UL 2089

STANDARD FOR SAFETY

Vehicle Battery Adapters

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UL Standard for Safety for Vehicle Battery Adapters, UL 2089

Third Edition, Dated November 22, 2011

SUMMARY OF TOPICS

This revision of ANSI/UL 2089 dated April 25, 2023 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated March 3, 2023.

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UL 2089

Standard for Vehicle Battery Adapters

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Second Edition – December, 2003

Third Edition

November 22, 2011

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through April 25, 2023.

The most recent designation of ANSI/UL 2089 as a Reaffirmed American National Standard (ANS) occurred on April 25, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover portable vehicle battery adapters rated 24 V dc or less that are intended to be supplied from a vehicle cigarette lighter receptacle or power outlet. Vehicle battery adapters may supply outputs for appliances such as portable radios, tape players, battery chargers, and tools.

1.2 Products covered by this standard include:

a) Cord assemblies consisting of the connector for insertion into a cigarette lighter receptacle, adjacent cord, and connector intended for connection to an appliance; and

b) Units consisting of the connector for insertion into a cigarette lighter receptacle, adjacent cord, and permanently attached filtering or regulating circuitry which may include an additional enclosure, output cord, and connector or battery receptacle.

1.3 This standard does not cover products intended for marine use in areas where ignition-protected equipment is required.

1.4 Power inverters intended to be supplied from the cigarette lighter receptacle of a vehicle are covered by the requirements in the Standard for Power Converters/Inverters and Power-Converter/Inverter Systems for Land Vehicles and Marine Craft, UL 458.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the applicable requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

2.2 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.

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

2.4 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.

3 Units of Measurement

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

4 Undated References

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

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5 Glossary

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

5.2 CIGARETTE LIGHTER CONNECTOR – The male connector provided as part of a vehicle battery adapter for insertion into a cigarette lighter receptacle or a power outlet.

5.3 CIGARETTE LIGHTER RECEPTACLE – The female connector typically provided in a vehicle for the purpose of energizing the vehicle's cigarette lighter. The connector typically has the center contact connected to the positive side of the vehicle battery supply and the outer shell is connected to the negative (chassis) side of the supply. For the purposes of this Standard, the terms cigarette lighter receptacle and power outlet are considered equivalent.

5.4 CLASS 2 OUTPUT – An output complying with the construction, performance, and marking requirements in the Standard for Class 2 Power Units, UL 1310.

5.5 DIRECT CURRENT (DC) – A voltage or current waveform where the instantaneous value does not vary.

5.6 LOW-VOLTAGE LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving a potential of not more than 42.4 V peak for AC, or 60 V DC, with limited energy as described in Low-Voltage Limited-Energy Circuits, 15.2.

5.7 POWER OUTLET – The female connector typically provided in a vehicle for the purpose of accessory plug devices other than a cigarette lighter. The connector typically has the center contact connected to the positive side of the vehicle battery supply and the outer shell is connected to the negative (chassis) side of the supply. For the purposes of this Standard, the terms cigarette lighter receptacle and power outlet are considered equivalent.

5.8 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist if the voltage between parts exceeds the value specified in 16.2.2.

5.9 RISK OF FIRE – A risk of fire is considered to exist if the conditions as specified in 27.1.2(a) and (b) occur.

5.10 RISK OF INJURY – A risk of injury to persons is considered to exist if one or more of the following conditions exist:

a) If sharp edges, burrs, or projections are present that may result in injury during use or servicing;

b) If the stability of a product is such that it may result in injury to persons; or

c) If there is likelihood that a part of the body could be endangered or that clothing would be entangled by the moving part, resulting in injury to persons.

The words "injury to persons" are in reference to physical harm to persons other than the physiological effects of electric shock.

5.11 TOOL – A screwdriver, coin, key, or any other object that may be used to operate a screw, latch, or similar fastening means.

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CONSTRUCTION

6 Mechanical Assembly

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

6.2 A unit shall have all parts reliably secured in place.

6.3 An enclosure, an opening, a frame, a guard, a knob, a handle, or the like shall not be sufficiently sharp to constitute a risk of injury to persons in normal maintenance or use.

6.4 A unit shall be constructed so that it is not necessary to open or remove the enclosure when the unit is used as intended.

6.5 Each lampholder, switch, and similar component shall be mounted securely and shall be restrained from turning by more than friction between surfaces. For example, the use of a lock washer is an acceptable means to restrain the turning of a device having a single hole mounting means.

Exception No. 1: A lampholder of a type in which the lamp cannot be replaced (such as a neon pilot or indicator light in which the lamp is sealed in by a nonremovable lens) need not be restrained from turning if rotation does not reduce spacings below the minimum acceptable values or produce stress on an electrical connection.

Exception No. 2: A switch or other similar component need not comply with this requirement if the turning of such a component and servicing of the part introduces no additional risk of fire or electric shock, such as reduced spacings below minimum acceptable values or stress on an electrical connection.

6.6 A replaceable lamp in a unit shall be replaceable without opening the enclosure.

6.7 A nonreplaceable pilot lamp, such as an indicating-type overload- or short-circuit protector, a neon light, or an indicator light, is one in which the lamp is sealed-in, such as by an unremovable lens.

6.8 A switch or an overcurrent-protective device shall be located within the unit enclosure and protected in such a manner as not to be accessible or exposed to tampering nor subject to mechanical damage during normal use or as a result of abuse. This requirement does not apply to the actuating means of a switch.

6.9 The requirements in 6.8 also apply to the actuating means – toggle, handle, or the like – if the dislodging of such part exposes live parts or film-coated magnet wire that can be contacted as specified in Accessibility of Live Parts, Section 16.

6.10 The overall mass of the cigarette lighter connector shall not exceed 250 g (8.8 oz). The product of (the total mass) and (the distance between the center of gravity and the input contact positioned to simulate full insertion into a power outlet) shall not exceed 13500 g-mm (18.7 oz-in). For a unit with an attached cord, the determination shall be made with the cord severed at the enclosure, or at the strain-relief means if the strain-relief means is outside the enclosure. For a unit with a detachable cord, the determination shall be made with the cord severed from the mating connector connected to the cigarette lighter connector.

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7 Enclosure

7.1 A unit shall be provided with an enclosure that shall house all current-carrying parts that present a risk of electric shock. The enclosure shall have the strength and properties necessary to reduce the risk of mechanical damage to the various parts.

7.2 A unit shall have no openings larger than those complying with Section 16, Accessibility of Live Parts.

7.3 If an acceptable grade of vulcanized fiber is used as part of the enclosure for the support of parts (terminals and the like) that do not present a risk of fire or electric shock, the amount of fiber shall not be more than is necessary to support the parts in question. The fiber shall not be less than 1/32 in (0.8 mm) thick and shall not introduce a risk of fire, electric shock, or injury to persons as a result of abuse.

7.4 An enclosure constructed of sheet metal shall be formed from stock having a thickness not less than that specified in Table 7.1. The thickness of enclosure sheet metal other than steel or aluminum shall not be less than that specified in Table 7.1 for uncoated steel and shall have the necessary strength and rigidity.

Table 7.1
Minimum acceptable thickness of enclosure metal

Metal	At small, flat, unreinforced surfaces and at surfaces of a shape or size to provide adequate mechanical strength	
	inch	(mm)
Die-cast	3/64	(1.2)
Cast malleable iron	1/16	(1.6)
Other cast metal	3/32	(2.4)
Uncoated sheet steel	0.026	(0.66)
Galvanized sheet steel	0.029	(0.74)
Nonferrous sheet metal other than copper	0.036	(0.91)
Copper	0.033	(0.84)

7.5 In addition to the performance tests specified in this Standard, the material of a polymeric enclosure shall have a minimum flammability classification of V-0, V-1, or V-2 and shall provide the level of performance specified in Table 7.2 for the corresponding electrical properties.

Exception: An enclosure material may be accepted based on the end-product tests specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Table 7.2
Maximum performance level category (PLC) for enclosure material

Test specified[a]	Flammability rating of material[a]		
	V-0	V-1	V-2
High current arc ignition (HAI)	3	2	2
Hot wire ignition (HWI)	4	3	2

[a] HAI and HWI are determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Flammability ratings are determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

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7.6 A conductive coating applied to a nonmetallic surface such as the inside surface of a cover, enclosure, and the like shall comply with the applicable requirements 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 spacings or the bridging of live parts that may result in a risk of fire, electric shock, or injury to persons.

7.7 An adhesive used in the assembly of the enclosure shall be investigated as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: Methods utilizing fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding need not be investigated.

8 Protection Against Corrosion

8.1 Except as noted in 8.2, iron and steel parts shall be protected against corrosion by galvanizing, plating, enameling, or other equivalent means if the corrosion of such unprotected parts would be likely to result in a risk of fire, electric shock, or injury to persons.

8.2 The requirement in 8.1 applies to all enclosing cases or to other parts upon which intended mechanical operation may depend. It does not apply to laminations and small minor parts of iron or steel, such as washers, screws, and bolts, that are not current carrying, if the corrosion of such unprotected parts would not be likely to result in a risk of fire, electric shock, or injury to persons, or result in the device not operating as intended. A part made of stainless steel does not require additional protection against corrosion.

9 Switches

9.1 The requirements in 9.2 and 9.3 apply to switches not in a Class 2 circuit, and to switches in a Class 2 circuit the breakdown of which electrically or mechanically is likely to result in a risk of fire or electric shock.

9.2 A switch subjected to a temperature higher than 50°C (122°F) shall be investigated with respect to the temperature limits of the materials used.

9.3 A switch or other control device shall be acceptable for the application and shall have current and voltage ratings not less than those of the load that it controls.

10 Protective Devices

10.1 A protective device built into a unit shall comply with the requirements for that device.

10.2 Crossed or nicked (reduced) cross-section conductors shall not be employed as a protective device.

10.3 Protective devices as mentioned in 10.1 include, but are not limited to, eutectic material, fuses, overtemperature and overcurrent protectors, thermal protectors, and similar devices intended to interrupt or limit the flow of current as a result of overload.

10.4 A manually reset thermostat shall be so constructed that automatic tripping of the thermostat is not precluded by any setting or position of the reset mechanism.

10.5 An automatically or manually reset protective device or replaceable overcurrent-protective device shall not open when the unit is delivering its rated output. See Temperature Test, Section 25.

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10.6 A fuse or protective device shall be located in or adjacent to the cigarette lighter connector in the positive side of the supply.

10.7 The fuse or protective device required by 10.6 shall have a current rating not greater than the ampacity of the interconnecting cord as specified in Table 13.1, and in no case greater than 20 A.

10.8 If the fuse or protective device is not located within the cigarette lighter connector, the length of wire between the connecting means and the protective device shall not be greater than 5 in (127 mm).

10.9 A protective device shall be acceptable for the application and shall have voltage and current ratings not less than those of the circuit in which it is connected.

11 Components

11.1 A component (such as a fixed resistor, PTC or NTC resistor, diode, or the like) used to limit the output of a unit to within the required current or power levels, or otherwise used to obtain acceptable performance, shall have permanence and stability so as not to decrease its limiting capacities. Among the factors considered when determining the acceptability of a limiting component are:

a) Effect of operating temperature;

b) Electrical stress level; and

c) Resistance to moisture.

12 Coil Insulation

12.1 Coil insulation, unless inherently moisture resistant, shall be treated to render it moisture resistant.

12.2 Film-coated magnet wire is considered moisture resistant.

13 Flexible Cords

13.1 A unit shall be provided with a flexible cord and shall be type SP-2, SPE-2, SPT-2, SV, SVE, SVT, S, SE, SO, SP-3, SPT-3, ST, STO, SJ, SJE, SJO, SJT, or SJTO. The length of cord external to the unit and including the cigarette lighter connector shall not be less than 3 ft (0.9 m) as measured from the end of the cigarette lighter connector to the point of attachment or entry. Cord AWG size shall be in accordance with Table 13.1.

Exception No. 1: Output wiring for Class 2 or Low Voltage Limited Energy circuits may be parallel cord insulated with rubber, neoprene, or thermoplastic having a wall thickness of not less than 0.013 in (0.33 mm).

Exception No. 2: For units rated 10 A or less, an equivalent style appliance wiring material (AWM) may be employed.

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Table 13.1
Cord sizes

Adapter input fuse rating, Amps	Minimum cord conductor size, AWG
10 A and less	18[a]
12	17
13	16
18	14
20	12

[a] Size not specified for conductors in Class 2 or Low Voltage Limited Energy Circuits.

14 Input Contacts

14.1 The diameter of the center (positive) contact shall not be less than 9/64 in (3.57 mm).

15 Output Connections

15.1 General

15.1.1 A unit shall be provided with an output cord for each output, attached or detachable, which:

a) Terminates in a connector for connection to a low voltage appliance; or

b) Is permanently attached to an intermediate enclosure for filtering or regulating circuitry. The intermediate enclosure shall be provided with means for connection of the output consisting of a cord, insulated leads, output connectors, or battery receptacle.

Exception: An output cord is not required to be provided with the unit if the Operating Instructions include the following wording or equivalent: "WARNING – Do not hang any type of accessory or accessory bracket from the plug".

15.2 Low voltage limited energy circuits

15.2.1 A low-voltage limited-energy (LVLE) circuit is defined as a circuit with an open-circuit potential of not more than 42.4 V peak ac, or 60 V dc, with the energy available to the circuit limited:

a) So that the current under any condition of load including short circuit is not more than 8 A for potentials up to 42.4 V peak, and $150/V_{max}$ for potentials from 30 to 60 V dc, measured after 1 minute of operation by:

1) An isolating transformer; or

2) A fixed impedance or reliable regulating network; or

b) By a fuse or nonadjustable manually reset circuit protective device that is rated or set at not more than the value specified in Table 15.1.

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Table 15.1
Rating for fuse or circuit protector

Open-circuit potential, V	Current rating, A
0 – 21.2 (peak)	5
21.3 – 42.4 (peak)	3.2
Over 30 to 60 dc only	$150/V_{max}$ [a]
[a] V_{max} is defined as the maximum voltage obtained under any condition of load or no load in volts rms.	

15.3 Output connectors

15.3.1 Output connectors mounted on the enclosure and intended for direct connection of accessories, such as separable battery holders and the like, 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.

15.3.2 A fitting having female contacts shall be constructed so that it does not receive the blades of a standard attachment plug. A fitting having male contacts shall be constructed so that the contacts will not touch a live part of a standard attachment-plug receptacle.

15.4 Bushings

15.4.1 At a point where a flexible cord passes or is intended to pass through an opening in a metal wall, barrier, or enclosing case, there shall be a bushing or the equivalent that shall:

a) Be secured in place; and

b) Have a smooth, rounded surface against which the cord may bear.

15.4.2 If the cord hole is in a non-conducting material, a smooth, rounded surface is considered to be the equivalent of a bushing.

16 Accessibility of Live Parts

16.1 General

16.1.1 A live part that presents a risk of electric shock shall be located or enclosed so that protection against contact is provided.

16.1.2 The input impedance of the voltmeter used to measure voltage in accordance with 16.2.1 and 16.3.1 is to be a minimum of 1 MΩ. The input impedance of a meter with more than 1 MΩ input impedance can be lowered by using shunt impedance.

16.1.3 A guard, baffle, or cover that can be removed without using a tool is to be removed when determining if a live part is accessible to the user. A live part that can be contacted by the test pin, articulate probe, or accessibility probe illustrated in Figure 16.1, Figure 16.2, or Figure 16.4, is considered to be accessible.

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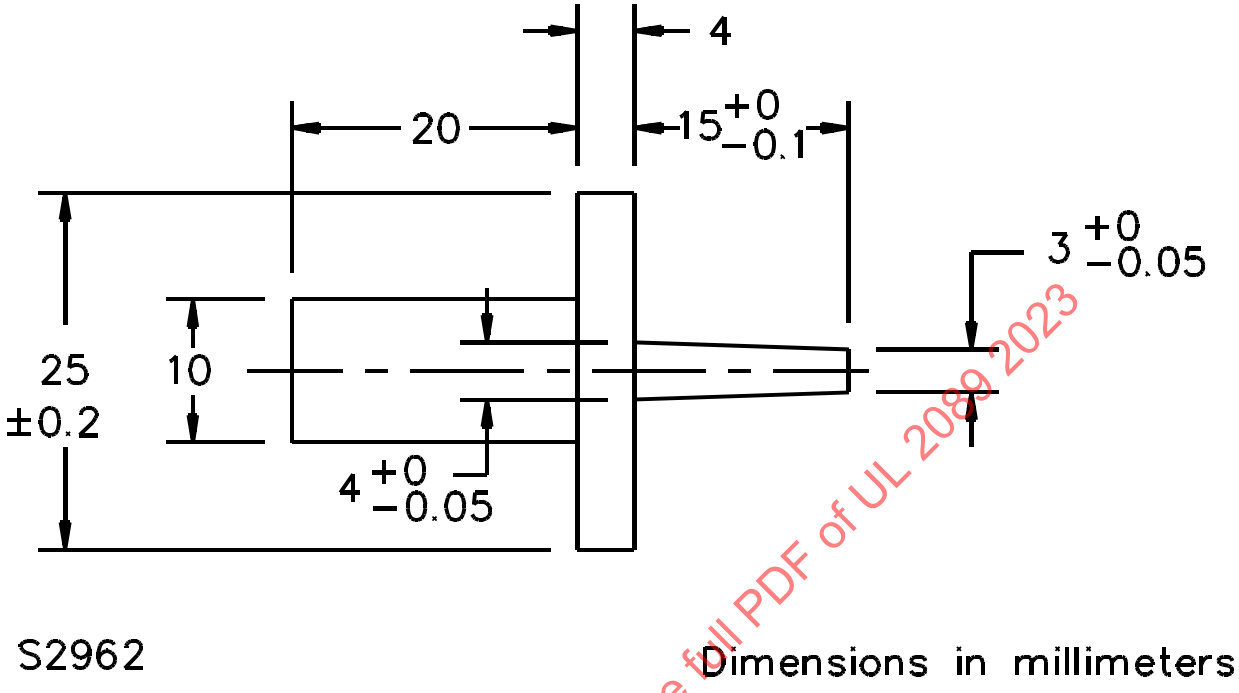
Figure 16.1

Test pin



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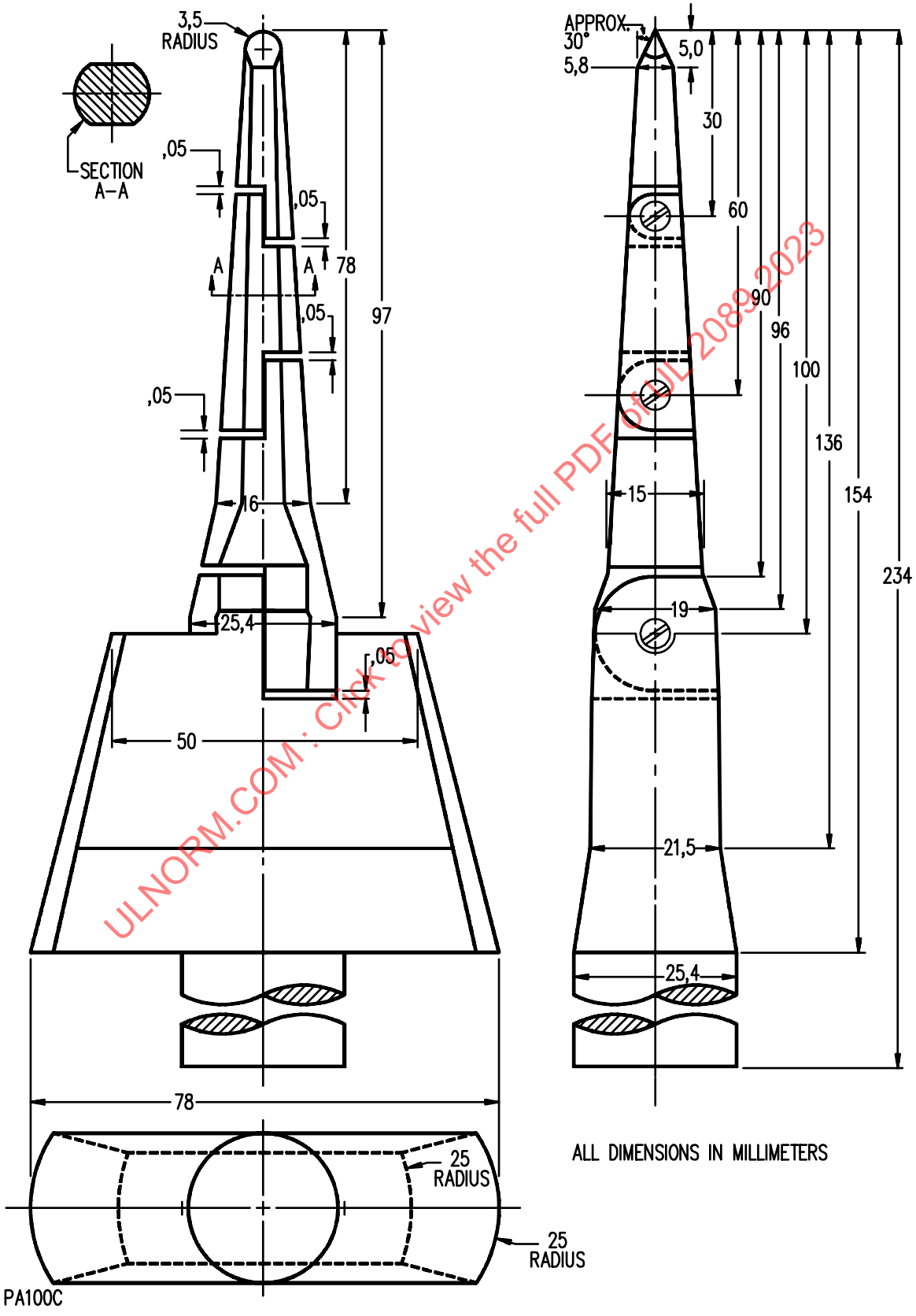
16.2 Live parts other than exposed wiring terminals

16.2.1 The test pin and articulate probe illustrated in Figure 16.1 and Figure 16.2, respectively, when applied as described in 16.2.3, shall not contact any live part with a voltage greater than that specified in 16.2.2 with respect to the vehicle chassis or any other live part simultaneously accessible, in a different location, to the test pin or articulate probe.

Figure 16.2

Articulate probe with web stop



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16.2.2 The maximum voltages which may be accessible in accordance with 16.2.1 are:

a) 42.4 V peak for sinusoidal or nonsinusoidal ac;

b) 60 V for continuous dc;

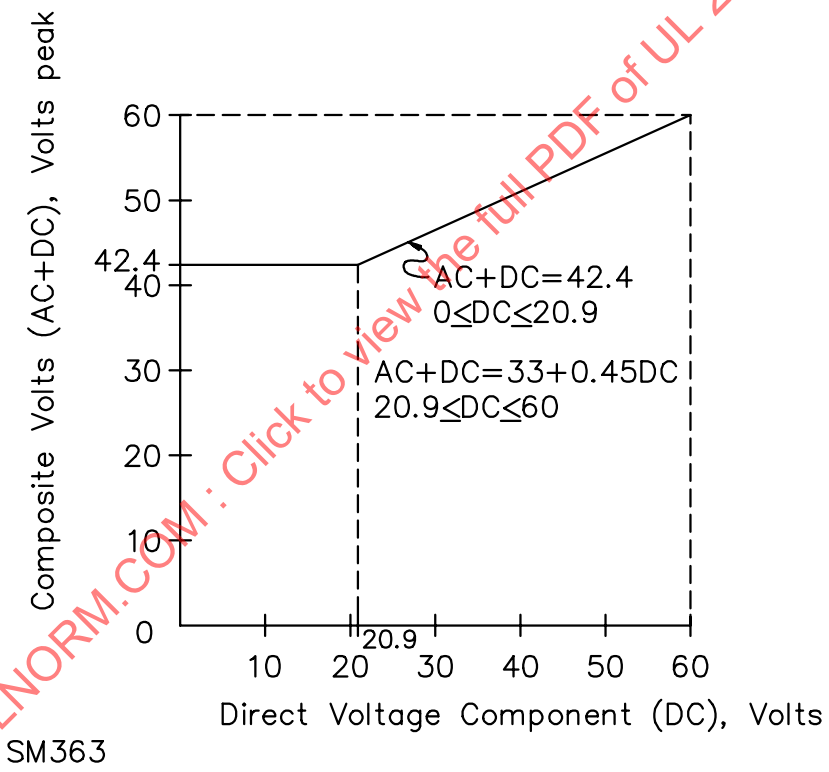
c) 24.8 V peak for dc interrupted at a rate of 200 Hz or less with approximately 50 percent duty cycle; and

d) As indicated in Figure 16.3 for combinations of ac and dc.

Exception: The voltage limits specified may be exceeded if the current through a 1500 Ω resistor connected between the accessible points does not exceed 0.5 mA.

Figure 16.3

Maximum acceptable voltage



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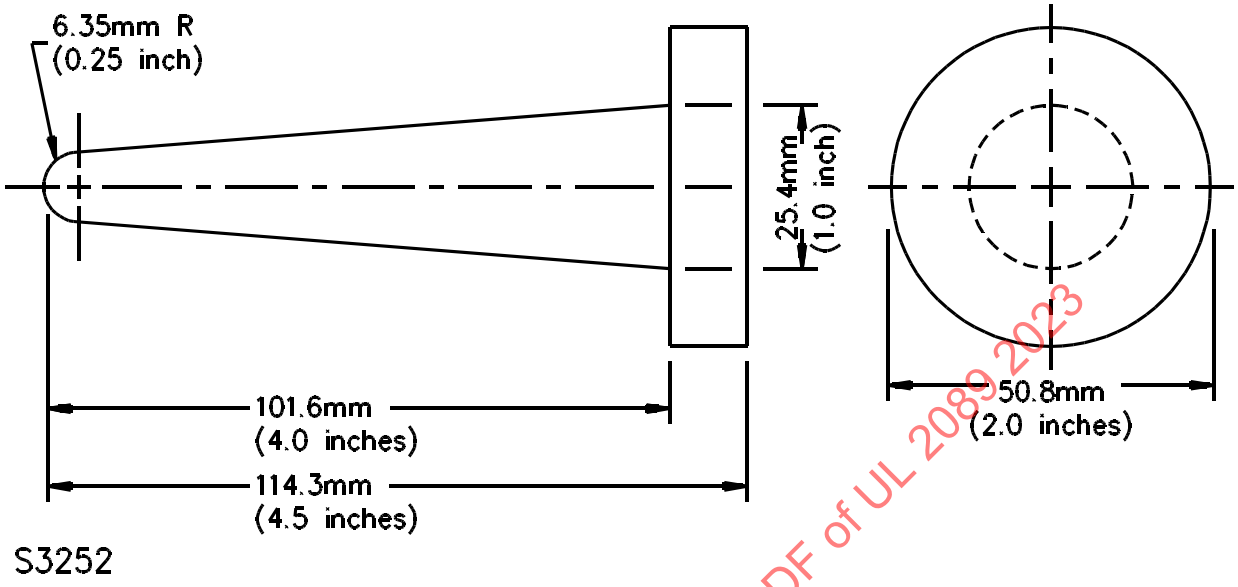
16.2.3 The test pin and articulate probe referenced in 16.2.1 are to be applied with a force not exceeding 1 lbf (4.4 N) to determine whether the live parts are accessible. The test pin shall not be applied to fuseholders and the like.

16.3 Exposed wiring terminals

16.3.1 The accessibility probe illustrated in Figure 16.4, when applied as described in 16.3.3 shall not contact an exposed wiring terminal with a voltage greater than that specified in 16.3.2 with respect to the vehicle chassis or to any other terminal simultaneously accessible to the probe.

Figure 16.4

Accessibility probe



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16.3.2 The maximum voltages which may be accessible in accordance with 16.3.1 are:

a) 42.4 V peak for sinusoidal or nonsinusoidal ac;

b) 42.4 V for continuous dc;

c) 24.8 V peak for dc interrupted at a rate of 200 Hz or less with approximately 50 percent duty cycle; and

d) 42.4 V peak for combinations of ac and dc.

16.3.3 The accessibility probe referenced in 16.3.1 is to be applied with a force not exceeding 5.62 lbf (25 N) to determine whether the exposed wiring terminals are accessible.

17 Live Parts

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

17.2 An uninsulated live part shall be secured to the base or mounting surface so that it does not turn or shift in position if such motion may result in a reduction of spacings below the minimum acceptable values.

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

18 Strain Relief

18.1 Strain relief shall be provided between the cigarette lighter connector and its adjacent cord, and shall be tested in accordance with the Strain Relief Test, Section 29.

18.2 Means shall be provided to prevent the cord or wiring from being pushed into the enclosure through the cord-entry hole when such displacement results in:

a) Subjecting the cord or wiring to mechanical damage;

b) Exposing the cord or wiring to a temperature higher than that for which it is rated;

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

d) Damaging internal connections or components.

To determine compliance, the cord shall be tested in accordance with Section 30, Push-Back Relief Test.

19 Internal Wiring

19.1 The internal wiring of a unit shall consist of insulated conductors having mechanical strength, dielectric properties, and ampacity for the application.

19.2 Each splice and connection shall be mechanically secure, shall provide reliable electrical contact, and shall be provided with insulation at least equivalent to that of the wire involved unless acceptable permanent spacing between the splice and all other metal parts will be maintained. When determining the required minimum thickness of splice insulation, the circuit voltage and interaction with other circuits shall be taken into consideration.

19.3 A wire connector for making a splice in a unit shall be a type that is applied by a tool in which the applicable force of the tool making the splice is independent of the force applied by the operator of the tool.

19.4 The connection between a lead, including a flexible cord, and the transformer winding or other part of the unit shall be soldered, welded, or otherwise securely connected within the enclosure. A soldered joint shall be mechanically secure before soldering.

19.5 If a lead is rigidly held in place without the use of solder, or if it is retained in place so as not to be subjected to any motion, no additional mechanical security is required. Mechanical securement of a lead is not required if separation of the connection does not result in a risk of fire or electric shock.

19.6 Unless it is to be considered as an uninsulated live part, insulated internal wiring – including an equipment-grounding conductor – shall consist of wire of a type or types acceptable for the application with respect to:

a) The temperature and voltage to which the wiring is likely to be subjected;

b) Exposure to oil, grease, cleaning fluid, or other substances likely to have a deleterious effect on the insulation; and

c) Other conditions of service to which it is likely to be subjected.

19.7 An insulated conductor shall be located or protected to reduce the risk of contact with any sharp edge, burr, fin, moving part, or the like, that can damage the conductor insulation.

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20 Insulating Materials

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

20.2 An insulating material is to be investigated with respect to its acceptability for the application in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Materials, such as mica, ceramic, or some molded compounds are usually acceptable for use as the sole support of live parts. If it is necessary to investigate a material to determine its acceptability, consideration is to be given to such factors as its mechanical strength, resistance to ignition sources, dielectric strength, insulation resistance, and heat-resistant properties in both the aged and unaged conditions, the degree to which it is enclosed, and any other features that could result in a risk of fire and electric shock.

21 Printed-Wiring Boards

21.1 A printed-wiring board in a unit shall comply with the Standard for Printed-Wiring Boards, UL 796, and shall be classed V-1 or less flammable, in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A V-2 printed-wiring board may be used if the unit is closed beneath the material or has an equivalent barrier.

PERFORMANCE

22 General

22.1 The number of representative samples indicated in Table 22.1 shall be subjected to the tests described in Sections 23 – 29. Unless otherwise specified, all tests are to be conducted at the marked d-c voltage. The test supply of rated voltage shall have a minimum capacity of 30 A.

22.2 With respect to 22.1 and footnotes a and b of Table 22.1, a sample may be used for more than one test, provided that the previous test did not damage the sample.

22.3 The cheesecloth mentioned in this standard is to be bleached cheesecloth running 14 – 15 yd^2/lb (approximately 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 threads in the other direction (for any square centimeter, 13 threads in one direction and 11 in the other direction).

22.4 The tests described in Sections 23 – 29 are to be conducted in an ambient air temperature within the range of 21 – 30°C (70 – 86°F).

Exception: The normal temperature test described in Section 25, Temperature Test, with or without standard fuses, but without the other forms of overcurrent or overtemperature protectors may be conducted in an ambient air temperature within the range of 10 – 40°C (50 – 104°F).

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Table 22.1
Performance tests

Section	Test	Number of samples to be subjected to test
23	Maximum Output Voltage	1
24	Power Input	1
25	Temperature	1
26	Dielectric Voltage-Withstand	1
27	Abnormal:	
	Battery-Supply Cord Short Circuit	3
	Reverse Polarity	1
	Component Malfunction or Breakdown	1[a]
	Abnormal Temperature Test	1
28	Resistance to Crushing	1
29	Strain Relief	1
–	Tests for Thermoplastic Enclosures:	b
	Mold Stress Relief Distortion	1
	Strain Relief Test after Mold Stress Relief Distortion	1

[a] Additional samples may be required if multiple components are present. One sample is required for each component to be faulted.
[b] Based on the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

22.5 For tests which specify rated load conditions, a sample is to be connected to the load specified in Table 22.2.

Table 22.2
Unit output loading

Intended use	Load for test
Other than battery charger	Variable resistor adjusted to result in rated output current.
Battery charger	Variable resistor in parallel with a 10,000 µF capacitor adjusted to result in rated output current; or, for the temperature test, a load as noted in 24.3, 24.4, or 24.5 if a battery charger is intended for use with specific batteries.

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22.6 With reference to Table 22.2, if an output is rated in watts or volt-amperes, the rated output current is considered to be the quotient of the watt or volt-ampere rating and the voltage rating.

23 Maximum Output Voltage Test

23.1 The maximum output voltage under any load condition (including no load) between any two output terminations of a unit shall not be more than the peak voltages specified in 16.2.2.

23.2 If a unit has more than one pair of output terminations, the output voltage mentioned in 23.1 is to be measured with any combination of interconnections of the output terminations.

23.3 The maximum voltage between output terminations of a multiple output unit may exceed the values specified in 23.1 when the output terminations are interconnected, if the following conditions are met:

a) The maximum output voltage between any two terminations is not more than the values indicated in 16.2.2 when no connections are made between the output terminations; and

b) The unit is marked in accordance with 32.6.

24 Power Input Test

24.1 The current or watts input to a vehicle battery adapter, when connected to a supply adjusted to the rated input voltage and supplying rated output into a load as described in Table 22.2, shall not be more than 110 percent of the rated value.

24.2 A battery charger intended for use with a specific battery pack shall be tested using the battery pack as its intended load.

24.3 If a vehicle battery adapter intended to charge batteries is to be tested using a lead-acid battery or batteries as the load, each battery is to be discharged to 1.75 V per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer, but in any case, the rate of the discharge is not to exceed one-sixth of the ampere-hour capacity of the battery. See Table 22.2.

24.4 If a battery charger is to be tested with a typical 1.2 V per cell nickel-cadmium battery or batteries as the load, each battery is to be discharged to 0.9 V per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer.

24.5 If a battery charger is to be tested with a battery or batteries other than those specified in 24.3 and 24.4, the battery is to be discharged in accordance with the battery manufacturer's maximum recommended discharge rate to an appropriate discharge voltage.

25 Temperature Test

25.1 The unit is to be mounted as in intended service and connected as described in 24.1. With the unit operating at its maximum marked duty cycle, the unit shall not reach a temperature at any point high enough to cause a risk of fire, to damage any material used, or to exceed the temperature rises specified in Table 25.1.

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Table 25.1
Maximum acceptable temperature rises

	°C	(°F)
A. COMPONENTS		
1. Fuses	65	(117)
2. Rubber-or thermocouplastic-insulated conductors[a]	35	(63)
3. Silicon components[b]	75	(135)
B. ELECTRICAL INSULATION – GENERAL		
1. Class 105 insulation systems:		
Resistance method	75	(135)
Thermocouple method	65	(117)
2. Class 130 insulation systems:		
Resistance method	95	(171)
Thermocouple method	85	(153)
3. Fiber employed as electrical insulation	65	(117)

Table 25.1 Continued on Next Page

Table 25.1 Continued

	°C	(°F)
4. Phenolic composition [a]	125	(225)
5. Varnish-cloth insulation	60	(108)
C. SURFACES		
1. Surface temperature, metal[c]	30	(54)
2. Surface temperature, nonmetallic[c]	50	(90)
3. Wood or similar material	65	(117)

[a] The limitation on phenolic composition, rubber and thermoplastic insulation does not apply to compounds that have been investigated and found to be acceptable for use at a higher temperature. The maximum acceptable temperature rise in any case is 25°C (77°F) less than the acceptable temperature limit in question.

[b] Does not apply to a material that has been investigated and found acceptable for a higher temperature.

[c] A material having a coefficient of thermal conductivity greater than 2.419 Btu/hr/ft^2/ft/°F (0.01 c/s/cm^2/cm/°C) is considered to be metal.

25.2 If the load specified in 24.1 includes a variable resistance, the load is to be adjusted after 15 minutes of operation, if necessary, to return the output to the original value. If the load consists of a battery, the battery is to be discharged as specified in 24.4 or 24.5 as applicable.

25.3 If a battery charger which is not likely to be used for consecutive charging of batteries is tested with a battery load, the test is to be continued until temperatures peak. The load is to be replaced by a second discharged battery. The test is terminated when temperatures peak, or temperatures stabilize, whichever occurs first during the second load condition.

25.4 A battery charger which is likely to be used for consecutive charging of batteries is to be tested with the intended battery load. The test is to be conducted in accordance with 25.5.

25.5 With respect to 24.4, a consecutive charger is to be tested in accordance with the following:

a) For a charger with no charge status indicator, the test is to be continued until temperatures peak. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

b) For a charger with a visual charge status indicator, the test is to be continued until the visual indicator indicates that the charge cycle is complete. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

c) For a charger with a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

d) For a charger with both a visual charge status indicator and a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed or until the visual indicator indicates that the charge cycle is complete, whichever occurs first. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

25.6 With reference to 25.1, a unit having voltage adjustment taps for intended use shall operate within the temperature limits at any setting including the maximum and intermediate positions.

25.7 A protective device shall not operate during the temperature test.

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25.8 A unit intended for mounting or support in more than one position or in a confined location is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-in (25.4-mm) thick soft-pine boards.

25.9 Unless investigated and found acceptable, a supporting means formed of soft rubber or rubberlike material is to be removed prior to the temperature test. If the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the power unit supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

25.10 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of which the temperature is being measured. Usually 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.

25.11 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method may be used for a coil that is inaccessible for mounting thermocouples, such as a coil:

a) Immersed in sealing compound;

b) Wrapped with thermal insulation; or

c) Wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32 in (0.8 mm) thick.

25.12 The temperature rise of a winding is determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise of the winding in degrees C;

R is the resistance of the coil at the end of the test in ohms;

r is the resistance of the coil at the beginning of the test in ohms;

t_1 is the room temperature in degrees C at the beginning of the test;

t_2 is the room temperature in degrees C at the end of the test; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

The winding is to be at room temperature at the start of the test.

25.13 All values for temperature rises in Table 25.1 are based on an assumed ambient temperature of 25°C (77°F).

25.14 Thermocouples are to consist of wires not larger than 24 AWG and not smaller than 30 AWG. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer type

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instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements specified in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

25.15 A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no further increase.

26 Dielectric Voltage-Withstand Test

26.1 While still in a heated condition, a unit shall withstand for 1 minute without breakdown the application of a 60-Hz essentially sinusoidal potential of:

a) 500 V between a circuit operating at 60 V dc or less or 50 V ac rms (70 V peak) or less and dead metal parts; and

b) 1000 V plus twice the maximum circuit voltage between a circuit operating at more than 60 V dc or more than 50 V ac rms (70 V peak) and dead metal parts.

26.2 The unit is to be tested using a 500 VA or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

27 Abnormal Tests

27.1 General

27.1.1 A unit shall not emit flame or molten metal or become a risk of fire or electric shock when subjected to the reverse polarity test in 27.2, the component breakdown test in 27.3, and the battery-supply cord short circuit test in 27.4.

27.1.2 A risk of fire or electric shock is considered to exist if any of the following occurs:

a) Charring of cheesecloth;

b) Emission of flame or molten material from the unit enclosure and output cord, if provided; or,

c) Any condition that exposes live parts which present a risk of electric shock as specified in Section 16, Accessibility of Live Parts.

27.1.3 Each test is to be conducted on a separate sample unless the manufacturer requests that more than one test be conducted on the same sample.

27.1.4 A polarity-protection circuit provided to prevent output-current flow until a battery is connected as intended to the output is to be made inoperative so that the required output current will flow.

27.1.5 During all abnormal tests, the unit is to be draped with a double layer of cheesecloth conforming to the outline of the unit.

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27.2 Reverse polarity test

27.2.1 For a device intended for charging batteries and provided with nonpolarized output connections, the external output leads are to be connected in reverse polarity to a fully charged battery intended for the application. The unit is then to be connected to its maximum test voltage, and operated until the ultimate condition is observed, or 4 hours if cycling of an automatically reset protector occurs.

27.3 Component breakdown test

27.3.1 A unit having components – such as diodes, resistors, transistors, capacitors, and the like – with a single component fault of short or open, shall not result in the output exceeding the levels specified in 16.3.2, or any condition as specified in 27.1.2. The unit is to be connected to the maximum test voltage and operated until ultimate conditions are observed, or for 4 hours if cycling of an automatically reset protector occurs.

Exception: This test need not be conducted for component breakdowns that result in open or short circuiting of the output.

27.4 Battery-supply cord short circuit test

27.4.1 The battery-supply cord shall be short-circuited at any point on the cord, but not within 5 inches (127 mm) of the cigarette lighter connector. As a result of this test, the fuse required by 10.7 and 10.8 shall open prior to any damage to the battery-supply cord or the cigarette lighter connector.

27.5 Abnormal temperature test

27.5.1 Immediately following the temperature test described in Section 25, Temperature Test, one sample of the unit shall be subjected to the test described in 27.5.2 – 27.5.4. As a result of the test, the unit shall not attain a temperature high enough to result in a risk of fire, electric shock, or damage to materials, or exceed the temperature rises specified in Table 25.1 by more than 20°C (36°F).

27.5.2 The unit shall be tested in accordance with the Temperature Test, Section 25, using the input voltages specified in 27.5.3 and 27.5.4, as applicable. The test is to be terminated when temperatures peak, stabilize, or decrease.

27.5.3 A unit intended to be connected to a nominal 12 Vdc supply shall be tested at the minimum input voltage at which the unit operates but not less than 10.5 Vdc. The test is to be repeated using the same sample at the maximum input voltage at which the unit operates but not greater than 14.5 Vdc.

27.5.4 A unit intended to be connected to a nominal 24 Vdc supply shall be tested at the minimum input voltage at which the unit operates but not less than 21 Vdc. The test is to be repeated using the same sample at the maximum input voltage at which the unit operates but not greater than 29 Vdc.

28 Resistance to Crushing Test

28.1 One sample of the cigarette lighter connector shall withstand for 1 minute a steady crushing force of 75 lbf (334 N). The cigarette lighter connector is to be tested between two parallel, flat, maple blocks, each not less than 1/2 in (12.7 mm) thick. The crushing force is to be applied gradually in a direction normal to the mounting surface.

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