Edition – August, 1971
Third Edition – December, 1974
Fourth Edition – March, 1989

Fifth Edition

September 23, 1994

This UL Standard for Safety consists of the Fifth Edition including revisions through November 8, 2011.

The Department of Defense (DoD) has adopted UL 353 on January 27, 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 limit controls, furnace fan controls, and other interlocks which are essentially switches responding to changes in liquid level, pressure, or temperature. Although not limited to such specific applications, these safety controls include those intended primarily to safeguard heating appliances, heating systems, processing systems, and air-conditioning and ventilating systems.

1.2 These requirements do not cover thermal protectors for motors and fluorescent-lamp ballasts.

1.3 These controls are for use in ordinary locations. Requirements for the installation and use of limit controls are included in Standards of the National Fire Protection Association, such as those for Installation of:

Air-Conditioning and Ventilating Systems, NFPA 90A-1993,

Warm-Air Heating and Air-Conditioning Systems, NFPA 90B-1993,

Oil-Burning Equipment, NFPA 31, ANSI Z95.1-1993,

National Fuel Gas Code, NFPA 54-1990,

Ovens and Furnaces, NFPA 86-1990, and

Prevention of Furnace Explosions in Fuel Oil and Natural Gas-Fired Watertube Boiler Furnaces With One Burner, NFPA 85C-1991.

1.4 These requirements cover equipment rated not more than 600 volts and intended for installation in accordance with the requirements of the National Electrical Code, ANSI/NFPA 70.

1.5 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.

1.5 revised April 30, 2001

2 General

2.1 Units of measurement

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

2.1.1 revised April 30, 2001

2.2 Components

2.2 deleted April 22, 2011

2.2.1 *deleted April 22, 2011.*

2.2.2 *deleted April 22, 2011.*

2.2.3 *deleted April 22, 2011.*

2.2.4 *deleted April 22, 2011.*

3 Glossary

3.1 For the purpose of this standard, the following definitions apply.

3.1A COMPONENT – A device or fabricated part of the control covered by the scope of a safety standard dedicated to the purpose. When incorporated in a control, equipment otherwise typically field installed (e.g. luminaire) is considered to be a component. Unless otherwise specified, materials that compose a device or fabricated part, such as thermoplastic or copper, are not considered components.

3.1A added April 22, 2011

3.2 CONTROL, FAN – An automatic control responsive to changes in temperature, intended to control the operation of the fan on forced air appliances.

3.3 CONTROL, LIMIT – An automatic safety control responsive to changes in liquid level, pressure, or temperature and normally set beyond the operating range for limiting the operation of the controlled equipment.

3.4 CONTROL, OPERATING – A control, other than a safety control or interlock to start or regulate appliances according to load demand and to stop or regulate output on satisfaction of demand or upon reaching normal temperature or pressure in the appliances. Operating controls may also actuate auxiliary equipment.

3.5 CONTROL, SAFETY or PROTECTIVE – Automatic controls and interlocks (including relays, switches and other auxiliary equipment used in conjunction therewith to form a safety-control system) which are intended to prevent unsafe operation of the controlled equipment.

3.5 revised April 22, 2011

3.5A CONTROL, WATER HEATER REGULATING – An automatic control responsive to changes in temperature, intended to regulate the operation of the water heater and provides protective function.

3.5A added April 22, 2011

3.5B CONTROL, WATER HEATER LIMIT – A manual type control responsive to changes in temperature, intended to provide protective function of the water heater.

3.5B added April 22, 2011

3.6 ELECTRICAL CIRCUITS:

a) High-Voltage Circuit – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage or an isolated limited secondary circuit.

b) Low-Voltage Circuit – A circuit involving a potential of not more than 30 volts alternating current (ac) [42.4 volts peak or direct current (dc)] and supplied by a primary battery or by a standard Class 2 transformer, or by a combination of transformer and fixed impedance which, as a unit, complies with all the performance requirements for a Class 2 transformer. (A circuit derived from a source of supply classified as a high-voltage circuit, using resistance in series with the supply circuit as a means of limiting the voltage and current, is not considered to be a low-voltage nor an isolated limited secondary circuit.)

c) Safety-Control Circuit – A circuit involving one or more safety controls.

d) Isolated Limited Secondary Circuit – A circuit of limited energy derived from an isolated secondary winding of a transformer having a maximum capacity of 100 volt-amperes and open-circuit secondary voltage not exceeding 1000 volts.

e) Intrinsically Safe Circuit – A circuit involving equipment and wiring which is incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture. Abnormal conditions include accidental damage to any part of the equipment or wiring, insulation or other failure of electrical components, application of overvoltage, adjustment and maintenance operations, and other similar conditions.

3.7 INTERLOCK – A control to prove the physical state of a required condition, and to furnish that proof to the primary safety-control circuit. A limit control is a type of interlock.

3.8 REPEATABILITY – The ability of a control or interlock to maintain a constant set point characteristic.

3.9 SET POINT – A predetermined value to which a control or interlock is adjusted and at which it performs its intended function.

3.10 SUPERVISE – To sense a condition requiring attention and initiate corrective action if necessary.

3.11 TOOLS, SPECIAL – Those tools that are not generally available on the open retail market.

3.12 VENT LIMITING MEANS – A means which limits the flow of fluid from an atmospheric diaphragm chamber to the atmosphere.

CONSTRUCTION

3A Components

3A added April 22, 2011

3A.1 General

3A.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 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 end product 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.

3A.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.

3A.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 risk of electric shock, fire, or personal injury, shall be additionally evaluated in accordance with the applicable standard, and shall comply with items (b) – (d) of 3A.1.1.

3A.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 353.

3A.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.

3A.2 Attachment plugs, receptacles, connectors, and terminals

3A.2.1 Attachment plugs and receptacles shall comply with the Standard for Attachment Plugs and Receptacles, UL 498. See 3A.2.9.

3A.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.

3A.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. See 3A.2.9.

3A.2.4 Wire connectors shall comply with the Standard for Wire Connectors, UL 486A-486B.

3A.2.5 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

3A.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 Multi-Pole Splicing Wire Connectors, UL 2459. See 3A.2.9.

3A.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.

3A.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 Insulating Material, Section 8; Field Wiring Connections, Section 10; Current-Carrying Parts, Section 10; and Spacings, Section 18 of this standard. This exception does not apply to protective conductor terminal blocks.

3A.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, a connector that can be used to interrupt the current of a motor load shall have a suitable horsepower rating when tested with its mating plug.

3A.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.

3A.3 Batteries and battery chargers

3A.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.

3A.3.2 Rechargeable nickel cadmium (Ni-Cad) cells and battery packs shall comply with the applicable construction and performance requirements of this standard.

3A.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.

3A.4 Electrical boxes and raceways

3A.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.

3A.5 Capacitors and filters

3A.5 revised November 8, 2011

3A.5.1 A capacitor located in the line voltage circuit shall comply with the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414.

3A.5.2 Electromagnetic interference filters with integral enclosures shall comply with the Standard for Electromagnetic Interference Filters, UL 1283.

3A.5.3 *deleted November 8, 2011.*

3A.5A Surge Protective Devices

3A.5A added November 8, 2011

3A.5A.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 3A.5A.2 through 3A.5A.6 are applicable.

Exception: These requirements do not apply to SPDs located in a Class 2 circuit.

3A.5A.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 3A.1.

Table 3A.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

3A.5A.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 SPDs and Type 4 Component Assemblies have been subjected to all the Current Tests in accordance with UL 1449, section 39 during its investigation, the MCOV may have a rating equal to or greater than the working voltage of the circuit connected.

3A.5A.4 Type 4 or Type 5 discrete component SPDs and Type 4 Component Assemblies shall be rated in accordance with (a) or (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 3A.1, or

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

Exception: For SPDs used in other than across-the-line applications such as across the contacts of a switching relay or 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 Operating Duty Cycle Peak Current (A_p) rating of the SPD may be less than that defined in Table 3A.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 (In) in accordance with Table 3A.2, based on the working voltage of the circuit connected.

Exception: For SPDs used in other than across-the-line applications such as across the contacts of a switching relay or 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 Nominal Discharge Current rating, I_n, of the SPD may be less than that defined Table 3A.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 3A.2
Required Ratings of Type 4 or 5 SPDs

SPD Circuit Characteristic				Required ratings of Type 4 or 5 SPDs	
Phase-to-Ground Voltage, Vac[a] by Overvoltage Category [b]				Minimum Operating Duty Cycle Peak voltage (kV_p)(1.2 x 50 µs)	Operating Duty Cycle Peak Current or Minimum Nominal Discharge Current, NDC (In) 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. Users of this standard will need to establish that rated impulse voltage values are appropriate for the expected applications of the products covered.

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.

3A.5A.5 Electronic safety controls shall, in addition to the requirements noted in 3A.5A.2 and 3A.5A.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 program when tested with the SPD removed, the SPD need only comply with 3A.5A.2 and 3A.5A.3

3A.5A.6 SPDs are not permitted to be used between line / mains / non-Class 2 circuits and Class 2 circuits.

3A.5A.7 Discrete SPDs (such as MOVs, gas tubes, etc., with or without coating) shall be considered non-insulated live conductive parts. Spacings between discrete SPDs and metal parts shall comply with the spacing requirements of this standard.

3A.6 Gaskets and seals

3A.6.1 Gaskets and seals shall comply with the Standard for Gaskets and Seals, UL 157. Also, the requirements of Section 41, Volume Change test, and Section 42, Weight loss test, are applicable, as appropriate.

3A.7 Insulation systems

3A.7.1 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.

3A.7.2 All insulation systems employing integral ground insulation shall comply with the requirements specified in the Standard for Systems of Insulating Materials – General, UL 1446.

3A.8 Overcurrent protection

3A.8.1 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.

3A.8.2 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.

3A.8.3 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.

3A.8.4 Supplementary protectors shall comply with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077.

3A.8.5 Fusing resistors shall comply with the Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television-Type Appliances, UL 1412.

3A.9 Marking and labeling systems

3A.9.1 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 47 of this standard is considered to fulfill the requirement.

3A.10 Power supplies

3A.10.1 A Class 2 power supply shall comply with one of the following:

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

b) The Standard for Information Technology Equipment, 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”.

3A.10.2 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, Part 1: General Requirements, UL 60950-1.

3A.11 Printed wiring boards

3A.11.1 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 the 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.

3A.12 Semiconductors

3A.12.1 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 32 of this standard.

3A.12.2 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 32 of this standard.

3A.13 Supplemental insulation, insulating bushings, and assembly aids

3A.13.1 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.

3A.13.2 Wire positioning devices shall comply with sections 8 and 20. A device that complies with the Standard for Positioning Devices, UL 1565, is considered to comply with this requirement.

3A.13.3 Insulating bushings that comply with 3A.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.

3A.14 Valves (electrically operated) and solenoids

3A.14.1 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.

3A.14.2 Solenoids shall comply with the applicable construction and performance requirements of this standard.

4 General

4.1 A component of a control shall be used in accordance with 3A.1.

4.1 revised April 22, 2011

4.2 A safety control incorporating a transformer, relay, or the like, shall be supplied by a circuit consisting of a two-wire, one-side grounded system having a voltage rating of not more than a nominal 120 volts. A switch or protective device shall be in the circuit electrically connected to the ungrounded supply conductor.

4.3 A control shall withstand without damage or shift of calibration in excess of limits specified in 29.1.5 – 29.1.9, the effects of overriding temperature or pressure on the sensing element when tested in accordance with these requirements.

4.4 Switch contacts, a resistance heating element, or an item that may arc or glow in a control for supervising a flammable gas shall not be located in a compartment containing the gas, including a compartment that may contain gas in case of the rupture of a bellows or diaphragm.

Exception No. 1: Electrical parts including switch contacts and resistance elements may be located in a gas-containing compartment of a control intended for use only in an intrinsically safe circuit.

Exception No. 2: A coil may be located in a gas-containing compartment of a control rated at not more than 125 volt ac provided the coil assembly (coil and leads) is encapsulated, and is arranged and located so that only one side of the encapsulated coil assembly is exposed to the gas.

4.5 A temperature operated limit control actuated by a change in the pressure of a fluid confined in a self-contained bulb or capillary tube shall be designed in conformance with 4.6 and 4.9 or 4.7 – 4.9.

4.6 The upward shift of operating temperature upon loss of any of the fluid-charge shall not exceed 5 percent of the initial operating temperature based on degrees Fahrenheit.

4.7 As an alternate to 4.6, if the design is such that the contacts of the control will not assume an open position upon loss of the fluid-charge and/or loss of a small amount of the charge may cause an upward shift of operating temperature, the control shall confirm with 4.8 and the fluid-charge containing parts of each control shall be subjected to the following production test by the manufacturer.

a) Prior to filling the system with the charge, the complete system consisting of the bulb, capillary tube, and the diaphragm or bellows shall be checked for leakage with air or gas. There shall be no evidence of leakage at a pressure 50 percent greater than that developed within the system when the control sensing element is subjected to a temperature of 110 percent of the rated nominal operating temperature of the control, and

b) After determining the operating temperature of the completely assembled control, the sensing element shall be subjected to its maximum rated operating temperature for a period of 24 hours. Following this exposure test, the control is to be cooled to 77°F (25°C). The operating temperature of the control is to be determined. There shall be no deviation from the original operating temperature;

c) With reference to (a) and (b) above, other tests may be considered and accepted if found to achieve the results contemplated.

4.8 The temperature sensing element shall be located or constructed so that it is not likely to be damaged during installation or use. The bulb and capillary tube of a remote sensing element shall conform to 37.4. A separate shroud or sleeve may be employed for protection of the bulb and capillary tubing to achieve conformance with 37.4.

4.9 The contacts of the control shall remain closed at an ambient temperature of 0°F (minus 17.8°C).

4.10 The maximum temperature set point of a control shall not exceed the safe limits of temperature of bimetals or other materials employed in the zone of the media to be controlled.

4.11 A pressure control, in which a flexible diaphragm, bellows or similar construction constitutes the only flammable-fluid seal, shall have the atmospheric side of the diaphragm or bellows enclosed in a casing constructed to limit external leakage in the event of diaphragm or bellows rupture, or shall have provisions for connection of a vent pipe or tubing intended to use routed to the outdoors or other location acceptable for venting. See 5.5, 5.6, and 36.5.

4.12 A control that is intended to supervise the pressure of fuel oil Nos. 1 – 6 is not required to comply with 4.11 provided three samples of the control, when subjected to a 100,000-cycle endurance test, comply with 31.1 without leakage during the test and when subjected to a hydrostatic test of four times the rated pressure following the Endurance Test, Section 31, the control complies with 5.5 or 5.6.

4.13 The requirement of 4.11 and 4.12 do not apply to a pressure-operated control part subjected to pressure in a self-contained system, such as a bulb or capillary tube arrangement.

4.14 Metal parts coming in contact with a diaphragm shall have no sharp edges, burrs, projections, etc., which might chafe or abrade the diaphragm.

4.15 An operation spring shall be retained and arranged to prevent abrasion, binding, buckling, or interference with its free movement.

4.16 A liquid level limit control may include snubbers, time delay, or other means to delay control action for the purpose of preventing unnecessary shut-downs due to fluctuating liquid level. Such means shall conform with all requirements for materials, secureness, spacings, etc., specified herein and shall be so constructed that its failure will not negate the function of the control. Under normal service conditions the time delay shall not exceed 90 seconds. See 29.1.11.

4A Safety Related Software

4A.1 Fan, regulating, water heater temperature-regulating, and limit controls that employ microprocessors that include safety-related software shall be evaluated using the Standard for Software in Programmable Components, UL 1998, as modified in Supplement SA of this Standard, Software in Programmable Components.

Exception: Unless otherwise declared by the manufacturer or determined by specific end-product application, water feed controls are generally considered as operating (non-safety) controls and a software evaluation per clause 4A.2 is not required.

Revised 4A.1 effective June 30, 2011

4A.2 When applying the requirements in the Standard for Software in Programmable Components, UL 1998, the software Class for boiler liquid level controls, pressure limit controls, and temperature limit controls shall be defined as Class 2. The software Class for fan controls and for regulating controls shall be defined as Class 1.

4B Electronic Controls

4B.1 Fan, regulating, water heater temperature-regulating, and limit controls shall be designed so that failure of an electronic component results in either continued operation with all safety functions operating properly or detection of the fault and safe shutdown of the control. The faults to be evaluated are specified in 31A.3.

Exception: Unless otherwise declared by the manufacturer or determined by specific end-product application, water feed controls are generally considered as operating (non-safety) controls. As such, the relevant safety requirements of this standard apply with respect to electric shock and fire hazards.

Revised 4B.1 effective June 30, 2011

4B.2 For controls that incorporate electronic circuits, compliance is to be determined by Section 31A, Failure Mode Effect Analysis (FMEA) Procedures, 31B, Mains Borne Perturbations, Magnetic and Electromagnetic Disturbances, and 31C, Thermal Cycling Test for Electronic Devices.

5 Materials

5.1 A fluid-confining part (for example, a pressure switch for gas or oil) or an operating part, if deterioration or breakage of the part will allow leakage of a fluid that may result in a risk of injury to persons or prevents the control from functioning, shall be made of material having a melting point (solidus temperature) of not less than 950°F (510°C) and a tensile strength of not less than 10,000 psi (68.9 MPa) at 400°F (204°C). Such a part shall not sag, distort, melt, oxidize, or leak fuel during any of the tests specified in this standard.

Exception: The requirements regarding melting point and tensile strength do not apply to a seal ring, diaphragm, or gasket that is resistant to the action of fluid with which it may be in contact.

5.2 A part, including a sheath, capillary tube, bulb, well, bellows, or diaphragm, shall be resistant to atmospheric corrosion and attack by the liquid or gas it may contact in service if failure of the part will permit external leakage of a combustible fluid or cause the control to malfunction.

5.3 A brass alloy containing less than 81 percent copper and more than 9 percent zinc is not considered resistant to the corrosive effects of fuel oils.

5.4 A part made of brass containing more than 15 percent zinc shall withstand the 10-Day Moist Ammonia Air Stress Cracking Test, Section 39, if failure of the part in operation of the controlled equipment may result in a risk of fire, explosion, or injury to persons.

5.5 If a control with a bellows, Bourdon tube, diaphragm, or similar element is made of Type 316 or 321 stainless steel, or material of equivalent resistance to corrosion, it shall be constructed so that leakage from a ruptured element will be into the control enclosure, the leakage shall be released to the exterior of the control before entering any opening provided for conduit connection.

5.6 If a control with a bellows, Bourdon tube, diaphragm, or similar element is made of Type 301 stainless steel, or material of equivalent resistance to corrosion, it shall be constructed so that leakage from a ruptured element will be to the exterior of the control enclosure only.

6 Frame and Enclosure

6.1 General

6.1.1 The mechanism of a control shall be protected by an enclosure to avoid damage to or interference with operating parts.

6.1.1 effective November 3, 1995

6.1.2 An electron tube shall be enclosed or protected against damage. Such tubes, as well as means provided for manual manipulation, shall be so located with respect to uninsulated live parts that there will be no liability of a person coming in contact with such live parts during the normal changing of the tube or during manual manipulation of parts intended for such purpose.

6.1.3 A piece such as a dial or nameplate which is in effect a part of the enclosure, shall be of a metal or other material as specified for the enclosure.

6.1.4 A nonmetallic part such as a reset knob, lever, or button protruding through a hole in the enclosure shall be made of self-extinguishing material if the hole is not larger than the area of a 7/8 inch (22.2 mm) diameter circle. Nonmetallic parts protruding through a hole larger than the area of a 7/8 inch (22.2 mm) diameter circle shall be made of materials conforming to 6.1.10.

6.1.5 Openings for connection to piping (including vent lines) shall be threaded in accordance with the Standard for General Purpose (Inch) Pipe Threads, ANSI/ASME B1.20.1-1983(R1992).

6.1.6 Cast metal for an enclosure shall be at least 1/8 inch (3.2 mm) in thickness at every point, of greater thickness at reinforcing ribs and door edges, and not less than 1/4 inch (6.4 mm) in thickness at tapped holes for conduit; except that, other than at plain or threaded conduit holes die-cast metal shall be not less than 3/32 inch (2.4 mm) in thickness for an area greater than 24 square inches (155 cm^2) or having any dimension greater than 6 inches (152.4 mm), and shall be not less than 1/16 inch (1.6 mm) in thickness for an area of 24 square inches (155 cm^2) or less and having no dimensions greater than 6 inches (152.4 mm). The area limitations for metal 1/16 inch (1.6 mm) in thickness may be obtained by the provision of reinforcing ribs subdividing a larger area. Die-cast metal of 0.035 inch (0.89 mm) minimum thickness may be employed in lieu of 1/16 inch (1.6 mm) thick die-cast metal if the enclosure will not be used as a splice box and if the voltage rating of the complete control is such that the potential between any two conductors does not exceed 250 volts ac or dc, and die-cast metal of 0.028 inch (0.71 mm) minimum thickness may be employed in lieu of 1/16 inch (1.6 mm) thick die-cast metal for an enclosure housing only low-voltage circuits.

6.1.7 The thickness of a sheet-metal enclosure shall be as indicated in Table 6.1, except that steel shall be not less than 0.032 inch (0.81 mm) thickness [0.034 inch (0.86 mm) if zinc-coated] and nonferrous metal shall be not less than 0.045 inch (1.14 mm) in thickness at points where a wiring system is to be connected.

6.1.8 A transformer shall be housed within its own enclosure or within the main enclosure of a control or within a combination thereof. A sheet-steel transformer enclosure shall have a thickness of not less than 0.026 inch (0.6 mm) (No. 22 MSG) if uncoated and not less than 0.029 inch (0.74 mm) (No. 22 GSG) if galvanized; except that sheet steel having a thickness of not less than 0.020 inch (0.51 mm) (No. 24 MSG) if uncoated and not less than 0.023 inch (0.85 mm) (No. 24 GSG) if galvanized may be used for a drawn end bell having maximum dimensions of 2-1/4 inch (57.2 mm) on the flat portion and 1-1/2 inch (38.1 mm) at the base of the drawn portion. A cast-metal transformer enclosure shall comply with the requirements of 6.1.6.

6.1.9 Glass covering an observation opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 4 inches (101.6 mm) in any dimension shall be not less than 1/16 inch (1.6 mm) in thickness. 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 (304.8 mm), shall be not less than 1/8 inch (3.2 mm) in thickness.

6.1.10 *deleted April 22, 2011.*

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Table 6.1
Thickness of sheet metal

Table 6.1 revised September 30, 2010

Group	Maximum dimensions of enclosure				Minimum thickness of sheet metal in inches											
					Steel[a]								Copper, brass, or aluminum[a]			
					Without supporting member				Without reinforcing support							
	Length or width		Area in		Zinc-coated		Uncoated		Zinc-coated		Uncoated		Without supporting member		With reinforcing support[c]	
	Inch	mm	Inch^2	cm^2	Inch	mm	Inch	mm	Inch	mm	Inch	mm	Inch	mm	Inch	mm
A	3	76.4	6[b]	38.7	0.023[c] (24)	0.584	0.020[c] (24)	0.508	0.023[c] (24)	0.584	0.020[c] (24)	0.508	0.023[d] (22)	0.584	0.023[d] (22)	0.584
B	8	203.2	36	232.3	0.029[gc] (22)	0.740	0.026[c] (24)	0.660	0.023[c] (24)	0.584	0.020[c] (24)	0.508	0.036 (18)	0.910	0.029 (20)	0.740
C	12	304.8	90	580.7	0.034 (20)	0.864	0.032 (24)	0.813	0.023[c] (24)	0.584	0.020[c] (24)	0.508	0.045 (16)	1.143	0.029 (16)	0.740
D	18	457.2	135	871.0	0.045 (18)	1.143	0.042 (20)	1.067	0.034 (20)	0.864	0.032 (20)	0.813	0.058 (14)	1.473	0.045 (16)	1.143
E	24	609.6	360	2322.1	0.056 (16)	1.422	0.053 (18)	1.346	0.045 (18)	1.143	0.042 (18)	1.067	0.075 (12)	1.905	0.058 (14)	1.473
F	48	1219.2	1200	7742.0	0.070 (14)	1.778	0.067 (16)	1.702	0.056 (16)	1.422	0.053 (16)	1.346	0.095 (10)	2.413	0.075 (12)	1.905
G	60	1524.0	1500	9678.0	0.097 (12)	2.464	0.093 (16)	2.362	0.056 (16)	1.422	0.053 (16)	1.346	0.122 (8)	3.099	0.075 (12)	1.905
H	Over 60	1524.0	Over 1500	9678.0	0.126 (10)	3.200	0.123 (16)	3.124	0.056 (16)	1.422	0.053 (16)	1.346	0.153 (6)	3.886	0.075 (12)	1.905

[a] The figures in parentheses are the GSG numbers (for zinc-coated steel), the MSG numbers (for uncoated steel), and the AWG numbers (B&S) numbers (for copper, brass, or aluminum) which provide the specified minimum thickness of metal.

[b] Volume of enclosure not more than 12 cubic inches (196.7 cm^3).

[c] Sheet steel for an enclosure intended for outdoor use (raintight) is required to be not less than 0.034 inch (0.87 mm) (No. 20 GSG) in thickness if zinc coated and not less than 0.032 inch (0.81 mm) in thickness if uncoated (No. 20 MSG).

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use (raintight) is required to be not less than 0.029 inch (0.74 mm) in thickness (20 AWG).

6.1.11 deleted April 22, 2011.

6.1.12 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or if a construction that has been determined to be equivalent is used, there shall not be less than 3 threads in the metal, and the construction of the control shall be such that a conduit bushing can be attached as intended.

6.1.13 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 that have been determined to be 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.

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

6.1.15 Except as noted in 6.1.18, a conduit hub or nipple attached to the enclosure of a control 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 (67.8 N·m), each applied in turn for 5 minutes.

6.1.16 For the pullout test, the control is to be supported by rigid conduit in the intended manner and is to support a weight of 200 pounds (90.7 kg).

6.1.17 For the bending and twisting tests, the control is to be rigidly supported by means other than the conduit fittings. In the bending test, the force is to be applied to the conduit at right angles to its axis, and the lever arm is measured from the wall of the enclosure in which the hub or stud is located to the point of application of the bending force. 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.

6.1.18 With regard to 6.1.16 and 6.1.17, distortion of the enclosure does not constitute a failure. The test may be discontinued when noticeable distortion occurs.

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6.1.19 A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

a) 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

b) 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 plates or plugs shall be securely mounted.

6.1A Polymeric materials and enclosures

6.1A added April 22, 2011

6.1A.1 The mechanical strength of a nonmetallic enclosure shall be at least equivalent to a sheet metal enclosure of the minimum thickness specified in Table 6.1.

6.1A.2 Unless otherwise specified in sections 6 and 8, 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 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.

6.1A.3 Metallized or painted polymeric parts or enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. 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.

6.2 Accessibility of live parts

6.2.1 Electrical parts of controls 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.

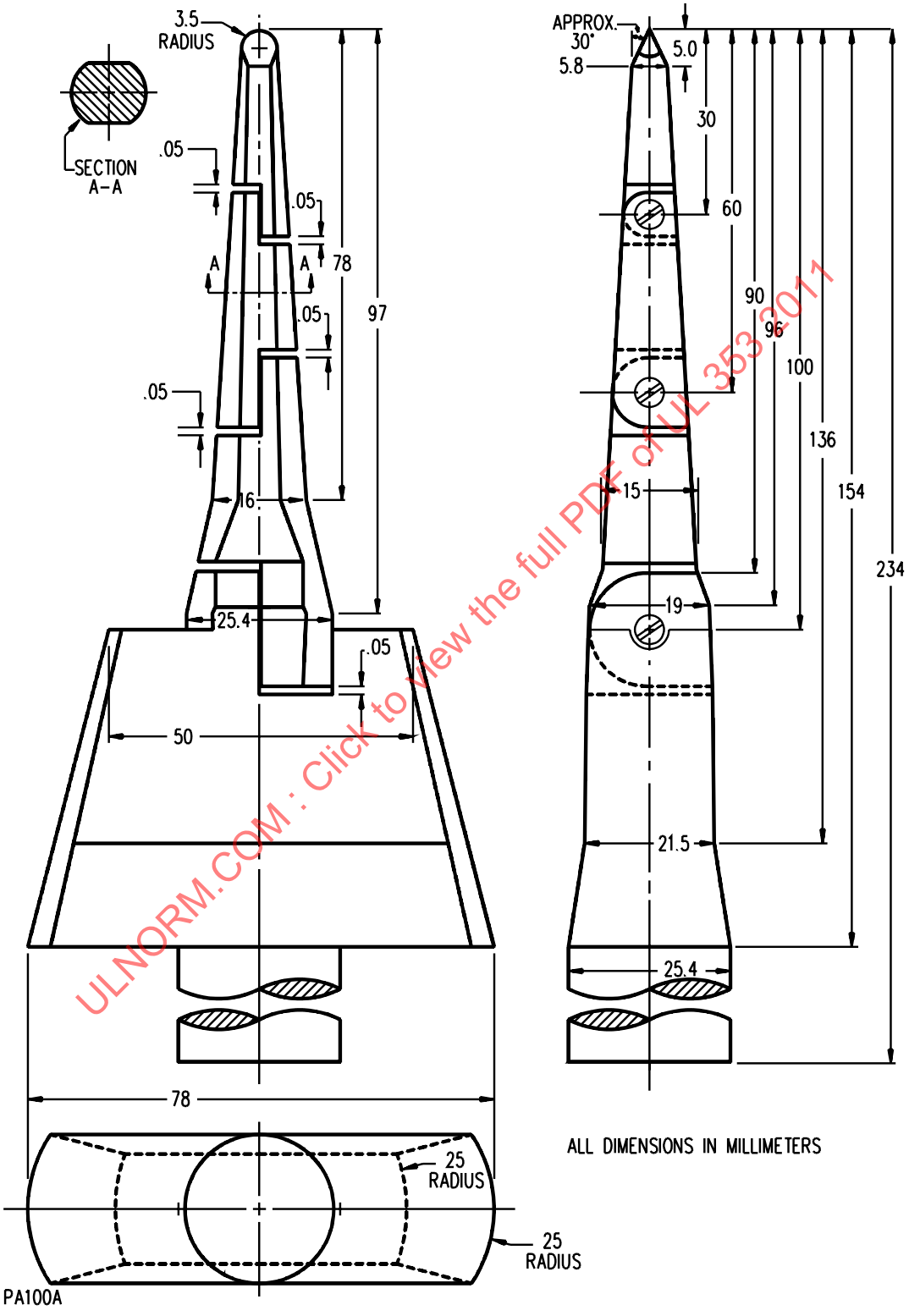
6.2.2 An opening in an enclosure of a control may be used if an accessibility probe as illustrated in Figure 6.1, when inserted into the opening, cannot be made to touch any part that involves the risk of electric shock to the end-user or service personnel. However, in no case shall the opening be large enough to permit the entrance of a 1 inch (25.4 mm) diameter rod.

6.2.3 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.

6.2.4 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.

Figure 6.1
Accessibility probe

Figure 6.1 effective November 3, 1995



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6.3 Covers and doors

6.3.1 Doors or covers shall be provided with means for securing them to the enclosure.

6.3.2 Sheet metal screws threading directly into metal brackets or enclosure walls shall not be used for attachment of covers, or doors which have to be removed for installation or operation of the equipment. They may thread into spring steel nuts permanently held in place and protected against corrosion. Machine screws and self-tapping machine screws may thread directly into sheet-metal walls.

6.3.3 A snap-on cover which gives access to bare live parts and which does not require a tool for removal shall withstand the following tests:

a) A cover, which can be removed with one hand, shall not be released when a squeezing force of 14 pounds (62.3 N) is applied at any two points, the distance between which shall not exceed 5 inches (127 mm), as measured by a tape stretched tightly over that portion of the surface of the cover which 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 not become disengaged from the case when a direct pull of 14 pounds (62.3 N) is applied. For this test, the cover is to be gripped at any two convenient points. The test shall be performed before and after ten removal and replacement operations; and

c) A cover shall be capable of withstanding an impact force of 1 foot-pound (0.138 kg-m) applied to the accessible faces of the cover (one blow per face) without being displaced. The radius of the ball used for this test shall be not less than 1 inch (25.4 mm).

6.3.4 All nonmetallic covers which give access to bare live parts shall comply with the requirements in 6.3.3 with the cover screws tightened, and with the cover screws loosened one full turn.

6.3.5 An enclosure cover shall be hinged if it gives access to fuses, thermal cutouts, or any protective device, the normal functioning of which requires renewal or resetting, or if it is necessary to open the cover in connection with the normal operation of the control.

6.3.6 A door or cover giving access to fuses or thermal cutouts in other than low-voltage circuits shall shut against a 1/4 inch (6.4 mm) rabbet, or the equivalent, or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the walls of the box and shall overlap the edges of the box not less than 1/2 inch (12.7 mm). A construction which affords equivalent protection or a combination of flange and rabbet is acceptable.

6.3.7 Strips used to provide rabbets or angle strips 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 (152.4 mm) apart.

6.3.8 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 catch or spring latch; except that if a hinged cover is provided, although not required, a hasp, sliding latch, or other means for holding the cover closed may be employed.

6.3.9 No wires other than those leading to a part mounted on the door or cover or those of a low-voltage nonsafety circuit shall be brought out through the door or cover of an enclosure.

6.3.10 If low-voltage nonsafety wiring is brought out through the door or cover, the construction shall conform with 9.1.15 and 20.1.3. Also, the construction shall be such that the wires are not subject to strain or mechanical injury when the door is opened as the cover is removed.

6.4 Openings

6.4.1 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 6.3.6 – 6.3.8.

6.4.2 The following requirements apply to openings:

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:

a) A mounting opening.

b) 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).

c) 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 6.2 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 (2.54 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 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 the opening.

g) Air from an opening, either forced or otherwise, shall not be directed:

1) Into a duct or into a concealed space in a building,

2) Against the mounting surface, and

3) 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 (457 mm), but less than 48 inches (1.2 m); eight holes for an enclosure with a maximum dimension of 48 inches (1.2 m) 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 6.3. The dimensions shown in Figure 6.3 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 judged with regard to the enclosure dimensions and configuration.

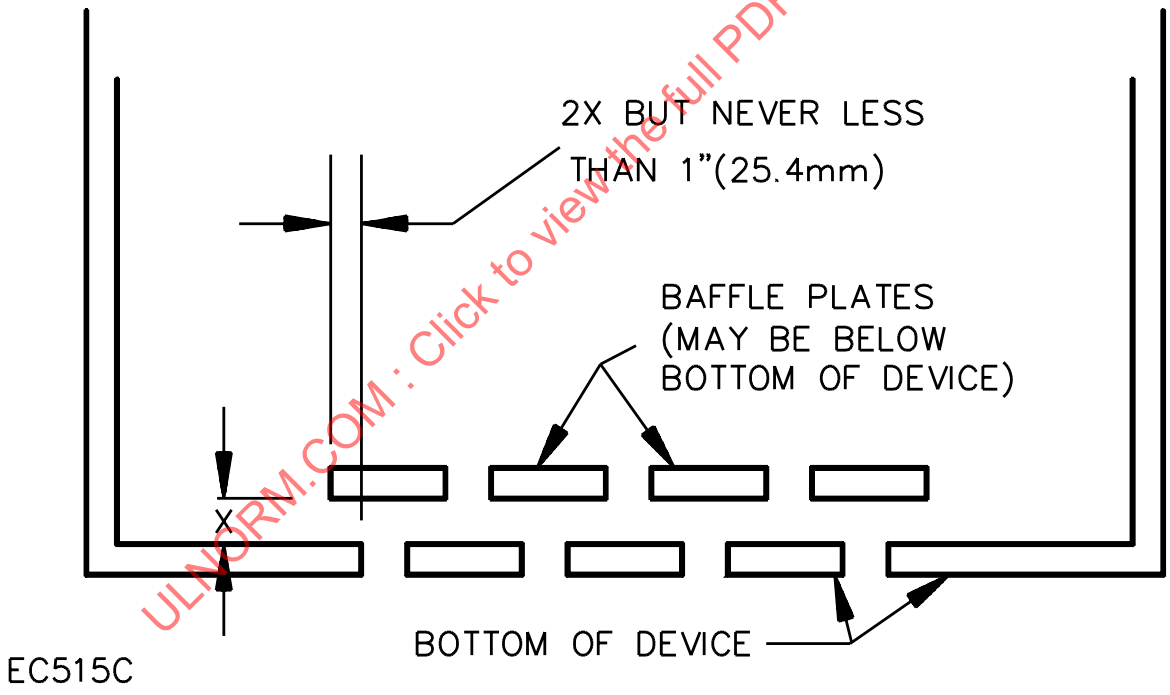
6.4.2 effective November 3, 1995

6.4.3 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, and the like.

6.4.3 effective November 3, 1995

Figure 6.2
Bottom surface openings of enclosures

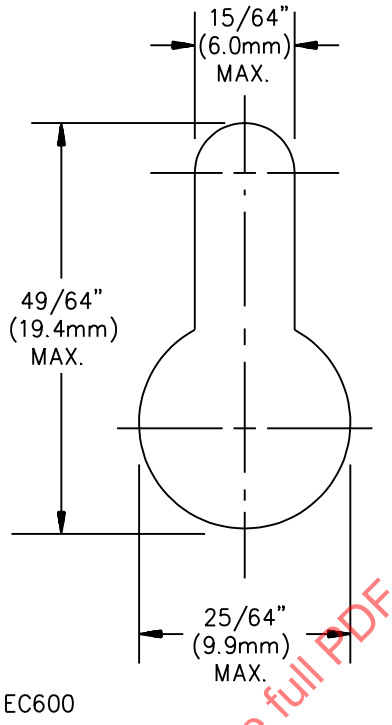
Figure 6.2 revised February 15, 1999



7 Corrosion Protection

7.1 Iron and steel parts, except bearings, thermal elements, laminated relay cores, etc., where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

Figure 6.3
Keyhole slot



7.2 The requirement of the preceding paragraph applies to enclosing cases whether of sheet steel or cast iron, and to other parts upon which proper mechanical operation may depend. It does not apply to parts of iron or steel which are not current carrying, if the failure of such unprotected parts would not be liable to result in a hazardous condition. Parts made of stainless steel do not require additional protection against corrosion.

8 Insulating Material

8.1 Insulating materials for the support or separation of live parts shall withstand the most severe normal and abnormal conditions liable to be met in service, including the influence of the arc formed by the operation of contacts.

8.2 Among the factors to be considered in evaluating electrical insulation are mechanical and electrical strength; resistance to burning, moisture, arcing, and creep (flow due to stress); and thermal endurance and resistance to temperatures encountered in use.

8.2.1 A polymeric electrical insulating materials 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.

8.2.1 added April 22, 2011

8.3 Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers but not as the sole support for uninsulated current-carrying parts of other than low-voltage circuits.

9 Field Wiring Connections

9.1 General

9.1.1 In 9.1.2– 9.3.1 and particularly where wiring terminals or leads are mentioned, wiring connections are considered to be those that are made to the control when the control is installed in the field.

9.1.2 A control shall be provided with wiring terminals or leads for the connection of conductors of at least the size required by the National Electrical Code ANSI/NFPA 70, corresponding to the rating of the control.

9.1.3 A terminal box or wiring compartment shall be so located that wire connections therein will be accessible for inspection, without disturbing either high-voltage or safety-circuit wiring, after the control is installed in the intended manner; except that for an outlet box mounted control, wire connections may be accessible upon removal of the control from the outlet box.

9.1.4 A wiring space or compartment intended to enclose wires shall be free of any sharp edge, burr, fin, moving part, or the like that may abrade the insulation on conductors or otherwise damage wires.

9.1.5 A lead shall be Type T wire or wire having insulation equivalent in electrical and mechanical properties to Type T wire. A lead shall have a free length of at least 6 inches (152.4 mm).

9.1.6 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 is intended to be connected, and shall not be smaller than 18 AWG (0.82 mm^2).

Exception: The lead may be more than 2-wire sizes smaller than the copper conductor to which it is intended to be connected in the field, but shall not be smaller than 18 AWG (0.82 mm^2), if more than one factory-provided copper lead is intended for connection to the same supply lead, and the construction complies with all of the following conditions:

a) A wire connector for connection of the supply wire is provided as part of the unit or remote control assembly, and the wire connector is intended for use with the combination of wires that will be spliced.

b) The factory-provided leads are grouped in a manner that prevents stress on an individual lead.

c) The product is marked in accordance with 45.6.

9.1.6 revised September 30, 2010

9.1.7 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:

a) The screw or connector is rendered unusable for field-wiring connection; or

b) The lead is insulated at the unconnected end and a marking on the unit clearly indicates the intended use of the lead.

9.1.8 The free end of any 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 an equipment grounding lead, see 9.1.11.

9.1.9 Leads for field connections shall be provided with strain relief to prevent mechanical stress from being transmitted to terminals, splices or interior wiring. Each lead shall be capable of withstanding for 1 minute a pull of 10 pounds (4.45 N).

9.1.10 The surface of an insulated lead intended solely for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other conductor visible to the installer shall be so identified.

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

9.1.12 9.1.10 is not applicable to low-voltage nonsafety circuits under the following conditions:

a) The leads or wiring to low-voltage terminals are located remote from the location where high-voltage connections are made and segregation is in accordance with 20.1.4, or

b) The low-voltage leads or terminals are specifically marked with the intended use, such as ″THERMOSTAT″ requiring no reference to a wiring diagram.

9.1.13 A control shall have provision for connection of one of the wiring systems that, in accordance with the National Electrical Code ANSI/NFPA 70, would be suitable for the control.

9.1.14 A control which is suitable for use only with fittings of one type of wiring system shall be supplied with such a fitting and the control shall be marked to indicate that it must be installed with the applicable wiring system. The marking shall be located so that it is visible at the time the installation connections are made.

9.1.15 An opening with an insulating bushing may be provided for the entry of a conductor(s) of a low-voltage circuit other than a safety control circuit. The bushing may be mounted in place in the opening or may be within the enclosure for mounting when the control is installed.

9.1.16 A bushing of rubber or rubber-like material provided in accordance with 9.1.13 shall be 1/8 inch (3.2 mm) or more in thickness along the inside edge of the opening, except that it shall not be less than 1/16 inch (1.6 mm) in thickness (with a minus tolerance of 1/64 inch (0.4 mm) if the metal around the hole is eyeleted or similarly treated to ensure smooth edges. A bushing shall be so located that it will not be exposed to oil grease, oily vapors, or other substance 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, etc., which might damage the bushing.

9.2 Terminals

9.2.1 A wiring terminal shall be provided with a soldering lug or pressure terminal connector fastened in place (for example, firmly bolted or held in place by a screw.)

Exception No. 1: A wire binding screw is able to be employed at a wiring terminal intended to accommodate a No. 10 (5.3 mm^2) or smaller conductor when upturned lugs, corners, or the equivalent are provided to hold the wire in place.

Exception No. 2: Push-in terminals are able to be employed for connection of No. 12 (3.3 mm^2) or smaller conductors.

Exception No. 3: A quick connect type terminal is able to be employed for low-voltage circuits that are not safety-control circuits.

Revised 9.2.1 effective March 5, 1999

No Text on This Page

9.2.2 A wire-binding screw shall be minimum No. 8 (4.2 mm diameter).

Exception: A No. 6 (3.5 mm diameter) screw may be used for the connection of a conductor not heavier than 14 AWG (2.1 mm^2).

9.2.2 revised September 30, 2010

9.2.3 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) in thickness for a 14 AWG (2.1 mm^2) or smaller wire, and not less than 0.050 inch (1.27 mm) in thickness for a wire larger than 14 AWG (2.1 mm^2); and in either case, there shall be not less than two full threads in the metal.

9.2.3 revised September 30, 2010

9.2.4 A wire-binding screw shall thread into metal.

9.2.5 Push-in (screwless) terminals shall be evaluated on the basis of pullout and temperature tests described in Section 40, Push-In Terminals.

9.2.6 Quick connect type terminals shall be provided with means to permit them to be mechanically interlocked to the mating terminals and the mating terminals shall be shipped with the control together with instructions for their installation.

9.2.7 Except for low-voltage nonsafety circuit terminals shall be so constructed that the conductor will make metal to metal contact with the terminal plate as well as with any wire binding screw when the conductor is secured to the terminal.

9.2.8 A terminal intended for connection of a grounded supply conductor shall be of or plated with metal that is substantially white in color and shall be readily distinguishable from other terminals, or identification of that terminal shall be shown in some other manner, such as on an attached wiring diagram. A lead intended for connection of a grounded supply conductor shall be finished to show a white or gray color and shall be distinguishable from the other leads.

9.2.8 revised September 30, 2010

9.2.9 A terminal solely for the connection of an equipment grounding conductor shall be capable of securing a conductor of the size intended for the particular application, in accordance with the National Electrical Code ANSI/NFPA 70. The connection shall be made by means of a pressure connector, clamp, or the equivalent. A connection device or fitting that depends solely on solder shall not be used. Sheet-metal screws shall not be used to connect grounding conductors to enclosures.

Exception No. 1: A No. 10 or larger wire-binding screw or stud-and-nut combination is able to be employed at a wiring terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor when upturned lugs or the equivalent are provided to hod the wire in position. See 9.2.1.

Exception No. 2: A No. 8 screw or stud-and-nut combination is able to be used at a terminal intended only for the connection of a 12 AWG (3.3 mm^2) conductor.

Exception No. 3: A No. 6 screw or stud-and-nut combination is able to be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor.

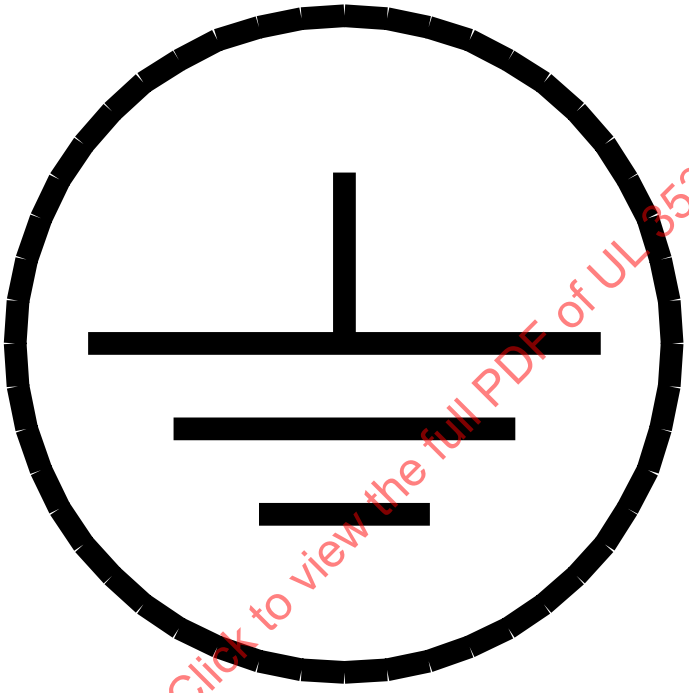
9.2.9 revised September 30, 2010

9.2.10 A wire binding screw intended for the connection of an equipment grounding conductor shall have a slotted or hexagonal green-colored head. A pressure wire connector intended for connection of such a conductor shall be identified by being marked G, GR, GROUND, GROUNDING, the grounding symbol illustrated in Figure 9.1, or by a marking on a wiring diagram provided on the control. The wire-binding screw or pressure wire connector shall be located so that it is unlikely to be removed during intended servicing of the fan.

9.2.10 revised March 5, 1997

Figure 9.1
Grounding symbol

Figure 9.1 revised February 15, 1999



9.2.11 If a control includes a lampholder of the Edison screw shell type, the identified terminal or lead shall be electrically connected to the screw shell of the lampholder.

9.3 Wiring space

9.3.1 Space shall be provided within the enclosure of a control to allow room for the distribution and stowing of wires and cables required for the wiring of the control. See also 23.3.

10 Current-Carrying Parts

10.1 Current-carrying parts shall be silver, copper, copper alloys, or other metal recognized for such use.

10.2 Uninsulated live parts, including terminals and contact assemblies, shall be secured to their supporting surfaces by methods other than friction between surfaces so that they will be prevented from turning or shifting in position.

10.3 A lock washer is generally acceptable to prevent turning of a terminal or connection stud.

11 Internal Wiring

11.1 The internal wiring of a control shall consist of wires of types which are suitable for the temperature and voltage to which the wiring is to be subjected. Internal wiring composed of insulated conductors shall comply with the Standard for Appliance Wiring Material, UL 758.

Exception No. 1: Insulated conductors need not comply with UL 758 if they comply with one of the following:

a) 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 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.

11.1 revised April 22, 2011

11.2 Except as provided in 11.4 and 11.5, the internal wiring of a control shall consist of insulated conductors having a voltage rating and ampacity suitable for their intended load. An insulated conductor for a high-voltage circuit shall be Type T wire or wire having insulation equivalent in mechanical and electrical properties to that of Type T wire. An insulated conductor for a low-voltage safety-control and isolated limited secondary circuit shall be Type RFH-1, TF, or wiring having insulation equivalent in electrical and mechanical properties to that of Type RFH-1 or TF wire.

11.3 These requirements are not intended to exclude the use of printed wiring material.

11.4 Where the use of a short length of suitable insulated conductor is not feasible (e.g., a short coil lead or the like), noncarbonized beads or electrical insulating tubing may be employed. Tubing is not to be subjected to sharp bends, tension, compression, or repeated flexing, and is not to contact sharp edges, projections, or corners. The wall thickness at any point for the smallest sizes of polyvinyl chloride tubing is to be not less than 0.017 inch (0.43 mm). For insulating tubing of other types, the thickness shall be not less than that providing mechanical strength, dielectric properties, heat and moisture-resistant characteristics, etc., at least equal to those of 0.017 inch (0.43 mm) thick polyvinyl chloride tubing.

11.5 A bare conductor may be employed within an enclosed control for a short wire length if it is impractical to insulate such conductor.

11.6 A bare conductor or a conductor utilizing tubing or noncarbonizable beads for insulation shall not be employed outside of an enclosed control. A bare conductor shall be so supported that the required spacings will be maintained.

11.7 Wireways shall be smooth and free from sharp edges, burrs, fins, moving parts, etc., which may cause abrasion of the insulation on conductors. Mounting screws shall not project more than 3/16 inch (4.8 mm) into a wireway and such screws shall have flat or blunt ends.

11.8 Holes in sheet-metal walls through which insulated wires pass and on which they may bear shall be provided with smoothly rounded bushings or shall have smooth, rounded surfaces upon which the wires may bear to prevent abrasion of the insulation.

11.9 A joint or connection shall be mechanically secure and provide reliable electrical contact without strain on connections and terminals. Except as noted in 11.10, soldered connections shall be mechanically secure before being soldered.

Exception: Joints and connections need not be made mechanically secure before soldering if a soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used.

11.10 Connections made to a printed wiring board need not be made mechanically secure if:

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 is passed through a hole in a printed wiring board and bent 90 degrees to the board to make contact with the conductor before soldering; or

c) Soldering is done by a machine process in which the soldering time and solder temperature are automatically controlled.

11.11 A joint shall be provided with insulation equivalent to that required for the wires involved if permanence of spacing between the joint uninsulated live parts of opposite polarity or grounded dead-metal parts is not ensured.

12 Grounding

12.1 A control, except one intended for use only in low-voltage circuits, shall have provision for grounding all noncurrent-carrying metal parts which are exposed or which are liable to be touched by a person during normal operation of adjustment of the control, and which are liable to become energized as a result of an electrical fault.

12.2 To determine if a part is liable to become energized, it will be evaluated on the basis of factors such as proximity to wiring and live parts, thickness and type of insulation, and by tests which may include burnout and dielectric withstand after overload, endurance, conditioning, or aging. Guards, baffles, and internal covers which do not require tools for removal will be removed when determining whether a part is exposed to contact. A part that can be contacted by a 3/4 inch (19.1 mm) diameter rod of any length or by probe shown in Figure 6.1, when inserted through openings in permanently attached guards or baffles, is considered exposed for the purposes of grounding.

12.3 Metal parts as described below need not be grounded:

a) Adhesive-attached metal-foil markings, screws, handles, etc., which are located on the outside of enclosures or cabinets and isolated from electrical components or wiring by grounded metal parts.

b) Isolated metal parts, such as magnet frames and armatures, small assembly screws, etc., which are separated from wiring and uninsulated live parts.

c) Panels and covers which do not enclose uninsulated live parts if insulated live parts and wiring are separated from the panel or cover.

d) Panels and covers which are insulated from electrical components and wiring by an attached insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick.

e) A part on the back side of a component mounting panel or a part located so as to require major disassembly by using tools, unless it is likely that servicing will be done while energized after the disassembly has been made.

12.4 Except as indicated in 12.3, uninsulated metal parts of cabinets, electrical enclosures, motor frames and mounting brackets, controller mounting brackets, capacitors and other electrical components, interconnecting tubing and other piping, etc., are to be bonded for grounding if they may be contacted by the user or serviceman.

12.5 The following are considered to constitute means for connection to a ground:

a) In a control intended to be connected to a metal-enclosed wiring system – a knockout or equivalent opening in the metal enclosure of the control.

b) In a control intended to be connected to a nonmetal-enclosed wiring system (e.g., nonmetallic-sheathed cable) – an equipment-grounding lead or terminal.

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

12.7 An internal connection for bonding internal parts to the enclosure for grounding (but not for a field-installed grounding conductor) may employ a quick-connect terminal, provided the connector is not liable to be displaced. The component is to be limited for use with a branch circuit protective device rated 60 amperes or less and the size of the quick-connect terminals is to be as specified in Table 12.1.

Table 12.1
Quick-connect terminals for grounding internal parts

Maximum rating of branch circuit protective device, amperes	Nominal dimensions of quick-connect terminals,	
	Inches	(mm)
20 or less	0.020 by 0.187 by 1/4	(0.51 by 4.75 by 6.35)
	0.032 by 0.187 by 1/4	(0.81 by 4.75 by 6.35)
	0.032 by 0.205 by 1/4	(0.81 by 0.52 by 6.35)
60 or less	0.032 by 1/4 by 5/16	(0.81 by 6.35 by 7.94)

12.8 The 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. The grounding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. The grounding point shall be so located that it is unlikely that the grounding means will be removed during normal servicing.

12.9 Except as noted in 12.10, the circuitry of a limit control shall be arranged so that the equipment grounding connection or conductor, the enclosure, the frame, the component mounting panel, and the earth ground do not carry current except in the instance of an electrical fault.

12.10 A single point reference ground may be employed in a low-voltage or isolated limited secondary circuit. The enclosure, frame or panel, including bolted joints may carry the current of a low-voltage circuit. In neither of these instances is such current to be carried through the field-equipment grounding means, the metallic raceway or other power-supply grounding means, or the earth ground.

12.11 A grounded circuit conductor shall not be grounded at or in conjunction with a limit control.

12.12 Live parts and wiring shall be maintained away from unbonded parts such as relay and contactor magnets and armatures by clamping, routing, or equivalent means.

12.13 If a component such as a remote sensor is likely to be separated from its normal grounding means after installation in the end-use appliance for purposes of testing or adjustment while the equipment is energized, it is to be provided with a bonding terminal or with a bonding conductor which does not require removal for such service.

12.14 Bonding conductors shall be of copper, a copper alloy, or other material recognized for use as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or equivalent means. A separate bonding conductor or strap shall:

a) Be protected from mechanical damage or be located within the confines of the outer enclosure or frame; and

b) 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.

12.15 Bonding shall be by a positive means such as by clamping, riveting, bolted or screwed connection, or welded or soldered connections using materials having a melting point (solidus temperature) greater than 850°F (455°C) or by an equivalent construction conforming to 12.20. A bonding connection shall penetrate nonconductive coatings such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

12.16 The continuity of a grounding system shall not rely on the dimensional integrity of nonmetallic material.

12.17 A single machine screw that is used for bonding purposes through screw threads shall engage at least two full threads in the metal. Two sheet metal or machine screws will be considered an equivalent construction.

12.18 Unless tested as specified in 12.20, the size of a conductor or strap used for bonding a motor frame or component shall be as specified in Table 12.2 or shall be the same as that of the conductor supplying the motor or component, whichever is the smaller.

Table 12.2
Bonding wire conductor size

Rating of overcurrent device, amperes	Size of bonding conductor[a]			
	Copper wire		Aluminum wire	
	AWG	(mm^2)	AWG	(mm^2)
15	14	(2.1)	12	(3.3)
20	12	(3.3)	10	(5.3)
30	10	(5.3)	8	(8.3)
40	10	(5.3)	8	(8.3)
60	10	(5.3)	8	(8.3)
100	8	(8.3)	6	(13.3)

[a] Or equivalent cross-sectional area.

12.19 If more than one size branch circuit overcurrent device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor. For example, if a motor 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 sized on the basis of the overcurrent device intended for ground-fault protection of the motor.

12.20 The adequacy of a bonding connection or conductor that does not comply with the requirements in 12.15 and 12.18 shall be established by subjecting the connection to the following tests:

a) The connection or conductor shall not open under an overload test of twice the branch-circuit overcurrent device rating, but not less than 40 amperes, maintained for the interval indicated in Table 12.3.

b) Three samples of the connection or conductor shall be tested and none of these shall open under a limited short-circuit test of a current specified in Table 12.4 in series with a fuse of the rating of the branch circuit overcurrent device to which the equipment will be connected. The test circuit is to have a power factor of 0.9 – 1.0 and is to be limited to the current specified, at the voltage stated in Table 27.1. The open-circuit voltage of the test circuit is to be not less than 100 percent nor more than 105 percent of the specified voltage. The circuit is to be connected through a non-renewable fuse, the design characteristics of which are such that the fuse will not open in less than 12 seconds when carrying twice the fuse rating current.

Table 12.3
Duration of current flow, bonding conductor test

Rating of overcurrent device, amperes	Minimum duration of current flow, minutes
30 or less	2
31 – 60	4
61 – 100	6

Table 12.4
Circuit capacity for short circuit tests

Combined rating of device					
Volts	Volt-amperes, single-phase	Volt-amperes, three-phase	Volt-amperes, direct-current	Horsepower	Circuit capacity in amperes
0 – 250	0 – 1176	0 – 832	0 – 624	0 – 1/2	200
	1177 – 1920	833 – 1496	625 – 1128	Over 1/2 – 1	1000
	1921 – 4080	1497 – 3990	1129 – 3000	Over 1 – 3	2000
	4081 – 9600	3991 – 9145	3001 – 6960	Over 3 – 7-1/2	3500
	Over 9600	Over 9145	Over 6960	Over 7-1/2	5000
251 – 600	0 – 1920	0 – 1496	0 – 1128	0 – 1	1000
	Over 1920	Over 1496	Over 1128	Over 1	5000

12.21 The resistance between the point of connection of the equipment grounding means, at or within the device, and any other point in the grounding circuit shall be not more than 0.1 ohm.

12.22 Compliance with the requirements of 12.21 may be determined by a Wheatstone Bridge, except that if unacceptable results are recorded, 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 included in this measurement.

12.22 revised December 12, 1995

13 Protection of Users and Service Personnel

13.1 These requirements apply to live parts in other than low-voltage circuits.

13.2 Live parts shall be located and enclosures and covers arranged so that persons are not likely to be exposed to electric shock while removing or replacing a cover. This requirement is also applicable to controls which are mounted on or form a cover for a junction box or wiring enclosure.

13.3 Live parts which are recessed at least 1/8 inch (3.2 mm) from any point of contact during the process of removal and replacement of a cover, are considered as not presenting a risk of electric shock if it is demonstrated by trial removal and replacement of the cover that the live parts cannot be contacted during the removal and replacement process. Projections or guards may be incorporated for the purpose of providing the equivalent of the 1/8 inch (3.2 mm) recess.

13.4 Unless the cover construction conforms with requirements for hinged covers in 6.3.5 and 6.3.8, and unless all live parts are protected as specified in 13.6, a handle, knob, or other operating means provided for manual manipulation shall be arranged so that such manipulation may be done exterior to the control enclosure. The position of such operating means shall be marked, if necessary, as a guide for proper operation.

13.5 Devices which involve manual operations which might be done only at the time of installation, during servicing procedures, or seasonally, need not comply with 13.4 provided that the construction complies with the requirements in 13.6, 13.7, 13.14, 13.16, 13.18 and 13.19.

13.6 An uninsulated live part shall be located, guarded, or enclosed so as to reduce the likelihood of contact by persons with nearby live or hazardous moving parts while relamping, changing fuses, adjusting controls, lubricating motors, or during other normal operations.

13.7 If the marking or operating instructions refer to a hole or opening in the enclosure through which a tool is to be inserted for adjustment or similar activity, the construction shall be such that uninsulated live parts cannot be contacted through the hole or opening by a 1/16 inch (1.6 mm) diameter rod of any length.

13.8 Controls which are to be adjusted only at the time of installation, servicing, or seasonally, are to be evaluated with respect to the foregoing requirement.

13.9 A live heat sink for a solid state component, a live relay frame, and the like, shall comply with 13.6, 13.14 and 13.18, but regardless of its location shall either be guarded to prevent contact by persons or the equipment shall be marked in accordance with 46.3, except as permitted in 13.12.

13.10 With respect to 13.9, it is to be noted that the size, shape, material, and color give a heat sink or relay-frame the appearance of a dead-metal part. Other types of live parts which can be mistaken for dead are to be evaluated similarly.

13.11 Guards, baffles, and internal covers which do not require tools for removal will be removed when determining whether a part is exposed to contact by the user. A part which can be contacted by a 3/4 inch (19.1 mm) diameter rod of any length or by probe shown in Figure 6.1, when inserted through openings in permanently attached guards or baffles, is considered exposed for the purposes of protecting persons.

13.12 A part on the back side of a component mounting panel or a part located so as to require major disassembly by using tools is not considered to be exposed to the user, and such parts are not considered exposed to the serviceman unless it is likely that servicing will be done while energized after the disassembly has been made.

13.13 Parts of controls which are subject to contact during normal operation, adjustments, and user servicing shall be free of sharp corners and edges.

13.14 An uninsulated live part or a hazardous moving part shall be located, guarded, or enclosed so as to prevent accidental contact by service personnel adjusting or resetting controls, etc., or performing mechanical (refrigeration, plumbing, or pneumatic temperature-control systems, lubricating motors, etc.), service functions which may have to be performed with the equipment energized.

13.15 Mechanical service functions which may have to be performed with the equipment energized include: Operation of valves or connection to fittings which may be necessary during charging or pneumatic-system adjustment, adjusting water control, or expansion valves; adjusting the setting of temperature or pressure controls with or without marked dial settings; resetting control trip mechanism; operating manual switches; adjusting air-flow dampers. A factory-set and sealed control, having the set point sealed as described in 21.2 and 21.3 and not having marking or instructions for adjustment, is not considered to be adjustable.

13.16 Adjustable or resettable electrical control or manual switching devices 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:

a) Not located in front (in the direction of access) of the mechanism; and

b) Are not located near any side or behind the mechanism, unless guarded.

13.17 In determining compliance with the preceding, bare live parts in 30-volt or less limited-energy circuits in accordance with of 2.6(b) and (d) are not to be considered.

13.18 An electrical component which may require examination, adjustment, servicing, or maintenance while 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 service functions without subjecting the serviceman to the likelihood of electric shock or to accidents from adjacent hazardous moving parts. Access to the components in the control assembly is not to be impeded in the direction of access by other components or by wiring.

13.19 Accessibility and protection from the likelihood of electric shock and accidents may be obtained by mounting the control components in an assembly so that unimpeded access is provided to each component through an access cover or panel in the outer cabinet (if provided) and the cover of the control assembly enclosure.

13.20 The electrical components referred to in the preceding paragraphs include the following: Fuses; adjustable or resettable overload relays; manual or magnetic motor controllers; magnetically operated relays; adjustable or resettable pressure or temperature controls; 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 in accordance with of 3.6(b) or (d), are to comply with the requirements of 13.18 in their relation to bare live parts in a circuit of greater energy level and to hazardous moving parts.

13.21 Totally enclosed current or potential type start relays for single-phase motors are not considered as requiring the accessibility state in foregoing paragraphs.

13.22 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 suitable insulating overwraps at least 0.028 inch (0.71 mm) thick, or equivalent (see 18.12); enclosed motor windings; terminals and splices with recognized insulation; and insulated wire.

14 Transformers

14.1 A transformer designed to furnish power to a low-voltage circuit shall be of the isolated-secondary type.

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

Exception: A transformer that is completely enclosed within the end product enclosure, and that meets the applicable construction and transformer performance requirements of UL 353 meets the intent of this requirement.

14.2 added April 22, 2011

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

Exception: Transformers located in a low voltage circuit, and that do not involve a risk of fire or personal injury, need not comply with this requirement.

14.3 added April 22, 2011

15 Fuseholders

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

15.2 Fuseholders shall comply with:

a) The Standard for Fuseholders, UL 512; or

b) The Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and applicable Part 2 (e.g. UL 4248-9)

15.2 added April 22, 2011

16 Switches

16.1A Switches shall comply with one of the following and, as applicable, the overload and endurance test cycle level requirements in UL 353:

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; or

d) The requirements of UL 353 applicable to switches when evaluated as an integral switching part of the control.

Exception: Switching devices used for operating control functions that comply with the appropriate UL standard for specialty applications (e.g. limit controls), industrial use (e.g. contactors, relays, auxiliary devices), or are integral to another component (e.g. switched lampholder), and as applicable, the overload and endurance test cycle level requirements in UL 353 need not apply.

16.1A added April 22, 2011

16.1 A mercury tube switch shall be housed in an enclosure. Wire leads shall be as short as possible and shall terminate at eyelets or the equivalent, or in soldered connections at terminal plates on the supporting box or shall be fastened so that no strain will be put upon the mechanism. See also 32.11.

17 Coil Windings and Film-Coated Wire (Magnet Wire)

17.1 Coil windings of motors, relays, transformers, etc., shall resist the absorption of moisture.

17.2 The component requirements for film coated wire and Class 105 (A) insulation systems are not specified.

17.2 added April 22, 2011

17.3 Film coated wire in intimate combination with one or more insulators, and incorporated 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.

17.3 added April 22, 2011

18 Spacings

18.1 General

18.1.1 Live screwheads or nuts on the underside of base shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and then covered with a waterproof, insulating, sealing compound which will not melt at a temperature 15°C (27°F) higher than the normal temperature the material will attain in service, and not less than 65°C (149°F) in any case; except that if such parts are staked, upset, or otherwise prevented from loosening, they need not be recessed, and they 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 elsewhere in this Standard.

18.1.2 All uninsulated live parts connected to different circuits shall be spaced from one another as though they were parts of opposite polarity accordance with the requirement of 18.2.1 and shall be evaluated on the basis of the highest voltage involved.

18.1.3 The spacing at wiring terminals is to be measured with appropriate wires in place and connected to the terminals as in actual service.

18.2 High-voltage circuits

18.2.1 Except as indicated in 18.2.7, spacings in controls shall be not less than those indicated in Table 18.1 or, at other than field wiring terminals and between uninsulated live parts and a metal enclosure, as specified in Alternate Spacings – Clearances and Creepage Distances, Section 19. Greater spacings may be required if the enclosure, because of its size, shape, or the material used, is not considered to be sufficiently rigid to warrant the minimum spacings.

18.2.2 To determine if a control is within the volt-ampere limitation with respect to the spacing requirements of Table 18.1, the input voltage is considered to be in accordance with Table 26.1 and the volt-ampere consumption of the control is to be added to the volt-ampere consumption of the equipment intended to be controlled. The sum of the inputs to and the switch ratings of the control is the value to be used to determine if the rating is within the volt-ampere limitation. This principle applies in the case of a control which does not contain a number of individual components as mentioned in 18.2.5, and also when individual components are evaluated in accordance with the provision of that paragraph.

18.2.3 The volt-ampere rating of a multiple pole, a double-throw or a sequencing control is to be taken as the maximum consumption of the control and the load controlled at any one time.

18.2.4 The volt-ampere equivalent of a horsepower rating is to be taken as the product of the voltage of the full-load current as given in Tables 30.2 and 30.3 and, in the case of a polyphase device, the appropriate numerical multiplier.

18.2.5 If more than one control is included in one enclosure, the spacing from one control to another, and from any one control to the enclosure or other uninsulated dead-metal part excluding its mounting surface, are based on the maximum voltage and total volt-ampere rating of the overall assembly and not on the individual control rating. The inherent spacings within an individual control such as a relay (including spacings from a live part to the mounting surface other than the enclosure) are evaluated on the basis of the volt-ampere consumed and controlled by the individual control.

18.2.6 The inherent spacings within a component device such as a snap switch or lampholder, in other than a safety circuit, and the inherent spacings within a motor or clock motor, are evaluated under the requirements for the component. The spacings from such a component to another component and to the enclosure, and the spacings at wiring terminals are to be evaluated under the requirements in 18.2.1 and Table 18.1.

Table 18.1
Minimum spacings

Item	Voltage range	Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part				Between any uninsulated live part and walls of a metal enclosure including fittings for conduit of metal-clad cable	
		Through air or oil		Over surface		Shortest distance	
		Inch	(mm)	Inch	(mm)	Inch	(mm)
A. General	0 – 150	1/8[a,b]	(3.2)	1/4	(6.4)	1/2	(12.7)
	151 – 300	1/4[b]	(6.4)	3/8	(9.5)	1/2	(12.7)
	301 – 600	3/8[b,g]	(9.5)	1/2[g]	(12.7)	1/2	(12.7)
B. Maximum Rating of 2000 Volt-Amperes	0 – 300	1/8[a,b]	(3.2)	1/4	(6.4)	1/4	(6.4)
C. Maximum Rating of 100 Volt-Amperes[d]	0 – 600	1/8[a,c]1/16[a,f]	(3.2, 1.6)	1/4[e]1/16[f]	(6.4, 1.6)	1/4	(6.4)
	601 – 1000	1/4[a,c]3/16[a,f]	(6.4, 4.8)	3/8[e]3/16[f]	(9.5, 4.8)	1/2	(12.7)

[a] The spacing between wiring terminals by which connections are to be made to the control, regardless of polarity, and between a wiring terminal and a dead-metal part (including the enclosure) which may be grounded when the device is installed, shall be not less than 1/4 inch (6.4 mm).

[b] The spacings between uninsulated live parts of the same polarity, except at contacts, are required to be not less than 1/32 inch (0.8 mm) through air and not less than 1/16 inch (1.6 mm) over the surface of insulating material, and the construction of the parts is required to be such that these spacings will be maintained permanently. Otherwise, the spacings in a safety control shall comply with the requirements of the table.

[c] For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is liable to reduce spacings between the metal piece and uninsulated live parts.

[d] These spacing values apply to a safety circuit connected to an isolated secondary of a 100 volt-ampere or smaller transformer. Short-circuiting of the parts involved regardless of polarity, shall not result in unsafe operation of the controlled equipment. These values apply only to spacings between components of the circuit under consideration, or between these components and the dead-metal – no reduction of spacings to other circuits of combination equipment is acceptable.

[e] Between an uninsulated live part and an exposed isolated (insulated) dead-metal part.

[f] Between uninsulated live parts of opposite polarity and between an uninsulated live part and a grounded metal part other than the enclosure.

[g] In a self-actuated, alternating-current, pilot-duty contact control (which may have an external adjusting knob or handle, but not an operating one) rated at 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 indicated for a voltage range of 151 – 300.

18.2.7 If required in place of spacings between a magnet-coil winding and other uninsulated live parts or grounded dead-metal parts, the type of insulation may differ from that required in 18.2.8, and 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 18.2.8, provided that the coil is capable of withstanding a Dielectric Voltage-Withstand Test, Section 32 between coil-end leads after breaking the inner coil lead where it enters the layer, or an equivalent opposite polarity test. The application of the test potential is to be in accordance with 32.1 – 32.7.

18.2.8 An insulating lining or barrier of vulcanized fiber or similar materials employed where spacings would otherwise be insufficient shall be not less than 0.028 inch (0.71 mm) in thickness and shall be so located or of such material that it will not be adversely affected by arcing; except that vulcanized fiber not less than 0.013 inch (0.33 mm) in thickness may be used in conjunction with an air spacing of not less than 50 percent of the spacing required for air alone.

Exception: Insulating material having a thickness less than that specified may be used if it has equivalent mechanical and electrical properties.

18.2.9 Unless of a material conforming to 8.1, a barrier or liner shall be used in conjunction with at least 1/32 inch (0.8 mm) air space.

18.2.10 Mica not less than 0.013 inch (0.33 mm) in thickness may be used in lieu of the through-air spacing required in Table 18.1, provided the mica is tightly held in a fixed position by the parts between which the spacing is required.

18.2.11 Film-coated wire is considered to be the same as an uninsulated live part in determining compliance of a device with the spacing requirements of this Standard.

18.3 Low-voltage circuits

18.3.1 Spacings shall be as indicated in 18.3.2 – 18.3.4 if a short circuit between the parts involved may result in a risk of fire or electric shock. Spacings within a low-voltage nonsafety circuit need not be defined if the product complies with the requirements of the applicable Dielectric Voltage-Withstand Test, Section 32, and the Operation Tests, Section 29.

18.3.2 The spacing between an uninsulated live part and the wall of a metal enclosure, including fittings for the connection of conduit or metal-clad cable, shall be not less than 1/8 inch (3.2 mm).

18.3.3 The spacing between wiring terminals, regardless of polarity, and between a wiring terminal and a dead-metal part (including the enclosure) which may be grounded when the device is installed shall be not less than 1/4 inch (6.4 mm).

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

19 Alternate Spacings – Clearances and Creepage Distances

19.1 As an alternative to the measurement method specified in Section 18, the minimum acceptable clearances (through air spacings) and creepage distances (over surface spacings) may be evaluated using the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, as specified in 19.2 – 19.4. The spacing requirements of UL 840 shall not be used for through air and over surface spacings between the field-wiring terminals and between the uninsulated live parts and a metal enclosure.

19.1 revised September 28, 1995

19.2 When applying the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, for unencapsulated assemblies and uncoated printed wiring boards, pollution degree 3 shall be considered applicable. Pollution degree 1 requirements are applicable to encapsulated assemblies and to coated printed wiring boards complying with the printed wiring board coating performance test requirements. The pollution degrees are as defined for Creepage Distances in UL 840.

19.3 For Clearance B (controlled overvoltage) requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the applicable overvoltage category for line voltage circuits is Category III. Category I is applicable to low-voltage circuits if short circuit between the parts involved may result in operation of the controlled equipment that increases the risk of fire or electric shock. Any overvoltage protection device to achieve these categories shall be provided as an integral part of the control.

19.4 Where measurement of clearances and creepage distances is involved to establish the minimum spacings, the methods specified for Measurement of Clearance and Creepage Distances in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, shall be used.

20 Separation of Circuits

20.1 General

20.1.1 Unless provided with insulation recognized for the highest voltage involved, insulated conductors of different circuits (internal wiring) shall be separated by barriers or shall be segregated; and shall, in any case, be so separated or segregated from uninsulated live parts connected to different circuits or opposite polarity parts of the same circuit.

20.1.2 Segregation of insulated conductors as required in 20.1.1 may be accomplished by clamping, routing, or equivalent means which ensures permanent separation from insulated or uninsulated live parts of a different circuit.

20.1.3 Field-installed conductors of any circuit shall be segregated or separated by barriers from:

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

b) Uninsulated live parts of any other circuit of the control.

c) Any uninsulated live parts whose short-circuiting may permit unsafe operation of the controlled appliance, except that a construction in which field-installed conductors may make contact with wiring terminals is acceptable, provided that Type T, RF-2, or equivalent conductors are or will be installed when wired in accordance with the National Electrical Code ANSI/NFPA 70.

20.1.4 Segregation of field-installed conductors from other field-installed conductors and from uninsulated live parts of the control connected to different circuits may be accomplished by arranging the location of the openings in the enclosure for the various conductors (with respect to the terminals or other uninsulated live parts) so that there is no liability of the intermingling of the conductors or parts of different circuit. If the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the control, and if each opening is located opposite a set of terminals, it is to be assumed, for the purpose of determining compliance with 20.1.3 that the conductors entering each opening will be connected to the terminals opposite the opening. If more than the minimum number of openings are provided, the possibility of conductors entering at points other than opposite the terminals to which they are intended to be connected and contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated. To determine if a device complies with the requirement of 20.1.3, it is to be wired as it would be in service; and in doing so, a reasonable amount of slack is to be left in each conductor, within the enclosure, and no more than average care is to be exercised in stowing this slack into the wiring compartment.

20.2 Barriers

20.2.1 If a barrier is used to provide separation between the wiring of different circuits or between operating parts and field-installed conductors, it shall be of metal or of insulating material and be held in place.

20.2.2 A metal barrier shall have a thickness at least as great as that required by Table 6.1 based on the size of the barrier. A barrier of insulating material shall be not less than 0.028 inch (0.71 mm) in thickness and shall be of greater thickness if its deformation may be readily accomplished so as to defeat its purpose. Any clearance at the edges of a barrier shall be not more than 1/16 inch (1.6 mm) wide.

20.2.3 Openings in a barrier for the passage of conductors shall be not 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 which will need to pass through the barrier. The closure for any other opening shall present a smooth surface wherever an insulated wire may be in contact with 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 also 11.8.

21 Calibration Means

21.1 Means provided for factory calibration of controls shall be factory secured to prevent accidental shifting after calibration.

21.2 The means for calibration, if accessible or apparent, shall be modified, guarded, or sealed as by soldering to effectively prevent manipulation by hand or ordinary tools subsequent to the factory calibration.

21.3 A calibration means considered to be not accessible or apparent is one not showing, one not exposed to manipulation by conventional tools, or one not readily displaced. The complete concealment of conventional tool engaging means in a screw such as a slot, recessed head, etc., by the use of solder, brazing material, or cement, is considered adequate for purpose of preventing manipulation so long as the calibration means cannot be changed readily by gripping with conventional tools and engagement of manipulation is prevented at all other locations.

22 Mounting

22.1 Provision shall be made for securely mounting a control in position. Bolts, screws, or other parts used for mounting a control shall be independent of those used for securing parts of the control to its frame, base, or panel. A mounting bracket or similar part shall not depend solely on friction to maintain a control in position if the control may malfunction when moved from its normal position.

22.2 If the function or calibration of a control is affected by its being placed out of level, the control shall be provided with a leveling indicator such as a bubble, pendulum, or a horizontal or vertical line. Such a control, when attached as intended, shall resist without moving, a torque of 100 pound-inches (11.3 N·m).

22.3 If a control requires a mounting bracket to conform to these requirements, the bracket shall be furnished with the control. The bracket shall be marked with a part number and reference to the bracket and its part number, and use shall be indicated on the control. Such reference may be placed on the inside of the control cover.

23 Operating Mechanism

23.1 If screws and nuts serve to attach operating parts to movable members, they shall be upset or otherwise locked.

23.2 The operating mechanism of a manually operated switch shall not subject parts to damage.

23.3 Operating parts shall be separated by barriers or by their physical location from conductors to be connected to the control to avoid obstruction of such parts by stowed wiring. See also 9.3.1.

24 Adjustment and Stops

24.1 The set point shall be indicated on the control in a recognizable and legible manner. Units of measurement such as inches or millimeters, degrees F or C, pounds per square inch, etc. shall be employed. A set point for liquid level may be indicated by a horizontal line.

24.2 If a control is nonadjustable following factory calibration, it may be marked with a single set point.

24.3 If a control is adjustable in the field, stops or equivalent means shall be provided for limiting the adjustments to values within the rated set point range of the control. The set points over the range of allowable field adjustment shall be indicated thereon at increments of not more than 25 percent of the range.

24.4 An adjustable stop employed for limiting a set point shall not be used for other adjustments. It shall be secured by a means provided solely for that purpose and in a manner such that the maximum or safe setting cannot be increased except by the use of special tools or by deliberate bending or removal of some part. Nuts, screws, etc., used for this purpose shall be provided with integral lock washers or the equivalent. Parts used for support of the adjustment means shall have strength sufficient to resist accidental bending.

24.5 If a set point may be altered by resetting or removing the stop or if a control includes on it directions for altering the set point, a statement shall be on the dial, scale, or stop, or directly adjacent thereto or on the outside (not inside) of the cover. This statement shall be to the effect that the setting is a safety stop and is not to be altered to permit a higher or less safe operating point, for example ″SAFETY STOP – DO NOT ALTER.″

25 Reset Mechanism

25.1 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 value at or below control set point.)

25.2 A control which is intended to be reset manually shall not reset automatically as a result of changes in environmental temperature at temperatures above minus 35°C (minus 31°F).

25.3 A manually operated reset device shall be trip-free; that is, the automatic tripping shall be independent of the manipulation or position of the rest button, handle, lever, etc.

25.4 A manually operated reset device of a control may provide one or another of the following kinds of reset function.

a) A control to be designated ″Manual Reset 1″ or ″M1″ permits the control to automatically reset to the ″closed″ position after safe operation conditions have been restored, if the reset means is held in the ″reset″ position. The operating tolerances specified in 29.1.5 – 29.1.11 shall not be exceeded if the reset means is held in the ″reset″ or ″ON″ position.

b) A control to be designated ″Manual Reset 2″ or ″M2″ shall not permit the control to function as an automatic-reset device if the reset means is held in the ″reset″ or ″ON″ position.

25.5 A control with a manual reset shall be resettable exterior to the control enclosure.

25.6 A manually operated reset mechanism shall not subject the operating mechanism or means of support to undue strain.

PERFORMANCE

26 General Tests

26.1 Except as otherwise indicated, representative commercial samples of a control shall be subjected to the required tests. Tests shall be conducted at rated frequency and at the voltage indicated in Table 27.1.

26.2 An alternating-current control having no frequency rating is to be tested on a circuit having a frequency of 60 cycles, except that a circuit having a lower frequency may be employed if agreeable to those concerned.

26.3 Where reference is made to ac voltages and currents of 60-hertz they are intended to indicate rms values, unless otherwise specified.

26.4 A control which must be mounted in a definite position in order to function properly is to be tested in that position provided directions for mounting in the correct position are given on the control or on an instruction sheet supplied with the control. See 22.2.

26.5 A part made of an elastomer shall not crack or show visible evidence of deterioration following air oven aging for 70 hours at 100°C (212°F).

26.5 revised January 10, 1996

26.6 For a control that is rated for use in a prevailing ambient temperature greater than 25°C (77°F), the Temperature Test, Section 28, overvoltage and undervoltage tests on the electromagnet (29.5.1 – 29.5.3), Overload Test, Section 30, and the Endurance Test, Section 31, are to be conducted at the rated ambient temperature. However, the overload and endurance tests under electrical load may be conducted at room ambient in accordance with note (d) of Table 28.1.

26.7 For a control that is rated for use in an ambient temperature less than 25°C (77°F), the electromagnet undervoltage test and any other tests that may be affected by the cold ambient are to be conducted at the rated low ambient. This test shall be in addition to the test conducted at the room ambient or at the rated elevated ambient temperature.

27 Input Test

27.1 The input to a control shall not exceed the marked rating of the control by more than 10 percent when it is operated under the conditions of normal use and with the control connected to a supply circuit as indicated in Table 27.1.

Table 27.1
Test voltages

Rated voltage[a]	Normal test voltage	Overvoltage ac or dc	Undervoltage	
			ac	dc
110– 120	120	132	102	96
220 – 240	240	264	204	192
254 – 277	277	305	235	222
440 – 480	480	528	408	384
550 – 600	600	660	510	480

[a] Voltage rating of control and load terminals and corresponding test potential in volts. If the rating of the control does not fall within any of the indicated voltage ranges, the test voltages are to be based on its rated voltage.

28 Temperature Test

28.1 General

28.1.1 A control when tested under the conditions described below shall not attain a temperature at any point sufficiently high to constitute a risk of fire or to damage any materials employed in the device, nor show temperature rises at specific points greater than those indicated in Table 28.1.

28.1.2 All values for temperature rises given in Table 28.1 apply to a control intended for use in ambient temperatures normally prevailing in occupiable spaces, which usually are not higher than 25°C (77°F) but may be as high as 40°C (104°F) occasionally and for brief periods. Tests of a control for service with such ambient temperatures may be conducted (without correction) and with any ambient temperature in the range of 10 – 40°C (50 – 104°F). If a control is intended specifically for use in a prevailing ambient temperature constantly more than 25°C (77°F), the test of the control is to be made in such higher ambient temperature, and the allowable temperature rises specified in the table are to be reduced by the amount of the difference between the higher ambient temperature and 25°C (77°F).

28.1.3 The ambient or room air temperature is to be measured by a thermocouple not heavier than 24 AWG (0.21 mm^2) or a thermometer suitably shielded from direct radiation and located so as to reflect actual room air temperature in the vicinity of the control. If a control is intended specifically for use in a prevailing ambient temperature constantly more than 25°C (77°F), see 28.1.2, a means for maintaining the test control in such higher temperature is to be employed. Such means is to consist of an enclosure providing for the maintenance of essentially still air (less than 20 feet or 6.1 meters per minute) in the vicinity of the control. The enclosure is to be constructed from nonmetallic materials having low emissivity characteristics.

28.1.3 revised September 30, 2010

Table 28.1
Maximum temperature rises

Device or material		Degrees	
		C	F
A.	COMPONENTS		
	1. Capacitors		
	Electrolytic type	40	72
	Other types[f]	65	117
	2. Contacts, buses, and connecting bars[d]	65	117
	3. Sealing compounds	Maximum Temperature	
		15°C (27°F) less than its melting point	
	4. Field-wiring terminals	50	90
	5. Points on or within a terminal box or compartment on which conductors to be connected to the control may rest[a]	36	63
	6. Transformer enclosures		
	a. Class 2 transformer enclosure	60	108
	b. Power transformer enclosure	65	117
B.	INSULATION SYSTEMS		
	1. Class 105 insulation system[e]		
	Thermocouple method	65	117
	Resistance method	85	153
	2. Class 130 insulation systems[e]		
	Thermocouple method	85	153
	Resistance method	105	189
	3. Class C insulation systems	Not Specified	
	4. Class 180 insulation	As determined by test	
C.	INSULATING CONDUCTORS		
	1. Appliance wiring material		
	75°C rating	50	90
	80°C rating	55	99
	90°C rating	65	117
	105°C rating	80	144
	200°C rating	175	315
	250°C rating	225	405
	2. Other types of insulated wires	See Note c	
	3. Wire, Code[b]		
	Types RH, RFH, FFH, RHW	50	90
	Types FHW, THW, THWN	50	90
	Types RUW, T, TF, TFF, TW	35	63
	Type TA	65	117
D.	INSULATING MATERIALS		
	1. Fiber employed as electrical insulation	65	117
	2. Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock[b]	125	225
	3. Varnished-cloth insulation	60	108
E.	GENERAL		
	1. Knobs, handles, dials, buttons and surrounding surfaces likely to be contacted by the user during intended operation[g,i]		
	a. Metal	35	63
	b. Nonmetallic[h]	60	108

Table 28.1 Continued on Next Page

Table 28.1 Continued

Device or material	Degrees	
	C	F
[a] The temperature rise observed on the terminals and at points within a terminal box may exceed the value specified, provided the control is marked in accordance with 45.3 and 45.4. The wiring may not attain a temperature higher than 90°C (194°F).		
[b] The limitation on phenolic composition and on rubber and thermoplastic insulation does not apply to compounds that have been investigated and recognized as having special heat-resisting properties.		
[c] For standard insulated conductors other than those mentioned, references should be made to the National Electrical Code; and the maximum allowable temperature rise in any case is not to be more than the recognized temperature limit of the wire in question minus 25°C (77°F).		
[d] Contacts of silver or a silver alloy in a control which is designed to function where a high ambient temperature prevails are acceptable without any additional tests if they do not attain a temperature higher than 100°C (212°F) when the control is tested at the ambient temperature in question. If the contacts attain a temperature higher than 100°C (212°F) but not higher than 150°C (302°F) they are required to be capable of withstanding with acceptable results, Overload and Endurance Tests conducted at the high ambient temperature in question.		
[e] The temperature rise, observed by means of a thermocouple on the surface of a coil, where Class 105 or Class 130 insulation is involved and where the temperature at that point is affected by an external source of heat, may be 15°C (27°F) higher than that indicated in the table, provided that the temperature rise by the resistance method for the item in question is not more than specified in the table.		
[f] These limitations do not apply to capacitors which are recognized as being suitable for service at higher temperatures.		
[g] Points likely to be contacted by a hand or finger include those points on the gripping surface and adjacent surfaces close enough to be touched while adjusting the control in the intended manner. Points on a surface are considered not likely to be contacted if they are protected by a barrier not less than 5/8 inch (15.9 mm) wide on which the temperature rise does not exceed the value indicated in subitem 1 of item E or if a through-air spacing of not less than 1-1/2 inches (38 mm) at the index finger is provided from the gripping surface to the hot part.		
[h] A knob, handle, dial, or button made of nonmetallic material that is plated or clad with metal having a thickness of 0.005 inch (0.13 mm) or less is considered to be and is judged as a nonmetallic part.		
[i] The temperature rises specified in subitem 1 of item E are not applicable to a control intended specifically for use in a prevailing ambient temperature constantly more than 85°C (185°F).		

28.1.4 Except at coils, temperature readings are to be obtained by means of thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and 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. The primary (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 employed for a temperature measurement at any point where supplementary heat insulation is employed. If thermocouples are used in the determination of temperatures in connection with the heating of electrical devices, it is necessary to employ thermocouples consisting of 30 AWG (0.06 mm^2) iron and constantan wires and a potentiometer type of indicating instrument; and such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

28.1.4 revised September 30, 2010

28.1.5 To determine if a control complies with the requirement of 28.1.1, the control is to be operated under normal conditions, except as otherwise noted. A control intended to be mounted on or in a burner heat exchanger, chimney connector or the like is to be so mounted during the heating test and electrically energized to operate continuously at rated load during the test so that actual service conditions will be approximated. The temperature of a test fluid is to correspond to the maximum set point of the control. The potential of the supply circuit is to be as indicated in Table 27.1.

28.1.6 A control, to supervise fluids at temperatures consistent with ambient temperatures normally prevailing in occupiable spaces, may be bench-tested without contact with the fluid.

28.1.7 A low-potential source of supply may be utilized for conducting temperature tests on parts other than coils or transformer windings. Before starting tests, contacts are to be opened and closed under load several times. Unless otherwise noted, the tests on all parts are to be made simultaneously, as the heating of one part may affect the heating of another part.

28.1.8 The temperature rise attained by the motor of a timing device, when stalled and while connected to a supply circuit as indicated in Table 27.1, shall not exceed the limits given in Table 28.1, if stalling the motor is part of the normal operation. If stalling the motor is not part of the normal operation, the limits given in Table 28.1 do not apply; but the motor shall incorporate impedance, thermal, or overload protection.

28.2 Temperature test of temperature control for air or other gas

28.2.1 The test apparatus for a temperature control for air or gas, other than flue gases, which is intended for external mounting (except for the sensing element which is immersed in the heated gas) is to consist of an electrically heated, forced-circulation, warm-air oven described in 28.2.2. The test oven is to be located in a room free of drafts and in which the ambient air temperature may be controlled and maintained reasonably constant for the period of a test. The control to be tested is to be mounted in accordance with the manufacturer's instructions. The test is to be continued until equilibrium temperatures are attained.

28.2.2 The surface for mounting the control to be tested is to consist of a No. 26 GSG (0.022 inch) (0.56 mm) plate which shall be the sole separation between the heated air and mounting surface of the control. The plate shall allow immersion of the sensing element in the heated air as intended in service. The circulating fan and air distribution elements of the oven are to be so arranged as to provide a controlled horizontal movement of heated air across the mounted plate and the sensing element. The velocity of the heated air is to be not less than 100 feet (30.5 m) and not more than 200 feet (61 m) per minute. The means for heating the recirculated air in the oven is to be such that the temperature of the air in the area of the sensing element will be maintained within plus or minus 1 percent of the rated operating temperature of the control.

28.2.3 Temperature tests are ordinarily not conducted on a control designed to be entirely immersed in the air to be controlled, because it is assumed that the entire control will be at the temperature of the surrounding air. If for any reason such a control is to be tested, its location within the oven should be the same as described in 28.2.2 for the sensing element of an externally mounted control. The test is to be continued until equilibrium temperatures are attained.

28.3 Temperature test of temperature control for liquids

28.3.1 A boiler is to be used for testing a control of the insertion element type. The control is to be mounted in accordance with the manufacturer's instructions through a vertical plate having dimensions equivalent to the largest dimension of the control. The control is to be mounted using an opening in the face plate of proper size for the control without the use of bushings.

28.3.2 If the control is of the surface mounting type, the test apparatus is to consist of a pipe system or tank containing water. Water is to be agitated or circulated to provide normal transfer of its heat to the control mounting surface. A control intended for mounting on a pipe is to be applied to a section of 3 inch (ANSI B36.10M) pipe. For other applications, the control is to be mounted on the surface of a galvanized steel tank having a diameter of 12 inches (305 mm).

28.3.3 The pipe section or tank is to be arranged in a horizontal or vertical plane to suit the design of the control.

28.3.4 Schedule 40 black iron or steel pipe having surfaces free from rust, scale, or paint is to be used for the test section. All pipe connections to the pipe or tank section and any sources of steam or hot water adjacent to the test control location are to be insulated.

28.3.5 The temperature of the hot water is to be maintained at the maximum temperature for which the control is designed. The test is to be continued until equilibrium temperatures are attained.

28.4 Temperature test of steam pressure or boiler water-level limit control

28.4.1 The test apparatus for a control to be used for supervising steam pressure or for mounting adjacent to a boiler at the water line is to consist of a boiler capable of generating steam at the pressure for which the control is designed.

28.4.2 A pressure control is to be mounted above an uninsulated flange. A water level device is to be connected using full-size piping which is to be uninsulated. Controls are to be mounted or connected as close to the boiler surfaces as permitted by the use of syphon tubes, pigtails, special connecting fittings, etc., but are to be installed in accordance with the manufacturer's instructions. The boiler surfaces are to be insulated.

28.4.3 The temperature of the steam is to be maintained at the maximum temperature for which the control is designed. If a syphon tube or pigtail is recommended by the manufacturer's instructions to provide a water seal between the control and live steam, the syphon tube or pigtail is to be filled with water prior to the start of the test. The test is to be continued until equilibrium temperatures are attained.

28.5 Temperature test of stack-mounted control

28.5.1 A control intended to sense flue gas temperatures in a chimney or chimney connector is to be attached to a vertical chimney connector of a cast-iron steam boiler with an uninsulated top such as shown in Figure 28.1. The boiler is to be fired to maintain a flue gas temperature of 680°F (360°C) above room temperature with a draft as measured at the flue collar of the boiler of 0.04 inch (1.02 mm) water column. The flue gas temperature is to be measured by a thermocouple such as illustrated by Figure 28.2. The axis of the thermocouple is to be at right angles to the axis of the control sensing element with the hot junction just below but not touching the sensing element.

Figure 28.1
Test setup for a stack-mounted control

Figure 28.1 revised February 15, 1999

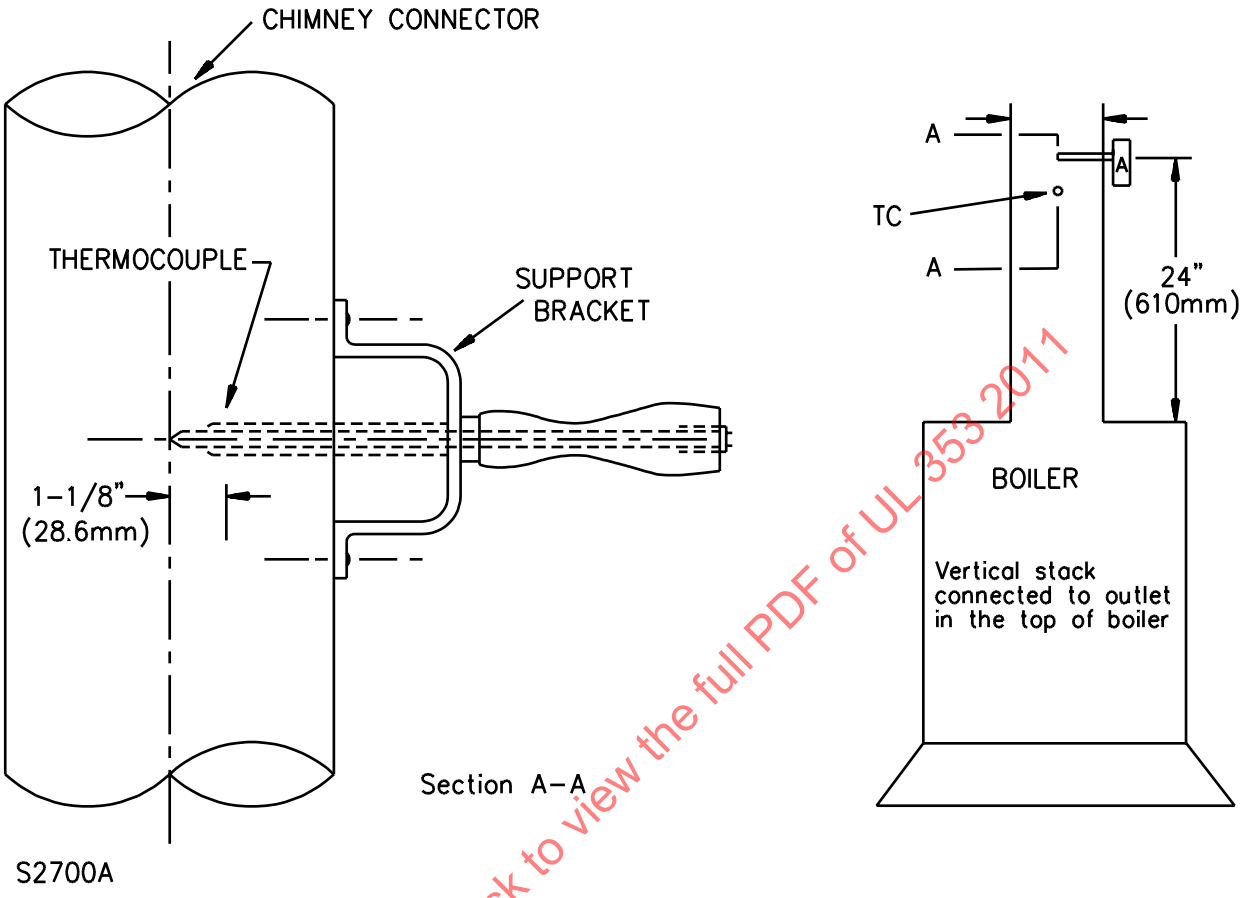
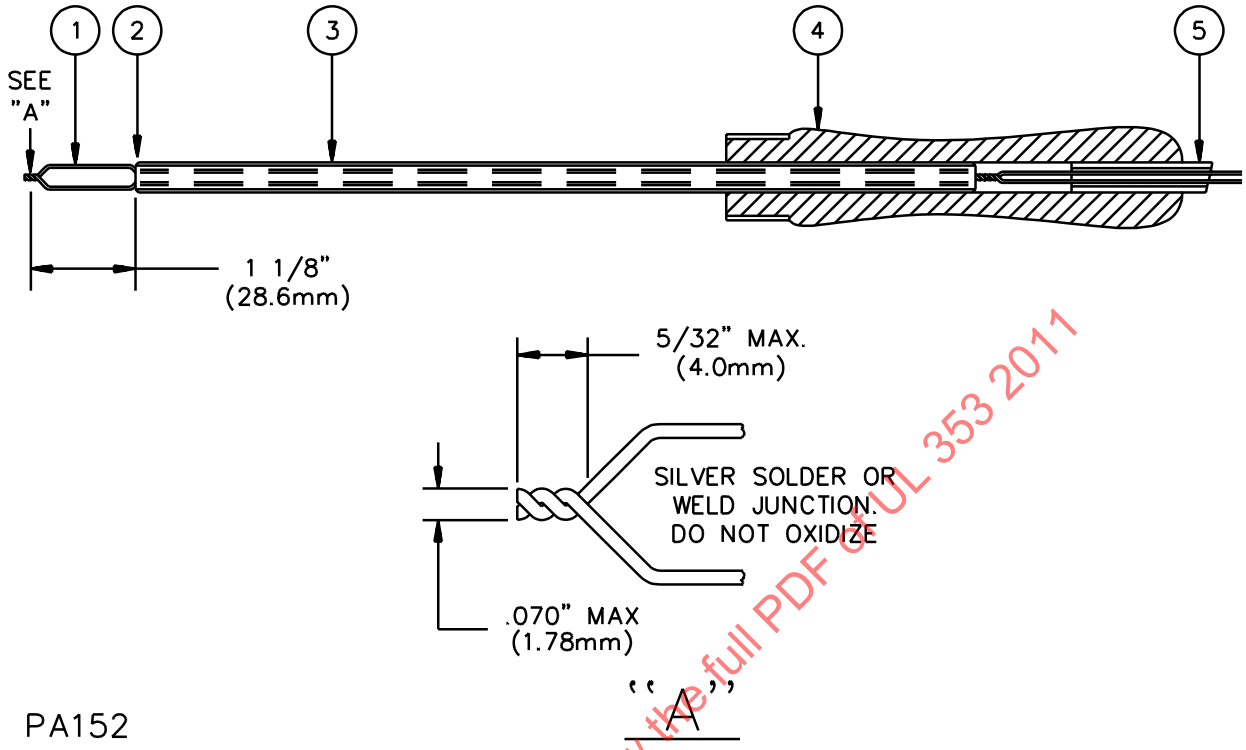


Figure 28.2
Thermocouple for flue-gas temperature

Figure 28.2 revised September 30, 2010



1. 20 AWG (0.51 mm^2) iron-constantan, asbestos, or woven-glass-covered thermocouple wires extending from hot junction to potentiometer or reference junction.

2. 1 – Leeds & Northrup Standard 714B, or equal 1/4 inch (6.4 mm) outside diameter of two-hole porcelain insulator cut to length and ends beveled on two sides.

3. 1 – 5/16 inch (7.9 mm) outside diameter by 0.032 inch (0.81 mm) wall tubing. Ream, if necessary, to fit over insulator; then crimp ends over beveled ends of insulator.

4. 1 – Small wooden handle.

5. 1 – Piece of rubber tubing, approximately 5/16 by 3/32 by 2 inches long (7.9 by 2.4 by 50.8 mm long).

6. In lieu of individual components described in (1), (2) and (3) above, any combination of preassembled parts of tubing, insulators and thermocouples may be used.

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29 Operation Tests

29.1 General

29.1.1 A pressure or temperature sensing control shall perform its intended function in accordance with the following. The allowable tolerances shall not be applied for the purpose of deliberately exceeding the maximum set point.

29.1.2 The operating temperature or pressure of the control is to be determined on representative production samples that have been produced and calibrated within the same tolerances representative of factory production. The set-point temperature or pressure of the sample is to be the maximum for which the device is intended.

29.1.3 For a control that employs multiple sets of electrical load-controlling terminals, each of which are individually adjusted for set-point temperature or pressure, each set of terminals shall operate in compliance with the requirements of 29.1.5 – 29.1.10. If all terminals are controlled by a single adjustment, the requirements specified in 29.1.5 – 29.1.10 shall apply to the terminals that operate to de-energize the circuit at the highest temperature or pressure.

29.1.4 For a control that employs single pole double throw (SPDT) electrical load-controlling terminals, the requirements specified in 29.1.5 – 29.1.10 shall apply to the terminals that are de-energized at the temperature or pressure increase.

29.1.5 The operating pressure of a pressure control, having a maximum rated set point of 0.1 inch (2.54 mm) water column or less, shall be within plus 100 and minus 50 percent of its maximum rated set point pressure. Following the Endurance Test, Section 31, the operating pressure shall not vary from the operating pressure initially determined by more than 20 percent of the maximum rated set point pressure.

29.1.6 The operating pressure of a control, having a maximum rated set point of greater than 0.1 inch (2.54 mm) water column, but less than 10 inch (254 mm) water column, shall be within ±20 percent of the maximum rated set point pressure. Following the Endurance Test, Section 31, the operating pressure shall not vary from the operating pressure initially determined by more than 20 percent of the maximum rated set point pressure.

29.1.7 The operating pressure of a pressure control having a maximum set point of greater than 10 inch (254 mm) water column, but less than 1 pound per square inch gauge (6.9 kPa) or less, shall be within ±10 percent of its maximum set point pressure. Following the Endurance Test, Section 31, the operating pressure shall not vary from the operating pressure initially determined by more than 10 percent of the maximum set point pressure.

29.1.8 The operating pressure of a pressure control having a set point above 1 pound per square inch gauge (6.9 kPa) shall be within plus or minus 5 percent of its maximum set point pressure. After being subjected to the Endurance Test, Section 31, the operating pressure shall not vary from the operating pressure initially determined by more than 5 percent of the maximum set point pressure.

29.1.9 The operating temperatures initially and after the Endurance Test, Section 31, for the various temperature-operated controls shall be in accordance with Table 29.1. Where variation is expressed in percent, it shall be based on degrees Fahrenheit.

29.1.10 For controls which have adjustable set points, the initial operating pressure or temperature shall be determined at the maximum and minimum set points and at a set point approximately midway between the maximum and minimum. For such controls the maximum variations, as specified in 29.1.7 and 29.1.8 and in Table 29.1 for the initial operating pressure or temperature, are applicable to the maximum set point. A 5 percent scale error, based on the maximum setting, may be applied to minimum and midway set points. This scale error may be in addition to the maximum variations.

Table 29.1
Temperature-operated controls

Type of control	Rated maximum operating temperature, degrees	Maximum variations in operating temperature[a]			
		Initial variation from rated operating temperature		After endurance test variation from initial operating temperature	
		In percent	In degrees	In percent	In degrees
Water Heater Limit	Any	–	5°F (2.8°C)	5	10°F (5.5°C)
Water Heater Regulating	Above 170°F (76.7°C)	–	7°F (3.9°C)	5	10°F (5.5°C)
Fan and Boiler or Warm Air Limit	Any	5	15°F (8.3°C)	5	–

[a] Where both the percent and degree variations are indicated, the greater value may be used for the maximum variation.

29.1.11 For a liquid level limit control which includes means for delaying the control action, the rated time delay shall be maintained in accordance with the following:

a) If the time-delay is provided by mechanical means, the observed time-delay shall not vary from the rated time-delay by more than 10 percent. After being subjected to the Endurance Test, the time-delay shall not vary from the time-delay initially determined by more than 5 percent.

b) If the time-delay is provided by electrical means (electrically heated bimetal, electronic circuit, etc.,), the observed time-delay shall not exceed the rated time-delay by more than 10 percent when the control is tested under the conditions of rated voltage and frequency (see Table 27.1) and normal ambient temperature. When tested in ambients ranging from 32°F (0°C) to 150°F (66°C) and with input voltage ranging from 85 to 110 percent of rated voltage, the maximum observed time-delay under a combination of any voltage and ambient temperature between these limits shall not be more than 150 percent of the time-delay observed at rated voltage and ambient temperature. After being subjected to the Endurance Test, the time-delay shall not vary from the time-delay initially determined by more than 5 percent.

29.1.12 Unless otherwise specified by the manufacturer, the normal ambient temperature for the purpose of tests indicated in 29.1.11 is assumed to be room temperature maintained between the limits of 70°F (21°C) and 77°F (25°C).

29.1.13 A temperature or pressure-operated control is to be cycled at least:

a) Twice immediately before determining its operating temperature or pressure in accordance with 29.2 – 29.4; and

b) Twice before and after the appropriate endurance (cycling tests), see Endurance Test, Section 31.

29.1.14 The cycling specified in 29.1.13 is to be accomplished by starting at room temperature for temperature-operated controls and at atmospheric pressure for pressure-operated controls. If the control has an adjustable setting, the set-point is to be adjusted to the maximum temperature or pressure setting unless the control is a vacuum-operated pressure type, in which case it is to be adjusted to the minimum setting. The temperature (for temperature-operated controls) is to be increased in accordance with 29.2.1 or 29.3.2 or the pressure (for pressure-operated controls) is to be increased or decreased in accordance with 29.4.1 until the control operates. The temperature or pressure then is to be decreased (or increased) to the reset temperature or pressure and the cycle then is to be repeated.

29.1.15 The operating temperature or pressure of controls is to be determined in accordance with 29.2.1 – 29.4.1, as appropriate. Two trials are to be made at each setting. If the operating temperatures or pressures of the two trials are not within 1 percent of each other, a third trial is to be made and averaged with the first two trials. This average is to be considered as the operating temperature or pressure of the set-point.

29.2 Test of immersion-type temperature-operated control

29.2.1 A temperature-operated control having a sensing element intended to be immersed in a liquid, or in a well to be immersed in a liquid, is to be tested with the element or well immersed as intended in a liquid bath which is agitated to maintain uniform temperatures. A control for air or gas may be tested using either a forced air circulating warm-air oven of the type described in 28.2.2, or the liquid bath if appropriate to the design of the control. The control is to be mounted with only the sensing element or the entire control immersed in the test medium, whichever is appropriate. In all cases equilibrium conditions of temperature prior to the start of the test are to be established at a level approximately 20°F (11.1°C) below the anticipated set point value. The temperature of the test medium is then to be increased at a rate not in excess of 1°F (0.6°C) per minute until the control functions. The temperature of the test medium at the instant the control functions is to be considered the set point.

29.2.1 revised September 28, 1995

29.3 Test of surface-mounted temperature-operated control for hot-water heating systems

29.3.1 A surface-type temperature-operated control for hot-water heating systems is to be mounted as described in the manufacturer's instructions. The appropriate test apparatus described for the Temperature Test of such controls, 28.3.2 – 28.3.5, is to be used except if the control is intended for hot-water heating systems limited to 250°F (121°C) maximum, the control is to be applied to the outside surface of a vertical section of nominal 1 inch (ANSI B36.10M) black iron pipe.

29.3.2 The circulating system is to be arranged to raise the temperature of the water in the system at the maximum rate of 1°F (0.6°C) per minute from a temperature 20°F (11.1°C) below the indicated set point of the control to a temperature sufficient to cause the control to function. The temperature of the water measured at the elevation of the control at the instant the control functions is to be considered the set point.

29.4 Test of pressure-operated control

29.4.1 A pressure-operated control is to be connected to a source of aerostatic or hydrostatic pressure whichever is consistent with its intended use. The source of pressure is to be capable of being accurately controlled and measured. During the test, pressures near the set point are to be increased or decreased at a maximum rate of 1/2 pound per square inch gauge (3.5 kPa) per minute.

29.5 Test of electromagnet

29.5.1 An electromagnet for use on dc shall be able to withstand 10 percent above its rated voltage continuously without damage to the operating coil and to operate successfully at 20 percent less than rated voltage. A control having a voltage rating within one of the ranges given in Table 27.1 shall be tested at the test voltage specified in that table.

29.5.2 An electromagnet for use on ac shall be able to withstand 10 percent above its rated voltage continuously without damage to the operating coil and to operate successfully at 15 percent less than rated voltage. A control having a voltage rating within one of the ranges given in Table 27.1 shall be tested at the test voltage specified in that table.

29.5.3 For the operation at minimum voltage, the coil is to be subjected to the normal high-voltage until equilibrium temperature is reached and then tested immediately for operation at the minimum voltage.

30 Overload Test

30.1 An ampere-rated switch not intended for controlling a motor shall be capable of performing 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 indicated in Table 27.1. There shall be no electrical or mechanical failure of the device, nor undue burning, pitting, or welding of the contacts.

30.2 Except as noted in 30.6 and 30.7 a switch intended for full-voltage motor starting shall be capable of performing 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 the following paragraphs, at the voltage indicated in Table 27.1. There shall be no electrical or mechanical failure of the device, nor undue burning, pitting, or welding of the contacts.

30.3 The current for the Overload Tests mentioned in 30.2, 30.6, and 30.7 is to be as indicated in Table 30.1.

Table 30.1
Method of determining currents for overload tests

Device rated in	Current in amperes for overload test described in paragraph indicated	
	Locked rotor test[a]	150 percent current test[b]
Horsepower (kW)	AC: Six times the full-load current indicated in Table 30.3 DC: Ten times the full-load current indicated in Table 30.2	AC: 1.5 times the full-load current indicated in Table 30.3 DC: 1.5 times the full-load current indicated in Table 30.2
Full-load and locked-rotor amperes	Rated locked-rotor amperes	1.5 times rated full-load amperes

[a] 30.2, 30.6 and 30.7.
[b] 30.6 and 30.7.

30.4 A control designed for pilot duty shall be capable of performing 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 indicated in Table 30.1 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 for which the control is rated, the normal current to be determined from the voltage and volt-ampere rating of the device. The test coils shall be those described in 31.4. The test shall be conducted with the contactor free to operate, i.e., not blocked in either the open or closed position. There shall be no electrical or mechanical failure of the device nor undue pitting or burning of contacts.

30.5 A control which has been tested and found suitable for controlling an alternating-current motor is acceptable for alternating-current pilot duty without further overload or endurance tests provided that:

a) During the locked-rotor test, 30.2, 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 indicated in the second column of Table 28.1 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:

1) The rated locked-rotor motor current of the device, or

2) The locked-rotor current corresponding to the horsepower rating, depending on the basis on which the device is rated.

30.6 A switch which is not intended primarily to make and break motor current under locked-rotor conditions, but which has a manual adjusting or regulating means which may cause it to be used, shall comply with the requirements of 30.2 for a locked-rotor test; except that, for such a switch intended for operation on dc, the number of operations shall be five, conducted at intervals of 30 seconds, and the switch shall also comply with the requirements of 30.7 pertaining to the 150 percent overload test.

30.7 A switch which may make a motor circuit under locked-rotor conditions, but which will not be called upon to break the circuit under such conditions, shall be capable of performing 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 indicated in the third column of Table 30.1. For an ac control, the voltage of the test circuit shall have the value indicated in Table 30.1. For a dc control, it shall be 50 percent of that value. The switch shall also be subjected to the locked-rotor test described in 30.2, except that it is to make (not break) the circuit only. There shall be no electrical or mechanical failure of the device, no undue burning, pitting, or welding of the contacts.

30.8 The test cycle is to be 1 second on and 9 seconds off, if the nature of the control permits the test to be so made.

30.9 If an ampere-rated control has the same ampere rating at more than 1 voltage, a test at the highest voltage is considered to be representative of tests at the lower voltages; but if the control has a greater ampere rating at the lower voltage than at the higher ones, tests are to be made at the highest and lowest voltages.

30.10 If a horsepower-rated control has more than 1 voltage rating, the Overload Test is to cover the conditions of maximum voltage, power, and current. A separate control is to be used for testing each condition.

30.11 Except as noted in 30.4 and 31.4, a current-interrupting control for use on dc shall be tested with a noninductive resistance load. A current-interrupting control for use on ac shall be tested with an inductive load.

30.12 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.

30.13 Tables 30.2 and 30.3 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 30.2
Full-load motor-running currents in amperes corresponding to various d-c horsepower (kw output) ratings

Horse-power	Rating (kW)	Volts 110 – 120	Volts 220 – 240	Volts 550 – 600
1/10	(0.08)	2.0	1.0	–
1/8	(0.09)	2.2	1.1	–
1/6	(0.13)	2.4	1.2	–
1/4	(0.19)	2.9	1.5	–
1/3	(0.25)	3.6	1.8	–
1/2	(0.37)	5.2	2.6	–
3/4	(0.56)	7.4	3.7	1.6
1	(0.75)	9.4	4.7	2.0
1-1/2	(1.12)	13.2	6.6	2.7
2	(1.49)	17.0	8.5	3.6
3	(2.24)	25.0	12.2	5.2
5	(3.73)	40.0	20.0	8.3

Table 30.3
Full-load motor-running currents in amperes corresponding to various a-c horsepower (kw output) ratings

Horse-power	(kW)	110 – 120 volts			220 – 240 volts			440 – 480 volts		550 – 600 volts	
		Single-phase	Two-phase	Three-phase	Single-phase	Two-phase	Three-phase	Two-phase	Three-phase	Two-phase	Three-phase
1/10	(0.08)	3.0	–	–	1.5	–	–	–	–	–	–
1/8	(0.09)	3.8	–	–	1.9	–	–	–	–	–	–
1/6	(0.13)	4.4	–	–	2.2	–	–	–	–	–	–
1/4	(0.19)	5.8	–	–	2.9	–	–	–	–	–	–
1/3	(0.25)	7.2	–	–	3.6	–	–	–	–	–	–
1/2	(0.37)	9.8	4.0	4.0	4.9	2.0	2.0	1.0	1.0	0.8	0.8
3/4	(0.56)	13.8	4.8	5.6	6.9	2.4	2.8	1.2	1.4	1.0	1.1
1	(0.75)	16.0	6.4	7.2	8.0	3.2	3.6	1.6	1.8	1.3	1.4
1-1/2	(1.12)	20.0	9.0	10.4	10.0	4.5	5.2	2.3	2.6	1.8	2.1
2	(1.49)	24.0	11.8	13.6	12.0	5.9	6.8	3.0	3.4	2.4	2.7
3	(2.24)	34.0	16.6	19.2	17.0	8.3	9.6	4.2	4.8	3.3	3.9
5	(3.73)	56.0	26.4	30.4	28.0	13.2	15.2	6.6	7.6	5.3	6.1

30.14 Except as noted for a dc control in 30.7 and 31.1, all current-interrupting tests are to be made at the voltage indicated in Table 27.1. The open-circuit voltage of the supply circuit is to be not less than 100 percent nor more than 105 percent of the specified test voltage, except that a higher voltage may be employed if agreeable to those concerned. The current-carrying capacity of the supply circuit is to be such that the closed-circuit voltage with rated current flowing is within 2-1/2 percent of the specified test voltage.

30.15 For a grounded neutral system, 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 shall be connected through such a fuse to the live pole least likely to strike (arc) to ground. The fuse shall not blow during the test.

31 Endurance Test

31.1 Relocated as 31.1.2 April 30, 2001

31.1.1 The tests described in 31.1.2 – 31.5 are for testing the contacts of electromagnetic relays and other non-electronic switching devices. These conditions are able to be used to test the complete controls or the switching devices separately, when the switching devices are combined with electronic circuits that need to be evaluated to the thermal cycling test, in accordance with Section 31C.

Added 31.1.1 effective April 30, 2004

31.1.2 A control shall perform as intended when operated manually, thermally, by pressure or by means of, an automatic cycling device, as appropriate, for the number of cycles indicated in 31.2. The cycling rate is to be 6 cycles per minute, unless the nature of the control requires a longer time to complete a cycle of operation or a different cycling rate is specified in 31.3. If an electrical load is involved, this test is to be preceded by the Overload Test, Section 30. During the Endurance Test and except as otherwise noted, a switch shall make and break its rated current at the voltage indicated in Table 27.1. 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 30.2 or 30.3, whichever is applicable. If the switch contacts control a dc motor and in the intended application the switch will make but not break the motor circuit under locked-rotor condition, the potential of the test circuit is to be 50 percent of the value indicated in Table 27.1. The control shall be mechanically and electrically operable at the conclusion of the test and shall perform its intended function.

31.1 relocated as 31.1.2 April 30, 2001

31.2 The condition for the Endurance Test shall be as described in 30.8 – 30.15. The Endurance Test for controls shall consist of at least 30,000 cycles for a fan control or temperature regulating control for water heaters and at least 100,000 cycles for other automatic-reset controls. A manual-reset control shall be tested at least 6000 cycles; 1000 cycles with current and 5000 cycles without current.

31.3 Magnetic, manual, and motor-operated switches may be tested at the rate of 6 cycles per minute. Temperature- and pressure-operated switches shall be operated by temperature or pressure as appropriate, at the rate indicated in Table 31.1, unless the contacts of such switches are always operated by snap action, regardless of the rate of temperature or pressure increase or decrease and prior to the snap action there is no loss of contact pressure. Snap action switches may be operated at the same rate as magnetic, manual, and motor-operated switches.

31.4 A switch designed for pilot duty shall be capable of performing acceptably when operated for the number of cycles indicated in 31.2, making and breaking a circuit of rated frequency and at the voltage indicated in Table 27.1. Unless the nature of the control requires a longer time to complete a cycle of operation or a different cycling rate is specified by 31.3, the rate of speed of operation for the test shall be as follows: for a manually operable control, the first 1000 cycles shall be at the rate of 1 cycle per second (except that the first 10 or 12 operations shall be made as rapidly as possible) and the remaining cycles shall be at the rate of 6 cycles per minute, with the switch closed for approximately 1 second each cycle; and for a self-actuated control, the entire number of cycles shall be at the rate of 6 cycles per minute, with the switch closed for approximately 1 second each cycle. The load shall consist of an electromagnet representative of the magnet-coil load intended to be controlled, the normal current to be determined from the voltage and volt-ampere rating of the control. The test current shall be the normal current, and for an ac rating, the power factor shall be 0.35 or less and, unless a different inrush current is specified in accordance with 44.2(a), the inrush current shall be ten times the normal current. The test shall be conducted with the contactor free to operate, i.e., not blocked either open or closed. There shall be no electrical or mechanical failure of the control nor undue pitting or burning of contacts.

Table 31.1
Number of cycles and cycling rate for endurance test

Type of control	Total number of cycles of operation		Cycling rate			
			First portion of test		Second portion of test	
	With current	Without current	No. of cycles	Maximum cycles per minute	No. of cycles	Maximum cycles per minute
Automatic-Reset	100,000	–	75,000	6	25,000	1[a]
Fan and Temperature Regulating Controls	30,000	–	24,000	6	6,000	1[a]
Manual Reset	1,000	5,000	1,000[b]	1[a]	5,000	6

[a] The test shall be conducted with 50 ±20 percent "on" time obtained by slow rate of change of temperature or pressure.

[b] The test shall be conducted with current.

31.5 If a control requiring an endurance test of 100,000 cycles has two or more electrical ratings (i.e., different currents at different voltages) which are approximately equal in volt-amperes, it may be tested for not less than 25,000 cycles at each rating, but the total number of cycles on any one sample shall be not more than 100,000. At least one sample, however, is to be tested for a total of 100,000 operations. Similarly, a control requiring an Endurance Test of 30,000 cycles is to be tested for not less than 7500 cycles at each rating.

31A Failure Mode Effect Analysis (FMEA) Procedures

Added 31A effective April 30, 2004

31A.1 In order to determine compliance with 4B.2, a control that includes electronic circuits and components is to be subjected to a component failure mode effect analysis in accordance with 31A.2 – 31A.5. A control complies with the requirements when, with one component faulted, it operates in accordance with (a) or (b).

a) The control continues to operate normally within the declared timings and sequence. In this event, the component is to be left in the failed state and a second component is to be faulted (see 31A.5) until all circuit components are faulted, one at a time, in conjunction with the original faulted component. The control shall either continue to operate within the declared timings and sequence or (b) shall occur.

b) The control operates to de-energize its load contacts associated with the controlled circuit immediately.

31A.2 For this analysis, the control is to be at a room temperature of 25 ±5°C (77 ±9°F) and energized at rated voltage. Tests are also to be conducted at 85 percent and 110 percent of rated voltage and in rated high and low ambients when it is observed that introduction of faults is able to affect the control programming and response timings.

31A.3 Except as stated in 31A.1(a), faults are to be introduced to one component at a time, and observations for each fault are to be continued long enough to determine the ultimate effect. The faults in Table 31A.1 are to be evaluated.

Table 31A.1
Electrical faults

Component	Type of fault	
	Open circuit	Short circuit
Resistor		
Thin film	yes	no
Metal film	yes	no
Wire wound	yes	no
All others	yes	yes
Capacitors	yes	yes
Diodes	yes	yes
Transistors		
Each pin connection to circuit[a]	yes	Not applicable
Pins to each other[b]	Not applicable	yes
Intergrated circuits		
Each pin connection to circuit[a]	yes	Not applicable
Adjacent pins to each other[b]	Not applicable	yes
Each pin to referenced ground[a]	Not applicable	yes
Each pin to power supply[a]	Not applicable	yes
Relay coils	yes	no

[a]One pin at a time only.
[b]One pair of the pins at a time only.

31A.4 When faulting of a component damages the component or other components and renders the circuit inoperable after the fault is removed, the damaged components are to be replaced for analysis of other faults.

31A.5 With respect to 31A.1(a) when two or more components are provided for redundancy, in case of a fault of a single component, only one of the redundant components is to be faulted at a time, when:

a) The failure of one of the components does not electronically overload the others; and

b) A single fault occurring in the circuit does not introduce a faulted condition to redundant components.

31B Mains Borne Perturbations, Magnetic and Electromagnetic Disturbances

Added 31B effective April 30, 2004

31B.1 General

31B.1.1 The controls that include solid-state circuits or components are to be subjected to the tests specified in the Standard For Tests For Safety-Related Controls Employing Solid-State Devices, UL 991, using the test parameters and conditions specified in 31B.1.2 – 31B.7.3.

31B.1.2 After each test, the control shall comply with either (a) or (b):

a) The control continues to operate within its ratings and normal operating sequence; or

b) The control immediately operates to de-energize its output associated with the limit circuit.

Operating normally means that when the control senses the abnormal condition, it will de-energize its output associated with the limit circuit. Once a safe condition is restored, the control will automatically reset or will require a manual reset to initiate operation again.

31B.1.3 The determination for normal operation is to be made with the control operating in an ambient temperature of 25 ±5°C (77 ±9°F) and at rated voltage. Tests are also to be conducted at 85 percent and 110 percent of rated voltage and in rated high and low ambient temperatures, when it is observed that introduction of the disturbances affect the control operation.

31B.1.4 A separate sample is to be used for each test, unless all parties agree that multiple tests are to be performed on a single sample. When a single sample is used, it is to be determined that the control operates in its normal operating sequence and at declared ratings after each test . See 31B.1.3.

31B.2 Voltage dips and interruptions

31B.2.1 After the application of each voltage dip or voltage interruption, as described in 31B.2.2 and 31B.2.3, the control shall comply with the criteria specified in Tables 31B.2 and 31B.3, as applicable, for the specific operating sequence during which the dip or the interruption was applied.

31B.2.2 The control is to be initially operated at its rated voltage and then subjected to instantaneous voltage dips and voltage interruptions in accordance with 31B.2.3 and Table 31B.1.

Table 31B.1
Voltage dip and interruptions test

Test	Test Conditions	
	Percent of dip based on rated voltage	Duration of dip or interruption
Voltage dips	30	0.5 second
	60	0.5 second
Voltage interruptions	100	1/2 and 1 cycle of supply waveform
	100	0.5 second
	100	60 seconds

31B.2.3 Each voltage dip or voltage interruption test is to be performed three times in each of the following operating conditions:

a) During the standby time, if applicable;

b) During the normal running condition, with the control sensing normal conditions (i.e. the control has not sensed an abnormal condition to cause the control to remove power from the safety contacts); and

c) While the control is sensing an abnormal condition, such as low water, high temperature, high pressure, or similar condition.

Table 31B.2
Required performance for voltage dip tests

Voltage dip applied during the operating sequence indicted by the referenced item of 31B.2.3	Required performance as indicated by the referenced item of 31B.1.2	
	30 percent of rated voltage	60 percent of rated voltage
(a)	(a)	(a), (b)
(b)	(a)	(a), (b)
(c)	(a)	(a)

Table 31B.3
Required performance for voltage interruption tests

Voltage interruption applied during the operating sequence indicated by the referenced item of 31B.2.3	Required performance as indicated by the referenced item of 31B.1.2		
	1/2 and 1 cycle of waveform	0.5 second	60 seconds
(a)	(a)	(a),(b)	(b)
(b)	(a)	(a),(b)	(b)
(c)	(a)	(a)	(a)

31B.3 Ramp voltage tests

31B.3.1 After each of the tests in 31B.3.2 and 31B.3.3, the control shall operate in accordance with any of the applicable operating conditions specified in 31B.1.2.

31B.3.2 Each control is to be subjected to a gradual input voltage increase, starting initially with the voltage reduced to 20 percent of rated input. The voltage is then continuously increased to rated voltage, at the rate of 40 percent of rated voltage per second. This test is to be repeated three times, in each of the operating conditions specified in 31B.2.2.

31B.3.3 Each control is to be subjected to a gradual voltage decrease. Starting with the rated voltage, the input is to be decreased to 20 percent of rated voltage, at the rate of 40 percent of rated voltage per second. This test is to be repeated three times, in each of the operating conditions specified in 31B.2.2.

31B.4 Voltage/current surge tests

31B.4.1 After each of the Severity Level I tests for low voltage controls and Severity Level II tests for line voltage controls, the controls shall operate in accordance with 31B.1.2(a). After each of the Severity Level II tests for low voltage controls and Severity Level III tests for line voltage controls, the controls shall operate in accordance with any one of the criteria specified in 31B.1.2.

31B.4.2 Each control is to be tested using the unidirectional wave surge generator circuit and waveshapes shown in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. For the Transient Overvoltage Test and under the severity levels specified in 31B.4.3, each control is to be subjected to five (5) impulses at each polarity, plus (+) and minus (-), applied in turn, between the power supply terminals of the control and between each of the load terminals, at intervals not less than 60 seconds. For these tests, the control is to be energized at rated voltage. Half of the tests are to be conducted with the control in the abnormal condition and the other half during other operating sequences which are determined to be most affected by the voltage or current surges.

31B.4.3 Both the low voltage and line voltage rated controls are to be tested at two of the severity levels of the peak values of open-circuit voltage and short-circuit current of the surges, in accordance with Table 31B.4.

Table 31B.4
Maximum input

Maximum rated input voltage,	Peak value of the surges					
	Severity Level I		Severity Level II		Severity Level III	
V	kV	kA	kV	kA	kV	kA
30	0.5	0.25	0.8	0.4	+	+
300	+	+	1.6	0.8	2.5	1.25

31B.5 Ring wave test

31B.5.1 The ring wave test is to be conducted under the same conditions as the voltage/current surge tests in 31B.4, except a ring wave generator is to be used. The ring wave generator is to produce a wave form consisting of a pulse with a rise time of 0.5 microsecond, followed by an oscillation at 100 kHz with a decrement such that each peak is 60 percent of the preceding peak.

31B.5.2 The severity levels, based on the rated input voltages and the peak voltage of the pulse, shall be the same as specified in 31B.4.2.

31B.5.3 After each of the Severity Level I tests for low voltage controls and Severity Level II tests for line voltage controls, the controls shall operate in accordance with 31B.1.2(a). After each of the Severity Level II tests for low voltage controls and Severity Level III tests for line voltage controls, the controls shall operate in accordance with any one of the criteria specified in 31B.1.2.

31B.6 Electrostatic discharge tests

31B.6.1 Each control is to be subjected to electrostatic-discharge tests, in accordance with the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, except as described in 31B.6.2 and 31B.6.3. After each of the Severity Level I tests, the controls shall operate in accordance with 31B.1.2(a). After each of the Severity Level II tests, the controls shall operate in accordance with any one of the criteria specified in 31B.1.2.

31B.6.2 Each control is to be subjected to five sequences of discharges at two severity levels of voltage ranges. At Severity Level I, the range is to be 2.0 to 5.0 kV, ±5 percent. At Severity Level II, the range is to be 2.0 to 15.0 kV, ±5 percent. The discharges are to be applied to all accessible surfaces, including surfaces which are accessible after detachment of parts that need to be removed for installation of the control. The discharge electrode tip is to be moved as fast as possible toward the control.

31B.6.3 Two of the five discharges are to be applied with the control in the abnormal condition. The remaining three discharges are to be applied with the control in operating sequences which are determined to be most affected by the discharges.

31B.7 Radiated electromagnet field test

31B.7.1 Each control is to be subjected to tests in accordance with Radiated EMI Tests in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, except as described in 31B.7.2.

31B.7.2 Each control is to be subjected to two sweeps of the frequency range of 27 MHz to 500 MHz at two severity levels of the field strength. At Severity Level I, the field strength is to be 3 volts/meter. At Severity Level II, the field strength is to be 10 volts/meter.

31B.7.3 One of the sweeps is to be conducted while the control is in the abnormal condition. The other sweep is to be conducted with the control operating in a sequence which is determined to be most affected by the electromagnetic radiation.

31B.7.4 After each of the Severity Level I tests, the controls shall operate in accordance with 31B.1.2(a). After each of the Severity Level II tests, the controls shall operate in accordance with any one of the criteria specified in 31B.1.2.

31C Thermal Cycling Test for Electronic Devices

Added 31C effective April 30, 2004

31C.1 Controls employing electronic circuits or devices shall be subjected to a 14-day thermal cycling test as described in 31C.2 – 31C.5.

31C.2 The control is to be tested in a chamber in which the ambient temperature is able to be varied between the minimum and maximum operating temperatures declared by the manufacturer, in accordance with 31C.3. During the test, the control is to be energized at 110 percent of rated voltage, except that for 30 minutes during each 24 hour period, the voltage is to be reduced to 90 percent of rated voltage. The change in voltage is not to be synchronized with a change in ambient temperature. The load terminals of the control are to be connected to the maximum rated loads, as declared by the manufacturer.

31C.3 The rate of change in the ambient temperature, as specified in 31C.2, is to be 2°F (1°C) per minute. When the minimum or maximum ambient temperature is reached, that temperature is to be maintained for one hour before initiating another change.

31C.4 During the test, the control is to be cycled through its normal operational modes of start-up, flame sensing, and shutdown, at the fastest rate possible, up to a maximum of six operating cycles per minute.

31C.5 When agreeable to all parties concerned, and upon request, the testing of the contacts of the non-electronic switching devices shall be combined with the test described in 31C.1 – 31C.3. For this, the number of cycles accumulated during the test in 31C.1 – 31C.3 shall be recorded. After completion of the 14-day test, the test voltage is to be adjusted to rated voltage, and the test temperature is to be maintained at the manufacturer's declared maximum ambient rating. The test is then to be continued, and a total of 100,000 cycles of operation is to be accumulated.

32 Dielectric Voltage-Withstand Test

32.1 High-voltage portions of a control shall be capable of withstanding for 1 minute without breakdown the application of a 60 cycle alternating potential of 1000 volts plus twice maximum rated voltage of the circuits involved:

a) Between uninsulated high-voltage live parts and grounded or exposed metal parts or the enclosure with the contacts open and closed;

b) Between high-voltage terminals of opposite polarity with the contacts closed;

c) Between uninsulated high-voltage live parts and components of circuits classified under Column C in Table 18.1 or as low-voltage;

d) Between uninsulated metal parts of one high-voltage circuit and such parts of another high-voltage circuit; and

e) Between uninsulated live parts of a circuit classified under Column C of Table 18.1 and components of any other circuit.

32.2 A control employing an isolated limited secondary circuit shall be capable of withstanding for 1 minute without breakdown the application of an alternating potential of 1000 volts plus twice the maximum rated secondary voltage, at rated frequency, between all uninsulated live parts connected to the secondary circuit and grounded dead-metal parts.

32.3 Liquid-level electrode assemblies for boilers shall conform to 32.1 and also to the following:

a) Three assemblies in the as-received condition, are to be tested to dielectric breakdown between live parts and grounded-metal parts.

b) Three additional assemblies are to be tested to dielectric breakdown between live parts and grounded-metal parts after conditioning for ten days at maximum rated service conditions (temperature and pressure).

32.4 The dielectric withstand of the assemblies tested after conditioning shall be comparable to the dielectric withstand of the assemblies tested in the as-received condition.

32.5 A control employing a low-voltage circuit shall be capable of withstanding for 1 minute without breakdown the application of a 60 cycle alternating potential of 500 volts applied between uninsulated low-voltage live parts of opposite polarity (with contacts, if any, closed), and between uninsulated low-voltage live parts and the enclosure and grounded dead-metal parts.

32.6 Within a portion of a circuit that is low-voltage and nonsafety, beyond any fixed impedance as described in 2.6(b), the opposite polarity dielectric voltage-withstand test may be omitted.

32.7 A Class 2 transformer shall be capable of withstanding without breakdown, for a period of 1 minute, 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.

32.8 A power transformer shall be capable of withstanding without breakdown, for a period of 1 minute, 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 be capable of withstanding 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 in the case of an autotransformer.

32.9 If a barrier or liner is employed to insulate an exposed dead-metal part, the control shall be capable of withstanding a Dielectric Withstand Test as indicated in 32.1 between uninsulated live parts and the exposed dead-metal part. See also note (c) of Table 18.1.

32.10 If a control includes a meter or meters, such instruments shall be disconnected from the circuit and tested separately.

32.11 The insulation on a flexible pigtail lead for a high-voltage circuit or for a low-voltage safety-control circuit where failure may cause unsafe operation shall be capable of withstanding for 1 minute without breakdown, when dry, an alternating potential of 1000 volts plus twice maximum rated voltage; and after exposure to moist air, such a lead shall be capable of withstanding without breakdown an alternating potential of rated voltage plus 500 volts. A flexible pigtail lead for other low-voltage circuits shall comply with the requirement of 32.4.

32.12 A lead which is to be tested dry is to be conditioned for 24 hours in a desiccator with dry calcium chloride; and a lead which 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 (89.6 ±3.6°F).

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