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OUTLINE OF INVESTIGATION
FOR
BATTERY OPERATED RIDE-ON LAWN MOWERS

Issue No. 1

August 30, 2012

Summary of Topics

This is the first issue of the Outline of Investigation for Battery Operated Ride-On Lawn Mowers, which covers rechargeable battery powered reel and rotary ride-on lawn mowers intended as consumer products for household use.

The UL Foreword is no longer located within the UL Outline of Investigation. For information concerning the use and application of the requirements contained in this Outline of Investigation, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net.ul.com/ulforeword.html>.

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INTRODUCTION

1 Scope

1.1 This Outline of Investigation covers rechargeable reel and rotary ride-on battery powered lawn mowers intended as consumer products for household use.

1.2 These requirements do not cover equipment for use in hazardous locations as defined in the National Electrical Code, NFPA 70.

1.3 This Outline of Investigation does not cover:

- a) Robotic Lawn Mowers that are unattended and operate automatically;
- b) Battery-operated Lawn Mowers which are covered under the Standard for Electric Lawn Mowers, UL 1447; or
- c) Ride-on mowers employing lithium-ion batteries.

2 General

2.1 In addition to complying with the requirements in this Outline of Investigation, rechargeable reel and rotary ride-on battery powered lawn mowers shall also comply with Consumer Turf Care Equipment – Walk-Behind Mowers and Ride-On Machines with Mowers – Safety Specifications, ANSI B71.1, applicable sections in Part I: General and Part III: Ride-on mowers, lever steer mowers, lawn tractors, and lawn and garden tractors.

2.1.1 A component of a product covered by this Outline of Investigation shall with each of the following:

- a) Comply with the requirements for that component as indicated in 2.2 – 2.20;
- b) Be used in accordance with its rating established for the intended conditions of use;
- c) Be used within its established use limitations or conditions of acceptability; and
- d) Additionally comply with the applicable requirements of this Outline of Investigation.

2.1.2 A component of a product covered by this Outline of Investigation is not required to comply with a specific component requirement that:

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

2.1.3 A component that complies with a UL component standard other than those specified in 2.2 – 2.20 is acceptable if:

- a) The component also complies with the applicable component standard specified in 2.2 – 2.20; or
- b) The component standard:
 - 1) Is compatible with the ampacity and overcurrent protection requirements in National Electrical Code, NFPA 70, where appropriate;
 - 2) Considers long-term thermal properties of polymeric insulating materials in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and
 - 3) Any use limitations of the other component UL standard is identified and appropriately accommodated in the end use application. For example, a component used in a household application, but intended for industrial use and complying with the relevant component standard may assume user expertise not common in household applications.

2.1.4 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.

2.2 Attachment plugs, receptacles, connectors, and terminals

2.2.1 Attachment plugs, receptacles, appliance couplers, appliance inlets (motor attachment plugs), and appliance (flatiron) plugs, shall comply with the Standard for Attachment Plugs and Receptacles, UL 498. See 2.2.8.

Exception: Attachment plugs and appliance couplers integral to cord sets or power supply cords are investigated in accordance with the Standard for Cord Sets and Power-Supply Cords, UL 817, and need not comply with UL 498.

2.2.2 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 0.110, 0.125, 0.187, 0.205, and 0.250 inch (2.8, 3.2, 4.8, 5.2, and 6.3 mm), intended for internal wiring connections in appliances, or for the field termination of conductors to the appliance, shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310.

Exception: Other sizes of quick-connect terminals shall be investigated with respect to crimp pull out, insertion-withdrawal, temperature rise, and all tests shall be conducted in accordance with UL 310.

2.2.3 Single and multi-pole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory assembly to copper or copper alloy conductors, or for factory assembly to printed-wiring boards, shall comply with the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977. See 2.2.8.

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

2.2.5 Splicing wire connectors shall comply with the Standard for Splicing Wiring Connectors, UL 486C.

2.2.6 Multi-pole splicing wire connectors that are intended to facilitate the connection of hard-wired utilization equipment to the branch-circuit conductors of buildings shall comply with the Standard for Insulated Multi-Pole Splicing Wire Connectors, UL 2459. See 2.2.9.

2.2.7 Equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors, shall comply with the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

2.2.8 Terminal blocks shall comply with the Standard for Terminal Blocks, UL 1059, and if applicable, be suitably rated for field wiring.

2.2.9 Female devices (such as receptacles, appliance couplers, and connectors) that are intended, or that may be used, to interrupt current in the end product, shall be suitably rated for current interruption of the specific type of load, when evaluated with its mating plug or connector. For example, an appliance coupler that can be used to interrupt the current of a motor load shall have a suitable horsepower rating when tested with its mating plug.

2.3 Batteries and Chargers

2.3.1 Rechargeable nickel cadmium (Ni-Cad) cells and battery packs shall comply with the applicable construction and performance requirements of the Outline of Investigation for Batteries for Use in Light Electric Vehicle (LEV) Applications, Subject 2271.

Exception: The requirements for the flammability rating in 10.7 of this Outline shall be required in lieu of the exception in 5.1.1 of the Outline of Investigation, Subject 2271.

2.3.2 Rechargeable nickel metal-hydride (Ni-MH) battery cells and packs shall comply with construction and performance requirements of the Outline of Investigation for Batteries for Use in Light Electric Vehicle (LEV) Applications, Subject 2271.

Exception: The requirements for the flammability rating in 10.7 of this Outline shall be required in lieu of the exception in 5.1.1 of the Outline of Investigation, Subject 2271.

2.3.3 A battery charger shall comply with one of the following:

- a) The Standard for Power Units Other Than Class 2, UL 1012;
- b) The Standard for Industrial Battery Chargers, UL 1564.

2.3.4 Lead acid type batteries shall comply with the Construction requirements of the Standard for Standby Batteries, UL 1989. In addition, lead acid-type batteries shall comply with the Pressure Release Test or the Flame Arrester Vent Cap Tests of UL 1989, whichever applies. See 10.5.

2.4 Capacitors and filters

2.4.1 The component requirements for a capacitor are not specified. A capacitor complying with the Standard for Capacitors, UL 810, is considered to fulfill the requirements.

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

2.5 Controls

2.5.1 General

2.5.1.1 Auxiliary controls shall be evaluated using the applicable requirements of this Outline of Investigation and the requirements in Controls – End Product Test Parameters, Section 21.

2.5.1.2 Operating (regulating) controls shall be evaluated using the applicable component standard requirements specified in 2.5.2 – 2.5.6, and if applicable, the requirements in Controls – End Product Test Parameters, Section 21, unless otherwise specified in this Outline of Investigation.

2.5.1.3 Operating controls that rely upon software for the normal operation of the end product where deviation or drift of the control may result in a hazard, such as a speed control unexpectedly changing its output, shall comply with one or both of the following standards:

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and the Standard for Software in Programmable Components, UL 1998; and/or
- b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

2.5.1.4 Protective (limiting) controls shall be evaluated using the applicable component standard requirements specified in 2.5.2 – 2.5.6, and if applicable, the parameters in Controls – End Product Test Parameters, Section 21, unless otherwise specified in this Outline of Investigation.

2.5.1.5 Solid-state protective controls that do not rely upon software as a protective component shall comply with one or both of the following standards:

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and/or
- b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1, except the Controls Using Software.

2.5.1.6 Protective controls that rely upon software as a protective component shall comply with one or both of the following standards:

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and the Standard for Software in Programmable Components, UL 1998; and/or
- b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

2.5.1.7 An electronic, non-protective control that is simple in design need only be subjected to the applicable requirements of this Outline of Investigation. A control that does not include an integrated circuit or microprocessor, but does consist of a discrete switching device, capacitors, transistors, or resistors, is considered simple in design. Such controls shall comply with the Abnormal Operation Test, Section 25.

2.5.2 Electromechanical and electronic controls

2.5.2.1 A control, other than as specified in 2.5.3 – 2.5.6, shall comply with one of the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series.

2.5.3 Motor and speed controls

2.5.3.1 A control used to start, stop, regulate or control the speed of a motor shall comply with one of the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

2.5.4 Pressure controls

2.5.4.1 A pressure control shall comply with one of the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Automatic Electrical Pressure Sensing Controls Including Mechanical Requirements, UL 60730-2-6.

2.5.5 Temperature controls

2.5.5.1 A temperature control shall comply with one of the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

2.5.5.2 A temperature positive temperature coefficient (PTC) or a negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control shall comply with the Standard for Thermistor-Type Devices, UL 1434.

2.5.5.3 A thermal cutoff shall comply with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691, (Thermal Cutoffs) for Use in Electrical Appliances and Components.

2.5.6 Timer controls

2.5.6.1 A timer control shall comply with one of the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

2.6 Cords, cables, and internal wiring

2.6.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817. See 11.4.2.

2.6.2 Flexible cords and cables shall comply with the Standard for Flexible Cords and Cables, UL 62. Flexible cord and cables are considered to fulfill this requirement when preassembled in a cord set or power supply cord complying with the Standard for Cord Sets and Power Supply Cords, UL 817.

2.6.3 Internal wiring composed of insulated conductors shall comply with one of the following:

- a) The Standard for Appliance Wiring Material, UL 758;
- b) The Standard for Thermoset-Insulated Wires and Cables, UL 44;
- c) The Standard for Thermoplastic-Insulated Wires and Cables, UL 83;
- d) The Standard for Fixture Wire, UL 66; or
- e) The applicable UL standard for other insulated conductor types specified in Wiring Methods and Materials of the National Electrical Code, NFPA 70.

Exception: Insulated conductors for specialty applications (e.g. data processing or communications) and located in a low-voltage circuit not involving the risk of fire or personal injury need not comply.

2.7 Film-coated wire (magnet wire)

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

2.7.2 Film-coated wire in intimate combination with one or more insulators, and incorporated in an insulation system rated Class 120 (E) or higher, shall comply with the magnet wire requirements in the Standard for Systems of Insulating Materials – General, UL 1446.

Exception: Components located in a low voltage circuit or limited power circuit need not comply with this requirement.

2.8 Gaskets, seals and tubing

2.8.1 Gaskets, o-rings, seals, and tubing the failure of which would increase the risk of fire, electric shock, injury to persons, or other hazards shall comply with the Standard for Gaskets and Seals, UL 157. See 6.8.

Exception: Rubber or neoprene compounds relied upon for protection from rain are only required to comply with Accelerated Aging Test, Section 32

2.9 Inverters, converters and controllers

2.9.1 Inverters, converters and controllers with a nominal output of 24 Vdc or less shall comply with the Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458.

2.9.2 Inverters and converters with a nominal output of more than 24 Vdc shall comply with the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

2.10 Light sources and associated components

2.10.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

2.11 Marking and labeling systems

2.11.1 A marking and labeling system shall comply with the Standard for Marking and Labeling Systems, UL 969, and be rated for the surface and temperature involved, and for exposure to water, oil and rated for outdoor use.

2.12 Motors and motor overload protection

2.12.1 General

2.12.1.1 General-purpose type motors having a NEMA frame size shall comply with the requirements specified in 2.12.2. This includes fractional HP motors rated up to 1 HP (typically NEMA frame sizes 42, 48, or 56), and integral HP motors rated 1 HP and greater (typically NEMA frame sizes 140 – 449T).

2.12.1.2 Motors not enclosed, or partially enclosed, by the end-product enclosure shall comply with the requirements specified in 2.12.2.

2.12.1.3 Component type motors completely enclosed within the end-product enclosure shall comply with the requirements specified in 2.12.2 or 2.12.3.

2.12.1.4 Motors located in a low voltage circuit are evaluated for the risk of fire and personal injury in accordance with the applicable requirements of this Outline of Investigation.

2.12.2 General-purpose type motors

2.12.2.1 A general-purpose type motor shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, unless they are located in NEC Class 2 circuits or limited power circuits.

2.12.3 Motor overload protection

2.12.3.1 A ride-on lawn mower employing a motor that incorporates electronic, thermal or overload protection to maintain compliance with this standard shall comply with the applicable requirements in 2.12.3.2 or 2.12.3.5.

2.12.3.2 Thermal protection devices integral with the motor shall comply with one of the following:

- a) The Standard for Overheating Protection for Motors, UL 2111; or
- b) The Standard for Thermally Protected Motors, UL 1004-3.

2.12.3.3 Impedance protection shall comply with one of the following:

- a) The Standard for Overheating Protection for Motors, UL 2111; or
- b) The Standard for Impedance Protected Motors, UL 1004-2.

2.12.3.4 Electronic protection integral to the motor shall comply with the Standard for Electronically Protected Motors, UL 1004-7.

2.12.3.5 Except as indicated in 2.12.3.4, electronically protected motor circuits shall comply with one of the following (See 2.5.4, for basic control requirements):

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. When the protective electronic circuit is relying upon software as a protective component, it shall comply with the requirements in the Standard for Software in Programmable Components, UL 1998. If software is relied upon to perform a safety function, it shall be considered software Class 1;
- b) The Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1; If software is relied upon to perform a safety function, it shall be considered software Class B; or
- c) The Standard for Power Conversion Equipment, UL 508C.

Exception: Compliance with the above standards is not required for an electronically protected motor circuit if there is no risk of fire, electric shock, or casualty hazard during abnormal testing with the motor electronic circuit rendered ineffective; compliance with the applicable requirements of this Outline of Investigation is then required.

2.13 Overcurrent protection

2.13.1 Fuses shall comply with the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; and the applicable UL 248 Part 2 (e.g. the Standard for Low-Voltage Fuses – Part 5: Class G Fuses, UL 248-5). Defined use fuses that comply with UL 248-1 the Standard for Automotive Glass-Tube Fuses, UL 275, and another applicable UL standard for fuses are considered to fulfill this requirement. All fuses shall be found suitable for the intended application.

2.13.2 Fuseholders shall comply with the Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and the applicable UL 4248 Part 2 (e.g. the Standard for Fuseholders – Part 9: Class K, UL 4248-9).

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

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

2.13.5 Overcurrent protection of the size necessary to reduce the likelihood of overheating of the smallest conductor in the circuit. A fuse shall conform with the following and shall be found suitable for the intended application:

- a) The Standard for Low-Voltage Fuses, UL 248, Fuses shall be rated DC with a fault current of 1000 A;
- b) The Standard for Automotive Glass-Tube Fuses, UL 275; and
- c) The Outline for Automotive Blade Type Fuses, UL 275A.

2.14 Polymeric materials and enclosures

2.14.1 Polymeric enclosure materials or a polymeric device which provides mechanical support or electrical insulation or separation whose deterioration would reduce spacings between uninsulated live parts or could result in a risk of fire, electric shock, or risk of injury shall comply with the following standards unless superseded by the requirements in this Outline of Investigation:

- a) The Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A;
- b) The Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and
- c) The Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

2.14.2 Polymeric materials molded or fabricated by a source other than the manufacturer, shall be identified according to the Standard for Polymeric Materials – Fabricated Parts, UL 746D.

2.14.3 Metallized or painted polymeric parts or enclosures shall comply with the applicable requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. This requirement is not applicable to exterior surfaces of polymeric enclosure materials or parts provided that the metallized coating or paint does not offer a continuous path for an internal flame to propagate externally.

2.14.4 A nonmetallic enclosure or enclosure part shall have mechanical strength and durability and be formed so that operating parts will be protected against damage and shall resist the abuses likely to be encountered during installation and normal use and service.

2.14.5 An enclosure or enclosure part shall protect persons against a risk of electric shock, and the material shall not create or contribute to a risk of fire, electric shock, or injury to persons.

2.14.6 A polymeric enclosure shall be evaluated to the following tests in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C:

- a) Mold Stress Relief Distortion; and
- b) Ball Impact Test.

2.14.7 The enclosure, guard or cover shall withstand the Ball Impact Test described in Section 26, without increasing the risk of shock, fire, or personal injury.

2.14.8 A polymeric electrical enclosure of a ride-on lawn mower enclosing part or all of an integral charging system that is connected directly to a branch circuit shall be rated 5V in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The enclosure shall not contain openings which increase the risk of fire as determined by abnormal testing.

Exception: Circuitry which does not involve a risk of fire is not required to be enclosed. A risk of fire is determined to exist at any two points in a circuit where:

- a) The open circuit voltage is more than 42.4 V peak and the energy available to the circuit under any condition of load, including short circuit, results in a current of 8 Amps or more after 1 minute of operation; or*
- b) A power of more than 15 watts is delivered into an external resistor connected between the two points.*

2.14.8.1 A polymeric battery enclosure, shall have a minimum flammability rating of V-1 in accordance with the Standard for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and shall be subjected to the Impact Test of Section 26 of this Outline of Investigation.

2.14.8.2 An electrical and mechanical enclosure shall have a minimum flammability rating of HB in accordance with the Standard for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and shall be subjected to the Impact Tests of Section 26 of this Outline of Investigation.

2.14.9 Among the factors taken into consideration when a nonmetallic frame or enclosure is investigated are its:

- a) Material flammability properties;
- b) Mechanical strength;
- c) Resistance to impact;
- d) Moisture-absorptive properties;
- e) Combustibility and resistance to ignition from electrical sources;

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- f) Resistance to corrosion;
- g) Resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use; and
- h) Dielectric properties, insulation resistance, and resistance to arc tracking.

2.14.10 External nonmetallic frame and enclosure parts shall be resistant to UV exposure as indicated through compliance with the Ultraviolet Light Exposure Test of UL 746C.

2.15 Power supplies

2.15.1 A non-Class 2 power supply shall comply with one of the Standard for Power Units Other Than Class 2, UL 1012.

2.16 Printed-wiring boards

2.16.1 A printed-wiring board included as part of the circuitry of a mower shall comply with requirements in the Standard for Printed-Wiring Boards, UL 796. The printed-wiring board shall have a flammability rating of V-2 or better as determined by an evaluation to the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances UL 94.

Exception No. 1: A printed-wiring board in a Class 2 non-safety circuit is not required to comply with the bonding requirements in UL 796, if the board is separated from parts of other circuits such that loosening of the bond between the foil conductor and the base material will not result in the foil conductors or components coming in contact with parts of other circuits of the control or of the end-use product.

Exception No. 2: A printed-wiring board located in a secondary circuit that complies with the requirements for Class 2 or limited voltage/current circuits shall have a minimum flame Class of HB.

2.16.2 The laminate material in a printed-wiring board used in a circuit that involves a risk of fire or electric shock shall:

- a) Comply with the direct support of current-carrying parts performance level requirements specified in the Standard for Printed-Wiring Boards, UL 796; and
- b) Be marked with:
 - 1) "Δ"; or
 - 2) Have a unique type designation that is limited to such printed-wiring boards to indicate compliance with the UL 796, requirements.

2.16.3 A conformal coating employed on the surface of a printed-wiring board, intended to be used for the acceptance of reduced spacings as described in 16.1.3 – 16.1.4, is acceptable if it complies with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

2.16.4 Creepage and clearances on printed-wiring boards involving safety circuits or a risk of fire shall be judged in accordance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840. Allowances for potting compounds and conformal coatings shall also be judged in accordance with UL 840.

2.16.5 When evaluating printed-wiring boards according to the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, determination shall be made on the basis that the mower operates in a pollution degree 3 environment for all safety circuits and circuits involving an electric shock or risk of fire.

2.16.6 It is anticipated the equipment will be rated overvoltage category II as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

2.17 Semiconductors and small electrical and electronic components

2.17.1 A power switching semiconductor device that is relied upon to provide isolation to ground shall comply with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. It shall have been evaluated for a minimum 750 volts isolation.

2.17.2 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this Outline of Investigation shall comply with the Standard for Safety for Optical Isolators, UL 1577. It shall have been evaluated for a minimum 1,500 volts isolation.

2.17.3 Except as otherwise specified in this outline of investigation, component requirements are not specified for small electrical parts on printed-wiring boards, including diodes, transistors, resistors, inductors, integrated circuits, and capacitors not directly connected to the supply source.

2.17.4 Where an electronic component is determined to be a critical component during the Abnormal Operation Test, Section 25 in this Outline of Investigation, the circuit shall comply with one or both of the following standards (see 6.4 for the test parameters to be used):

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, including its Follow-Up Program; and as applicable, the Standard for Software in Programmable Components, UL 1998, for controls that rely upon software as a protective component; and/or
- b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

2.17.4.1 A critical component is a component that performs one or more safety-related functions whose failure results in a condition, such as the risk of fire, electric shock, or injury to persons, in the end-product application.

2.17.4.2 A critical component may also be identified using a failure-mode and effect analysis (FMEA) in accordance with the Failure-Mode and Effect Analysis (FMEA), requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991.

2.17.4.3 Portions of a circuit comprised of a microcontroller or other programmable device that performs a back-up, limiting, or other safety function intended to reduce the risk of fire, electric shock, or injury to persons shall comply with Controls Using Software requirements in the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

2.18 Supplemental insulation, insulating bushings, and assembly aids

2.18.1 The requirements for supplemental insulation (e.g. tape, sleeving or tubing) are not specified unless the insulation or device is required to comply with a performance requirement of this Outline of Investigation. In such cases, the insulation or device shall comply with the following applicable standards:

- a) Insulating tape shall comply with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510;
- b) Sleeving shall comply with the Standard for Coated Electrical Sleeving, UL 1441; or
- c) Tubing shall comply with the Standard for Extruded Insulating Tubing, UL 224.

2.18.2 Wire positioning devices required to comply with the requirements of this Outline of Investigation shall comply with the Standard for Positioning Devices, UL 1565.

2.18.3 Insulating bushings shall comply with the Standard for Insulating Bushings, UL 635, and be suitable for the application with respect to the hole size and shape, maximum use temperature and wire size or type. To determine if the hole size and shape is suitable for the bushing, the applicable test specified in this Outline of Investigation (e.g. Strain Relief Test, Push-Back Relief Test, and Mold Stress Evaluation Test) should be conducted.

2.19 Switches

2.19.1 Switches shall comply with one of the following, as applicable:

- a) The Standard for Special Use Switches, UL 1054;
- b) The Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1;
- c) The Standard for General-Use Snap Switches, UL 20; or
- d) The Standard for Nonindustrial Photoelectric Switches for Lighting Control, UL 773A.

Exception: Switching devices that comply with the applicable UL standards for specialty applications (e.g. transfer switch equipment), industrial use (e.g. contactors, relays, auxiliary devices), or are integral to another component (e.g. switched lampholder) need not comply with this requirement.