UL 8750

STANDARD FOR SAFETY

Light Emitting Diode (LED) Equipment for Use in Lighting Products

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UL Standard for Safety for Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750

Second Edition, Dated September 15, 2015

Summary of Topics

This revision to ANSI/UL 8750 dated December 7, 2022 was issued to incorporate the following changes in requirements:

- ***Scope Update to Include Power Sources; 1.1, 3.13, 3.21 – 3.23, 8.1.3, 8.2.2 and 8.7.3.1***
- ***Adding UL 62368-1 to 4.1 List of Standards***
- ***Requirements for Coin Cell Lithium Batteries; 6.1.7***
- ***Correction for Dimensional Requirements in Exception No. 3 of 6.4.1***
- ***Clarification for Grounding and Bonding; 7.2A.1.4***
- ***Supply Connection Options for Built-in Products; 7.4.1.4***
- ***Correct cross reference in 7.11.2.4(b)***
- ***Dielectric Voltage Withstand Testing for Products with Integral SPDs; 8.6.1***
- ***Specifications for Cheesecloth in 8.7.1.1(d)***
- ***Updates to Marking Requirements; 3.2.1, 3.7.3, 9.1.4 – 9.1.8, 9.2.2, 9.2.4, 9.2.5, Section 9.2A, 9.3.1, 9.3.7 – 9.3.9, Section SB4, SC5.1, SC5.2, SC5.5, SD9.2 – SD9.4, Figure SD9.1, SE5.3, SF8.3, SF8.5, SF8.6, SG5.2, Section SH4, SI6.1, Section SJ7 and Appendix C***
- ***Clarification for SA3.3***
- ***Control Circuit Lead Wire Colors; SF4.2***

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 16, 2022.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover LED equipment that is an integral part of LED luminaires or lighting systems. These requirements cover LED drivers, controllers, arrays (modules), and packages as defined within this standard. These requirements also cover power sources that are integrated into LED luminaires or lighting systems for functions other than a LED driver (e.g., DALI bus power supply).

1.1.0 LED equipment covered by this standard are intended for operation in the visible light spectrum between 400 – 700 nm. Coherent light sources (e.g. laser sources) are not covered by this standard.

Exception No. 1: LED packages as described in Supplement SD may have applications other than general illumination and may operate outside of the visible light spectrum.

Exception No. 2: Special Use LED arrays as described in Supplement SJ have intended applications other than general illumination and may operate outside of the visible light spectrum.

1.1.1 *Deleted*

1.1.2 *Deleted*

1.1.3 These requirements do not cover LED controllers within the scopes of the following standards:

a) Standard for Safety for Plug-In Locking Type Photocontrols for Use with Area Lighting, UL 773, or

b) Standard for Safety for Solid-State Dimming Controls, UL 1472.

1.2 These lighting products are intended for installation on branch circuits of 600 V nominal or less in accordance with the National Electrical Code (NEC), ANSI/NFPA 70, and for connection to isolated (non-utility connected) power sources such as generators, batteries, fuel cells, solar cells, and the like.

1.3 LED equipment is utilized in lighting products that comply with the end-product standards listed below. The requirements in this standard are intended to supplement those in other end-product standards. Included are:

a) Electric Signs, UL 48,

b) Portable Electric Luminaires, UL 153,

c) Underwater Luminaires and Submersible Junction Boxes, UL 676,

d) Emergency Lighting and Power Equipment, UL 924,

e) Stage and Studio Luminaires and Connector Strips, UL 1573,

f) Track Lighting Systems, UL 1574,

g) Luminaires, UL 1598,

h) Direct Plug-In Nightlights, UL 1786,

i) Low Voltage Landscape Lighting Systems, UL 1838,

j) Self-Ballasted Lamps and Lamp Adapters, UL 1993,

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k) Luminous Egress Path Marking Systems, UL 1994, and

l) Low Voltage Lighting Systems, UL 2108.

1.4 The requirements in this standard do not anticipate additional construction, performance and marking considerations for the following end-applications: LED equipment subject to weather (outdoor use), LED equipment installed in air handling spaces or in other environmental air spaces (plenums), LED equipment intended for Emergency Lighting and Power Equipment, LED equipment with integral batteries (and battery packs), and LED equipment used in fire rated installations. LED equipment with such end-applications is subject to additional evaluation per applicable standards.

2 General

2.1 Components

2.1.1 Except as indicated in this clause, a component of a product covered by this standard shall comply with the requirements for that component. See the Standards for Components appendix for a list of standards covering components generally used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

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 Units of measurement

2.2.1 Except for conductor size, values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

2.2.2 All values of voltage and current are true root mean square (rms) values unless otherwise indicated.

2.2.3 For customary purposes wire sizes are in American Wire Gauge (AWG).

2.3 Reference publications

2.3.1 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 Definitions

3.1 For the purpose of these requirements, the following definitions apply.

3.2 BARRIER – A part of the unit intended to physically limit access to parts that pose a risk of electric shock.

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3.2.1 BUILT-IN PRODUCT – A component or subassembly that is intended for installation within an enclosure. See 3.4.1.

3.3 CIRCUIT, CLASS 2 – A circuit supplied by an isolating source that complies with the requirements of the Standard for Class 2 Power Units, UL 1310, or the Class 2 requirements of the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

3.4 CIRCUIT, ISOLATED LOW VOLTAGE LIMITED ENERGY (LVLE) – A circuit supplied by an isolating source (i.e. no direct electrical connection between input and output, such as provided by a transformer or optical isolator), and with output parameters as noted in 8.16.1.

Note – Throughout this standard LVLE circuits are afforded the same exemptions for risks of fire and electric shock as with Class 2 circuits. However, end-product lighting standards may have additional provisions for LVLE circuits. For example, UL 1598 (Luminaires) does not provide for a risk of fire exemption when the LVLE circuit is not contained within the luminaire.

3.4.0 DIRECT PLUG-IN LED DRIVER – A unit which employs a blade assembly on the enclosure for connection to the branch circuit. Output supply is typically provided via a cable terminating in a connector.

3.4.1 ENCLOSURE – A housing of a unit that is intended to prevent contact with uninsulated parts that represent a risk of electric shock (electrical enclosure), contain any fire initiated within the unit (fire enclosure), and prevent mechanical damage to internal parts.

3.5 ENCLOSURE, ELECTRICAL – A part of the equipment intended to limit access to parts operating at voltage levels that represent a risk of electric shock per 3.24.

3.6 ENCLOSURE, FIRE – A part of the equipment that encloses circuits that are considered a risk of fire per 3.25.

3.6.1 ENCLOSURES INTENDED FOR CONDUIT CONNECTION – An enclosure with facility for connection to branch circuit via conduit. In this standard this type of enclosure is utilized for remote LED drivers and for LED drivers that are secured to an exterior surface of a luminaire enclosure. The LED driver output may also be connected via conduit. When installed as intended, unused conduit knockouts and other openings are covered so the electrical and fire enclosure requirements of the standard are fulfilled.

3.7 ENVIRONMENTAL LOCATIONS

a) DRY LOCATION – A location not normally subject to dampness, but may include a location subject to temporary dampness, as in the case of a building under construction, provided ventilation is adequate to prevent an accumulation of moisture.

b) DAMP LOCATION – An exterior or interior location that is normally or periodically subject to condensation of moisture in, on, or adjacent to, electrical equipment, and includes partially protected locations.

c) WET LOCATION – A location in which water can drip, splash, or flow on or against electrical equipment.

3.7.1 FEEDTHROUGH CIRCUIT – Circuitry integral to LED equipment designed to pass its input power source to other utilization equipment- often another LED equipment of the same design- from the same source of supply without conditioning. In this standard feedthrough circuits are treated as output circuits with the same supply characteristics as the input supply.

3.7.2 FEEDTHROUGH RECEPTACLE – A feedthrough circuit in through cord LED drivers terminating in an integral receptacle, where the receptacle may be suitable for 1) a NEMA plug, 2) a mating connector, or

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3) an appliance coupler. For through-cord LED drivers, the feedthrough may be provided in a length of supply cord terminating in the receptacle.

3.7.3 INSTRUCTION SHEET – A generic term for information that is provided with the product in printed form (e.g. an insert, or a booklet). Required product markings may be provided in an instruction sheet, where so permitted by this standard. The manufacturer may include other materials – unrelated to the marking requirements of this standard – in the instruction sheet. Also see 9.2A.

3.8 INSULATION-PIERCING TERMINAL – A terminal having a contact pin that punctures the conductor insulation and penetrates between the conductor strands.

3.9 ISOLATED CIRCUIT – A circuit with only magnetic, capacitive, or optical connection to any ground-referenced supply source. A low voltage circuit derived by a dropping resistor is not isolated.

3.10 LED (LIGHT EMITTING DIODE) – A solid-state component embodying a p-n junction, emitting optical radiation when excited by an electric current.

3.11 LED ARRAY (LED MODULE) – An assembly of one or more LED discrete electronic components on a printed circuit board, typically with optics and additional thermal, mechanical, and electrical interfaces.

3.12 LED CONTROLLER – A device or electronic circuitry that is designed to control light output characteristics, control/manage electrical supply to one or more luminaires, or sense and transmit luminaire operational performance and building environmental data. Control may be via signals transmitted through wired circuits (see Supplement SF) or via wireless signals.

3.13 LED DRIVER – A power source that adjusts the voltage or current to LED loads, ranging in complexity from a resistor to a constant voltage or constant current power supply. Also referred to as Lamp Control Gear.

3.13.1 LED LIGHTING SYSTEM – A network of LED lighting elements (luminaires, controllers, drivers, etc.) that are interconnected (through wired and wireless signaling) to manage operation of the equipment. Lighting system elements may be physically integrated together into one assembly or they may be remotely located from each other. Lighting system elements may be powered from a single source of supply or they may be separately supplied.

Note: The scope of this standard does not cover LED lighting systems. The definition provides clarity about potential applications for LED equipment that are in scope of this standard, see 1.1, as part of the system.

3.14 LED PACKAGE – An assembly of one or more LED die that contains wire bond connections and may include an optical element and thermal, mechanical, and electrical interfaces. The package does not include a power source and is not connected directly to the branch circuit.

3.15 MEASUREMENT INDICATION UNIT (MIU) – The rms equivalent value of a 60 Hz sinusoidal leakage current in milliamps (mA), adjusted to compensate as necessary for leakage currents composed of complex waveforms or frequencies other than 50 or 60 Hz. It is determined by dividing the output voltage (V3) in millivolts (mV) rms by 500 (the value in ohms of the resistance in parallel with V2) in the measurement instrument circuit in Figure 8.6.

3.16 PART, DEAD CONDUCTIVE – A conductive part that, under normal operating conditions, carries no electrical current other than leakage current.

3.17 PART, HAZARDOUS LIVE – A part located in a circuit that is operating in excess of the risk of electric shock or risk of fire limits.

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3.18 PART, LIVE – A conductive part that has an electrical difference of potential with respect to earth ground or any other conductive part. A part connected to a grounded supply (neutral) conductor is considered to be a live part.

3.19 PLC (PERFORMANCE LEVEL CHARACTERISTIC) VALUE – An integer that defines a range of test values for a given electrical/mechanical property test for polymeric (plastic) materials as defined in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

3.19.1 POTTING – A process of filling the case of an electrical/ electronic assembly with material that may provide electrical insulation, environmental protection, heat transfer, vibration reduction, etc.

3.19.2 POTTING COMPOUND – Asphalt or Polymeric materials used to fill an electrical/ electronic assembly.

a) ASPHALT POTTING COMPOUND – Bituminous materials that are heated to flow, poured into an electronic assembly case and allowed to cool into a semi-solid. These materials are generally made from refined petroleum-based products mixed-in with inorganic materials (e.g. quartz, sand, etc.).

b) POLYMERIC POTTING COMPOUND – Plastics based materials that are typically poured, in liquid form, into an electronic assembly case and cured/ hardened in-place. These materials can be thermosetting or thermoplastic.

3.20 POWER LIMITED CIRCUIT – See Section 725 of the National Electrical Code (NEC), ANSI/NFPA 70.

3.21 POWER SOURCE, CLASS 2 – A power supply or transformer that complies with the requirements of the Standard for Class 2 Power Units, UL 1310, or the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3 respectively.

3.22 POWER SOURCE, ISOLATED LOW VOLTAGE LIMITED ENERGY (LVLE) – A power supply or transformer as defined by 3.4.

3.23 POWER SOURCE – An electronic device, assembled from components that collectively control its output current, voltage, or power within its design limits.

3.24 RISK OF ELECTRIC SHOCK – A risk of electric shock exists between any two conductive parts or between a conductive part and earth ground if the continuous current flow between the two points exceeds the leakage current limits determined by the Leakage Current Measurement Test, Section 8.9, and if the open circuit voltage exceeds the following limits:

	Maximum Voltage	
Waveform Type[a]	**Dry and Damp Locations**	**Wet Locations**
Sinusoidal ac	30 V rms	15 V rms
Non-sinusoidal ac	42.4 V peak	21.2 V peak
dc[b, c]	60 V	30 V
[a] The voltage limits for a composite AC + DC waveform (V peak) shall be per Figure 3.1 based on the Direct Voltage component (V DC) of the waveform. The graph line for locations where wet contact is not likely to occur refers to Dry and Damp locations. The graph line for locations where wet contact is likely to occur refers to wet locations.		
[b] If the peak-to-peak ripple voltage on a dc waveform exceeds 10 percent of the dc voltage, the waveform shall be considered a composite waveform per footnote a above.		
[c] DC waveforms interrupted at frequencies between 10 – 200 Hz shall be limited to 24.8 V in dry and damp locations, and 12.4 V in wet locations.		

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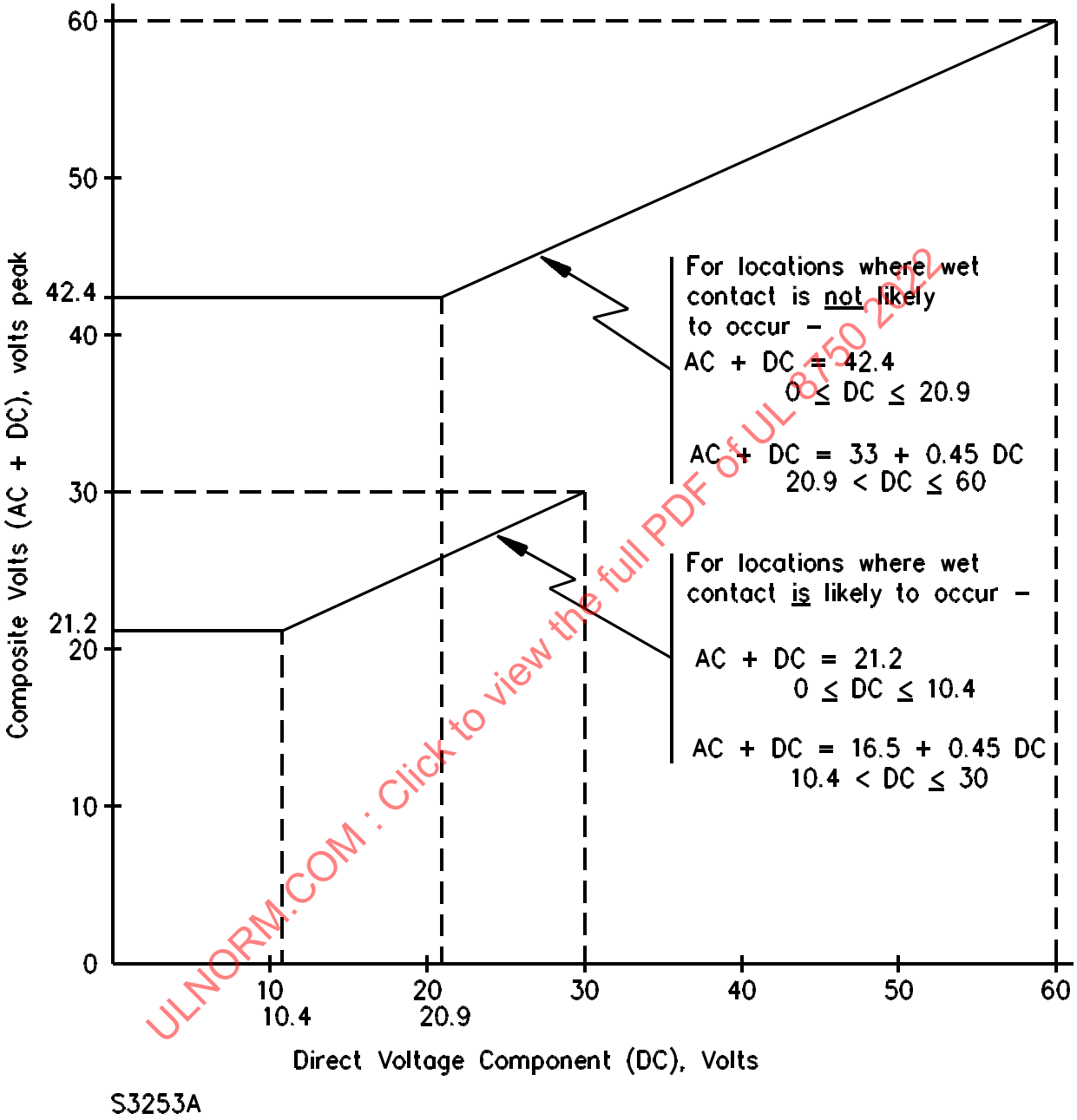
Figure 3.1

Maximum voltage



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3.25 RISK OF FIRE – A risk of fire exists in all electrical circuits except:

a) A Class 2 circuit,

b) An LVLE circuit, or

c) A circuit of 15 W maximum power limit under normal and single fault conditions, as measured in accordance with 8.8.

3.26 SECONDARY OPTIC – An optically transparent or translucent structure that is mechanically separate from the one or more LED packages it encloses. A secondary optic is generally intended to enhance performance by directing light paths and/or through the use of phosphors that shift the optical spectrum. In some cases, a secondary optic can serve as a fire enclosure, an electrical enclosure, an environmental barrier, and/or a UV emissions filter.

3.27 *Deleted*

3.27.1 THROUGH CORD LED DRIVERS – A unit which employs a cord and plug assembly for connection to the branch circuit. Output supply is typically provided via a cable terminating in a connector. Through cord LED drivers are not considered built-in products.

3.28 UNIT – A generic term meaning any discrete device, subassembly, or assembly.

3.29 UNIT, FIXED – A unit intended to be permanently connected electrically to the wiring system.

3.30 UNIT, PORTABLE – A unit that is easily carried or conveyed by hand, and is provided with a power-supply cord for connection to the supply circuit.

3.31 UNIT, STATIONARY – A unit that is intended to be fastened in place or located in a dedicated space, and is provided with a power-supply cord for connection to the supply circuit.

4 Power supplies, LED Drivers, and Transformers

4.1 A power supply or LED driver shall comply with the requirements of this standard. Compliance with the requirements of one or more of the following standards shall be considered to meet the intent of any equivalent requirements within this standard:

a) The Standard for Class 2 Power Units, UL 1310,

b) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1,

c) The Standard for Power Units Other Than Class 2, UL 1012,

d) The Standard for Fluorescent-Lamp Ballasts, UL 935, or

e) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1, UL 62368-1.

4.2 A transformer for use with LED units that complies with any one of the following standards is considered to meet the intent of the requirements of this standard:

a) 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,

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b) The Standard for Transformers and Motor Transformers for Use in Audio-, Radio- and Television-Type Appliances, UL 1411,

c) The Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2, or

d) The Standard for Dry-Type General Purpose and Power Transformers, UL 1561.

4.3 A power supply, LED driver, or transformer shall be used within its rated input, output, and environmental ratings.

CONSTRUCTION

5 Environmental Considerations

5.1 A unit intended for dry locations only shall be so identified and shall not be provided with any information such as markings, instructions, or illustrations that implies or depicts damp or wet use.

5.2 A unit intended for damp locations shall be:

a) Subjected to the environmental tests of 8.14 unless all live parts and traces on the printed wiring board are potted (see 6.7) or conformal coated (see 7.7.6),

b) If provided with a polymeric enclosure, comply with the Resistance to Impact test of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, using a preconditioning temperature of 0 ±2.0°C (32 ±3.6°F), and

c) Eligible to be marked as suitable for damp locations, and not be provided with any information such as markings, instructions, or illustrations that implies or depicts wet use.

Exception: A circuit operating at Class 2 or LVLE power levels in which voltage levels are below those that present a risk of electric shock per 3.24 is not required to be subjected to parts (a) and (b) above.

5.3 A unit intended for use in wet locations shall:

a) Be subjected to the environmental tests of 8.14 unless all live parts and traces on the printed wiring board are potted (see 6.7) or conformal coated (see 7.7.6),

b) If provided with a polymeric enclosure, comply with the UV Light Exposure and Cold Impact Test of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, using a preconditioning temperature of minus 35.0 ±2.0°C (minus 31.0 ±3.6°F), and

c) Be eligible to be marked as suitable for wet locations.

Exception: A circuit operating at Class 2 or LVLE power levels in which voltage levels are below those that present a risk of electric shock per 3.24 is not required to be subjected to parts (a) and (b) above.

6 Mechanical Construction

6.1 General

6.1.1 A unit intended to be used in an application identified by one of the standards specified in 1.3 shall comply with the mechanical construction requirements of that standard. If an end-use application is not specified or identified, or if a particular construction feature is not covered by the identified standard, the unit shall comply with the mechanical construction requirements of this section.

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6.1.2 *Deleted*

6.1.3 Circuits that represent a risk of electric shock or risk of fire shall be provided with an electrical or fire enclosure that complies with 6.2 or 6.3.

6.1.4 An electrical or fire enclosure secured in place by adhesive shall comply with the Adhesive Support Test of 8.13. Fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding are permitted without test.

6.1.5 In addition to complying with the construction requirements specified in this standard, a direct plug-in unit shall comply with the Mechanical Assembly, Input Connections, and Accessibility of Live Parts requirements specified in the Standard for Class 2 Power Units, UL 1310.

6.1.6 In addition to complying with the construction requirements specified in this standard, a LED controller that is intended to be installed in a wall-box (or provided with an enclosure for flush or surface mounting) shall comply with the following requirements in the Standard for Safety for Solid-State Dimming Controls, UL 1472 as applicable:

a) Means for mounting,

b) Current-carrying parts,

c) Switches,

d) Flush-device cover plates, and

e) Touch dimmers.

Note: This requirement applies to LED controllers that are not covered within the scope of the Standard for Safety for Solid-State Dimming Controls, UL 1472. See 1.1.3(b).

6.1.7 Where LED equipment includes coin cell lithium batteries, such as a wireless remote control for a LED controller, the design shall comply with the Standard for Products Incorporating Button or Coin Cell Batteries of Lithium Technologies, UL 4200A.

Exception: This requirement is not applicable to LED equipment where the battery is not intended to be user replaceable and is not referenced in the product markings or instructions sheet.

6.2 Metal parts

6.2.1 The thickness of a metal enclosure shall be in accordance with Table 6.1.

Exception: A part of an enclosure that complies with the mechanical strength tests for metal enclosures of 8.15 need not comply with the thickness specified in Table 6.1.

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Table 6.1
Minimum thickness of metal enclosures

Metal	At small, flat, unreinforced surfaces and at surfaces of a shape or size to provide adequate mechanical strength		At surfaces to which a wiring system is to be connected in the field		At relatively large unreinforced flat surfaces	
	mm	(in)	mm	(in)	mm	(in)
Die-cast	1.2	(3/64)	–	–	2.0	(5/64)
Cast malleable iron	1.6	(1/16)	–	–	2.4	(3/32)
Other cast metal	2.4	(3/32)	–	–	3.2	(1/8)
Uncoated sheet steel	0.66	(0.026)	0.81	(0.032)	0.66	(0.026)
Galvanized sheet steel	0.74	(0.029)	0.86	(0.034)	0.74	(0.029)
Nonferrous sheet metal other than copper	0.91	(0.036)	1.14	(0.045)	0.91	(0.036)

6.2.2 All ferrous metal parts, including hinges, bolts, and fasteners, exposed after assembly shall be protected against corrosion by painting, coating, or plating, except for edges, punched holes, and spot welds in prefinished steel, enclosed steel pipe, and hanger locations for painting or plating. Copper, aluminum, alloys of copper and aluminum, stainless steel, and similar materials having inherent resistance to atmospheric corrosion are not required to have additional corrosion protection.

6.2.3 A protective coating need not be applied to steel enclosure parts when:

a) The interior of an enclosure is completely filled with potting compound,

b) Flat metal surfaces are tightly clamped together, or

c) Where not practical due to bearings, sliding surfaces of a hinge or shaft, hinge pins, and similar parts.

6.3 Polymeric materials

6.3.1 A polymeric material for which mechanical, electrical, or thermal characteristics are relied upon for compliance with the requirements of this standard shall have an electrical, mechanical with impact and mechanical with strength relative thermal index (RTI), or a generic thermal index as specified in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, that is equal to or greater than the temperature measured during the Temperature Test, Section 8.3.

6.3.2 A polymeric material used as an electrical or fire enclosure shall comply with the minimum material characteristic requirements identified in Table 6.2.

Table 6.2
Polymeric enclosure requirements

Performance characteristic[a]	Function	
	Electrical enclosure	Fire enclosure
Impact[b]	X	X
UV Resistance[c]	X	X
Flammability		X[d,e,f]

Table 6.2 Continued on Next Page

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Table 6.2 Continued

Performance characteristic[a]	Function	
	Electrical enclosure	Fire enclosure
Mold Stress	X	X
Comparative Tracking Index (CTI)		Performance Level Category (PLC) of 4[g]
Hot Wire Ignition (HWI)		PLC of 3[g]
High Ampere Arc (HAI)		PLC of 2[g]

[a] These characteristics are as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Polymeric parts with deficient minimum performance characteristics can be evaluated per applicable end-product requirements in UL 746C.

[b] 6.8 J (5 ft-lb) ball impact for dry or damp location, fixed or stationary units; 0.91 m (3 ft) drop impact for portable units. For damp or wet location, fixed units, the impact test is to be conducted after cold conditioning in accordance with UL 746C.

[c] For wet location units.

[d] V2 for portable units and track lighting luminaires.

[e] 5VA for fixed or stationary units. See 6.3.4 and 6.3.6 for additional options for secondary optics.

[f] Direct plug-in units are evaluated as portable units. A through cord unit with screw holes or other means for fastening in-place is considered a stationary unit. A through cord unit with keyholes only is considered a portable unit.

[g] Not required when all live parts are > 0.8 mm (0.030 in) from the material.

6.3.3 A conductive coating applied to a surface such as the inside surface of a cover, enclosure, and the like shall comply with the appropriate requirements for metallized parts in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, unless it can be determined that flaking or peeling of the coating does not result in a reduction of spacing of electrical parts or the bridging of live parts that may result in a risk of fire or electric shock.

6.3.4 With respect to footnote (e) of Table 6.2, if a fire barrier consisting of metal or of a polymeric material having a minimum flammability rating of 5VA is positioned between a circuit that represents a risk of fire and the secondary optic, the secondary optic need only be evaluated as an electrical enclosure per the requirements in Table 6.2. LED packages that comply with the applicable requirements of this standard (see Supplement SD) as suitable to form a part of an enclosure need not be covered by the fire barrier.

6.3.5 The lens of an LED package which is intended to form a part of the fire enclosure shall comply with the applicable requirements for LED packages in Supplement SD.

6.3.6 With respect to footnote (e) of Table 6.2, a secondary optic that serves as a fire enclosure where all live parts are insulated or spaced more than 0.8 mm (0.030 in) from the secondary optic shall have a minimum V0 rating.

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6.3A Metal Enclosures intended for conduit connection

6.3A.1 Unthreaded openings for conduit and the area surrounding the opening shall comply with the requirements in Table 6.3.

Table 6.3
Dimensions of unthreaded opening for conduit and diameter of the area surrounding the opening

Nominal trade size of conduit	Unthreaded opening diameter[a]		On interior of component, minimum unobstructed diameter of flat surface surrounding conduit opening	
in	mm	(in)	mm	(in)
1/2	22.2	(0.875)	28.09	(1.11)
3/4	28.2	(1.109)	34.04	(1.34)
1	34.9	(1.375)	42.85	(1.69)
1-1/4	44.0	(1.734)	55.07	(7.10)

[a] A plus tolerance of 0.81 mm (0.032 in) and a minus tolerance of 0.38 mm (0.015 in) applies to the knockout diameter. Knockout diameters are to be measured other than at points where a tab attaches the knockout.

6.3A.2 A threaded opening for conduit shall comply with Table 6.4. When tapped all the way through, the opening shall have at least 3.5 but no more than 5 threads and comply with the minimum unobstructed diameter of flat surface in Table 6.3 to accommodate the conduit bushing. When not tapped all the way through, the opening shall have at least 5 threads.

Table 6.4
Throat diameters for conduit openings

Nominal trade size of conduit	Minimum throat diameter		Maximum throat diameter	
in	mm	(in)	mm	(in)
1/2	13.4	(0.528)	15.8	(0.622)
3/4	17.7	(0.697)	20.8	(0.819)
1	22.4	(0.882)	26.7	(1.051)
1-1/4	29.7	(1.169)	35.1	(1.382)

6.3A.3 A unit provided with a means of conduit connection shall be shipped with provision to close all but one of the conduit openings.

6.3A.4 Conduit closure plugs shall be suitable for the purpose with respect to environmental and enclosure flammability criteria.

6.3A.5 Conduit and other knockouts or twistouts shall be secured in place so they can be removed without distorting the enclosure but remain in place during normal handling, as determined by the Knockout Secureness Test, Section 8.17.

6.3A.6 Unless provided with a reliably separated wiring compartment, an opening provided for the purpose of making field connections to a branch circuit supply, shall be located greater than 152 mm (6 in) from the following:

a) Uninsulated live parts,

b) Low voltage circuitry,

c) Heat producing components,

d) Moving parts, and

e) Any electrical or mechanical component not specifically identified above that could result in an increased risk of fire or risk of shock.

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6.3A.7 The area adjacent to an opening where branch circuit supply connections are to be made in the field and which has components located within 152 mm (6 in) of the opening shall be enclosed within a wiring compartment having a volume of at least 98 cm^3 (6 in^3) or as required by 6.3A.10, whichever is larger.

6.3A.8 A field-wiring compartment intended for connection of a wiring system shall be attached to the unit in a manner that will prevent it from turning.

6.3A.9 An outlet box, terminal box, wiring compartment, or the like in which connections to the unit will be made in the field shall be free from any sharp edge, including screw threads, a burr, a fin, a moving part, or the like, that may abrade the insulation on conductors or otherwise damage the wiring.

6.3A.10 The minimum volume of an integral field-wiring compartment for branch circuit connections shall be determined using Table 6.5. All conductors entering or leaving the compartment shall be included in the calculation; uninsulated grounding or bonding conductors integral to the unit are not to be included. Field wiring shall assume size 12 AWG (3.31 mm^2) conductors unless the ampacity of the unit requires larger conductors. A terminal block/push-in terminal that accepts small gauge wires (e.g., 18 AWG) requires use of wires [up to 152 mm (6 in)] to transition to branch circuit wiring (e.g., 12 AWG). These wires shall be included in the volume calculations.

Table 6.5
Determination of minimum wiring compartment volume

Conductor size	Volume per conductor	
AWG	cm^3	(in^3)
18	8.2	(0.5)
16	9.8	(0.6)
14	12.3	(0.75)
12	16.4	(1.0)
10	27.9	(1.7)

6.3A.11 An enclosure intended for pulling conductors shall be tested for rigidity as described in 8.19.

6.3A.12 An enclosure that is assembled using snap-in or tab-mounted parts without use of fastening methods such as screws, rivets, or welds shall be tested in accordance with 8.20.

6.4 Enclosure openings

6.4.1 Other than for supply connections, open holes shall not be permitted in any surface of a fire or electrical enclosures of LED equipment intended for conduit connection and LED equipment intended for installation in a concealed space.

Exception No. 1: Open holes are permitted in an enclosure intended for installation on or over an outlet box when the outlet box will serve to complete the enclosure of the equipment under test.

Exception No. 2: Open holes are permitted in an enclosure intended for installation to an exterior surface of a luminaire where the luminaire will serve to complete the enclosure of the equipment under test.

Exception No. 3: A maximum of four open holes are permitted on the inside mounting surface of an enclosure intended for conduit connection. The maximum area of each hole shall be 26 mm^2 (0.040 in^2).

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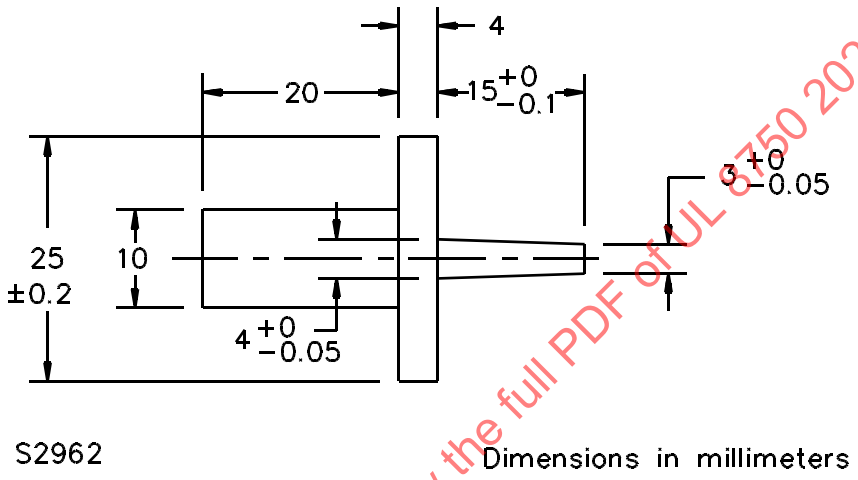
6.4.1.1 Direct plug-in or through-cord units may have openings, if circuits posing a risk of shock cannot be contacted due to the test instruments noted below being inserted through the openings applying a force not exceeding 4.45 N (1 lbf).

a) Test pin illustrated in Figure 6.1, and

b) Articulate probe illustrated in Figure 7.1.

Figure 6.1

Test pin



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6.4.2 Open holes are permitted for LED equipment types not described in 6.4.1 and 6.4.1.1, subject to the accessibility criteria described in 7.2. Line of sight to open core and coil components shall be louvered or baffled.

6.5 Conductor protection

6.5.1 Conductors that pass over edges or through openings in metal shall be secured from contacting the edges or be protected from cutting and abrasion. For sheet metal less than 1.1 mm (0.042 in) thick, protection shall be provided by one of the following methods:

a) Rolling the edge of the metal not less than 120 degrees,

b) A bushing or grommet of a material other than rubber at least 1.2 mm (0.047 in) thick, or

c) Glass sleeving at least 0.25 mm (0.010 in) thick.

6.6 Strain relief

6.6.1 A strain relief and cord pushback device or positive mechanical means shall be provided to facilitate compliance with the test requirements of 8.10. This requirement applies when a supply cord or field wiring lead wire operates above the limits for risk of fire or electric shock, and its displacement could result in:

a) Subjecting the supply cord or field wiring lead to mechanical damage,

b) Exposing the supply cord or field wiring lead to a temperature higher than that for which it is rated,

c) Reducing spacing (such as to a metal strain-relief clamp) below the minimum required values, or

d) Damage to internal connections or components.

Exception: A supply cord or field wiring lead wire embedded in a potting compound inside the enclosure at the supply cord or lead wire entrance is considered to provide the necessary positive mechanical means.

6.7 Polymeric potting compound

6.7.1 Polymeric potting compound shall not leak, drip, or be released from a unit during any test conducted in accordance with this standard.

6.7.1.1 In a given design – the type of polymeric potting compound, the potting process and the volume of potting compound (case fill percentage) are considerations to confirm acceptability based on the specific application. When inorganic materials (e.g. quartz, sand, etc.) are mixed in with a polymeric potting compound, additional consideration is necessary to confirm acceptability based on the specific application.

6.7.2 During the Temperature Test of 8.3, a polymeric potting compound shall not exceed its Relative Thermal Index (RTI).

Exception No. 1: Thermosetting materials are exempt from this requirement.

Exception No. 2: Thermoplastic materials may be used if the maximum potting compound temperature doesn't exceed 90°C (194°F).

Exception No. 3: Thermoplastic materials may be used if the maximum potting compound temperature is at least 15°C (27°F) less than the softening point of the compound as determined by the Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus, ASTM E28.

Exception No. 4: Thermoplastic materials may be used if the maximum potting compound temperature is at least 25°C (77°F) less than the softening point of the compound as determined by the Standard Test Methods for Vicat Softening Temperature of Plastics, ASTM D1525.

6.7.3 Polymeric potting compound that can touch any part of the insulation system of a transformer shall be tested in accordance with Supplement SA – Substitutions or Modification to an Electrical Insulation System in the Standard for Systems of Insulating Materials – General, UL 1446.

Exception No. 1: This test does not apply if the transformer is not used for the mitigation of the risk of electric shock or is not used to separate Class 2 circuits or LVLE circuits from hazardous circuits.

Exception No. 2: This test does not apply if the transformer insulation system already includes the potting.

Exception No. 3: This test does not apply if the insulation system is used up to the temperature permitted for class 105 (A) according to Table 8.1 of this standard.

Exception No. 4: This test does not apply for thermosetting potting compounds where the insulation system of a transformer utilizes a thermoset varnish which completely encloses the coil windings-preventing the potting compound from making contact with the winding wire insulation.

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6.8 Asphalt potting compound

6.8.1 Asphalt potting compound shall not leak, drip, or be released from a unit during any test conducted in accordance with this standard.

6.8.2 The volume of asphalt potting compound (case fill percentage) is a consideration to confirm acceptability based on the specific application.

6.8.3 During the Temperature Test of 8.3, asphalt potting compound shall remain at least 15°C (27°F) below its softening point as determined by the Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus), ASTM D36/D36M.

7 Electrical Construction

7.1 General

7.1.1 A unit intended to be used in an application identified by one of the standards specified in 1.3 shall comply with the electrical construction requirements of that standard. If an end-use application is not specified or identified, or if a particular construction feature is not covered by the identified standard, the unit shall comply with the electrical construction requirements of this section.

7.1.2 A current-carrying part shall be gold, silver, copper, a copper alloy, plated iron or steel, stainless steel, or other corrosion-resistant alloys acceptable for the application.

Exception: Trace conductors and wire bonds on a printed wiring board are permitted to be of aluminum.

7.1.3 An uninsulated live part shall be secured so that it does not turn or shift in position if such motion results in a reduction of spacings below the minimum acceptable values.

7.1.4 Friction between surfaces is not acceptable as a means to prevent shifting or turning of a live part but a lock washer is acceptable.

7.2 Accessibility

7.2.1 A live part that is a risk of electric shock shall be located or guarded by an enclosure or barrier so it is inaccessible to contact, by persons while using the product as intended, using the articulate probe shown in Figure 7.1, applying a force not exceeding 4.45 N (1 lbf).

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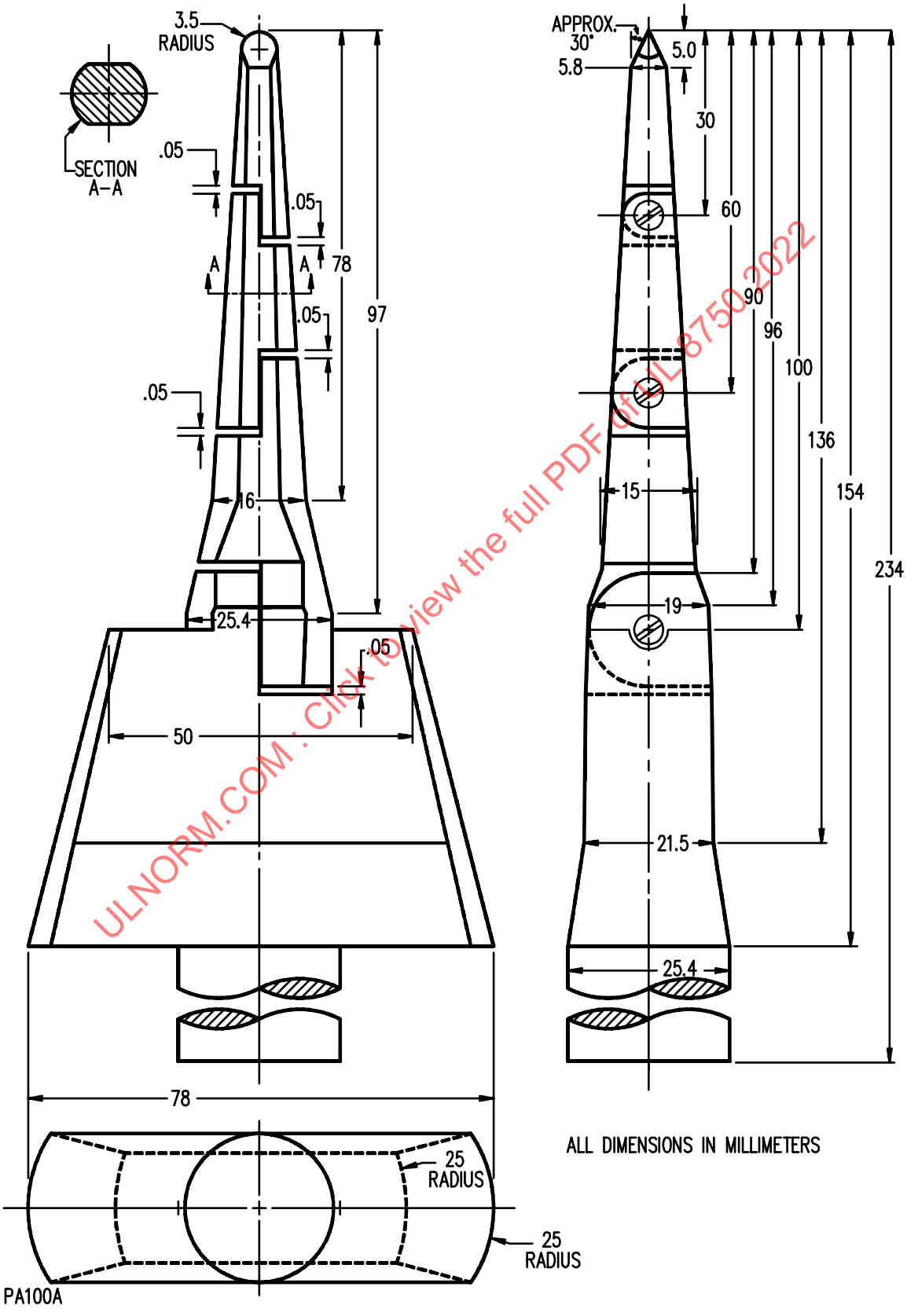
Figure 7.1

Articulate probe with web stop



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7.2.1.1 A live part that is a risk of electric shock shall be located or guarded by an enclosure or barrier, to reduce the likelihood of unintentional contact with such part by persons during product installation or servicing that is not likely to be performed by qualified personnel. Direct plug-in and cord-connected units are not likely to be installed or serviced by qualified personnel.

7.2.2 A part that can be removed without using a tool is to be removed when determining accessibility to the probe.

7.2.3 An insulating barrier used to prevent access to live parts shall not be less than 0.71 mm (0.028 in) thick.

7.2.4 An insulating barrier used in conjunction with not less than half the required spacing through air is permitted to be less than 0.71 mm (0.028 in) thick, but not less than 0.33 mm (0.013 in) thick if the barrier or liner is of insulating material that is:

a) Resistant to moisture,

b) Of acceptable mechanical strength if exposed or otherwise likely to be subjected to mechanical damage,

c) Reliably held in place, and

d) Located so that it is not adversely affected by operation of the device – particularly arcing.

7.2.5 An insulating barrier in the secondary circuit where the potential is not more than 50 V is permitted to be less than 0.71 mm (0.028 in) thick but not less than 0.25 mm (0.010 in) thick if it is:

a) Resistant to moisture,

b) Of acceptable mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, and

c) Reliably held in place.

7.2.6 An insulating barrier is permitted to have a thickness less than 0.71 mm (0.028 in) thick if separately evaluated as an internal barrier in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and found to have insulating characteristics equivalent to 0.71 mm (0.028 in) thick vulcanized fiber.

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7.2A Grounding and bonding

7.2A.1 General

7.2A.1.1 Metal enclosures intended for conduit connection shall be bonded to ground and shall comply with the bonding circuit impedance test of 8.21.

7.2A.1.2 When LED equipment is provided with a grounding connection means, it shall be conductively bonded to a ground termination point in the product. The ground termination point may be a metal enclosure, an internal non-current-carrying metal part or a metallized polymeric part.

Note: Based on other requirements (construction and performance) in this standard, certain LED equipment designs are acceptable without a grounding connection means (e.g. metal enclosures that are reliably isolated from live parts).

7.2A.1.3 When LED equipment include a grounding connection feed through at the output, the feed through circuit shall be subject to the requirements in 7.2A.1.4 and 7.2A.2 as applicable.

7.2A.1.4 The ground path from the grounding connection to its ground termination point in the product shall comply with the bonding circuit impedance test of 8.21. PWB traces may form part of the ground path subject to acceptable results according to this test.

7.2A.2 Grounding

7.2A.2.1 The grounding connection means shall be in the same location as the power supply connection means and shall be a pigtail lead grounding conductor, a pressure terminal connector, a wire binding screw, or the equivalent.

7.2A.2.2 The ground termination point in the product shall not be located on a removable part of the product, unless the removal of the part does not interrupt the bonding continuity. A ground termination point in the product that is potted is not considered removable.

7.2A.2.3 A grounding conductor shall not be smaller than the gauge of wire used for the luminaire supply conductors and in no case less than 18 AWG (0.82 mm^2).

7.2A.2.4 A screw provided for grounding shall:

a) Not be used for any other purpose,

b) Be limited to conductors of size 10 AWG (5.26 mm^2) or smaller,

c) Comply with Table 7.0,

d) Have a cupped washer or similar provision, or the area around the screw shall be provided with two raised areas in accordance with Figure 7.1.1,

e) Have a green-colored head, or the area directly adjacent to the screw shall be marked in accordance with 7.4.2.3.3,

f) Be a machine or thread-forming screw, and

g) Be capable of withstanding 1.6 N·m (14 lb-in) of tightening torque. Compliance is determined by the ground-screw assembly strength test in 8.22.

Table 7.0
Ground screw size

Screw size		Wire size (AWG)
M3.5	(No. 6)	18 – 14
M4	(No. 8)	18 – 12
M5	(No. 10)	18 – 10

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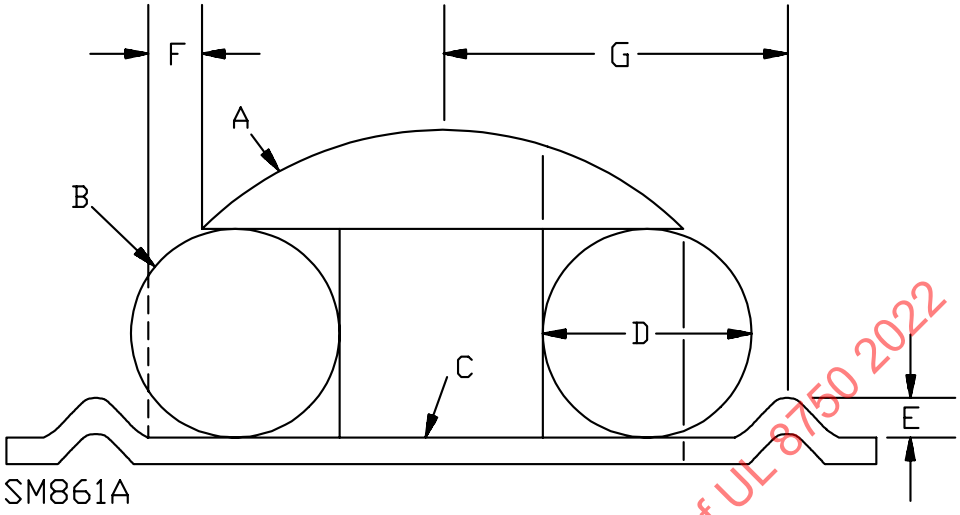
Figure 7.1.1

Terminal-conductor relationship



Legend:

A – wire binding screw

B – conductor

C – terminal plate

D – maximum conductor diameter, but not less than 2 mm (0.08 in)

E – minimum height of raised areas = 1 mm (0.04 in)

F – the horizontal dimension from the edge of the screwhead to the inside edge of the raised area = 0 to 1/4 D

G – the horizontal dimension from the center of the raised area to the center of the screwhead = minimum 3.2 mm (0.125 in)

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7.2A.2.5 A terminal plate intended for use with a wire binding screw shall be of metal and shall provide a minimum of two full threads engagement with the screw.

7.2A.2.6 A pressure- or screw-type terminal block shall be suitable for the conductors involved, and the ground termination point in the product shall be marked in accordance with 7.4.2.3.3.

7.2A.2.7 When the path between the grounding connection means and the ground termination point in the product includes PWB traces, the construction is to be evaluated per the bonding conductor tests in 8.23.

7.2A.3 Bonding

7.2A.3.1 Bonding refers to connection of non-current-carrying metal parts and metallized polymeric parts to the ground termination point in the product. Bonding is required if these parts are accessible (during normal use, installation, user maintenance or component replacement) and can involve the risk of shock. A bonding means shall consist of one of the following:

a) A pigtail lead bonding conductor of at least 18 AWG (0.82 mm^2),

b) A terminal,

c) A welded, soldered, or brazed joint,

d) A screw, rivet, or welded stud,

e) A pressure terminal connector,

f) An assembly of bolt, nut, and lockwasher or starwasher, or other compressive fastener that complies with the bonding circuit impedance test of 8.21, or

g) An equivalent conductive path that complies with the bonding circuit impedance test of 8.21.

7.2A.3.2 The bonding of a conductive part that is coated with vitreous enamel, paint, or similar coatings can require treatment of the part, such as masking, removal of the coating at points of connection, or the use of fastening means that penetrate the surface coating. If special treatment is required or if continuity is not obvious, acceptability shall be determined by the bonding circuit impedance test of 8.21.

7.2A.3.3 A part shall be provided with a 18 AWG (0.82 mm^2) or larger stranded bonding conductor.

7.2A.3.4 A bonding conductor shall be secured by one of the following methods:

a) A machine screw and nut,

b) A screw that threads into metal, with at least two full threads engaging,

c) Rivets, or

d) Equivalent means as determined by evaluation.

7.2A.3.5 The bonding conductor shall not be smaller than the gauge of wire used for the luminaire supply conductors and in no case less than 18 AWG (0.82 mm^2). PWB traces may form part of the bonding path subject to acceptable results according to the bonding circuit impedance test of 8.21.

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7.3 Internal wiring

7.3.1 Internal wiring shall consist of insulated conductors having the mechanical strength, dielectric voltage withstand properties and ampacity for the application.

7.3.2 Each splice and connection shall be mechanically secured, shall provide reliable electrical contact, and shall be provided with insulation at least equivalent to that of the voltage involved unless acceptable permanent spacing is maintained between the splice and all other uninsulated current-carrying parts at different potentials and non-current-carrying metal parts.

7.3.3 The electrical and mechanical connection between a conductor and any circuitry operating above the limits for risk of fire or electric shock shall be contained within an enclosure and be inaccessible in accordance with 7.2.

7.3.4 Soldered connections to printed wiring boards shall be secured by one of the following methods:

a) A conductor passed through a hole and soldered on the opposite side.

b) A solder connection covered with epoxy, silicone rubber, or potting.

c) A surface mount connection with solder reflow.

d) A conductor held rigidly in place (without the use of solder) so as to preclude any movement at the point of electrical connection.

e) Surface Mount Device (SMD) components and components without integral leads soldered to the printed wiring board. Surface mounted connector receptacles and associated connectors with leads are acceptable without additional mechanical securement where the lead wires are not subject to movement after assembly.

f) Where supplied by a Class 2 or LVLE source, solder alone is sufficient if detachment will not reduce spacings of electrical parts to non-Class 2 or non-LVLE circuits below the applicable required spacings of 7.8.

g) A wave-solder connection to a metal-clad printed-circuit board without any further mechanical security.

h) Any other method that offers mechnical securement of the connection before soldering.

7.3.5 Conductors shall be minimum 18 AWG (0.82 mm^2), except as specified in 7.3.6 and 7.3.7, and shall be rated for the voltage, current, temperature, and conditions of service for normal operation.

7.3.6 Conductors of a size smaller than 18 AWG (0.82 mm^2) but no smaller than 24 AWG (0.21 mm^2) are permitted under the following conditions:

a) Where completely enclosed,

b) Where not subject to movement under normal use, and

c) In the secondary of a transformer or in a circuit containing solid-state devices.

7.3.7 Conductors of any size are permitted when the conductors are in Class 2 or isolated LVLE circuits only and are physically separated from all other non-Class 2 or non-isolated LVLE circuits, such as by a barrier or reliably fixed spacing of minimum 6.4 mm (0.25 in).

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7.4 Supply and load connections

7.4.1 General

7.4.1.1 Input and output wiring shall comply with the requirements for internal wiring as specified in 7.3 in addition to the applicable requirements in this section.

7.4.1.2 Power limited circuit wiring that is intended to be routed within a building structure shall be of a type suitable for application (e.g. CL2, CL2P, CL3, CL3P, CL3R, CM, CMP, CMR, or PLTC) and in accordance with Article 725 of the National Electrical Code (NEC), ANSI/NFPA 70.

7.4.1.3 Units that are not intended as built-in components shall have provision for connection to a branch circuit source of supply by field wiring in 7.4.2, integral blade assembly of a direct plug-in unit in 7.4.3, or supply cord and attachment plug assembly in 7.4.3.

7.4.1.4 Units that are intended as built-in components may have provision for connection to a source of supply utilizing methods other than criteria in 7.4.1.3 – including use of supply leads terminating in connectors, terminal blocks, and PWB edge connections. For such constructions additional considerations are necessary to determine suitability – including insulating materials in 7.6, electrical spacings in 7.8, and ratings (voltage, current, power).

7.4.2 Permanently-connected units

7.4.2.1 Conduit connection

7.4.2.1.1 A unit intended to be connected to a branch circuit in accordance with the National Electrical Code (NEC), ANSI/NFPA 70, shall be provided with either field-wiring leads complying with 7.4.2.2 or field-wiring terminals complying with 7.4.2.3.

7.4.2.1.2 Connection to a permanent wiring system shall be by providing a means for conduit connection.

7.4.2.1.3 *Revised and relocated*

Table 7.1
Dimensions of unthreaded opening for conduit and diameter of the area surrounding the opening

Table 7.1 revised and relocated

7.4.2.1.4 *Revised and relocated*

Table 7.2
Throat diameters for conduit openings

Table 7.2 revised and relocated

7.4.2.1.5 *Revised and relocated*

7.4.2.1.6 *Revised and relocated*

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7.4.2.1.7 *Revised and relocated*

7.4.2.1.8 *Revised and relocated*

7.4.2.1.9 *Revised and relocated*

7.4.2.1.10 *Revised and relocated*

7.4.2.1.11 *Revised and relocated*

7.4.2.1.12 *Revised and relocated*

Table 7.3
Determination of minimum wiring compartment volume

Table 7.3 revised and relocated

7.4.2.2 Field-wiring leads

7.4.2.2.1 A field-wiring lead shall be no smaller than 18 AWG (0.82 mm^2).

7.4.2.2.2 The free length of a field-wiring lead shall be 15.2 cm (6 in) or more. Where a wiring compartment is provided, the free length is measured from the point of entry of the lead into the wiring compartment to the free end.

7.4.2.2.3 The insulation of a lead intended for the connection of a grounded conductor (common or neutral) shall:

a) Be colored white or grey,

b) Be of any color except green, with a continuous white tracer throughout its length,

c) Be identified at the point where connected to the branch circuit by white paint, tape, ink, or permanent tag, or

d) Be provided with one or more raised longitudinal ridges, if a parallel conductor flexible cord.

7.4.2.2.4 The insulation of a lead intended for the connection of an ungrounded (hot) conductor shall be any color other than white, gray, green, or green with yellow stripe.

7.4.2.2.5 A lead intended for the connection of a grounding conductor shall be bare (no insulation) or green, or green with yellow stripe.

7.4.2.3 Field-wiring terminals

7.4.2.3.1 A pressure wire type terminal or a wire binding screw shall be of the type suitable for field wiring. The field wiring terminal shall not be rated for leads smaller than 18 AWG (0.82 mm^2).

7.4.2.3.2 A terminal intended for connection of a grounded conductor of an ac supply shall be of metal substantially white or silver in color or be marked with the words “NEUTRAL”, “N”, “W” or “White”. No other terminal shall be substantially white or silver in color.

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7.4.2.3.3 A terminal intended for connection of a grounding conductor shall have a green colored head, or the area directly adjacent to the terminal shall be marked with a grounding symbol or abbreviation, as follows: G or GR or GRD or GND or GRND or GROUND or the symbol ⏚(IEC Publication 417, Symbol 5019).

7.4.2.3.4 A terminal intended for connection of a dc supply where polarity of the supply connection is required shall be marked with the symbols "−" and "+" on or immediately adjacent to the supply terminals.

7.4.2.3.5 Where dislocation of a secured lead wire can result in a risk of electric shock or a reduction of required spacings, a terminal plate tapped for a wire-binding screw or stud shall be of brass or other nonferrous metal, or plated steel, not less than 0.76 mm (0.030 in) thick, and shall provide not less than two full threads in the metal for the binding screw.

Exception No. 1: Two full threads are not required if a lesser number of threads results in a secure connection in which the threads do not strip when subjected to the tests and requirements of the security of output terminals test of 8.11.

Exception No. 2: A plate may be less than 0.76 mm (0.030 in) thick if the tapped threads have acceptable mechanical strength as determined by the security of output terminals test of 8.11.

7.4.2.3.6 A wire-binding screw or terminal stud shall not be smaller than 3.5 mm diameter (No. 6) and shall not have more than 32 threads per 25.4 mm (1 in). The screw or stud shall be of brass, brass alloy, or plated iron or steel.

7.4.2.3.7 Terminal studs shall be prevented from turning by means other than friction between mounting surfaces. The acceptability of a lock washer or similar means to prevent turning shall be determined by the security of output terminals test of 8.11.

7.4.2.4 Push-in terminals

7.4.2.4.1 A push-in wiring terminal for connection of supply leads shall only allow for the termination of the branch circuit conductor supplying the power source, and not provide for additional connections, unless the push-in wiring terminal has been evaluated to handle full branch circuit current. The push-in wiring terminal shall not be rated for leads smaller than 18 AWG (0.82 mm^2).

7.4.2.4.2 The temperature rise of a push-in wire terminal shall not exceed 30°C during the temperature test of 8.3.

7.4.2.4.3 A unit that employs push-in terminals shall be marked in accordance with 9.3.1.

7.4.3 Cord-connected and direct plug-in units

7.4.3.1 A unit shall be provided with either:

a) A cord-connected or direct plug-in power supply or LED driver, with an output cord for mating with the unit, or

b) A power supply cord and attachment plug.

7.4.3.2 A unit having an attachment plug or direct plug-in blade configuration shall be polarized or a grounding-type as shown in Figure 7.2.

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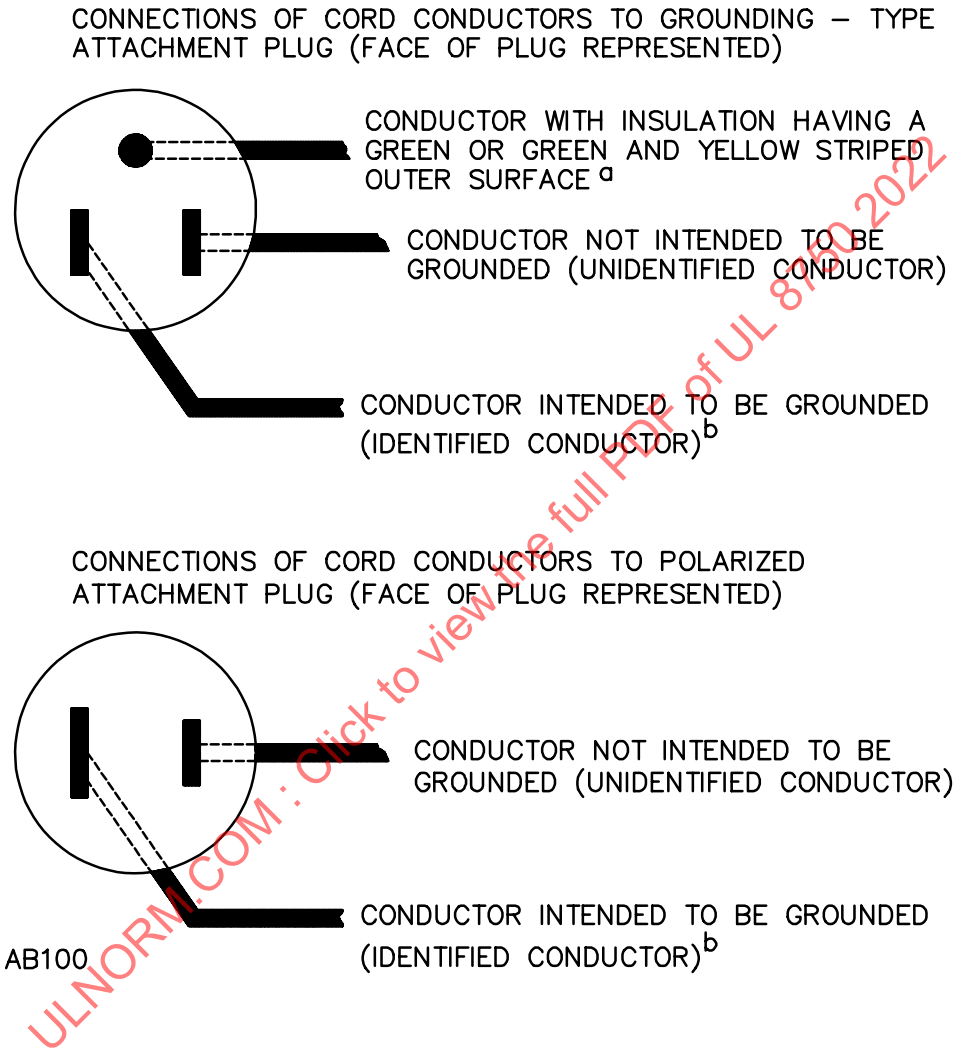
Exception: A 2-conductor unit is not required to be supplied with a polarized plug when it does not include any single pole switches or fuses and parts that represent a risk of electric shock that may be accessible during operation or service.

Figure 7.2

Connection to attachment plug



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In the figure:

a) The blade to which the green conductor is connected may have a U-shaped or a circular cross section.

b) The identified conductor is the conductor that intended to be grounded.

7.4.3.3 A three-conductor flexible cord with ground shall be provided with conductor identification to identify grounded and grounding conductors. A jacketed cord such as a SJT type shall have the grounding conductor within the jacket colored green or green with a yellow stripe and the grounded conductor shall be colored white or gray.

7.4.3.4 A component with no accessible dead-metal parts is not required to be provided with a supply cord of the grounding type, when identified for use in an end-product with no dead metal needing to be grounded or only for use in an end-product such as portable luminaires where under certain uses grounding is not required.

7.4.3.5 When a two-conductor flexible cord is provided for connection to the source of supply and polarity is required, the conductors shall be connected to a polarized parallel-blade attachment plug with the identified grounded conductor (neutral) connected to the wider blade. A parallel cord such as Type SPT-2 shall have a stripe, ridge, or groove on the exterior of the cord surface of the grounded (neutral) conductor for identification.

7.4.3.6 A power supply cord shall be minimum 18 AWG (0.82 mm^2).

7.4.3.7 The power supply cord provided on a unit designated for dry location only shall be Type SP-2, Type SPE-2, Type SPT-2, or heavier. The power supply cord on a product intended for use in wet locations shall be additionally rated for outdoor use by a surface marking “W” or “Water Resistant.”

7.4.3.8 A power supply cord shall be minimum 1.5 m (5 ft) in length. The length shall be measured from the point where the cord emerges from the unit, after any strain-relief means provided, to the point where the cord enters an attachment plug.

7.4.3.9 Where a knot in a flexible power supply cord serves as strain relief, the surface upon which the knot contacts or bears shall not have burrs, fins, sharp edges, and projections that could damage the insulation on a cord.

7.4.3.10 A power supply cord shall be provided with a bushing at the point where the cord passes through an opening in a metal enclosure or through a non-rounded opening of a polymeric enclosure. The bushing shall be secured in place and have a smooth, rounded surface against which the cord bears. The bushing shall be nonmetallic if the cord is Type SVT or lighter.

7.4.3.11 The attachment plug of a cord-connected unit shall be configured for a 15- or 20-A branch circuit receptacle and shall comply with either the requirements in the Standard for Attachment Plugs and Receptacles, UL 498, or the Standard for Cord Sets and Power-Supply Cords, UL 817, or both.

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7.4.3A Feedthrough receptacles

7.4.3A.1 Receptacles shall have suitable voltage and current load ratings and shall comply with one of the applicable requirements noted below.

a) For NEMA receptacles; the Standard for Attachment Plugs and Receptacles, UL 498,

b) For connectors; the standard for component connectors for use in Data, Signal, Control and Power Applications, UL 1977 with consideration for accessibility concerns as noted in 7.2, or

c) For appliance couplers; the standard for Appliance Couplers for Household and Similar General Purposes, UL 60320-1.

7.4.3A.2 Receptacles shall:

a) Have suitable voltage and current load ratings, and

b) Be of the same type as the attachment plug used in the input circuit.

7.4.3A.3 A supply cord terminating in a receptacle shall:

a) Comply with the Standard for Cord Sets and Power Supply Cords, UL 817,

b) Be of the same type as the supply cord used in the input circuit,

c) Have suitable voltage and current load ratings, and

d) Comply with the applicable requirements in 7.4.3 including strain relief, except that the cord may be shorter than the requirement in 7.4.3.8.

7.4.3A.4 The receptacle (or the supply cord terminating in a receptacle) shall be wired to provide the same grounding or polarity scheme as the input supply.

7.4.3A.5 Internal wiring from the input supply to the receptacle (or the supply cord terminating in a receptacle), shall be:

a) Of the same wire gauge and electrical ratings of the input supply, and

b) Wired to provide the same grounding or polarity scheme as the input supply.

7.4.4 Leads, terminals, and connectors for other than branch circuit connections

7.4.4.1 General

7.4.4.1.1 Input and output leads, terminals and connectors shall be rated for the voltage, current and temperature involved.

7.4.4.2 Leads

7.4.4.2.1 Input and output leads shall comply with the requirements for internal wiring of 7.3 and be of sufficient length to allow for the intended connection.

7.4.4.3 Output connectors

7.4.4.3.1 A unit with multiple Class 2 or LVLE supply or load connections where interconnection could cumulatively exceed Class 2 or LVLE limits shall be provided with polarized connectors that inhibit such interconnection.

7.4.4.3.2 Output connectors mounted on the enclosure and intended for direct connection of accessories shall provide a secure connection between mating parts. The connections shall be polarized if the output is direct current or if multiple outputs are provided.

7.4.4.3.3 Coaxial cable connectors shall not be used for output connections.

7.4.4.4 Insulation-piercing connections

7.4.4.4.1 Units employing insulation-piercing terminals intended for use with flexible cord or stranded conductor wire operating above Class 2 or LVLE limits shall be for factory assembly only.

7.4.4.4.2 Flexible cord and wire for insulation-piercing connections shall be rated minimum 105° C (221°F).

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7.4.4.4.3 Units operating above Class 2 or LVLE limits and intended for insulation-piercing connections shall be subjected to the insulation-piercing connection thermal cycling conditioning test of 8.12 and comply with the temperature test of 8.3.

7.5 Separation of circuits

7.5.1 Insulated conductors of different circuits that may contact each other, including wires in a terminal box or compartment, shall have insulation rated for the highest of the circuit voltages or shall be reliably separated a minimum of 6.35 mm (0.25 in).

7.5.2 Where units have field-installed connections for Class 2 or LVLE circuits inside the enclosure wiring compartment, the minimum 6.35 mm (0.25 in) separation from non-Class 2 or LVLE circuits shall be provided by means of separate entries for Class 2 or LVLE and non-Class 2 wiring, or the reliable routing of the conductors within the unit, or the effective use of barriers.

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

7.5.4 For a Class 2, Class 3, or LVLE power limited circuit, terminals and wire connectors shall have a minimum spacing of 6.35 mm (0.25 inch) between the points where the field supply wiring and the Class 2, Class 3, or LVLE circuit connect to the driver.

7.6 Insulating materials

7.6.1 Integral parts such as insulating washers and bushings, and bases or supports for mounting of live parts, shall be of moisture-resistant materials that are not damaged by the temperatures and stresses to which they are subjected under conditions of actual use.

7.6.2 An insulating material is to be evaluated for the application in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, with respect to:

a) Mechanical strength,

b) Resistance to ignition sources,

c) Dielectric strength,

d) Insulation resistance,

e) Heat-resistant properties in both the aged and unaged conditions,

f) The degree to which it is enclosed,

g) Resistance to moisture if the unit is other than rated for dry locations, and

h) Any other features affecting the risk of fire and electric shock.

Exception: Materials, such as mica, ceramic, or some molded compounds are usually acceptable for use as the sole support of live parts.

7.7 Printed wiring boards

7.7.1 Printed wiring boards shall comply with the Standard for Printed Wiring Boards, UL 796.

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7.7.2 Conductive traces shall be bonded to the substrate for the minimum conductor width and maximum unpierced area as required by the Standard for Printed-Wiring Boards, UL 796.

Exception No. 1: Printed-wiring boards that are completely encased in potting compound are permitted to exceed their specified minimum conductor width or maximum unpierced area.

Exception No. 2: A printed-wiring board connected within a Class 2 or LVLE circuit need not comply when means (such as position, distance, or barrier) are provided to ensure that the limited energy traces cannot contact non-energy limited live parts should the traces become detached from the substrate.

7.7.3 Temperatures measured in the temperature test of 8.3 shall not exceed the maximum operating temperature (MOT) of the printed wiring board.

Exception: A printed-wiring board connected within a Class 2 or LVLE circuit need not comply when means (such as position, distance, or barrier) are provided to ensure that the limited energy traces cannot contact non-energy limited live parts should the traces become detached from the substrate.

7.7.4 The flammability rating of the printed wiring board shall be no less than V-1 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A circuit supplied by a Class 2 or LVLE source need not comply.

7.7.5 Printed wiring boards shall comply with the requirement for direct support of current carrying parts.

Exception No. 1: A printed wiring board that contains only a Class 2 or LVLE circuits need not comply.

Exception No. 2: A printed wiring board that is completely encased in potting compound need not comply.

7.7.6 Where a conformal coating is used to meet the requirements of this standard, it shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and be suitable for use in combination with the printed wiring board.

Exception: Conformal coatings applied to PWBs that contain only Class 2 or LVLE circuits need not comply.

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7.8 Electrical spacings

7.8.1 Minimum spacings shall not be less than those shown in Table 7.4, between:

a) Uninsulated live parts of opposite polarity,

b) Uninsulated live parts and a grounded dead-metal part,

c) Uninsulated live parts and an accessible dead-metal part, and

d) Circuits that are required to be electrically isolated from one another.

Exception: Alternate minimum spacings values, applicability criteria, and evaluation methods are specified in other clauses in this section.

Note: Wiring terminals, located in other than Class 2 and LVLE circuits, are subject to this clause and Table 7.4. Spacings for PWB mounted wiring terminals in the area where the supply leads terminate into the terminal are evaluated per 7.8.1 and Table 7.4. However, spacings between the wiring terminal pins interfacing with the PWB are evaluated per 7.8.2 and Table 7.5.

Table 7.4
Minimum Spacings

Potential involved	Through air		Over surface	
V rms	mm	(in)	mm	(in)
0 – 50	1.6[a]	(1/16)[a]	1.6[a]	(1/16)[a]
51 – 150	3.2[a]	(1/8)[a]	6.4	(1/4)
	1.6[a,b]	(1/16)[a,b]	3.2[a,b]	(1/8)[a,b]
151 – 300	6.4	(1/4)	9.5	(3/8)
	1.6[a,b]	(1/16)[a,b]	3.2[a,b]	(1/8)[a,b]
301 – 600	9.5	(3/8)	12.7	(1/2)
	4.8[a,b,c]	(3/16)[a,b,c]	9.5[b,c]	(3/8)[b,c]

[a] The spacing between field-wiring terminals of opposite polarity and the spacings between a field-wiring terminal and a grounded dead-metal part shall not be less than 6.4 mm (1/4 in) if short-circuiting or grounding of such terminals may result from projecting strands of wire. Examples of means that prevent stray wire strand contact include rating the unit for solid wire only, and design features such as recessed terminal pockets.

[b] The alternate spacings identified in Table cells associated with this footnote apply to wiring terminals complying with the requirements of the Standard For Terminal Blocks, UL 1059, [Application for Industrial, devices having limited ratings] when the measured and rated current load on any single circuit of the terminal block does not exceed;

1. 15 amperes at 51 – 150 volts,
2. 10 amperes at 151 – 300 volts, and
3. 5 amperes at 301 – 600 volts.

[c] Linear interpolation is permitted to be calculated by the following formulas, where V is the measured potential:

Through Air Minimum Spacing, mm = 0.0107V – 1.6

Over Surface Minimum spacing, mm = 0.0210V – 3.1

Note 1 – The calculated minimum spacings using this method shall be rounded up to the next higher 0.1 mm increment.

Note 2 – The provisions of footnote 'a' also apply when this method will result in spacings of less than 6.4 mm for field-wiring terminals.

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7.8.2 Minimum spacings on printed wiring boards and for board-mounted components shall be not less than those shown in Table 7.5 between:

a) Uninsulated live parts of opposite polarity,

b) Uninsulated live parts and a grounded dead-metal part,

c) Uninsulated live parts and an accessible dead-metal part, and

d) Circuits that are required to be electrically isolated from one another.

Internal spacings of board-mounted components are not specified in this clause. Internal component spacings are subject to additional requirements of this standard (e.g. clause 7.11 for coil insulation) and the applicable component standards (e.g. Optical Isolators). Spacings between the pins of the component interfacing with the PWB are evaluated per 7.8.2 and Table 7.5.

Minimum spacings for components mounted along the edge of a printed wiring board shall take into consideration the possible movement of the component and the printed wiring board itself. When applying the limits in Table 7.5, the printed wiring board is to be positioned, when movement is possible, in the direction that yields the smallest spacings between the parts in question.

With regards to (b) and (c) positioning of PWB traces with respect to PWB mounting hardware and use of metal backed PWBs present instances where an evaluation is necessary.

Exception No. 1: Spacings between uninsulated live parts of different voltage on non-conformal coated printed wiring boards, their connectors, and board-mounted electrical components wired on the load side of line filters or similar voltage peak reduction networks and components, are permitted to be 0.58 mm (0.0230 in) plus 0.005 mm (0.0002 in) per V peak.

Exception No. 2: Compliance with the dielectric withstand test specified in 8.6 shall be accepted as an alternative means to determine compliance of spacings on a printed wiring board between any uninsulated live part of opposite polarity.

Exception No. 3: Spacings between adjacent PWB traces are permitted to be evaluated based on short circuit tests between the traces. This alternate method is not applicable when the adjacent PWB traces provide spacings:

1) Between electrically isolated circuits, or

2) Between live parts and ground.

Sample preparation shall be per 8.7.1.1 – 8.7.1.2. Compliance shall be determined per 8.7.1.3 criteria.

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Table 7.5
Spacings on printed wiring boards and for board-mounted components

Locations	Maximum voltage between parts, Vrms (Vpeak=1.4 Vrms)				
	0 – 50	51 – 150	151 – 300	301 – 450	451 – 600
	Minimum spacings in millimeters (inches) [through air/over surface distance]				
Parts potted or conformal coated	–/0.18[a] (–/0.007)	–/0.3[a] (–/0.012)	–/0.7 (–/0.028)	–/0.8 (–/0.030)	–/0.8 (–/0.030)
Live parts reliably positioned AND insulator with CTI ≥ 600 (PLC = 0)[b, e, f]	0.2/0.6 (0.008/0.025)	0.5/0.8 (0.020/0.030)	1.5/1.5 (0.060/0.060)	2.25/2.25 (0.090/0.090)	3.0/3.0 (0.120/0.120)
Live parts reliably positioned AND insulator with CTI ≥ 100 (PLC ≤ 4)[c, e, f]	0.2/1.2 (0.008/0.045)	0.5/1.6 (0.020/0.065)	1.5/3.0 (0.060/0.120)	2.25/4.5 (0.090/0.175)	3.0/6.1 (0.120/0.250)
1) Parts on a printed wiring board and Board mounted components that are soldered in place but can move in production prior to soldering to fixed parts[d,e] **or** 2) Uninsulated live parts on a printed wiring board (including the traces) to grounded or accessible dead metal that can deflect[d, e] or 3) Uninsulated live parts on board mounted components to grounded or accessible dead metal that can deflect[d,e]	3.0/– (0.120/–)	3.0/– (0.120/–)	3.9/– (0.155/–)	4.7/– (0.185/–)	5.6/– (0.220/–)
Live parts and dead conductive parts in a conventional magnetic device construction where the coil size can vary due to random wind OR where coil assembly placement can vary in production	3.2/6.4 (0.125/0.250)	3.2/6.4 (0.125/0.250)	6.4/9.5 (0.250/0.375)	6.4/9.5 (0.250/0.375)	9.5/9.5 (0.375/0.375)

NOTE: D = distance in millimeters, V = voltage in volts

[a] Or as determined from the investigation of the conformal coating, whichever is greater.

[b] Linear interpolation is permitted for over surface distance to be calculated by the following formulas:

for V ≤ 160, **D = 0.002V + 0.5**
for V > 160, **D = 0.005V**

[c] Linear interpolation is permitted for over surface distance to be calculated by the following formulas:

Table 7.5 Continued on Next Page

Table 7.5 Continued

Locations	Maximum voltage between parts, Vrms (Vpeak=1.4 Vrms)				
	0 – 50	51 – 150	151 – 300	301 – 450	451 – 600
	Minimum spacings in millimeters (inches) [through air/over surface distance]				
for V ≤ 160, **D = 0.004V + 1.0** for V > 160, **D = 0.01V** [d] Linear interpolation is permitted for through air distance to be calculated by the following formula: for 150 < V < 600, **D = 0.0059V + 2.09** [e] Deflection refers to reduction in spacings due the mechanical tests in 8.15. Compliance is determined after the sample has been tested per mechanical tests in 8.15. [f] i.e., a) Adjacent PWB traces, b) Lead pins of board mounted components (e.g. semiconductor devices to their mounting surface(s) that cannot deflect, or c) PWB traces to adjacent grounded or accessible dead metal that cannot deflect.					

7.8.3 Minimum spacings are permitted to be in accordance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840. Overvoltage Category II applies to circuits directly connected to the supply source. Printed wiring boards are presumed to have a minimum CTI of 100 unless known to be greater.

Exception No. 1: This provision does not apply to minimum spacings at field-wired branch circuit supply terminals.

Exception No. 2: This provision does not apply to minimum spacings between uninsulated live parts and grounded or accessible dead metal parts (e.g., enclosure) that can deflect. Deflection refers to reduction in spacings after the mechanical tests in 8.15. Compliance is determined after the mechanical tests in 8.15.

7.8.4 The inherent spacings of discrete components along with other conductive parts at their point of connection to these discrete components, as well as the spacings of circuits supplied by a Class 2 or LVLE source between points of opposite polarity and to dead metal, are exempt from the spacings requirements in this section.

7.8.5 Enameled and similar film-coated wire is identified as an uninsulated live part.

7.8.6 The spacings between output circuitry and dead metal for a ground-referenced circuit shall be based on the maximum open-circuit voltage to ground.

7.8.7 Parts subject to movement relative to other parts shall be positioned in their most severe orientation prior to measurement of spacings, unless reliably held in place.

7.9 Circuit components

7.9.1 A fixed resistor, semiconductor, thermistor, Positive Temperature Coefficient (PTC) or Negative Temperature Coefficient (NTC) resistor, or the like relied upon to limit the output of a unit or otherwise achieve acceptable performance shall have permanence and stability which does not decrease its limiting capabilities over time and use. Among the factors considered when evaluating a limiting component are the cumulative effects of temperature, electrical transients, moisture, and other environmental conditions.

7.9.2 A component that bridges two circuits otherwise required to be isolated from one another shall be one of the following:

a) A Class Y capacitor complying with the requirements specified in the Standard for Safety Requirements for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional

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Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14 (see Table 7.6),

b) Two capacitors connected in series, each capacitor individually complying with the dielectric voltage withstand test of 8.6,

c) An isolator complying with the requirements of the Standard for Optical Isolators, UL 1577, with a suitable isolation voltage rating,

d) A transformer that complies with the applicable construction and performance requirements in this standard, or

e) A relay (electromechanical or solid-state) that complies with the applicable requirements of the Standard for Industrial Control Equipment, UL 508.

7.9.3 A relay shall have appropriate ratings (i.e., voltage, current, or watts) in accordance with the Standard for Industrial Control Equipment, UL 508. Additionally, a relay that operates (make or break) non-isolated circuits shall be rated based on load type as noted below:

a) LED array loads are evaluated as resistive loads.

b) AC transformer (magnetic) loads are evaluated as general purpose loads. Relays with this rating can also be used with LED array loads.

c) Electronic (switch mode) transformers, LED drivers, and LED light engines are evaluated as tungsten lamp loads with endurance testing in accordance with the Standard for Industrial Control Equipment, UL 508, requirements for electronic fluorescent ballasts. Relays with this rating can also be used with LED array and AC transformer (magnetic) loads.

Exception: When a circuit is designed to trigger operation (make or break) of an electromechanical relay at the same angle of the ac sinusoidal waveform, such as at zero crossing, the relay may be evaluated based on related ratings (i.e., DC voltage, current, or watts) for the load types noted above. If the relay is triggered by an electronic circuit, this circuit shall additionally meet with one of the following requirements:

a) Compliance with the applicable requirements of Supplement SA as a protective function, or

b) Compliance with the Abnormal Switching Test in 8.18.

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Table 7.6
Bridging capacitor

Capacitor subclass according to the Standard for Safety Requirements 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	Rated voltage of the capacitor V rms
Y1	Up to and including 500V
Y2	Over 150V up to and including 300V
Y4	Up to and including 150V
Rules for the application of Table 7.6: 1) The voltage rating of the capacitor shall be equal to the RMS working voltage across the insulation being bridged. 2) It is permitted to use a higher grade capacitor than the one specified, as follows: – Subclass Y1 if subclass Y2 is specified;	

Table 7.6 Continued on Next Page

Table 7.6 Continued

Capacitor subclass according to the Standard for Safety Requirements 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	Rated voltage of the capacitor V rms
– Subclass Y1 or Y2 if subclass Y4 is specified. 3) It is permitted to use two or more capacitors in series in place of the single capacitor specified, as follows: – Subclass Y1 or Y2 if subclass Y1 is specified; – Subclass Y2 or Y4 if subclass Y2 is specified; – Voltage rating of each individual capacitor must be equal to or greater than the RMS working voltage of insulation being bridged.	

7.10 Protective devices

7.10.1 A protective device relied upon for compliance with this standard shall comply with those requirements applicable to that component that specifically relate to protecting the equipment from the current overload or other conditions described in Performance, Section 8. Protective devices include fuses, fusible resistors, over temperature and over current protectors, thermal protectors, and similar devices.

7.10.2 A protective device in a primary circuit shall not be connected in the neutral (grounded) conductor unless the device simultaneously interrupts the grounded and ungrounded supply conductors.

7.10.3 An overcurrent protective device relied upon for construction or performance requirements shall be inaccessible to tampering or shall not be interchangeable with a device having a higher current rating.

7.10.4 The fuse type identification and ampere rating shall be marked in accordance with 9.3.2 on or adjacent to a user serviceable fuse or fuseholder.

7.10.5 A printed wiring board trace relied upon as an overcurrent protective device shall be conformal coated or potted, and shall comply with the limited short circuit and foil trace calibration tests specified in the Standard for Fluorescent-Lamp Ballasts, UL 935.

7.10.6 Thermostatic protectors that are relied as limiting controls shall be evaluated as control for fluorescent ballast per requirements in the Standard for Temperature-Indicating and -Regulating Equipment, UL 873 or the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, and UL 60730-2-3.

7.10.7 Testing for a fusible resistor shall include the Limited Short Circuit test while installed in the application, unless the test was previously conducted in accordance with UL 1412, using a 20 A test circuit with a 200 A short circuit capacity. If a clearance to combustible materials was used during the Overload Test, as permitted in UL 1412, the clearance shall be maintained or, the Overload Test shall be conducted while the resistor is installed in the application.

7.11 Coil insulation

7.11.1 General

7.11.1.1 A coil shall be provided with insulation between the coil and any dead-metal part, and between adjacent windings. Physical insulation material is not required if the electrical spacing requirements of 7.8 are met without any insulation material in place.

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Exception No. 1: Two or more secondary windings may be considered as a single winding and interposing insulation is not required if, when interconnected, the windings comply with the performance requirements for a single winding.

Exception No. 2: Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353, is considered suitable insulation between the coil and any dead-metal part.

Exception No. 3: The adequacy of insulation between windings of a coil can be determined by shorting the windings to each other when:

a) The insulation is not relied upon for separating circuits that are required to be isolated from each other, and

b) The coil core is isolated from ground and all accessible dead metal.

Sample preparation shall be per 8.7.1.1 – 8.7.1.2. Compliance shall be determined per 8.7.1.3 criteria.

7.11.1.2 Coil insulation shall either be inherently moisture resistant or treated to render it moisture resistant. Film-coated magnet wire is considered to be moisture resistant.

7.11.2 Insulation for transformers

7.11.2.1 Insulation between uninsulated, primary wires of opposite polarity shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.3 mm (0.01 in),

b) Other insulating material having a dielectric breakdown strength of not less than 2500 V in the thickness used as determined by the tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

c) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

7.11.2.2 Insulation between primary and secondary windings shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total minimum thickness of 0.3 mm (0.01 in),

b) A molded polymeric material such as a coil form or bobbin having a minimum thickness of 0.65 mm (0.03 in),

c) Other than a molded polymeric material and having a dielectric breakdown strength of not less than 2500 V in the thickness used as determined by the tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

d) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

7.11.2.3 Tape used as insulation in lieu of spacings for a concentrically-wound bobbin transformer shall provide a continuous 0.8-mm (1/32-in) minimum wide bent up edge against the bobbin flanges.

7.11.2.4 A concentrically-wound bobbin transformer shall be subjected to the output loading test requirements of 8.7.3. The test shall be continued for 15 days if the transformer has:

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a) The primary winding wound over the secondary winding or the secondary winding wound over the primary winding, and

b) The primary winding insulated from the secondary winding by a layer of insulating material other than that specified in 7.11.2.2(b).

Exception: The test is not required to be applied for 15 days if the following requirements are met:

a) Multiple layered winding wire is used, which has been evaluated to the requirements for miscellaneous insulating devices and materials of the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, and the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C,

b) The primary-to-secondary winding spacings are reliably maintained and comply with Table 7.4,

c) The requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are reliably maintained for the primary-to-secondary creepage distance, and a Comparative Tracking Index (CTI) rating of 100 for all insulating material is determined, or

d) Insulated wiring is used which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

7.11.2.5 Insulation between the primary winding and the core shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist moisture, having a minimum total thickness of 0.3 mm (0.01 in),

b) A molded polymeric material such as a coil form or bobbin having a minimum thickness of 0.65 mm (0.03 in),

c) Other than a molded polymeric material and having a dielectric breakdown strength of not less than 2500 V in the thickness used as determined by the tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

d) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

Exception: Insulation may be reduced or waived between the primary and core when all of the following conditions are met:

a) The core is of a low electrical conductance material, for example ferrite used in switch-mode product,

b) The core is treated as a live and electrically conductive part when judging insulation and spacings between the core and:

i) Accessible metal parts,

ii) The secondary windings, and

iii) Any other output circuitry.

c) In applying (b), the core shall be considered to be at the maximum potential of the primary winding, and

d) Insulation between secondary windings and core are in accordance with the above requirement.

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7.11.2.6 Insulation between the primary winding lead connections and a metallic enclosure shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, not less than 0.3 mm (0.01 in) thick if used in conjunction with an air spacing of no less than one-half that specified in 7.8,

b) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture having a total thickness of not less than 0.7 mm (0.03 in) when the insulation is in contact with the enclosure,

c) Insulation having a dielectric breakdown strength of not less than 2500 V in the thickness used for (a) and 5000 V in the thickness used for (b) as determined by tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

d) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

7.11.2.7 Insulation in accordance with 7.11.2.8 shall be provided between a crossover lead and:

a) The turns of the winding to which it is connected,

b) The adjacent winding,

c) The metallic enclosure, and

d) The core.

7.11.2.8 To comply with 7.11.2.7, insulation shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.3 mm (0.01 in),

b) Other insulating material having a dielectric breakdown strength of not less than 2500 V in the thickness used as determined by the tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

c) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

Exception No. 1: Any type or thickness of insulation, or a through air spacing less than specified in 7.8, between a crossover lead and the winding to which it is connected may be used if the coil withstands the dielectric voltage withstand test of 8.6 with the potential applied between the coil leads and with the coil lead cut at the point where it enters the inner layer.

Exception No. 2: This requirement does not apply to insulation between a Class 2 secondary crossover lead and:

a) The secondary winding to which the crossover lead is connected,

b) The metallic enclosure, and

c) The core.

7.11.2.9 With reference to Exception No. 1 to 7.11.2.8, the magnetic coil of a molded bobbin transformer having a slot for the crossover or start lead – unspliced at the windings – is acceptable as crossover lead insulation if:

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a) The slots provide a graduated through air spacing to the winding, increasing to the end turns, and

b) The magnet-coil winding withstands the dielectric voltage withstand test of 8.6.

7.11.2.10 Insulation between the primary-lead connections and the adjacent winding, and between secondary-lead connections and the primary winding shall be one of the following:

a) Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.7 mm (0.03 in),

b) Other insulating material having a dielectric breakdown strength of not less than 5000 V in the thickness used as determined by tests on insulating materials specified in the Standard for Class 2 Power Units, UL 1310, or

c) Insulated wiring which complies with the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

7.11.3 Electrical insulation systems

7.11.3.1 A transformer or coil that operates above Class 105 (A) temperature limits as indicated in Table 8.1 during the Temperature Test of 8.3 shall incorporate an electrical insulation system that complies with the Standard for Systems of Insulating Materials – General, UL 1446.

Exception: Under conditions a, b or c below, the integral insulation materials for a transformer or coil need not be evaluated as an electrical insulation system but shall operate within the relative thermal index (RTI) or generic thermal index of the individual insulation material:

a) The transformer or coil windings are wholly connected within Class 2 or LVLE circuits,

b) The coil consists of a single winding with a core that is isolated from ground and all accessible dead metal, or

c) The transformer or coil windings are not relied upon for electrical isolation and the core is isolated from ground and all accessible dead metal.

7.12 Class 2 output circuits

7.12.1 When an output is marked or otherwise identified as being Class 2 (see 3.3), that output shall comply with the performance, and marking requirements described in the Standard for Class 2 Power Units, UL 1310, including performance under normal, abnormal, and fault conditions as defined in UL 1310.

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PERFORMANCE

8 Performance Tests

8.1 General

8.1.1 A unit intended to be used in an application identified by one of the standards specified in 1.3 shall comply with the performance test requirements of that standard. If an end-use application is not specified or identified, or if a safety-related aspect of the unit's performance is not covered by the identified standard, the unit shall comply with the performance requirements of this section.

8.1.2 All electrical measurements, unless otherwise specified, are to be conducted:

a) In a draft-free environment,

b) At an ambient temperature of 25 ±5°C (77 ±9°F) unless a higher ambient temperature is specified by the manufacturer, and

c) With the unit connected to a supply source of nominal frequency that is adjusted to within 5 percent of the marked rated voltage.

8.1.3 LED driver outputs, and LED controller outputs intended to supply LED loads shall be loaded using resistive, electronic, or LED loads. LED loads may be used in series with variable resistance to allow for output adjustment. Power source outputs shall be loaded using resistive, or electronic loads.

8.1.4 Each test in this section is to be conducted on a separate sample unless:

a) All parties agree that more than one test can be conducted on the same sample, or

b) Where a sample is conditioned by one test to be followed by another.

8.1.5 In addition to complying with the applicable performance requirements specified in this standard, a direct plug-in unit shall comply with Direct Plug-In Blade Secureness, Security of Input Contacts, and Abuse Tests as defined in the Standard for Class 2 Power Units, UL 1310.

8.1.6 In addition to complying with the construction requirements specified in this standard, a LED controller that is intended to be installed in a wall-box (or provided with an enclosure for flush or surface mounting) shall comply with the following tests in the Standard for Safety for Solid-State Dimming Controls, UL 1472 as applicable:

a) Temperature test,

b) Security of lead test,

c) Torque and pull-out tests,

d) Limited short-circuit test,

e) Leakage current test for touch dimmers,

f) Leakage current test, and

g) Field replaceable actuator assembly test.

Note: This requirement applies to LED controllers that are not covered within the scope of the Standard for Safety for Solid-State Dimming Controls, UL 1472. See 1.1.3(b).

8.1.6 When LED equipment includes a feedthrough circuit, applicable tests are to be performed with this output loaded to its maximum rating using resistive or electronic loads.

8.2 Input test

8.2.1 For LED modules or arrays:

a) For constant current input units, the input current shall be set at rated value; measured power shall not exceed 110 percent of rating.

b) For constant voltage input units, the input voltage shall be set at rated value; measured power shall not exceed 110 percent of rating.

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8.2.2 For LED controllers, LED drivers, and power sources:

a) For constant voltage input units, the input voltage shall be set at rated value and supplying rated load. Measured input current and input power shall not exceed 110 percent of each rating respectively.

b) For constant current input units, the input current shall be set at rated value and supplying rated load. Measured input voltage and input power shall not exceed 110 percent of each rating respectively.

8.3 Temperature test

8.3.1 A unit shall be subjected to a temperature test to determine that the temperatures do not exceed the limits on the specified components in Table 8.1 during normal operation of the unit. The unit shall be positioned in an alcove or still-air test oven, see Section 8.4 or 8.5, as appropriate for the product and maintained in an ambient temperature as specified in Table 8.2.

Table 8.1
Maximum acceptable temperatures

Materials and components	°C	°F
A. COMPONENTS		
1. Capacitor (other than oil filled)	a	a
2. Fuses	a	a
3. Internal wiring	a	a
4. Potting compound	b	b
5. Printed-wiring boards	a	a
6. Switches, terminal blocks, and connectors	a	a
B. ELECTRICAL INSULATION		
7. Class 105 (A) Insulation systems:		
Outer surface – thermocouple method	90	194
Average – resistance method (fully potted)	105	221
Average – resistance method (open core and coil)	95	203
Class 130 (B) Insulation systems:		
Outer surface – thermocouple method	110	230
Average – resistance method	120	248
Class 155 (F) Insulation systems:		
Outer surface – thermocouple method	135	275
Average – resistance method	140	284
Class 180 (H) Insulation systems:		
Outer surface – thermocouple method	150	302
Average – resistance method	165	329
8. Vulcanized fiber employed as electrical insulation for other than coil systems	90	194
C. SURFACES		
9. A surface upon which the unit is placed or mounted in service	90	194
10. A non-metallic surface of a direct plug-in or through-cord unit	75	167
11. A metallic surface of a direct plug-in or through-cord unit	55	131

Table 8.1 Continued on Next Page

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Table 8.1 Continued

Materials and components	°C	°F
12. Interior surface of field-wiring compartment	See 8.3.3	
[a] There are no temperatures specified; the manufacturer's rated temperature of the material or component is to be used.		
[b] See 6.7 or 6.8 based on potting compound type (Asphalt or Polymeric).		

Table 8.2
Ambient temperature test condition

Device	Test chamber	Ambient temperature
Remote, through-cord, or direct plug-in	Alcove	25°C (77°F)
Used within a luminaire	Test oven	40°C (104°F)

8.3.2 A unit integral to a luminaire product shall be tested in accordance with the applicable luminaire product standard.

8.3.3 The temperature on any surface inside a terminal or splice compartment when corrected to 25°C (77°F) shall not be more than 60°C (140°F) unless the device is marked maximum 75°C (167°F) or maximum 90°C (194°F) in accordance with 9.3.3.

8.3.4 A temperature test may be performed at any ambient-air temperature within ±5°C (±9°F) of the value noted in Table 8.2. The variation from the value noted in Table 8.2 may be added to or subtracted from the observed temperature readings.

8.3.5 The average of two or more thermocouple readings is to be taken for the air temperature within the test enclosure. Thermocouples as described in 8.3.18 are to be located so that the temperature-sensing portions are 76.2 mm (3 in) from the floor of the test enclosure, and not less than 76.2 mm (3 in) from the nearest wall.

8.3.6 The test is to continue until constant temperatures are obtained. A temperature is considered constant if:

a) The test has been running for at least 3 hours, and

b) Three successive readings, taken at 15-minute intervals, are within 1°C (1.8°F) of one another and are still not rising.

8.3.7 The LED driver input and output supply electrical parameters (V, A, W), are to be recorded 15 minutes after the start of the test and at the end of the test. The input current measurements shall comply with 8.2.2. The output current recorded at the end of the test shall be within 10 percent of the initially recorded value.

8.3.8 For all tests in which a direct plug-in unit is to be energized from a source of supply, the unit is to be operated from an outlet representing the following constructions:

a) Duplex receptacle outlet with nonmetallic faceplate,

b) Receptacle mounted on a nonmetallic outlet box, not more than 196 cm^3 (12 in^3) in volume, and

c) Outlet box mounted in a vertical wall section approximately 100 mm (3-1/2 in) thick with plywood or gypsum wallboard surfaces and loosely filled with fiberglass or equivalent thermal insulation.

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8.3.9 A unit intended to be used inside of a luminaire shall be supported in a test oven with its mounting surface down and 76 mm (3 in) above the base of the enclosure in a central position on two 76 mm (3 in) wooden or ceramic cleats. To determine the temperature produced on the device surface, thermocouples shall be attached to the case in the areas of major heat sources. Temperatures on the device case shall be determined by means of thermocouples, and in the coils by the thermocouple or rise-of-resistance method. The unit shall be conditioned in the test oven until all parts reach the temperature of the heated air therein prior to the test.

8.3.10 For a unit with potting it would be necessary to apply thermocouples to interior components prior to potting.

8.3.10.1 When potting compound temperature is necessary to determine compliance with criteria in 6.7 or 6.8, the observed temperatures of the potting compound and components that are touching or submerged in the potting compound are used to calculate the average value of the potting compound temperature.

8.3.11 A thermocouple junction and the adjacent thermocouple lead wire are to be securely held in thermal contact with the surface of the material of which the temperature is being measured. In most cases, adequate 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.

8.3.12 It may be necessary to test a modified sample, with additional lead wires that are extended, so that the temperature of each coil of a device may be measured by the resistance method.

8.3.13 The following explanation pertains to coil insulation temperatures. The insulation system temperature (class) is also the internal hot spot temperature limit. The average coil temperature, obtained by the change of resistance method, is the average of the entire coil from internal hot spots to the cooler, outer surface; hence, the average limit is lower than the internal hot spot, or system limit. The thermocouple measurement method gives the temperature of the cooler, outer surface; hence, the outer surface limit is lower than the average limit. In end-product applications, the thermocouple measurement method is primarily for convenience. At the point on the surface of a device where the temperature is affected by another source of heat, the temperature may exceed the value given in Table 8.1 provided the average temperature is not exceeded.

8.3.14 The temperature on a coil may be measured by the thermocouple method or determined by the change-of-resistance method (comparing the resistance of the winding at the temperature to be measured with its resistance at a known temperature) using the formula specified below.

8.3.15 The temperature of a winding is to be calculated by the following formula:

$$T_H = \frac{R_H}{R_C}[k + A_C] - k + [A_C - A_H]$$

in which:

T_H is the temperature of the coil at the end of the test, °C

R_H is the resistance of the coil at the end of the test, in Ω

R_C is the resistance of the coil at the beginning of the test, in Ω

k is a constant which represents the temperature coefficient for the coil = 234.5 for copper or 225.0 for electrical conductor grade (EC) aluminum

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A_C is the ambient temperature of the coil at the beginning of the test when R_C is measured, °C. Normally 25°C unless the coil is being tested in an oven at a higher ambient temperature.

A_H is the ambient temperature at the end of the test when R_H is measured, °C

8.3.16 As it is generally necessary to de-energize the winding before measuring R_H, the value of R_H at shutdown is determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve plotted showing the resistance values as a function of time may then be extrapolated to give a value of R_H at shutdown.

8.3.17 If a manual method is used to collect the data, generally the values of resistance are to be taken over a 30 second period, 5 seconds apart. The extrapolated value (to the time of power shutdown) can be determined by a graphical computer spreadsheet application. If a computer spreadsheet application is used, the trend-line equation can be from the best fit of a linear, polynomial, or exponent regression. If a computer automated (and quicker) method is used to collect the data, the values of resistance can be taken as permitted by the equipment. The extrapolated value (to the time of power shutdown) can be determined by a linear regression.

8.3.18 The junction of the thermocouple is to be firmly secured with the point on the surface on which the temperature is to be measured. When radiation may affect thermocouple measurement of polymeric material, it is permitted to embed the junction of the thermocouple within the material such that the thermocouple junction is shielded from direct optical radiation. The thermocouple is to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). Thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan (Type J) wires are to be used whenever a referee temperature measurement by thermocouples is necessary. Thermocouples consisting of chromel-alumel (Type K) or copper-constantan (Type T) wires may be used if it is determined that high frequency operation results in eddy current heating of iron and constantan thermocouples.

8.3.19 *Deleted*

8.3.20 In situations where optical radiation from the light source is expected to affect the accuracy of a temperature measurement, with the agreement of all parties involved, linear regression is permitted to be used. A series of temperature measurements shall be taken at 5-second increments immediately after the light source has been de-energized for a total duration of 130 seconds. The data from the first 10 seconds shall be discarded and the remaining 120 seconds of data plotted on a time vs. temperature graph. Using a linear regression formula, the temperature at time zero shall be calculated and recorded to represent the temperature measurement value.

8.3.21 *Deleted*

8.3.22 *Deleted*

Figure 8.1

Leading edge phase-cut type dimmer output waveform

Figure deleted

8.3.23 *Deleted*

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8.4 Temperature test alcove

8.4.1 The test alcove shown in Figure 8.2 shall have three sides made of plywood conforming to 8.4.2, joined at right angles to form a corner with butt-fitted seams secured by wood screws or nails. Each side shall project 300 mm (12 in) beyond the luminaire.

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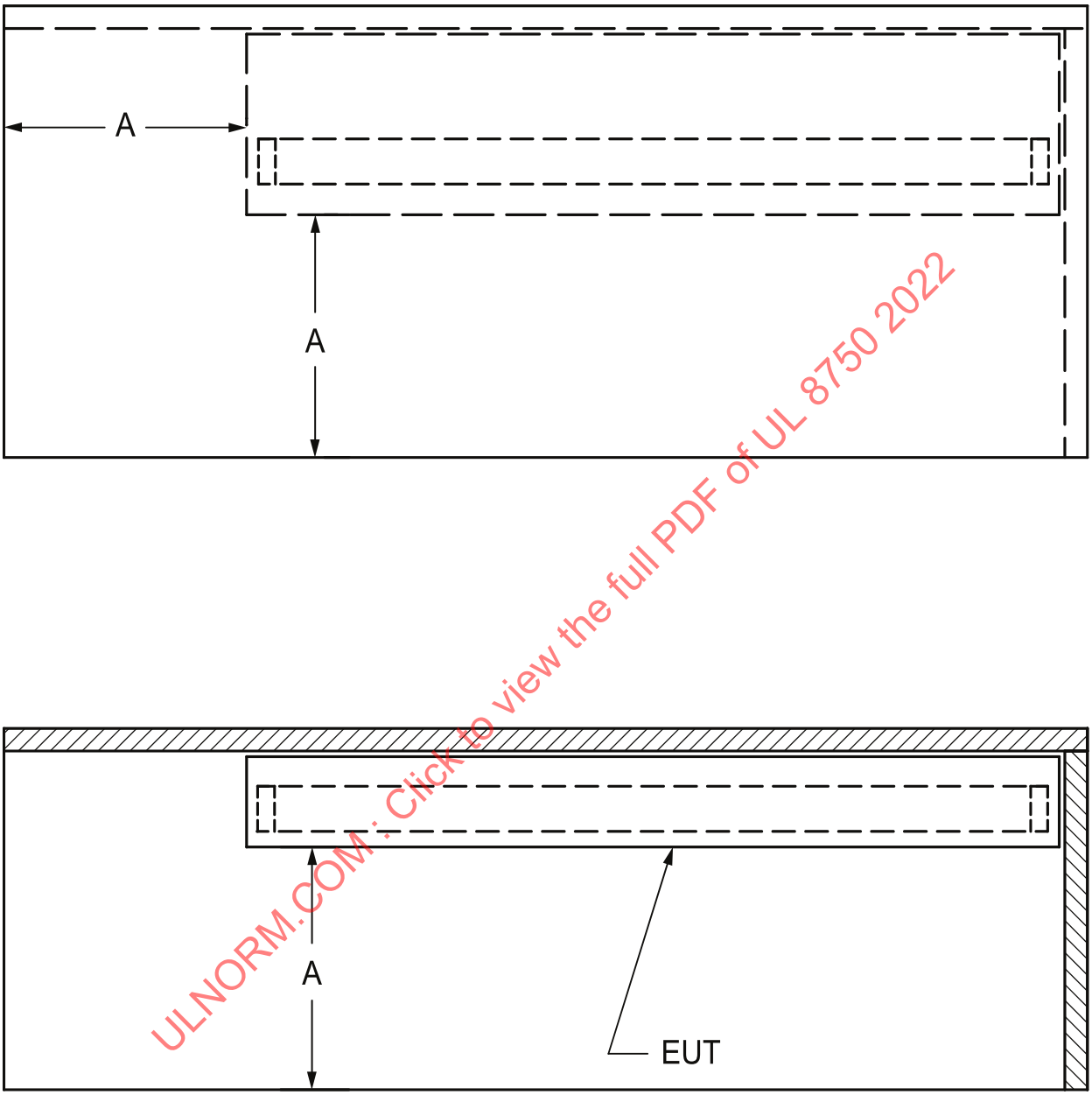
Figure 8.2

Temperature test alcove



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Notes:

1) The upper drawing is the top view.

2) The lower drawing is a section through the center of the top view.

3) Dimension A is 300 mm (12 in).

4) EUT = equipment under test

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8.4.2 The plywood used shall be 12 mm (0.5 in) thick, with at least one side that has all voids filled and sanded.

8.4.3 The product shall be mounted inside so it touches two walls and the top of the alcove, in the configuration and orientation that result in the highest temperatures.

8.5 Temperature test oven

8.5.1 During the test the equipment under test is to be supported as illustrated in Figure 8.3. The floor between the heaters and the equipment under test is to be of a thermal insulating material. The test compartment of the enclosure is to have internal dimensions of 610 by 610 mm (24 by 24 in). The floor of the test compartment is to be 559 by 559 mm (22 by 22 in), permitting an air space of 25.4 mm (1 in) all around the floor for circulation of the heated air. A 76.2-mm (3-in) deep heater compartment is to be provided below the floor of the test area for the heating elements. One side of the test compartment may be removable, but is to be constructed so that it can be securely fastened to the remainder of the enclosure. One of the sides is to have a 152-mm (6-in) square opening located centrally at the bottom edge of the test compartment, and the enclosure is to be constructed so that the only possibility of air circulation will be through this opening. The opening is to be covered by an aluminum shield positioned so that it extends 12.7 mm (1/2 in) beyond the perimeter of the opening.

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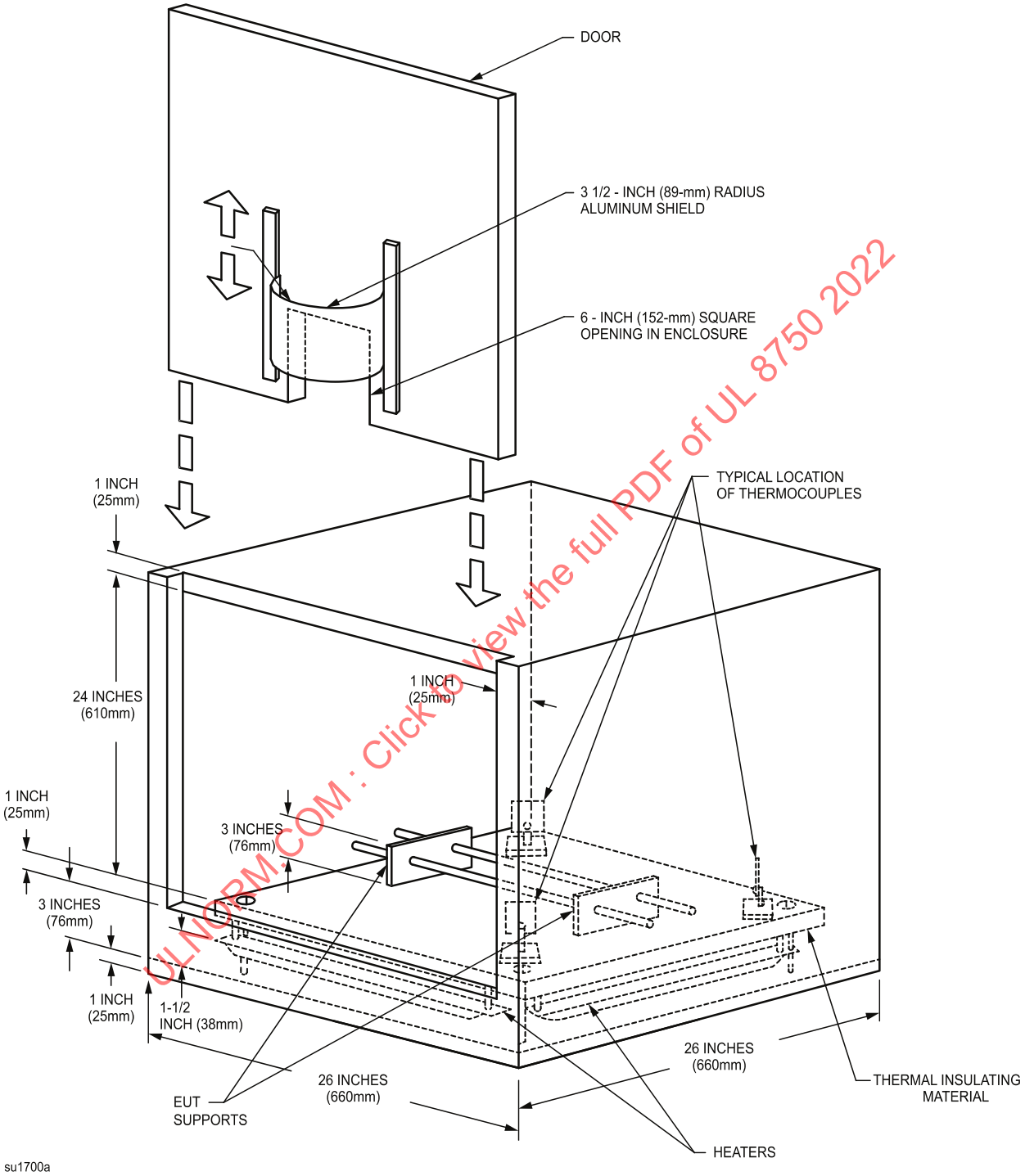
Figure 8.3

Test oven



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Note:

EUT = equipment under test

8.5.2 The heat source used for the test oven described in 8.5.1 is to consist of four 300-watt, 230-volt, strip heaters having heating surface dimensions of approximately 38 mm by 305 mm (1-1/2 by 12 in). The elements are to be connected in parallel to a 120-volt supply source. The elements are to be mounted in the 76-mm (3-in) deep heater compartment midway between the test-compartment floor and the base, and are to be arranged so that they form a square with the outside edge of each element 63.5 mm (2-1/2 in) from the adjacent inside wall of the compartment. The elements are to be controlled by a thermostat.

8.5.3 The heaters located below the floor of the oven compartment are to be thermostatically controlled to provide the required oven temperature regardless of the heat gain from the device under test. Glowing coils shall not radiate directly onto the unit under test. The volume of the oven compartment is to be between 0.156 m^3 (5-1/2 ft^3) and 0.226 m^3 (8 ft^3).

8.5.4 In lieu of the oven construction described in 8.5.1 – 8.5.3, the oven may be a commercially manufactured oven having still-air convection heating. The heaters are to be located below the floor of the oven compartment, and are to be thermostatically controlled to provide the required oven temperature regardless of the heat gain from the device under test. Glowing coils shall not radiate directly onto the enclosure for the equipment under test. The volume of the oven compartment is to be between 0.156 m^3 (5-1/2 ft^3) and 0.226 m^3 (8 ft^3).

8.6 Dielectric voltage withstand test

8.6.1 The unit shall withstand for one minute, without breakdown, the test potential specified in Table 8.3, using the test equipment specified in 8.6.2 where V is the maximum AC (rms) voltage between the parts under test.

Note 1: If there is excess capacitive leakage current, the capacitors are permitted to be removed or the test may be conducted using a DC potential at 1.414 times the AC potential.

Note 2: Surge protective devices bridging the circuit locations under test may be removed for this test.

Table 8.3
Dielectric voltage withstand potential

Test potential, V ac	Circuit location
2V + 1000	Between primary circuits and accessible dead conductive parts
	Between secondary circuits operating at greater than 70 V peak and accessible dead conductive parts
	Between the primary and secondary windings of a transformer that are relied upon for separating circuits that are required to be isolated
	Between PWB traces or other parts operating at different potentials
500 V	Between a secondary circuit operating at no more than 70 V peak and accessible dead conductive parts

8.6.2 The dielectric withstand test equipment shall employ a transformer of 500-VA or larger capacity and have a variable output voltage that is essentially sinusoidal or continuous direct current. The applied potential is to be increased from zero at a substantially uniform rate until the required test level is reached, and is to be held at that level for 1 minute.

Exception: A 500-VA or larger capacity transformer is not required if the transformer is provided with a voltmeter to measure directly the applied output potential.

8.6.3 Insulation breakdown is considered to have occurred when the current that flows as a result of the application of the test voltage, rapidly increases in an uncontrolled manner. (e.g., the insulation does not

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restrict the flow of the current). Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

8.7 Abnormal tests

8.7.1 General

8.7.1.1 During each test:

a) The grounding means, if provided, is to be connected to ground through a 3-A non-time delay fuse,

b) The unit is to be placed on a softwood surface covered with tissue paper and draped with a double layer of cheesecloth conforming to the outline of the unit,

c) The white tissue paper shall be nominally 0.025 mm (0.001 in) thick, commonly used for gift wrapping,

d) The cheesecloth shall be bleached cheesecloth, 36 inches (91.4 cm) wide, running 14 – 15 square yards per pound (26 – 28 m^2/kg) and having what is known in the trade as a count of 32 by 28; that is, for any square inch 32 threads in one direction and 28 in the other direction (for any square centimeter, 13 threads in one direction and 11 in the other direction). The cloth is to be loosely draped over the device under test in order to serve as a flame indicator (presence of ash, or burnt holes) not as a blanket to trap heat,

e) The unit is to be energized at rated input voltage and frequency,

f) The supply circuit is to be connected in series with a 20 A branch circuit-rated fuse (time delay type), of which the characteristics are such that the fuse does not open in less than 12 s when carrying 40 A, and

g) The unit is to be operated at ambient temperatures of 25°C ±5°C (77°F ±5°F).

8.7.1.2 After ultimate results have been obtained for each test, the sample shall be permitted to cool to room temperature and the dielectric voltage withstand test of 8.6 shall be repeated.

8.7.1.3 A risk of fire or electric shock is considered to exist with any of the following results:

a) Opening of the ground fuse,

b) Charring of the cheesecloth or tissue paper,

c) Emission of flame or molten material from the unit,

d) Ignition or dripping of a compound from the unit,

e) Exposure of live parts that pose a risk of electric shock under the requirements for accessibility of 7.2, or

f) Breakdown during the subsequent dielectric voltage withstand test.

Opening of the 20A time delay fuse is acceptable provided none of the other conditions noted in (a) through (f) occurs.

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8.7.2 Component failure test

8.7.2.1 A unit having components such as resistors, semiconductor devices, capacitors, and the like shall not exhibit a risk of fire or electric shock when a simulated short circuit or open circuit is imposed. In preparation for component failure tests, the equipment, circuit diagrams, and component specifications are examined to determine those fault conditions that might reasonably be expected to occur. Examples include: short-circuits and open circuits of semiconductor devices and capacitors, faults causing open circuits of resistors and internal faults in integrated circuits.

Exception No. 1: Circuits in which maximum power levels have been determined to not exceed 50 W need not be evaluated for component failure.

Exception No. 2: Devices supplied by a source operating within the limits for risk of fire and electric shock need not be subject to this test.

8.7.2.2 Each component is to be short circuited or open circuited, one at a time (one fault per test). Each test shall continue until either the unit is no longer operable, or until conditions are obviously stable (as determined by no visual changes or detectable thermal increase) for at least 30 minutes.

Exception: Components whose reliability against failure which have already been evaluated shall not be faulted. Examples of such components: optical isolators evaluated to the Standard for Optical Isolators, UL 1577, and capacitors evaluated to the Standard for Standard for Safety Requirements 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.

8.7.3 Output loading test

8.7.3.1 LED equipment with supply outputs (LED controllers, LED drivers, and power sources) shall not exhibit a risk of fire or electric shock when subjected to the following tests.

8.7.3.2 During the tests of 8.7.3.4 and 8.7.3.5, a circuit protector provided as part of the unit is to remain in the circuit, and a user replaceable fuse is to be replaced by the largest fuse the fuseholder will accept. A manually reset protector is to be operated for 10 cycles and the protector contacts shall be operative upon completion of the test. If an automatic reset protector is provided, or the input current is a value other than zero, the test is to be continued for:

a) 7 hours, or

b) 15 days if required in accordance with 7.11.2.4.

8.7.3.3 For units with more than one output, the remaining outputs are to be open circuited or loaded to rated conditions, whichever results in a more severe operating condition.

8.7.3.4 Each output is to be short-circuited in turn. The temperature on the enclosure shall not exceed 90°C (194°F) for through-cord or direct plug-in types and 110°C (230°F) for all other types. These limits apply to output short-circuit test conditions which continue 30 minutes or longer.

8.7.3.5 Each output is to be overloaded in turn. Each overload condition is to be conducted with the output loaded to a current (I_L) equal to the rated current (I_R) plus X percent of the difference between the maximum obtainable output current (I_{max}) and the rated output current (I_R). In the tests, the values of X are to be 100, 75, 50, 25, 20, 15, 10, and 5, in that order. If a load current results in continuous operation, further tests need not be conducted. For each test, a variable resistance load is to be adjusted to the required value and readjusted, if necessary, one minute after application of the source of supply.

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Exception: The alternate test method of 8.7.4 may be used for units that employ a:

a) Thermal link complying with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691, or

b) Fuse complying with the Standard for Low-Voltage Fuses – Part 14: Supplemental Fuses, UL 248-14.

8.7.4 Output loading – alternate method

8.7.4.1 With reference to the Exception to 8.7.3.5, if the output short circuit test of 8.7.3.4 results in opening of a thermal link or fuse, the alternate method of 8.7.4.2 or 8.7.4.3 may be performed in lieu of 8.7.3.5.

8.7.4.2 If short circuiting causes opening of a thermal link, the device is to be shunted and a thermocouple attached to its body. The load current is to be raised slowly until a temperature equal to the rated trip temperature of the device plus 5°C (9°F) is reached. Without further readjustment of the load, the unit is to be operated for the remainder of the specified time length (7 hours or 15 days, as applicable).

8.7.4.3 If short circuiting causes opening of a fuse, the unit is to be tested with a load current that causes the maximum current to flow in the fused circuit without opening the fuse. The maximum current to be delivered through the fuse is to be determined by the following formula:

$$I_{FC} = 1.1\,(I_{FR})\,[1 + n(0.02)]$$

in which:

I_{FC} is the fuse overload current,

I_{FR} is the fuse current rating, and

n is an integer that causes the unit to run such that I_{FC} is able to be maintained at its continuous maximum current (7 hours or 15 days, as applicable).

8.7.4.4 When conducting this test, at least two load conditions are to be used; one load condition where I_{FC} (n = c) results in continuous operation, and one load condition where I_{FC} (n = c + 1) results in opening of the fuse prior to the specified time length (7 hours or 15 days, as applicable). Prior to each test, the sample is to be at room temperature.

8.8 Circuit power limit measurement test

8.8.1 This test shall be used to determine if the power available to a circuit under any loading condition, including short circuit, measured after one minute of operation exceeds a defined limit. For the purposes of this test, the limit (for example, 15W or 50W) is referred to as PLIMIT. This test is applied to a circuit (under evaluation) to determine if it has a power draw of PLIMIT or less.

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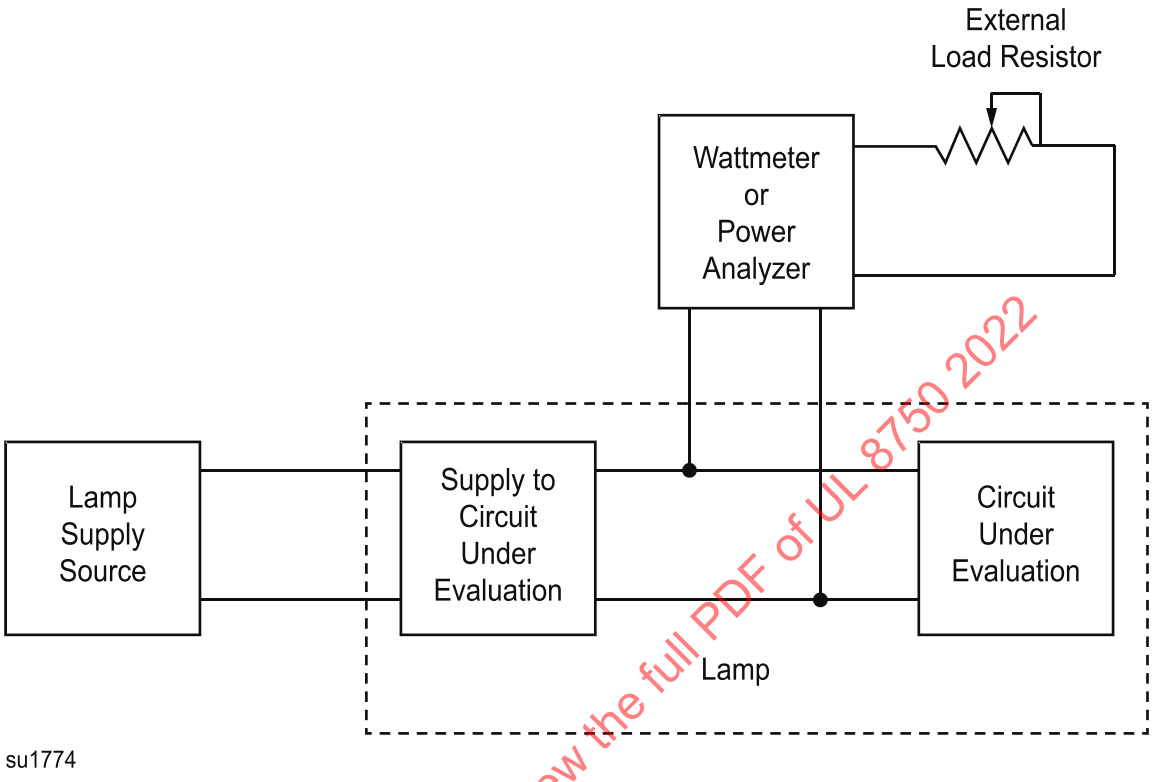
Figure 8.4

Connection of wattmeter



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8.8.2 The point in the circuit under evaluation is to be connected to the measurement circuit as shown in Figure 8.4. While the circuit is operating with the anticipated normal load, the external adjustable load resistor is reduced gradually to the point where PLIMIT is being dissipated. The load shall be re-adjusted as needed to maintain PLIMIT for one minute. If PLIMIT cannot be attained and maintained for one minute under any load condition, the test shall be discontinued.

8.8.3 For a circuit without a designated current limiting device, a circuit component that opens in less than 1 minute at any power delivery level less than PLIMIT and that precludes delivery of PLIMIT for more than one minute is considered to effectively limit the circuit output to less than PLIMIT, if the test can be repeated two additional times on new samples with comparable results.

8.8.4 For a circuit with a designated current limiting device, a closed shorting switch is to be connected across the current limiting device and the adjustable resistance is then to be reduced to result in a power dissipation of exactly PLIMIT as indicated by the meter. The switch across the current limiting device is then to be opened and the time required for the device to open is to be recorded. A current limiting device that opens the circuit in less than 1 minute is considered to effectively limit the circuit output to less than PLIMIT.

8.8.5 If the test is disrupted by the failure of other circuit components (i.e.: capacitor, diode, coil winding, foil trace, etc.) then that test shall be repeated two additional times, with new samples, under the same test condition. Test disruption by opening of the same, or a different, component during these repeated tests is acceptable.

8.8.6 If the supply to the circuit under evaluation consists of other than a single resistor, the test described in this section shall be repeated under any single component fault conditions within the supply circuit likely to result in greater output power availability. The fault condition shall first be applied, and then

the variable resistance load shall be adjusted as needed. A new sample shall be used for each component fault.

Exception: Components whose reliability against failure has been deemed acceptable by a separate investigation shall not be faulted. Examples of such components: Optical isolators evaluated to Standard for Optical Isolators, UL 1577; Capacitors evaluated to Standard for Safety Requirements 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; etc.

8.8.7 If there is any indication of component overheating during any of the tests described in 8.8.2 – 8.8.6 (i.e.: odor, smoke, discoloration, glowing, cracking, melting, or changes in circuit current through the fault), the test condition shall be repeated as part of the Component Failure Test in 8.7.2.

8.9 Leakage current measurement test

8.9.1 A unit connected to a branch circuit supply voltage shall be tested in accordance with this section. Leakage current shall not be more than:

a) 0.5 MIU for units connected to a supply voltage of 150 volts or less to ground,

b) 0.75 MIU for units connected to a supply voltage of greater than 150 volts to ground.

Exception: To address end-product standards where a measurement is not required when the supply connection is fixed, this test can be waived when a unit is 1) intended to be connected and grounded only to a fixed supply connection based on manufacturer installation instructions and 2) marked in accordance with 9.3.7.

8.9.2 All accessible conductive parts are to be tested for leakage currents. Leakage currents from these parts are to be measured to the earth ground as depicted in Figure 8.5 individually as well as collectively if simultaneously accessible, and from one part to another if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible conductive parts are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor of the product and the grounded supply conductor.

8.9.3 If a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 10 by 20 cm (4 by 8 in) in contact with the surface. If the conductive surface has an area less than 10 by 20 cm (4 by 8 in), the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface but is not to remain in place long enough to affect the temperature of the product.

8.9.4 The measurement circuits for leakage current is illustrated in Figure 8.5. During the test the grounding connection from the unit is left open and not connected to the grounding conductor of the branch circuit supply.

Note – Refer to Appendix B for additional information regarding the circuit in Figure 8.5.

8.9.4.1 The meter input network is defined in Figure 8.6. The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

a) The measured ratio V_1/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_1/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 8.6.

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b) The measured ratio V_3/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_3/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 8.6. V_3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts can be converted to MIU by dividing the reading by 500 ohm and then multiplying the quotient by 1,000. The mathematic equivalent is to simply multiply the RMS voltage reading by 2.

Figure 8.5

Circuit for leakage current test

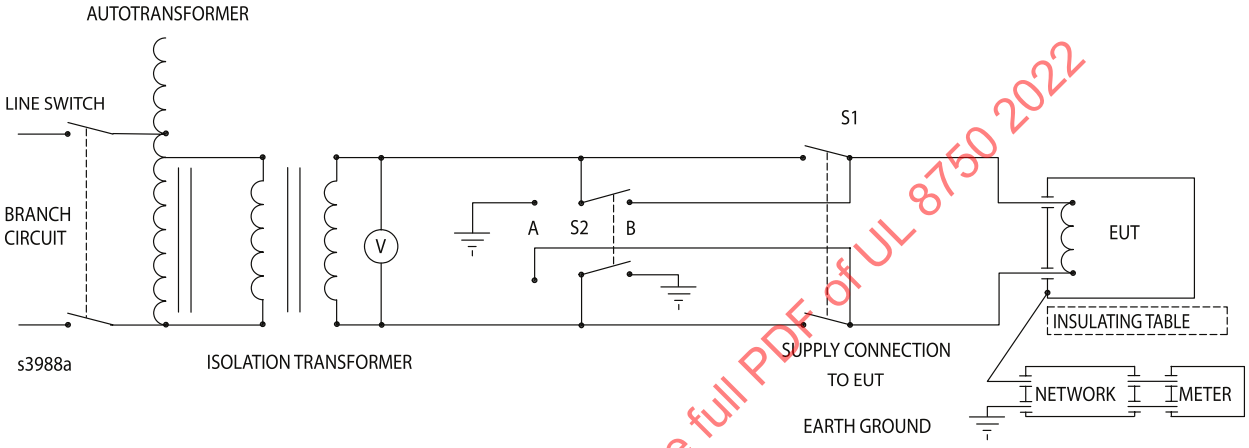
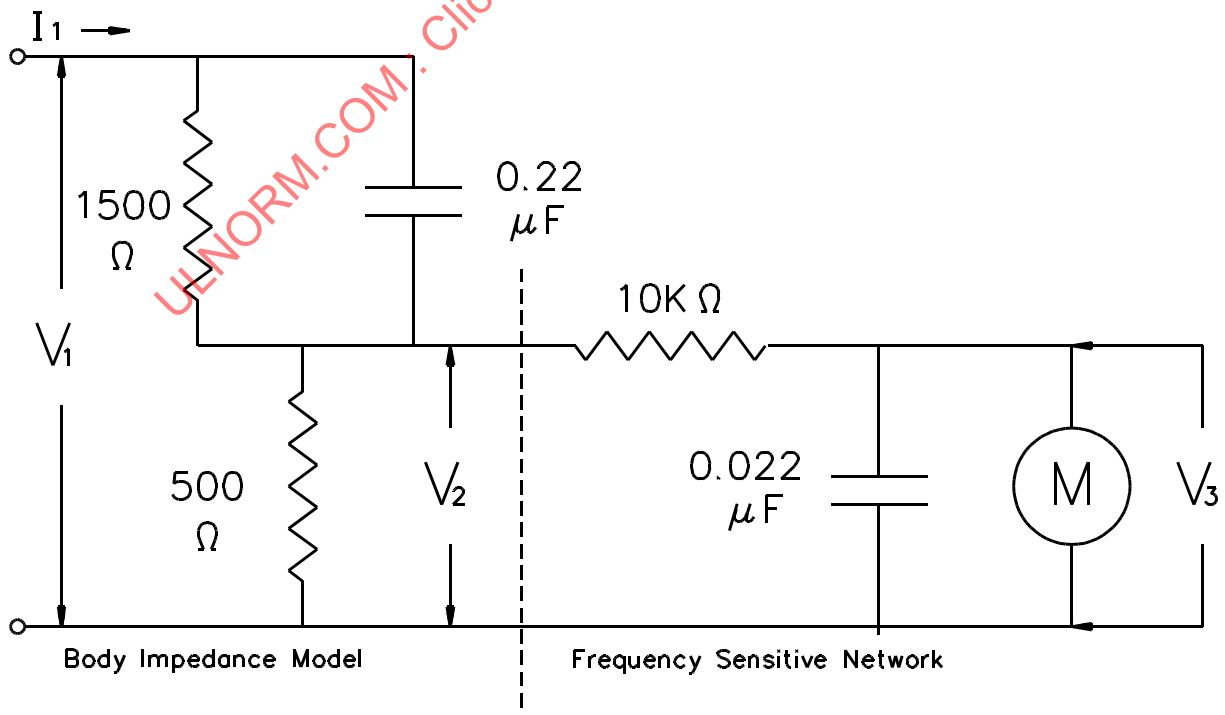


Figure 8.6

Measurement instrument for reaction (leakage) current



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8.9.5 Unless the measurement instrument is being used to measure leakage current from one part of a unit to another, it is to be connected between accessible parts and the grounded supply conductor.

8.9.6 The sample unit is to be tested for leakage current without prior energization, except as may occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage. The test sequence is to be as follows, with reference to the Figure 8.5 measurement circuit:

a) With switch S1 open, the unit is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2, and with the unit switching devices in all their normal operating positions.

b) Switch S1 is then to be closed, energizing the unit. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the unit switching devices in all their normal operating positions.

c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.

8.9.7 Using a commercially available meter having the network shown in Figure 8.6 or built to conform to the Standard for Leakage Current for Appliances, ANSI C101, meets the intent of these requirements. The meter is to be set to “reaction” curve.

8.10 Cord strain and pushback relief test

8.10.1 A supply cord shall be subject to a pulling force of 156 N (35 lbf) applied for 1 min in a direction perpendicular to the plane of entrance into the unit.

8.10.2 Following the test of 8.10.1, the supply cord is to be gripped 25.4 mm (1 in) from the point where it emerges from the product. When a removable bushing that extends further than 25.4 mm (1 in) is present, it is to be removed prior to the test. When the bushing is an integral part of the cord, the test is to be carried out by holding the bushing. The cord is to be pushed back into the product in 25.4-mm (1-in) increments until the cord buckles, or the force applied exceeds 26.7 N (6 lbf).

8.10.3 A field wiring lead wire shall be subject to an applied force as follows:

a) For a unit with leads extending from the enclosure – 89 N (20 lbf) or four times the weight of the unit, whichever is less but not less than 22 N (5 lbf), for a period of 1 minute.

b) For a unit with leads located within a wiring compartment – 44.5 N (10 lbf) or four times the weight of the unit, whichever is less but not less than 22 N (5 lbf) (per lead) for a period of 1 minute.

8.10.4 The results of 8.10.1 – 8.10.3 shall exhibit no:

a) Movement of the flexible cord more than 1.6 mm (0.063 in),

b) Movement of a lead wire that indicates stress was applied to internal connections,

c) Damage to conductors, connectors, or other components, or loosening of connections inside the enclosure of the unit, or

d) Exposure of the supply cord or lead wire to temperatures higher than for what they are rated.

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8.11 Security of output terminals

8.11.1 A wire-binding screw terminal having fewer threads or lesser thickness than required by 7.4.2.3.5, or that relies upon a lockwasher to prevent turning per 7.4.2.3.7, shall be subject to 100 cycles of conductor connection and disconnection as described in 8.11.2.

8.11.2 The appropriate wires are to be inserted, and the tightening torque specified in Table 8.4 is to be applied for 10 seconds to the terminals. The screw terminals are then to be loosened fully. Following 100 cycles, the screw terminals shall not turn or exhibit any signs of damage.

Table 8.4
Tightening torque for wire-binding screws

Size of terminal screw		Wire sizes to be tested		Tightening torque	
mm	No.	AWG	(mm^2)	N·m	(lbf·in)
3.5	6	16 – 22	(1.3 – 0.32)[a]	1.4	(12)
4.0	8	14	(2.1)[b]	1.8	(16)
		16 – 22	(1.3 – 0.32)[a]		
5.0	10	10 – 14	(5.3 – 2.1)[b]	2.3	(20)
		16 – 22	(1.3 – 0.32)[a]		

[a] Stranded
[b] Solid wire

8.12 Insulation-piercing connection thermal cycling test

8.12.1 Six units shall be assembled to conductors of the size and type for which they are intended. The temperature of the insulation-piercing terminal connections shall be monitored continuously for seven hours while carrying the maximum rated load. The units shall then be subject to 180 cycles at a rate of 3-1/2 hours on and 1/2 hour off (the off-cycle time may be extended for the convenience of measurement), while continuing to monitor the temperatures of the insulation-piercing terminal connections. After the last cycle, the units shall be energized for a period of seven hours, while still monitoring temperatures.

8.12.2 Temperatures of the insulation-piercing terminal connections on each LED unit at the end of the test shall not be more than 30°C (54°F) higher than the temperatures measured on the same unit after the initial seven hours of operation. At no point during the testing shall the temperature of any insulation-piercing terminal connection exceed 90°C (194°F).

8.13 Adhesive support test

8.13.1 An adhesive relied upon to secure a part to another part shall have sufficient strength to withstand a pulling force equal to five times the weight of the supported part after the conditioning described in 8.13.2.

8.13.2 The adhesive secured parts shall be conditioned at 23°C (73.4°F) for 48 hours. They shall then be placed in an air-circulating oven at the temperature and for the time specified by Table 8.5. The adhesive rating temperature shall be based on results from the temperature test of 8.3; the associated conditioning time shall be by mutual agreement of the parties.

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Table 8.5
Adhesive support oven temperature and time

Adhesive rating, °C	Oven temperature, °C			
	300 h (12.5 d)	720 h (30 d)	1000 h (42 d)	1440 h (60 d)
60	125	115	110	100
75	145	135	125	110
90	160	150	140	130
105	180	170	160	145
130	200	190	180	170
155	220	215	205	195
180	245	235	230	220
200	280	265	255	245
220	295	285	275	265
240	N/A	300	290	280

8.13.3 After conditioning, the sample is to be removed from the oven and allowed to cool to room temperature. A separating force shall then be evenly applied for one minute, perpendicular to the primary axis of the adhesive joint. The parts shall remain secured together.

8.14 Environmental tests

8.14.1 Humidity exposure

8.14.1.1 A unit intended for use in damp or wet locations shall be exposed for 168 hours to moist air having a relative humidity of 88 ±2 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F) to be followed by the dielectric voltage withstand test of 8.6.

8.14.1.2 A unit intended for wet locations is to be tested for water exposure in accordance with 8.14.2.

8.14.2 Water exposure

8.14.2.1 A unit intended for use in wet locations shall be subjected to a simulated rain produced in accordance with 8.14.2.4 – 8.14.2.6.

8.14.2.2 After the exposure, outer surfaces shall be dried and the dielectric voltage withstand test of 8.6 shall be repeated. There shall be no breakdown as a result of the dielectric voltage withstand test.

8.14.2.3 After the dielectric voltage withstand test of 8.6, the unit shall be carefully opened to determine if water entered. There shall be no water in contact with electrical parts, except for components suitable for the condition.

8.14.2.4 During the test the unit is to be oriented in the position that is most likely to result in the wetting of live parts, or in accordance with orientation markings specifically provided for the purpose.

8.14.2.5 The rain test apparatus shall consist of three spray heads mounted in a water supply pipe rack as shown in Figure 8.7. Spray heads are to be constructed in accordance with the details shown in Figure 8.8. The assembly is to be positioned in the focal area of the spray heads so that the greatest quantity of water is likely to enter the component. The water pressure is to be maintained at 34.5 kPa (5 psi) at each spray head.

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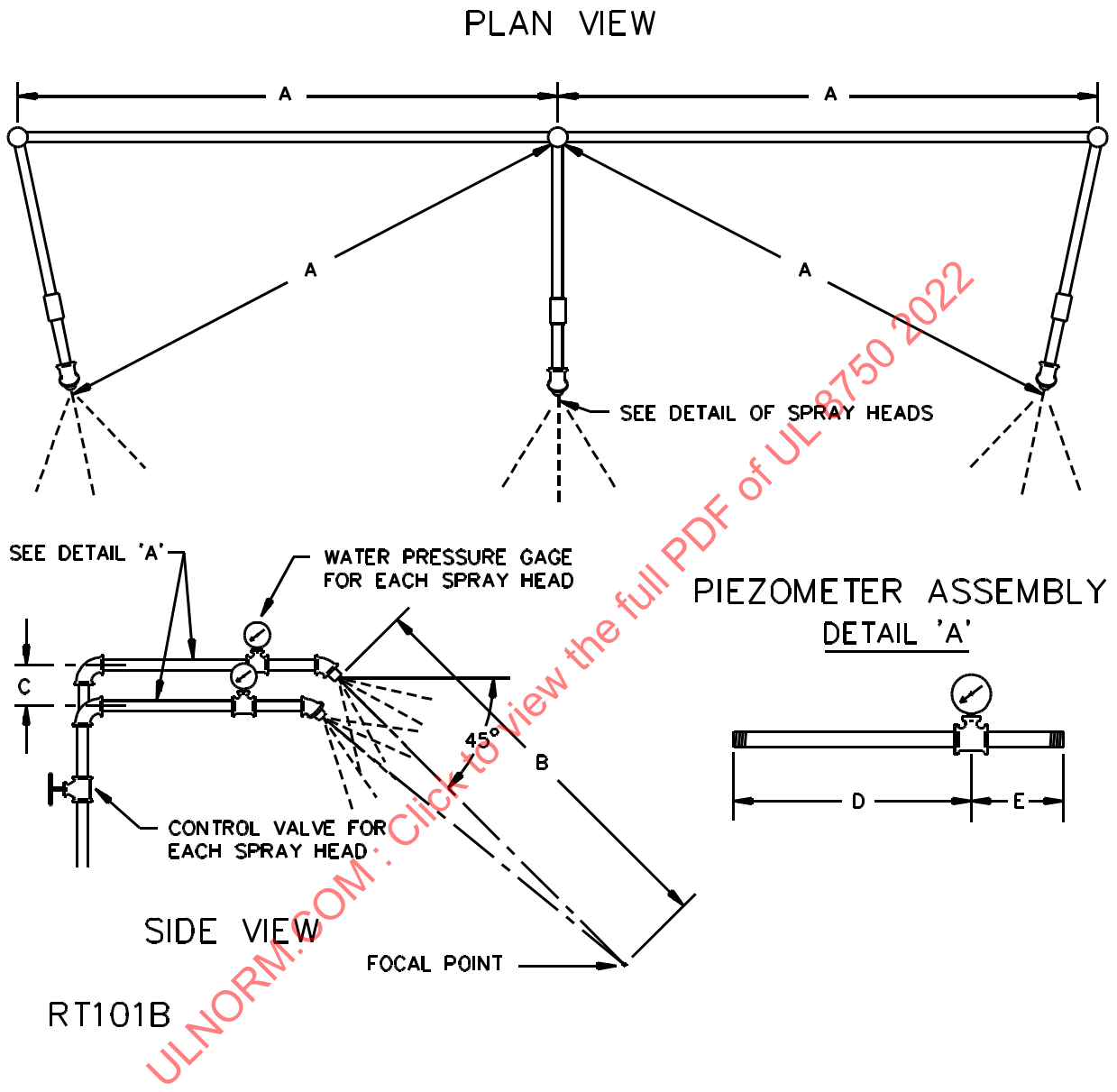
Figure 8.7

Spray head piping



Item	mm	(in)
A	710	(28)
B	1400	(55)
C	55	(2.25)
D	230	(9)
E	75	(3)

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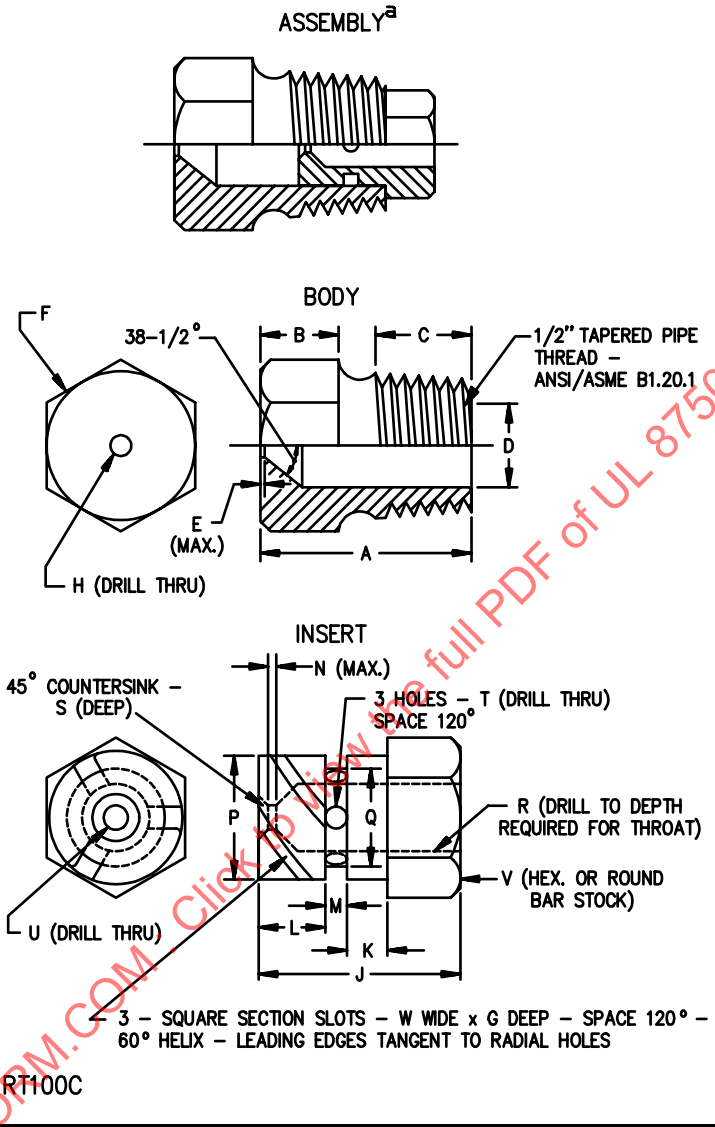
Figure 8.8

Spray head assembly



Item	mm	(in)	Item	mm	(in)
A	31.00	(1.219)	M	2.38	(0.094)
B	11.00	(0.438)	N	0.80	(0.031)
C	14.00	(0.563)	P	14.61 – 14.63	(0.575 – 0.576)
D	14.68 – 14.73	(0.578 – 0.580)	Q	11.51 – 11.53	(0.453 – 0.454)
E	0.40	(0.016)	R	6.35	(0.250)
F	Optional	Optional	S	0.80	(0.031)
G	1.52	(0.060)	T	2.80	(0.110)
H	5.00	(0.196)	U	2.50	(0.980)
J	18.30	(0.719)	V	16.00	(0.625)
K	3.97	(0.156)	W	1.52	(0.060)
L	6.35	(0.250)			

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8.14.2.6 The assembly shall be subjected to the water spray for a total of 4 hours. During the 4 hours the assembly is to be energized and de-energized in the following sequence:

Test duration, h	Test period, h	Operational	Water
0 – 1.0	1.0	On	Off
1.0 – 1.5	0.5	Off	On
1.5 – 3.5	2.0	On	On
3.5 – 4.0	0.5	Off	On

8.15 Mechanical strength tests for metal enclosures

8.15.1 An enclosure part that is required by other parts of this standard to comply with this section shall withstand the two tests, in sequence, described in 8.15.2 and 8.15.3:

a) Without permanent distortion to the extent that spacings are reduced below the values specified in 7.8,

b) Without transient distortion that results in contact with live parts other than those connected in a Class 2 or LVLE circuit, and

c) Without development of openings that expose parts that involve a risk of electric shock or injury. Any openings resulting from the test are to be judged under the requirements for accessibility of 7.2.

8.15.2 The enclosure part is to be subjected to a 111 N (25 lbf) for 1 minute. The force is to be applied by means of a steel hemisphere 12.7 mm (1/2 in) in diameter.

8.15.3 The enclosure part is to be subjected to an impact of 6.8 J (5 ft-lb). The impact is to be applied by means of a smooth, solid, steel sphere 50.8 mm (2 in) in diameter and having 535 g (1.18 lb) mass. The sphere is to fall freely from rest through a vertical distance of 1.29 m (51 in).

8.16 Determination of low-voltage, limited-energy circuit status

8.16.1 LVLE circuits shall be limited in available current and voltage values as noted below, when tested according to other requirements of 8.16:

a) 8 amps for a voltage up to 42.4 V peak ac or 30 V dc, or

b) 150/V amps for a voltage between 30 – 60 V dc.

8.16.2 The input to the source under evaluation shall be connected as intended in the end product. The output to the circuit under evaluation shall be connected to a variable resistance load. If the source under evaluation has multiple outputs, all other outputs shall be open-circuited. The output voltage to the circuit under evaluation shall first be measured under open circuit conditions. The variable resistance load on the output under test shall then be adjusted from open circuit to short circuit until an available current of 8 A can be obtained and sustained for one minute of operation. If 8 A cannot be sustained for one minute under any condition of load, the test shall be discontinued.

8.16.3 When a secondary fuse or similar device is used to limit the output current to the circuit under evaluation, it shall be rated as indicated in Table 8.6. Any value may be used for a primary fuse; however, the maximum available output current levels shall be maintained. A fuse replacement marking (voltage and current rating) shall be provided adjacent to any fuse relied upon to limit the output current level, per 9.3.2.

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Table 8.6
Output limiting secondary fuse

Open circuit potential, V_{peak} or DC	Maximum fuse rating, amps
0 – 20	5.0
> 20 – 60	100 / V_{peak} or DC

8.16.4 When a fixed impedance or regulating network is used to limit the voltage and/or current, it shall limit the voltage and current accordingly under any single component fault condition.

8.17 Knockout secureness test

8.17.1 A force of 44 N (10 lbf) shall be applied to a knockout for 1 min by means of a 6.4 mm (0.25 in) diameter mandrel with a flat end. The force shall be applied to the exterior surface of the knockout, in a direction perpendicular to the plane of the knockout, and at the point most likely to result in movement.

8.17.2 The knockout shall remain in place, and the clearance between the knockout and the opening shall be no more than 1.6 mm (0.063 in) when measured after the force has been removed.

8.18 Abnormal switching test

8.18.1 Two test samples are prepared and connected as follows:

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

b) The general abnormal test procedures described in 8.7.1.1 are followed as applicable.

8.18.2 The prepared test samples shall be operated in accordance with the applicable endurance test requirements in the Standard for Industrial Control Equipment, UL 508, based on the load types noted in 7.9.3 using random switching. The test samples shall be operated until either the required number of endurance test cycles is achieved or until ultimate results are demonstrated for 1 hour stabilized duration.

8.18.3 Immediately after each abnormal switching test, each control shall be subjected to the dielectric voltage withstand test of 8.6.

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

a) No opening of the ground arc detection fuse.

b) No emission of the flame or molten metal, or ignition of the cheesecloth.

c) No opening of the branch circuit protection device.

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

8.19 Metal enclosure for conduit connection – rigidity

8.19.1 The enclosure shall be secured on a 12.7-mm (0.5-in) thick wood panel so that it is rigidly affixed to the wood panel. The panel dimensions shall extend beyond the junction box.

8.19.2 All enclosure covers shall be removed.

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8.19.3 The weight specified in Table 8.7 shall be attached to a conduit fitting that has been installed to the enclosure so the force is applied from inside the enclosure at the point most likely to result in deformation. The weight is attached by a wire or cord so that it does not contact any surface of the enclosure.

8.19.4 After 2 min, the weight shall be removed and any permanent deformation from the original shall be measured.

Table 8.7
Deformation forces

Number of conductors in or out	Force (lb)	
	12 AWG	14 AWG
1 or 2	15	14
More than 2	30	16

8.19.5 Permanent deformation of the enclosure, its hardware, or its attachment to the luminaire shall not exceed 3.2 mm (0.125 in).

8.20 Metal enclosure for conduit connection – snap-in or tab-mounted parts pull test

8.20.1 A length of rigid conduit shall be connected to the opening in the enclosure part to be tested. The total length of exposed conduit shall be 305 mm (12 in).

8.20.2 When the enclosure is intended for conduit connection, a 133-N (30-lb) force shall be applied for 1 min at the end of the conduit in a direction perpendicular to the plane of the enclosure part being tested.

8.20.3 A 45-N (10-lb) force shall be applied for 1 min at the end of the conduit in a direction parallel to the plane of the enclosure part being tested and in the direction most likely to dislodge the enclosure part.

8.20.4 Before and after each test, the enclosure shall comply with the bonding circuit impedance test of 8.21.

8.20.5 After each test, the enclosure part shall remain attached to the enclosure, and permanent deformation of the enclosure or its parts shall not exceed 3.2 mm (0.125 in).

8.21 Bonding circuit impedance test

8.21.1 The test apparatus shall be an ohmmeter or similar indicating instrument capable of measuring 0.10 Ω. The measured resistance between the point of connection of the branch circuit equipment grounding conductor and any non-current carrying metal parts of the enclosure shall not exceed 0.10 Ω.

8.21.2 If the resistance measured in 8.21.1 exceeds 0.10 Ω, the test of 8.21.3 shall be conducted.

8.21.3 The test apparatus shall consist of an indicating instrument and an ac or dc power supply of approximately 12 V providing a current of 30 A through the bonding means being evaluated. The measured voltage between the point of connection of the branch circuit equipment grounding conductor and any non-current carrying metal parts of the enclosure shall comply with 8.21.4.

8.21.4 The test of impedance shall be performed by passing a 30 A current from a part to be grounded to the grounding terminal means for a period of 2 min and measuring the potential drop between them at the end of the period.

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8.21.5 When tested in accordance with 8.21.4:

a) The resulting voltage drop shall not exceed 4.0 V,

b) There shall be no melting of any conductor or metal in the bonding circuit, and

c) There shall be no heating or burning that is likely to create a fire hazard.

8.22 Ground-screw assembly strength test

8.22.1 A 12 AWG (3.31 mm^2) solid-copper, insulated conductor shall be stripped to a length of 2.5 cm (1 in) minimum. The wire shall be wrapped around the screw under the screw head so that it makes a minimum 180-degree turn. The conductor shall be seated to follow any wire guides or dimples provided to align the conductor with the mating surface. The ground screw shall be tightened with a calibrated torque screwdriver to 1.6 N·m (14 lb-in).

8.22.2 When tested as described in this section, there shall not be:

a) Damage to the head of the ground screw which would prevent the 1.6 N·m (14 lb-in) of tightening torque to be achieved, or

b) Stripping of the ground screw assembly.

8.23 Bonding conductor tests

8.23.1 The bonding conductor path described in 7.2A.2.7 shall be subjected to the following tests.

a) A test current of 40 amperes for 2 minutes. Results are acceptable if the bonding conductor can carry this current for this duration. Also see 8.23.5 for additional acceptable results criteria; and

b) A limited-short-circuit test according to 8.23.2 – 8.23.4. Results are acceptable if the bonding conductor can carry the current until the fuse described in 8.23.3 opens. Also see 8.23.5 for additional acceptable results criteria.

Separate samples are to be used for each test, unless use of the same sample is acceptable to all parties involved.

8.23.2 The unit shall be prepared per 8.7.1.1 items (b) to (d) and (g).

8.23.3 The bonding conductor path shall be subjected to this test using the test current tabulated in Table 8.8 while connected in series with a 20A fuse as described in 8.7.1.1(f).

8.23.4 The test circuit is to have a power factor of 0.9 – 1.0 and a closed-circuit-test voltage equal to the maximum rated input voltage of the unit. The open-circuit voltage is to be 100 – 105 percent of the closed-circuit voltage.

8.23.5 During and following the test, the test shall not result in:

a) Emission of flame, molten metal, glowing or flaming particles through any openings;

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth;

c) Ignition of the enclosure;

d) Creation of any openings in the enclosure that results in accessibility of live parts;

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e) Evidence of degradation or separation of the trace from the printed-wiring board (when provided); or

f) Opening of the bonding conductor path or its solder connection.

Table 8.8
Circuit capacity for bonding conductor limited short-circuit test

Rating of unit, volt-amperes	Volts	Capacity of test circuit, amperes
0 – 1176	0 – 250	200
0 – 1176	251 – 600	1000
1177 – 1920	0 – 600	1000

9 Markings

9.1 General

9.1.1 A unit intended to be used in an application identified by one of the standards specified in 1.3 shall comply with the marking requirements of that standard. If an end-use application is not specified or identified, or if a construction or performance related marking of the unit is not covered by the identified standard, the unit shall comply with the marking requirements of this section.

9.1.2 A marking shall be legible, with minimum 1.6 mm (0.062 in) lettering and use one or more of the following methods:

a) Lettering on a pressure-sensitive label,

b) Paint stenciled lettering,

c) Ink-stamped machine lettering,

d) Ink-hand-stamped lettering,

e) Indelibly printed lettering,

f) Die-stamped lettering,

g) Embossed, molded, or cast lettering, raised or recessed a minimum of 0.010 in (0.25 mm) in depth,

h) Etched lettering,

i) Ink-jet lettering,

j) Laser engraving, or

k) Silk screening and transfer printing.

Exception: Identification and ratings markings in 9.2 are not subject to the minimum letter height requirement.

9.1.3 Pressure-sensitive labels and nameplates of the permanent type that are secured by adhesive shall comply with the Standard for Marking and Labeling Systems, UL 969, and be suitable for the mounting surface material and temperature involved, and the environment to which it will be subjected.

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9.1.4 Markings in this section are to be applied on the product, unless the specific clause provides other options (e.g. markings in an instruction sheet, or smallest unit container in which the product is packaged).

9.1.5 Markings permitted to be in an instruction sheet may be alternatively (or additionally) provided via a publicly accessible web site, if the equipment is marked as follows; See (specific URL or QR code inserted here) for additional supporting information for this product.

9.1.6 Markings that are provided in an instruction sheet (or a website), shall be sized in proportion to the other text presented in the same area.

9.1.7 When the product is evaluated per a Supplement in this standard, markings in this section apply along with additional markings in the Supplement.

Exception: This requirement does not apply to Supplement SD – LED packages.

9.1.8 When the product is evaluated per a Supplement in this standard, the required product markings from the Supplement are not subject to the minimum letter height requirements in 9.1.2 except where otherwise noted.

9.2 Identification and ratings

9.2.1 All units shall bear the following markings:

a) Company name,

b) Model designation,

c) Factory identification or code, for any component produced or assembled at more than one factory, and

d) Date of manufacture.

9.2.2 LED controllers shall be provided with markings (a) through (e). LED drivers and power sources shall be provided with markings (a) through (d):

a) Environmental suitability (dry, damp, or wet location),

b) Input supply limitations (e.g., Class 2 input only), if applicable,

c) Input supply ratings: Voltage (V), Nature of supply (AC or DC; Constant Current or Constant Voltage), Frequency (if applicable), Current (A), and Power (W),

Note 1: For LED drivers with a feedthrough receptacle, input supply ratings shall include the current/ power draw from the feedthrough output.

d) Output ratings: Voltage (V), Nature of supply (AC or DC; Constant Current or Constant Voltage), Frequency (if applicable), Current (A). and Power (W), and

Note 2: Feedthrough receptacles are treated as an output of the LED driver in this standard.

Note 3: When the output can be programmed, ratings ranges for each parameter shall be provided on the product.

e) Output load type(s) for LED controllers.

Exception No. 1: For built-in products, this information may be provided in an instruction sheet.

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Exception No. 2: When the device is marked for a specific load (i.e. by manufacturer's name and model number), items (d) and (e) are omitted.

Exception No. 3: When the device includes a light source (i.e. light engine) and has no supply output, items (d) and (e) are omitted.

9.2.3 Each output of a power source or controller intended to supply a Class 2 circuit shall comply with 7.12 and be marked "Class 2."

9.2.4 *Deleted*

9.2.5 An LED array (module) shall be marked with the following:

a) Environmental suitability (dry, damp, or wet location),

b) Input limitations (i.e., Class 2 input only), if applicable, and

c) Input supply ratings:

1) For constant voltage: voltage, nature of supply (AC, DC), power (W), and frequency (if applicable).

2) For constant current: current, nature of supply (AC, DC), power (W), and frequency (if applicable).

Exception: For built-in products, this information may be provided in an instruction sheet.

9.2A Instruction sheet

9.2A.1 LED equipment shall be provided with an instruction sheet to describe the following; intended function, electrical and environmental location ratings, recommended installation method(s) and mounting hardware, wiring diagrams and any other information necessary for proper integration into LED luminaires and lighting systems.

9.2A.2 When the output of a LED controller, LED driver, or a power source can be programmed, the technical details to identify the relationship between the programmed output parameters shall be provided in the instruction sheet (e.g. a curve or table that clarifies how output voltage will vary based on output current setting).

9.3 Construction-related markings

9.3.1 The instruction sheet for a unit that employs push-in terminals shall additionally include the following information:

a) For releasing the wire from the terminal connection,

b) The intended wire size(s),

c) Whether the terminal is intended for both solid and stranded or just solid wire,

d) The length to strip the insulation from conductors, and

e) The terminal relationship to the internal circuitry.

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9.3.2 Where required, a fuse replacement marking shall be provided on or adjacent to the fuseholder, and shall identify the appropriate fuse type and ampere rating.

9.3.3 When the temperature on any surface within a terminal compartment or splice compartment exceeds 60°C (140°F) during the temperature test of 8.3, a unit shall be marked with the following statement or the equivalent, located so that it is readily visible when connections are made: “For Connections Use Wire Rated for at Least _____,” in which the temperature is to be either 75°C (167°F) or 90°C (194°F) as determined by the temperature test.

9.3.4 *Deleted*

9.3.5 *Deleted*

9.3.6 A metal enclosure for conduit connection that is not intended for pulling conductors shall be marked "FOR CABLE USE ONLY – NOT FOR PULLING WIRES" or equivalent.

9.3.7 When the Exception to 8.9.1 has been applied, the unit shall be marked "For use in permanently connected (fixed) equipment only" or the equivalent.

Exception: For built-in products, this information may be provided in the instruction sheet.

9.3.8 LED drivers with a feedthrough receptacle (or a supply cord terminating in a receptacle) shall be marked:

a) “Max ‘X’ model ‘Y’ units”, where the ‘X’ identifies the maximum permitted number of identical units from the same manufacturer, and ‘Y’ identifies the model number, and/or

b) “Max ‘X’ amps” or “Max ‘X’ watts”, where ‘X” identifies the maximum permitted electrical load.

9.3.9 The instruction sheet for a LED driver with a feedthrough receptacle (or a supply cord terminating in a receptacle) shall include the manufacturer's recommendations for its proper use (e.g. intended use, output ratings and maximum electrical load (current, power), acceptable number of units that can be supplied from the same supply source, considerations for load distribution, cumulative leakage currents, etc.).

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SUPPLEMENT SA – REQUIREMENTS FOR SAFETY-RELATED ELECTRONIC CIRCUITS

SA1 Scope

SA1.1 These requirements apply to safety-related electronic circuits. Bold text in Section SA3 identifies defined terms from Section SA2.

SA1.2 These requirements are not intended to serve as the sole basis for evaluating risk. End-product requirements may amend or supersede these requirements, as appropriate.

SA2 Definitions

SA2.1 CRITICAL CONTROL FUNCTION – A function performed by a discrete component or a component network whose primary purpose is normal operation of the product, but whose failure could cause the device to exceed the electrical or thermal limits for normal operation as defined in its product standard. An example would be a dimming function that operates by controlling output current, where a circuit fault causes the device to exceed the maximum acceptable temperature limits defined in the end-product standard (e.g.: normal temperature test).

SA2.2 CRITICAL FAILURE (MODE) – A software or hardware fault which can result in a risk.

SA2.3 PRODUCT – The device into which the safety-related electronic circuit is integrated.

SA2.4 PROGRAMMABLE COMPONENT – Any microelectronic hardware that can be programmed in the design center, the factory, or in the field. Here the term "programmable" is taken to be "any manner in which one can alter the software wherein the behavior of the component can be altered." This includes discrete components (e.g.: microcontrollers, memory storage ICs) that store or execute software instructions in response to thermal or electrical conditions.

SA2.5 PROTECTIVE COMPONENT – A discrete component or component network that has been separately evaluated to reliably perform a protective function. Examples of such components include thermal protectors evaluated to the Standard for Automatic Electrical Controls for Household and Similar Use, Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9 and fuses evaluated to the Standards for Low-Voltage Fuses, UL 248, series of standards.

SA2.6 PROTECTIVE FUNCTION – A function performed by a discrete component or component network relied upon to reduce risk during abnormal operating conditions. Examples include functions that:

a) Limit or reduce power in response to elevated ambient conditions or discrete component failures, analogous to the function of a thermal protector in recessed luminaires,

b) Disconnect power in response to the opening of a service compartment access panel, analogous to the function of a mechanical interlock switch to prevent contact with a hot surface or high voltage circuit during maintenance,

c) Limit or reduce available voltage or current at accessible terminals during routine maintenance, such as at the pins of a lamp or lamp holder during lamp replacement, and

d) Maintain electrical outputs within limits defined as non-hazardous during abnormal operation, such as those defined for Class 2 or low-voltage limited-energy (LVLE) power sources.

SA2.7 RISK – The unacceptable potential for fire, electric shock, or injury to persons as defined by the product standard of the device being evaluated.

SA2.8 SAFETY-RELATED SOFTWARE – Computer programs, procedures, and data resident on the hardware or remotely interactive with the hardware pertaining to the operation of a programmable component that provides safety-related elementary functionality as follows:

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a) Exercises direct control over the state of microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data are capable of resulting in a risk.

b) Monitors the state of microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data provide data that is capable of resulting in a risk.

c) Exercises direct control over the state of the microelectronic or product hardware. When not performed, performed out of sequence, or performed incorrectly, such programs, procedures, and data are capable of, in conjunction with other human actions, product hardware or environmental failure, resulting in a risk.

SA2.9 SAFETY-RELATED ELECTRONIC CIRCUIT – An electronic circuit that implements one or more control or protective functions. These circuits may incorporate any combination of active, passive, programmable, and protective components or semiconductors.

SA3 General

SA3.1 To ensure an acceptable level of circuit redundancy or supervision, **safety-related electronic circuits (SREC)** shall be subject to the reliability evaluation in SA4.

*Exception: **SRECs** that comply with SA3.2 and SA3.3 are exempt from this requirement.*

SA3.2 A design review of the **SREC** shall be conducted to determine if all the conditions below are true.

a) All **critical failure modes** that can occur in the **SREC** hardware due to any discrete component or integrated circuit fault can be identified, simulated and applied via a suitable FMEA or other circuit analysis methods (complexity of the circuit);

b) All **critical failure modes** that can occur in the **SREC** due to a software fault or defect that affect the **critical control function** or **protective function** of the **SREC** can be identified, simulated and applied to determine if the software is relied upon for a **critical control function** or **protective function** to work properly. This assessment does not require an analysis of the software itself; rather this is an analysis of all **critical failure modes** of the **SREC** due to software faults (complexity of the circuit and software);

SA3.3 If the design review in SA3.2 indicates that all of the conditions are true, then all product tests shall be conducted using special samples with each of the **critical failure modes** identified in SA3.2 applied, in turn, in the manner likely to result in the most adverse operating condition for each test.

a) The single component faults or simulated software faults **(critical failure modes)** applied to either a **critical control function** or **protective function** shall not lead to unacceptable test results (e.g. temperatures above permissible limits; voltage, current or power levels above permissible limits at a Class 2 output; etc.) or create a **risk** during any applicable test outlined in UL 8750 or the end-product standard. See (b) – (d) below for additional details.

b) When the product test is an abnormal condition test, this **SREC** fault is in addition to the component faults or abnormal conditions required by the test.

c) The product under test need not function normally during these tests provided there is no **risk**.

d) Testing will require consideration for several **critical failure modes** and the fault type may differ from test to test. To manage the total number of test conditions, based on the design review, tests that will represent the most onerous conditions can be selected.

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SA4 Reliability Evaluation

SA4.1 Safety-related electronic circuits shall be evaluated to the requirements of the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; including Annex H: Requirements for Electronic Controls. Safety-related electronic circuits that do not rely on safety-related software need not comply with Clause H.11.12.

SA4.2 When a product contains a safety-related electronic circuit intended to provide the function of thermal protection in recessed luminaires, it shall additionally comply with the Automatic Electrical Controls for Household and Similar Use, Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

SA4.3 In reference to SA4.1, and unless specifically superseded by a relevant Part 2 standard, the following parameters apply from Annex H in the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1:

a) Safety-related software shall be evaluated as Software Class B.

b) The Thermal Cycling test shall be performed using the ambient operating temperature range designated by the manufacturer or the temperature parameters below, whichever are more severe:

1) The lower parameter shall be -35°C (-31°F) for wet location products, 0°C (32°F) for damp location products, and 10°C (50°F) for all other products; and

2) The upper parameter shall be 40°C (104°F).

c) When evaluating for compliance with the EMC Requirements – Immunity:

1) Protective circuits are considered Type 2 Protective Controls; and

2) Critical control circuits are considered Type 2 Operating Controls.

d) The Test of Influence of Voltage Unbalance is not applicable.

e) For the Ring Wave test, use Overvoltage Category III.

f) The Test of Influence of Supply Frequency Variations is not applicable if the safety-related electronic circuit does not rely on the power line frequency for timing or control.

g) The Power Frequency Magnetic Field Immunity test is not applicable if the safety-related electronic circuit does not rely on Hall-effect devices, such as current-sensing transformers.

SA4.4 With regard to the Evaluation of Compliance in Annex H:

a) The requirements in the product standard applicable to creepage, clearance and dielectric voltage withstand shall be used when they are more severe; and

b) As a result of each test, the product incorporating the safety-related electronic circuit shall not exhibit a risk and either:

1) Continue to function as intended with no degradation to the critical control or protective functions (i.e.: normal performance with no loss of protective functions);

2) Cease to function, with normal function restored by an automatic, user-resettable or user-replaceable protective component or function such as an automatic or manual-reset protector, a fuse replacement, or cycling the power to the product (i.e.: loss of protective function with safety shut down); or

3) Cease to function permanently.

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SUPPLEMENT SB – REQUIREMENTS FOR TYPE HL LED DRIVERS

SB1 Scope

SB1.1 This Supplement has explosion protection by encapsulation requirements for LED drivers that are intended for use in a Class I, Division 2 hazardous (classified) location luminaires. LED drivers which meet the requirements in this supplement are identified as Type HL.

Note: These requirements provide only one option for evaluation of LED drivers that are intended for use in hazardous (Classified) location luminaires. LED drivers that do not comply with the requirements of this Supplement can be evaluated for hazardous (classified) location applications per alternate requirements in the Standard for Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations, ANSI/ISA-12.12.01. These alternate requirements provide options for compliance that cannot be addressed by this Supplement.

SB2 Construction

SB2.1 A Type HL LED driver shall comply with all applicable construction requirements of this standard.

SB2.2 *Deleted*

SB2A Explosion Protection by Encapsulation Construction

SB2A.1 A Type HL LED driver provides a Class I, Division 2 means for explosion protection when all parts are fully encapsulated by being fully submerged in potting compound, unless otherwise permitted by this Supplement. Such fully potted constructions provide a seal for the potential sources of ignition from the flammable atmosphere.

SB2A.2 Parts that shall be fully submerged in potting compound include the body and leads of all capacitors, potentiometers, relays/switches, transformers, inductors, coils, resistors, diodes, and printed wiring boards. Such parts shall not be visible or accessible external to the potting compound for any reason, including adjustments. Potentiometers shall not be permitted to be accessible external to the potting compound. Exposed integral functioning antennae shall not be permitted to be marked Type HL, as such an antennae presents a risk of explosion and requires an evaluation in accordance with the Standard for Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations, UL 121201, for Class I, Division 2.

SB2A.3 Parts that may be visible and accessible external to the potting compound are limited to the following:

a) Cords, cables, leads and their terminals for input or output power,

b) Terminals for wired control and antenna interconnection, and

c) The portion of a printed wiring board on which the parts detailed in (a) and (b) may be terminated.

For cords, cables and leads for input or output power that enter directly into the potting compound, it is not necessary to remove any outer jacket from around the cords, cables or leads at the point of entry into the potting compound.

SB2A.4 Batteries and battery packs are not permitted in this Supplement. LED drivers with batteries and battery packs for Class I, Division 2 applications are covered under the Standard for Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations, UL 121201.

SB2A.5 Compliance with this Supplement is determined by visual examination, in particular that all parts in accordance with SB2A.2 are fully submerged in potting compound, with no visible gaps or breaks.

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SB3 Performance

SB3.1 A Type HL LED driver shall comply with all applicable performance requirements of this standard.

SB4 Marking

SB4.1 *Deleted*

SB4.2 An LED driver may be marked “Type HL” if it complies with the requirements of this supplement. The marking may be provided on the LED driver, the smallest shipping container, or in the instruction sheet.

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SUPPLEMENT SC – REQUIREMENTS FOR TEMPERATURE LIMITED (TYPE TL) LED DRIVERS

SC1 Scope

SC1.1 These requirements apply to Temperature Limited (Type TL) LED drivers.

SC2 Definitions

SC2.1 CALCULATED $T_{ref\ max}$ – The calculated temperature limit for the LED driver at T_C under normal operating conditions.

SC2.2 MEASURED T_{ref} – The measured temperature at T_C under normal operating conditions.

SC2.3 TEMPERATURE MEASUREMENT POINT, T_C – A specific temperature measurement location assigned by the manufacturer on the LED driver case (exterior surface).

SC2.4 $T_{ref\ max}$ – The temperature limit for the LED driver at T_C, under normal operating conditions, as assigned by the manufacturer.

SC3 Construction

SC3.1 A Type TL LED driver shall comply with all applicable construction requirements of this standard and the following criteria to facilitate parity amongst LED drivers that meet thermal profile requirements of this Supplement:

a) The driver shall not rely upon external overcurrent or over temperature protection for compliance with requirements of this standard;

b) The driver shall not rely upon external heat management methods such as forced air cooling or non-integral heat-sinking or external temperature sensors for compliance with requirements of this standard;

c) The driver shall be provided with both an integral fire and electrical enclosure in accordance with the applicable requirements described in Section 6;

Exception No. 1: A driver with wiring leads, terminals, or push-in terminals.

Exception No. 2: A driver that is intended for installation on or over an outlet box, in areas where the outlet box will serve to complete the enclosure of the equipment under test.

d) The driver shall be provided with supply connections that comply with 7.4.1 and one of the methods described in 7.4.2 (i.e., conduit connection, wiring leads, terminals, or push-in terminals). The driver shall be provided with load connections that comply with 7.4.1 and 7.4.4; and

e) Drivers that are not otherwise restricted by requirements in 6.4 may have openings as follows:

1) Circular openings have a diameter not exceeding 3 mm (0.12 in) and minimum spacing between circular openings is 3 mm (0.12 in);

2) Rectangular (or square) openings have dimensions not exceeding 3 mm (0.12 in) across and 30 mm (1.18 in) in length; and

3) The pattern of openings for metal enclosures is such that the through air spacings (clearance) between live parts and the dead metal enclosure is not reduced below the values specified in Electrical Spacings, 7.8, when the enclosure is subjected to the Mechanical Strength Tests for Metal Enclosures, 8.15. The pattern of openings for polymeric enclosures is not specified.

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SC4 Performance

SC4.1 A Type TL LED driver shall comply with all applicable performance requirements of this standard and the requirements in this section (SC4.2 – SC4.5, temperature testing, SC4.6 – SC4.8, abnormal testing, and SC4.9, leakage current measurement testing).

SC4.2 During the Temperature Test per Section 8.3, temperatures at T_C and other exterior surface test points are monitored. Testing is performed at ambient temperatures noted in Table 8.2. The Measured T_{ref} and the Calculated $T_{ref\ max}$ value is determined as follows:

a) The temperature measured at T_C is normalized per 8.3.4 as necessary. The result is designated as the Measured T_{ref}. When the driver is subject to multiple temperature tests based on the requirements of this standard, the highest Measured T_{ref} value is designated.

b) The difference between the maximum permitted temperature (per Table 8.1 and SC4.4) and the measured temperature is calculated for each component (T_C and other exterior surface test points ΔT_1. . . ΔT_n). The values are normalized per 8.3.4 as necessary. The smallest difference is designated ΔT. When the driver is subject to multiple temperature tests based on the requirements of this standard, the Calculated ΔT values shall be determined for each test ΔT_{t1}. . . ΔT_{tn}. The lowest value for all tests is ΔT.

c) This ΔT is added to the Measured T_{ref} at T_C. The result is designated as the Calculated $T_{ref\ max}$.

d) The Measured T_{ref} and the Calculated $T_{ref\ max}$ values are to be rounded to the nearest 1° C (1.8°F).

SC4.3 The $T_{ref\ max}$ value shall not exceed the Calculated $T_{ref\ max}$ value.

SC4.4 The maximum permitted temperature for Measured T_{ref} and $T_{ref\ max}$ is 90°C (194°F).

SC4.5 The maximum permitted temperature for the exterior surface plus the ΔT calculated in SC4.2 is 90°C (194°F).

SC4.6 Abnormal Tests shall be performed at any ambient-air temperature within ±5°C (±9°F) of the value noted in Table 8.2. The variation from the value noted in Table 8.2 shall be added to or subtracted from the observed temperature readings. When tests terminate in less than 30 minutes, the tests may be performed at ambient temperatures of 25 ±5°C (77 ±5°F).

SC4.7 During the Abnormal Tests, Section 8.7, exterior surface temperatures shall not exceed 110°C (230°F). These limits apply to:

a) Component failure tests which continue 30 minutes or longer, and

b) Output loading test conditions which continue 30 minutes or longer.

SC4.8 The exceptions to 8.7.2.1 (component failure test) do not apply for a Type TL LED driver.

SC4.9 The exception to 8.9.1 (leakage current test) does not apply for a Type TL LED driver.

SC5 Marking

SC5.1 *Deleted*

SC5.2 An LED driver that complies with the requirements of this supplement shall be marked with a specified T_C point location.

SC5.3 An LED driver that complies with the requirements of this supplement may be marked “Type TL.”

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SC5.4 When an LED driver is marked “Type TL,” the $T_{ref\ max}$ and Measured T_{ref} values shall be marked on the LED driver in one of the following formats:

“T_C XX/YY °C,” or

“Type TL XX/YY °C,”

Where XX is the $T_{ref\ max}$ temperature value, and YY is the Measured T_{ref} temperature value in °C.

SC5.5 A driver with wiring leads, terminals, or push-in terminals shall be marked "Use only within an enclosure" or equivalent. The marking may alternatively be provided in the instruction sheet.

Exception: A driver that is intended for installation on or over an outlet box.

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SUPPLEMENT SD – REQUIREMENTS FOR LIGHT EMITTING DIODE (LED) PACKAGES

SD1 Scope

SD1.1 These requirements apply to light emitting diode packages. These requirements are intended for the evaluation of LED packages as components. Additional considerations may be necessary as LED packages are integrated into end devices. Figure SD1.1 (single emitter) and Figure SD1.2 (multiple emitters) depict typical LED package constructions. Different designs will vary in that:

a) Not all elements may be present, and

b) The elements may not be positioned as shown.

Figure SD1.1

Typical LED package construction – single emitter

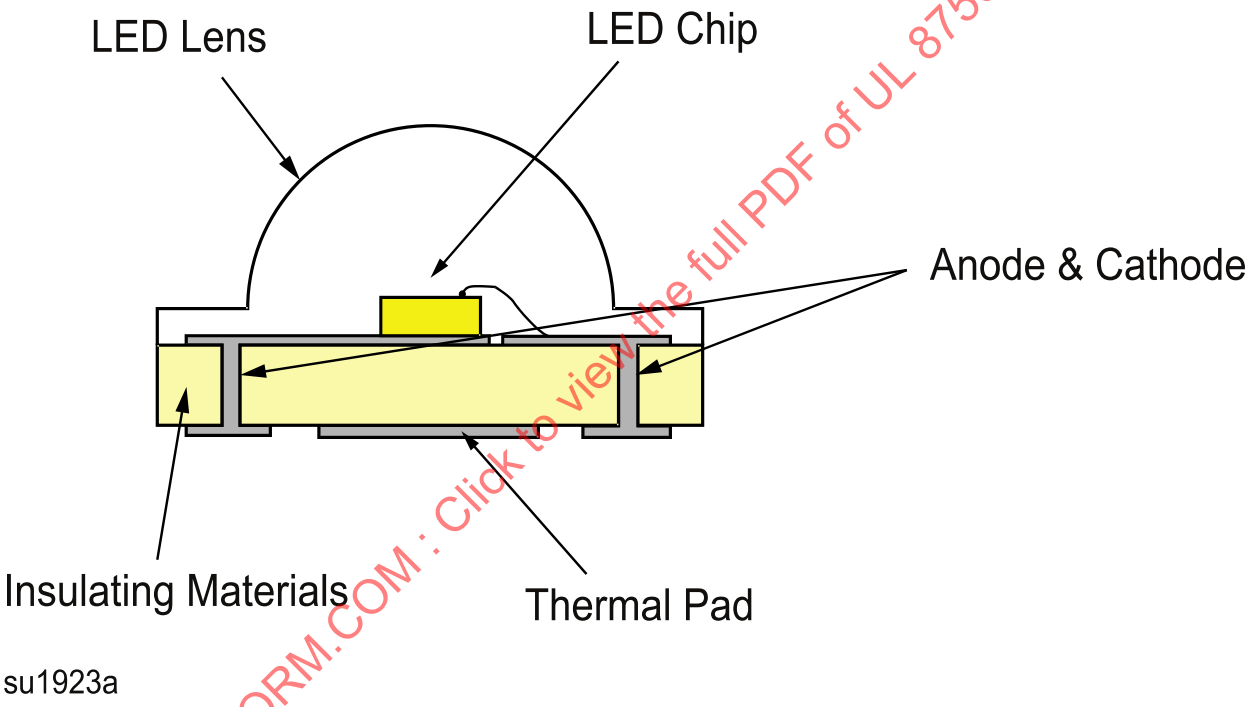

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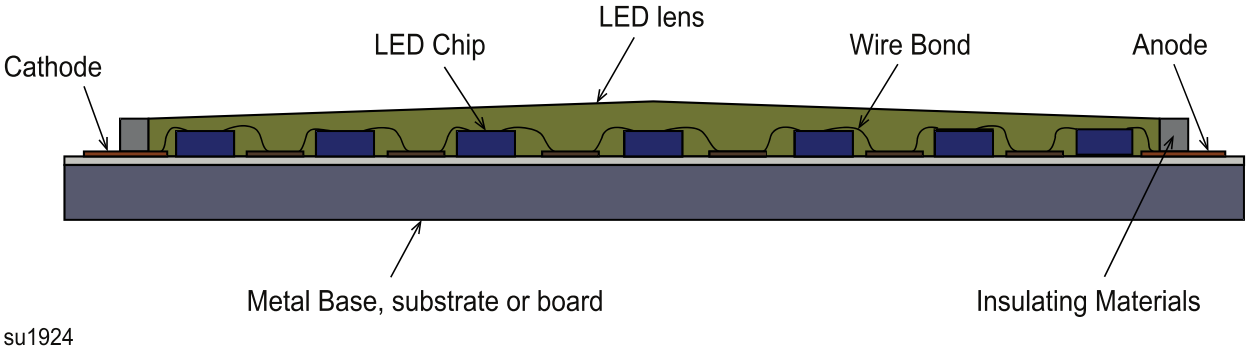
Figure SD1.2

Typical LED package construction – multiple emitters



SD2 Definitions

SD2.1 ENCLOSURE – Refers to parts of a Component LED package that are intended to form part of the final fire or electrical enclosure for the end device.

SD2.2 INSULATING MATERIALS – Any material providing electrical insulation between the LED package supply contacts (anode and cathode) and the following parts of an LED package based on the construction presented:

a) Thermal pad,

b) Metal base, and

c) LED package parts designated by the manufacturer as suitable to form part of an enclosure.

SD2.3 ISOLATION VOLTAGE – The maximum voltage (RMS) between the LED package supply contacts (anode and cathode) and the following parts of an LED package based on the construction presented:

a) Thermal pad,

b) Metal base, and

c) LED package parts designated by the manufacturer as suitable to form part of an enclosure.

The default Isolation Voltage is the forward voltage when the LED package is operated at rated forward current, as specified by the manufacturer. The manufacturer may designate a higher value.

SD2.4 LED LENS – An integral part of an LED package through which light is emitted.

SD2A Ratings

SD2A.1 Construction, performance and marking criteria in this Supplement are based on the following ratings as designated by the manufacturer:

a) Environmental (dry, damp, or wet location),

b) Input supply (non-isolated, isolated, Class 2),

c) Electrical and thermal (e.g. Maximum Forward Voltage, Junction Temperature),

d) Suitability to form part of an enclosure, and

e) Spectral Power Distribution Characteristics (as graph or data-set).

Exception: Item (e) is not required when the LED package operates in the visible light spectrum only.

SD2B Reference Publications

SD2B.1 In addition to those in the main body of this standard, the following normative references apply:

a) IEC 62471:2006, *Photobiological safety of lamps and lamp systems*;

b) IEC/TR 62471-2:2009, *Photobiological Safety of Lamps and Lamp Systems – Part 2: Guidance on Manufacturing Requirements Relating to Non-Laser Optical Radiation Safety*

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SD3 Environmental Considerations

SD3.1 Humidity conditioning

SD3.1.1 LED packages designated by the manufacturer for the characteristics tabulated below shall be exposed for 168 hours to moist air having a relative humidity of 88 ±2 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F) followed by the dielectric voltage withstand test in Dielectric Voltage Withstand Test, Section SD6:

a) Suitable for damp or wet locations, and

b) Suitable for operation from other than Class 2 circuits.

SD3.2 Dry locations

SD3.2.1 LED packages designated by the manufacturer for the characteristics tabulated below shall be subjected to the Steady Force Test, Section SD7:

a) Suitable for dry locations,

b) Suitable for operation from other than Class 2 circuits, and

c) Suitable to form part of an enclosure.

Exception: LED lens securement using integrally-molded compounds or fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding are permitted without test.

SD3.3 Damp locations

SD3.3.1 LED packages designated by the manufacturer for the characteristics tabulated below shall be subjected to cold conditioning for 24 hours at 0.0 ±1.0°C (32.0 ±1.8°F) to be followed by the Steady Force Test, Section SD7:

a) Suitable for damp locations,

b) Suitable for operation from other than Class 2 circuits (dry and damp location limits), and

c) Suitable to form part of an enclosure.

SD3.4 Wet locations

SD3.4.1 LED packages designated by the manufacturer for the characteristics tabulated below shall be subjected to cold conditioning for 24 hours at minus 35.0 ±2°C (minus 32.0 ±3.6°F) to be followed by the Steady Force Test, Section SD7:

a) Suitable for wet locations,

b) Suitable for operation from other than Class 2 circuits (wet location limits), and

c) Suitable to form part of an enclosure.

SD4 Construction

SD4.1 Spacings

SD4.1.1 LED packages designated by the manufacturer as suitable for operation from other than Class 2 circuits shall be evaluated for spacings (distances between current-carrying parts) using the Dielectric Voltage Withstand Test, Section SD6.

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SD4.2 Printed Wiring Boards (PWBs)

SD4.2.1 PWBs of LED packages that are designated by the manufacturer as suitable for operation from other than Class 2 circuits shall comply with the Standard for Printed Wiring Boards, UL 796, with maximum operating temperature (MOT) and flame ratings as noted in SD4.3.1 and SD4.4.1, respectively.

Exception No. 1: Ceramic substrates with patterned metal electrical vias are not subject to this requirement.

Exception No. 2: PWBs meeting both exceptions in SD4.3.1 and SD4.4.1 need not comply with the Standard for Printed Wiring Boards, UL 796.

SD4.3 Polymeric and other insulating materials – Relative Thermal Index (RTI)

SD4.3.1 Polymeric and other insulating materials shall have relative thermal index (RTI) or the generic thermal index ratings which are equal to or exceed the manufacturer-designated LED package maximum junction temperature. PWBs shall have maximum operating temperature (MOT) ratings which are equal to or exceed the manufacturer-designated LED package maximum junction temperature.

Exception No. 1: Ceramic substrates are not subject to this requirement.

Exception No. 2: LED packages that comply with Thermal Aging, Section SD8, need not comply with this requirement.

SD4.4 Polymeric and other insulating materials – Flame rating

SD4.4.1 Polymeric and other insulating materials and PWBs of an LED package that is designated by the manufacturer as suitable for operation from other than Class 2 circuits shall have a minimum flammability rating of V1 or VTM-1 in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: If the total volume of polymeric and other insulating materials in an LED package is 2500 mm^3 (0.15 in^3) or less, the requirement does not apply. In calculating the total volume, contributions from the following materials can be subtracted as applicable:

a) Metal bases of PWBs,

b) Mica,

c) Ceramic, and

d) Polymeric materials that are flame rated V-1, VTM-1, or better.

SD5 Performance

SD5.1 Tests in Sections SD6 – SD9 apply when specified by requirements in Sections SD3 and SD4.

SD6 Dielectric Voltage Withstand Test

SD6.1 The insulating materials of an LED package that is designated by the manufacturer as suitable for operation from other than Class 2 circuits shall withstand for one minute, without breakdown, the AC test potential specified in Table SD6.1, where V is the Isolation Voltage. The test may be conducted using a DC test potential at 1.414 times the AC test potential denoted in Table SD6.1.

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Table SD6.1
Dielectric voltage withstand potential

Test potential, V AC	Designated by the manufacturer as suitable for operation from
2V + 1000	Non-isolated input circuits where V is greater than 70 V peak
2V + 500	Isolated circuits where V is greater than 70 V peak
500	Non-isolated and isolated circuits where V is 70 V peak or less

[a] Non-isolated input circuits are connected to the branch circuit.

[b] Isolated circuits are separated from the branch circuit using magnetic, capacitive, or optical isolation. A low voltage circuit derived from the branch circuit by a dropping element (galvanic connection to the primary) resistor is not isolated.

SD6.2 The dielectric withstand test equipment shall employ a transformer of 500-VA or larger capacity and have a variable output voltage that is essentially sinusoidal or continuous direct current. The applied potential is to be increased from zero at a substantially uniform rate until the required test level is reached, and is to be held at that level for 1 minute.

Exception: A 500-VA or larger capacity transformer is not required if the transformer is provided with a voltmeter to measure directly the applied output potential.

SD6.3 The LED package is to be mounted by the manufacturer, on a PWB assembly to represent the recommended mounting and solder methods. The PWB assembly shall include appropriate electrical connection means to the LED package anode, cathode, thermal pad or metal base, or both, so the dielectric tester test leads can be properly connected to these points.

SD6.4 The test shall be conducted with the anode and cathode connected together to one of the dielectric tester test leads. This test shall be performed between this connection and the following:

a) LED package parts designated by the manufacturer as suitable to form part of an enclosure, when applicable, and

b) Thermal pad (or LED package metal base, or both), when applicable.

SD6.5 For test conditions involving LED package lens [see SD6.4(a)] or any other non-conductive LED package part that is designated by the manufacturer as suitable to form part of an enclosure, the test is to be conducted using a moveable cylindrical brass or stainless steel rod 6.4 mm (1/4 in) in diameter, with edges rounded to a 0.8-mm (1/32-in) radius. The electrode is to weigh 50 ±2 g (1.8 ±0.7 oz).

SD6.6 Test is to be conducted by placing LED package directly under the probe with the accessible surface of the LED package part being evaluated in direct contact with the bottom of the flat surface of the 6.4-mm (1/4-in) diameter probe described above. Care should be taken to assure that full weight of the probe is supported by the surface being evaluated.

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SD7 Steady Force Test – 30 N

SD7.1 The test shall be conducted on three samples.

SD7.2 Using the test finger shown in Figure SD7.1, the LED lens on the package shall be subjected to the test described in SD7.4.

SD7.3 Prior to the test in SD7.4, the LED package is to be mounted by the manufacturer, on a PWB assembly to represent the recommended mounting and solder methods. The PWB assembly is to be placed on a hard, flat surface and restrain it from moving during the test.

SD7.4 The test probe is placed at 45 degrees from horizontal and in contact with the LED lens as follows:

For LED packages with domed or raised lenses with tip of the test probe in contact with lens and longitudinal axis of the test probe running through the center of the LED package, see Figure SD7.3.

For LED packages with flat lens the tip of the probe shall contact center of the lens surface being evaluated, see Figure SD7.4.

A steady force of 30 ±3N for a period of 5 seconds is applied along the longitudinal axis of the finger probe.

During the test the finger probe is to be restrained from moving in any direction other than along its longitudinal axis.

SD7.5 Test results are considered acceptable if:

a) A visual inspection does not show damage or displacement of the LED lens, and

b) A subsequent dielectric test, performed per SD6, achieves acceptable results.

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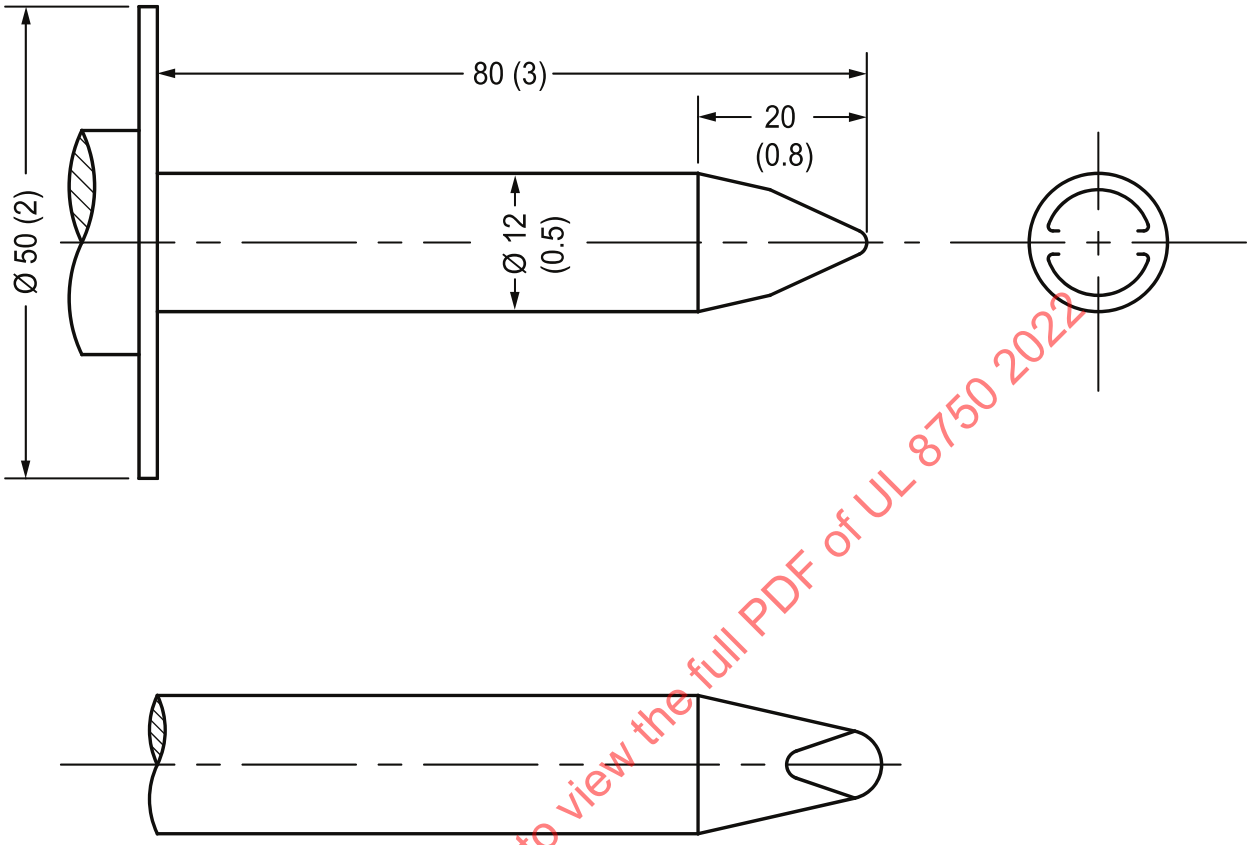
Figure SD7.1

Finger probe



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Notes:

a) This test finger is test probe 11 of Figure 7 in the Protection of Persons and Equipment by Enclosures – Probes for Verification, IEC 61032. Dimensions are in millimeters (inches).

b) See Figure SD7.2 for probe tip dimensional requirements that are not specified in this figure.

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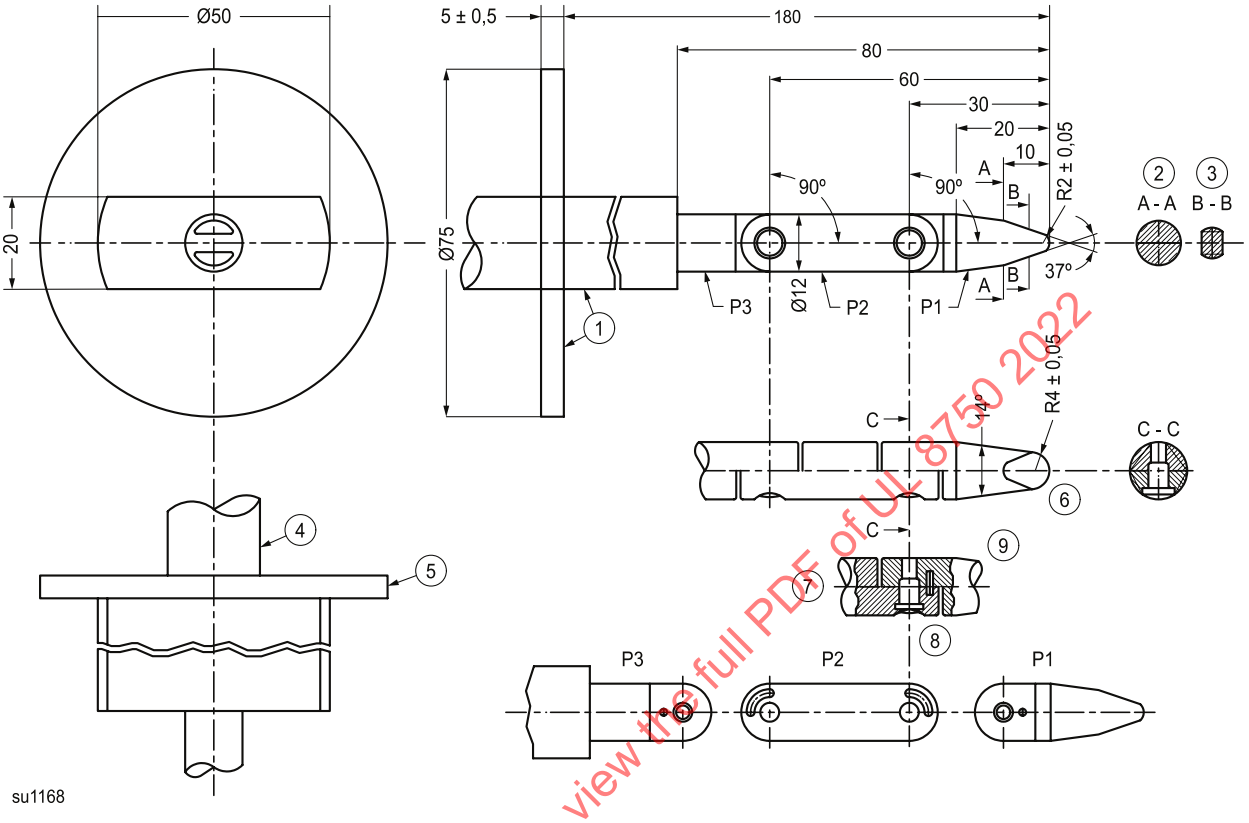
Figure SD7.2
Jointed test finger



Key

1 insulating material
2 section AA
3 section BB
4 handle
5 stop plate
6 spherical
7 detail x (example)
8 side view
9 chamfer all edges

Dimensions in millimetres

Tolerances on dimensions without specific tolerance:

– on angles: $^{0}_{-10'}$
– on linear dimensions:
  up to 25 mm: $^{0}_{-0,05}$ mm
  over 25 mm: ±0,2 mm

Material of finger: heat-treated steel, etc.

Both joints of this finger may be bent through an angle of $(90\ ^{+10}_{0})°$, but in one plane only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason, dimensions and tolerances of these details are not given in the drawing. The actual design shall ensure a $(90\ ^{+10}_{0})°$ bending angle.

Note: This test finger is the same as test probe B of IEC 61032, Figure 2.

Note: The jointed test figure is only referenced in note b of Figure SD7.1. Figure SD7.2 is being included as it contains probe tip dimensional requirements that are not specified in Figure SD7.1.

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Figure SD7.3
LED packages with domed or raised lens

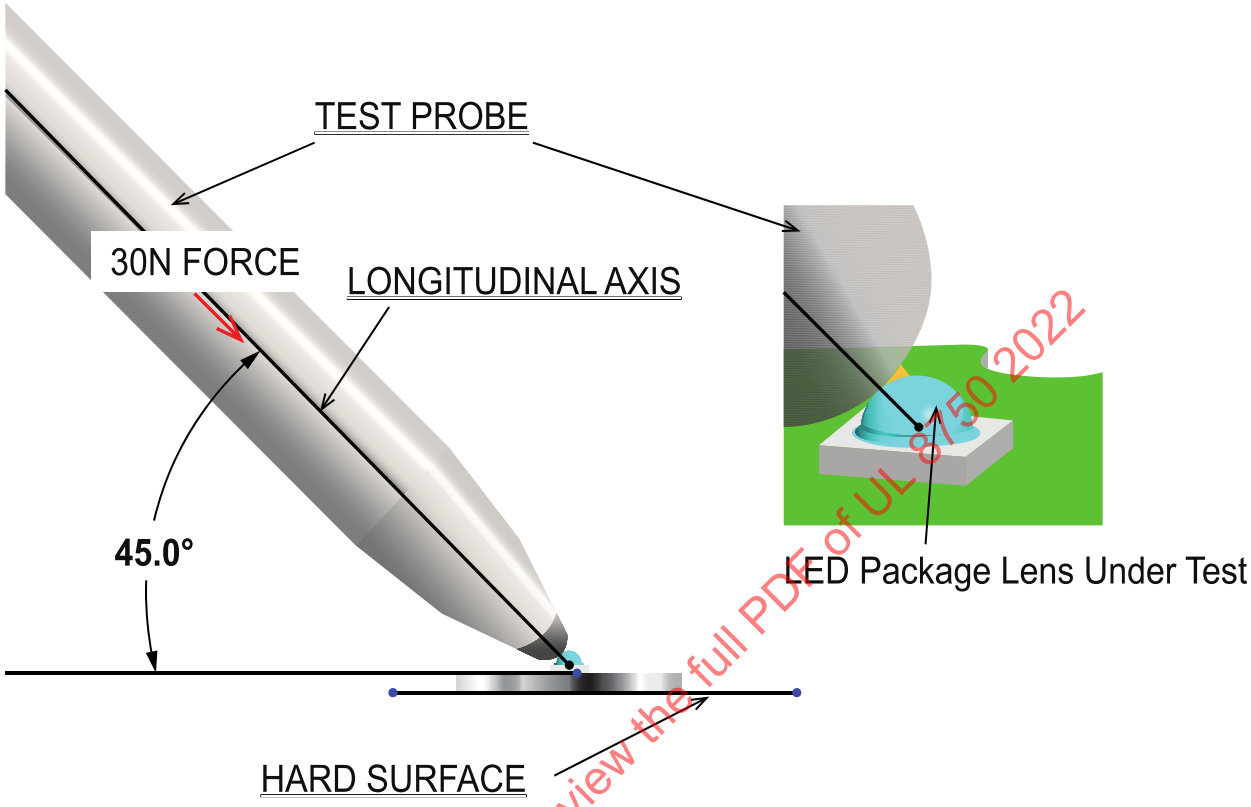

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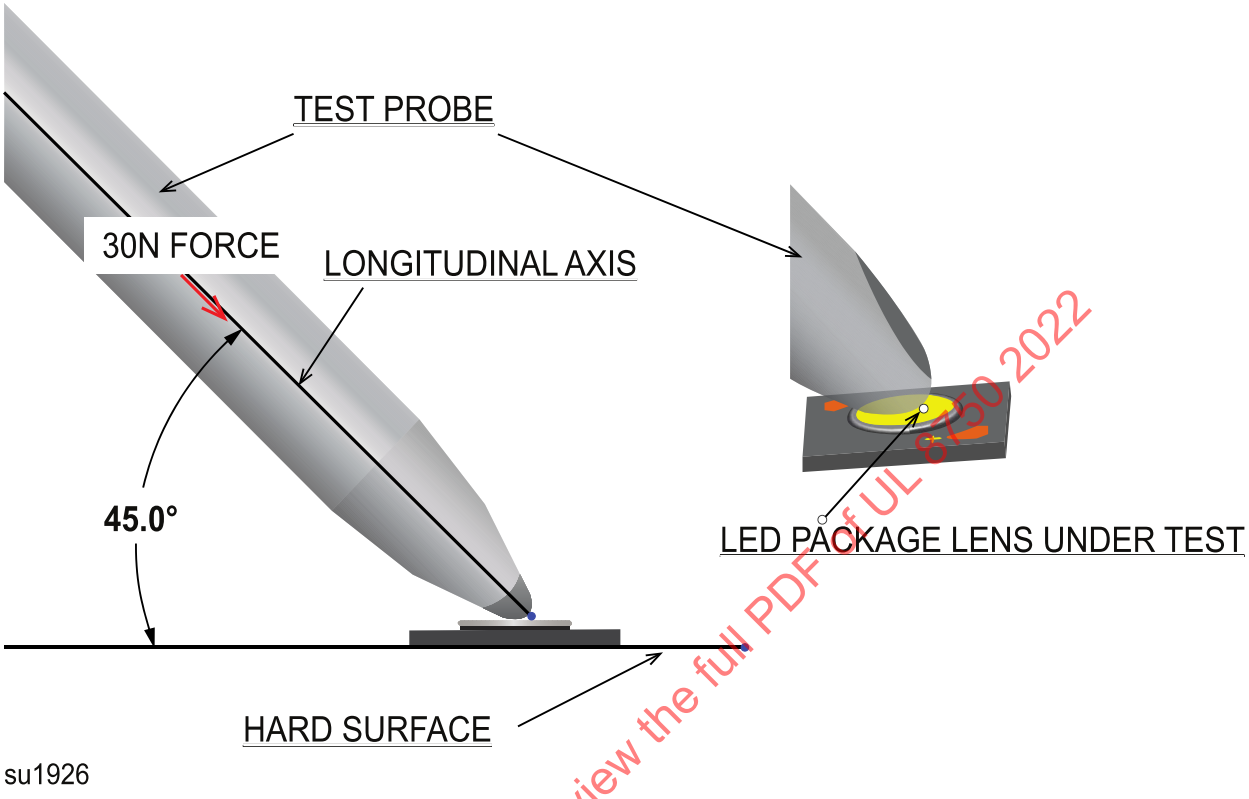
Figure SD7.4
LED packages with flat lens



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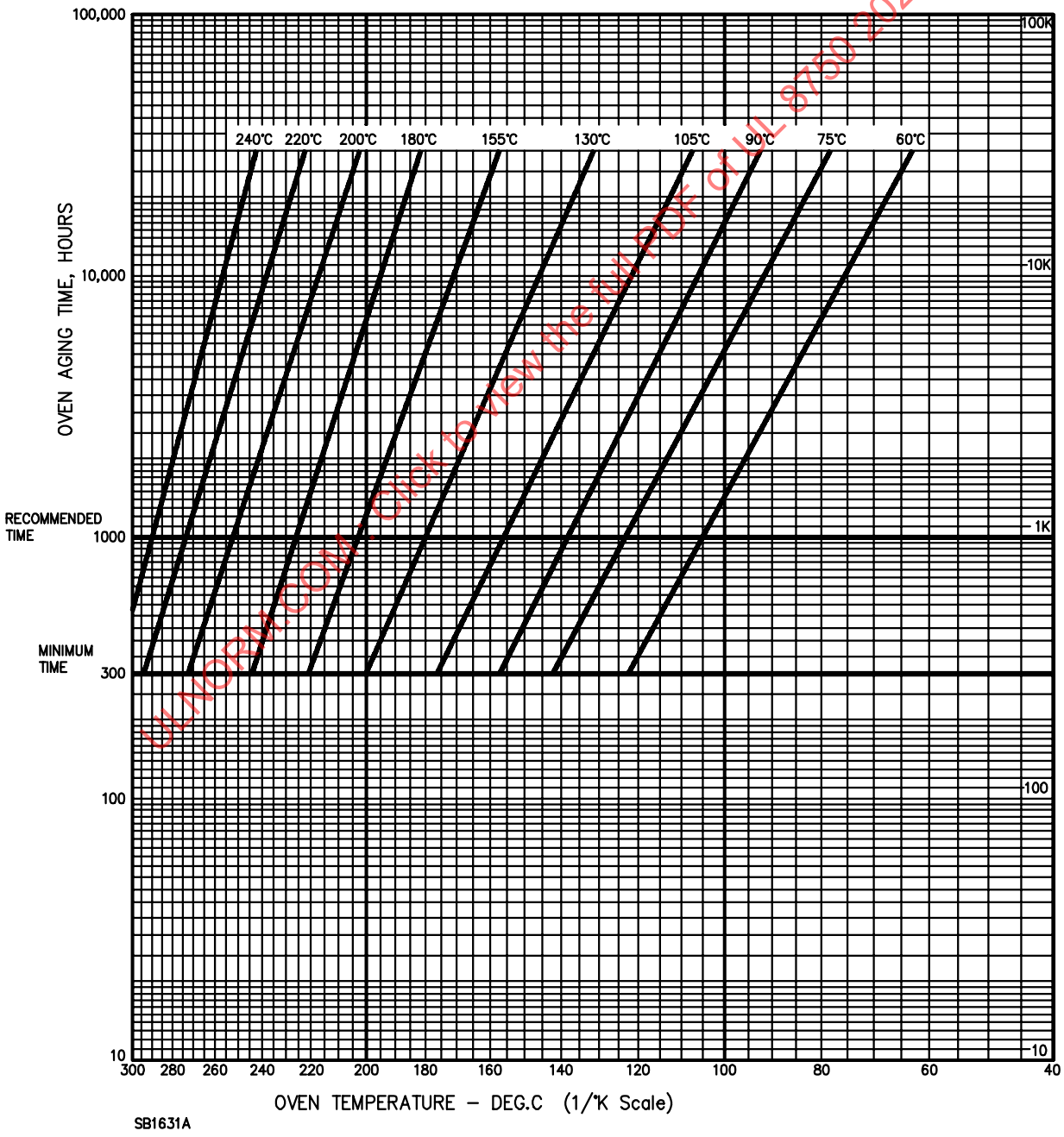
SD8 Thermal Aging Test

SD8.1 The test shall be conducted on three samples.

SD8.2 LED packages are aged in a full-draft oven at a temperature and time chosen from the graph in Figure SD8.1 using the index line that corresponds to the maximum junction temperature as specified by the manufacturer. Interpolation is permitted for maximum junction temperatures that fall between the index lines in the graph. All samples shall be conditioned for 1000 hours unless otherwise agreed by all concerned. LED packages shall not be subjected to conditioning less than 300 hours.

Figure SD8.1

Oven conditioning time versus oven temperature for temperature index for insulating materials



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SD8.3 The air oven is to be essentially as indicated in the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423 (Type II ovens), and the Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5374. A portion of the air may be recirculated, but a substantial amount of air is to be admitted continuously to maintain an essentially normal air content surrounding the representative LED package. The oven is to be adjusted to achieve 100 – 200 complete fresh-air changes per hour.

SD8.4 Test results are considered acceptable if:

a) A visual inspection does not show:

1) Damage or displacement of the LED lens,

2) Deformation of the LED package substrate/PWB, or

3) Deformation or lifting of traces of the LED package substrate/PWB.

b) For an LED package that is designated by the manufacturer as suitable for operation from other than Class 2 circuits, a subsequent dielectric test, performed per SD6, achieves acceptable results.

SD8A Photobiological Safety Assessment

SD8A.1 The requirements in this section apply to Special-use LED packages with spectral power distribution characteristics outside of the visible light spectrum (400 – 700 nm).

Note: Evaluation per Section SD8A, may be performed for other LED package types based on manufacturer request.

SD8A.2 LED packages shall be investigated to determine their risk group classification in accordance with the requirements in IEC 62471. The assessment is to determine the level of optical radiation emitted, if any, within the following spectral bands. The measurement shall be performed with a stop aperture providing 1.7 mrad field of view (FOV) with a measurement distance of 200 mm as recommended in IEC 62471 for a non-GLS (general lighting services) light source.

a) Ultraviolet hazard – 200 nm to 400 nm;

b) Retinal blue light hazard – 300 nm to 400 nm;

c) Cornea/lens infrared hazard – 780 nm to 3000 nm; and

d) Retinal thermal, weak visual stimulus hazard – 780 nm to 1400 nm.

SD8A.3 The LED package is to be mounted by the manufacturer on a PWB assembly to represent the recommended mounting (heat dissipation) and solder methods. The PWB assembly shall include appropriate electrical connection means to the LED package (anode and cathode) so the supply test leads can be properly connected.

SD8A.4 The LED package shall be powered by a supply according to manufacturer recommendations for the rated forward current(s).

SD9 Markings

SD9.1 The following markings shall be provided on the smallest unit container in which the product is packaged:

a) Company name,

b) Model designation, and

c) Factory identification or code, for any component produced or assembled at more than one factory.

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SD9.2 When the LED package is evaluated per Section SD8A, the instruction sheet shall include the intended application as well as markings noted in SD9.3 – SD9.6 as applicable. This is to identify potential photobiological hazards that must be considered as part of integration of the LED package into end equipment.

Exception: The markings in SD9.3 – SD9.5 are not required for LED packages that are classified as both:

a) Risk Group 1 or 0 for both Retinal Blue Light spectral bands; and

b) Risk Group 0 for the remaining spectral bands. However, the manufacturer may optionally provide the marking described in SD9.5.

SD9.3 See Appendix C Table 1 for text of applicable markings based on Hazard and Risk Group.

SD9.4 The markings shall be presented in bold block print within a black-bordered two-section box on a yellow background, as follows. See Figure SD9.1.

a) The risk group classification is to be identified in the upper box. When the LED package exceed Risk Group 0 in more than one spectral band, the most severe risk group classification shall be used.

b) The required labeling, information and guidance text is to be included in the lower box. When more than one hazard is noted, the text shall be printed in order of descending severity, each separated by a blank line.

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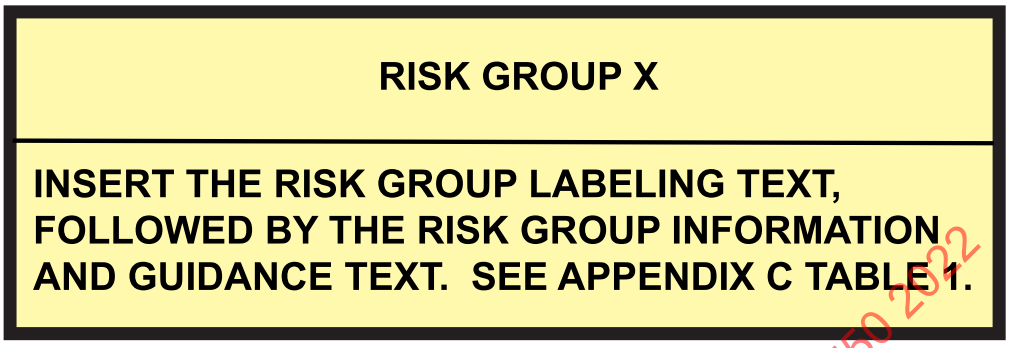
Figure SD9.1
Marking Format



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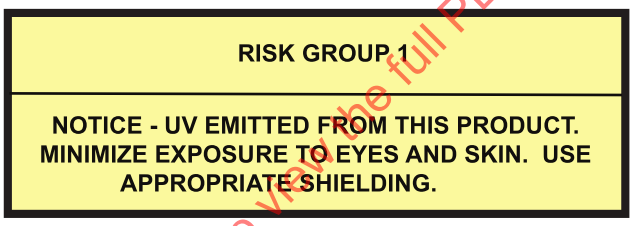
Example



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SD9.5 The following marking shall be provided verbatim:

"CAUTION – RISK OF PERSONAL INJURY. THIS LED PACKAGE IS NOT INTENDED FOR GENERAL ILLUMINATION AND MAY REQUIRE THE USE OF SPECIAL SAFEGUARDS. INSTALL AND USE ONLY IN STRICT ACCORDANCE WITH THE PRODUCT AND PACKAGING MARKINGS."

SD9.6 When the apparent source size (of the LED package) is smaller than the FOV, the following marking or equivalent shall be included in the specification sheet.

"Integration of this LED package into LED light sources (arrays, lamps or luminaries) or addition of reflective or magnifying optics may change the expected photobiological safety characteristics of such devices. The assigned risk group classification of this LED package may not necessarily indicate the risk group classification of the LED light source."

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SUPPLEMENT SE – REQUIREMENTS FOR CLASS P LED DRIVERS

SE1 Scope

SE1.1 These requirements apply to Class P LED drivers.

SE1.2 In this supplement, the term “driver” refers to a Class P LED driver unless otherwise noted.

SE2 Definitions

SE2.1 CLASS P LED DRIVER – A LED driver that is inherently or integrally protected from overheating under the specified conditions of this standard.

SE3 Construction

SE3.1 A driver shall comply with all applicable construction requirements of this standard and the following criteria to facilitate parity amongst LED drivers that meet thermal profile requirements of this supplement:

a) The driver shall not rely upon external overcurrent or over temperature protection for compliance with the requirements of this standard;

b) The driver shall not rely upon external thermal management methods such as forced air cooling, non-integral heat-sinking, or external temperature sensors for compliance with the requirements of this standard;

c) The driver shall be provided with both an integral fire and electrical enclosure in accordance with the applicable requirements described in Section 6;

Exception No. 1: A driver with field-wiring wiring leads, field-wiring terminals, or push-in terminals.

Exception No. 2: A driver that is intended for installation on or over an outlet box, in areas where the outlet box will serve to complete the enclosure of the equipment under test.

d) With regard to (c), polymeric materials serving as fire or electrical enclosures shall have a relative thermal index (RTI) with impact of at least 90°C (194°F);

e) The driver shall be provided with supply connections that comply with 7.4.1 and one of the methods described in 7.4.2 (i.e., conduit connection, field-wiring leads, field-wiring terminals, or push-in terminals). The driver shall be provided with load connections that comply with 7.4.1 and 7.4.4. Additionally, integral wiring terminals and lead wires shall be suitable for at least 90° C (194°F); and

f) Drivers that are not otherwise restricted by requirements in 6.4 may have openings as follows:

1) Circular openings have a diameter not exceeding 3 mm (0.12 in) and minimum spacing between circular openings is 3 mm (0.12 in),

2) Rectangular (or square) openings have dimensions not exceeding 3 mm (0.12 in) across and 30 mm (1.18 in) in length,

3) The pattern of openings for metal enclosures is such that the through air spacings (clearance) between live parts and the dead metal enclosure is not reduced below the values specified in Electrical Spacings, Section 7.8, when the enclosure is subjected to the Mechanical Strength Tests for Metal Enclosures, Section 8.15. The pattern of openings for polymeric enclosures is not specified.

SE3.2 Drivers with field-wiring leads, field-wiring terminals, or push-in terminals shall be rated Dry or Damp based on compliance with related construction and performance requirements of this standard.

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Exception: Drivers with power supply cords that are surface marked "W" or "Water Resistant" are permitted to be rated Wet based on compliance with related construction and performance requirements of this standard.

SE4 Performance

SE4.1 General

SE4.1.1 A driver shall comply with all applicable performance requirements of this standard and the additional criteria in this section.

SE4.1.2 During these tests a driver shall be operated in its worst-case electrical and thermal operating condition, as defined by its markings and electrical ratings.

SE4.2 Temperature test

SE4.2.1 In addition to the criteria in 8.3, the temperature on any point on the exterior surface shall not exceed 90°C (194°F) when tested in the ambient environment in Table 8.2.

SE4.3 Class P abnormal tests

SE4.3.1 Test criteria

SE4.3.1.1 These requirements supplement the criteria in 8.7.1.

SE4.3.1.2 During any Class P abnormal test:

a) The driver shall not exhibit a risk of fire or electric shock as defined in 8.7.1.3;

b) The temperatures on any point on the driver enclosure shall not exceed 150°C (302°F); and

c) If any point on the driver enclosure exceeds 110°C (230°F), the driver's operating time shall not exceed the applicable time limit specified in Table SE4.1.

Table SE4.1
Temperature-versus-time criteria

Highest measured temperature		Time limit [a]
°C	(°F)	Minutes
150	(302)	5.3
145	(293)	7.1
140	(284)	10
135	(275)	14
130	(266)	20
125	(257)	31
120	(248)	53
115	(239)	120

[a] Apply the time limit that corresponds to the highest measured temperature. Operating time is measured between the instant the enclosure temperature exceeds 110°C (230°F) and either:

a) The temperature drops below 110°C; or

b) The driver input drops to 10% or less of its rated input current, whichever comes first.

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