

UL 244A

ISBN 1-55989-444-X

Solid-State Controls for Appliances

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

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

Second Edition, Dated January 3, 1994

Revisions: This Standard contains revisions through and including February 23, 1998.

The new requirements are substantially in accordance with UL's Bulletin on this subject dated October 1, 1997. The bulletin is now obsolete and may be discarded.

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New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing, Recognition, and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
tr1 – tr4	February 23, 1998
1	January 3, 1994 (Reprinted: February 23, 1998)
2	August 25, 1994
3	October 13, 1997
4	January 3, 1994
5 – 7	August 25, 1994
8 – 15	January 3, 1994
16	February 23, 1998
17 – 21	January 3, 1994
22, 22A, 22B	August 25, 1994
23 – 28	January 3, 1994
29	October 13, 1997
30, 31	January 3, 1994
32	October 13, 1997
33 – 54	January 3, 1994
A1	October 13, 1997
A2	January 3, 1994
CRG1 – CRG4	February 23, 1998

No Text on This Page

JANUARY 3, 1994
(Title Page Reprinted: February 23, 1998)



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UL 244A

Standard for

Solid-State Controls for Appliances

First Edition – February, 1986

Second Edition

January 3, 1994

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated January 3, 1994 and August 25, 1994 except paragraph 19.1.3. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL 244A-1987, April 28, 1987
Approved as ANSI/UL 244A-1995, January 3, 1995

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

ISBN 1-55989-444-X

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

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

1.2 For a control covered by this standard, it is assumed that no voltage greater than 600 volts above ground will be present in a control, that an isolation transformer, if provided, will generally furnish power at a lower potential than the primary voltage, and that the output of the control will not be located in a circuit operating at greater than 600 volts above ground in the end-use equipment. If conditions other than these are provided, consideration shall be given to the need for additional examination and testing.

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

1.4 A control intended for connection only to a low-voltage circuit of limited power supplied by a primary battery or by a Class 2 transformer where a failure of such a control would cause a risk of fire, electric shock, or injury to persons to occur in the end-use equipment, is considered to be within the scope of these requirements.

1.5 These requirements do not cover a control intended for installation in or on refrigeration or air conditioning equipment that is used in industrial applications or in hazardous locations as defined in the National Electrical Code, NFPA 70. Such equipment is covered in the Standard for Temperature-Indicating and -Regulating Equipment, UL 873. Additional considerations should be given to a control which is exposed to oil, grease vapors, lint, or other contaminants and high humidity in the end application.

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

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

1.7 revised August 25, 1994

2 Undated References

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

3 Glossary

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

3.2 CLASS 2 CIRCUIT – An isolated secondary circuit involving a potential of not more than 42.4 volts 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) above that together comply with the performance requirements for an inherently-limited Class 2 transformer; or
- e) One or more combinations of a Class 2 transformer and an overcurrent protective device that together comply with the performance requirements for a noninherently-limited Class 2 transformer.

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

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

3.4 CONTROLLED ENVIRONMENT – An environment:

- a) Relatively free of conductive contaminants, such as normal cooking vapors, carbon dust, and the like, which may be a result of the end-use equipment to which a control will be installed or may be due to the location of the end-use equipment, and
- b) Protected against humidity and the formation of condensation. A controlled environment may be provided by means of a:
 - 1) Hermetically sealed enclosure;
 - 2) Encapsulation;
 - 3) A conformal coating; or
 - 4) A gasketed, tight-fitting enclosure or filter system preventing contamination in conjunction with a system preventing condensation (for example, the maintaining of the surrounding air at constant temperature and a suitably low relative humidity).

- 3.5 DEAD-CASE-MOUNTED SEMICONDUCTOR – A semiconductor, such as a triac or silicon-controlled rectifier, employing an integral metal tab or stud that is insulated from live parts.
- 3.6 ELECTRICAL STRESS FACTOR – For a circuit component, the ratio of operating electrical stress to rated electrical stress. Examples include the ratio of operating wattage to maximum rated wattage of a resistor and operating voltage to maximum rated voltage of a capacitor. A circuit component having no assigned maximum operating electrical rating is made the subject of an investigation.
- 3.7 HAZARDOUS ENERGY – Circuit energy that involves a possible risk of fire or electric shock.
- 3.8 ISOLATED SECONDARY CIRCUIT – A circuit derived from an isolated secondary winding of a transformer and that has no direct connection back to the line-connected circuit (other than through the grounding means). A secondary circuit that has a direct connection back to the line-connected circuit is considered part of the line-connected circuit.
- 3.9 LIMITED-ENERGY CIRCUIT – A line-connected circuit in which the wattage from any point in the circuit to any return to the power supply is limited to 15 watts; or an isolated secondary circuit in which the wattage as noted above is limited to 50 watts.
- 3.10 LINE-CONNECTED CIRCUIT – A type of circuit in which the wiring and components are conductively connected to the branch circuit. It is also called a primary- or direct-connected circuit. See also 3.8.
- 3.11 OPPOSITE POLARITY – A difference in potential between two points, such that shorting of these two points would result in a condition involving an overload, rupturing of printed wiring-board-tracks, components, or fuses, and the like.
- 3.12 OPTICAL ISOLATOR (PHOTON-COUPLED ISOLATOR) – A circuit-coupling device that provides circuit isolation, consisting of a light source and sensor integrated into a single package.
- 3.13 SAFETY CIRCUIT – A primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, injury to persons, operation of controlled equipment that could result in a risk of fire, electric shock, or injury to persons, or risk of electrical energy. 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 equipment to acceptable levels.
- 3.14 THYRISTOR – A bistable semiconductor device comprised of three or more junctions that can be switched from the off state to the on state or vice versa, by means of the controlled conductivity of the semiconductor, with such switching occurring within at least one quadrant of the principal voltage-current characteristics. Such switching may be random in which conduction occurs at any phase angle of the alternating current load voltage cycle or regulated in which conduction occurs at some precise phase angle or load-voltage magnitude. A phase-controlled semiconductor device is one in which the semiconductor conducts for some portion of the load-voltage cycle.
- a) Bidirectional Triode Thyristor (Triac) – A three-terminal thyristor having substantially the same switching behavior in the first and third quadrants of the principal voltage-current characteristics.
 - b) Silicon-Controlled Rectifier (SCR) – A reverse blocking triode thyristor. A three-terminal thyristor that conducts only for positive anode-to-cathode voltages and exhibits a reverse blocking state for negative anode-to-cathode voltages.

3.15 TRANSFORMER – The term transformer may be considered to include a motor-transformer or an autotransformer. For the purpose of these requirements, the types of transformers likely to be encountered in order to supply power to controls are:

- a) Class 2 – An isolation type transformer as specified in the Standard for Class 2 and Class 3 Transformers, UL 1585.
- b) Power – A transformer other than Class 2 that is intended to transmit power. A power transformer may be of the isolation or nonisolation (for example, autotransformer) type.
- 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 Sense – An isolation-type transformer designed to have its 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 and may or may not be electrically separated from all other secondary windings.

4 Components

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

4.2 A component need not comply with a specific requirement that:

- a) Involves a feature or characteristic not needed in the application of the component in the product covered by this standard; or
- b) Is superseded by a requirement in this standard.

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

4.4 Specific components are recognized as being 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 for which they have been recognized.

5 Units of Measurement

5.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

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

CONSTRUCTION

6 General

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

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

6.3 A risk of electric shock is considered possible 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. However, a risk may not exist if the available current through an appropriate impedance connected between the parts in question is less than the value specified in the end product standard for normal operation as determined by the type of equipment involved. A current measurement on the control alone would have to be weighed with the currents from other parts of the end equipment.

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

7 Frame and Enclosure

7.1 A partial or complete enclosure of a control that is considered part of the enclosure of the end-use equipment shall be investigated under the enclosure requirements for the end-use equipment.

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

8 Accessibility of Live Parts

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

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

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

- 1) 30 volts (42.4 volts peak) where wet contact is not likely to occur; and
- 2) 15 volts (21.2 volts peak) where wet contact is likely to occur.

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

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

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

in which:

Z is the minimum impedance, including tolerances;

V is the open-circuit voltage; and

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

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

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

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

- a) Greater than 0.5 during all conditions of normal operation; or
- b) Greater than 1.0 after single component failure.

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

- a) Minimum electrical spacings shall be in accordance with Section 17, Spacings, 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 abnormal (short circuit) test specified in 30.1.1.

9 Current-Carrying Parts

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

Exception No. 1: Stainless steel may be used as a current-carrying part.

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

10 Internal Wiring

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

10.2 Internal wiring shall be routed and secured so that neither it nor related electrical connections are likely to be subjected to stress or mechanical damage, especially wiring smaller than No. 24 AWG (0.21 mm²) or having insulation less than 1/32 inch (0.79 mm) thick. Flexing, vibration, impact, and exposure of the wiring shall be evaluated per the end-product standard.

10.3 The internal wiring of a control, including grounding conductors, shall be suitable for the particular application when considered with respect to temperature, voltage, exposure to oil, grease, or moisture, and other conditions of service to which the wiring may be subjected.

11 Splices and Connections

11.1 General

11.1.1 Each splice and connection shall be mechanically secure and shall provide adequate and reliable electrical continuity without strain on connections and terminals. Consideration shall be given to vibration, flexing, motion, and the like, when judging the mechanical security of an electrical connection.

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

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

- a) A minimum of one full wrap is provided around a terminal;
- b) A lead not integral with a component on a printed wiring board is passed through an eyelet or opening and if hand-soldered is bent 90 degrees to the board;
- c) A lead integral with a component is inserted through an opening of a printed wiring board;
- d) A lead is twisted with other conductors; or
- e) A lead is inserted into a U- or V-shaped slot in the terminal.

11.1.4 Placement of a lead along a flat surface and tack soldering is not acceptable unless it can be demonstrated that a risk of fire, electric shock, or injury to persons would not result when the lead is detached.

11.1.5 Other means of securing leads, such as push-on terminals, spade-type connectors, and wire wrapping are to be investigated to determine if the mechanical security is acceptable. Quick-connect terminals shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Mechanical splicing devices shall comply with either the Standard for Wire Connectors and Soldering Lugs for Use with Copper Conductors, UL 486A, or the Standard for Wire Connectors for Use with Aluminum Conductors, UL 486B, whichever is applicable.

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

- a) Acceptable 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 will not result in a risk of fire, electric shock, or injury to persons.

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

11.2 Wire-wrapped connections

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

11.2.2 The wire for a wire-wrapped connection shall be solid, copper wire and shall be a wire size of No. 24, 22, or 20 AWG (0.511, 0.643, or 0.813 mm). Other sizes and types of wires shall be subjected to an investigation.

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

11.2.4 The wrap shall:

- a) Have a minimum of 20 points on the corners of the terminal in contact with the wire; and
- b) Have a minimum of 16 points closely wrapped with no overlapping.

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

Table 11.1
Typical number of wraps

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

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

- a) There shall be no gaps between adjacent turns greater than one half of the diameter of the wire exclusive of gaps on the first and last turns; and
- b) The sum of all gaps on any side of a connection shall not exceed the diameter of the wire exclusive of gaps on the first and last turns.

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

11.3 Connections to frame

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

Exception: The frame may be used as a current-carrying part of an isolated secondary circuit.

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

12 Separation of Circuits

12.1 General

12.1.1 Separation of circuits:

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

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

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

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

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

**Table 12.1
Separation of circuits**

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

^a The numbers 1 and 2 refer to the circuits in question for which separation is to be maintained. See 12.1.1.

^b Acceptable means of separation are:

A) Spacings – The through air spacings as indicated in Table 17.1 shall be used to determine adequate separation based on the highest voltage involved (see 17.3).

1) Require spacing.

2) Twice required spacing.

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

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

D) Barriers – A barrier shall be of adequate mechanical strength, reliably held in place, and suitably interposed between the parts in question when openings in the barrier are considered.

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 be subjected to an investigation in accordance with the requirements applied to internal barriers in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C.

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

12.1.5 When evaluating the required separation of the circuits in accordance with 12.1.1, consideration shall be given to such effects as deterioration of insulation resulting in abnormal operation involving overload, short-circuit, component failure conditions and the like.

13 Insulating Material

13.1 General

13.1.1 Insulating material shall be judged with respect to its acceptability for the application. Consideration shall be given to:

- a) The material's mechanical strength and rigidity, resistance to ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions;
- b) The degree to which the material is enclosed; and
- c) Any other feature affecting the risk of fire, electric shock, or injury to persons.

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

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

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

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

13.2 Support of live parts

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

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

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

14 Printed-Wiring Boards

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

Exception: A printed-wiring board in a Class 2 nonsafety circuit need not comply with the bonding requirements in UL 796 if it 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 equipment.

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

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

14.2 revised February 23, 1998

15 Components

15.1 Switching devices

15.1.1 An electromechanical switching device:

- a) Shall be acceptable for the particular application;
- b) Shall have a voltage rating and a current rating, a horsepower rating, or both, not less than that of the load that it controls; and
- c) Shall be rated for the type of load that it 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-watt or smaller pilot or indicating lamp need not be provided with a tungsten rating.

- 5) Electric discharge lamp.
- 6) Pilot duty – for example, solenoid, contactor, relay, or other electromagnetic load.
- 7) Motor.

Exception: A switching device that is intended to control a universal motor shall additionally be judged under the requirements for the end-use equipment.

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

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

15.2 Capacitors

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

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

15.2.3 A capacitor connected across the supply circuit shall comply with the requirements in the Standard for Across-the-Line, Antenna-Coupling, and Line-By-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414.

15.2.4 With reference to the requirements in 15.2.3, a capacitor other than a motor capacitor is considered to be across the supply circuit if, in a shorted condition, a current of more than 1 ampere passes through it while the control is in a heated condition. The current through the capacitor may be limited to 1 ampere or less by a fixed impedance or an acceptable protective device rated 1 ampere or less.

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

15.3 Power-switching semiconductors

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

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

15.4 Isolation devices

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

- a) To reduce the risk of fire, electric shock, or injury to persons; or
- b) Because isolation is required by this standard between specific circuits (for example, a device that isolates Class 2 circuit outputs from circuits involving a risk of electric shock),

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

16 Transformers

16.1 General

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

16.1.2 A Class 2 transformer shall comply with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585.

16.1.3 A power transformer shall comply with the applicable requirements in the Standard for Specialty Transformers, UL 506 and with the overload heating requirements specified in the Standard for Class 2 and Class 3 Transformers, UL 1585. See 16.2.5.

16.2 Isolation transformers

16.2.1 A transformer having separate windings shall be constructed to prevent any 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 would result in a risk of fire or electric shock, operation of the controlled equipment in a manner that would involve 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 considered.

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

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

- a) Uninsulated primary wires or terminals of opposite polarity;
- b) The primary winding including lead connections and terminals and each secondary winding and associated lead connections and terminals;
- c) The primary winding including lead connections and terminals and the core or other dead metal parts;
- d) Each secondary winding including lead connections and terminals and the core or other dead metal parts; and
- e) Adjacent secondary windings including lead connections and terminals.

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

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

Table 16.1
Minimum acceptable spacings at isolation transformers

Potential involved, volts, 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 – The spacings apply to coils, crossover leads, splices, uninsulated lead wires and terminals. The spacings do not apply to turn-to-turn spacings of a coil.

16.2.5 The insulation of a pulse transformer or an isolation type power transformer shall comply with the applicable coil construction requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585.

17 Spacings

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

- a) Between uninsulated live parts of opposite polarity within a circuit;
- b) Between an uninsulated live part of one circuit and an uninsulated live part of any other circuit; and
- c) Between an uninsulated live part of any circuit and a dead metal part.

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

Exception No. 2: At closed-in points in which contamination is unlikely 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 volts or less.

Exception No. 3: Spacings are not specified within Class 2 circuits as defined in 3.2 and complying with the requirements in Section 20, Class 2 Circuits, and between such circuits and dead metal parts unless such circuits are safety circuits. If short circuit between the parts in a Class 2 safety circuit may 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 Spacings, Section 20 and between such parts and dead metal, provided that the construction is such that spacings will be permanently maintained.

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

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

Table 17.1
Minimum acceptable spacings for circuits elsewhere
than at isolation transformers

Potential involved in volts, 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 ^b	1.6 ^b	1/16 ^b	1.6 ^b	3/64	1.2	3/64	1.2
51 – 125 (72.1 – 176.8)	1/16 ^b	1.6 ^b	1/16 ^b	1.6 ^b	1/16 ^b	1.6 ^b	1/16 ^b	1.6 ^a
126 – 250 (178.2 – 353.5)	3/16	4.8	1/8	3.2	3/32	2.4	3/32	2.4
251 – 300 (354.9 – 424.2)	3/8 ^a	9.5 ^a	1/4 ^a	6.4 ^a	3/8 ^a	9.5 ^a	1/4 ^a	6.4 ^a
301 – 600 (425.6 – 848.4)	1/2 ^a	12.7 ^a	3/8 ^a	9.5	1/2 ^a	12.7	3/8 ^a	9.5 ^a

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

^b 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.

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

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

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

17.6 An insulating barrier or liner that is used in addition to an air space in place of the required spacing through air shall not be less than 0.028 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 intended for the support of uninsulated live parts, the air space and barrier together shall be such that, upon investigation, are found to be adequate 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 may be less than 0.028 inch (0.71 mm) but not less than 0.013 inch (0.33 mm) thick provided the barrier or liner is of a material that is intended for the mounting of uninsulated live parts, of adequate mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, and located so that it will not be adversely affected by operation of the equipment in service.

17.7 Insulating material having a thickness less than that specified in 17.5 and 17.6 may be used if, upon investigation, it is found to be acceptable for the particular application.

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

18 Alternate Spacings – Clearances and Creepage Distances

18.1 As an alternative to the specified spacing requirements of Section 17, Spacings, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. 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 end-use application is to be considered and may modify those characteristics given in 18.2 – 18.5.

18.2 When applying specific requirements in UL 840, it is anticipated that the degrees of pollution expected or controlled will be as indicated in Table 18.1.

**Table 18.1
Degrees of pollution**

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

18.3 When applying specific requirements in UL 840, it is anticipated that the equipment will be identified by overvoltage categories as indicated in Table 18.2.

Table 18.2
Overvoltage categories

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

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

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

19 Bonding of Internal Parts for Grounding

19.1 General

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

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

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

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

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

Added 19.1.3 effective November 28, 1994

19.2 Bonding conductor

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

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

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19.2.3 The size of a bonding conductor shall be based on the rating of the overcurrent protective device of the branch circuit to which the end-use equipment will be connected in accordance with the National Electrical Code, NFPA 70-1993. A conductor other than a wire such as noted in 19.2.2 shall have a cross-sectional conducting area equal to or greater than that of the required wire size.

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

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

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

**Table 19.1
Duration of current flow, bonding test**

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

19.3 Bonding connections

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

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

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

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

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

- a) No softening, cracking, or other distortion of the material or damage to the bonding connection; and
- b) No change in the voltage drop through the bonding path.

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

- 1) An overcurrent test in which a current equal to twice the rating of the branch circuit overcurrent protective device is passed through the bonding path for the time specified in Table 19.1.
- 2) Creep and mold stress-relief tests in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, followed by an overcurrent test as specified in (1).

20 Class 2 Circuits

20.1 A Class 2 circuit, as defined in 3.2, shall be judged under the requirements for primary circuits unless:

- a) It does not perform a required safety related function, that is, it is not a required safety circuit;
- b) It complies with the requirements in this section; and
- c) Malfunctions or shorting of deficient spacings in the circuit will not cause a risk of fire, electric shock, or injury to persons to occur in the controlled equipment. However, it may be necessary for a Class 2 circuit to comply with certain primary circuit requirements (for example, wiring, securing of live parts, or the like) to reduce the risk of fire, electric shock, or injury to persons.

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

20.3 A circuit is considered to be 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 volts 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 amperes measured after 1 minute of operation; and

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

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

20.4 The current or voltage referred to in 20.3 may be limited by:

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

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

c) A fuse or other overcurrent protective device located in the primary or secondary circuit if the power supply complies with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585, when the overcurrent protective device is bypassed.

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

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

20.7 If the power supply employs a regulating network or fixed impedance to limit the current or voltage in accordance with 20.3, its 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, and the like, in the power supply to the extent that the impedance or regulating network ceases to satisfactorily perform its limiting function. For a discrete, multiple (more than two) terminal device, such as a transistor, SCR, triac, or similar device, any combination of terminals taken two at a time shall be open- or short-circuited. For an integrated circuit device, the following combinations of terminals shall be tested:

a) Each pair of adjacent terminals shorted;

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

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

d) Each input terminal shorted to each power supply;

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

f) Each terminal open-circuited.

Exception No. 1: A resistor investigated for its acceptability with respect to end use conditions and incorporating acceptable insulation and/or spacings to prevent a short circuit or reduction in resistance need not be open- or short-circuited.

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

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

Exception No. 4: Testing of an integrated circuit device may be reduced if it can be determined by circuit analysis that the tests noted in (a) – (f) above will not affect the limiting function.

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

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

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

20.11 The overcurrent protective device mentioned in 20.4 shall:

- a) Not be of the automatic reclosing type;
- b) Be trip-free from the reclosing mechanism;
- c) Be nonadjustable;
- d) Not be readily interchangeable with a device of a different rating, unless a marking in accordance with 36.4 is provided adjacent to the device;
- e) Be rated or set in accordance with Table 20.1 if it is provided in the secondary circuit; and
- f) Comply (in conjunction with the power supply) with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585, for noninherently limited transformers whether it is located in the primary or secondary circuit.

Table 20.1
Maximum rating for overcurrent protection

Open-circuit potential, V_{oc} Volts	Current rating, Ampere
0 – 20.0	5
20.1 – 30.0	$100/V_{oc}$

20.12 A circuit is considered to be Class 2 if it is supplied by more than one inherently-limited source or more than one noninherently limited source (for example, an isolating transformer with multiple secondary windings or several power supplies that each include an isolating transformer) that when interconnected comply with the applicable requirements in 20.3 – 20.10 for inherently limited or noninherently-limited power supplies. The circuit shall not incorporate voltage-multiplier or other such voltage increasing circuit elements that increase the voltage in the circuit to greater than 42.4 volts 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.

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

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

20.14 A device having exposed Class 2 outputs that:

- a) May be contacted during normal operation or servicing; and
- b) Have clearances between the Class 2 circuit and an overvoltage protected line-voltage circuit that have been evaluated in accordance with Clearance B requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840,

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

PERFORMANCE

21 General

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

21.2 Unless otherwise indicated, tests are to be conducted at the rated input frequency of the end product and at a test potential not less than 120, 208, 240, 277, 480, or 600 volts as appropriate for the input voltage rating (single value or voltage range) of the end product. A control intended to be installed in equipment having a dual frequency input rating is to be tested at 60 hertz if 60 hertz is included in the rating and may also be tested at the second frequency if such testing is warranted.

Exception: Tests may be conducted at the rated input, single or dual frequency, of the control and at a test potential not less than the appropriate voltage value as noted above for the input voltage rating of the control.

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

22 Temperature Test

22.1 General

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

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

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

- a) Intended specifically for use within a prevailing ambient temperature constantly more than 25 °C (77 °F);
or
- b) Assigned a maximum operational ambient temperature rating (see 35.3.1)

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

22.1.4 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 judged on the basis of temperature ratings assigned after investigation.

22.2 Operation

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

- a) The control shall be operated under condition(s) of normal use that will result in maximum temperatures. The control shall be tested at all power levels or speed settings and at continuous operation (that is, not intermittent or short-term operation) until constant temperatures are attained. For a control employing a power-switching semiconductor, the effects at each setting of any dc offset voltage on the temperatures shall be considered when determining the most severe setting. See DC Offset voltage Test, Section 23.
- b) For a control employing a power-switching semiconductor, the test is to be conducted with the control modified to result in half-wave operation of the intended load. The control is to be set in the full-on position and then switched to half-wave operation when the end-use equipment is fully energized. The end-use equipment is to be operated at the power level(s) or speed setting(s) under the condition(s) of normal use that will result in maximum temperatures.

Exception No. 1: The test described in (b) may be omitted if the end product will not continue to operate in a manner considered to be a possible condition of use and if the test described in 22.2.5 is conducted.

Exception No. 2: The test described in (b) may be omitted if the intended load is noninductive.

Exception No. 3: See 22.2.2.

22.2.2 With reference to Exception No. 3 to 22.2.1, to determine the effects of heating on the control due to the control itself, the temperature test may be conducted with the control:

- a) Mounted on a flat horizontal nonconductive surface in the most adverse position with regard to heating from adjacent parts or components unless the proper orientation and separation of parts is obvious;
- b) Connected to a source of supply as indicated in 21.2; and
- c) Operated under the condition(s) of normal use that will result in maximum temperatures.

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

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

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

- a) DC offset voltage when using the criteria specified in 23.1; and
- b) Half-wave operation on the end product

shall be considered in the end product investigation.

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

22.2.5 revised October 13, 1997

Table 22.1
Maximum acceptable temperature rises

Materials and components ^a	Degrees	
	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 would result in a risk of fire or electric shock:		
(a) Laminated	100 ^b	180 ^b
(b) Molded	125 ^b	225 ^b
4. Insulated wire or tubing	25	77
	less than its temperature rating	
5. Wood or other combustible material	65	117
6. Capacitor cases:		
(a) Electrolytic	40 ^c	72 ^c
(b) Other type	65	117
7. Rectifiers at any point		
(a) Selenium or germanium	50 ^b	90 ^b
(b) Silicon	75 ^b	135 ^b
8. Solderless wrapped connections	75	135
9. Transformer windings:		
(a) Class 105 insulation systems		
Thermocouple method	65	117
Resistance method	75	135
(b) Class 130 insulation systems:		
Thermocouple method	85	153
Resistance method	95	171
10. Windings of relays, coils, buzzers, and the like:		
(a) Class 105 insulation systems:		
Thermocouple method	65	117
Resistance method	85	153
(b) Class 130 insulation systems:		
Thermocouple method	85	153
Resistance method	105	189

^a See 22.1.4.

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

^c A capacitor that operates at a temperature rise of more than 40 °C (117 °F) for an electrolytic type and more than 65 °C (117 °F) for other types may be judged on the basis of its marked temperature limit. However, the measured temperature shall not exceed the temperature rating of the capacitor based on a 25 °C (77 °F) ambient temperature.

22.3 Temperature measurements

22.3.1 If reference temperature measurements are necessary, thermocouples consisting of No. 30 AWG (0.05 mm²) iron and constantan wires and a potentiometer type of indicating instrument are to be employed.

22.3.2 The temperature of a coil or winding may be measured by either the thermocouple or resistance method, except that the resistance method only is to be used if the coil:

- a) Employs thermal insulation; or
- b) Is encapsulated or otherwise inaccessible for mounting thermocouples.

22.3.3 If thermocouples are used to measure temperatures, the thermocouples are to consist of wires not larger than No. 24 AWG (0.21 mm²) and not smaller than No. 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 for special thermocouples as listed in the table of limits of error of thermocouples in Temperature Measurement Thermocouples, ANSI MC96.1–1982.

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

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

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

in which:

Δt is the temperature rise in degrees C;

R₁ is the resistance of the coil at the beginning of the test;

R₂ is the resistance of the coil at the end of the test;

t₁ is the room temperature in degrees C at the beginning of the test;

t₂ is the room temperature in degrees C at the end of the test; and

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

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

23 DC Offset Voltage Test

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

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

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

24 Abnormal Operation Test

24.1 Motor

24.1.1 A motor in the end product controlled by a control employing a power-switching semiconductor shall comply with the Locked Rotor Test requirements in the Standard for overheating Protection for Motors, UL 2111, except:

- a) The winding temperature requirements are not applicable; and
- b) The power supply is to provide for 15 days each:
 - 1) Half wave output; and
 - 2) A 2-volt dc offset voltage imposed on the ac voltage waveform by an acceptable method. The 2-volt dc 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 volt dc bias is measured on the switched ac output waveform. The dc bias may be measured by a dc voltmeter having a frequency damped response in the range of 0 – 120 hertz.

24.1.1 revised October 13, 1997

24.2 Component failure

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

- a) Each pair of adjacent terminals shorted;
- b) Each input terminal shorted to (referenced) ground terminal;
- c) Each output terminal shorted to (referenced) ground terminal;
- d) Each input terminal shorted to each power supply;
- e) Each output terminal shorted to each power supply;
- f) Each terminal open-circuited.

Exception No. 1: A resistor investigated for its acceptability with respect to end use conditions and incorporating acceptable insulation and/or spacings to prevent a short circuit or reduction in resistance need not be open- or short-circuited.

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

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

Exception No. 4: For a line-connected circuit, if redundant circuit components are relied upon to limit the voltage or current, then one or more of such components may be open- or short-circuited simultaneously, except that components of a different type (for example, metal film resistors versus carbon resistors, electrolytic capacitors versus ceramic capacitors, silicon versus germanium diodes, and the like) are not to be open- or short-circuited simultaneously. When applying this exception, consideration shall also be given to Exception Nos. 1 – 3 to this paragraph.

Exception No. 5: Abnormal operation testing of an integrated circuit device may be reduced if it can be 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.

25 Limited Power Point Determination Test

25.1 General

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

Exception: See 8.6(a).

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

25.2 Option no. 1

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

a) The minimum spacings specified are maintained:

- 1) Between points that are both capable of delivering a power greater than 15 or 50 watts; and
- 2) Between points that are capable of delivering a power greater than 15 or 50 watts and points that are not capable of delivering a power greater than 15 or 50 watts.

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

b) The conditions noted in 25.5.1 do not occur when the circuit is subjected to an overload test in which each point nearest the power supply that is not capable of delivering a power greater than 15 or 50 watts 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 watts may be less than specified in Table 17.1 if the circuit complies with the requirements in 25.2.4.

25.2.2 With reference to 25.2.1, to determine the points capable of delivering a power of more than 15 or 50 watts, whichever is applicable, the external resistor is to be set for maximum resistance before being connected to the circuit under investigation. The external resistor is to be adjusted until the maximum wattage is consumed by it as indicated by a peak reading of the wattmeter. A reading of greater than 15 or 50 watts indicates that the points are capable of delivering greater than 15 or 50 watts. 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 watts. During the test, the control is to be connected to a source of supply as indicated in 21.2, and operated in the full on condition.

25.2.3 With reference to 25.2.1, if an acceptable type of 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 it dissipates is 15 or 50 watts 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 seconds or less while the resistor is dissipating 15 watts, the first circuit point not capable of delivering more than 15 watts has been located. If the protective device opens the circuit in 60 seconds or less while the resistor is dissipating 50 watts, the first circuit point not capable of delivering 50 watts has been located. See 36.4.

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

- a) That the maximum available power does not exceed 15 or 50 watts when an external variable resistor is connected across points delivering greater than 15 or 50 watts and having spacings less than those required. Beginning with the variable load resistor set for maximum resistance, the resistor is to be adjusted until it consumes maximum wattage, as indicated by the reading of the wattmeter.
- b) If an acceptable type of 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 watts 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 watts or shall open within 60 seconds if the applicable power value in question is 50 watts. During the test, the control is to be connected to a source of supply as indicated in 21.2 and operated in the full on condition. See 25.4.1 and 36.4.
- c) That the conditions noted in 25.5.1 do not occur when the circuit is subjected to an overload test in which any combination of points in the greater than 15 or 50 watt circuit having spacings less than those required, are shorted together.

25.3 Option no. 2

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

25.3.2 With reference to the requirements in 25.3.1, the total output power of the secondary winding(s), is the maximum of the values determined in (a) and (b) below 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) above or to the maximum power obtained by combining any remaining windings. This process is to be continued until each combination of two, three, or more , interconnected windings has been tested.

25.4 Component failure

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

- a) Each pair of adjacent terminals shorted;
- b) Each input terminal shorted to (referenced) ground terminal;
- c) Each output terminal shorted to (referenced) ground terminal;
- d) Each input terminal shorted to each power supply;
- e) Each output terminal shorted to each power supply; and
- f) Each terminal open-circuited.

Exception No. 1: A resistor investigated for its acceptability with respect to end-use conditions and incorporating acceptable insulation or spacings to reduce the likelihood of a short circuit or reduction in resistance is not 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 described in the Standard for Across-the-Line, Antenna-Coupling and Line-By-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414, and investigated for its 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 Section 32, Electronic Component Evaluation, need not be open- or short-circuited.

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

25.4.2 The tests mentioned in 25.4.1 may or may not change the location in the circuit of the first point not capable of delivering more than 15 or 50 watts.

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

25.5 Overload test

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

- a) Any electronic circuit element relied upon to limit power to the points in question shall not:
 - 1) Experience an electrical stress factor greater than 0.5 (1.0 when the test is repeated under single component failure); or
 - 2) Change in value to the extent that the specified power limit is exceeded.
- b) There shall be no ignition of the tissue paper, wood, or cheesecloth.
- c) There shall be no dielectric breakdown when the dielectric voltage-withstand test specified in Section 33 is repeated.
- d) A 3-ampere nontime-delay fuse, connected between dead metal parts of the control and/or of the end product and earth ground during the test, shall not open.
- e) There shall be no abnormal operation of the end product or control (such as asymmetrical switching of an ac load or chattering of electromagnetic contacts) or impairment of a safety device to the extent that a risk of fire, electric shock, or injury to persons could result.
- f) There shall be no unintended operation of the end product (such as discontinuous operation, spontaneous start-up or failure of the control to terminate operation) unless it can be demonstrated that such unintended operation will not result in a risk of fire, electric shock, or injury to persons.

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

25.5.3 Unless ultimate results are obtained in less time, each overload test is to be conducted for a minimum of 1 hour. If at the end of 1 hour there is no evidence of overheating of parts, the test may be discontinued. If there is evidence of overheating, the test is to be continued for 7 hours. Overheating of parts may be detected by odor, smoke, discoloration, cracking of material, charring, flaming, glowing, arcing, or similar phenomenon or by changes in circuit current measured through the applied fault.

26 Isolation Tests

26.1 General

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

- a) There is no ignition of the tissue paper, wood, or cheesecloth;
- b) The 3-ampere 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 product or control such as noted in 25.5.1.

26.1.2 During the tests, the control and/or the end product is to be covered with a single layer of cheesecloth and placed on a softwood surface that has been covered with white tissue paper. The end product is then to be connected to a source of supply as indicated in 21.2. Dead metal parts of the control and/or end product are to be connected to earth ground through a 3-ampere nontime-delay fuse. Unless results are obtained in less time, each test is to be conducted for at least 1 hour. If at the end of 1 hour there is no evidence of overheating of parts, the test may be discontinued. If there is evidence of overheating, the test is to be continued for 7 hours. Overheating of parts may be detected by odor, smoke, discoloration, cracking of material, charring, flaming, glowing, arcing, or similar phenomenon or by changes in circuit current measured through the applied fault.

26.1.3 If a circuit element or printed wiring foil opens to terminate a test, the test is to be repeated two additional times. Operation of a reliable thermal or overcurrent device is not to necessitate repeating the test.

26.2 Pulse transformer burnout tests

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

- a) Each secondary winding of the pulse transformer is to be short-circuited (singly). For each test, the pulse transformer is to be subjected to one of the input conditions noted below.
 - 1) The pulse transformer is to be connected normally into the circuit. The control is to be operated in the full on condition;
 - 2) The output terminals of each isolating transformer secondary winding which supplies power to the circuit containing the primary winding of the pulse transformer are to be connected directly to the primary winding of the pulse transformer. If a tapped winding serves to supply power to the circuit, the ends of the tapped winding are to be connected to the pulse transformer.

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

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

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

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

26.2.2 With reference to 26.2.1, after each test a dielectric voltage-withstand test shall be conducted on the pulse transformer. The test potential is to be the value specified in 33.2.2 applied for 1 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).

26.3 Optical isolator tests

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

- a) Each pair of output terminals of the optical isolator is to be short-circuited (singly). For each test, the optical isolator shall be subjected to one of the following input conditions:
 - 1) The optical isolator is to be connected normally into the circuit. The control is to be in the full on condition.

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

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

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

26.3.2 With reference to 26.3.1, after each test a dielectric voltage withstand test shall be conducted on the optical isolator for 1 minute between the input and output terminals of the optical isolator. The test potential shall be the value specified in 33.2.2.

26.4 Component failure

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

Exception No. 1: A resistor investigated for its acceptability with respect to end-use conditions and incorporating acceptable insulation or spacings to reduce the likelihood of a short circuit or reduction in resistance is not to be open- or short-circuited.

Exception No. 2: A capacitor, capacitor (parallel combination of a capacitor and resistor), or similar circuit component, complying with requirements for antenna coupling and line bypass components in the Standard for Across-the-Line, Antenna-Coupling and Line-By-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414, and investigated for its suitability 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 need not be open- or short-circuited.

27 Power-Switching Semiconductors

27.1 General

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

27.1.2 There shall be no electrical or mechanical malfunction of a power-switching semiconductor nor opening of the fuse connected to dead metal parts when a sample of the control is subjected to these tests. The criteria for judging malfunctioning of the semiconductor is not limited to opening or shorting but includes such conditions as half-wave operation, asymmetrical switching other than half-wave, and discontinuous operation unless such conditions do not present a risk of electric shock because of the type of load involved or because of tests required elsewhere in this standard addressing the condition (see 23.2). For each test, the semiconductor is to be cycled at a rate of 6 cycles per minute with an "on" time of 1 second. The fuse noted above shall be a 3-ampere nontime-delay type, connected between dead metal parts of the control and the live pole considered least likely to strike to ground.

27.1.3 Alternating-current interrupting tests shall be conducted on a circuit having a frequency of 60 hertz. However, tests at 25 – 60 hertz may be considered to be representative.

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

Exception: The tests need not be conducted in the end product if heat sinking, ambient temperature conditions, and the like for which the tests are to be conducted are duly noted for end-use considerations.

27.2 Overload

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

- a) General Purpose AC ampere Rating – The load shall be 150 percent of the rated current, at rated voltage. The power factor shall be 0.75 to 0.80.
- b) General Purpose DC ampere Rating – The load shall be 150 percent of rated current obtained by using a noninductive resistive load at rated voltage.
- c) Resistive ampere Rating – The load shall be 150 percent of rated current, at rated voltage. The power factor shall be 0.95 to 1.0.
- d) Tungsten Lamp Rating – The load shall be tungsten filament lamps with a steady state current of 150 percent of rated current at rated voltage. Multiple lamp loads are to be sequenced such that each lamp is off for not less than 59 seconds between each on period.
- e) Electric Discharge Lamp Rating – The load shall be three times rated current, at rated voltage. The power factor shall be 0.40 to 0.50.

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

g) AC Horsepower or AC Full Load/Locked Rotor Rating – The load shall be six times the full-load motor current at a power factor of 0.40 to 0.50. See Table 27.1 for full-load motor currents corresponding to the various AC horsepower ratings.

Exception No. 1: The overload test may be conducted using the end product load but modified to produce an overload current consistent with the appropriate rating category noted above.

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

Table 27.1
Full-load motor-running currents in amperes for various
single phase AC horsepower ratings

Horsepower	Volts			
	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

^aTo obtain full-load currents for 200 and 208 volt motors, increase corresponding 220 – 240 volts ratings by 15 and 10 percent, respectively.

27.3 Endurance

27.3.1 The endurance test shall consist of 6000 or 100,000 cycles (see 27.1.1) of operation and is to be conducted on the same sample used for the overload test. The test load shall be in accordance with the following as appropriate for the output rating of the control or intended load of the semiconductor. The test voltage is to be the rated output voltage of the control. See 27.3.2.

- a) General Purpose AC ampere Rating – The load is to be 100 percent of the rated current, at rated voltage. The power factor shall be 0.75 to 0.80.
- b) General Purpose DC ampere Rating – The load shall be 100 percent of rated current obtained by using a noninductive resistive load at rated voltage.
- c) Resistive ampere Rating – The load shall be 100 percent of the rated current, at rated voltage. The power factor shall be 0.95 to 1.00.
- d) Tungsten Lamp Rating – The load shall be tungsten filament lamps with a steady state current of 100 percent 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 shall be two times the rated current, at rated voltage. The power factor shall 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 conducted using the actual electromagnet as the load.
- g) AC Horsepower or AC Full Load/Locked Rotor Rating – The load shall be the full-load motor current at a power factor of 0.75 to 0.80. See Table 27.1.

Exception: The endurance test may be conducted using the end-product load.

27.3.2 If a power-switching semiconductor is employed in a control that is constructed such that under normal operating conditions, the semiconductor would complete 100,000 cycles of operation in less than 15 days, the test is to be continued for 15 days at the normal rate.

28 Overvoltage and Undervoltage Test

28.1 The following tests shall be conducted if unintended operation of the end product (such as spontaneous start-up or operation does not terminate as intended) could cause a risk of fire or injury to persons to occur. Three samples are to be subjected to each test.

28.2 The control and/or the end product is to be connected to a source of supply adjusted to equal 85 percent of the test potential specified in 21.2. 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 control. The control is then to be adjusted as noted in 28.3(a) and (b). Unintended operation shall not be a result of the applied undervoltage.

28.3 The control and/or the end product is to be connected to a source of supply adjusted to equal 110 percent of the test potential specified in 21.2. The output of the control is to be connected in series with a load adjusted to produce the overall rated output current at rated output voltage and a source of supply adjusted to equal 110 percent of the rated output voltage.

- a) The control is to be adjusted for the standby condition and is not to operate as a result of the applied overvoltage.
- b) The control is to be adjusted to cause operation in the full on condition and then is to be adjusted to cause operation to terminate. The control is to terminate operation as intended in spite of the applied overvoltage.

29 Voltage Surge Test

29.1 A control shall be constructed so as not to be adversely affected by transient electrical disturbances likely to be encountered on the supply line.

29.2 Compliance with the requirement specified in 29.1 is to be determined by subjecting samples of the end product employing the control to the voltage surge test specified in 29.3 – 29.5. The conditions specified in 25.5.1 shall not occur when the end product is exposed to the voltage surges. Following each voltage surge test, the sample shall be subjected to a repeat of the overvoltage and undervoltage tests specified in Section 28, if applicable.

Exception No. 1: If it can be determined without tests that a control will not be adversely affected at the input or output by line transient disturbances, a portion or all of the voltage surge test can be waived.

Exception No. 2: The intended installation of the end product employing the control with respect to location from service mains may necessitate additional surge testing using an "impulse" (that is, nonringing) type surge generator.

Exception No. 3: The effects of transient electrical disturbances may be conducted on the control itself; however, such testing shall also be conducted during the end-product investigation on the complete end product with the control installed.

29.3 The end product or control 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 control and/or end product are to be earth grounded through a 3-ampere nontime delay fuse. The sample is to be connected to a supply source in accordance with 21.2.

- a) With the control adjusted for the standby condition, the control and/or the end product 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 control operated in any other normal mode (for example, full power, partial power, or the like) considered likely to adversely affect circuit components during the surge. Additional samples are to be used for each operating mode checked, except that the same samples may be used for all modes checked if agreeable to those concerned.

29.4 Each of the samples tested shall be subjected to 500 randomly triggered (with respect to the 60 hertz supply waveform) applications of a 6 kilovolt 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."

29.5 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 microsecond between 10 and 90 percent of the peak amplitude;
- b) A period of 10 microseconds for the ensuing oscillatory wave; and
- c) Successive peaks of alternating polarity with each peak being 60 percent of the preceding peak.

A typical surge generator and control relay are shown in Figures 29.1 and 29.2.

Figure 29.1
Surge generator circuit

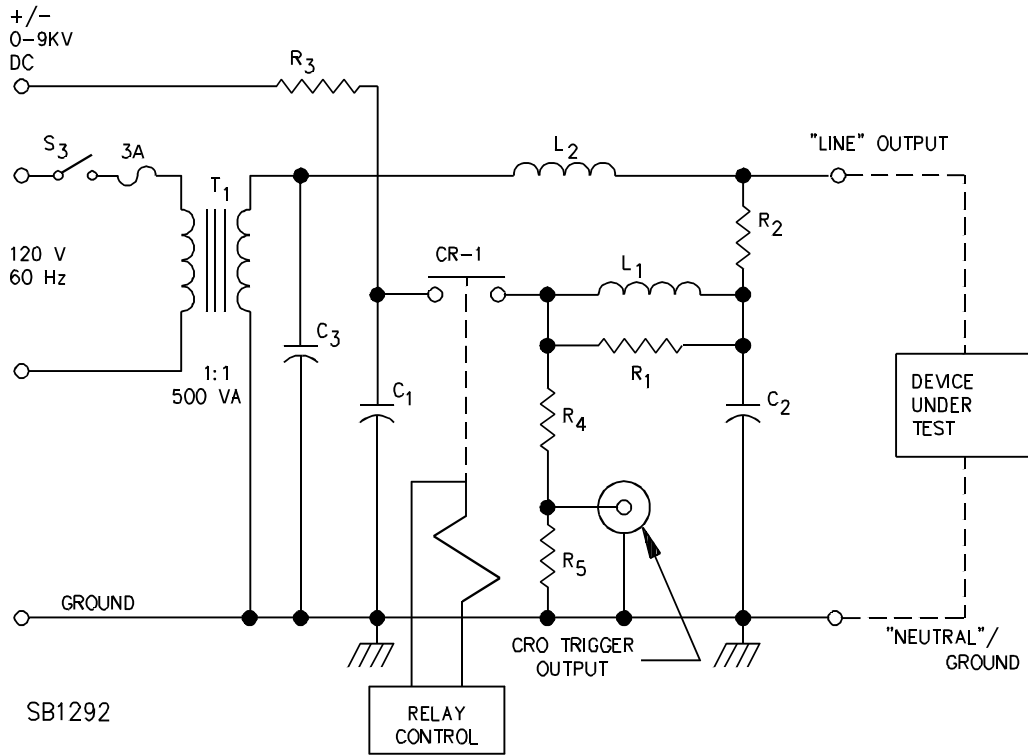
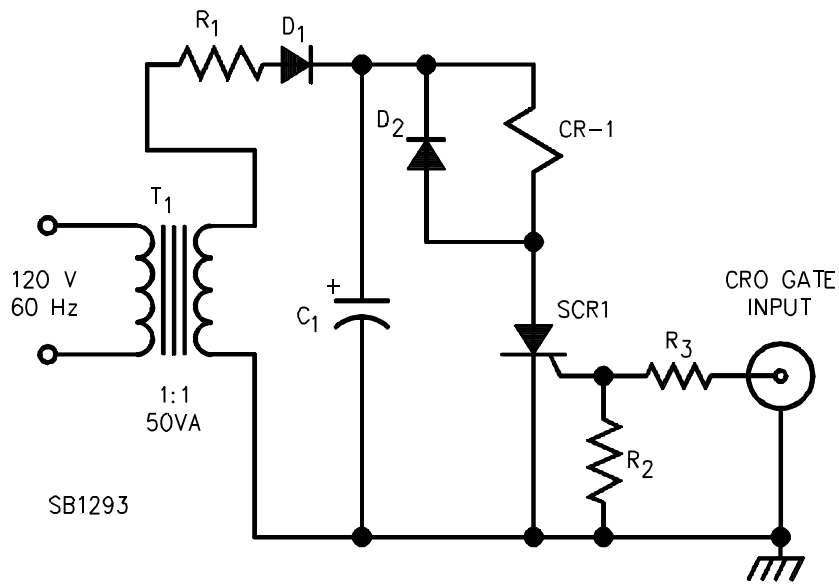


Figure 29.2
Relay control circuit for surge generator



30 Power Supplies

30.1 Short circuit

30.1.1 A control employing a fixed impedance or regulating network that serves to limit the current or voltage as noted in 8.2 or 20.3 shall be subjected to a 7-hour abnormal (short circuit) test at the point at which the current and/or voltage are limited. For the test, the control and/or end product 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 21.2. Dead metal parts of the control and/or end product are to be earth grounded through a 3-ampere nontime-delay fuse. The conditions specified in 25.5.1 shall not occur as a result of the short-circuit test. See 26.1.3.

30.2 Stalled rotor

30.2.1 If a control is provided with or supplied by a motor-transformer, stalling the rotor shall not result in a risk of fire, electric shock, or cause a loss of isolation between windings.

30.2.2 Three samples of the control and/or end product are to be prepared as follows and then subjected to the stalled-rotor test for 7 hours:

- a) Each sample is to be placed on a softwood surface that has been covered with white tissue paper.
- b) Exposed dead metal parts and one end of each secondary winding are to be connected to earth ground through a 3-ampere nontime-delay fuse unless such a connection might create a condition that is not likely under single-fault conditions.
- c) A single layer of cheesecloth is to be draped loosely over each sample or its individual enclosure.
- d) Each sample is to be connected to a supply circuit as specified in 21.2.
- e) The rotor is to be stalled while all secondary windings are loaded to rated power or current.

30.2.3 The results of the test are not acceptable if the cheesecloth or tissue paper glows or flames, the 3-ampere fuse opens, or a breakdown occurs as a result of repeating the dielectric voltage-withstand test specified in 33.4.1 while the sample is still in a heated condition from the stalled rotor test.

31 Component Failure Test

31.1 The component failure tests specified in Sections 20, 24, 25, and 26 relate to specific circuits or constructions. Section 31 covers component failure in such circuits or in parts of the circuitry not covered in the sections noted above, such as in a line-connected circuit, that may present a risk of fire, electric shock, or injury to persons.

31.2 With reference to 31.1, each circuit component is to be open- or short-circuited one at a time. During these tests, the control and/or the end product 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 21.2. Dead metal parts of the control and/or end product are to be earth grounded through a 3-ampere nontime-delay fuse. The control is to be operated in any normal mode (for example, full power, partial power, standby, or the like) considered likely to cause the most adverse results. A discrete multiple terminal device or an integrated circuit device shall be tested in accordance with 25.4.1. The conditions specified in 25.5.1(b) – (f) shall not occur as a result of these tests. Also, see 26.1.2 and 26.1.3.

Exception No. 1: See Exception No. 1 to 25.4.1.

Exception No. 2: See Exception No. 2 to 25.4.1.

Exception No. 3: See Exception No. 3 to 25.4.1.

Exception No. 4: Components in a Class 2 or limited-energy circuit that is not a safety circuit need not be open- or short-circuited. See 25.2.2 for the criteria for determining whether a circuit is considered to be a limited-energy circuit.

Exception No. 5: Component failure testing need not be conducted 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.

31.3 Rather than the component failure tests specified in 31.1 and 31.2, a component evaluation study may be used to determine the likelihood of specific open- and short-circuits.

32 Electronic Component Evaluation

32.1 A component evaluation study shall be considered necessary when investigating a control incorporating safety circuits or where single-mode component faults will result in unacceptable overheating, a risk of fire, electric shock, or other injury to persons to occur in the control or the controlled equipment.

32.2 A component solid-state appliance control 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.

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

32.4 If a single-mode component fault is not likely (for example, see Exception Nos. 1 and 2 of 25.4.1), a component need only undergo a limited investigation.

32.5 Circuit components, which taken together are relied upon to limit power, current, or voltage in accordance with the requirements in Sections 8, 20, and 25 shall be subjected as a unit to an evaluation program.

33 Dielectric Voltage-Withstand Test

33.1 General

33.1.1 The insulation and spacing of a control shall be capable of withstanding without breakdown for a period of 1 minute the application of the test potentials described in this section with the control in a heated condition.

33.1.2 A source employed to supply the required test potential shall have sufficient capacity (at least 500 volt - amperes) 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.

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

33.1.4 Printed-wiring assemblies and other electronic-circuit components that would be adversely affected by the application of the test potential or which would short circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand test is conducted. 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 conducted to avoid destroying them by a fault elsewhere.

33.1.5 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.

33.2 Primary circuits

33.2.1 An essentially sinusoidal potential at a frequency in the range of 40 – 70 hertz is to be applied as noted below. The test potential is to be as indicated in 33.2.2:

- 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 33.2.4);
- 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).

33.2.2 The test potential shall be:

- a) One thousand volts for a rating or voltage involved of 250 volts or less; and
- b) One thousand volts plus twice the maximum rating or voltage involved for a rating or voltage involved of greater than 250 volts.

33.2.3 If an autotransformer is in the circuit, an essentially sinusoidal potential of 1000 volts plus twice the rated voltage at a frequency in the range of 40 – 70 hertz is to be applied as specified in 33.2.1(a), (b), (d), and (e) to all wiring involving a potential greater than 250 volts. 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.

33.2.4 If the charging current through a capacitor or capacitor-type filter connected across the line is large enough to make it impossible to maintain the required alternating-current test potential, the capacitors and capacitor-type filters may be tested as specified in 33.2.5.

33.2.5 The capacitors and capacitor-type filters mentioned in 33.2.4 are to be subjected to a dc test potential of 1414 volts for equipment rated at 250 volts or less, or 1414 volts plus 2.828 times the rated voltage for equipment rated at more than 250 volts. The dc test potential shall be maintained for 1 minute without breakdown.

33.3 Isolated secondary circuits

33.3.1 An essentially sinusoidal potential at a frequency in the range of 40 – 70 hertz 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.

The test potential shall be as indicated in Table 33.1.

Exception: Two circuits of the type specified in 20.1.3 are to be subjected to a test at a test potential of 500 volts applied between the circuits.

Table 33.1
Magnitude of test potential

Maximum rms (peak) voltage in secondary circuit ^a			Test potential
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

^aWhere the peak voltage is greater than 120 percent of 1.414 times the rms voltage, the circuit is to be tested as if the voltage were peak voltage divided by 1.414.

33.4 Transformers

33.4.1 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). The intended maximum operating temperature of the bobbin shall be noted for end-use consideration. Following the conditioning, the transformer shall withstand for 1 minute without electrical breakdown the application of an essentially sinusoidal potential at a frequency in the range of 40 – 70 hertz and at a value indicated in 33.2.2. 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: (c) and (d) above may be omitted if the risks noted in 16.2.1 are not present.

Exception No. 2: A transformer complying with 16.1.2 or 16.1.3 need not be subjected to this test.

MANUFACTURING AND PRODUCTION LINE TESTS

34 DC Offset voltage Test

34.1 The output voltage for each ac rated control employing a power-switching semiconductor and intended to control a load likely to be affected by asymmetrical switching shall not have a dc component greater than the maximum value measured per 23.1 under the conditions of 34.2 – 34.4.

34.2 The dc voltage is to be measured by means of a dc voltmeter as specified in 23.3.

34.3 The test is to be conducted with the control connected and operated in the normally intended manner.

34.4 The control may 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

35 Details

35.1 Input

35.1.1 A control shall be rated in volts and frequency.

Exception: An input rating may be omitted if the control is tested in conjunction with a specific end product.

35.2 Output

35.2.1 Unless otherwise indicated, a control shall be provided with an output rating in volts, amperes, horsepower, or a combination of both. The rating shall indicate whether the control is for direct or alternating current, pilot duty, or for controlling a resistive, tungsten lamp, or electric discharge lamp load. For an alternating current device, the ratings shall indicate the number of phases and (if necessary) the frequency; except that a single-pole or other device obviously intended only for single-phase use need not include the phase rating.

Exception: The output rating may be omitted if the control is tested in conjunction with a specific end product.

35.2.2 A control intended to control a motor shall be rated in horsepower and may also be rated in full-load and locked-rotor current provided the full-load current value is consistent with the horsepower rating (see Table 27.1) 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: See exception to 35.2.1.

Exception No. 2: A device intended to control a motor rated 2 horsepower or less need not have a horsepower rating if it 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 need not be a value defined by a typical horsepower rating.

Exception No. 3: A device intended to control a motor shall not be rated in horsepower if it is tested in accordance with Exception No. 2 of 27.2.1. It shall be rated in FLA and LRA based on the actual full-load and locked-rotor currents to which it was tested.

35.3 Operational ambient temperature

35.3.1 A control shall be assigned a maximum operational ambient temperature rating in degrees centigrade if such a rating is needed because of the requirements in 22.1.3.

MARKINGS

36 General

36.1 A control shall be plainly and permanently marked with the following. For a system of separate components, the markings shall be located on a major part of the system.

- a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified.
- b) A distinctive catalog number or the equivalent for the overall system.
- c) A distinctive marking, which may be in code, by which the product may be identified as the product of a particular factory if a manufacturer produces or assembles it at more than one factory.
- d) A marking identifying other parts of a system of separate components that are specified by the control manufacturer as part of the system.
- e) A marking identifying the type of equipment for which the control is intended to be used if the control is to be used only with certain equipment.

Exception: The markings in (a) – (e) may be omitted if the control is tested in conjunction with a specific end product.

36.2 With reference to 36.1(d), all separate parts of a system (other than the major part) shall be marked with the manufacturer's name, trademark, or the like, and a distinctive catalog number or the equivalent for the part.

36.3 A heat sink or other part considered live by virtue of insufficient spacings or insulation, or both, to other than Class 2 parts, likely to be mistaken as dead metal, and likely to be 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 likely to be 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 may be applied adjacent to the part in a location such that it is obvious to which part the marking applies.

36.4 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 20.4 and 20.11 or power in accordance with 25.2.2 or 25.2.4, 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.

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APPENDIX A**Standards for Components**

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard – UL Standard Designation

Capacitors, Across-the-Line, Antenna-Coupling, and Line-By-Pass for Radio- and Television-Type Appliances – UL 1414

Double Insulation Systems for Use in Electrical Equipment – UL 1097

Motors, Overheating Protection for – UL 2111

Optical Isolators – UL 1577

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

Polymeric Materials – Short Term Property Evaluations – UL 746A

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

Printed Wiring Boards, Electrical – UL 796

Protectors, Supplementary, for Use in Electrical Equipment – UL 1077

Semiconductor Devices, Electrically Isolated – UL 1557

Terminals, Electrical Quick-Connect – UL 310

Transformers, Class 2 and Class 3 – UL 1585

Transformers, Specialty – UL 506

Wire Connectors and Soldering Lugs for Use with Copper Conductors – UL 486A

Wire Connectors for Use with Aluminum Conductors – UL 486B

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CRG 244A

CANADIAN REQUIREMENTS COMPARISON GUIDE

UL AND CANADIAN
STANDARDS FOR
SOLID-STATE CONTROLS FOR APPLIANCES



Product Category: Appliance Controls
UL Category Control Number: ATNZ7, ATNZ8

UL Standard: Standard for Solid-State Controls for Appliances
UL 244A
Second Edition

Canadian Standard: Clock-Operated Switches
CAN/CSA-C22.2 No. 177-92
Second Edition

This Canadian Requirements Comparison Guide is only intended to identify Canadian requirements that must be applied in addition to the requirements in the UL Standard to obtain a c-UL Mark. The guide is not intended to replace a thorough review and comparison of the requirements applicable to the product category as contained in the applicable UL and Canadian Standards. Where requirements are not specifically addressed, compliance with the requirements in the UL Standard satisfy the requirements in the Canadian Standard.

The actual requirements applied for a c-UL product investigation may differ from those identified in this guide based on the specific features, characteristics, components, materials, or systems used in the product.

CRG: 244A
Issue No.: 2
Issue Date: February 23, 1998

Revisions of this guide will be made by issuing revised or additional pages bearing their date of issue. A Canadian Requirement Comparison Guide is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revision pages for the Guide.

The following outlines the requirements contained in CSA C22.2 No. 177-92 that are in addition to the requirements in UL 244A that must be met in order for a product to bear the appropriate UL Marking. UL provides a certification program for products that meet the Canadian requirements. The c-UL Mark is the manufacturers assurance that products as evaluated by UL, continue to comply with the appropriate Canadian requirements.

<u>Requirements Topics</u>	<u>CSA Clause</u>	<u>Comparison</u>
Tests – General	6.1.1	At least 3 controls shall be subjected to the following tests in order given: leakage current, overload, endurance, temperature, and dielectric.
Leakage current test	6.3	Test is to be conducted on 3 unconditioned samples.
Overload test	6.4	Test is to be conducted on 3 samples.
	6.4.11	The fuse connected between dead metal and one supply terminal is to be rated 15 A.
Endurance test	6.5	Test is to be conducted on 3 samples.
	6.5.1	The fuse connected between dead metal and one supply terminal is to be rated 15 A.
Temperature test	6.6	Test is to be conducted on 3 samples.
Snap-action switches	6.6.2	A switch that does not have a quick make-and-break mechanism or whose blade or blades can be left in other than a full off or full on contact position shall comply with the requirement in Clause 6.4.1 with the mechanism in any on position in which it can be left.
VA rated controls	6.6.3	A switch incorporating a volt ampere rating shall be capable of carrying continuously a current of 10 A without showing temperature rises greater than those specified in Table 9.
Dielectric strength test	6.9.1	The test is to be conducted at 1000 volts plus twice the rated voltage of the control.
Moisture absorption test	6.12	Insulating materials intended for direct contact with live parts shall not absorb more than 10 percent of water by weight when subjected to this test.
Covers	6.13	Snap-on covers as described in Clause 4.2.5.2 shall comply with release characteristics, cover removal, and impact withstand requirements in Clause 6.13.
Knockouts	6.14	A knockout shall remain in place when a force of 44 N is applied at right angles to the knockout by means of a mandrel with a 6.3 mm diameter flat end. The mandrel is to be applied at the point most likely to result in movement of the knockout.
Bonding resistance	6.16	Bonding resistance shall not be more than 0.1 ohm.
Insulation resistance	6.17	An insulation material for coil windings likely to be affected adversely by moisture shall have an insulation resistance of not less than 50,000 ohms.

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