



UL 498B

STANDARD FOR SAFETY

Receptacles with Integral Switching Means

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UL Standard for Safety for Receptacles with Integral Switching Means, UL 498B

First Edition, Dated August 19, 2022

SUMMARY OF TOPICS

This First Edition ANSI/UL 498B, Standard for Receptacles with Integral Switching Means, dated August 19, 2022 covers a receptacle with integral switching means rated 600 V or less, used in ordinary dry locations and intended for connection to a branch circuit in accordance with the National Electrical Code, NFPA 70.

The requirements are substantially in accordance with Proposal(s) on this subject dated March 11, 2022 and June 24, 2022.

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UL 498B

Standard for Receptacles with Integral Switching Means

First Edition

August 19, 2022

This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 498B as an American National Standard (ANSI) occurred on August 19, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover a receptacle with integral switching means rated 600 V or less, used in ordinary locations and intended for connection to a branch circuit in accordance with the National Electrical Code, NFPA 70. A receptacle with integral switching means that is intended for energy management and building automation, in accordance with Article 406 of the National Electrical Code, NFPA 70, shall also comply with Annex [A](#) of this standard.

1.2 This standard contains Annex [A](#) – (Normative) – Receptacles with Integral Switching Means Intended for Energy Management and Building Automation.

1.3 This standard contains Annex [B](#) – (Normative) – Weather-Resistant Receptacles with Integral Switching Means.

1.4 A receptacle with integral switching means covered by this standard shall meet the following requirements:

- a) No voltage greater than 600 V above ground will be present in the device;
- b) An isolation transformer, if provided, shall furnish power at a lower potential than the primary voltage;
- c) The output of the device shall not be located in a circuit operating at greater than 600 V above ground; and
- d) The switching device shall be integral to the receptacle.

1.5 This standard does not apply to the following devices and the associated standards:

- a) A receptacle that does not employ an integral switching means but are marked with the word "CONTROLLED" and the symbol shown in [Table A8.1](#) Reference No. 2 is covered by the Standard for Attachment Plugs and Receptacles, UL 498 and are intended for use in energy management and building automation.
- b) A health care facility outlet assembly is covered by the Outline of Investigation for Cord-and-Plug-Connected Health Care Facility Outlet Assemblies, UL 2930.

1.6 This standard does not directly apply to, but may supplement the following standards:

- a) Devices produced integrally with flexible cord or cable, covered by the Standard for Cord Sets and Power-Supply Cords, UL 817;
- b) Current taps and adapters covered by the Standard for Current Taps and Adapters, UL 498A;
- c) Devices employing male or female screwshells, covered by the Standard for Lampholders, UL 496;
- d) Single and multipole connectors intended for factory assembly to copper or copper alloy conductors or printed wiring boards for use in data, signal, control and power applications within and between electrical equipment, covered by the Standard for Component Connectors for Data, Signal, Control and Power Applications, UL 1977;

- e) Devices intended for installation and use in hazardous (classified) locations in accordance with the National Electrical Code, NFPA 70, covered by the Standard for Explosion-Proof and Dust-Ignition-Proof Equipment for Use in Hazardous (Classified) Locations, UL 1203;
- f) Devices intended for use with telecommunications networks, covered by the Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1, or the Standard for Communications Circuit Accessories, UL 1863;
- g) Devices incorporating ground-fault circuit interruption circuitry, covered by the Standard for Ground-Fault Circuit Interrupters, UL 943;
- h) Direct plug-in devices incorporating transient voltage surge suppression circuitry, covered by the Standard for Surge Protective Devices, UL 1449;
- i) Direct plug-in devices incorporating electromagnetic interference filter circuitry, covered by the Standard for Electromagnetic Interference Filters, UL 1283;
- j) Cord-connected, relocatable power taps intended only for indoor use as a temporary extension of a grounding alternating-current branch circuit for general use, covered by the Standard for Relocatable Power Taps, UL 1363;
- k) Energy management equipment covered by the Standard for Energy Management Equipment, UL 916.

2 Components

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

- a) Comply with the requirements for that component as specified in this standard;
- b) Be used in accordance with its rating(s) established for the intended conditions of use; and
- c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a product covered by this standard is not required to comply with a specific component requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product;
- b) Is superseded by a requirement in this standard; or
- c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

2.3 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.

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

3 Units of Measurement

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

4 Referenced Publications

4.1 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.

4.2 The following publications are referenced in this standard:

ASTM 653, *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*

ASTM A90, *Standard Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings*

ASTM E230/E230M, *Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

ASTM G151, *Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources*

ASTM G153, *Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials*

ASTM G155, *Standard Practice For Operating Xenon Arc Light Apparatus For Exposure Of Non-Metallic Materials*

NEMA WD6, *Wiring Devices – Dimensional Specifications*

NFPA 70, *National Electrical Code*

UL 13, *Power-Limited Circuit Cables*

UL 20, *General-Use Snap Switches*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 224, *Extruded Insulating Tubing*

UL 496, *Lampholders*

UL 498, *Attachment Plugs and Receptacles*

UL 498A, *Current Taps and Adapters*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 746E, *Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards*

UL 796, *Printed Wiring Boards*

UL 817, *Cord Sets and Power-Supply Cords*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 916, *Energy Management Equipment*

UL 943, *Ground-Fault Circuit-Interrupters*

UL 969, *Marking and Labeling Systems*

UL 1097, *Double Insulation Systems for Use in Electrical Equipment*

UL 1203, *Explosion Proof and Dust-Ignition Proof Electrical Equipment for Use in Hazardous (Classified) Locations*

UL 1283, *Electromagnetic Interference Filters*

UL 1363, *Relocatable Power Taps*

UL 1449, *Surge Protective Devices*

UL 1557, *Electrically Isolated Semiconductor Devices*

UL 1863, *Communications-Circuit Accessories*

UL 1977, *Component Connectors for Data, Signal, Control and Power Applications*

UL 2930, *Outline of Investigation for Cord-and-Plug-Connected Health Care Facility Outlet Assemblies*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-2, *Low Voltage Transformers – Part 2: General Purpose Transformers*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 60384-14, *Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains*

UL 60730-2-2, *Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Thermal Motor Protectors*

UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

5 Glossary

5.1 For the purpose of this standard the following definitions apply:

5.2 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.
- f) 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 [26](#).

5.3 CLASS 2 SEPARABLE LEAD ASSEMBLY – Consists of a factory-made, power-limited cable assembly provided with a connector, intended for Class 2 signaling between a device such as a sensor, timer or energy-management equipment and a wired controlled receptacle.

5.4 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.

5.5 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.

5.6 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.

5.7 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.

5.8 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.

5.9 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.

5.10 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 [5.8](#).

5.11 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.

5.12 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.

5.13 SAFETY CIRCUIT – A primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, injury to persons, or 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.

5.14 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.

5.15 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 UL 5085-1 and UL 5085-3.

b) **POWER** – A transformer other than Class 2 that is intended to transmit power. Included are isolation and non-isolation (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.

5.16 WIRED CONTROLLED RECEPTACLE – A receptacle that employs an integral switching means where a Class 2 signaling device such as a sensor, timer or energy-management equipment is connected to the device by a Class 2 separably lead assembly.

5.17 WIRELESS CONTROLLED RECEPTACLE – A receptacle that employs an integral switching means where the signaling device such as a sensor, timer or energy-management equipment is wirelessly connected to the controlled receptacle by radio-signal.

CONSTRUCTION

6 General

6.1 In addition to the construction requirements contained in this standard, a receptacle with integral switching means shall also comply with the applicable construction requirements of UL 498.

6.2 A receptacle with integral switching means 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.

6.3 A receptacle with integral switching means shall be formed and assembled so that the device has the strength and rigidity necessary to resist the foreseeable abuse to which the device 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.

6.4 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](#).

6.5 For a controlled environment, the means used to prevent contamination and condensation shall be rated for the purpose. The controlled environment in a non-production indoor area in an ordinary location free of conductive contaminants shall be evaluated for the means used to prevent condensation only.

6.6 A Class 2 separable conductor lead assembly, provided with or intended for use with a wired control receptacle, shall only be located behind the plane of the wired control receptacle mounting yoke and not be accessible when a cover plate is installed.

7 Configurations

7.1 A receptacle with integral switching means referenced in this standard are in accordance with NEMA WD6.

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 shall be in accordance with UL 498.

8.2 A live part of a receptacle with integral switching means 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.

d) 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 (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 (c), shall be of the fixed type and shall be evaluated 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 (c):

- a) Minimum electrical spacings shall be in accordance with Spacings, Section [23](#), 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-hour short-circuit test specified in [38.1](#).

9 Current-Carrying Parts

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

10 Internal Wiring

10.1 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 mm²) or having insulation less than 1/32 inch (0.79 mm) thick.

INTERNAL SPLICES AND CONNECTIONS

11 General

11.1 Internal splices and connections 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.

11.2 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.

11.3 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.

11.4 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.

11.5 A printed-wiring board connector intended to facilitate interconnection within a receptacle with integral switching means 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.

12 Wire-Wrapped Connections

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

12.2 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 evaluation.

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

12.4 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.
- c) See [Table 12.1](#). A smaller number of wraps shall be subjected to evaluation. 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 12.1
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

12.5 The term "closely wrapped" in [12.4\(b\)](#) 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.

12.6 The requirements in [12.5](#) 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 [12.5](#).

13 Wiring Terminals and Leads

13.1 A receptacle with integral switching means shall comply with the terminal and leads requirements of UL 498.

14 Separation of Circuits

14.1 Separation of circuits between insulated conductors or other insulated live parts of different circuits, and 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 14.1](#).

Table 14.1
Separation of Circuits

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

^a The letters a and b refer to separation (See [14.1](#)) 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.

^b Acceptable means of separation are:

A) Spacings – The through air spacings as indicated in [Table 23.1](#), based on the highest voltage involved, shall be used to determine compliance of separation. See [23.3](#).

1) Required spacing.

2) Twice required spacing.

B) Double Insulation – Two separate and distinct insulations with each rated for the highest voltage involved, see [23.3](#), and complying with the requirements in 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 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 inch (0.71 mm), 0.007 inch (0.18 mm), and 0.006 inch (0.15 mm), respectively. Other materials shall comply with the requirements applicable to internal barriers in UL 746C.

3) Insulating Material (Sole Separation) – Insulating material shall comply with the requirements in [23.5](#) and [23.7](#).

14.2 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.

14.3 With reference to [14.1](#), a limited energy circuit derived from a circuit by limiting impedance shall be treated as one circuit.

14.4 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 [14.1](#). The strain relief means shall comply with the requirements for the end-use product.

14.5 When determining the required separation of the circuits in accordance with [14.1](#), 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.

15 Insulating Material

15.1 A receptacle with integral switching means shall comply with the insulating material requirements of UL 498. Additionally, a polymeric material used to enclose the power supply circuitry shall have a flame rating not less than 5V, or comply with the 127 mm Flame Test specified in UL 746C.

15.2 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.

15.3 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.

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

16 Printed-Wiring Boards

16.1 A printed-wiring board, including the coatings, shall comply with the requirements in 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 non-safety 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.

16.2 A printed-wiring board, including the coating, shall have a minimum flammability classification of V-2 as specified in the 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.

COMPONENTS

17 Switching Devices

17.1 An electromechanical switching device:

a) 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

b) 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) Motor.

17.2 A switch shall be evaluated with respect to the temperature limitations of the materials employed.

17.3 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.

18 Capacitors

18.1 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.

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

18.3 A capacitor connected across the supply circuit shall comply with UL 60384-14.

18.4 With reference to the requirements in [18.3](#), 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.

18.5 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 [34](#), and having a diameter of more than 0.394 inch (10 mm), shall be provided with a means for relieving excessive internal pressure.

19 Power-Switching Semiconductors

19.1 A power-switching dead-case-mounted semiconductor shall comply with 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.

20 Isolation Devices

20.1 If a device intended to provide electrical isolation, such as an optical isolator, pulse transformer, relay, or similar device, is provided to reduce the risk of fire, electric shock, or injury to persons, or 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:

- a) Comply with the requirements for such devices;
- b) Be suitable for the voltage and temperature involved; and
- c) Be subjected to the tests specified in Isolation Tests, Section [35](#), to determine the effects on the insulating properties of the isolating medium.

21 Transformers

21.1 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.

21.2 A Class 2 transformer shall comply with the applicable requirements in UL 5085-1 and UL 5085-3.

21.3 A power transformer shall comply with the applicable requirements in UL 5085-1 and UL 5085-2 and with the overload heating requirements in UL 5085-1 and UL 5085-3. See [22.5](#).

22 Isolation Transformers

22.1 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.

22.2 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.

22.3 With reference to [22.2](#), 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.

Exception: Insulation or spacings are not required between parts noted in [22.3](#) (d) and (e) if the risks noted in [22.1](#) are not present.

22.4 Spacings between parts noted in [22.3](#) (a) – (e) shall not be less than the applicable value specified in [Table 22.1](#). The potential involved is the maximum voltage in any winding or the normal operating voltage existing between the parts in question, whichever is greater.

Table 22.1
Minimum Spacings at Isolation Transformers

Potential involved, V, rms	Through air		Over surface	
	inch	(mm)	inch	(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.				

22.5 The insulation of a pulse transformer or an isolation type power transformer shall comply with the applicable coil construction requirements in UL 5085-1 and UL 5085-3.

23 Spacings

23.1 Unless otherwise noted and as provided in Alternate Spacings – Clearances and Creepage Distances, Section 24, spacings within a control receptacle shall be as indicated in Table 23.1:

- 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 spacing of a receptacle with integral switching means contact and terminal shall comply with the spacings requirements of UL 498.

Exception No. 2: The minimum acceptable spacings specified in Table 23.1 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. 3: 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 inch (1.2 mm) is acceptable in a circuit rated at 250 V or less.

Exception No. 4: Spacings are not specified within Class 2 circuits as defined in 5.2 and complying with Class 2 Circuits, Section 26, 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 inch (0.8 mm) are acceptable between uninsulated live parts within a Class 2 safety circuit that complies with the requirements in Class 2 Circuits, Section 26 and between such parts and dead metal, if the construction is such that spacings will be permanently maintained.

Exception No. 5: In other than safety circuits, a spacing less than the minimum specified in Table 23.1 is acceptable under the conditions described in Limited Power Point Determination Test, Section 34.

Table 23.1
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	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
0 – 50 (0 – 70.7)	1/16 ^a	(1.6) ^a	1/16 ^a	(1.6) ^a	3/64	(1.2)	3/64	(1.2)
51 – 125 (72.1 – 176.8)	1/16 ^a	(1.6) ^a	1/16 ^a	(1.6) ^a	1/16 ^a	(1.6) ^a	1/16 ^a	(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 ^b	(9.5) ^b	1/4 ^b	(6.4) ^b	3/8 ^b	(9.5) ^b	1/4 ^b	(6.4) ^b
301 – 600 (425.6 – 848.4)	1/2 ^b	(12.7) ^b	3/8 ^b	(9.5) ^b	1/2 ^b	(12.7) ^b	3/8 ^b	(9.5) ^b

^a Spacings within a circuit less than those indicated but not less than 3/64 inch (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.

^b Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 inch (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.

23.2 Spacings between different circuits shall be based on the voltage involved. The output voltage rating of a control receptacle 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.

23.3 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.

23.4 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 23.1](#) regardless of the position of such parts.

23.5 An insulating barrier or liner used as the sole separation between parts noted in [23.1](#) shall be of material of a type that is suitable for mounting uninsulated live parts and shall not be less than 0.028 inch (0.71 mm) thick.

23.6 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 inch (0.71 mm) thick. If the barrier or liner is of vulcanized fiber, the air space shall not be less than 1/32 inch (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 evaluation, 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 inch (0.71 mm) but not less than 0.013 inch (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 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.

23.7 Insulating material having a thickness less than that specified in [23.5](#) and [23.6](#) is acceptable if, upon evaluation, the material is found to be rated in accordance with UL 746C, for the particular application.

23.8 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 heat shrink tubing is acceptable.

24 Alternate Spacings – Clearances and Creepage Distances

24.1 As an alternative to the specified spacing requirements of Section 23, Spacings, the spacing requirements in 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 24.2 – 24.5 modified accordingly.

24.2 When applying specific requirements in UL 840, the degrees of pollution shall be as indicated in Table 24.1.

Table 24.1
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 UL 840.	

24.3 When applying specific requirements in UL 840, the spacing requirements in UL 840, shall be based on intended for fixed wiring connection, overvoltage category III.

24.4 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.

24.5 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 UL 746E, are considered to have a minimum comparative tracking index of 100 without further evaluation.

25 Bonding of Internal Parts for Grounding

25.1 Internal dead metal parts of a receptacle with integral switching means (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 or grounding lead.

25.2 Circuitry shall be arranged such that a grounding connection or conductor will not carry current.

26 Class 2 Circuits

26.1 A Class 2 circuit, as defined in 5.2, shall comply with the requirements for primary circuits unless:

- 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 control receptacle.

26.2 When a Class 2 circuit is intended to be used for a safety-related function, or when malfunction in the circuit results in a risk of fire, electric shock, or injury to persons to occur in the receptacle with integral switching means, the Class 2 circuit shall be evaluated to 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 [23.1](#) are acceptable.

26.3 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 [38.1](#).
- 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.

26.4 With reference to [26.3](#), 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 UL 5085-1 and UL 5085-3, when the overcurrent protective device is bypassed.

26.5 A power supply is inherently limited if it does not rely upon a fuse or other overcurrent protective device to comply with [26.3](#)(b).

26.6 The voltage limit specified in [26.3](#) is to be measured with the control, the power supply, or the transformer primary connected to the voltage specified in [27.2](#) 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 [26.10](#).

26.7 If the power supply employs a regulating network or fixed impedance to limit the current or voltage in accordance with [26.3](#), 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 evaluated for acceptability with respect to end-use conditions and incorporating insulation complying with 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 UL 60384-14 and evaluated 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.

26.8 Components which taken together comprise a fixed impedance or regulating network used to limit current or voltage in accordance with [26.3](#) shall be tested 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.

26.9 An electronic circuit element relied upon to limit voltage or current in accordance with [26.3](#) shall not experience an electrical stress factor greater than 0.5 during all conditions of normal operation or 1.0 after single component failure.

26.10 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 [26.6](#).

26.11 The overcurrent protective device mentioned in [26.4](#) 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 [44.4](#) is provided adjacent to the device;
- e) Be rated or set in accordance with [Table 26.1](#) if the device is provided in the secondary circuit; and
- f) Comply (in conjunction with the power supply) with the applicable requirements in UL 5085-1 and UL 5085-3 for non-inherently limited transformers whether the device is located in the primary or secondary circuit.

Table 26.1
Maximum Rating for Overcurrent Protection

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

26.12 A circuit is Class 2 if the circuit is supplied by more than one inherently-limited source or more than one non-inherently 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 [26.3](#) – [26.10](#) for inherently limited or non-inherently-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.

26.13 The load circuits of two or more power supplies, each of which is separately a Class 2 circuit in accordance with the requirements in [26.3](#) – [26.10](#) and that is not interconnected, shall be considered as separate circuits. Spacings, insulation, and separation between such circuits shall be as noted elsewhere in this standard.

26.14 A device having exposed Class 2 outputs as specified below shall be provided with a mechanism to indicate the failure of the overvoltage protective device or system:

- a) The Class 2 outputs 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 comply with Clearance B requirements in UL 840. 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.

27 Class 2 Separable Lead Assembly

27.1 A Class 2 separable lead assembly shall consist of type CL3, CL3P, or CL3R cable surrounded by tubing, with one end terminating in a molded-on or permanently attached separable connector, as described in [27.2](#) – [27.5](#).

27.2 A separable lead assembly shall be provided with type CL3, CL3P, or CL3R cable which complies with UL 13. The CL3, CL3P, or CL3R cable shall have a minimum 300 V rating and shall be not less than 18 inches (457 mm) in length.

27.3 Tubing surrounding the type CL3, CL3P, or CL3R cable shall comply with UL 224, have a minimum 300 V rating, and be provided over the entire length. The tubing shall be continuous and firmly fixed to the Class 2 separable lead assembly.

27.4 One end of a Class 2 separable lead assembly shall be provided with a molded-on or permanently attached separable connector to be inserted into mating connector located on the body of the controlled receptacle. Permanently attached can be achieved by crimping, welding, riveting, or equivalent to render the connector non-rewireable.

27.5 The connector of separable lead device located on the lead and on the body of the controlled receptacle shall have contacts that are not likely to be contacted by branch circuit wiring when mated or

unmated. Openings less than 0.062 inch (1.6 mm) in diameter are deemed to comply with this requirement.

PERFORMANCE

28 General

28.1 A receptacle with integral switching means shall be evaluated by subjecting the requisite number of samples representative of commercial form to the applicable tests described in this standard.

28.2 Unless otherwise indicated, tests are to be performed at the rated input frequency of 60 Hz and at a test potential not less than 120, 208, 240, 277, 480, or 600 V corresponding to the input voltage rating.

28.3 The cheesecloth mentioned in this standard is bleached cotton cloth, running 14 – 15 yard²/lb (26 – 28 m²/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.

29 Input Test

29.1 A receptacle with integral switching means, when wired as intended and connected to a supply circuit shall be operated so that it carries its maximum rated load. The switched receptacle circuit shall not have an output greater than 110 % of its marked rating.

29.2 One sample shall be subjected to this test.

30 Overvoltage and Undervoltage Test

30.1 A receptacle with integral switching means shall not exhibit unintended operation as a result of Over / Under voltage conditions.

30.2 Three samples are to be subjected to each test.

30.3 The receptacle with integral switching means shall be connected to a source of supply adjusted to equal 85 % of the marked potential. The output of the control is to be connected in series with a load and a source of supply each adjusted to produce the overall rated output current and voltage of the controlled circuit. The test is then repeated at 110 % of marked potential.

31 Temperature Test

31.1 General

31.1.1 When tested as described in this Section, a receptacle with integral switching means 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 31.1](#).

Table 31.1
Maximum Temperature Rises

Materials and components	°C	°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 ^a	(180) ^a
(b) Molded	125 ^a	(225) ^a
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 ^b	(72) ^b
(b) Other type	65 ^b	(117) ^b
7. Rectifiers at any point		
(a) Selenium or germanium	50 ^a	(90) ^a
(b) Silicon	75 ^a	(135) ^a
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 These limitations do not apply to compounds and components that have been evaluated and found acceptable for a higher temperature. ^b 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, shall be evaluated 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.		

31.1.2 The values in [Table 31.1](#) are based on an assumed ambient of 25 °C (77 °F).

31.1.3 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.

31.2 Operation

31.2.1 To determine whether a receptacle with integral switching means complies with the temperature test requirements, the device is to be operated under the condition of intended use that results in maximum temperatures. The control shall be tested until constant temperatures are attained. For a device 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 [32](#).

31.3 Temperature measurements

31.3.1 If referee temperature measurements are necessary, thermocouples consisting of 30 AWG (0.05 mm²) iron and constantan wires and a potentiometer type of indicating instrument are to be employed.

31.3.2 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.

31.3.3 If thermocouples are used to measure temperatures, the thermocouples are to consist of wires not larger than 24 AWG (0.21 mm²) and not smaller than 30 AWG (0.05 mm²). 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 Tolerances on Initial Values of EMF versus Temperature tables in ASTM E230/E230M.

31.3.4 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 may be brazed or soldered to the metal if necessary. The adjacent thermocouple lead is to be secured to provide strain relief.

31.3.5 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.

31.3.6 A temperature is considered to be stabilized when three consecutive readings, taken at no less than 5-minute intervals, indicate no further rise above the ambient temperature.

32 DC Offset Voltage Test

32.1 For a device 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 is to 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 are to be used in the Temperature Test, Section 31, and the overload and endurance tests in Power-Switching Semiconductors, Section 36. Following the overload and endurance tests, the sample is to be subjected to a repeat of the dc offset voltage test.

32.2 With respect to 32.1, the device shall not have a dc component greater than 2 Vdc, either "as-received" or following the endurance test.

32.3 This test is to be performed with the device connected, loaded, and operated as for normal operation. A voltmeter is to 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.

33 Abnormal Operation Test

33.1 Motor

33.1.1 A device employing a power-switching semiconductor shall comply with the Locked-Rotor Endurance Test in UL 60730-2-2.

Exception No. 1: The winding temperature requirements in UL 60730-2-2 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.

33.2 Component failure

33.2.1 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 evaluated for acceptability with respect to end-use conditions and incorporating insulation complying with 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 UL 60384-14, and evaluated 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 [40](#), 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](#).

33.3 Abnormal switching test

33.3.1 A device 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.

33.3.2 Two test samples are to be 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 to be connected to accessible dead metal of the control. The ground arc detection fuse shall be rated not greater than 3 Amps and not less than the working voltage.
- c) The device is to be supported on a tissue paper covered softwood surface, and is to be covered with a single layer of cheesecloth, as specified in [21.3](#), conforming to the outline of the device.
- d) The rated supply is to be connected through a branch circuit protection device sized according to installation requirements.
- e) The device is to be connected to its rated electrical load.

33.3.3 The prepared test samples are to be operated in accordance with the endurance test described in [28.2](#) (General purpose ac ampere rating - The load is to be 150 % of the rated current at rated voltage. The power factor is to be 0.75 to 0.80), specifying the number of operating cycles and on/off periods using random switching. The test samples are to be operated until either the required number of endurance test cycles are achieved or until ultimate results are demonstrated for a 1-hour stabilized duration.

33.3.4 Immediately after each abnormal switching test, each device is to be subjected to the Dielectric Voltage-Withstand Test, Section [41](#).

33.3.5 The device 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; and
- d) No breakdown during the post-dielectric withstand testing.

34 Limited Power Point Determination Test

34.1 General

34.1.1 Spacings within a portion of a circuit or within the entire circuit less than the applicable values specified in [Table 23.1](#) 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 (c), minimum electrical spacings shall be in accordance with Spacings, Section [23](#), up to the point at which the voltage, current, or both is limited, regardless of the maximum available power involved.

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

34.2 Option No. 1

34.2.1 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 seconds, or 50 W for more than 60 seconds, 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 [34.2.2](#). The circuit shall then be evaluated 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;
 - 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; and
 - 3) Spacings are not specified between points both not capable of delivering a power greater than 15 or 50 W.
- b) The conditions noted in [34.5.1](#) 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 23.1](#) are acceptable if the circuit complies with [34.2.4](#).

34.2.2 With reference to [34.2.1](#), 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. 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 [28.2](#), and operated in the full on condition.

34.2.3 With reference to [34.2.1](#), 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 [44.4](#).

34.2.4 With reference to the Exception to [34.2.1](#), the circuit shall be further evaluated 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 seconds if the applicable power value in question is 15 W or shall open within 60 seconds 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 [28.2](#) and operated in the full on condition. See [34.4.1](#) and [44.4](#).
- c) That the conditions noted in [34.5.1](#) 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.

34.3 Option No. 2

34.3.1 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.

34.3.2 With reference to [34.3.1](#), 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.

34.4 Component failure

34.4.1 A device shall comply with the requirements in [34.2.1](#) and [34.2.4](#) 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 [34.2.2](#)) 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 incorporating insulation complying with 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 UL 60384-14, 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 [40](#), 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.

34.4.2 If the test specified in [34.4.1](#) 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 [34.2.1](#) at the new point.

34.4.3 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 evaluated as a unit with respect to end-use conditions.

34.5 Overload test

34.5.1 The device 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 receptacle with integral switching means is to be connected to a source of supply as indicated in [28.2](#), operated in the full on condition, and subjected to the tests noted in [34.2.1](#) (b) and [34.2.4](#) (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 [41](#).

d) A 3-Amp 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 receptacle with integral switching means (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 (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.

34.5.2 With reference to [34.5.1](#), unless components need to be replaced after conducting the tests, a dielectric voltage-withstand test shall be performed upon completion of the last test.

34.5.3 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.

35 Isolation Tests

35.1 General

35.1.1 A receptacle with integral switching means 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 [35.1.2](#) – [35.4.1](#). The results of these tests are acceptable if:

- a) There is no ignition of the tissue paper, wood, or cheesecloth;
- b) The 3-Amp 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 [34.5.1](#).

35.1.2 During the tests, the device 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 receptacle with integral switching means is then to be connected to a source of supply as indicated in [28.2](#). Dead metal parts of the device are to be connected to earth ground through a 3-Amp 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 hours. 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.

35.1.3 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.

35.2 Pulse transformer burnout tests

35.2.1 A device employing a pulse transformer that is relied upon to maintain required isolation between circuits shall be subjected to the following tests. A separate sample is to 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 a source of supply and a load. The intended supply and load are to be adjusted to produce the overall rated output voltage and

current of the receptacle with integral switching means. 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 receptacle with integral switching means 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).

35.2.2 With reference to [35.2.1](#), 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 [41.2.2](#) applied for one minute. 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).

35.3 Optical isolator tests

35.3.1 A device 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 receptacle with integral switching means 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 a source of supply and a load. The supply and load are to be adjusted to produce the overall rated output voltage and current of the receptacle with integral switching means. 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 receptacle with integral switching means 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).

35.3.2 With reference to [35.3.1](#), after each test a dielectric voltage withstand test is to be performed on the optical isolator for one minute between the input and output terminals of the optical isolator. The test potential is to be the value specified in [41.2.2](#).

35.4 Component failure

35.4.1 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 receptacle with integral switching means 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 [35.2.2](#) or [35.3.2](#), whichever is applicable.

Exception No. 1: A resistor evaluated for acceptability with respect to end-use conditions and incorporating insulation complying with 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 UL 60384-14, and evaluated 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 [40](#), are not required to be open- or short-circuited.

36 Power-Switching Semiconductors

36.1 General

36.1.1 A device 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 [36.2.1](#). A receptacle with integral switching means 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 [36.3.1](#)).

36.1.2 There shall not be electrical or mechanical malfunction of a power-switching semiconductor or opening of the fuse connected to dead metal parts when a sample of the receptacle with integral switching means 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 [32.2](#)). For each test, the semiconductor is to be cycled at a rate of 6 – 10 cycles/minute with an "on" time of one second. The fuse shall be a 3-Amp nontime-delay type, connected between dead metal parts of the control and the live pole least likely to strike to ground.

36.1.3 Alternating-current interrupting tests are to 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.

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

36.2 Overload test

36.2.1 The overload test is to consist of 50 cycles of operation. Other than as noted in (f), the test voltage is to be the rated output voltage of the receptacle with integral switching means. The test load is to be in accordance with the following rating categories as applicable for the output rating of the receptacle with integral switching means:

- a) General purpose ac ampere rating – The load is to be 150 % of the rated current at rated voltage. The power factor is to be 0.75 to 0.80.
- b) General purpose dc ampere rating – The load is to be 150 % of rated current obtained by using a noninductive resistive load at rated voltage.
- c) Resistive ampere rating – The load is to be 150 % of rated current at rated voltage. The power factor is to be 0.95 to 1.0.
- d) Tungsten lamp rating – The load is to be tungsten filament lamps with a steady state current of 150 % of rated current at rated voltage. Multiple lamp loads are to be sequenced such that each lamp is "off" for not less than 59 seconds between each "on" period.
- e) Electric discharge lamp rating – The load is to be three times rated current at rated voltage. The power factor is to be 0.40 to 0.50.
- f) Pilot-duty rating – The load is to 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 % of the rated voltage.
- g) AC horsepower or full-load/locked-rotor ac rating – The load is to be six times the full-load motor current at a power factor of 0.40 to 0.50. See [Table 36.1](#) for full-load motor currents corresponding to the various ac horsepower ratings.

Table 36.1
Full-Load Motor-Running Currents in Amperes for Various Single Phase AC Horsepower Ratings

Horsepower	V			
	110 – 120	220 – 240 ^a	440 – 480	550 – 600
1/10	3.0	1.5	–	–
1/8	3.8	1.9	–	–
1/6	4.4	2.2	–	–
1/4	5.8	2.9	–	–
1/3	7.2	3.6	–	–
1/2	9.8	4.9	2.5	2.0
3/4	13.8	6.9	3.5	2.8
1	16.0	8.0	4.0	3.2
1-1/2	20.0	10.0	5.0	4.0
2	24.0	12.0	6.0	4.8
3	34.0	17.0	8.5	6.8
5	56.0	28.0	14.0	11.2

^a To obtain full-load currents for 200 and 208 V motors, increase corresponding 220 – 240 V ratings by 15 and 10 %, respectively.

36.3 Endurance

36.3.1 The endurance test shall consist of 6000 or 100,000 cycles (see [36.1.1](#)) of operation and is to be performed on the same sample used for the overload test. The test voltage is to be the rated output voltage of the control. See [36.3.2](#). The test load is to be in accordance with the output rating of the receptacle with integral switching means as following:

- a) General purpose ac ampere rating – The load is to be 100 % of the rated current at rated voltage. The power factor is to be 0.75 to 0.80.
- b) General purpose dc ampere rating – The load is to be 100 % of rated current obtained by using a non-inductive resistive load at rated voltage.
- c) Resistive ampere rating – The load is to be 100 % of the rated current at rated voltage. The power factor is to be 0.95 to 1.00.
- d) Tungsten lamp rating – The load is to be tungsten filament lamps with a steady state current of 100 % of the rated current at rated voltage. Multiple lamp loads are to be sequenced such that each lamp is "off" for not less than 59 seconds between each "on" period.
- e) Electric discharge lamp rating – The load is to be two times the rated current at rated voltage. The power factor is to be 0.40 to 0.50.
- f) Pilot-duty rating – The load is to 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.
- g) AC horsepower or full-load/locked-rotor rating – The load is to be the full-load motor current at a power factor of 0.75 to 0.80. See [Table 36.1](#).

Exception: It is acceptable to use the end-product load for the endurance test.

36.3.2 If a power-switching semiconductor is employed in a receptacle with integral switching means that is constructed such that under normal operating conditions the semiconductor completes 100,000 cycles of operation in less than 15 days, the test is to be continued for 15 days.

37 Voltage Surge Test

37.1 A device shall be constructed so as not to be adversely affected by transient electrical disturbances on the supply line.

37.2 Compliance with [37.1](#) is to be determined by subjecting samples of the receptacle with integral switching means to the voltage surge test specified in [37.3](#) – [37.5](#). The conditions specified in [34.5.1](#) shall not occur when exposed to the voltage surges.

Exception No. 1: If it is determined without tests that a receptacle with integral switching means will not be adversely affected at the input or output by line transient disturbances, a portion or all of the voltage surge test may be waived.

Exception No. 2: The intended installation with respect to location of the receptacle with integral switching means from service mains might necessitate additional surge testing using an "impulse" (that is, non-ringing) type surge generator.

Exception No. 3: The effects of transient electrical disturbances may be performed on the receptacle with integral switching means separately.

37.3 The sample is to be covered with a single layer of cheesecloth and placed on a softwood surface that has been covered with white tissue paper. Dead metal parts of the receptacle with integral switching means are to be earth grounded through a 3-Amp nontime-delay fuse. The sample is to be connected to a supply source in accordance with [28.2](#).

a) With the device adjusted for the standby condition, the device shall be subjected to the voltage surges applied first to each point separately where power is supplied to the product and then concurrently to any combination of such points. A separate sample is to be used for each test.

b) The tests specified in (a) are to be repeated with the device operated in any other normal mode (for example, full power, partial power, or similar mode) that adversely affects circuit components during the surge. Additional samples are to be used for each operating mode checked, except that use of the same samples for all modes checked is acceptable if agreeable to those concerned.

37.4 Each of the samples tested is to be subjected to 500 randomly triggered (with respect to the 60 Hz supply waveform) applications of a 6-kV surge impulse superimposed on the ac supply at 60 second intervals. Two hundred fifty surges are to be applied with the initial peak of the surge positive with respect to "ground" and 250 surges with the initial peak negative with respect to "ground."

37.5 The surge generator shall have a source impedance of 50 ohms. With no load on the generator, the surge waveform shall have the following characteristics:

- a) An initial rise time of 0.5 μ s between 10 and 90 % of the peak amplitude;
- b) A period of 10 μ s for the ensuing oscillatory wave; and
- c) Successive peaks of alternating polarity with each peak being 60 % of the preceding peak.

37.6 A typical surge generator and control relay are shown in [Figure 37.1](#) and [Figure 37.2](#).

Figure 37.1
Surge Generator Circuit

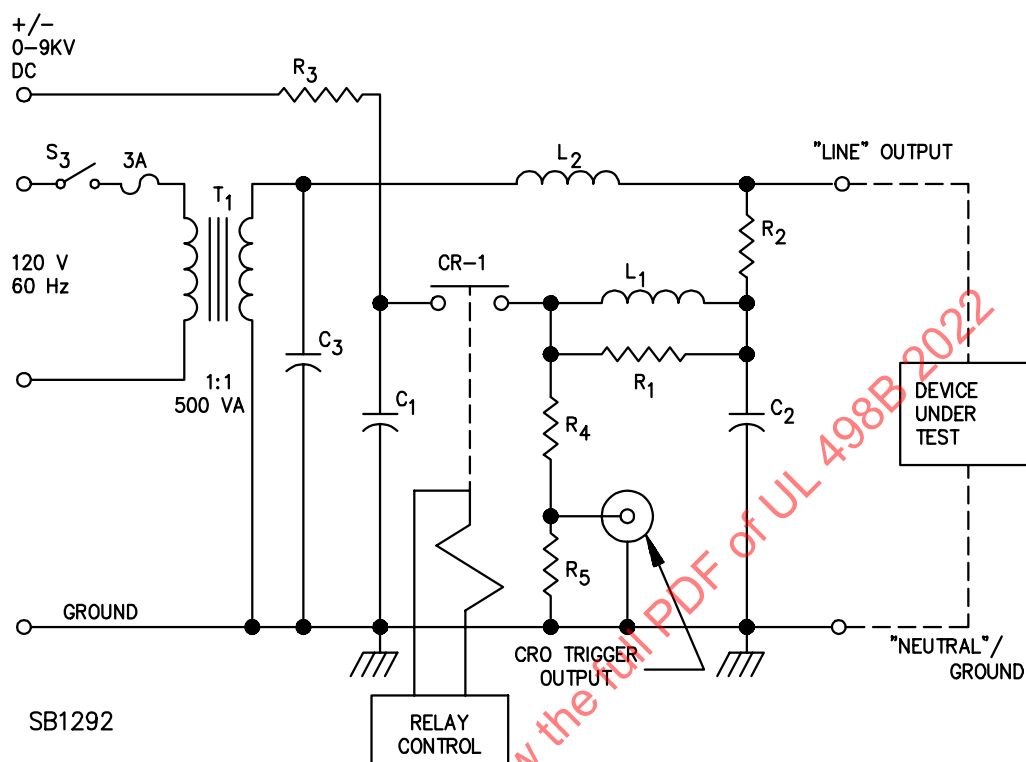
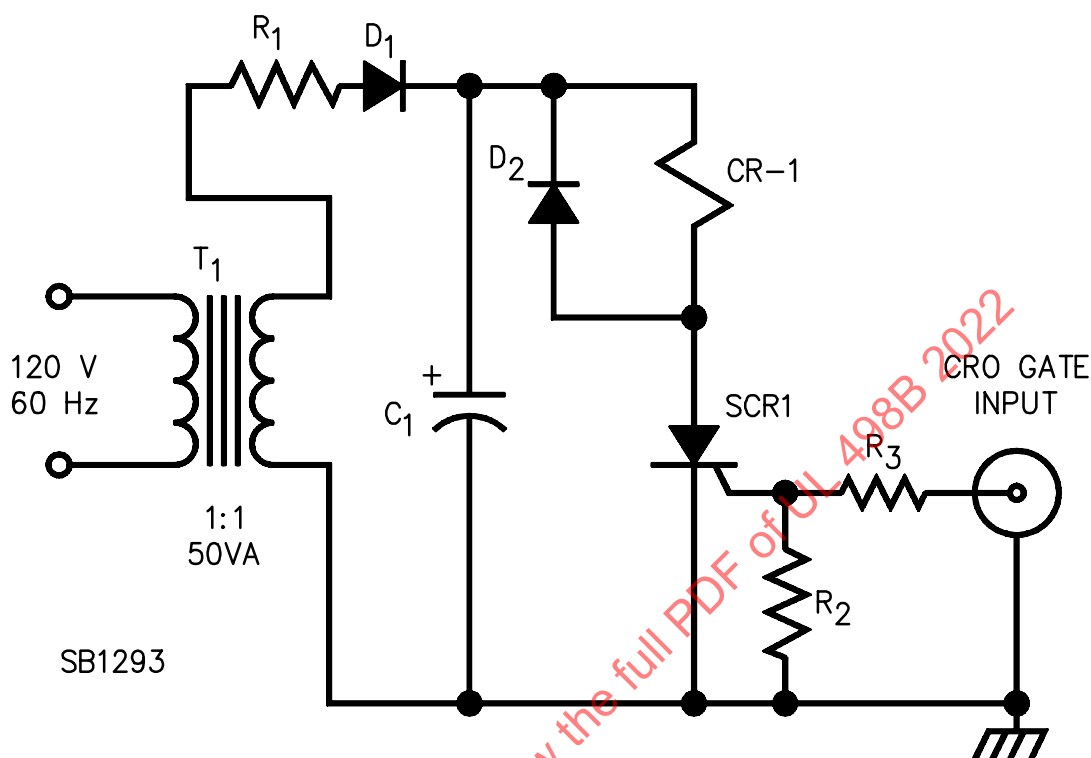


Figure 37.2
Relay Control Circuit for Surge Generator



38 Power Supplies – Short Circuit

38.1 A device employing a fixed impedance or regulating network that serves to limit the current or voltage as noted in [8.2](#) or [26.3](#) shall be subjected to a 7-hours abnormal (short circuit) test at the point at which the current, voltage, or both is limited. For the test, the receptacle with integral switching means is to be covered with a single layer of cheesecloth and placed on a softwood surface that has been covered with white tissue paper and then connected to a source of supply as indicated in [28.2](#). Dead metal parts of the receptacle with integral switching means are to be earth grounded through a 3-Amp nontime-delay fuse. The conditions specified in [34.5.1](#) shall not occur as a result of the short-circuit test. See [35.1.3](#).

39 Component Failure Test

39.1 The component failure tests specified in Sections [26](#), [33](#), [34](#), and [35](#) relate to specific circuits or constructions. Section [39](#) covers component failure in such circuits or in parts of the circuitry not covered in the Sections noted, such as in a line-connected circuit, that presents a risk of fire, electric shock, or injury to persons.

39.2 With reference to [39.1](#), each circuit component is to be open- or short-circuited one at a time. During these tests, the receptacle with integral switching means 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 sample is to be connected to a source of supply as indicated in [28.2](#). Dead metal parts of the receptacle with integral switching means are to be earth grounded through a 3-amp nontime-delay fuse. The receptacle with integral switching means is to be operated in any normal mode (for example, full power, partial power, standby, or similar mode) to cause the most adverse results. A discrete multiple terminal device or an integrated circuit device shall be tested in accordance with [34.4.1](#). The conditions specified in [34.5.1](#) (b) – (f) shall not occur as a result of these tests. Also, see [35.1.2](#) and [35.1.3](#).

Exception No. 1: See Exception Nos. 1 – 3 in [34.4.1](#).

Exception No. 2: Components in a Class 2 or limited-energy circuit that is not a safety circuit are not required to be open- or short-circuited. See [34.2.2](#) for the criteria for determining if a circuit is a limited-energy circuit.

Exception No. 3: Component failure testing is not required if circuit analysis indicates that no other component or portion of the circuit will be seriously overloaded and that a risk of fire, electric shock, or injury to persons will not occur as a result of the assumed open- or short-circuiting of another component.

39.3 Rather than the component failure tests specified in [39.1](#) and [39.2](#), a component evaluation study may be used to determine the of specific open- and short-circuits.

40 Electronic Component Evaluation

40.1 A component evaluation study shall be performed when evaluating a receptacle with integral switching means incorporating safety circuits or where single-mode component faults will result in overheating, a risk of fire, electric shock, or other injury to persons to occur in the control or the controlled equipment.

40.2 A solid-state component that performs a back-up, limiting, or other function intended to reduce the risk of fire, electric shock, or injury to persons shall comply with the requirements for an electronic component evaluation.

40.3 If a safety circuit is being evaluated, consideration shall be given, depending on the circuit design and the intended function, to the need for additional testing.

40.4 If a single-mode component fault is not likely (for example, see Exception Nos. 1 and 2 to [34.4.1](#)), a component need only undergo a limited evaluation.

40.5 Circuit components, which taken together are relied upon to limit power, current, or voltage in accordance with the requirements in Sections [8](#), [26](#), and [34](#) shall be subjected as a unit to an evaluation program.

41 Dielectric Voltage-Withstand Test

41.1 General

41.1.1 The insulation and spacing of a device shall be capable of withstanding without breakdown for a period of one minute the application of the test potentials described in this Section with the control in a heated condition.

41.1.2 A source employed to supply the required test potential shall have sufficient capacity (at least 500 VA) to maintain the potential indicated, except in the case of breakdown. The test potential is to be increased from zero, until the prescribed test potential is reached or until breakdown occurs. The increase in the test potential is to be at a substantially uniform rate and as rapid as is consistent with correct indication of its value by a voltmeter.

41.1.3 Breakdown is normally indicated by the tripping of an overload protector in the test equipment, but an abrupt decrease or retarded advance of the voltmeter reading is also indicative of insulation or spacing failure. Particular attention shall be given to the effects of high-impedance circuits in the control to verify that breakdowns resulting in a risk of fire, electric shock, or injury to persons are detected.

41.1.4 Printed-wiring assemblies and other electronic-circuit components that are adversely affected by the application of the test potential or short circuits as a result of the application of the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand test is performed. A representative subassembly may be tested instead of an entire unit. Rectifier diodes in the power supply may be individually shunted before the test is performed to avoid destroying the diodes by a fault elsewhere.

41.1.5 For each test, either a sufficient number of switching devices are to be closed or separate applications of the test potential are to be made so that all parts of the circuits are tested.

41.2 Primary circuits

41.2.1 An essentially sinusoidal potential at a frequency in the range of 40 – 70 Hz is to be applied as noted in (a) – (e). The test potential is to be as specified in [41.2.2](#):

- a) Between primary circuits and dead metal parts;
- b) Between each different type of primary circuit (for example, the input and output circuits of a control both of which are intended to be conductively connected to the branch circuit in the end application);
- c) Between terminals of opposite polarity on a capacitor that is connected across the line (see [41.2.4](#));
- d) Between current-carrying parts of the primary circuit of an isolating transformer and each secondary circuit of that or any other isolating transformer; and
- e) Across any other insulation or spacing involving a primary circuit that is required to reduce the risk of fire, electric shock, or injury to persons (for example, at the input and output terminals of an isolation device).

41.2.2 The test potential shall:

- a) Be 1000 V for a rating or potential difference of 250 V or less; and
- b) Be 1000 V plus twice the maximum rating or potential difference for a rating or potential difference greater than 250 V.

41.2.3 If an autotransformer is in the circuit, an essentially sinusoidal potential of 1000 V plus twice the rated voltage at a frequency in the range of 40 - 70 Hz is to be applied as specified in [41.2.1](#) (a), (b), (d), and (e) to all wiring involving a potential greater than 250 V. The primary of the autotransformer is to be disconnected and the test potential is to be applied directly to the wiring that involves the higher potentials.

41.2.4 If the charging current through a capacitor or capacitor-type filter connected across the line is large enough so that the required alternating-current test potential cannot be maintained, the capacitors and capacitor-type filters are to be tested as specified in [41.2.5](#).

41.2.5 The capacitors and capacitor-type filters mentioned in [41.2.4](#) are to be subjected to a dc test potential of 1414 V for equipment rated at 250 V or less, or 1414 V plus 2.828 times the rated voltage for equipment rated at more than 250 V. The dc test potential shall be maintained for one minute without breakdown.

41.3 Isolated secondary circuits

41.3.1 An essentially sinusoidal potential at a frequency in the range of 40 – 70 Hz is to be applied:

- a) Successively between isolated secondary circuits and dead metal with all chassis-connected components (if any) disconnected at the chassis; and
- b) Between separate isolated secondary circuits supplied from separate transformer windings.

41.3.2 The test potential shall be as indicated in [Table 41.1](#).

Exception: Two circuits of the type specified in [26.13](#) are to be subjected to a test at a potential of 500 V applied between the circuits.

Table 41.1
Test Potential

Maximum rms (peak) voltage in secondary circuit ^a		Test potential, V
Greater than	But less than or equal to	
0	30 (42.4)	No test
30 (42.4)	50 (70.7)	500
50 (70.7)	100 (141.4)	Ten times the maximum voltage in the circuit
100 (141.4)	333.3 (471.3)	1000
333.3 (471.3)	600 (848.4)	Three times the maximum voltage in the circuit
^a Where the peak voltage is greater than 120 % of 1.414 times the rms voltage, the circuit is to be tested as if the voltage were peak voltage divided by 1.414.		

41.4 Transformers

41.4.1 Each of three samples of a transformer (including a pulse transformer) employing a thermoplastic bobbin is to be subjected to 7 hours of conditioning in an air-circulating oven. The oven temperature is to be 10 °C (18 °F) higher than the intended maximum operating temperature of the bobbin but not less than 70 °C (158 °F). Following the conditioning, the transformer shall withstand for one minute without electrical breakdown the application of an essentially sinusoidal potential at a frequency in the range of 40 – 70 Hz and at a value indicated in [41.2.2](#). The potential shall be applied:

- a) Between the primary winding and any dead metal part;
- b) Between the primary winding and each isolated secondary winding;
- c) Between live parts of an isolated secondary winding and live parts of any other secondary winding (isolated or not); and
- d) Between each secondary winding and any dead metal parts.

Exception No. 1: If the risks noted in [22.1](#) are not present, the tests specified in (c) and (d) are not required.

Exception No. 2: A transformer complying with [21.2](#) or [21.3](#) is not required to be subjected to this test.

MANUFACTURING AND PRODUCTION LINE TESTS

42 DC Offset Voltage Test

42.1 The output voltage for each ac rated device employing a power-switching semiconductor and intended to control a load affected by asymmetrical switching shall not have a dc component greater than the maximum value measured per [32.1](#) under the conditions of [42.2](#) – [42.4](#).

42.2 The dc voltage is to be measured by means of a dc voltmeter as specified in [32.3](#).

42.3 The test is to be performed with the device connected and operated in the normally intended manner.

42.4 It is acceptable for the device to be in a heated or unheated condition for the test. The dc component is to be measured over the full range of the control and at the minimum and maximum settings of any trim potentiometers.

RATING

43 Details

43.1 Input

43.1.1 A receptacle with integral switching means shall be rated in volts, current, and frequency.

43.2 Output

43.2.1 Unless otherwise indicated, a receptacle with integral switching means shall be provided with an output rating in volts and in amperes. The rating shall indicate whether the device is for direct or alternating current, or for controlling a resistive, tungsten lamp, or electric discharge lamp load.

43.2.2 A receptacle with integral switching means intended to control a motor shall be rated in horsepower. It is also acceptable for the control to be rated in full-load and locked-rotor current provided the full-load current value is consistent with the horsepower rating (see [Table 36.1](#)) and the locked-rotor current value is six times (for alternating current) or ten times (for direct current) the rated full-load current.

Exception No. 1: A receptacle with integral switching means intended to control a motor rated 2 horsepower or less is not required to have a horsepower rating if the device has a full-load current rating and a locked-rotor current equal to six times (for alternating current) or ten times (for direct current) the rated full-load current. The full-load current is not required to be a value defined by a typical horsepower rating.

Exception No. 2: A receptacle with integral switching means intended to control a motor shall not be rated in horsepower if the device is tested in accordance with Exception No. 2 to [36.2.1](#). The device shall be rated in FLA and LRA based on the actual full-load and locked-rotor currents to which the device was tested.

43.3 Operational ambient temperature

43.3.1 A receptacle with integral switching means shall be assigned a maximum operational ambient temperature rating in degrees centigrade if such a rating is needed because of the requirements in [31.1.3](#).

MARKINGS

44 General

44.1 A receptacle with integral switching means shall be plainly and permanently marked with the following:

- a) The manufacturer's name, trade name, trademark, or other descriptive marking identifying the organization responsible for the product.
- b) A distinctive catalog number.
- c) A distinctive marking identifying the product as the product of a particular factory if a manufacturer produces or assembles the product at more than one factory. Use of a code for identification is acceptable.
- d) A marking identifying the type of product for which a receptacle with integral switching means is intended to be used.

44.2 With reference to [44.1\(d\)](#), all separate parts of a system (other than the major part) shall be marked with the manufacturer's name, trademark, or similar identification, and a distinctive catalog number or the equivalent for the part.

44.3 A heat sink or other part that is live - due to insufficient spacings, insulation, or both to other than Class 2 parts - and that involves a risk of being mistaken as dead metal and a risk of being exposed to persons during servicing shall be permanently and legibly marked with the word "CAUTION " and the following or the equivalent: "Risk of Electric Shock - Plates (or other word describing the type or part) are live. Disconnect power supply before servicing." The marking shall be located on the live part so as to make the risk known before the part is touched. The word "CAUTION" shall be in letters not less than 3/32 inch (2.4 mm) high and emphasized to elicit the attention of the reader.

Exception: The marking applied adjacent to the part in a location such that it is obvious to which part the marking applies is acceptable.

44.4 If an interchangeable fuse (a fuse is interchangeable if any fuse of higher ampere rating will fit the fuseholder) is used to limit secondary-circuit power in accordance with [26.4](#) and [26.11](#) or power in accordance with [34.2.2](#) or [34.2.4](#), there shall be a legible and permanent marking indicating the ampere and voltage rating of the fuse to be used for replacement and located so that it is obvious to which fuse and fuseholder it applies. A control shall be permanently marked with the word "WARNING" and the following or the equivalent: "To reduce the risk of electric shock, replace only with the same type and rating of fuse." A single marking is acceptable for a group of fuses.

44.5 A separable Class 2 wire lead assembly provided with or intended for use with a wired control receptacle, shall be provided with a flag label indicating, "Class 2" and the electrical rating. The label shall also be marked with correlation markings stating "For Use Only with Listed Model _____ Receptacle" or equivalent.

INSTALLATION INSTRUCTIONS

45 General

45.1 A controlled receptacle shall be provided with installation instructions.

45.2 A Class 2 separable lead assembly provided with or intended for use with a wired control receptacle shall have a label marker located 18 inches from the separable molded-on connector to assure that Class

2 conductors do not terminate in the outlet box. The marker label shall be marked with the following or equivalent, "This marker must be located entirely outside of wall box. No portion may reside in the wall box clamp or inside the box".

Exception: Leads less than 18 inches if part of a complete system shall be marked with the following or equivalent, "These leads must be terminated to a specific Class 2 device, investigated for mounting in or on the device box".

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