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UL 244B

**Outline of Investigation for Cord-Connected Controls with Standard NEMA
Plugs and Receptacles, Direct Plug-In Controls, and Controls Intended to
be Mounted in Wiring Boxes**

Issue Number: 1

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Summary of Topics

This First issue of the Outline of Investigation for Cord-Connected Controls with Standard NEMA Plugs and Receptacles, Direct Plug-In Controls, and Controls Intended to be Mounted in Wiring Boxes, UL 244B, covers electrical controls that are complete in construction.

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APPENDIX A

Standards for Components..... A1

INTRODUCTION

1 Scope

1.1 These requirements cover electrical controls that are complete in construction and designed specifically for installation in North America. These products are intended to be installed within the guidelines and requirements of the National Electrical Code, NFPA 70 and other relevant building codes. Products such as cord-connected controls with standard NEMA plugs and receptacles, direct plug-in controls and controls intended to be mounted in wiring boxes are covered under the scope of this standard.

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

- a) No voltage greater than 600 V above ground will be present in a control,
- b) An isolation transformer, if provided, will generally furnish power at a lower potential than the primary voltage, and
- c) The output of the control will not be located in a circuit operating at greater than 600 V above ground in the end-use product.

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

1.3 A control covered by this outline 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 of the loads. The maximum number of integrated controlled outlets on the control shall not exceed four and the maximum total current draw of the control shall not exceed 85% of the branch circuit protection rating.

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

1.5 These requirements do not cover a control intended for installation in, on or in association with appliances, refrigeration or air conditioning equipment or similar equipment. Such equipment and those intended for the global market are covered in the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series.

1.6 Products that are intended to be used in conjunction with or part of a building automation control system are not covered under the scope of this standard. Such products are covered under UL 60730-1, the standard for Automatic Electrical Controls.

1.7 The following products are not covered under the scope of this standard:

- Receptacles with integral Switching Means – Such products are covered under UL 498B, Outline of Investigation for Receptacles with Integral Switching Means.
- Controls that employ a dimming function as a primary function and are intended to be permanently installed in outlet boxes are covered under UL 1472, the Standard for Solid-State Dimming Controls.

- Solid state fan speed controls provided with a power supply cord, those intended for permanent connection and direct plug-in devices are covered under the scope of UL 1917, the Standard for Solid-State Fan Speed Controls.
- Controls of the light-sensitive or presence-sensitive types, or both; for indoor or outdoor service are covered under the scope of UL 773A, the Standard for Nonindustrial Photoelectric Switches for Lighting Control.

2 Undated References

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

3 Glossary

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

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

- a) An inherently-limited Class 2 transformer;
- b) A combination of an isolated transformer secondary winding and a fixed impedance or regulating network that together comply with the performance requirements for an inherently-limited Class 2 transformer;
- c) A dry-cell battery having output characteristics not greater than those of an inherently-limited Class 2 transformer;
- d) Any combination of (a), (b), and (c) that together comply with the performance requirements for an inherently-limited Class 2 transformer; or
- e) One or more combinations of a Class 2 transformer and an overcurrent protective device that together comply with the performance requirements for a noninherently-limited Class 2 transformer.

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

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

3.4 CONTROLLED ENVIRONMENT – An environment:

- a) Relatively free of conductive contaminants, such as normal cooking vapors, carbon dust, and similar contaminants, which are a result of the end-use product in which a control will be installed or due to the location of the end-use product, and
- b) Not subject to humidity and the formation of condensation. A controlled environment is provided, for example, by means of a:
 - 1) Hermetically sealed enclosure;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- a) Class 2 – An isolation type transformer as specified in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.
- b) Power – A transformer other than Class 2 that is intended to transmit power. Included are isolation and nonisolation (such as an autotransformer) types.
- c) Pulse – An isolation-type transformer designed to pass pulse waveforms as distinguished from sine waves. It is not considered to be a power transformer.
- d) Current Sensing – An isolation-type transformer designed to have the primary winding connected in series with a circuit carrying current to be measured or controlled. In window type current transformers, the primary winding is provided by a separate conductor and is not an integral part of the transformer.
- e) Isolating – A transformer in which one or more secondary windings are electrically separated by insulation, spacings, or both, from the primary windings. Secondary windings are not required to be electrically separated from other secondary windings.

4 Components

4.1 Except as indicated in 4.2, a component of a product covered by this outline 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 outline.

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

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this outline, or
- b) Is superseded by a requirement in this outline.

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

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

5 Units of Measurement

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

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

CONSTRUCTION

6 General

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

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

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

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

6.5 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts upon which proper mechanical operation may depend.

Exception: This requirement does not apply to:

- a) Bearings, thermal elements, sliding surfaces of a hinge, or shaft, and the like, where such protection is impracticable;*
- b) Small parts of iron or steel, such as washers, screws, bolts, and the like, that are not current carrying, if the corrosion of such parts would not be likely to result in a risk of fire, electric shock, or injury to persons; and*
- c) Parts made of stainless steel that are polished or treated, if necessary.*

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

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

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

7 Frame and Enclosure

7.1 The frame and enclosure of a control shall comply with the relevant requirements of Clause 7 of UL 508.

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

7.3 A polymeric enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

7.4 A polymeric electrical enclosure shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

8 Accessibility of Live Parts

8.1 The method of determining the accessibility of an uninsulated live part that involves a risk of electric shock and other electrical parts, such as those in a safety circuit or nonlimited energy circuit, is to be in accordance with Clause 7.17 of UL 508.

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

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

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

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

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

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

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

in which:

Z is the minimum impedance, including tolerances;

V is the open-circuit voltage; and

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

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

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

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

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

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

- a) Minimum electrical spacings shall be in accordance with Spacings, Section 17, up to the point at which the voltage, current, or both is limited, regardless of the maximum available power involved.
- b) A risk of fire, electric shock, or injury to persons shall not result when the circuit is subjected to the 7-h short-circuit test specified in 30.1.1.

9 Current-Carrying Parts

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

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

Exception No. 2: Plated iron or steel is acceptable as a current-carrying part if it is used in the construction of a frame or enclosure that is intended for connection to an isolated secondary circuit or it is used as part of a component in accordance with the requirements for that component. See 10.4.1.

10 Internal Wiring

10.1 General

10.1.1 The wiring and connections between parts of the equipment shall be protected from mechanical damage during installation.

10.1.2 Internal wiring shall be routed and secured so that the wiring and related electrical connections are not subjected to stress or mechanical damage, especially wiring smaller than 24 AWG (0.21 mm²) or having insulation less than 1/32 in (0.79 mm) thick. Wire insulation shall be at least 1/32 inch (0.8 mm) thick if it is subjected to movement, flexing, or handling during its intended use, or during maintenance.

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

10.1.4 A hole through which insulated wires pass in a sheet metal wall within the enclosure of the equipment shall be provided with a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wires may bear to reduce the risk of abrasion of the insulation.

10.1.5 Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and the like, that can abrade the wire insulation.

10.1.6 Wiring that is subject to flexing during servicing such as that from a stationary part to a part mounted on a hinged door shall be provided with additional insulation at any point where it is flexed, unless the wiring is flexible cord.

Exception: Additional insulation is not required if the test described in Wire Flexing, Section 63 of UL 508 is completed without evidence of damage to the wiring.

10.1.7 Insulation, if used, shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

10.2 Splices and connections

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

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

10.2.3 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.

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

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

10.2.6 A non-general use attachment plug or receptacle, or a printed-wiring board connector intended to facilitate interconnection within a control shall be:

- a) Rated for the current, voltage, and temperature involved; and
- b) Provided with mechanical locking or securing means other than friction for providing electrical continuity, maintenance of spacings, and separation of circuits

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

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

10.2.8 If stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire cannot contact other uninsulated live parts not always of the same polarity as the wire, and de-energized metal parts. This can be accomplished by any acceptable means including use of machine- or tool-applied pressure terminal connectors, soldering lugs, or crimped eyelets, or soldering all strands of the wire together.

10.2.9 A splice shall be provided with insulation equivalent to that of the wires involved.

10.2.10 A splice shall be provided with insulation equivalent to that of the wires involved.

10.3 Wire-wrapped connections

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

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

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

10.3.4 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 10.1. A smaller number of wraps shall be subjected to an investigation. Contact points shall produce compression or flow of the conductor rather than a nick that weakens the mechanical strength of the conductor such that fracture is able to occur.

Table 10.1
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

10.3.5 The term "closely wrapped" in 10.3.4(b) means:

- a) There shall not be gaps between adjacent turns greater than one half of the diameter of the wire exclusive of gaps on the first and last turns; and
- b) The sum of all gaps on any side of a connection shall not exceed the diameter of the wire exclusive of gaps on the first and last turns.

10.3.6 10.3.5 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 10.3.5.

10.4 Connections to frame

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

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

10.4.2 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.

10.5 Clamps and guides

10.5.1 Clamps and guides, either metallic or nonmetallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or cold flow of the insulation cannot occur. Auxiliary nonconducting mechanical protection shall be provided under a metallic clamp that exerts pressure on a conductor having thermoplastic insulation less than 1/32 inch (0.8 mm) thick and having no overall braid.

11 Interconnecting Cords and Cables

11.1 The means provided for the interconnection of equipment shall comply with the requirements of 11.2 – 11.5, except that equipment with field wiring provisions to facilitate interconnection by means of permanently installed field wiring shall comply with the requirements of Supply Connections, Section 16.

11.2 Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a system shall be of a type that is acceptable for the service or use involved and shall be provided with bushings and strain relief.

11.3 Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts that are accessible to the operator shall not result in mechanical damage or a risk of fire, electric shock, or injury to persons.

11.4 If either or each end of an external interconnecting cable terminates in a connector external to the enclosure on which there are one or more exposed contacts, risk of electric shock shall not exist between earth ground and any contact that is exposed on either the connector or its receptacle mounted on an enclosure surface while the connector is out of its receptacle.

11.5 An interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected is an acceptable method of complying with the requirement in 11.4.

12 Separation of Circuits

12.1 General

12.1.1 Separation of circuits:

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

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

Table 12.1
Separation of circuits

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

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

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

^b Acceptable means of separation are:

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

- 1) Required spacing.
- 2) Twice required spacing.

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

C) Reinforced Insulation - Improved basic insulation rated for the highest voltage involved with such mechanical and electrical qualities that, in itself,

- 1) provides the same degree of protection against risk of electric shock as two single insulations and
- 2) complies with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

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

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

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Table 12.1 Continued

Part ^a			Separation requirement ^b
Insulation			
Rated for highest voltage involved	Not rated for highest voltage involved	Uninsulated	
2) Insulating Material – Vulcanized fiber, polyethylene terephthalate (PETP) film, and resin-bonded mica shall have thicknesses not less than 0.028 in (0.71 mm), 0.007 in (0.18 mm), and 0.006 in (0.15 mm), respectively. Other materials shall be subjected to an investigation in accordance with the requirements applied to internal barriers in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.			
3) Insulating Material (Sole Separation) - Insulating material shall comply with the requirements in 17.5 and 17.7.			

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

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

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

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

13 Insulating Material

13.1 General

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

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

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

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

13.1.3 Insulating material, including a barrier between parts of opposite polarity and material that is subject to the influence of an arc shall be rated for the application and comply with the internal barrier requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

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

13.2 Support of live parts

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

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

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

14 Printed-Wiring Boards

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

Exception: A printed-wiring board in a Class 2 nonsafety circuit is not required to comply with the bonding requirements in UL 796 if board is separated from parts of other circuits such that loosening of the bond between the foil conductor and the base material will not result in the foil conductors or components coming in contact with parts of other circuits of the control or of the end-use product.

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

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

15 Components

15.1 Switching devices

15.1.1 An electromechanical switching device:

- a) Shall be rated for the particular application;
- b) Shall have a voltage rating and a current rating, a horsepower rating, or both, not less than that of the load that the device controls; and
- c) Shall be rated for the type of load that the device controls as follows:

- 1) General purpose ac (0.75 to 0.80 power factor) - for example, transformer load.
- 2) General purpose dc.
- 3) Resistive.
- 4) Tungsten lamp.

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

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

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

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

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

15.2 Capacitors

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

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

15.2.3 A capacitor connected between two line conductors in a primary circuit, or between one line conductor and the neutral conductor or between primary and accessible secondary circuits or between the primary circuit and protective earth (equipment grounding conductor connection) shall comply with one of the subclasses of the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, and shall be used in accordance with its rating. Details for damp heat, steady state test can be found in 4.12 of UL 60384-14.

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

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

15.3 Power-switching semiconductors

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

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

15.4 Isolation devices

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

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

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

15.5 Transformers

15.5.1 General

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

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

15.5.1.3 A power transformer shall comply with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2 and with the overload heating requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3. See 15.5.2.5.

15.5.2 Isolation transformers

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

15.5.2.2 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.

15.5.2.3 With reference to 15.5.2.2, 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.

15.5.2.4 Spacings between parts noted in 15.5.2.3(a) – 15.5.2.3(e) shall not be less than the applicable value specified in Table 15.1. 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 15.5.2.3(d) and 15.5.2.3(e) if the risks noted in 15.5.2.1 are not present.

Table 15.1
Minimum spacings at isolation transformers

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

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

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