UL 244A

STANDARD FOR SAFETY

Solid-State Controls for Appliances

UL Standard for Safety for Solid-State Controls for Appliances, UL 244A

Third Edition, Dated April 30, 2003

SUMMARY OF TOPICS

The revisions to UL 244A dated August 15, 2013 are being issued to adopt the following proposals:

1. Addition Of The Abnormal Operations Test

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The new requirements are substantially in accordance with Proposal(s) on this subject dated April 12, 2013.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.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 244A

Standard for Solid-State Controls for Appliances

First Edition – February, 1986
Second Edition – January, 1994

Third Edition

April 30, 2003

This UL Standard for Safety consists of the Third Edition including revisions through August 15, 2013.

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 component electronic controls intended to be factory installed on or in appliances and other utilization equipment rated 600 V or less, used in ordinary dry locations as defined in the National Electrical Code, NFPA 70, and that comply with the requirements for such appliances and equipment.

1.2 For a control covered by this standard, it is assumed that:

a) No voltage greater than 600 V above ground will be present in a control,

b) An isolation transformer, if provided, will generally furnish power at a lower potential than the primary voltage, and

c) The output of the control will not be located in a circuit operating at greater than 600 V above ground in the end-use product.

If conditions other than these are provided, consideration shall be given to the need for additional requirements.

1.3 A control covered by this standard is a single device or a series of separate components with interconnecting wiring employing one or more input power and possibly signal ports, solid-state circuitry, and one or more output switching components to directly control all or a portion of the end-use product load. Included are controls that respond directly or indirectly to changes in temperature, humidity, or pressure to affect operation of an appliance, function as an electronic timer, or electronically store or process information by virtue of a memory system.

1.4 These requirements cover controls intended for connection only to a low-voltage circuit of limited power supplied by a primary battery or by a Class 2 transformer, where a failure of such a control would result a risk of fire, electric shock, or injury to persons in the end-use product.

1.5 These requirements do not cover a control intended for installation in or on refrigeration or air conditioning equipment that is used in industrial applications or in hazardous locations as defined in the National Electrical Code, NFPA 70. Such equipment is covered in the Standard for Temperature-Indicating and -Regulating Equipment, UL 873. Compliance with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series fulfills these requirements.

1.5 revised March 4, 2010. UL 873 will be withdrawn on October 19, 2016.

1.6 These requirements do not cover controls for use where exposed to oil, grease vapors, lint, other contaminants, or high humidity in the end application.

1.7 These requirements address the potential risks unique to the electronic nature of a control. Equipment or components employing an electronic feature shall also comply with the basic requirements contained in the applicable end-product or component standard. These requirements are intended to supplement applicable end-product or component standards and are not intended to serve as the sole basis for investigating all risks associated with a control. For example, requirements for the means of enclosing live parts, mechanical assembly of components, corrosion protection, use of polymeric materials, evaluation of internal wiring and connections within the control, calibration, and similar requirements, are not included in this standard.

2 Undated References

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

3 Glossary

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

3.2 CLASS 2 CIRCUIT – An isolated secondary circuit involving a potential of not more than 42.4 V peak supplied by:

a) An inherently-limited Class 2 transformer;

b) A combination of an isolated transformer secondary winding and a fixed impedance or regulating network that together comply with the performance requirements for an inherently-limited Class 2 transformer;

c) A dry-cell battery having output characteristics not greater than those of an inherently-limited Class 2 transformer;

d) Any combination of (a), (b), and (c) that together comply with the performance requirements for an inherently-limited Class 2 transformer; or

e) One or more combinations of a Class 2 transformer and an overcurrent protective device that together comply with the performance requirements for a noninherently-limited Class 2 transformer.

A circuit derived from a line-connected circuit by connecting impedance in series with the supply circuit as a means of limiting the voltage and current is not a Class 2 circuit. See Class 2 Circuits, Section 20.

3.3 CONFORMAL COATING – An insulating coating which conforms to the configuration of the object coated and is used as a protective covering against environmental conditions or when electrical spacings are insufficient.

3.4 CONTROLLED ENVIRONMENT – An environment:

a) Relatively free of conductive contaminants, such as normal cooking vapors, carbon dust, and similar contaminants, which are a result of the end-use product in which a control will be installed or due to the location of the end-use product, and

b) Not subject to humidity and the formation of condensation. A controlled environment is provided, for example, by means of a:

1) Hermetically sealed enclosure;

2) Encapsulation;

3) A conformal coating; or

4) A gasketed, tight-fitting enclosure or filter system preventing contamination in conjunction with a system preventing condensation –for example, the maintaining of the surrounding air at constant temperature and a suitably low relative humidity.

3.5 DEAD-CASE-MOUNTED SEMICONDUCTOR – A semiconductor, such as a triac or silicon-controlled rectifier, employing an integral metal tab or stud that is insulated from live parts.

3.6 ELECTRICAL STRESS FACTOR – For a circuit component, the ratio of operating electrical stress to rated electrical stress. Examples include the ratio of operating wattage to maximum rated wattage of a resistor and operating voltage to maximum rated voltage of a capacitor. A circuit component having no assigned maximum operating electrical rating is made the subject of an investigation.

3.7 HAZARDOUS ENERGY – Circuit energy that involves a risk of fire or electric shock.

3.8 ISOLATED SECONDARY CIRCUIT – A circuit derived from an isolated secondary winding of a transformer and that has no direct connection back to the line-connected circuit, other than through the grounding means. A secondary circuit that has a direct connection back to the line-connected circuit is considered part of the line-connected circuit.

3.9 LIMITED-ENERGY CIRCUIT – A line-connected circuit in which the wattage from any point in the circuit to any return to the power supply is limited to 15 W; or an isolated secondary circuit in which the wattage from any point in the circuit to any return to the power supply is limited to 50 W.

3.10 LINE-CONNECTED CIRCUIT – A circuit in which the wiring and components are conductively connected to the branch circuit. It is also called a primary- or direct-connected circuit. See also 3.8.

3.11 OPPOSITE POLARITY – A difference in potential between two points, such that shorting of these two points results in a condition involving an overload; rupturing of printed wiring-board-tracks, components, or fuses; or similar condition.

3.12 OPTICAL ISOLATOR (PHOTON-COUPLED ISOLATOR) – A circuit-coupling device that provides circuit isolation by means of a light source and sensor integrated into a single package.

3.13 SAFETY CIRCUIT – A primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, injury to persons, operation of controlled equipment that is capable of resulting in a risk of fire, electric shock, or injury to persons. Examples include an interlock circuit, a circuit which limits leakage current to accessible parts, a circuit which limits the wattage to a limited-energy circuit, or a phase control or other circuit designed to limit temperatures in the end-use product to acceptable levels.

3.14 THYRISTOR – A bistable semiconductor device comprised of three or more junctions that can be switched from the off state to the on state or vice versa, by means of the controlled conductivity of the semiconductor, with such switching occurring within at least one quadrant of the principal voltage-current characteristics. Such switching includes random switching in which conduction occurs at any phase angle of the alternating current load voltage cycle or regulated switching in which conduction occurs at some precise phase angle or load-voltage magnitude. A phase-controlled semiconductor device is one in which the semiconductor conducts for some portion of the load-voltage cycle.

a) Bidirectional Triode Thyristor (Triac) – A three-terminal thyristor having substantially the same switching behavior in the first and third quadrants of the principal voltage-current characteristics.

b) Silicon-Controlled Rectifier (SCR) – A reverse blocking triode thyristor. A three-terminal thyristor that conducts only for positive anode-to-cathode voltages and exhibits a reverse blocking state for negative anode-to-cathode voltages.

3.15 TRANSFORMER – The term includes a motor-transformer or an autotransformer. For the purpose of these requirements, the types of transformers typically encountered in or supplying power to controls are:

a) Class 2 – An isolation type transformer as specified in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

b) Power – A transformer other than Class 2 that is intended to transmit power. Included are isolation and nonisolation (such as an autotransformer) types.

c) Pulse – An isolation-type transformer designed to pass pulse waveforms as distinguished from sine waves. It is not considered to be a power transformer.

d) Current Sensing – An isolation-type transformer designed to have the primary winding connected in series with a circuit carrying current to be measured or controlled. In window type current transformers, the primary winding is provided by a separate conductor and is not an integral part of the transformer.

e) Isolating – A transformer in which one or more secondary windings are electrically separated by insulation, spacings, or both, from the primary windings. Secondary windings are not required to be electrically separated from other secondary windings.

3.15 revised October 31, 2007

4 Components

4.1 Except as indicated in 4.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

4.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

5 Units of Measurement

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

5.2 Unless indicated otherwise, voltage and current values specified in this standard are rms, and wattage values are average power.

CONSTRUCTION

6 General

6.1 A control shall employ materials that are rated for the particular use, and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

6.2 A control shall be formed and assembled so that the control has the strength and rigidity necessary to resist the foreseeable abuse to which the control is subjected, without resulting in a risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

6.3 A risk of electric shock exists at any conductive part of a control if the open circuit voltage between the part and other conductive parts or between the part and earth ground exceeds the values specified in 8.2. A risk is not considered to exist if the available current through an impedance, equivalent to that in the end-use product, connected between the parts in question is less than the value specified in the end-use product standard for normal operation as determined by the type of product involved. A current measurement on the control alone is compared with the currents from other parts of the end-use product.

6.4 For a controlled environment, the means used to prevent contamination and condensation shall be rated for the purpose. The controlled environment in a nonproduction indoor area in an ordinary location free of conductive contaminants shall be investigated for the means used to prevent condensation only.

7 Frame and Enclosure

7.1 A partial or complete enclosure of a control that is considered part of the enclosure of the end-use product shall comply with the enclosure requirements for the end-use product.

7.2 A part, such as a control knob, button, cover, dial, window, switch casing, or similar part, that is mounted in or covers an opening and serves as a barrier to live parts, shall be considered part of the enclosure.

8 Accessibility of Live Parts

8.1 The method of determining the accessibility of an uninsulated live part that involves a risk of electric shock and other electrical parts, such as those in a safety circuit or nonlimited energy circuit, is to be in accordance with the end-use product standard.

8.2 A live part of a control is considered to involve a risk of electric shock unless it is in one of the following circuits:

a) A circuit supplied by one or more isolated secondary windings of a transformer in which the maximum open circuit voltage at the transformer is less than:

1) 30 V (42.4 V peak) where wet contact is not likely to occur; and

2) 15 V (21.2 V peak) where wet contact is likely to occur.

b) A circuit derived from a primary or isolated secondary circuit in which the maximum open circuit voltage, including voltage to earth ground, is less than the values specified in (a) by virtue of circuit impedance, regardless of the polarity.

c) A circuit derived from a primary or isolated secondary circuit in which the maximum open circuit voltage, including voltage to earth ground, is greater than the values specified in (a) but the available current measured through an impedance, equivalent to that in the end-use product, is limited by virtue of the circuit impedance to the value specified in the end-product standard for normal operation.

Each line in a circuit that employs such impedance shall satisfy the following equation:

$$Z \geq \frac{V}{I}$$

in which:

Z is the minimum impedance, including tolerances;

V is the open-circuit voltage; and

I is the current limitation of the end-product standard.

8.3 With reference to 8.2 (a) and 8.2 (b), if the circuit incorporates a voltage-multiplier or other circuit which increases the steady state potential, the maximum steady state potential shall not exceed the values specified.

8.4 Circuit elements, such as resistors, capacitors, rectifiers, and similar elements, which constitute the circuit impedance referred to in 8.2(b) and 8.2(c), shall be of the fixed type and shall be investigated as a unit for acceptability with respect to end-use conditions.

8.5 An electronic circuit element relied upon to limit the voltage, current, or both to the values specified in 8.2 shall not experience an electrical stress factor:

a) Greater than 0.5 during all conditions of normal operation; or

b) Greater than 1.0 after single component failure.

8.6 For supplies of circuits of the types specified in 8.2(b) and 8.2(c):

a) Minimum electrical spacings shall be in accordance with Spacings, Section 17, up to the point at which the voltage, current, or both is limited, regardless of the maximum available power involved.

b) A risk of fire, electric shock, or injury to persons shall not result when the circuit is subjected to the 7-h short-circuit test specified in 30.1.1.

9 Current-Carrying Parts

9.1 A current-carrying part shall be of silver, copper, a copper-base alloy, aluminum, or other material rated for the application. Iron or steel shall not be used as a current-carrying part.

Exception No. 1: Stainless steel is acceptable as a current-carrying part.

Exception No. 2: Plated iron or steel is acceptable as a current-carrying part if it is used in the construction of a frame or enclosure that is intended for connection to an isolated secondary circuit or it is used as part of a component in accordance with the requirements for that component. See 11.3.1.

10 Internal Wiring

10.1 The method of determining compliance of the protection of the wiring and connections between parts of a control shall be determined in accordance with the end-use product standard.

10.2 Internal wiring shall be routed and secured so that the wiring and related electrical connections are not subjected to stress or mechanical damage, especially wiring smaller than 24 AWG (0.21 mm^2) or having insulation less than 1/32 in (0.79 mm) thick. Flexing, vibration, impact, and exposure of the wiring shall comply with the requirements of the end-product standard.

10.2 revised October 31, 2007

10.3 The internal wiring of a control, including grounding conductors, shall be rated with respect to temperature, voltage, exposure to oil, grease, or moisture, and other conditions of service to which the wiring is subjected.

11 Splices and Connections

11.1 General

11.1.1 Each splice and connection shall be mechanically secure and shall provide electrical continuity without strain on connections and terminals. Vibration, flexing, motion, and similar conditions shall be taken into account when determining compliance of the mechanical security of an electrical connection.

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

11.1.3 A lead is considered to be mechanically secure when one or more of the following is provided prior to soldering:

a) A minimum of one full wrap is provided around a terminal;

b) A lead not integral with a component on a printed wiring board is passed through an eyelet or opening and if hand-soldered is bent 90 degrees to the board;

c) A lead integral with a component is inserted through an opening of a printed wiring board;

d) A lead is twisted with other conductors; or

e) A lead is inserted into a U- or V-shaped slot in the terminal.

11.1.4 Placement of a lead along a flat surface and tack soldering is not acceptable unless the construction is such that a risk of fire, electric shock, or injury to persons does not result when the lead is detached.

11.1.5 Other means of securing leads, such as push-on terminals, spade-type connectors, and wire wrapping shall be investigated to determine if the means provides mechanical security. Quick-connect terminals shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Mechanical splicing devices shall comply with the Standard for Wire Connectors, UL 486A-486B.

11.1.5 revised October 31, 2007

11.1.6 A nongeneral use attachment plug or receptacle, or a printed-wiring board connector intended to facilitate interconnection within a control or to the end-use product shall be:

a) Rated for the current, voltage, and temperature involved; and

b) Provided with mechanical locking or securing means other than friction for providing electrical continuity, maintenance of spacings, and separation of circuits.

Exception: This requirement is not applicable if loosening or removal of the connector does not result in a risk of fire, electric shock, or injury to persons.

11.1.7 Factors to be taken into account in the investigation of factory-wiring terminals and leads are the type and size of wire to be connected, the current rating of the terminals, and mechanical protection. These factors are dependent upon requirements for the end-use product.

11.2 Wire-wrapped connections

11.2.1 Solderless wrapped connections are not acceptable if subject to movement or flexure on the wires during normal operation or user servicing.

11.2.2 The wire for a wire-wrapped connection shall be solid, copper wire and shall be a wire size of 24, 22, or 20 AWG (0.511, 0.643, or 0.813 mm). Other sizes and types of wires shall be subjected to an investigation.

11.2.2 revised October 31, 2007

11.2.3 A terminal shall be made of copper or brass and have at least two sharp edges.

11.2.4 The wrap shall:

a) Have a minimum of 20 points on the corners of the terminal in contact with the wire; and

b) Have a minimum of 16 points closely wrapped with no overlapping.

See Table 11.1. A smaller number of wraps shall be subjected to an investigation. Contact points shall produce compression or flow of the conductor rather than a nick that weakens the mechanical strength of the conductor such that fracture is able to occur.

Table 11.1
Typical number of wraps

Number of sharp corners on the terminal	Number of closely wrapped turns	Total number of turns
4	4	5
2	8	10

11.2.5 The term ″closely wrapped″ in 11.2.4 (b) means:

a) There shall not be gaps between adjacent turns greater than one half of the diameter of the wire exclusive of gaps on the first and last turns; and

b) The sum of all gaps on any side of a connection shall not exceed the diameter of the wire exclusive of gaps on the first and last turns.

11.2.6 11.2.5 applies only to the actual number of wraps that are required. Gaps between any additional wraps that have been added at the manufacturer's option are not included when determining compliance with 11.2.5.

11.3 Connections to frame

11.3.1 The frame or enclosure of a control shall not be used as a current-carrying part.

Exception: It is acceptable to use the frame as a current-carrying part of an isolated secondary circuit.

11.3.2 If the frame is used as a current-carrying part of an isolated secondary circuit, hinges or other such movable parts shall not be relied upon as a current-carrying means.

12 Separation of Circuits

12.1 General

12.1.1 Separation of circuits:

a) Between insulated conductors or other insulated live parts of different circuits; and

b) Between insulated conductors or other insulated live parts of one circuit and uninsulated live parts of a different circuit

shall be accomplished by one or more of the means indicated in Table 12.1.

Table 12.1
Separation of circuits

Part[a]			Separation requirement[b]
Insulation			
Rated for highest voltage involved	Not rated for highest voltage involved	Uninsulated	
a and b			None
a	b		Footnote b(A)(1), (B), (C), (D)
a		b	Footnote b(A)(1), (B), (C), (D)(2), (D)(3)
	a and b		Footnote b(A)(1), (A)(2), (D)(2), (D)(3),
	a	b	Footnote b(A)(1), (A)(2), (D)(2), (D)(3)

[a] The letters a and b refer to separation (See 12.1.1) as follows:

a Separation between insulated conductors or other insulated live parts of different circuits; and

b Separation between insulated conductors or other insulated live parts of one circuit and uninsulated live parts of a different circuit.

Table 12.1 Continued on Next Page

Table 12.1 Continued

Part[a]			Separation requirement[b]
Insulation			
Rated for highest voltage involved	Not rated for highest voltage involved	Uninsulated	

[b] Acceptable means of separation are:

A) Spacings – The through air spacings as indicated in Table 17.1, based on the highest voltage involved, shall be used to determine compliance of separation. See 17.3.

1) Required spacing.

2) Twice required spacing.

B) Double Insulation – Two separate and distinct insulations with each rated for the highest voltage involved, see 17.3, and complying with the requirements in the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

C) Reinforced Insulation – Improved basic insulation rated for the highest voltage involved with such mechanical and electrical qualities that, in itself, (1) provides the same degree of protection against risk of electric shock as two single insulations and (2) complies with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

D) Barriers – A barrier shall have mechanical strength for the conditions of use, be secured in place, and if there are openings in the barrier, the barrier shall be located between the parts in question so that spacings between the parts are maintained.

1) Metal – A metal barrier shall be located and connected so that an electrical breakdown of one or two insulations will not result in the voltage of one circuit appearing in the other circuit.

2) Insulating Material – Vulcanized fiber, polyethylene terephthalate (PETP) film, and resin-bonded mica shall have thicknesses not less than 0.028 in (0.71 mm), 0.007 in (0.18 mm), and 0.006 in (0.15 mm), respectively. Other materials shall be subjected to an investigation in accordance with the requirements applied to internal barriers in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

3) Insulating Material (Sole Separation) – Insulating material shall comply with the requirements in 17.5 and 17.7.

12.1.2 Segregation of insulated conductors accomplished by clamping, routing, or an equivalent means that provides permanent separation from insulated or uninsulated live parts of a different circuit is acceptable.

12.1.3 With reference to 12.1.1, a limited energy circuit derived from a circuit by limiting impedance shall be treated as one circuit.

12.1.4 Wires and cables that are part of an isolated secondary circuit shall be provided with strain relief means if stresses on the wire or cable cause noncompliance with 12.1.1. The strain relief means shall comply with the requirements for the end-use product.

12.1.5 When determining the required separation of the circuits in accordance with 12.1.1, such effects as deterioration of insulation resulting in abnormal operation involving overload, short-circuit, component failure conditions and similar effects shall be taken into account.

13 Insulating Material

13.1 General

13.1.1 Insulating material shall be acceptable for the application. The following factors shall be taken into account in determining acceptability:

a) The material's mechanical strength and rigidity, resistance to ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions;

b) The degree to which the material is enclosed; and

c) Any other feature affecting the risk of fire, electric shock, or injury to persons.

All factors are to be investigated with respect to conditions of actual service.

13.1.2 A barrier or integral part, such as an insulating washer or bushing, and a base or a support for mounting live parts shall be of moisture-resistant material that will not be adversely affected by the temperature and stresses to which the material is subjected under conditions of use.

13.1.3 Insulating material, including a barrier between parts of opposite polarity and material that is subject to the influence of an arc shall be rated for the application.

13.1.4 Ordinary vulcanized fiber is acceptable for insulating bushings, washers, separators, and barriers, but shall not be used as sole support for uninsulated live parts.

13.2 Support of live parts

13.2.1 An uninsulated live part shall be mounted on porcelain, phenolic composition, or other material that is suitable for the particular application.

13.2.2 Polymeric material that is used to either directly or indirectly support live parts shall meet or exceed the limits for the performance-level tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C – as applicable for the particular usage of the material.

Exception: Materials employed in a component shall comply with the requirements for the class of component involved.

14 Printed-Wiring Boards

14.1 A printed-wiring board, including the coatings, shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796. A printed-wiring board containing circuitry in a line-connected circuit or a safety circuit shall comply with the direct-support requirements in UL 796.

Exception: A printed-wiring board in a Class 2 nonsafety circuit is not required to comply with the bonding requirements in UL 796 if 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.

14.2 A printed-wiring board, including the coating, shall have a minimum flammability classification of V-2 as specified in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A printed-wiring board, including the coating, in a Class 2 circuit or an isolated secondary limited-energy circuit shall have a minimum flammability classification of HB as specified in UL 94.

15 Components

15.1 Switching devices

15.1.1 An electromechanical switching device:

a) Shall be rated for the particular application;

b) Shall have a voltage rating and a current rating, a horsepower rating, or both, not less than that of the load that the device controls; and

c) Shall be rated for the type of load that the device controls as follows:

1) General purpose ac (0.75 to 0.80 power factor) – for example, transformer load.

2) General purpose dc.

3) Resistive.

4) Tungsten lamp.

Exception: A switching device intended to control a 15-W or smaller pilot or indicating lamp is not required to be provided with a tungsten rating.

5) Electric discharge lamp.

6) Pilot duty – for example, solenoid, contactor, relay, or other electromagnetic load.

7) Motor.

Exception: A switching device that is intended to control a universal motor shall additionally comply with the requirements for the end-use product.

15.1.2 A switch shall be investigated with respect to the temperature limitations of the materials employed.

15.1.3 A switching device, such as a relay, that is controlled in such a manner that the device will always switch current during the same positive or negative half of the normal ac sinusoidal waveform, shall be suitable for the current, the type of load involved, and the particular application under dc operation.

15.2 Capacitors

15.2.1 A capacitor shall employ such materials and shall be constructed so that the capacitor will not constitute a risk of fire. A capacitor shall not be adversely affected by the temperature the capacitor reaches under the most severe conditions of intended use.

15.2.2 A paper capacitor shall be impregnated or enclosed to exclude moisture.

15.2.3 A capacitor connected across the supply circuit shall comply with the requirements in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414.

15.2.4 With reference to the requirements in 15.2.3, a capacitor, other than a motor capacitor, is considered to be across the supply circuit if, in a shorted condition, a current of more than one ampere passes through the capacitor while the control is in a heated condition. Limiting the current through the capacitor to one ampere or less by a fixed impedance or by a protective device rated one ampere or less is acceptable.

15.2.5 A liquid-electrolyte, metalized-film or conductive-foil type electrolytic capacitor connected in a circuit capable of delivering a power greater than 15 W as determined in the Limited Power Point Determination Test, Section 25, and having a diameter of more than 0.394 in (10 mm), shall be provided with a means for relieving excessive internal pressure.

15.3 Power-switching semiconductors

15.3.1 A power-switching dead-case-mounted semiconductor shall be investigated in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557, for the voltage and temperature involved.

Exception: This requirement does not apply if the semiconductor is intended to be secured to an inaccessible metal part physically isolated, electrically insulated, or both from other live parts or accessible dead metal parts.

15.4 Isolation devices

15.4.1 If a device intended to provide electrical isolation, such as an optical isolator, pulse transformer, relay, or similar device, is provided:

a) To reduce the risk of fire, electric shock, or injury to persons; or

b) Because isolation is required by this standard between specific circuits (for example, a device that isolates Class 2 circuit outputs from circuits involving a risk of electric shock),

the device shall comply with the requirements for such devices, shall be suitable for the voltage and temperature involved, and shall be subjected to the tests specified in Isolation Tests, Section 26, to determine the effects on the insulating properties of the isolating medium.

16 Transformers

16.1 General

16.1.1 A coil of a transformer shall be wound and impregnated or otherwise enclosed to exclude moisture. Coil insulation, unless inherently moisture resistant, shall be treated or enclosed to render the insulation resistant to moisture. Film-coated magnet wire is not required to be additionally treated or enclosed to resist moisture absorption.

16.1.2 A Class 2 transformer shall comply with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

16.1.2 revised October 31, 2007

16.1.3 A power transformer shall comply with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2 and with the overload heating requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3. See 16.2.5.

16.1.3 revised October 31, 2007

16.2 Isolation transformers

16.2.1 A transformer having separate windings shall be constructed to reduce the risk of short-circuiting, under normal and overload conditions, between primary and secondary windings or between separate adjacent secondary windings if such shorting directly or through the core results in a risk of fire or electric shock, operation of the controlled equipment in a manner that involves a risk of fire, electric shock, or injury to persons, or affect the evaluation of the circuit the transformer supplies when the additive effects of each winding are taken into account.

16.2.2 Unless otherwise noted, electrical separation between windings and between windings and the core or other dead metal parts shall be accomplished by insulation, spacings, or both and shall not rely solely upon the coating of the magnet wire.

16.2.3 With reference to 16.2.2, insulation or spacings shall be provided between:

a) Uninsulated primary wires or terminals of opposite polarity;

b) The primary winding including lead connections and terminals and each secondary winding and associated lead connections and terminals;

c) The primary winding including lead connections and terminals and the core or other dead metal parts;

d) Each secondary winding including lead connections and terminals and the core or other dead metal parts; and

e) Adjacent secondary windings including lead connections and terminals.

16.2.4 Spacings between parts noted in 16.2.3(a) – 16.2.3(e) shall not be less than the applicable value specified in Table 16.1. The potential involved is the maximum voltage in any winding or the normal operating voltage existing between the parts in question, whichever is greater.

Exception: Insulation or spacings are not required between parts noted in 16.2.3(d) and 16.2.3(e) if the risks noted in 16.2.1 are not present.

Table 16.1
Minimum spacings at isolation transformers

Potential involved, V, rms	Through air		Over surface	
	In	(mm)	In	(mm)
0 – 50	1/16	1.6	1/16	1.6
51 – 150	1/8	3.2	1/4	6.4
151 – 250	1/4	6.4	3/8	9.5
251 – 600	3/8	9.5	1/2	12.7

NOTE – These spacings apply to coils, crossover leads, splices, uninsulated lead wires and terminals. These spacings do not apply to turn-to-turn spacings of a coil.

16.2.5 The insulation of a pulse transformer or an isolation type power transformer shall comply with the applicable coil construction requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

16.2.5 revised October 31, 2007

17 Spacings

17.1 Unless otherwise noted and as provided in Alternate Spacings – Clearances and Creepage Distances, Section 18, spacings within a control shall be as indicated in Table 17.1:

a) Between uninsulated live parts of opposite polarity within a circuit;

b) Between an uninsulated live part of one circuit and an uninsulated live part of any other circuit; and

c) Between an uninsulated live part of any circuit and a dead metal part.

Exception No. 1: The minimum acceptable spacings specified in Table 17.1 do not apply to the inherent spacings of a component of a control, such as a switch. The acceptability of spacings of a component is based on the requirements covering that component.

Exception No. 2: At closed-in points in which contamination is not able to occur (such as the screw-and-washer construction of an insulated terminal mounted in metal), a spacing of 3/64 in (1.2 mm) is acceptable in a circuit rated at 250 V or less.

Exception No. 3: Spacings are not specified within Class 2 circuits as defined in 3.2 and complying with Class 2 Circuits, Section 20, and between such circuits and dead metal parts unless such circuits are safety circuits. If a short circuit between the parts in a Class 2 safety circuit are able to result in a risk of fire, electric shock, or injury to persons, spacings of 1/32 in (0.8 mm) are acceptable between uninsulated

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live parts within a Class 2 safety circuit that complies with the requirements in Class 2 Circuits, Section 20 and between such parts and dead metal, if the construction is such that spacings will be permanently maintained.

Exception No. 4: In other than safety circuits, a spacing less than the minimum specified in Table 17.1 is acceptable under the conditions described in Limited Power Point Determination Test, Section 25.

Table 17.1
Minimum spacings for circuits elsewhere than at isolation transformers

Potential involved in V, rms (peak)		General environment				Controlled environment			
		Over surface		Through air		Over surface		Through air	
		In	(mm)	In	(mm)	In	(mm)	In	(mm)
0 – 50	(0 – 70.7)	1/16[b]	1.6[b]	1/16[b]	1.6[b]	3/64	1.2	3/64	1.2
51 – 125	(72.1 – 176.8)	1/16[b]	1.6[b]	1/16[b]	1.6[b]	1/16[b]	1.6[b]	1/16[b]	1.6[a]
126 – 250	(178.2– 353.5)	3/16	4.8	1/8	3.2	3/32	2.4	3/32	2.4
251 – 300	(354.9 – 424.2)	3/8[a]	9.5[a]	1/4[a]	6.4[a]	3/8[a]	9.5[a]	1/4[a]	6.4[a]
301 – 600	(425.6 – 848.4)	1/2[a]	12.7[a]	3/8[a]	9.5	1/2[a]	12.7	3/8[a]	9.5[a]

[a] Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 in (2.4 mm) over surface and through air is acceptable between a dead metal part and film-coated wire rigidly supported and held in place on a coil.

[b] Spacings within a circuit less than those indicated but not less than 3/64 in (1.23 mm) are acceptable at the connection to a printed wiring board of integrated circuits, optical isolators, and other similar multiple (three or more) terminal solid-state devices in which the spacing between adjacent connecting leads of the device is less than indicated in the table. However, spacings between circuits and between live and dead metal parts shall be as specified in the table.

17.2 Spacings between different circuits shall be based on the voltage involved. The output voltage rating of a control is to be used to determine what spacings apply in the output circuit of the control (for example, at the triac), or between the output circuit and other circuits or dead metal parts.

17.3 The potential involved between points in the same circuit shall be the normal operating voltage existing between the points in question. The potential involved between points in different circuits shall be the maximum voltage at either point (to a suitable reference point) or the normal operating voltage existing between the parts in question, whichever is greater.

17.4 If an uninsulated live part is not rigidly fixed in position by a means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall maintain spacings not less than the spacings specified in Table 17.1 regardless of the position of such parts.

17.5 An insulating barrier or liner used as the sole separation between parts noted in 17.1 shall be of material of a type that is suitable for mounting uninsulated live parts and shall not be less than 0.028 in (0.71 mm) thick.

17.6 An insulating barrier or liner that is used in addition to an air space in place of the required spacing through air shall not be less than 0.028 in (0.71 mm) thick. If the barrier or liner is of vulcanized fiber, the air space shall not be less than 1/32 in (0.79 mm). If the barrier or liner is of other material that is not used to support uninsulated live parts, the air space and barrier together shall be such that, upon investigation, are found to be acceptable for the particular application.

Exception: A barrier or liner that is used in addition to not less than one-half the required spacing through air and is less than 0.028 in (0.71 mm) but not less than 0.013 in (0.33 mm) thick is acceptable if the barrier or liner is of a material that is rated for the mounting of uninsulated live parts in accordance with the Standard for Polymeric Material – Use in Electrical Equipment Evaluations, UL 746C, has mechanical strength for the conditions of use if exposed or otherwise subjected to mechanical damage, and located so that the barrier or liner is not adversely affected by operation of the equipment in service.

17.7 Insulating material having a thickness less than that specified in 17.5 and 17.6 is acceptable if, upon investigation, the material is found to be rated in accordance with the Standard for Polymeric Material – Use in Electrical Equipment Evaluations, UL 746C, for the particular application.

17.8 Barriers shall be reliably held in place by means more secure than friction between surfaces. The elasticity of tubing shall not be depended on to hold the tubing in place, but dilated or heatshrink tubing is acceptable.

18 Alternate Spacings – Clearances and Creepage Distances

18.1 As an alternative to the specified spacing requirements of Section 17, Spacings, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are applicable. The spacing requirements in UL 840 shall not be used for spacings between field wiring terminals or between uninsulated live parts and a metal enclosure. In determining the pollution degree and overvoltage category, the environmental conditions to which the control is subjected in the end-use application shall be applied and those characteristics given in 18.2 – 18.5 modified accordingly.

18.2 When applying specific requirements in UL 840, the degrees of pollution shall be as indicated in Table 18.1.

Table 18.1
Degrees of pollution

Equipment	Pollution degree
Hermetically sealed or encapsulated equipment or printed wiring boards with protective coating.[a]	1
Equipment for ordinary locations and indoor use, such as residential controls, commercial controls for use in a clean environment, nonsafety controls for installation on or in appliances.	2
All safety or limit controls, equipment for outdoor use, and equipment influenced by surrounding environment, such as industrial controls, refrigeration controls, and water heater controls.	3

[a] Tested in accordance with the protective coating test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

18.3 When applying specific requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the spacing requirements in UL 840, shall be based on the overvoltage categories as indicated in Table 18.2.

Table 18.2
Overvoltage categories

Equipment	Overvoltage category
Intended for fixed wiring connection	III
Portable and stationary cord-connected	II
Power-limited and safety[a] low voltage	I

[a] Applicable to low-voltage circuits if a short circuit between the parts involved does not result in operation of the controlled equipment that increases the risk of fire or electric shock.

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

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

19 Bonding of Internal Parts for Grounding

19.1 General

19.1.1 For some end-use products, internal dead metal parts of a control (for example, power or Class 2 transformer cores, mounting brackets, heat sinks for power-switching semiconductors, and similar parts) are required to be electrically connected to an equipment-grounding terminal, a lead or a supply cord grounding conductor of the end-use product. A bonding conductor or other connection used for such purpose shall comply with the requirements in 19.2.1 – 19.3.5. Small isolated internal parts, such as cores of relay or pulse transformers, and similar parts, are not required to be bonded.

19.1.2 The resistance in the grounding path shall be kept as low as practical in the event that a control is subject to a 0.1 ohm resistance requirement in the end-use product.

19.1.3 Circuitry shall be arranged such that an equipment-grounding connection or conductor, an equipment-bonding connection or conductor, an enclosure, a frame, a component mounting panel, or a similar component will not carry current.

Exception No. 1: A single point reference ground employed in a Class 2 circuit, a Class 3 circuit, or an isolated secondary circuit is acceptable. It is acceptable for an enclosure, a frame, or a panel including bolted joints to conduct current of a low-voltage circuit. Such current shall not be conducted by the field equipment-grounding means, a metallic raceway, or other power-supply grounding means.

Exception No. 2: A current not exceeding 0.5 mA conducted along an equipment-grounding or the equipment-bonding conductor or connection is acceptable.

19.2 Bonding conductor

19.2.1 A bonding conductor shall be of copper, copper alloy, or other material that has been investigated and found to be rated for use as an electrical conductor. A ferrous-metal part in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

19.2.2 A bonding conductor shall be a bare or insulated wire, printed wiring foil, a clamp, strap, or similar construction, and shall be so installed that it is protected from mechanical damage.

19.2.3 The size of a bonding conductor shall be based on the rating of the overcurrent protective device of the branch circuit to which the end-use product will be connected in accordance with the National Electrical Code, NFPA 70-2002. A conductor other than a wire such as noted in 19.2.2 shall have a cross-sectional conducting area equal to or greater than that of the required wire size.

Exception No. 1: The bonding conductor for a component shall not be smaller than the conductors supplying power to the component regardless of the type of bonding conductor. However, the risk of energization of the dead metal of the component from external wiring in proximity to the component in question under normal and abnormal conditions shall be taken in to account.

Exception No. 2: The bonding conductor for a dead metal part that is not part of a component (for example, an enclosure or a partial enclosure, or a bracket) is not required to be larger than the conductors supplying power to components in proximity to or within the part regardless of the type of bonding conductor. However, the risk of energization of the part by such conductors under normal and abnormal conditions shall be taken in to account.

Exception No. 3: A smaller conductor complies with this requirement if the bonding conductor does not open, when carrying for the interval indicated in Table 19.1, a current equal to twice the rating of the branch-circuit overcurrent protective device.

Table 19.1
Duration of current flow

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

19.3 Bonding connections

19.3.1 Bonding shall be by a positive means providing metal-to-metal contact, such as by clamping, riveting, a bolted or screwed connection, brazing, or welding. The bonding connection shall penetrate nonconductive coatings, such as paint, enamel, or varnish. Solder alone shall not be used to maintain a bonding connection.

19.3.2 A bolted or screwed connection that incorporates a star washer under the screwhead, a serrated screwhead, or the equivalent, is acceptable for penetrating nonconducting coatings if required for compliance with 19.3.1. A serrated-edged ring terminal constructed of copper or copper alloy is not acceptable for penetrating a nonconductive coating.

19.3.3 If the bonding means depends upon screw threads, two or more screws or two full threads of a single screw engaging metal complies with 19.3.1.

19.3.4 If the compliance of a bonding connection is not able to be determined by examination, the connection shall not open, when carrying for the interval indicated in Table 19.1, twice the current equal to the rating of the branch circuit overcurrent protective device.

19.3.5 If continuity of a bonding system relies on dimensional integrity of a nonmetallic material, the dimensional stability of the material shall be taken into account in addition to such factors as mechanical strength, thermal aging characteristics, moisture-absorptive properties, combustibility, and resistance to impact, distortion, arcing, and ignition. The material shall be subjected to the following tests. As a result of the testing, there shall be:

a) No softening, cracking, or other distortion of the material or damage to the bonding connection; and

b) No change in the voltage drop through the bonding path.

A separate set of three samples is to be subjected to the tests in (1) and each series of tests in (2).

1) An overcurrent test in which a current equal to twice the rating of the branch circuit overcurrent protective device is passed through the bonding path for the time specified in Table 19.1.

2) Creep and mold stress-relief tests in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, followed by an overcurrent test as specified in (1).

20 Class 2 Circuits

20.1 A Class 2 circuit, as defined in 3.2, shall comply with the requirements for primary circuits unless;

a) The circuit does not perform a required safety-related function, that is, it is not a required safety circuit;

b) The circuit complies with the requirements in this Section; and

c) Malfunctions or shorting of deficient spacings in the circuit do not cause a risk of fire, electric shock, or injury to persons to occur in the controlled equipment. However, the need for a Class 2 circuit to comply with certain primary circuit requirements (for example, wiring, securing of live parts, and similar factors) in the controlled equipment to reduce the risk of fire, electric shock, or injury to persons shall be determined.

20.2 A Class 2 circuit intended to be used for a safety-related function, or if a malfunction in the circuit results in a risk of fire, electric shock, or injury to persons to occur in the controlled equipment, shall be investigated under all the requirements for primary circuits. However, if such a circuit complies with the requirements in this Section, spacings as noted in Exception No. 3 to 17.1 are acceptable.

20.3 A circuit is Class 2 if it is supplied by a single source (one input into the circuit) consisting of an isolating transformer, a power supply that includes an isolating transformer, or a dry-cell battery, in which:

a) The open-circuit potential at the source is not more than 42.4 V peak;

b) The energy available to the circuit is limited so that:

1) The current under any load condition including short circuit is not more than 8 A measured after one min of operation; and

2) A risk of fire, electric shock, or other risk does not result when the power supply is subjected to an abnormal (short-circuit) test. See 30.1.1.

c) The circuit does not incorporate a voltage-multiplier or other such voltage increasing circuit elements that increase the voltage in the circuit to greater than 42.4 V peak.

20.4 With reference to 20.3, it is acceptable to limit the current or voltage by:

a) The design of the isolating transformer or dry-cell battery;

b) The design or value of a fixed impedance or regulating network; or

c) A fuse or other overcurrent protective device located in the primary or secondary circuit if the power supply complies with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3, when the overcurrent protective device is bypassed.

20.4 revised October 31, 2007

20.5 A power supply is inherently limited if it does not rely upon a fuse or other overcurrent protective device to comply with 20.3(b).

20.6 The voltage limit specified in 20.3 is to be measured with the control, the power supply, or the transformer primary connected to the voltage specified in 21.2 and all load circuits disconnected from the transformer or the power supply under test. Measurement made at the output terminals of the transformer or power supply is acceptable. If a tapped transformer winding is used to supply a full-wave (two diode) rectifier, the voltage measurement is to be made from each end of the winding to the tap. See 20.10.

20.7 If the power supply employs a regulating network or fixed impedance to limit the current or voltage in accordance with 20.3, the limiting function shall not be adversely affected by the open- or short-circuiting of any circuit component, such as a resistor, capacitor, solid-state device, or similar component, in the power supply to the extent that the impedance or regulating network ceases to satisfactorily perform the limiting function. For a discrete, multiple (more than two) terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to the (referenced) ground terminal;

c) Each output terminal shorted to the (referenced) ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply; and

f) Each terminal open circuited.

Exception No. 1: A resistor investigated for acceptability with respect to end-use conditions and incorporating insulation complying with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, spacings, or both to reduce the risk of a short circuit or reduction in resistance is not required to be open- or short-circuited.

Exception No. 2: A capacitor, capristor (parallel combination of a capacitor and resistor), or similar circuit component, complying with the requirements for antenna coupling and line bypass components in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, and investigated for acceptability with respect to end-use conditions, is not required to be short-circuited.

Exception No. 3: Electronic circuit elements complying, as part of a circuit assembly, with a complete component evaluation program are not required to be open- or short-circuited.

Exception No. 4: Reduced testing of an integrated circuit device is acceptable if it is determined by circuit analysis that the tests noted in (a) – (f) will not affect the limiting function.

20.8 Components which taken together comprise a fixed impedance or regulating network used to limit current or voltage in accordance with 20.3 shall be investigated as a unit to determine that the network or impedance will not be adversely affected by end-use conditions to the extent that the impedance or regulating network ceases to satisfactorily perform the limiting function.

20.9 An electronic circuit element relied upon to limit voltage or current in accordance with 20.3 shall not experience an electrical stress factor greater than 0.5 during all conditions of normal operation or 1.0 after single component failure.

20.10 For a circuit in which the voltage and current are not limited by the construction of the transformer itself, the secondary winding of the transformer, the fuse or circuit-protective device, or the regulating network or fixed impedance and all wiring up to the point at which the current and voltage are limited shall comply with the requirements for primary circuits. This includes a tapped transformer/full-wave rectifier circuit as specified in 20.6.

20.11 The overcurrent protective device mentioned in 20.4 shall:

a) Not be of the automatic reclosing type;

b) Be trip-free from the reclosing mechanism;

c) Be nonadjustable;

d) Not be readily interchangeable with a device of a different rating, unless a marking in accordance with 36.4 is provided adjacent to the device;

e) Be rated or set in accordance with Table 20.1 if the device is provided in the secondary circuit; and

f) Comply (in conjunction with the power supply) with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3, for noninherently limited transformers whether the device is located in the primary or secondary circuit.

20.11 revised October 31, 2007

Table 20.1
Maximum rating for overcurrent protection

Open-circuit potential, Voc	Current rating, A
0 – 20.0	5
20.1 – 30.0	100/Voc

20.12 A circuit is Class 2 if the circuit is supplied by more than one inherently-limited source or more than one noninherently limited source (for example, an isolating transformer with multiple secondary windings or several power supplies that each include an isolating transformer) that when interconnected comply with the applicable requirements in 20.3 – 20.10 for inherently limited or noninherently-limited power supplies. The circuit shall not incorporate voltage-multiplier or other such voltage increasing circuit elements that increase the voltage in the circuit to greater than 42.4 V peak. Any combination of any number of secondary windings or power supplies are to be interconnected in such a way as to create the most severe condition at any output terminals. For these tests, any unconnected secondary windings or power supplies are to be open-circuited.

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Exception: If two or more power supplies are interconnected, this connection shall not be broken when determining the most severe condition.

20.13 The load circuits of two or more power supplies, each of which is separately a Class 2 circuit in accordance with the requirements in 20.3 – 20.10 and that are not interconnected, shall be considered as separate circuits and shall not be connected in any way in the end-use product. Spacings, insulation, and segregation between such circuits shall be as noted elsewhere in this standard.

20.14 A device having exposed Class 2 outputs that:

a) Are able to be contacted during normal operation or servicing; and

b) Have clearances between the Class 2 circuit and an overvoltage protected line-voltage circuit that have been investigated in accordance with Clearance B requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840,

shall be provided with a mechanism to indicate the failure of the overvoltage protective device or system. For example, the provision of a detection circuit that indicates a transient voltage surge suppressor is no longer functional due to the absorption of an excessive amount of energy.

PERFORMANCE

21 General

21.1 The performance of a control shall be investigated by subjecting the requisite number of samples representative of commercial form to the applicable tests described in this standard. Unless otherwise indicated, tests do not need to be performed with the control installed in the end-use product.

21.2 Unless otherwise indicated, tests are to be performed at the rated input frequency of the end-use product and at a test potential not less than 120, 208, 240, 277, 480, or 600 V corresponding to the input voltage rating (single value or voltage range) of the end-use product. A control intended to be installed in equipment having a dual frequency input rating is to be tested at 60 Hz if 60 Hz is included in the rating and also be tested at the second frequency if such testing results in more severe test conditions.

Exception: It is acceptable to conduct tests at the rated input, single or dual frequency, of the control and at a test potential not less than 120, 208, 240, 277, 480, or 600 V corresponding to the input voltage rating of the control.

21.3 The cheesecloth mentioned in this standard is bleached cotton cloth, running 14 – 15 $yard^2/lb$ (26–28 m^2/kg) and having what is known to the trade as a count of 32 by 28. Tests involving cheesecloth are to be made in a closed room with no forced air circulation.

22 Temperature Test

22.1 General

22.1.1 When tested as described in this Section, a control shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to damage any materials employed in the device, or to exceed the temperature rises specified in Table 22.1.

Table 22.1
Maximum temperature rises

Materials and components[a]	Degrees C	Degrees F
1. Fiber employed as electrical insulation	65	117
2. Fuses	65	117
3. Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock:		
(a) Laminated	100[b]	180[b]
(b) Molded	125[b]	225[b]
4. Insulated wire or tubing	25 less than its temperature rating	77 less than its temperature rating
5. Wood or other combustible material	65	117
6. Capacitor cases:		
(a) Electrolytic	40[c]	72[c]
(b) Other type	65[c]	117[c]
7. Rectifiers at any point		
(a) Selenium or germanium	50[b]	90[b]
(b) Silicon	75[b]	135[b]
8. Solderless wrapped connections	75	135
9. Transformer windings:		
(a) Class 105 insulation systems		
Thermocouple method	65	117
Resistance method	75	135
(b) Class 130 insulation systems:		
Thermocouple method	85	153
Resistance method	95	171
10. Windings of relays, coils, buzzers, and similar components:		
(a) Class 105 insulation systems:		
Thermocouple method	65	117
Resistance method	85	153
(b) Class 130 insulation systems:		
Thermocouple method	85	153
Resistance method	105	189

[a] See 22.1.4.

[b] These limitations do not apply to compounds and components that have been investigated and found acceptable for a higher temperature.

[c] It is acceptable to investigate a capacitor that operates at a temperature rise of more than 40°C (72°F) for an electrolytic type and more than 65°C (117°F) for other types on the basis of the capacitor's marked temperature limit. However, the measured temperature shall not exceed the temperature rating of the capacitor based on a 25°C (77°F) ambient temperature.

22.1.2 The values in Table 22.1 are based on an assumed ambient of 25°C (77°F), but it is acceptable to perform the temperature test at an ambient temperature within the range of 10 – 40°C (50 – 104°F). The ambient temperature is to be determined using either thermometers or thermocouples placed in the vicinity of the equipment being tested.

22.1.3 When testing a control that is not installed in the end-use product, a control:

a) Intended specifically for use within a prevailing ambient temperature constantly more than 25°C (77°F); or

b) Assigned a maximum operational ambient temperature rating (see 35.3.1)

is to be tested at the higher ambient temperature and the allowable temperature rises specified in Table 22.1 are to be reduced by an amount equal to the difference between the higher ambient temperature and 25°C.

22.1.4 The acceptability of temperatures for a component such as a printed wiring board, an optical isolator, a dead-case-mounted semiconductor, a switch, and for polymeric materials serving as support of live parts, insulation, or an enclosure are to be determined on the basis of the temperature ratings of the components.

22.2 Operation

22.2.1 To determine whether a control complies with the temperature test requirements, the control is to be mounted and connected to the end-use product controlling the intended load and operated as follows:

a) The control shall be operated under the condition of intended use that results in maximum temperatures. The control shall be tested at all power levels or speed settings and at continuous operation (that is, not intermittent or short-term operation) until constant temperatures are attained. For a control employing a power-switching semiconductor, the effects at each setting of any dc offset voltage on the temperatures shall be taken into account when determining the most severe setting. See DC Offset Voltage Test, Section 23.

b) For a control employing a power-switching semiconductor, the test is to be performed with the control modified to result in half-wave operation of the intended load. The control is to be set in the full-on position and then switched to half-wave operation when the end-use product is fully energized. The end-use product is to be operated at the power level, speed setting, or combination of power level and speed setting under the condition of intended use that results in maximum temperatures.

Exception No. 1: The test described in (b) is not required if the end-use product will not continue to operate in a manner foreseeable as a practicable condition of use and if the test described in 22.2.5 is performed.

Exception No. 2: The test described in (b) is not required if the intended load is noninductive.

Exception No. 3: See 22.2.2.

22.2.2 With reference to Exception No. 3 to 22.2.1, an acceptable method to determine the effects of heating on the control due to the control itself, is to conduct the temperature test with the control:

a) Mounted on a flat horizontal nonconductive surface in the most adverse position with regard to heating from adjacent parts or components unless the proper orientation and separation of parts is obvious;

b) Connected to a source of supply as indicated in 21.2; and

c) Operated under the condition or conditions of intended use that results in maximum temperatures.

During the test, the output of the control is to be connected in series with a load and a source of supply with each adjusted to produce the overall rated output current and voltage of the control.

22.2.3 If the test specified in 22.2.2 results or is known to result in unacceptable temperatures, the test is to be performed with the sample within an enclosure and provided with heat sinking, ventilation, orientation, separation between parts, or other necessary means to verify that the control has the capability of passing the test. The parameters of the enclosure, heat sink, ventilation, orientation, separation, and similar parameters, shall be chosen by the control manufacturer and noted for use in the investigation of the end-use product.

22.2.4 With reference to the test specified in 22.2.2, the effects of:

a) DC offset voltage when using the criteria specified in 23.1; and

b) Half-wave operation on the end-use product

shall be taken into account in the end-use product investigation.

22.2.5 For end-use product employing a motor which does not rotate, rotates in a manner not considered to be a practicable condition of use during the half-wave test described in 22.2.1(b), or after it is de-energized it will not restart using a half-wave source, the motor is to be tested with the rotor locked and the supply modified to produce half-wave output. During the test, the motor shall comply with the Locked-Rotor Temperature Test in the Standard for Overheating Protection for Motors, UL 2111.

22.3 Temperature measurements

22.3.1 If referee temperature measurements are necessary, thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer type of indicating instrument are to be employed.

22.3.1 revised October 31, 2007

22.3.2 The temperature of a coil or winding is to be measured by either the thermocouple or resistance method.

Exception: The resistance method only is to be used if the coil:

a) Employs thermal insulation; or

b) Is encapsulated or otherwise inaccessible for mounting thermocouples.

22.3.3 If thermocouples are used to measure temperatures, the thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to comply with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

22.3.3 revised October 31, 2007

22.3.4 A thermocouple junction is to have a secure thermal contact with the surface of the material being measured. In most cases, acceptable thermal contact will result from securely taping or cementing the thermocouple in place. If a metal surface is involved, the thermocouple is to be brazed or soldered to the metal if necessary. The adjacent thermocouple lead is to be secured to provide strain relief.

22.3.5 If the change-of-resistance method is used to determine the temperature of a coil or winding, the temperature rise is to be calculated from the equation:

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

in which:

Δt is the temperature rise in degrees C;

R_1 is the resistance of the coil at the beginning of the test;

R_2 is the resistance of the coil at the end of the test;

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

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

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other materials are to be determined when necessary.

22.3.6 A temperature is constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5-min intervals, indicate no change.

23 DC Offset Voltage Test

23.1 For a control employing a power switching semiconductor and intended to control a load affected by asymmetrical switching, the dc component of the output voltage from the control shall be measured. Ten samples in an ″as-received″ condition are to be tested at each power level or speed setting and over the full range of any trim potentiometers. The sample or samples having the greatest dc offset voltage shall be used in the Temperature Test, Section 22, and the overload and endurance tests in Power-Switching Semiconductors, Section 27. Following the overload and endurance tests, the sample shall be subjected to a repeat of the dc offset voltage test.

23.2 With respect to 23.1, after the endurance test, the dc offset voltage shall not exceed the ″as-received″ value, and a control intended to control a motor load shall not have a dc component greater than 2 Vdc, either ″as-received″ or following the endurance test.

23.3 This test shall be performed with the control connected, loaded, and operated as for normal operation, however, it is not necessary for the control to be installed in the end-use product. A voltmeter shall be used to measure the dc voltage across the test load if the voltmeter is a simple, pure dc voltmeter with a damped frequency response in the range of 0 – 120 Hz.

24 Abnormal Operation Test

24.1 Motor

24.1.1 A motor in the end-use product controlled by a control employing a power-switching semiconductor shall comply with the Locked-Rotor Endurance Test in the Standard for Overheating Protection for Motors, UL 2111.

Exception No. 1: The winding temperature requirements in UL 2111 do not apply.

Exception No. 2: The power supply is to provide for 15 days each:

a) Half wave output; and

b) A 2-Vdc offset voltage imposed on the ac voltage waveform by an acceptable method. For example, the 2-Vdc offset potential may be obtained by using a modified control having routing diodes and dual triggering circuits to allow independent adjustment of the positive and negative 1/2 cycle triac triggering points. The triggering points are to be adjusted so that a 2 Vdc bias is to be measured on the switched ac output waveform. The dc bias is to be measured by a dc voltmeter having a frequency damped response in the range of 0 – 120 Hz.

24.2 Component failure

24.2.1 A single malfunction (short or open) of any circuit component, such as a resistor, capacitor, solid-state device, or similar component, shall not cause the available voltage or current to exceed the limits specified in 8.2. For a discrete, multiple (more than two) terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to (referenced) ground terminal;

c) Each output terminal shorted to (referenced) ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply;

f) Each terminal open-circuited.

Exception No. 1: A resistor investigated for acceptability with respect to end-use conditions and incorporating insulation complying with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, spacings, or both to reduce the risk of a short circuit or reduction in resistance is not required to be open- or short-circuited.

Exception No. 2: A capacitor, capristor (parallel combination of a capacitor and resistor), or similar circuit component, complying with requirements for antenna coupling and line bypass components in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, and investigated for acceptability with respect to end-use conditions is not required to be short-circuited.

Exception No. 3: Electronic circuit elements used within a circuit assembly, and that have been subjected to a successful complete component evaluation program as described in Electronic Component Evaluation, Section 32, are not required to be open- or short-circuited.

Exception No. 4: For a line-connected circuit, it is acceptable to simultaneously open- or short-circuit more than one such component if redundant circuit components are relied upon to limit the voltage or current, except that components of a different type (for example, metal film resistors versus carbon resistors, electrolytic capacitors versus ceramic capacitors, and silicon versus germanium diodes) are not to be open- or short-circuited simultaneously. When applying this Exception, Exception Nos. 1 – 3 shall be taken into account.

Exception No. 5: Reduced testing of an integrated circuit device is acceptable if it is determined by circuit analysis that the tests noted in (a) – (f) will not result in the available voltage or current exceeding the limits specified in 8.2.

24.3 Abnormal switching test

24.3 added August 15, 2013

24.3.1 Controls incorporating electronic circuitry to trigger the control's output switching device at specific phase angles near zero degrees in order to achieve switching of higher capacity loads, shall be subjected to this abnormal switching test. This test is applicable when:

a) Loads and circuits are non-safety, and

b) Switching components are used beyond their evaluated ratings. These evaluated ratings of switching devices are typically determined without electronic triggering techniques, such as zero cross switching.

24.3.2 Two test samples are prepared and connected as follows:

a) The trigger circuit of the switching device is to be removed or modified to allow random switching.

b) A ground arc indicating fuse is connected to accessible dead metal of the control. The ground arc detection fuse shall be rated not greater than 3A and not less than the working voltage.

c) The control is to be supported on a tissue paper covered softwood surface, and is to be covered with a single layer of cheesecloth conforming to the outline of the control. The cheesecloth requirements shall be according to 21.3.

d) The rated supply shall be connected through a branch circuit protection device sized according to installation requirements, and

e) The control is connected to its rated electrical load.

24.3.3 The prepared test samples shall be operated in accordance with the endurance test requirements specifying the number of operating cycles and on/off periods using random switching. The test samples shall be operated until either the required number of endurance test cycles are achieved or until ultimate results are demonstrated for 1h stabilized duration.

24.3.4 Immediately after each abnormal switching test, each control shall be subjected to the Dielectric Voltage-Withstand Test, Section 33.

24.3.5 The control shall either operate as intended in accordance with the endurance test requirements, or demonstrate an end-of-life fail safe condition with no evidence of an imminent electrical shock, fire or injury to persons. There shall be:

a) No opening of the ground arc detection fuse,

b) No burning of the cheesecloth,

c) No opening of the branch circuit protection device, or

d) No breakdown during the post-dielectric withstand testing.

25 Limited Power Point Determination Test

25.1 General

25.1.1 Spacings within a portion of a circuit or within the entire circuit less than the applicable values specified in Table 17.1 are acceptable if one of the options specified in this Section is used.

Exception: For supplies of circuits of the types specified in 8.2(b) and 8.2(c), minimum electrical spacings shall be in accordance with Spacings, Section 17, up to the point at which the voltage, current, or both is limited, regardless of the maximum available power involved.

25.1.2 For these options, the applicable power value for an isolated secondary circuit is 50 W and for a line-connected circuit is 15 W.

25.2 Option No. 1

25.2.1 A determination shall be made as to which points in the circuit are capable of delivering a power greater than 15 W for more than 5 s, or 50 W for more than 60 s, whichever is applicable, into an external variable resistor connected singly between each point in the circuit and the circuit's supply return (circuit common). See 25.2.2. The circuit shall then be investigated to determine that for the applicable power value of 15 or 50 W:

a) The minimum spacings specified are maintained:

1) Between points that are both capable of delivering a power greater than 15 or 50 W; and

2) Between points that are capable of delivering a power greater than 15 or 50 W and points that are not capable of delivering a power greater than 15 or 50 W.

Spacings are not specified between points both not capable of delivering a power greater than 15 or 50 W.

b) The conditions noted in 25.5.1 do not occur when the circuit is subjected to an overload test in which each point nearest the power supply that is not capable of delivering a power greater than 15 or 50 W is short-circuited to a return to the power supply singly or simultaneously with the shorting of other such points located in the same or another supply circuit.

Exception: Spacings between points that are capable of delivering a power greater than 15 or 50 W less than specified in Table 17.1 are acceptable if the circuit complies with 25.2.4.

25.2.2 With reference to 25.2.1, to determine the points capable of delivering a power of more than 15 or 50 W, whichever is applicable, the external resistor is to be set for maximum resistance before being connected to the circuit under investigation. The external resistor is to be adjusted until the maximum wattage is consumed by the resistor as indicated by a peak reading of the wattmeter. A reading of greater than 15 or 50 W indicates that the points are capable of delivering greater than 15 or 50 W. The external resistor is then to be moved, point by point, from the point farthest from the load to other points toward the load side of the circuit until a point is reached where the maximum power consumed by the external resistor (as indicated by a peak reading of the wattmeter) is not more than 15 or 50 W. During the test, the control is to be connected to a source of supply as indicated in 21.2, and operated in the full on condition.

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25.2.3 With reference to 25.2.1, if a thermal or overcurrent protective device operates during the test, a shorting switch is to be connected across the protective device in the closed position. The external resistor is to be adjusted for maximum resistance before being connected in the circuit. The external resistor is then to be adjusted so that the power the resistor dissipates is 15 or 50 W as indicated by the wattmeter reading. The switch across the protective device is then to be opened and the time required for the protective device to open is to be recorded. If the protective device opens the circuit in 5 s or less while the resistor is dissipating 15 W, the first circuit point not capable of delivering more than 15 W has been located. If the protective device opens the circuit in 60 s or less while the resistor is dissipating 50 W, the first circuit point not capable of delivering 50 W has been located. See 36.4.

25.2.4 With reference to the Exception to 25.2.1, the circuit shall be further investigated to determine each of the following:

a) That the maximum available power does not exceed 15 or 50 W when an external variable resistor is connected across points delivering greater than 15 or 50 W and having spacings less than those required. Beginning with the variable load resistor set for maximum resistance, the resistor is to be adjusted until the resistor consumes maximum wattage, as indicated by the reading of the wattmeter.

b) If a thermal or overcurrent protective device operates during the test in (a), a shorting switch is to be connected across the protective device, in the closed position, and the variable load resistor is to be adjusted to dissipate exactly 15 or 50 W as indicated by the wattmeter reading. The shorting switch is then to be opened and the time required for the protective device to open is to be measured. The protective device shall open within 5 s if the applicable power value in question is 15 W or shall open within 60 s if the applicable power value in question is 50 W. During the test, the control is to be connected to a source of supply as indicated in 21.2 and operated in the full on condition. See 25.4.1 and 36.4.

c) That the conditions noted in 25.5.1 do not occur when the circuit is subjected to an overload test in which any combination of points in the greater than 15 or 50 watt circuit having spacings less than those required, are shorted together.

25.3 Option No. 2

25.3.1 Spacings are not specified if the circuit is supplied by one or more isolated windings of a transformer, and the total output power is less than 50 W.

25.3.2 With reference to 25.3.1, the total output power of the secondary winding or windings is the maximum of the values determined in (a) and (b) with the control transformer connected to the intended source of supply:

a) The maximum power that each winding can deliver into an external resistor is to be measured with the other secondary windings loaded to rated current or power. The total power is the sum of the maximum power from each winding.

b) Two or more secondary windings are to be interconnected to result in the maximum power that can be delivered into an external resistor while the other remaining windings (if any) are loaded to rated current or power. The maximum power from the combined winding is then to be added to the maximum power of each remaining winding (if any) obtained from (a) or to the maximum power obtained by combining any remaining windings. This process is to be continued until each combination of two, three, or more, interconnected windings has been tested.

25.4 Component failure

25.4.1 A control shall comply with the requirements in 25.2.1 and 25.2.4 with each resistor, capacitor, or other circuit element connected between the power supply and the first point capable of delivering less than 15 or 50 W (as determined according to the requirements in 25.2.2) open- or short-circuited one at a time. For a discrete device having more than two terminals, such as a transistor, SCR, triac, or similar device, any combination of two terminals shall be open- or short-circuited. For an integrated circuit device, the following combination of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

b) Each input terminal shorted to (referenced) ground terminal;

c) Each output terminal shorted to (referenced) ground terminal;

d) Each input terminal shorted to each power supply;

e) Each output terminal shorted to each power supply; and

f) Each terminal open-circuited.

Exception No. 1: A resistor investigated for acceptability with respect to end-use conditions and incorporating insulation complying with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, spacings, or both to reduce the risk of a short circuit or reduction in resistance is not required to be open- or short-circuited.

Exception No. 2: A capacitor, capristor (parallel combination of a capacitor and resistor), or similar circuit component, complying with requirements for antenna coupling and line bypass components in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, and investigated for acceptability with respect to end-use conditions, is not required to be short-circuited.

Exception No. 3: Electronic circuit elements used within a circuit assembly, and that have been subjected to a successful complete component evaluation program as described in Electronic Component Evaluation, Section 32, are not required to be open- or short-circuited.

Exception No. 4: Reduced testing of an integrated circuit is acceptable if the location of points capable of delivering more than 15 or 50 W, whichever is applicable, under the conditions in (a) – (f) can be determined by circuit analysis.

25.4.2 If the test prescribed in 25.4.1 results in a change in the location of the first point in the circuit capable of delivering more than 15 or 50 W as applicable, the circuit shall comply with 25.2.1 at the new point.

25.4.3 Circuit components, which when taken together are relied upon to limit power in connection with the requirements in this Section, shall be of the fixed type and shall be investigated as a unit with respect to end-use conditions.

25.5 Overload test

25.5.1 The control, end-use product, or both is to be covered with a single layer of cheesecloth and then placed on a softwood surface that has been covered with white tissue paper. The control is to be connected to a source of supply as indicated in 21.2, operated in the full on condition, and subjected to the tests noted in 25.2.1(b) and 25.2.4(c). At the conclusion of the tests:

a) Any electronic circuit element relied upon to limit power to the points in question shall not:

1) Experience an electrical stress factor greater than 0.5 (1.0 when the test is repeated under single component failure), or

2) Change in value to the extent that the specified power limit is exceeded.

b) There shall not be ignition of the tissue paper, wood, or cheesecloth.

c) There shall not be dielectric breakdown as a result of a repeated test in accordance with Dielectric Voltage-Withstand Test, Section 33.

d) A 3-A nontime-delay fuse, connected between dead metal parts of the control, end-use product, or both and earth ground during the test, shall not open.

e) There shall not be abnormal operation of the end-use product or control (such as asymmetrical switching of an ac load or chattering of electromagnetic contacts) or impairment of a safety device to the extent that a risk of fire, electric shock, or injury to persons results.

f) There shall not be unintended operation of the end-use product (such as discontinuous operation, spontaneous start-up or failure of the control to terminate operation) unless it is demonstrated that such unintended operation does not result in a risk of fire, electric shock, or injury to persons.

25.5.2 With reference to 25.5.1, unless components need to be replaced after conducting the tests, a dielectric voltage-withstand test shall be performed upon completion of the last test.

25.5.3 Unless ultimate results are obtained in less time, each overload test is to be performed for a minimum of one hour. If at the end of one hour there is no evidence of overheating of parts, continuation of the test is not required. If at the end of one hour there is evidence of overheating, the test is to be continued for 7 h. Evidence of overheating of parts exists when odor, smoke, discoloration, cracking of material, charring, flaming, glowing, arcing, or similar phenomenon is detected or when changes in circuit current measured through the applied fault occur.

26 Isolation Tests

26.1 General

26.1.1 A control employing a device relied upon to maintain required isolation between circuits (for example, between line-connected and isolated secondary circuits) shall be subjected to the tests specified in 26.1.2 – 26.4.1. The results of these tests are acceptable if:

a) There is no ignition of the tissue paper, wood, or cheesecloth;

b) The 3-A ground fuse does not open;

c) There is no indication of a dielectric breakdown following the test; and

d) There is no unintended or abnormal operation of the end-use product or control such as noted in 25.5.1.

26.1.2 During the tests, the control, end-use product, or both is to be covered with a single layer of cheesecloth and placed on a softwood surface that has been covered with white tissue paper. The end-use product is then to be connected to a source of supply as indicated in 21.2. Dead metal parts of the control, end-use product, or both are to be connected to earth ground through a 3-A nontime-delay fuse. Unless results are obtained in less time, each test is to be performed for at least one hour. If at the end of one hour there is no evidence of overheating of parts, discontinuing the test is acceptable. If there is evidence of overheating, the test is to be continued for 7 h. Evidence of overheating of parts exists when odor, smoke, discoloration, cracking of material, charring, flaming, glowing, arcing, or similar phenomenon is detected or when changes in circuit current measured through the applied fault occur.

26.1.3 If a circuit element or printed wiring foil opens to terminate a test, the test is to be repeated two additional times.

Exception: Operation of a thermal or overcurrent device that is rated for the application does not require repeating the test.

26.2 Pulse transformer burnout tests

26.2.1 A control employing a pulse transformer that is relied upon to maintain required isolation between circuits shall be subjected to the following tests. A separate sample shall be used for each test condition.

a) Each secondary winding of the pulse transformer is to be short-circuited (singly). For each test, the pulse transformer is to be subjected to one of the following input conditions.

1) The pulse transformer is to be connected normally into the circuit. The control is to be operated in the full on condition;

2) The output terminals of each isolating transformer secondary winding which supplies power to the circuit containing the primary winding of the pulse transformer are to be connected directly to the primary winding of the pulse transformer. If a tapped winding serves to supply power to the circuit, the ends of the tapped winding are to be connected to the pulse transformer.

Exception: If a power supply that includes an isolating transformer complies with the requirements for line-connected circuits, the output of such a supply is to be connected directly to the primary winding of the pulse transformer.

3) The output terminals of each isolating transformer secondary winding/rectifier combination which supplies dc power to the circuit containing the primary winding of the pulse transformer are to be connected directly to the primary winding of the pulse transformer.

Exception: If a power supply that includes an isolating transformer complies with all of the requirements for line-connected circuits and combines with a rectifier to furnish dc power to the circuit containing the primary winding of the pulse transformer, the output of the power supply/rectifier combination is to be connected directly to the primary winding of the pulse transformer.

b) Taken one at a time, each output circuit of the pulse transformer which is intended to provide a firing signal to the gate of a thyristor is to be connected in series with the intended end-use product load or with a source of supply and a load. The intended end-use product load or the supply and load are to be adjusted to produce the overall rated output voltage and current of the control. The output circuit of the pulse transformer may consist of the secondary winding of the pulse transformer alone or in combination with other circuit elements. For this test, the control is to be adjusted for the standby condition (that is, the condition which does not send a firing signal to the gate of the thyristor).

26.2.2 With reference to 26.2.1, after each test a dielectric voltage-withstand test shall be performed on the pulse transformer. The test potential is to be the value specified in 33.2.2 applied for one min. The potential is to be applied:

a) Between the primary and each secondary winding;

b) Between each secondary winding;

c) Between each secondary winding and the core unless the core is encapsulated or otherwise inaccessible and the insulation between the secondary winding and the core is not being relied upon to comply with (a) and (b); and

d) Between the primary winding and the core unless the core is encapsulated or otherwise inaccessible and the insulation between the primary winding and the core is not being relied upon to comply with (a) and (b).

26.3 Optical isolator tests

26.3.1 A control employing an optical isolator that is relied upon to maintain required isolation between circuits shall be subjected to the following tests. A separate sample shall be used for each test condition.

a) Each pair of output terminals of the optical isolator is to be short-circuited (singly). For each test, the optical isolator shall be subjected to one of the following input conditions:

1) The optical isolator is to be connected normally into the circuit. The control is to be in the full on condition.

2) The output terminals of each isolating transformer secondary winding which supplies power to the circuit containing the light emitting diode of the isolator are to be connected directly to the input terminals of the optical isolator. If a tapped winding serves to supply power to the circuit, the ends of the tapped winding are to be connected to the optical isolator.

Exception: If a power supply that includes an isolating transformer complies with all of the requirements for line-connected circuits, the output of such a supply is to be connected directly to the optical isolator.

b) Taken one at a time, each output circuit of the optical isolator that is intended to provide a firing signal to the gate of a thyristor is to be connected in series with the intended end-use product load or with a source of supply and a load. The intended end-use product load or the supply and load are to be adjusted to produce the overall rated output voltage and current of the control. The output circuit of the optical isolator generally will consist of the light sensitive semiconductor device in combination with other circuit elements. For this test, the control is to be adjusted for the standby condition (that is, the condition which does not send a firing signal to the gate of the thyristor).

26.3.2 With reference to 26.3.1, after each test a dielectric voltage withstand test shall be performed on the optical isolator for one min between the input and output terminals of the optical isolator. The test potential shall be the value specified in 33.2.2.

26.4 Component failure

26.4.1 A component such as a capacitor, resistor, or similar component incorporated in the output circuitry of an isolation device is to be open- or short-circuited (singly) to determine if an overcurrent condition can occur that will result in loss of isolation between circuits. For a discrete, multiple (more than two) terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. The control is to be operated in the most severe operating condition, including standby. After each test, a dielectric voltage-withstand test shall be performed in accordance with 26.2.2 or 26.3.2, whichever is applicable.

Exception No. 1: A resistor investigated for acceptability with respect to end-use conditions and incorporating insulation complying with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, spacings, or both to reduce the risk of a short circuit or reduction in resistance is not required to be open- or short-circuited.

Exception No. 2: A capacitor, capristor (parallel combination of a capacitor and resistor), or similar circuit component, complying with requirements for antenna coupling and line bypass components in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, and investigated for acceptability with respect to end-use conditions, is not to be short-circuited.

Exception No. 3: Electronic circuit elements used within a circuit assembly, and that have been subjected to a successful complete component evaluation program as described in Electronic Component Evaluation, Section 32, are not required to be open- or short-circuited.

27 Power-Switching Semiconductors

27.1 General

27.1.1 A control employing a power-switching semiconductor that is intended to function in a circuit with a level of energy that involves a risk of fire, electric shock, or injury to persons shall be subjected to the overload test specified in 27.2.1. A control employing a power-switching semiconductor relied upon as a safety device or as part of a safety circuit is to be additionally subjected to a 100,000-cycle endurance test, otherwise the test is to consist of 6000 cycles (see 27.3.1).

27.1.2 There shall not be electrical or mechanical malfunction of a power-switching semiconductor nor opening of the fuse connected to dead metal parts when a sample of the control is subjected to these tests. The criteria for determining malfunctioning of the semiconductor is not limited to opening or shorting but includes such conditions as half-wave operation, asymmetrical switching other than half-wave, and discontinuous operation unless such conditions do not present a risk of electric shock because of the type of load involved or because of tests required elsewhere in this standard addressing the condition (see 23.2). For each test, the semiconductor is to be cycled at a rate of 6 cycles/minute with an ″on″ time of one second. The fuse shall be a 3-A nontime-delay type, connected between dead metal parts of the control and the live pole least likely to strike to ground.

27.1.3 Alternating-current interrupting tests shall be performed on a circuit having a frequency of 60 Hz.

Exception: For a control rated other than 60 Hz and within the range of 25 – 60 Hz, it is acceptable to perform the test at rated frequency.

27.1.4 For these tests, the control is to be mounted to the end-use product as intended. A control intended specifically for use in an ambient temperature more than 25°C (77°F) shall be tested at the ambient temperature. Each cycle shall consist of starting with the semiconductor in the standby condition, initiation of the activation circuit, and restoration of the device to the standby condition.

Exception: The tests are not required to be performed in the end-use product if heat sinking, ambient temperature conditions, for which the tests are to be performed are duly noted for end-use.

27.2 Overload test

27.2.1 The overload test shall consist of 50 cycles of operation. Other than as noted in (f), the test voltage is to be the rated output voltage of the control. The test load is to be in accordance with the following rating categories as applicable for the output rating of the control or the intended load of the semiconductor:

a) General purpose ac ampere rating – The load shall be 150 percent of the rated current at rated voltage. The power factor shall be 0.75 to 0.80.

b) General purpose dc ampere rating – The load shall be 150 percent of rated current obtained by using a noninductive resistive load at rated voltage.

c) Resistive ampere rating – The load shall be 150 percent of rated current at rated voltage. The power factor shall be 0.95 to 1.0.

d) Tungsten lamp rating – The load shall be tungsten filament lamps with a steady state current of 150 percent of rated current at rated voltage. Multiple lamp loads are to be sequenced such that each lamp is off for not less than 59 s between each on period.

e) Electric discharge lamp rating – The load shall be three times rated current at rated voltage. The power factor shall be 0.40 to 0.50.

f) Pilot-duty rating – The load shall display inrush and normal characteristics of an electromagnetic load at rated voltage. If the semiconductor device controls an integral contactor, relay, or other magnetically-operated device, the test is to be performed using the actual electromagnet as the load. The test voltage is to be 110 percent of the rated voltage.

g) AC horsepower or full-load/locked-rotor ac rating – The load shall be six times the full-load motor current at a power factor of 0.40 to 0.50. See Table 27.1 for full-load motor currents corresponding to the various ac horsepower ratings.

Exception No. 1: It is acceptable to perform the overload test using the end-use product load modified to produce an overload current consistent with the rating category noted.

Exception No. 2: For an end-use product load consisting of a motor, the overload test is to be performed using the locked-rotor current of the motor.