ANSI/CAN/UL 2743:2023

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Portable Power Packs

Approved American National Standard

ANSI/UL 2743-2023

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Portable Power Packs, ANSI/CAN/UL 2743

Second Edition, Dated July 3, 2018

Summary of Topics

This revision of ANSI/CAN/UL 2743 dated April 14, 2023 includes the following changes:

– Clarification to definition of hazardous voltage level; 5.21

– Addition of definition of "portable or moveable"; 1.7, Table 1.1, 4.3, 5.29A

– Alignment of requirements for sub-enclosures with UL 746C; 7.3.2

– Receptacle output not supplied by AC mains; 12.3.1, 12.3.1A, 17.5, 70.24, 72.3, 4.3

– Increase the vehicle adapter voltage rating; 11.1.2

– Replacement of UL 60950-1 with UL 62368-1 for external charger standard; 11.3.2, 4.3

– Double insulated products with functional earthing; 5.18A, 14.2 – 14.6

– Alternative cell standard for Lithium and Lead Acid batteries; 28.2.1, 28.3.1, 4.3

– Addition of alternative standard for inverters in the power pack; 30.1, 4.3

– Addition of mass limitation for stability test; 37.1

– Addition of the induction output and energy hazard measurement test; 12.1.2, 12.1.3, 12.4.3, 12.5.3, Section 12.6, Section 47A

– Addition of LVLE circuit requirements and test; 5.27, 12.1.4, Section 12A, Section 47B

– Clarification of Leakage Current Test with hazardous voltage circuits; 46.1, 49.1

– Option of single fault condition in control circuit besides functional safety evaluation; 40.1, 50.1.7

– Clarification of the short circuit resistance for output short circuit test; 50.2.2, 50.2.3

– Charging current for Overcharging Test; 50.9.2

– Additional requirements for large energy storage systems (ESS); 28.3.7, 32.4, Section 50.11, 70.23

– Strain relief test for interconnecting cable; 11.2.2.1, 11.2.2.3, Section 54.1

– Updates to the Impact Test and Drop Test; 55.1.2, 55.2.1, 55.3.1, 55.3.2

– Clarification of the compliance criteria for the Rain Test; 5.15, 5.31A, 5.31B, 60.2, 60.2A, 60.3, 60.3A, 60.4, 69.1

– Power Pack Ampacity Test and booster ampacity rating marking; 65.1, 69.1

– Addition of UL 969A requirements for flag labels; 69.3, 4.3

– Revisions to Markings and Instructions; 70.11, 70.12, 72.3

– Addition of instruction for booster cable connection and disconnection to battery; 72.3

– Clarification to Annex A as Normative or Informative

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 new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 8, 2022 and December 2, 2022.

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JULY 3, 2018
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ANSI/CAN/UL 2743:2023

Standard for Portable Power Packs

First Edition – October, 2016

Second Edition

July 3, 2018

This ANSI/UL Standard for Safety consists of the Second Edition including revisions through April 14, 2023.

The most recent designation of ANSI/UL 2743 as an American National Standard (ANSI) occurred on April 14, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface, or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on April 14, 2023.

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Preface

This is the Second Edition of ANSI/CAN/UL 2743, the Standard for Safety for Portable Power Packs.

ULSE is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

Only metric SI units of measurement are used in this Standard. If a value for measurement is followed by a value in other units in parentheses, the second value may be approximate. The first stated value is the requirement.

Annex A is identified as Normative for Canada and Informative for the US. Informative text is for informational purposes only, and Normative text is considered to be mandatory.

This ANSI/CAN/UL 2743 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

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

This Edition of the Standard has been formally approved by the Technical Committee (TC) for Portable Power Packs, TC 2743.

This list represents the TC 2743 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE.

INTRODUCTION

1 Scope

1.1 These requirements cover portable and movable power packs provided with one or more batteries, electrochemical capacitors, or electrochemical capacitor modules. If provided with a battery, the battery shall be either a lead acid or lithium ion battery. The power packs are provided with one or more inputs and one or more outputs. For power packs provided with a booster function, the power packs are used for providing a temporary power source to a depleted land vehicle battery, rated 24 V dc maximum, to provide emergency starting power.

1.2 These requirements cover power packs suitable for outdoor use, temporary outdoor use, or indoor use only. Outdoor use packs are intended to be used outdoors with no restrictions. Temporary outdoor use packs are intended to be used outdoors in limited wet conditions and always stored indoors. Indoor use only packs are intended to be stored indoors and used indoors and are not intended to be used outdoors at any time. A power pack with a booster function is not considered indoor use only under any conditions.

1.3 These requirements cover power packs provided with additional systems such as an air compressor (tankless type) for inflating tires or other inflatable items, or with a light to act as warning lights to oncoming traffic, as a flashlight, or the like. These functions are also powered by the internal battery.

1.4 These requirements cover the power pack options such as lights, voltmeters, internal air compressor assemblies, associated gauges, inverters, vehicle adapters, and internal batteries, as well as the charging of the internal batteries, when these options are integral to the power pack.

1.5 These requirements do not cover wiring or cabling used in the recharging function of electric vehicle recharging equipment.

1.6 These requirements do not cover power banks which are covered in the Outline of Investigation for Power Banks, UL 2056.

1.7 These requirements do not cover power packs having a capacity exceeding the limits specified in Table 1.1 which are covered by the Standard for Energy Storage Systems and Equipment, UL 9540.

Table 1.1
Portable Power Pack Threshold Quantities

Portable power pack technology	Aggregate capacity	
	kWh	MJ
Lead-acid, all types	70	252
Lithium-ion, all types	20	72
Electrochemical Capacitors	3	10.8

2 Units of Measurement

2.1 The values given in SI (metric) units shall be normative. Any other values are for information only.

2.2 Values stated without parentheses are the requirement. Values within parentheses are considered explanatory or approximate information.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this Standard shall comply with the requirements for that component.

3.2 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.

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

3.4 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.

4 Referenced Publications

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.

4.2 Products covered by this Standard shall comply with the referenced installation codes and standards noted in this Section as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and standards for all countries where it is intended to be used.

4.3 The following publications are referenced in this Standard:

ASTM A90, Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

ASTM E230, Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

ASTM E376, Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension

ASTM B568, Standard Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

ASTM A653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

CSA C22.2 No. 0.15, Adhesive Labels

CAN/CSA C22.2 No. 0.17, Evaluation of Properties of Polymeric Mate

CAN/CSA C22.2 No. 0.2, Insulation Coordination

CSA C22.2 No. 42, General Use Receptacles, Attachment Plugs, and Similar Wiring Devices

CAN/CSA C22.2 No. 66.1, Low Voltage Transformers – Part 1: General Requirements

CAN/CSA C22.2 No. 66.2, Low Voltage Transformers – Part 2: General Purpose Transformers

CAN/CSA C22.2 No. 66.3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers

CAN/CSA C22.2 No. 68, Motor Operated Appliances (Household and Commercial)

CAN/CSA C22.2 No. 77, Motors With Inherent Overheating Protection

CSA C22.2 No. 107.1, Power Conversion Equipment

CSA C22.2 No. 107.2, Battery Chargers

CAN/CSA C22.2 No. 182.3, Special Use Attachment Plugs, Receptacles, and Connectors

CAN/CSA C22.2 No. 197, PVC Insulating Tape

CAN/CSA C22.2 No. 127, Equipment and Lead Wires

CAN/CSA C22.2 No. 210, Appliance Wiring Material Products

CSA C22.2 No. 223, Power Supplies With Extra Low Voltage Class 2 Outputs

CSA C22.2 No. 60335-2-29, Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements for Battery Chargers

CSA C22.2 E60730-1, Automatic Electrical Controls – Part 1: General Requirements

CSA C22.2 No. 60950-1, Information Technology Equipment – Safety – Part 1: General Requirements

CSA C22.2 No. 62133-2, Secondary Cells and Batteries Containing Alkaline and Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 2: Lithium Systems

CSA C22.2 No. 62368-1, Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements

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

UL 101, Leakage Current for Appliances

UL 498, Attachment Plugs and Receptacles

UL 506, Specialty Transformers

UL 510, Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape

UL 635, Insulating Bushings

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

UL 758, Appliance Wiring Material

UL 796, Printed-Wiring Boards

UL 810A, Electrochemical Capacitors

UL 840, Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment

UL 943, Ground-Fault Circuit Interrupters

UL 969, Marking and Labeling Systems

UL 969A, Marking and Labeling Systems – Flag Labels, Flag Tags, Wrap-Around Labels and Related Products

UL 1004-3, Thermally Protected Motors

UL 1012, Power Units Other Than Class 2

UL 1097, Double Insulation Systems for Use in Electrical Equipment

UL 1236, Battery Chargers for Charging Engine-Starter Batteries

UL 1310, Class 2 Power Units

UL 1437, Electrical Analog Instruments – Panel Board Types

UL 1450, Motor-Operated Air Compressors, Vacuum Pumps, and Painting Equipment

UL 1561, Dry-Type General Purpose and Power Transformers

UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords

UL 1642, Lithium Batteries

UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

UL 1839, Automotive Battery Booster Cables

UL 1973, Batteries for Use in Stationary and Motive Auxiliary Power Applications

UL 1977, Component Connectors for Use in Data, Signal, Control and Power Applications

UL 1989, Standby Batteries

UL 2089, Vehicle Battery Adapters

UL/ULC 2580, Batteries for Use In Electric Vehicles

UL 5085-1, Low Voltage Transformers – Part 1: General Requirements

UL 5085-2, Low Voltage Transformers – Part 2: General Purpose Transformers

UL 5085-3, Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers

UL 9540, Energy Storage Systems and Equipment

UL 60335-2-29, Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements for Battery Chargers

UL 60730-1, Automatic Electrical Controls – Part 1: General Requirements

UL 60950-1, Information Technology Equipment – Safety – Part 1: General Requirements

UL 62109-1, Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements

UL 62133-2, Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 2: Lithium Systems

UL 62368-1, Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements

5 Glossary

5.1 For the purpose of this Standard, the following definitions apply:

5.2 ACCESSIBLE – Able to be contacted by an accessibility probe.

5.3 BATTERY – An electrical storage unit consisting of two or more cells.

5.4 BOOSTER CABLE – The conductors that originate at the power pack's internal battery and terminate at the clamps that are intended to be temporarily connected to the land vehicle's battery. If the cable is connected through a switch and therefore does not have a continuous path to the exterior of the power pack's enclosure, then the definition shall apply to the portion of cable that exits the power pack's enclosure.

5.5 BOOSTER FUNCTION – When the power packs are used for providing a temporary power source to a depleted land vehicle battery, rated 24 V maximum, to provide emergency starting power.

5.6 CAPACITOR MODULE – A single or multiple series and/or parallel-connected, electrochemical capacitors with associated circuitry.

5.7 CHARGING SYSTEM – Combination of circuitry intended to charge, balance, and/or maintain the state of charge of the battery.

5.8 CLAMP – Devices located at the ends of the power pack's booster cables, and which contain the jaw ends, connectors, and handle ends, which are used to make the temporary connections to the land vehicles battery.

5.9 CLAMP CONNECTORS – Portion of the clamp that contacts the battery terminals.

5.10 CLASS 2 POWER SUPPLY – A source having limited voltage and energy capacity. Requirements for voltage and energy capacity limitations are as indicated in this document.

5.11 CLEARANCE – Shortest distance between two conductive parts, or between conductive parts and the conductive dead metal parts of the enclosure, measured through air.

5.12 CONDUCTORS – Wiring used internally and externally on the power pack.

5.13 CREEPAGE DISTANCE – Shortest distance between two conductive parts, or between conductive parts and the conductive dead metal parts of the enclosure, measured along the surface of insulating material.

5.14 ELECTROCHEMICAL CAPACITOR – An electric energy storage device where electrical charge is stored as a result of non-Faradaic processes at one or both of the electrodes. (A subset of electrochemical capacitors referred to as an “asymmetric electrochemical capacitor” have non-Faradaic processes at one electrode and Faradaic processes at the other electrode.) The unique highly-porous electrode increases its surface area for holding charge resulting in much larger capacitance and energy density than other types of capacitors. Electrochemical capacitors differ from common electrolytic capacitors in that they store charge at the liquid-solid interface of the electrodes when a potential is applied rather than in a solid dielectric material covering the surfaces of the electrodes. Some other common names for an electrochemical capacitor are “double layer capacitor”, “ultra-capacitor”, “electrochemical double layer capacitor”, “super-capacitor”, and EDLC.

5.15 ENCLOSURE – That part of the product that:

a) Renders inaccessible all or any parts of the equipment that may otherwise present a risk of electric shock or electric energy hazard; and

b) Retards propagation of flame initiated by electrical disturbances occurring within.

5.16 EXPOSED – Visible but not necessarily able to be contacted by an accessibility probe.

5.17 FULLY CHARGED BATTERY – A battery charged to the maximum state of charge permitted by the battery charging system intended for use with the appliance and in accordance with the manufacturer’s instructions.

5.18 FULLY DISCHARGED BATTERY – A battery that has been discharged at the manufacturer's recommended rate until the battery reaches a total voltage with an average voltage per cell equal to the end discharge voltage for the cell chemistry being used, or as specified by the manufacturer.

5.18A FUNCTIONAL EARTHING – Earthing a point or points in a system or in an installation or in equipment, for purposes other than electrical safety.

5.19 HANDLE END – Portion of the clamp that is held by the user and used to open the jaw ends to allow for the temporary connection to the positive battery terminal and to the land vehicle’s grounded chassis.

5.20 HAZARDOUS ENERGY LEVEL – A potential of 2 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more, between a live part and an adjacent dead metal part or between live parts of different polarity.

5.21 HAZARDOUS VOLTAGE LEVEL – For temporary outdoor and outdoor use applications, hazardous voltage level is the voltage having a value exceeding 30 V dc or 21.2 V peak AC. For indoor use only applications, hazardous voltage level is the voltage having a value exceeding 60 V dc, or 42.4 V peak AC.

5.22 INSULATION – Protective covering of the conductors, cable, and clamps.

5.23 INTERNAL BATTERY – The battery internal to the power pack's enclosure, which is used to provide the temporary power output of the power pack.

5.24 JAW END – Portion of the clamp that opens in order to accommodate the land vehicle's battery terminals.

5.25 LAND VEHICLE – An automobile, light duty truck, or other vehicle having a 12 or 24 volt dc electrical system.

5.26 LEAKAGE CURRENT – Electric current which flows through a person upon contact between accessible parts of a power pack and ground or other accessible parts of the power pack.

5.27 LOW VOLTAGE, LIMITED ENERGY (LVLE) – A circuit involving a potential below the hazardous voltage level in 5.21 and supplied by a low voltage battery, a Class 2 source, or a combination of an isolating transformer and one or more resistors or a regulating network, or overcurrent protective device that, as a unit, limits the available energy as described in 47B.1.

5.28 MAXIMUM CHARGING CURRENT – Highest current that lithium-ion cell is permitted to pass during charging for a specified range of temperatures in the Standard for Lithium Batteries, UL 1642. This is the maximum current used as the basis of the charging current during the abnormal charging test.

5.29 MIDDLE CONNECTOR – A connector located in the middle of the cables that is disconnected prior to the clamps being connected to the vehicle battery and then used to complete the connection once the clamps are connected to the respective vehicle battery terminals.

5.29A PORTABLE POWER PACK – A power pack which can be lifted and moved by a single person without mechanical aids and not permanently connected to an electrical system. It can be either:

a) Hand-held; or

b) Moveable and meets the following criteria:

1) 18 kg (39.7 pounds) or less in mass and is not fixed; or

2) Provided with wheels, casters, or other means to facilitate movement by an ordinary person as required to perform its intended use.

For a portable power pack powered by a detachable battery pack(s), which is mounted on the body of the portable power pack during operation, the weight of all detachable battery packs shall be included to determine if it is movable or portable.

5.30 POWER PACK – A portable or movable device that contains an integral or removable battery, or batteries, that when charged are intended to provide power to various outputs of the device, including booster functions for providing temporary emergency power to land vehicles, or power to receptacles and other outputs. All can be further designated as outdoor use, temporary outdoor use, or indoor use only.

5.31 PROTECTIVE DEVICE – A device that operates in a specific manner to prevent a hazardous situation under abnormal operation conditions.

5.31A RAINPROOF ENCLOSURE – An enclosure that provides protection to personnel against electric shock or electric energy hazards by preventing a degree of water entering inside of the portable power pack during the Rain Test.

5.31B RAINTIGHT ENCLOSURE – An enclosure that completely prevents water entering inside of the portable power pack during the Rain Test.

5.32 REPAIR FACILITY– A building or portion of a building where automotive repairs and maintenance work are conducted on gasoline powered land vehicles, whether only a portion of the land vehicles or all the land vehicles are gasoline powered.

5.33 SPECIFIED OPERATING REGION – Range of permissible operation expressed by lithium-ion cell parameter limits.

5.34 SPECIFIED OPERATING REGION FOR CHARGING – Conditions during charging in which the lithium-ion cell operates within its voltage and current range as specified by the cell manufacturer and evaluated in accordance with the Standard for Lithium Batteries, UL 1642. In general, the permissible range of voltage and current are dependent upon temperature.

5.35 UNINSULATED LIVE PART – A conductive part within the device that is not provided with integral insulation and during intended use has a potential difference with respect to earth ground or any other conductive part.

5.36 UPPER LIMIT CHARGING VOLTAGE – Highest voltage that a lithium-ion cell is permitted to attain during normal charging for a specified range of temperatures in the Standard for Lithium Batteries, UL 1642. This is the maximum voltage that is employed during the abnormal charging test.

CONSTRUCTION

6 General

6.1 If the operation and maintenance of a power pack by the user involves a risk of injury to persons, a risk of electric shock, or a risk of fire, means shall be provided to reduce the risk. When evaluating a power pack, consideration shall be given to reasonably foreseeable misuse of the product.

6.2 Power packs intended for use within a repair facility, and marked as such as indicated in 69.4, shall be provided with instructions containing the statement in 74.3 and shall be marked as shown in 70.17. Power packs that are not intended for use in a repair facility shall be marked in accordance with 70.18.

6.3 Outdoor use power packs shall be evaluated for all environmental considerations addressed by this Standard and are intended to be used and stored either outdoors or indoors. Temporary outdoor use power packs shall be evaluated for exposure to rain, shall be marked in accordance with 70.19 and 70.20, and shall be provided with instructions in accordance with 74.5. Indoor use only power packs shall be marked in accordance with 70.21 and shall be provided with instructions in accordance with 74.6. Indoor use only packs need not comply with the environmental considerations in 7.5.

6.4 For power packs not marked in accordance with 70.22, the device shall be subjected to the Vibration Test, Section 51.

7 Frame and Enclosure

7.1 General

7.1.1 An enclosure of a power pack shall be formed and assembled so that it has the strength and rigidity necessary to resist the abuses to which it may be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts, or other serious defects.

7.1.2 A power pack shall be provided with an enclosure suitable for the application. The enclosure shall house all live parts that may increase the risk of fire, electric shock, or injury to persons under any condition of use. This requirement does not apply to the power supply cord, the output leads, or output terminals.

7.1.3 If an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the meter, or both together, shall comply with the requirements for enclosures.

7.1.4 The enclosure for a power pack provided with an internal lead acid battery shall be ventilated to permit dispersion of gases from the internal battery during normal use and charging. See 7.4.

7.1.5 Enclosures for power packs shall comply with the requirements for environmental considerations in 7.5.

7.2 Metallic enclosures

7.2.1 Enclosures constructed of metallic materials shall be subjected to the Strength of Enclosure Tests, Section 55.

7.2.2 A metallic enclosure shall have a thickness not less than that specified in Table 7.1 and Table 7.2.

7.2.3 Metallic enclosures, if not constructed of a material that is corrosion resistant, shall be provided with corrosion protection in accordance with Corrosion Protection, Section 10.

Table 7.1
Minimum thickness of sheet metal for enclosure carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness uncoated		Minimum thickness coated	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]					
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inches)	mm	(inches)
10.2	(4)	Not limited		15.9	(6.25)	Not limited		0.51	(0.020)	0.58	(0.023)
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)				
15.2	(6)	Not limited		24.1	(9.5)	Not limited		0.66	(0.026)	0.74	(0.029)
17.8	(7)	22.2	(8.75)	25.4	(10)	31.8	(12.5)				
20.4	(8)	Not limited		30.5	(12)	Not limited		0.81	(0.032)	0.86	(0.034)
22.9	(9)	29.2	(11.5)	33.0	(13)	40.6	(16)				
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited		1.07	(0.042)	1.14	(0.045)
35.6	(14)	45.7	(18)	53.3	(21)	63.5	(25)				
45.7	(18)	Not limited		68.6	(27)	Not limited		1.34	(0.053)	1.42	(0.056)
50.8	(20)	63.5	(25)	73.7	(29)	91.4	(36)				
55.9	(22)	Not limited		83.8	(33)	Not limited		1.53	(0.060)	1.61	(0.063)
63.5	(25)	78.7	(31)	89.0	(35)	109.2	(43)				
63.5	(25)	Not limited		99.1	(39)	Not limited		1.70	(0.067)	1.78	(0.070)
73.7	(29)	91.4	(36)	104.1	(41)	129.5	(51)				

Table 7.1 Continued on Next Page

Table 7.1 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness uncoated		Minimum thickness coated	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]					
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inches)	mm	(inches)

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which are capable of being applied via the enclosure surface when it is deflected. A construction that is determined to have equivalent reinforcing can be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Constructions determined to be without a supporting frame include:

1) A single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure can have supports in common and be made of a single sheet.

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 12.7 mm (1/2 inch) wide.

Table 7.2
Minimum thickness of sheet metal for enclosures aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length [c]			
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inches)
7.6	(3)	Not limited		17.8	(7)	Not limited		0.58[d]	(0.023)
8.9	(3.5)	10.2	(4)	21.7	(8.5)	24.1	(9.5)		
10.2	(4)	Not limited		25.4	(10)	Not limited		0.74	(0.029)
12.7	(5)	15.2	(6)	26.7	(10.5)	34.2	(13.5)		
15.2	(6)	Not limited		35.6	(14)	Not limited		0.91	(0.036)
16.5	(6.5)	20.4	(8)	38.1	(15)	45.7	(18)		
20.4	(8)	Not limited		48.3	(19)	Not limited		1.14	(0.045)
24.1	(9.5)	29.2	(11.5)	53.3	(21)	63.5	(25)		
30.5	(12)	Not limited		71.1	(28)	Not limited		1.47	(0.058)
35.6	(14)	40.6	(16)	76.2	(30)	94	(37)		
45.7	(18)	Not limited		106.7	(42)	Not limited		1.91	(0.075)
50.8	(20)	63.4	(25)	114.3	(45)	139.7	(55)		
63.4	(25)	Not limited		152.4	(60)	Not limited		2.41	(0.095)
73.7	(29)	91.4	(36)	162.6	(64)	198.1	(78)		

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which are capable of being applied via the enclosure surface when it is deflected. Construction that is determined to have equivalent reinforcing can be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Construction determined to be without supporting frame includes:

1) Single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

Table 7.2 Continued on Next Page

Table 7.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]					
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length[c]		Minimum thickness	
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inches)
3) An enclosure surface loosely attached to a frame, for example, with spring clips.									
[b] The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure can have supports in common and be made of a single sheet.									
[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 12.7 mm (1/2 inch) wide.									

7.3 Nonmetallic enclosures

7.3.1 In addition to the performance tests specified in this Standard, the factors to be considered when evaluating the suitability of a polymeric enclosure include the requirements in 7.3.2 through 7.3.4.

7.3.2 The enclosure material shall have a minimum flame rating of V-1 in accordance with 8.1.

Exception: If a metal or minimum V-1 rated sub-enclosure houses all insulated or uninsulated live parts and internal wiring that involve a risk of fire, then the outer polymeric enclosure may be classed HB or better.

7.3.3 The enclosure material shall have a minimum Relative Thermal Index (RTI) value that exceeds the maximum temperature observed on the material during operation but no less than 80°C (176°F) for packs intended to be stored in the trunk or passenger compartment of a vehicle. If an RTI value that exceeds the maximum temperature observed on the material during operation, but is lower than 80°C (176°F), is used, the power pack shall be marked in accordance with 70.22 and provided with instructions as shown in 74.7.

7.3.4 A conductive coating applied to a nonmetallic surface such as the inside surface of an enclosure, shall be evaluated in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17, 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.

7.3.5 An adhesive used to secure parts of an enclosure shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17.

7.3.6 Enclosures of molded or formed nonmetallic materials shall be constructed so that any shrinkage or distortion of the material over time will not allow for the user to contact live parts at hazardous voltage or hazardous energy levels. Compliance is determined by the Mold Stress Test, Section 56.

7.3.7 Enclosures constructed of nonmetallic materials shall be subjected to the Strength of Enclosure Tests, Section 55.

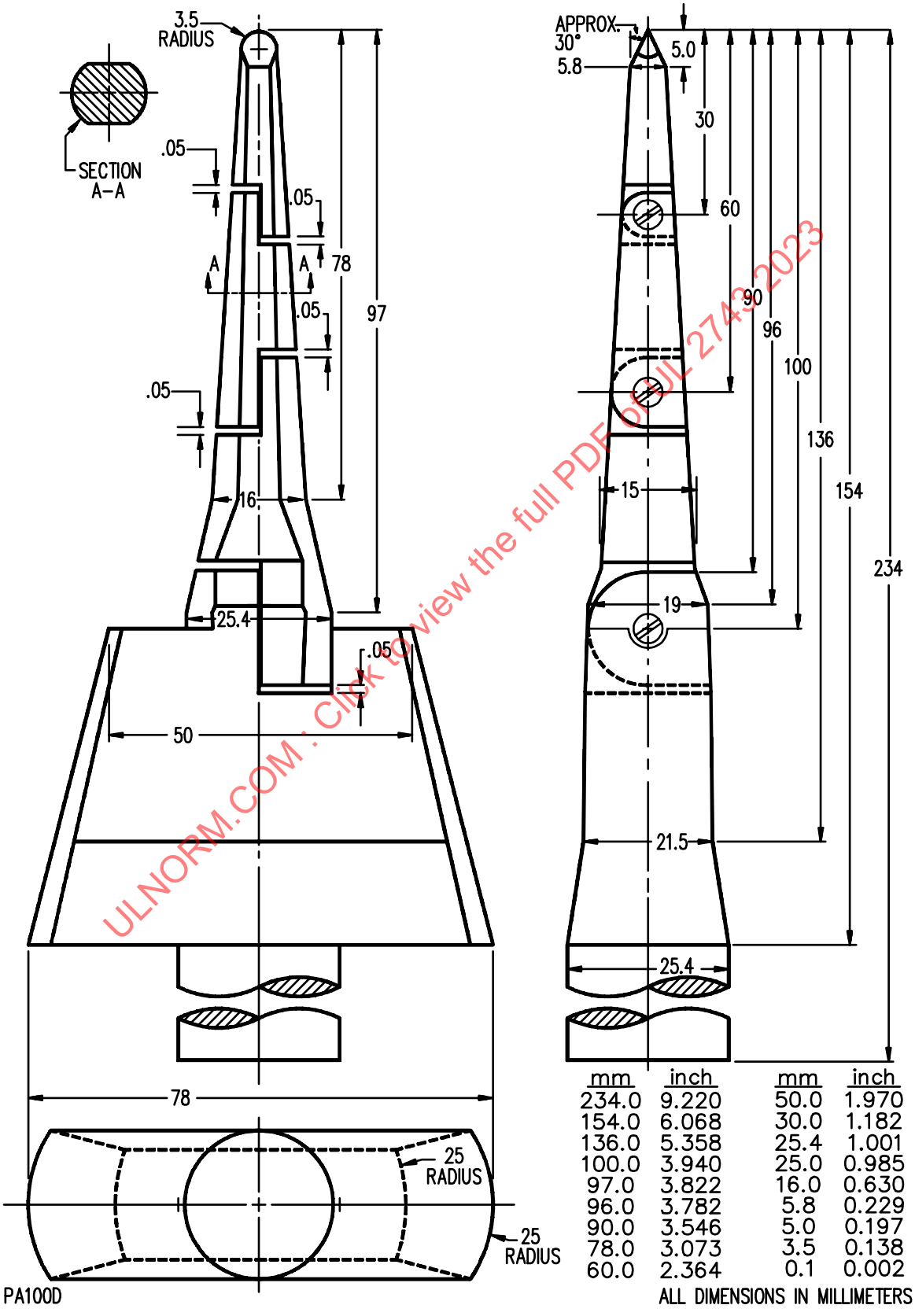
7.4 Openings in enclosures

7.4.1 Power pack enclosures shall not allow the entrance of water in accordance with 7.5.

7.4.2 A probe as illustrated in Figure 7.1, when inserted through an opening, shall not touch any uninsulated live part that can cause electric shock.

Figure 7.1

Articulate probe with web stop



mm	inch	mm	inch
234.0	9.220	50.0	1.970
154.0	6.068	30.0	1.182
136.0	5.358	25.4	1.001
100.0	3.940	25.0	0.985
97.0	3.822	16.0	0.630
96.0	3.782	5.8	0.229
90.0	3.546	5.0	0.197
78.0	3.073	3.5	0.138
60.0	2.364	0.1	0.002

ALL DIMENSIONS IN MILLIMETERS

7.4.3 Thermoplastic covering an opening for user servicing, such as replacement of a pilot lamp, and that reduces the risk of unintentional contact with a live part involving a risk of electric shock shall be evaluated as an enclosure. It shall be reliably retained in place.

7.4.4 An uninsulated live part at hazardous voltage or hazardous energy levels shall be located or enclosed so that protection against unintentional contact is provided.

7.4.5 A door or cover that provides access to a live part at hazardous voltage or hazardous energy levels shall be securely held in place so that it can be opened or removed only by using a tool.

Exception: A door or cover that provides access to a live part that is not at hazardous voltage or hazardous energy levels shall be securely held in place, but need not be secured so that it is necessary to use a tool to open or remove it.

7.4.6 The door or cover of an enclosure shall be hinged or attached in an equivalent manner if it provides access to an overload-protective device, the functioning of which requires renewal, or if it is necessary to open the cover in connection with the operation of the protective device. A door or cover providing access to a fuseholder shall be tight-fitting and shall be positively held closed.

Exception: A hinged cover is not required if the only overload-protective devices enclosed are:

a) Connected in control circuits, provided the protective devices and the circuit loads are within the same enclosure;

b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes;

c) Extractor fuses having an integral enclosure; or

d) Fuses connected in a low-voltage limited energy circuit.

7.4.7 The operating handle of a circuit breaker, an operating button of a manually operable protector, the capped portion of an extractor-type fuseholder, or a similar part may project outside the enclosure.

7.5 Environmental considerations

7.5.1 The enclosure of an outdoor use or temporary outdoor use power pack shall be constructed to exclude a beating rain in accordance with 7.5.2.

7.5.2 All outdoor use or temporary outdoor use power packs shall be subjected to the Rain Test, Section 60.

7.5.3 A gasket employed in a power pack in order to comply with 7.5.1 shall be tested in accordance with Accelerated Aging of Gaskets, Sealing Compounds, and Adhesives, Section 62.

7.5.4 A nonmetallic enclosure for an outdoor use power pack shall be judged on the basis of the effect of exposure to ultraviolet light and water in accordance with the applicable tests in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. Temporary outdoor use power packs need not comply with this requirement.

8 Flammability of Materials

8.1 Nonmetallic materials used for enclosures shall have a minimum flammability rating of V-1 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts

in Devices and Appliances, UL 94, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. As an alternative, finished enclosures may be tested in accordance with the 20 mm end-product flame test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. Metallic materials used for enclosures are considered to comply without further evaluation, except magnesium shall not be used for enclosure materials.

8.2 Nonmetallic materials used for internal parts within the overall enclosure shall be rated V-2 minimum.

Exception No. 1: The internal insulating system of components where component requirements exist need not comply with this requirement.

Exception No. 2: A small part, gasket, or other nonmetallic part that is located such that it cannot propagate flame from one area to another within the equipment, and is not located in close proximity to uninsulated live parts, is not required to comply with this requirement.

8.3 Nonmetallic materials located outside the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts shall be rated HB minimum.

8.4 Printed-wiring board materials shall be rated V-1 minimum.

8.5 For the requirements outlined in 8.2 – 8.4, the flammability rating of the material shall be provided as part of the material rating or the flammability rating may be determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17.

9 Assembly

9.1 An uninsulated live part shall be secured to the base or surface so that it is prevented from rotating or shifting in position as the result of normal stresses, if such movement results in a reduction of spacings below the minimum values indicated in Spacings, Section 29.

9.2 A component such as a control switch, lampholder, or connector, shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

9.3 With reference to 9.2, a switch is not required to be mounted as described in 9.2, if all of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated. A toggle switch is considered to be subject to forces that tend to turn the switch;

b) The means for mounting the switch makes it unlikely that operation of the switch will loosen it;

c) Spacings are not reduced below the minimum values indicated in Spacings, Section 29, if the switch rotates; and

d) Operation of the switch is by mechanical means rather than by direct contact by persons.

9.4 With reference to 9.2, a lampholder of the type in which the lamp cannot be replaced, such as a sealed neon pilot or indicator light, is not required to be mounted in accordance with 9.2, if rotation cannot reduce spacings below the minimum values indicated in Spacings, Section 29.

9.5 A small stem mounted device having a single hole mounting means may be prevented from rotating by a properly applied lock washer.

10 Corrosion Protection

10.1 Metal shall be used in combinations that are galvanically compatible.

10.2 Hinges and other attachments shall be resistant to corrosion.

10.3 The requirements in 10.5 – 10.15 do not contemplate corrosion that might be caused by exposure to the earth or other corrosive agents.

10.4 The requirements in 10.5 – 10.15 do not apply to a part, such as a decorative grill, that is not required to form a part of the enclosure.

10.5 A metallic enclosure shall be protected against corrosion as specified in 10.6 – 10.15.

10.6 Copper, bronze, brass containing not less than 80 percent copper, or stainless steel may be used without additional protection against corrosion. Sheet, extruded, or cast aluminum, die-cast zinc, and other metals shall be of a grade or alloy known to be resistant to atmospheric corrosion, shall be subjected to tests, or shall be additionally protected against corrosion.

10.7 An enclosure of cast iron or malleable iron at least 3.2 mm (1/8 inch) thick shall be protected against corrosion by:

a) A 0.0038 mm (0.00015 inch) thick coating of zinc, cadmium, or the equivalent on the outside surface, and a visible coating of such metal on the inside surface, or

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface.

10.8 Unless suitability of a paint can be determined by consideration of its composition, corrosion tests are required.

10.9 An enclosure of sheet steel less than 3.20 mm (0.126 inch) thick if zinc-coated or 3.12 mm (0.123 inch) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 10.12:

a) Hot-dipped, mill galvanized, sheet steel conforming with the coating designation G90 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653, with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.015 mm (0.00061 inch) on each surface with a minimum thickness of 0.014 mm (0.00054 inch). An annealed coating shall also comply with 10.14.

c) A zinc coating conforming with 10.10 (a) or (b), with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface applied after forming. See 10.8.

10.10 An enclosure of zinc coated steel 3.20 mm (0.0126 inch) thick or thicker or an enclosure of uncoated sheet steel 3.12 mm (0.123 inch) thick or thicker shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to give equivalent protection as described in 10.12:

a) Hot-dipped, mill galvanized, sheet steel conforming with the coating designation G60 or A60 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653, with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.010 mm (0.00041 inch) on each surface with a minimum thickness of 0.009 mm (0.00034 inch).

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. See 10.8.

d) Any one of the means specified in 10.9.

10.11 The requirements in 10.10 also apply to an enclosure of zinc-coated sheet steel 1.42 mm (0.056 inch) thick or thicker and an enclosure of uncoated sheet steel 1.35 mm (0.053 inch) thick or thicker if the enclosure is intended to be mounted within and protected from direct exposure to weather by the enclosure of other equipment. Such an enclosure shall not be marked rainproof or raintight.

10.12 With reference to 10.9 – 10.11, other finishes, including paints, metallic finishes, and combinations of the two, may be accepted if comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with 10.9(a) or 10.10(a), as applicable, indicate that they provide equivalent protection. Among the factors that are to be taken into consideration when judging the suitability of such coating systems are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water.

10.13 If tests are required, test specimens of a finish as described in 10.7, 10.9(c), 10.10(c), or 10.12 are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning, or pretreatment method, application method, number of coats, curing method, thickness, and the like.

10.14 A hot-dipped, mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted, shall be painted in the bent or formed area if the bending or forming process has damaged the zinc coating, except that such an area on the inside surface of an enclosure that is not exposed to water during the water spray test need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25-power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

10.15 If verification of the thickness of coatings in 10.9 and 10.10 is required, the thickness shall be established by the Metallic Coating Thickness Test, Section 63.

11 Supply Connections

11.1 General

11.1.1 Power packs are intended to be connected to the power supply circuit in order to recharge the internal battery, electrochemical capacitors, or electrochemical capacitor modules. Additionally, outputs of the power pack may be powered when the pack is connected to the supply circuit.

11.1.2 Power packs shall be provided with one or more of the following input options:

a) Cord and plug connection, rated at 240 V ac maximum, 60 Hz;

b) Photovoltaic panel or device with inverter;

c) Vehicle adapter, rated 24 V dc maximum;

d) USB input port (can also act as output port); or

e) Cables for charging from a vehicle battery rated up to 24 V dc maximum.

11.2 Flexible cord connection

11.2.1 General

11.2.1.1 For flexible cord connections, the power pack shall be connected to the power supply circuit by means of a flexible cord and an attachment plug. The flexible power cord shall be either a detachable or non-detachable type. For devices intended for use with a detachable cord set, the cord set need not be provided with the device when the power pack is marked in accordance with 70.17 and the instructions are in accordance with 73.2.

11.2.1.2 For power packs intended for use in a repair facility, a detachable flexible cord shall be provided with a means to insure that the flexible cord cannot be inadvertently detached during use.

Exception: A device intended for use in a repair facility may also be provided with a detachable cord set without a means to insure inadvertent detachment, when the power pack is marked in accordance with 70.17 and the instructions are in accordance with 73.2.

11.2.1.3 A flexible cord shall have a voltage rating not less than the rated voltage of the equipment and shall have an ampacity not less than the current rating of the equipment.

11.2.1.4 The attachment plug shall have an ampacity not less than the rated current of the product or the actual current measured during the Power Input Test, Section 42, whichever is greater, and a voltage rating equal to the rated voltage of the product. If a product is adaptable for use on two or more different values of voltage by field alteration of internal connections, the attachment plug provided with the product shall be rated for the voltage for which the product is connected when leaving the factory.

11.2.1.5 A flexible cord shall be Type G, SO, SJO, SJEO, SJTO, STO, or W, or a type at least equally serviceable for the particular application.

11.2.1.6 The length of a flexible cord, including the attachment plug, shall not be less than 1.8 m (6 feet).

11.2.1.7 If a product incorporates a disconnecting means, such as an appliance inlet, the arrangement shall be such that no hazardous live parts will be exposed under normal conditions.

11.2.1.8 A permanently attached flexible cord shall exit the enclosure in an area that is not in close proximity to a hot spot or moving part.

11.2.2 Strain relief

11.2.2.1 Strain relief shall be provided on a non-detachable flexible supply cord and output wiring to reduce the risk of mechanical stress being transmitted to terminals, splices, or interior wiring. See the Direct-Pull Strain Relief Test, 54.1. A knot in the flexible cord is not considered a form of strain relief.

11.2.2.2 A metal strain relief clamp or band provided in accordance with 11.2.2.1 shall be provided with auxiliary insulation over the cord if damage to the cord insulation results when the strain relief test is conducted without auxiliary insulation.

11.2.2.3 Means shall be provided to prevent a flexible supply cord and output wiring from being pushed into the equipment through the cord entry hole if such displacement would:

a) Result in mechanical damage to the cord;

b) Expose the cord to a temperature other than that for which it is rated; or

c) Reduce spacings, such as to a metal strain relief clamp, below the minimum values indicated in Spacings, Section 29.

To determine compliance, the flexible supply cord and output wiring shall be tested in accordance with the Push-Back Strain Relief Test, 54.2.

11.2.3 Bushings

11.2.3.1 At the point where a non-detachable flexible cord passes through an opening in the enclosure, there shall be a bushing or the equivalent that is secured in place, and that has a smooth, well rounded surface against which the cord may bear. An insulating bushing shall be provided, if the enclosure is of metal, or if the construction is such that the cord may be subjected to strain or motion. A bushing that complies with the applicable requirements in the Standard for Insulating Bushings, UL 635, is considered to comply with this requirement.

11.2.3.2 A hole in porcelain, phenolic composition, or other non-conducting material, having a smooth, rounded surface, is considered to be equivalent to a bushing.

11.2.3.3 A bushing of the same material as, and molded integrally with, a supply cord is acceptable if the built-up section is not less than 1.6 mm (1/16 inch) thick at the point where the flexible cord passes through the enclosure.

11.2.3.4 At a point of flexure, no additional flexible cords or wires shall be routed through a bushing or opening with the power supply cord.

11.3 External power supplies

11.3.1 As an alternative to flexible cord connections, the power pack may be provided with a DC voltage rated input connector intended for connection to the output of an external power supply.

11.3.2 The output rating of the external power supply shall be equal to or greater than the input rating of the power pack; and the output of the external power supply shall be a power source in accordance with any of the following:

a) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1 / CSA C22.2 No. 62368-1;

b) The Standard for Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements for Battery Chargers, UL 60335-2-29 / CSA C22.2 No. 60335-2-29;

c) A Class 2 power source in accordance with the Standard for Class 2 Power Units, UL 1310, and Power Supplies With Extra Low Voltage Class 2 Outputs, CSA C22.2 No. 223;

d) A power source other than Class 2 in accordance with the Standard for Power Units Other Than Class 2, UL 1012, and Battery Chargers, CSA C22.2 No. 107.2; or

e) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1 / CSA C22.2 No. 60950-1.

11.4 Vehicle adapters

11.4.1 A power pack intended for connection to an automobile cigar lighter receptacle shall be provided with a vehicle adapter that complies with the enclosure and input contacts requirements in the Standard for Vehicle Battery Adapters, UL 2089, and Power Supplies, CAN/CSA C22.2 No. 107.1. The connector plug shall incorporate a fuse or other protective device having a current rating not greater than 15 A.

Exception: The protective device may be provided in the output cord of the vehicle adapter not more than 127 mm (5 inches) from the vehicle adapter enclosure.

11.4.2 With reference to 11.4.1, if the fuse is user replaceable, the vehicle adapter shall be marked in accordance with 70.10. This marking shall appear adjacent to the fuseholder.

11.5 Photovoltaic panels

11.5.1 Power packs provided with a photovoltaic panel as an input for charging the internal battery shall be provided with an inverter and/or a charge controller and shall be in accordance with the applicable requirements in the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741; or with the applicable requirements in the Standard for Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements, UL 62109-1.

12 Output Connections

12.1 General

12.1.1 Power packs shall be provided with one or more outputs that terminate in a suitable connector or other connection means in accordance with the requirements in this Standard.

12.1.2 The output of the power pack shall include at least one of the output options shown in (a) – (d). Additional outputs are not restricted.

a) Booster cable assemblies, see 12.2;

b) Receptacles, see 12.3;

c) DC Connectors, see 12.4;

d) Vehicle adapter sockets, see 12.5;

e) USB Connectors, see 12.4;

f) Induction power transmitters, see 12.6.

12.1.3 If two or more bare parts (one of which may be earthed) of an output can be accessed and bridged by the test probe as illustrated in Figure 7.1 in a straight position without appreciable force, the maximum available power from the output shall not be more than 240 VA. Compliance shall be confirmed by the Energy Hazard Measurement Test, Section 47A.

Exception: A USB output need not comply with 12.1.3, and instead it shall comply with LVLE circuit requirements.

12.1.4 A USB output shall be a LVLE circuit and comply with the LVLE Circuit Test in Section 47B.

12.2 Booster cable assemblies

12.2.1 General

12.2.1.1 Booster cable assemblies shall be detachable or non-detachable assemblies. Detachable assemblies shall comply with 12.2.1.2 and the applicable requirements in 12.2.2 and 12.2.3. Non-detachable assemblies shall comply with 12.2.1.3 and the applicable requirements in 12.2.2 and 12.2.3.

12.2.1.2 For detachable booster cable assemblies, the connector shall be in accordance with the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CAN/CSA C22.2 No. 182.3, or the connector shall be in accordance with the Standard for Automotive Battery Booster Cables, UL 1839 (middle connectors). The connector shall have a voltage and current rating that is the same as or higher than the output rating of the booster cable assembly.

12.2.1.3 For non-detachable booster cable assemblies, the cable shall be provided with strain relief in accordance with Section 11.2.2 and bushings shall be provided in accordance with Section 11.2.3.

12.2.2 Cables

12.2.2.1 The cable provided with the booster cable assembly shall comply with the applicable requirements for cables in the Standard for Automotive Battery Booster Cables, UL 1839.

12.2.2.2 As an alternative to 12.2.2.1, the cable can be shown to comply with the requirements in 12.2.2.3 – 12.2.2.7, when the power pack is provided with a protection system for the cable assembly. The protection system shall provide output limiting such that a maximum current cannot be exceeded under normal or abnormal conditions and the maximum temperature of the cable insulation shall not be exceeded during the Normal Temperature Test, Section 47.

12.2.2.3 The conductors used within the cables shall:

a) Comply with the requirements in the Standard for Appliance Wiring Material, UL 758, and either Equipment and Lead Wires, CAN/CSA C22.2 No. 127, or Appliance Wiring Material Products, CAN/CSA C22.2 No. 210; and

b) Be suitably sized based on the rating of the output current associated with the booster function.

12.2.2.4 The final cable assembly shall be subjected to the Cold Bend Test, Section 67.

12.2.2.5 At all points where the cable enters the enclosure of the device or any other enclosure, excluding the cable connection to the clamp, the connection shall be subjected to a Strain Relief Test as described in Section 54.

12.2.2.6 The conductors of a booster cable set employing parallel conductors shall be separated at each end to allow the jaw ends of the clamps to span a minimum distance of 920 mm (3 feet). For power packs provided with a safety circuit that prevents energy from being available at the booster clamps prior to connection and immediately upon disconnection, such that arcing and sparking is prevented at the battery terminals, the 920-mm minimum distance can be reduced. The safety circuit shall be subject to the requirements in Section 40, Safety Circuits and Control Circuits.

12.2.2.7 The cable shall be subjected to the Power Pack Ampacity Test in Section 65.

12.2.3 Clamps

12.2.3.1 The clamp provided with the booster cable assembly shall comply with the applicable requirements for clamps in the Standard for Automotive Battery Booster Cables, UL 1839.

12.2.3.2 As an alternative to 12.2.3.1, the cable can be shown to comply with the requirements in 12.2.3.3 – 12.2.3.6, when the power pack is provided with a protection system for the cable assembly. The protection system shall provide output limiting such that a maximum current cannot be exceeded under normal or abnormal conditions and the maximum temperature of the cable insulation shall not be exceeded during the Normal Temperature Test, Section 47.

12.2.3.3 The clamp bodies shall be fabricated from nonmetallic materials and these materials shall have a flame rating of HB minimum.

12.2.3.4 The clamps shall be subjected to the Cold Drop Test using a conditioning temperature equal to the manufacturer's lower ambient temperature rating. See 68.2.

12.2.3.5 The clamps shall be subjected to the Dielectric Voltage-Withstand Test of 68.3.

12.2.3.6 The clamp shall be subjected to the Secureness Test of 68.4.

12.3 Receptacles

12.3.1 Receptacles provided as an output on power packs shall be of a NEMA type receptacle that is in accordance with the Standard for Attachment Plugs and Receptacles, UL 498, and General Use Receptacles, Attachment Plugs and Similar Wiring Devices, CSA C22.2 No. 42. Each AC output power circuit shall be provided with overcurrent protection for all ungrounded conductors in accordance with Section 31, Output Alternating Current Power Circuits, of the Standard for Power Units Other Than Class 2, UL 1012. Except as indicated in 12.3.1A, receptacles shall be rated 120 Vac, 15 A maximum, and shall consist of a double blade, ungrounded configuration.

12.3.1A Polarized receptacles rated 120 Vac, 30 A maximum, and that consist of a grounding configuration may be acceptable provided the criteria in either (a) or (b) is met:

a) The following criteria is met:

1) The polarized receptacles including their ground terminals are isolated from any of the AC mains input circuits by double insulation in accordance with Section 14, Double Insulation Products; and

2) The portable power pack is marked per 70.24 and provided with instructions per 72.3(q).

b) The polarized receptacles have GFCI protection for portable power pack users on all polarized receptacle outlets. The GFCIs shall be in accordance with the Standard for Ground-Fault Circuit Interrupters, UL 943, and shall interrupt the output supply circuit in the event of a ground fault of receptacles.

12.3.2 Markings shall be provided that indicate the maximum rating of the receptacle to the user. This marking shall be permanent.

12.4 DC output connectors and USB connectors

12.4.1 Power packs provided with USB connections as an output shall incorporate connectors that are in accordance with the Standard for Component Connectors for Use in Data, Signal, Control, and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CAN/CSA C22.2 No. 182.3.

12.4.2 DC output connectors provided as an output shall incorporate connectors that are in accordance with the Standard for Component Connectors for Use in Data, Signal, Control, and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CAN/CSA C22.2 No. 182.3.

12.4.3 *Deleted*

12.5 Vehicle adapter sockets

12.5.1 Adapter sockets provided as an output on a power pack, for connecting products with a standardized vehicle adapter connector, shall comply with 12.5.2.

12.5.2 The cable, if provided, shall be suitable for the voltage and ampacity of the output rating. The cable shall be in accordance with the Standard for Appliance Wiring Materials, UL 758, and either Equipment and Lead wires, CAN/CSA C22.2 No. 127, or Appliance Wiring Material Products, CAN/CSA C22.2 No. 210.

12.5.3 *Deleted*

12.6 Induction power transmitter

12.6.1 The induction power transmitter provided as an output on a power pack shall comply with 12.6.2.

12.6.2 The maximum power input to any single transmitting coil RF conversion circuit, with or without a single component fault of short or open circuit within power pack, shall not exceed 240 VA when the power pack is tested in accordance with the Energy Hazard Measurement Test, Section 47A.

12A LVLE Circuits

12A.1 Except as indicated in 12A.2, an LVLE circuit (see 5.27), including associated electronic components on printed-wiring boards, that does not extend out of the unit is not required to be evaluated.

12A.2 Safety circuits shall comply with the applicable requirements in this Standard. Printed-wiring boards, insulated wire, and motors shall be types that are required for the application. See Section 16, Internal Wiring, Section 25, Printed-Wiring Boards, and 19.2, Motors and Thermal Protection.

12A.3 A LVLE circuit shall comply with the maximum voltage and current limits as specified in 47B.1.

12A.4 A LVLE circuit shall be separated from a hazardous voltage circuit by an isolated transformer. The maximum current shall be limited through one or more resistors, a regulating network, or an overcurrent protective device (such as a fuse or nonadjustable manual-reset protective device).

12A.5 In a circuit of the type described in 12A.4, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited, shall be evaluated to the applicable requirements in this Standard.

13 Grounding

13.1 General

13.1.1 A product shall have a provision for grounding in accordance with 13.1.2 – 13.2.2 that is reliably connected when the unit is connected to the mains power source. The means for grounding may be contained within a separate or integral power supply that has been shown to comply with the applicable requirements for power supplies. In this case, no further evaluation of grounding is needed.

Exception: Double insulated products are not required to comply with Section 13. See Double Insulated Products, Section 14.

13.1.2 All exposed dead metal parts that are likely to become energized shall be reliably connected to the means for grounding.

13.1.3 The equipment grounding conductor of the power supply cord may be used for grounding.

13.1.4 The grounding conductor of a supply cord shall be secured to the metallic enclosure of the product by means of a separate screw or other equivalent means, intended for that purpose only, that is not likely to be removed during any servicing operation not involving the power supply cord. Solder alone shall not be used for securing the grounding conductor. Servicing as mentioned in this requirement include repair of the product by a qualified service person.

Exception: Products with no exposed dead metal parts need not comply with 13.1.4.

13.1.5 The grounding conductor and the dead metal parts shall be conductively connected to the grounding member of an attachment plug. The grounding member shall be fixed.

13.1.6 A separable connection, such as that provided by an attachment plug and a mating connector or receptacle, shall be such that the equipment grounding connection is made before and broken after the supply conductors.

13.1.7 The grounding terminal, intended solely for the connection of an equipment grounding conductor, shall be capable of securing a conductor of the size necessary for the application. A connection device that depends on solder alone shall not be provided for connecting the equipment grounding conductor.

13.1.8 A wire binding screw or pressure wire connector intended for the connection of an equipment grounding conductor shall be located so that it is unlikely to be removed during servicing of the power pack.

13.1.9 A screw used to secure the grounding conductor to the frame shall engage the metal by at least two full threads. The metal thickness shall not be less than 1.27 mm (0.050 inch) thick. The metal may be extruded to increase the effective thickness. Only the supply cord grounding conductor shall be secured by the grounding screw.

13.1.10 A stud and nut combination used to secure the grounding conductor to the frame shall be secured to the frame by welding the stud in place. The ground conductor shall be connected first and be in contact with the frame and secured in place by a dedicated nut and lock washer. Other bonding jumpers may be connected to the stud, but they shall be connected above the main ground connection and secured by separate nut and lock washers.

13.1.11 With reference to the requirement in 13.1.2, the following dead metal parts are not considered likely to become energized:

a) A small metal part, such as an adhesive attached foil marking, a screw, a handle, and the like, that is:

1) On the exterior of the enclosure and separated from all electrical components by grounded metal; or

2) Electrically isolated from all electrical components.

b) A panel, cover, or other metal part that is isolated from all electrical components by a barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture resistant insulating material not less than 0.80 mm (1/32 inch) thick and securely mounted in place; and

c) A panel, cover, or other metal part that does not enclose uninsulated live parts and is electrically isolated from other electrical components.

13.1.12 The main grounding path shall not include a trace on a printed-wiring board.

13.2 Grounding identification

13.2.1 The surface of the insulation on a grounding conductor of a flexible cord shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

13.2.2 The unit shall be marked at the point of grounding connection to the enclosure or frame with the grounding symbol ⏚ (IEC 60417 No. 5019).

14 Double Insulated Products

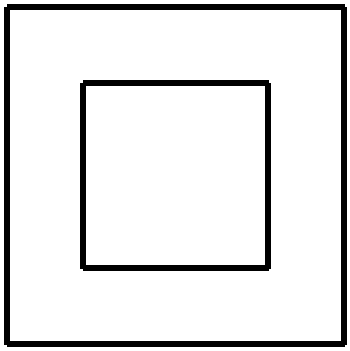
14.1 A device may be provided with a system of double insulation that complies with the requirements in the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097, in lieu of a means for grounding.

14.2 With reference to 14.1, hazardous parts shall be insulated from accessible conductive parts and accessible low voltage circuits by double insulation. The spacing requirement, Dielectric Voltage-Withstand Test, and Leakage Current Test requirements in UL 1097 shall be applied to the system of double insulation instead of the requirements in this Standard. In addition, the system of double insulation shall comply with the requirements in this Standard.

14.3 Except as indicated in 14.4, a product shall be marked as being a suitable double insulated product, see Figure 14.1. All such products shall not be provided with a means for grounding.

Figure 14.1

Double insulation marking



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14.4 If an earthing conductor in the mains supply cord for a power pack is only used for establishing functional earthing, and the power pack is provided with a system of double insulation, then the power pack shall bear the symbol , IEC 60417-6092.

14.5 With reference to 14.4, wiring terminals to be used only for the connection of functional earthing shall be marked with the symbol , IEC 60417-5018. These terminals shall not be marked with the symbol , IEC 60417-5017, or with the symbol , IEC 60417-5019, unless these symbols are provided on a component (for example, a terminal block) or subassembly.

14.6 With reference to 14.4, the power pack inlet, if used, shall comply with the creepage distance and clearance requirements for double insulation or reinforced insulation.

15 Current Carrying Parts

15.1 A current carrying part shall be of silver, copper, a copper alloy, stainless steel, or other material suitable for the application. Ordinary unplated iron or steel shall not be used for current carrying parts.

16 Internal Wiring

16.1 Mechanical protection

16.1.1 Wiring and connections between parts of equipment shall be protected or enclosed so that the conductor insulation is not exposed to contact with any rough, sharp, or moving part.

16.1.2 Insulated wiring accessible through an opening in an enclosure is considered to be protected as required in 16.1.1 if the opening complies with Openings in enclosures, 7.4. Internal wiring not so protected may be acceptable if it is so secured within the enclosure that it is not likely to be subjected to stress or mechanical damage.

16.1.3 An opening in the frame or enclosure through which insulated wires pass shall be provided with a smooth, well rounded bushing or shall have smooth, well rounded surfaces upon which the wires may lie.

16.1.4 Insulated wires, complying with the requirements for Separation of Circuits, Section 17, may be bunched and passed through a single smooth opening in a wall within the enclosure.

16.2 Wiring insulation

16.2.1 The internal wiring of power packs shall be of a type rated for the application, when considered with respect to the temperature and voltage involved, with respect to its exposure to oil and grease, and with respect to other conditions of service to which it is subjected.

16.2.2 The insulation of wiring used in a high voltage circuit shall have a flame retardant rating of VW-1 in accordance with the requirements in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

16.2.3 Sleeving, tape, and tubing used for insulation on wires shall be rated for the voltage and temperature involved.

16.3 Splices and connections

16.3.1 Splices and connections shall be mechanically secure and provide electrical contact. A soldered connection shall be made mechanically secure before being soldered.

16.3.2 Equipment subjected to vibration shall be provided with lock washers or other means to mechanically secure wire binding screws and nuts. A twist on type connector shall be additionally secured to the wires by means of at least two layers of tape. Tape used for this means shall be evaluated for its intended application and comply with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510, and PVC Insulating Tape, CAN/CSA C22.2 No. 197.

16.3.3 A splice shall be provided with insulation equivalent to that of the wires connected if spacing between the splice and other metal parts is not maintained.

16.3.4 The insulation on a splice may consist of a minimum of two layers of tape when the voltage involved is less than 250 volts. When evaluating the splice insulation consideration is to be given to such factors as its dielectric properties, heat resistance, and moisture resistance. Tape shall not be wrapped over a sharp edge.

16.3.5 If internal wiring is stranded, loose strands of wire shall not contact other uninsulated hazardous live parts of opposite polarity or dead metal parts. At a wire binding screw, this may be accomplished by using upturned lugs, a cupped washer, barriers, or other means to hold the wires under the head of the screw. Other means of retaining the loose stranded internal wiring in position are use of a pressure terminal connector, soldering lug, or crimped eyelet.

16.3.6 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current carrying parts, shall be terminated at each end by a method that is acceptable for the combination of metals involved at the connection point.

16.3.7 With reference to 16.3.6, a wire binding screw or a pressure terminal connector used as a terminating device shall be rated for use with aluminum under the condition involved – for example, temperature, heat cycling, vibration, and the like.

16.3.8 Insulation of internal wiring consisting of coated fabric, thermoplastic, or other types of tubing is to be considered with respect to electrical, mechanical, and flammability properties of the material.

17 Separation of Circuits

17.1 Conductors of different circuits operating at different potentials shall be separated or segregated from each other unless each conductor is provided with insulation rated for the highest potential involved.

17.2 An insulated conductor shall be positioned so that it cannot contact an uninsulated live part of a different circuit.

17.3 Segregation of insulated conductors may be accomplished by clamping, routing, or a means that maintains permanent separation from insulated and uninsulated live parts and from conductor of a different circuit.

17.4 A barrier used to separate or segregate internal wiring shall have the mechanical strength for the application, and it shall be reliably held in place.

17.5 Hazardous output circuits shall be isolated from DC low-voltage input circuit and DC low-voltage output circuits that may be user accessible by double insulation in accordance with Section 14, Double Insulation Products.

18 Insulating Materials

18.1 Insulating materials, used in circuits other than low-voltage, limited-energy circuits, shall be porcelain, phenolic composition, or other similar material, and shall be evaluated in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17.

18.2 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but shall not be used as the sole support for uninsulated hazardous live parts if shrinkage, current leakage, or warpage is likely to result in a risk of fire, electric shock, or injury to persons.

18.3 A thermoplastic material shall not be used for the sole support of hazardous live parts unless it complies with all of the following:

a) Mechanical strength;

b) Rigidity;

c) Resistance to heat;

d) Resistance to flame propagation;

e) Dielectric withstand; and

f) Resistance to abnormal heat.

19 Compressors

19.1 General

19.1.1 Air compressor assemblies provided with power packs, and housed within the overall power pack enclosure, shall comply with the requirements in 19.2 and 19.3. Air compressors supplied with the power pack, but as a separate unit shall be evaluated in accordance with the Standard for Motor-Operated Air Compressors, Vacuum Pumps, and Painting Equipment, UL 1450, and Motor Operated Appliances (Household and Commercial), CAN/CSA C22.2 No. 68.

19.2 Motors and thermal protection

19.2.1 A motor shall be acceptable for the application, and shall be capable of handling the maximum normal load of the power pack without creating a risk of fire, electric shock, or injury to persons.

19.2.2 A motor winding shall resist the absorption of moisture. Film coated wire used for motor windings is not required to be additionally treated to prevent moisture absorption. Fiber slot liners, cloth coil wraps, and similar moisture absorptive materials are to be provided with impregnation or otherwise treated to prevent moisture absorption.

19.2.3 A motor shall be provided with a thermal protector as described in 19.2.4.

19.2.4 With reference to 19.2.3, thermal protection shall be evaluated in accordance with the Standard for Thermally Protected Motors, UL 1004-3, and Motors With Inherent Overheating Protection, CAN/CSA C22.2 No. 77.

Exception No. 1: A thermally protected motor which drives a fully enclosed oil-less and tankless air compressor, or inflator, evaluated in accordance with the Standard for Motor-Operated Air Compressors, Vacuum Pumps, and Painting Equipment, UL 1450, and Motor Operated Appliances (Household and Commercial), CAN/CSA C22.2 No. 68.

Exception No. 2: A motor intended to move air only, by means of an air moving fan that is integrally attached, keyed, or otherwise fixed to the motor, is required to have locked rotor protection only.

Exception No. 3: A linear style pump is required to have locked rotor protection only.

19.2.5 The thermal protector shall have a current and voltage rating not less than the load that it controls.

19.3 Parts subject to pressure

19.3.1 A part of the power pack that is subject to pressure during normal or anticipated abnormal operation shall withstand, without rupture, a pressure corresponding to five times the maximum pressure that can be developed by the system.

19.3.2 In the event that a test is required to determine whether a part complies with the requirement in 19.3.1, two samples of the power pack are to be subjected to the Hydrostatic Strength Test, Section 59. Prior to the test, parts molded of polymeric material are to be conditioned in an air circulating oven for 7 hours at a temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature measured on the part under normal load, whichever is greater. The samples are to be removed from the oven and allowed to cool to room temperature prior to the test.

20 Capacitors and Electrochemical Capacitor Modules

20.1 Capacitors

20.1.1 A capacitor connected from one side of the line to the enclosure of a product shall have a capacitance rating of not more than 0.10 µF, or the power pack shall be subjected to the Capacitor Discharge Test, Section 45.

20.1.2 If a product employs a combination consisting of a rectifier and an electrolytic capacitor, no risk of fire, electric shock, or injury to persons shall result when either the rectifier or the capacitor is short-circuited.

20.1.3 Under both normal and abnormal conditions of use, a capacitor employing a liquid dielectric medium more flammable than askarel shall not expel the dielectric medium when tested in accordance with the performance requirements of this Standard.

20.2 Electrochemical capacitor modules

20.2.1 Electrochemical capacitor modules are allowed in power packs to provide the booster cable output. The electrochemical capacitor module shall comply with the requirements in the Standard for Electrochemical Capacitors, UL 810A, as well as the requirements in 20.2.2 – 20.2.4.

20.2.2 Electrochemical capacitor modules shall be provided with a means to monitor the voltage at the input of the module and shall shut down the power to the module if the voltage exceeds the voltage rating of the module. Any appropriate means is allowed, but any software or programmable components associated with this protection means shall be evaluated for reliability.

20.2.3 Electrochemical capacitor modules shall have temperatures of the module continuously monitored during any defined operating condition and the module shall be shut down if the temperature exceed the rated temperature of the module or individual capacitor in the module. Any approriate means is allowed, but any software or programmable components associated with this protection means shall be evaluated for reliability.

20.2.4 Means shall be provided such that the capacitor module shall not be allowed to discharge while the charging voltage is applied. Any attempt to jump start a vehicle while the power pack is plugged in shall be prohibited by the power pack itself. Any appropriate means is allowed, but any software or programmable components associated with this protection means shall be evaluated for reliability.

21 Resistors

21.1 The assembly of a power resistor, such as a wire wound type requiring a separate support, shall be reliable. The resistor shall be prevented from loosening or rotating by a means other than friction between surfaces.

21.2 An assembly employing lock washers may be considered to comply with 21.1.

22 Lampholders

22.1 The screw shell of a lampholder shall be connected to a conductor that is intended to be connected to the grounded conductor of the power supply circuit.

22.2 A lampholder shall be designed or installed so that uninsulated hazardous live parts, other than a screw shell, are not exposed to inadvertent contact by persons removing or replacing the lamp in normal service.

22.3 If the lampholder is supplied from an LVLE circuit, the requirements in 22.1 and 22.2 do not apply.

23 Transformers

23.1 Transformers provided as part of a power pack, shall comply with one of the following:

a) Standard for Specialty Transformers, UL 506;

b) Standard for Dry-Type General Purpose and Power Transformers, UL 1561; or

c) Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and CAN/CSA C22.2 No. 66.1, and one of the following:

1) Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2 and CAN/CSA C22.2 No. 66.2; or

2) Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3 and CAN/CSA C22.2 No. 66.3.

24 Switches and Controls

24.1 A switch or other control device shall be suitable for the application and shall have current and voltage ratings not less than those of the circuit that it controls when the power pack is operated as intended.

24.2 A primary circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer, and that does not have an inductive rating, shall be rated not less than twice the full load current rating of the load, or the switch shall be investigated for this application.

24.3 A switch or other control device not having an inductive rating that is connected in a transformer secondary circuit shall comply with the Normal Temperature Test, Section 47, and with the Overload of Switches and Controls Test of 53.2.

24.4 Unless rated for the application, a switch or other device that controls a motor and is not interlocked so that it will not break the locked rotor motor current shall be subjected to the Overload of Switches and Controls Test of 53.2, based on the locked rotor current of the motor.

24.5 A switch that controls a tungsten-filament lamp shall have a tungsten-filament lamp current rating not less than the maximum current it will control.

Exception: A switch having a tungsten-filament lamp current rating less than the maximum current it will control but rated 3 amperes or more may be used to control a 15-watt or smaller lamp.

24.6 A switch shall not disconnect the ground conductor of a circuit unless the switch simultaneously disconnects all other conductors.

24.7 If unintentional operation of a switch results in a risk of injury to persons, the actuator of the switch shall be located or guarded so that such operation is unlikely. The actuator of a switch may be guarded by recessing, ribs, barriers, or the like.

25 Printed-Wiring Boards

25.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, and have a minimum flammability classification of V-1.

25.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-wiring board to form a printed wiring assembly shall be secured so that it cannot be displaced to cause a risk of fire or electric shock by a force likely to be exerted on it during assembly, normal operation, or servicing of the power pack.

25.3 Consideration is to be given to a barrier or partition that is part of the power pack assembly and that provided mechanical protection and electrical insulation for a component connected to a printed-wiring board.

26 Interlocks

26.1 An interlock required to reduce the risk of electric shock or injury to persons shall comply with 26.2 – 26.6.

26.2 The interlock device shall not be defeated readily without:

a) Damaging the equipment;

b) Making wiring connections or alterations;

c) Using other than ordinary tools; or

d) Using materials other than those readily available. Adhesive tape, string, or conventional extension cord sets are identified as readily available.

26.3 The interlock device shall be such that during normal operation and user servicing:

a) The interlock is not defeated by improper disassembly, for example removal of the wrong screws during removal of the cover;

b) The cover in which the interlock is mounted shall not be rotated by its own weight about the interlock axis perpendicular to the cover during any stage of its removal or replacement, if such rotation gives access to a hazardous live part, or damages the interlock or cover;

c) The act of removal or replacement of the interlocked cover shall not subject the user to unintentional contact with hazardous live parts;

d) The interlocked cover is not capable of being readily misapplied to result in a risk of electric shock; and

e) The equipment is marked in accordance with 70.16.

26.4 If two momentary contact switches must be operated to energize the power pack, the arrangement shall be spaced from each other and from hazardous live parts so that, if the means are operated simultaneously by one individual, contact with hazardous live parts shall not occur.

26.5 With reference to 26.3(c), parts that are recessed more than 64 mm (2-1/2 inches) from the edge of the cabinet opening, normally in the plane of the cover, are excluded when determining that the act of removal or replacement of a cover will subject the user to unintentional contact with hazardous live parts.

26.6 An interlock shall comply with Overload of Interlocks in 53.4.

27 Overload Protection Devices

27.1 An overcurrent or thermal protective device shall be suitable for the application.

27.2 An automatic reset device used to comply with 27.1 shall be cycled through 200 operations. At the end of the 200 operations, the device shall be able to perform its intended function with no additional risk of fire, electric shock, or injury to persons. See Overload of Protection Devices, 53.3.

27.3 A fuse involving a risk of electric shock shall be inaccessible:

a) To the user from outside the enclosure; and

b) To the user during any user servicing.

27.4 A fuse that can be serviced by the user shall be secured in a fuseholder that is constructed and installed such that no uninsulated hazardous live parts will be accessible to contact by persons removing or replacing the fuse. The power pack shall be marked in accordance with 70.10. This marking shall be adjacent to the fuse.

27.5 The screw shell of a plug fuseholder and the accessible contact of an extractor type fuseholder shall be connected to the load.

28 Internal Battery

28.1 General

28.1.1 Connections to the terminals of the internal battery shall be secure. The connection means shall not allow the connection to loosen during normal operation to the point where the connection is lost, or where arcing or overheating may occur.

28.1.2 Internal batteries provided as part of power packs shall be lead acid, in accordance with 28.2, or lithium-ion, in accordance with 28.3.

28.1.3 If the internal battery is removable by the user, the battery pack shall be keyed or provided with a means to prevent inadvertent reverse polarity connections when replacing the battery pack. If the battery pack is not provided with this means of prevention, then the power pack shall be subjected to the test in 50.10.

28.2 Lead acid batteries

28.2.1 A lead acid battery shall comply with the requirements in the Standard for Standby Batteries, UL 1989, or the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications, UL 1973.

28.2.2 The power pack shall provide a means of reverse polarity protection or the test of 50.3 shall be performed.

28.2.3 The power pack shall provide short circuit protection for the battery or the test of 50.2 shall be performed.

28.2.4 The power pack shall provide a means to prevent overcharge of the battery or the test of 50.9 shall be performed.

28.2.5 The battery shall be subjected to the Normal Charging Operation Test, Section 43.

28.3 Lithium-ion batteries

28.3.1 A lithium-ion battery cell shall comply with the requirements in the Standard for Lithium Batteries, UL 1642, or the Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 2: Lithium Systems, UL 62133-2 / CSA C22.2 No. 62133-2, or the cell requirements in the Standard for Batteries for Use In Electric Vehicles, UL/ULC 2580, or the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications, UL 1973.

28.3.2 The power pack shall provide a means of reverse polarity protection or the test of 50.3 shall be performed.

28.3.3 The power pack shall provide short circuit protection for the battery or the test of 50.2 shall be performed.

28.3.4 The power pack shall provide a means to prevent overcharge of the battery or the test of 50.9 shall be performed.

28.3.5 The battery shall be subjected to the Normal Charging Operation Test, Section 43.

28.3.6 The power pack shall be subjected to the Lithium Charging System Test, Section 44.

28.3.7 A lithium-ion power pack with rated energy larger than 1 kWh shall be subjected to the Thermal Propagation Test in 50.11.

29 Spacings

29.1 Spacings between hazardous live parts of opposite polarity, and between hazardous live and dead metal parts shall not be less than specified in Table 29.1. If an uninsulated hazardous live part is not rigidly secured in position by means other than friction between surfaces, or if a movable dead metal part is in proximity to an uninsulated hazardous live part, the construction shall be such that at least the minimum spacings are maintained. See 29.2.

Exception No. 1: Spacings between traces on a printed-wiring board need not comply with Table 29.1 if the printed-wiring board complies with the Printed-Wiring Board Abnormal Test, 50.6. The requirements specified in 50.6 do not substitute for the minimum required spacings between the printed-wiring board foils and dead metal parts or the spacings between the primary and secondary board as specified in Table 29.1.

Exception No. 2: This requirement does not apply to spacings complying with 29.5 – 29.9.

Exception No. 3: This requirement does not apply to spacings complying with 29.10 and 29.11.

Table 29.1
Minimum spacings

Potential involved, volts	Minimum spacing, mm (inch)			
	Through air		Over surface	
50 or less	1.6	(1/16)	1.6	(1/16)
51 – 150	3.2	(1/8)	6.4	(1/4)
151 – 300	6.4	(1/4)	9.5	(3/8)

29.2 The spacing requirements in Table 29.1 do not necessarily apply to the inherent spacings of a component or assembly of a power pack. This includes switches, fuses, transformers, attachment plugs, and similar components or assemblies. Such spacings shall comply with the requirements for that component or assembly in question, where actual spacing requirements exist.

29.3 In a low voltage, limited energy secondary circuit, spacings between live parts of opposite polarity and between a live part and dead metal that is grounded are not specified.

29.4 Epoxy or equivalent material may be used to reduce spacings when all of the following are met:

a) Spacings of a minimum 0.8 mm (1/32 inch) are maintained prior to application of the encapsulant;

b) There are no significant voids in the encapsulant;

c) The encapsulant is a minimum 0.8 mm (1/32 inch) thick;

d) The area of reduced spacing, with the encapsulant applied, complies with the Dielectric Voltage Withstand Test, Section 48; and

e) The encapsulant temperature during the Normal Temperature Test, Section 47, does not exceed 65°C (117°F) rise [based on an assumed operating ambient rating of 25°C (77°F)] or 90°C (194°F) limit (when tested at an ambient rating of greater than 25°C).

Exception: When the encapsulant is suitable for use at a higher operating temperature, the temperature shall not exceed the material temperature rating.

29.5 As an alternative to the spacing requirements of Table 29.1, the spacing requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, and Insulation Coordination, CAN/CSA C22.2 No. 0.2, may be used. The spacing requirements of UL 840 and CAN/CSA C22.2 No. 0.2 are not to be used for spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end use application is to be considered and may modify those characteristics given in 29.6 and 29.7.

29.6 Power packs are considered to be used in a pollution degree 3 environment. Hermetically sealed or encapsulated enclosures, or coated printing-wiring boards in compliance with the Printed Wiring Board Coating Performance Test of the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, and Insulation Coordination, CAN/CSA C22.2 No. 0.2, are considered pollution degree 1.

29.7 It is anticipated the equipment will be rated overvoltage category II or overvoltage category I as defined in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, and Insulation Coordination, CAN/CSA C22.2 No. 0.2.

29.8 In order to apply clearance B spacings, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

29.9 For the purpose of power packs covered by these requirements, all printed-wiring boards are considered to have a minimum comparative tracking index of 100 without further evaluation.

29.10 An insulating liner or barrier of material such as vulcanized fiber or thermoplastic employed in lieu of required spacings shall not be less than 0.71 mm (0.028 inch) thick and shall be so located or of such material that it is not adversely affected by arcing.

Exception: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick or mica not less than 0.165 mm (0.0065 inch) thick may be used:

a) In conjunction with an air spacing of not less than 50 percent of the minimum through air spacing;

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 Vrms or less.

29.11 Insulating material having a thickness less than that specified in 29.10 may be used if, upon evaluation, it is found to comply with the requirements for the application, and has a dielectric breakdown strength of not less than 5000 volts in the thickness used for 29.10 – 2500 volts in the thickness used for the Exception to 29.10 – as determined by Tests on Insulating Materials, Section 61.

29.12 Film coated wire is regarded as an uninsulated live part when spacings are being considered.

30 Inverters

30.1 Inverters provided as part of the power pack shall be shown to comply with the applicable requirements in this Standard. See 30.2.

Exception No. 1: Inverters that comply with the Standard for Power Units Other Than Class 2, UL 1012, and Power Conversion Equipment, CSA C22.2 No. 107.1, comply without further evaluation.

Exception No. 2: Inverters that comply with the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741, comply without further evaluation.

30.2 With reference to 30.1, specific attention should be given to:

a) Printed-Wiring Boards, Section 45;

b) Spacings, Section 29;

c) Normal Temperature Test, Section 47;

d) Dielectric Voltage Withstand Test, Section 48; and

e) Abnormal Operation Tests, Section 50.

Other requirements shall also apply as applicable.

31 Charging Functions

31.1 Specialized packs that provide a charging function while connected to the source of supply that is intended to charge the external battery through the pack's booster cable assembly, or other output connection, shall have the charging circuits evaluated in accordance with the applicable requirements in the Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236, and Battery Chargers, CAN/CSA C22.2 No. 107.2.

PROTECTION AGAINST INJURY TO PERSONS

32 General

32.1 If the operation and maintenance of a power pack by the user involves a risk of injury to persons, means shall be provided to reduce the risk.

32.2 When judging a power pack with respect to the requirement in 32.1, consideration shall be given to reasonably foreseeable misuse of the power pack.

32.3 Whether a guard, a release, an interlock, or the like is required, and whether such a device meets the intent of the requirement, shall be determined from an evaluation of the complete power pack, its operating characteristics, and the likelihood of a risk of injury to persons resulting from a cause other than gross negligence. The evaluation shall include consideration of the results of breakdown or malfunction of any component, but not more than one component at a time, unless one event contributes to another. If the evaluation shows that breakdown or malfunction of a particular component can result in a risk of injury to persons, that component is to be investigated for reliability.

32.4 Portable power pack with rated capacity larger than 1 kWh shall be marked in accordance with 70.23.

33 Back Feed Protection

33.1 Power packs shall be provided with back feed protection such that no current is passed through the device from the internal battery to the power supply input connections. Constructional features shall be provided to prevent this under normal operation and single fault condition. As an alternate means of determining compliance, the measurements in the Back Feed Test, Clause 66, can be performed.

34 Sharp Edges

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

35 Strength of Enclosure

35.1 The enclosure shall be tested in accordance with the Strength of Enclosure Tests, Section 55.

36 Attachments

36.1 A functional attachment that is made available or recommended by the manufacturer for use with the basic power pack shall be included in the evaluation of the power pack. Unless the manufacturer recommends the use of two or more attachments at the same time, only one attachment at a time is to be evaluated with the product.

37 Stability

37.1 A power pack shall be tested as described in Stability Test, Section 58. The product shall not overturn as a result of the tests nor shall there be any risk of injury that develops due to the test.

Exception: A product with a mass equal to or less than 7 kg (15.4 pounds) is not required to be subjected to the Stability Test. The mass of the product is the total weight of a product which includes the weight of removable batteries and other removable parts.

38 Strength of Handles

38.1 A handle used to support or carry a product shall be subjected to the Strength of Handles Test, Section 57.

39 Surface Temperatures

39.1 During the Normal Temperature Test, Section 47, the temperature of a surface that may be contacted by the user shall not be more than the value specified in Table 39.1. If the test is conducted at a room temperature of other than 25°C (77°F), the results are to be corrected to that temperature.

Table 39.1
Maximum surface temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
	°C	(°F)	°C	(°F)
Handles or knobs that are grasped for lifting, carrying, or holding	50	(122)	60	(140)
Handles or knobs that are contacted but do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance	60	(140)	85	(185)
Surfaces subject to casual contact but not required to be contacted to operate the device	70	(158)	95	(203)

[a] A handle, knob, or similar device made of a material other than metal that is plated or clad with metal having a thickness of 0.127 mm (0.005 inch) or less is judged as a nonmetallic part.

40 Safety Circuits and Control Circuits

40.1 Circuits that are provided to limit outputs, switch outputs, control operational functions and the like, are considered safety circuits or control circuits, if their failure to provide their intended function will result in a hazardous condition or a risk of fire, shock, or injury to the user. Circuits that are classified as safety circuits or control circuits shall be evaluated to the applicable requirements in the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1 and CSA C22.2 E60730-1, and be allowed to remain in the device to provide protection during testing. A circuit not evaluated to UL 60730-1 or CSA C22.2 E60730-1 shall have its components subjected to single fault condition or bypassed during testing.

PERFORMANCE

41 General

41.1 For tests involving the overall device, complete samples of the power pack are required. The battery provided in the power pack shall be fully charged or fully discharged as indicated in the individual test. Unless otherwise stated, all tests are to be conducted at the rated input voltage and frequency for the power pack. For all electrical tests requiring connection to the branch circuit, the branch circuit shall be protected by a branch circuit protective device having a rating equal to the smallest rated receptacle to which the power pack could be connected. For tests where the internal battery is to deliver output power, the tests shall be performed with the output loaded to its maximum rating, unless otherwise specified.

41.2 Some tests may result in fire or explosion. It is therefore important that personnel be protected from the flying fragments, explosive force, sudden release of heat, chemical burns, intense light, and noise that may result from such explosions. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases.

41.3 Measurements of cell voltages during the tests of lithium-ion systems shall be made using a single pole resistive-capacitive low pass filter with a cut-off frequency of 5 kHz ±500 Hz. To determine if maximum charging voltages have been exceeded, the peak value of the voltage measured after this network shall be used. The measurement shall have a measurement tolerance within ±1 percent.

41.4 The tests are made in a draught-free location and at an ambient temperature of 20 ±5°C (68 ±9°F), unless otherwise specified. All test samples shall be stabilized to the ambient temperature prior to the test. If the temperature attained by any part is limited by a temperature sensitive device, or is influenced by temperature, the room temperature is, in case of doubt, maintained at 23 ±2°C (73.4 ±3.6°F).

41.5 Currents measured during battery charging shall be average current with the averaging period of 1 – 5 seconds.

41.6 The end of discharge voltages are 1.75 V/cell for lead acid batteries, and 2.5 V/cell for lithium-ion batteries, unless the cell manufacturer specifies a different voltage.

42 Power Input Test

42.1 The current input to a power pack shall not exceed 110 percent of the marked current rating of the power pack, when the power pack is operated under the conditions of maximum normal load.

42.2 Maximum normal load shall consist of the maximum current draw while the power pack is operating in all possible modes. For example, this may include running an air compressor, while a light is on, and the internal battery is charging. Any load that can be operated at the same time shall be operated in order to obtain the maximum normal load.

43 Normal Charging Operation Test

43.1 Charging a lithium-ion battery under normal conditions shall not exceed the specified operating region for charging of the cell.

43.2 Compliance with 43.1 is checked by the following tests in 43.3 – 43.7.

43.3 The battery is charged in accordance with the charging system instructions starting with a fully discharged battery. Testing is carried out at an ambient temperature of 20 ±5°C (68 ±9°F) and:

a) If the power pack is recommended to be operated at a minimum temperature lower than 4°C (39.2°F), the test is also conducted at that minimum temperature plus 0/minus 5 °C (plus 0/minus 9 °F); or

b) If the appliance is recommended to be operated at a maximum temperature greater than 40°C (104°F), the test is also conducted at that maximum temperature plus 5/minus 0 °C (plus 9/minus 0 °F).

43.4 All individual cell voltages, temperatures and the charging current (or multiple current measurements as in the case of parallel configurations unless analysis makes this unnecessary) are monitored. Cells shall not experience conditions outside their specified operating region for charging (e.g. limits of voltage and current). Below is an example result of such analyses.

The charging current for each branch of a parallel connection would not need to be monitored, if the maximum deliverable current of the charger did not exceed the maximum charging current of a single cell.

43.5 For batteries employing series configurations, the test is to be repeated with a deliberately imbalanced battery. The imbalance is to be introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge.

43.6 With reference to 43.5, if it can be demonstrated through testing and/or design evaluation that an imbalance less than 50 percent would actually occur in normal use, then this lower imbalance may be used. The following provides examples of testing and design:

a) An example for testing is repeated charging and discharging a battery in accordance with the manufacturer's instructions until its capacity has decreased to 80 percent of the rated capacity, using the imbalance at the end of the test.

b) Those designs that employ circuitry intended for maintaining balance between cells in the battery pack. Systems with a small number of cells in series may be shown to exhibit limited imbalance in practice, if the product ceases to operate with a battery prepared with a smaller initial imbalance.

43.7 Battery systems intended for use with power packs which may be left on, such as flashlights and fans shall additionally be tested with their battery discharged by allowing the appliance to remain "on" for at least 12 hours prior to recharging.

44 Lithium Charging System Test

44.1 A sample of the power pack subjected to this test shall be considered to comply with this test provided none of the following has occurred:

a) There has been no explosion during this test;

b) No charring or burning of the medical gauze, cheesecloth or tissue paper has resulted; and

c) The cells shall not have exceeded the upper limit charging voltage by more than 150 mV or, if they have, then the charging system shall be permanently disabled from recharging the battery.

44.2 With reference to 44.1(b), charring is defined as a blackening of the medical gauze or cheesecloth caused by combustion. Discoloration of the medical gauze or cheesecloth caused by smoke is acceptable. Charring or igniting of the tissue paper, cheesecloth, or medical gauze from the shorting means in not considered a failure.

44.3 With reference to 44.1(c), to determine if recharging is disabled, the battery shall be discharged by using the power pack to approximately a 50 percent charge, followed by an attempt to recharge the battery normally. There shall be no charging current after 10 minutes or after 25 percent of the nominal capacity has been delivered, whichever occurs first.

44.4 A sample of the power pack is to be placed on a soft wood surface covered by two layers of tissue paper. The sample is then to be covered by one layer of untreated 100 percent cotton medical gauze or cheesecloth. The power pack is to be operated as specified in the operating instructions in each of the abnormal conditions described in (a) – (d). The cumulative stress resulting from successive tests on electronic circuits or the battery is to be avoided. Additional samples may be used as necessary. As result of testing, there shall be no evidence of damage to the cell vent.

a) Components in the charging circuit are faulted as described in 44.6, one at a time, if the outcome of such a fault is uncertain based upon analysis. For each fault condition introduced, the state of the battery before charging is as follows:

1) A series configured battery is to have a deliberate imbalance. The imbalance is to be introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge;

2) If the test of Section 43, Normal Charging Operation Test, is conducted with an imbalance of less than 50 percent, a series configured battery is to have a deliberate imbalance as established in 44.6; or

3) A single cell or parallel only configuration battery is to be fully discharged.

b) If the test of Section 43, Normal Charging Operation Test, is conducted with an imbalance of less than 50 percent due to the function of circuit(s), and if a single fault of any component within that circuit(s) is shown to result in the loss of that function, then a series configured battery is to be

charged with a deliberate imbalance. The imbalance is to be introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge.

c) For a battery with a series configuration, all cells are to be at approximately 50 percent charge except for one which is shorted. The battery is to then be charged.

d) With a fully charged battery connected to the charger, a short is to be introduced to the charging system across a component or between adjacent PCB tracks at a location expected to produce the most unfavorable results to evaluate the effect of back-feed from the battery. For a charger with a cord that connects to the battery, the short is to be introduced at the point likely to produce the most adverse effects. The resistance of the short shall not exceed 10 mΩ.

44.5 During the tests of 44.4, each cell voltage is to be continuously monitored to determine if it has exceeded the limit conditions. Venting of the cells is to be permitted. The test is to be continued until the sample under test experiences a failure as described in 44.1, returns to room temperature or, if neither of these, until at least 7 hours or twice the normal charging period has elapsed, whichever is longer.

44.6 Fault conditions for components as required by 44.4 shall be as follows:

a) Open-circuit at the terminal of any component;

b) Short-circuit of capacitors, unless they are certified EMI capacitors;

c) Short-circuit of any two terminals of an electronic component, other than a monolithic integrated circuit. This fault is not applied between the two circuits of an optocoupler;

d) Failure of triacs in the diode mode; and

e) Failure of a monolithic integrated circuit or other circuits that cannot be assessed by the fault conditions (a) – (d). All possible output signals are considered under fault conditions within the integrated circuit. Components such as thyristors and triacs are not subjected to this fault condition.

45 Capacitor Discharge Test

45.1 A power pack provided with filtering capacitors, or other primary capacitors, rated in excess of 0.10 µF and connected between one side of the line and ground, shall be subjected to the Capacitor Discharge Test.

45.2 The device is to be connected to a supply source of rated voltage at 60 Hz. The output is to be connected to a suitable load such that rated current is drawn from the output of the device. A storage oscilloscope is to be connected across the point of disconnection of the supply.

45.3 The device is to be connected to the source of supply and energized. The power is to then be removed and the resulting discharge curve for the stored charge on capacitors is to be measured and captured on the oscilloscope. The value of the stored charge shall decay to less than 37 percent of its initial value within 1 second.

45.4 The test is to be repeated with all switches in all possible positions and combinations.

46 Leakage Current Test

46.1 A power pack with hazardous voltage circuits shall be tested in accordance with 46.2 – 46.7. Leakage current shall not be more than 0.5 mA.

Exception: The leakage current of a power pack provided with no AC supply shall be measured with the measurement instrument connected between the hazardous circuit (either hazardous input or output) to the output ground terminal and any user accessible conductive parts.

46.2 All accessible conductive parts are to be tested for leakage currents. Leakage currents from these parts are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one part to another if simultaneously accessible. A part is considered to be accessible unless it is guarded by an enclosure that has been evaluated for protection against the risk of electric shock. Conductive parts are considered to be simultaneously accessible 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 and the grounded supply conductor.

46.3 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 inches) in contact with the surface. If the conductive surface has an area less than 10 by 20 cm (4 by 8 inches), 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.

46.4 A typical measurement circuit for leakage current with the ground connection open is illustrated in Figure 46.1. The measurement instrument is defined in Figure 46.2. 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 46.2.

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 46.2. 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 ohms and then multiplying the quotient by 1,000. The mathematic equivalent is to multiply the RMS voltage reading by 2.

Figure 46.1

Typical leakage current measurement circuit

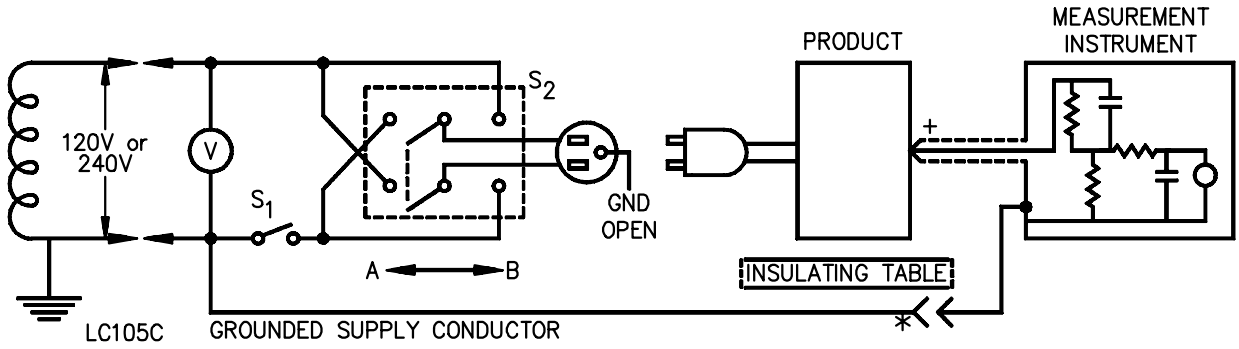
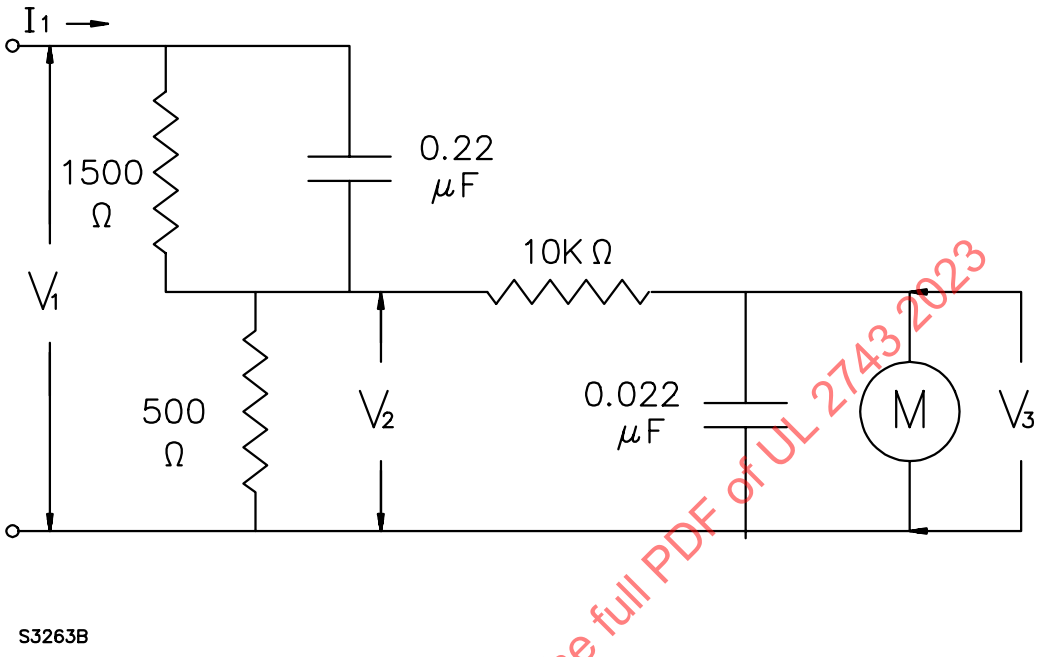


Figure 46.2

Measurement instrument for leakage current



Note – Detailed specifications and guidance for the calibration of this instrument are given in the Standard for Leakage Current for Appliances, UL 101.

46.5 Unless the measurement instrument is being used to measure leakage current from one part of the power pack to another, it is to be connected between accessible parts and the supply conductor connected to ground.

46.6 A sample of a product is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except as may occur as part of the production line testing. The supply voltage is to be adjusted to rated voltage.

46.7 The test sequence is to be as follows, with reference to the Figure 46.1 measurement circuit:

a) With switch S_1 open, the power pack is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S_2, and with the product switching devices in all their normal operating positions.

b) Switch S_1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S_2 and with the product switching devices in all their normal operating positions.

c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S_2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the Normal Temperature Test, Section 47.

d) The leakage current is also to be monitored with switch S_1 open while the product is at operating temperature and while cooling.

46.8 Normally a sample will be subjected to the entire leakage current test, as specified in 46.7, without interruption for other tests. With the concurrence of all those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

47 Normal Temperature Test

47.1 General

47.1.1 A power pack, when tested under the conditions of maximum normal load as described in 47.2 shall not reach a temperature high enough to cause a risk of fire, to damage any materials used, or exceed the temperature rises specified in Table 47.1. See Section 39, Surface Temperatures.

47.1.2 A thermal or overload protective device shall not open the circuit during the Temperature Test.

47.1.3 All values of temperature rise in Table 47.1 are based on an assumed ambient temperature of 40°C (104°F).

Table 47.1
Maximum temperature rises

Material and components	°C	(°F)
A. COMPONENTS		
1. Capacitors:		
(a) Electrolytic	40	(72)
(b) Other types[a]	65	(117)
2. Fuses[b]	65	(117)
3. Relay, solenoid, and coils (except transformers) with		
(a) Class 105(A) insulated systems		
Thermocouple method	65	(117)
Resistance method	85	(153)
(b) Class 130(B) insulation systems		
Thermocouple method	85	(153)
4. Sealing Compound[c]	40	(104)
5. Transformers		
(a) Class 105(A) insulation systems:		
Thermocouple method	55	(99)
Resistance method	60	(108)
(b) Class 120(E) insulation systems:		
Thermocouple method	70	(126)
Resistance method	75	(135)
(c) Class 130(B) insulation systems:		
Thermocouple method	80	(176)
Resistance method	85	(185)
(d) Class 155(F) insulation systems:		
Thermocouple method	110	(198)
Resistance method	115	(207)

Table 47.1 Continued on Next Page

Table 47.1 Continued

Material and components	°C	(°F)
(e) Class 180(H) insulation systems:		
Thermocouple method	125	(225)
Resistance method	135	(243)
B. CONDUCTORS		
1. Rubber- or thermoplastic insulated wires and cords[b]	35	(63)
C. ELECTRICAL INSULATION – GENERAL		
1. Fiber employed as electrical insulation	65	(117)
2. Phenolic composition employed as electrical insulation or as a part the deterioration of which could result in a risk of fire or electric shock[b]		
(a) Laminated	100	(180)
(b) Molded	125	(225)
3. Varnished-cloth insulation	60	(108)

[a] A capacitor is to be judged on the basis of its marked temperature limit when it operates at a temperature rise of more than 65°C (117°F).

[b] A fuse that has been investigated, and found to comply with requirements for use at a higher temperature is able to be used at that temperature.

[c] The temperature rise limit for sealing compounds indicates the maximum rise that may be observed on a sealing compound. However, the maximum temperature of the sealing compound shall not exceed the melting point of the sealing compound regardless of overall temperature rise.

47.1.4 For this test, the test voltage shall be the same as the rated voltage of the power pack.

47.1.5 A power pack shall be operated for a duration that is reasonable in comparison to its normal use. For example, when charging the internal battery, the duration of the charging function is complete when the battery is fully charged. See 47.2.

47.1.6 With reference to tests that are to be continued until thermal stabilization is obtained, thermal stabilization is considered to exist when three successive readings taken at intervals of 10 percent of the previously elapsed test duration, but not less than 5 minute intervals, indicate no change in temperature.

47.1.7 Coil winding temperatures are to be measured by thermocouples or by using the change-of-resistance method.

47.1.8 Thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). Whenever reference temperature measurements by thermocouples are necessary, thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type instrument are to be used. 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, ASTM E230.

47.1.9 When using the change-of-resistance method, the windings are to be at room temperature at the start of the test, and the temperature rise of a winding is to be calculated using the formula:

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

in which:

Δt = the temperature rise in degrees C;

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

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

t_1 = the initial room temperature in degrees C at the time "r" is measured

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

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

47.2 Maximum normal load

47.2.1 Maximum normal load is considered to be the load that approximates as closely as possible the most severe conditions of normal use. It is not a deliberate overload except as the conditions of actual use are likely to be somewhat more severe than the maximum load conditions that are recommended by the manufacturer of the power pack. A product having features not contemplated in these test procedures may be tested as necessary to meet the intent of these requirements.

47.2.2 A power pack may consist of separate components or assemblies such as lights, air compressors, internal battery, and the like. Each of these assemblies will create a load for the product. All functions that can be performed, and all assemblies that can be operated, at that same time are to be operated in order to create the maximum load. This would include turning on all lights, charging the internal battery, running the air compressor, and the like.

47.2.3 For a power pack that contains provisions for eliminating specific functions when others are in process the maximum normal load shall take this into account. In addition, the means for controlling such load balancing shall be investigated for reliability.

47.2.4 The unit shall be designed to minimize the allowable inrush current from the vehicle battery when jump starting. The unit shall be able to accept the maximum allowable inrush current from the clamp leads for at least 10 seconds with no damage to the power pack.

47.2.5 If the unit is provided with an inverter with AC output, the inverter should be able to operate if clamps are applied to external DC source.

47.2.6 A 12 volt DC output (cigarette lighter) shall be tested with 15A output to temperature stabilization, without risk of damage to unit.

47.2.7 Air compressors shall be tested under the following conditions with the internal battery fully charged:

a) Locked-rotor;

b) By operation with output under rated load based on the marked duty cycle provided by the manufacturer. If no marked duty cycle is provided, then the air compressor shall be tested by filling a 10-gallon air tank, with a duty cycle of 5 minutes on, 1 minute off; and

c) Continuous running unit with end of air-fill hose sealed.

For the condition in (c), the pressure shall be monitored and utilized for application of Section 59, Hydrostatic Strength Test, applied to the compressor and all hoses subject to pressure.

47.2.8 For power packs that allow outputs to be powered while the pack is connected to the source of supply, the test shall be performed with all allowable outputs loaded until thermal stabilization. For packs

where the output can only be powered by the internal battery, the test duration shall be determined based on the batteries capability of maintaining the supply current as is discharges.

47.3 Power pack ampacity temperature test

47.3.1 When conducting the Power Pack Ampacity Test of Section 65, the Power Pack Ampacity Temperature Test is also to be conducted. The Power Pack Ampacity Test is to be conducted for a duration of 25 seconds, or whatever duration is allowed by the inherent functionality of the battery pack, at the end of duration the output of the power pack is to be turned "off". During this time, the temperatures of the battery and all internal affected components including cables are to be recorded and shall be within the limits specified in Table 47.1. Additionally, the temperatures of the clamps are to be monitored from the start of the test and continuing through 2 minutes after the current is turned "off". At no time during this test shall the temperatures exceed those in Table 47.2:

Table 47.2
Maximum surface temperature rises on clamp

Clamp Location (portion adjacent to live-jaw)	Composition of surface			
	Metallic		Nonmetallic	
	°C	(°F)	°C	(°F)
Area between pivot and jaw-ends of clamp	45	(81)	70	(126)
Handle portion of clamp area between pivot and hand ends	25	(45)	35	(63)
NOTE – Maximum surface temperature rise of handle ends is based on UL Casualty Requirements for carrying and holding handles – Battery Booster Cables, SAE J1494 specifies 66°C (150°F) max.				

47A Energy Hazard Measurement Test

47A.1 When tested as specified in 47A.2 – 47A.5, the maximum energy measured in any output shall not exceed 240 VA, and the power input to any single transmitting coil RF conversion circuit measured shall not exceed 240 VA.

47A.2 The power pack is to be fully charged before the test.

Exception No. 1: The power pack may be fully charged and supplied by one of its specified power sources if it can result in a higher output energy at the measured output or a higher input power to the transmitting coil.

Exception No. 2: The power pack may be a lower SOC state and supplied by one of its specified power sources if it can result in a higher output energy at the measured output or a higher input power to the transmitting coil.

47A.3 For each of the conductive output connectors, an adjustable resistor is to be connected across the power terminals of the connector. The current through the resistor and voltage across the resistor are to be monitored using suitable meters. The resistance is to be adjusted to obtain maximum energy at the output.

47A.4 For any inductive output, an adjustable simulated load is to be used which incorporates an induction receiver appropriate to the induction power transmitter in the power pack. The simulated load shall be capable of providing a load demand to the transmitting coil greater than the maximum input of 240 VA. The input power to the transmitting coil is to be monitored while the simulated load is adjusted to result in the maximum power to the transmitting coil.

47A.5 The test in 47A.4 is to be repeated with a single fault condition (open or short) on any component which can result in a higher input power to the transmitting coil.

47B LVLE Circuit Test

47B.1 A control circuit that is considered an LVLE circuit shall comply with the maximum voltage and current limits in Table 47B.1 when tested as specified in 47B.2 – 47B.7:

Table 47B.1
Voltage and Current Limits for LVLE Circuits

Application	Open circuit voltage, V	Maximum current [b]
Outdoor use or temporary outdoor use	30 volts DC or 21.2 volts peak or less	8
Indoor use	30 volts DC or 42.2 volts peak or less	8
Indoor use	More than 30 but not greater than 60 volts dc	150/ V[a]

[a] V is the maximum output voltage of the power pack with all load disconnected and energized in accordance with 47B.2.

[b] The current is able to exceed the specified value when the circuit includes an overcurrent protection device as described in 47B.4 and 47B.5.

47B.2 The power pack shall be fully charged before testing, and then the maximum open circuit voltage is to be measured with all loading circuits disconnected.

Exception 1: The power pack should be fully charged and supplied by one of its specified power sources if it can result in a higher output voltage or current.

Exception 2: The power pack should be a lower SOC state and supplied by one of its specified power sources if it can result in a higher output voltage or current.

47B.3 The maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current.

47B.4 If a fuse or circuit-protective device is used to limit the current, the fuse shall be rated or set at not more than the values specified in Table 47B.2. In this case, the maximum current is not required to be measured.

Table 47B.2
Rating for Secondary Fuse or Circuit Protector

Circuit voltage, V rms	Maximum overcurrent protection, amperes
20 or less	5
More than 20 and not greater than 60	100/V[a]

[a] V is the maximum output voltage of the power pack with all load disconnected and energized in accordance with 47B.2.

47B.5 If a fuse or circuit-protective device connected to the primary of a transformer is used to limit the secondary circuit current in accordance with 47B.1, the fuse shall comply with 47B.4 and additionally operate to open the circuit in not more than the time indicated in Table 47B.3 when the transformer is delivering the specified secondary current.

Table 47B.3
Maximum Time to Open for Overcurrent Protective Device

Maximum transformer open circuit secondary voltage (Vmax), volts	Secondary test current, amperes	Maximum time for overcurrent protective device to open, minutes
20 or less	10	2
20 or less	6.75	60
Over 20	200/Vmax	2
Over 20	135/Vmax	60

47B.6 To determine whether a fuse or circuit protective device complies with the requirement in Table 47B.3, the transformer is to deliver the test current to a resistance load with the primary connected to a circuit as described in 47B.2. During the 2-minute test, the load is to be adjusted continuously to maintain the required test current. During the 60-minute test, the load is to be adjusted once after 15 minutes of operation, and the test is to be continued without further adjustment. Where the fuse or circuit protective device is used to protect more than one secondary winding or taps, each winding or partial winding is to be tested with the remaining windings delivering rated load if applicable.

47B.7 If a regulating network is used to limit the voltage or current in accordance with 47B.1, the performance testing is to be conducted both under normal operating conditions and after any simulated single fault in the regulating network (open circuit or short circuit of component), excluding a resistor.

48 Dielectric Voltage Withstand Test

48.1 While in a well-heated condition, a power pack shall withstand for 1 minute without breakdown the application of a 60 Hz essentially sinusoidal potential of:

a) 1000 volts plus twice the maximum rated voltage between:

1) The primary circuit and dead metal parts;

2) The primary and secondary circuits;

3) Secondary circuits operating above 50 V and dead metal parts; and

4) Secondary circuits operating above 50 V and secondary circuits operating below 50 V.

b) 500 volts between:

1) Secondary circuits operating below 50 volts and dead metal parts, and

2) Secondary circuits operating below 50 volts and other secondary circuits operating below 50 V.

Exception: The ac potentials shown above may be replaced with a dc potential equal to 1.414 times the ac potential for this test.

48.2 To determine if the power pack complies with the requirements in 48.1, the power pack is to be tested using a 500 volt-ampere 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 a substantially uniform rate as rapid as is consistent with correct identification of its value by a voltmeter.

49 Leakage Current Following Humidity Conditioning

49.1 A power pack with hazardous voltage circuits shall comply with the requirements for leakage current in Section 46, Leakage Current Test, following exposure for 48 hours to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).

49.2 To determine whether a product complies with the requirement in 49.1, a sample of the power pack is to be heated to a temperature just above 34°C (93°F) to reduce the likelihood of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 49.1.

49.3 Following the conditioning, the sample is to be tested as described in the Leakage Current Test, Section 46, while either in the humidity chamber or immediately after removal of the conditioned sample from the humidity chamber. For each test condition, the maximum leakage current is to be recorded and the test is to be discontinued when the leakage current stabilizes or decreases.

50 Abnormal Operation Tests

50.1 General

50.1.1 A power pack shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons when subjected to the tests specified in 50.2 – 50.10. Separate samples are to be used for conducting each test, unless using a sample for more than one test is agreeable to all concerned.

50.1.2 Following each test, the Dielectric Voltage Withstand Test specified in Section 48 is to be conducted.

50.1.3 With reference to 50.1.1, a risk of fire, electric shock, or injury to persons exists when:

a) Flame, burning oil, or molten metal is emitted from the enclosure of the power pack as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper; or

b) The insulation breaks down when tested in accordance with 50.1.2 or hazardous live parts are made accessible.

50.1.4 During these tests, the device is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 26 – 28 m^2/kg (14 – 15 square yards per pound), and having, for each 6.45 cm^2 (1 $inch^2$), a count of 32 threads in one direction and 28 in the other direction.

Exception: When it is impractical to drape cheesecloth over the entire enclosure, the cheesecloth is required to be placed only over all ventilation openings.

50.1.5 The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20 ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The rated voltage and frequency are to be used for this test.

50.1.6 Each test is to be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of acceptable test terminations:

a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices.

b) Opening of the intended branch circuit overcurrent protection device described in 50.1.5.

c) Opening of an internal fuse.

50.1.7 During the abnormal tests specified in 50.2, 50.3, 50.9, and 50.10 for the battery, control circuits used to limit the output or input shall be evaluated in accordance with Section 40, Safety Circuits and Control Circuits. Fuses and other protective devices determined reliable are to remain in the device to protect the battery. A control circuit not evaluated to UL 60730-1 or CSA C22.2 E60730-1 shall have its components subjected to single fault condition or bypassed during testing.

50.2 Output connections short circuit test

50.2.1 The power pack is to be tested as described in 50.2.2. The device shall comply with the requirements in 50.1.1.

50.2.2 With reference to 50.2.1, fuses and other protective devices provided as part of the power pack are to remain in the circuit. The output connections of the power pack are to be short-circuited at the connector with a resistance not exceeding 10mΩ and the power pack connected to a source of supply adjusted to its rated voltage. The test is to be continued until the internal protection opens or constant temperatures are obtained. When an automatically reset protector or a manually reset protector ends the test, the test is to be continued as indicated in 50.1.6.

50.2.3 If the power pack is provided with an output cable (e.g. booster cable), then the short shall also occur at the end of the cable in order to judge that cables ability to withstand the fault for the duration.

50.2.4 If the power pack is provided with an on/off switch which is used to control an output, the test shall be conducted with that switch opened and closed.

50.3 Reverse polarity of booster cables

50.3.1 A power pack with a booster function is to be tested in accordance with 50.3.2. The power pack shall comply with the requirements in 50.1.1.

50.3.2 With reference to 50.3.1, fuses and other protective devices provided as part of the power pack are to remain in the device. The output booster cable connections of the power pack are to be reverse connected to a fully charged battery. The test is to be continued until the internal protection opens or constant temperatures are obtained. When an automatically reset protector or a manually reset protector ends the test, the test is to be continued as indicated in 50.1.6.

50.3.3 If the power pack is provided with a switch that controls the booster cable output function, the test shall be conducted with that switch opened and closed.

50.4 Component faults

50.4.1 A component, such as a capacitor, diode, solid state device, resistor, or similar component, connected in the power pack are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required where circuit analysis indicates that no other component or portion of the circuit is overloaded. At the end of each component fault condition, the power pack shall comply with the requirement in 50.1.1.

50.5 Relay and solenoid burnout

50.5.1 An electromagnetic relay or a solenoid having an open coil construction is to be tested by blocking the armature or the plunger in the de-energized position. The test shall be continued until constant temperatures are obtained or for 7 hours maximum. The test results shall comply with 50.1.1.

50.6 Printed-wiring board abnormal test

50.6.1 To comply with Exception No. 1 to 29.1, a printed-wiring board is to be tested as described in 50.6.2 – 50.6.5.

50.6.2 During this test, if a printed-wiring board trace opens, the gap is to be electrically shorted and the test continued until ultimate results occur. This procedure applies to each occurrence. If the circuit is interrupted by the opening of a component other than described in 50.6.3, the test is to be repeated two more times using new components as necessary.

50.6.3 Operation of an overcurrent protective device other than the branch circuit overcurrent protective device is allowed.

50.6.4 A sample of the power pack employing a printed-wiring board is to be connected to its rated supply voltage. A foil trace is to be short-circuited to each of its adjacent traces that do not have the spacing specified in Table 29.1, one at a time.

50.6.5 The test is to be continued for 1 hour or until one of the conditions described in 50.1.3 occurs. However, if at the end of 1 hour no condition described in 50.1.3 occurs, but indications are that such a condition may eventually occur, the test is to be continued until ultimate results are obtained (usually 7 hours).

50.7 Disconnected fan test

50.7.1 A device having forced ventilation is to be operated with the fan disconnected. For a device having more than one fan, the test is to be conducted with each fan disconnected, one at a time, or with two or more fans disconnected, if they are controlled or powered by the same connection. If part of the circuitry senses a disconnected fan and shuts down the unit, the circuitry shall be bypassed to allow operation with the fans disconnected or the circuitry shall be evaluated for suitability of this protective function.

50.8 Blocked ventilation test

50.8.1 A power pack provided with ventilation openings for allowing air flow to cool internal components shall be subjected to this test. The vents are to be blocked, and the unit is to be operated at maximum normal load, as defined in 47.2. The test is to continue until constant temperatures are obtained or for 7 hours maximum. During the test, the power pack shall comply with 50.1.1.

50.9 Overcharging test

50.9.1 Power packs shall withstand abusive overcharging without risk of fire or explosion when tested in accordance with 50.9.2.

50.9.2 The power pack is to be placed on a soft wood surface covered by two layers of tissue paper and one layer of untreated 100 percent cotton medical gauze. The battery is to be charged at a rate as described in (a) or (b) for 1.25 hours:

a) For a universal charging port, the maximum charging voltage and 3 times the maximum charging current for the power pack, with or without a single fault condition in the charging protection circuit; or

b) For a non-universal charging port, the maximum voltage and current output that is available from an external charger or internal charging circuit provided for the battery with or without a single fault condition in the charging protection circuit.

There shall be no explosion and no charring or burning of the gauze or tissue paper. Charring is defined as a blackening of the gauze caused by combustion. Discoloration of the gauze caused by smoke is acceptable. Venting of the cells is acceptable.

50.10 Internal battery reverse polarity test

50.10.1 For power packs with removable internal batteries that are not keyed or otherwise prevented from being connected incorrectly, the test of 50.10.2 is to be carried out and the pack shall comply with 50.1.1.

50.10.2 During this test, fuses and other protective devices provided as part of the power pack are to remain in the device. Two samples are to be tested. The first sample is to be tested by connecting a fully discharged internal battery in reverse polarity and then attempting to charge the internal battery with a normal charging cycle. The second sample is to be tested by connecting a fully charged internal battery in reverse polarity and then attempting to use the pack under the conditions of maximum normal load. In both cases, the test is to be continued until the internal protection opens or constant temperatures are obtained. When an automatically reset protector or a manually reset protector ends the test, the test is to be continued as indicated in 50.1.6.

50.11 Thermal propagation test

50.11.1 A lithium-ion power pack with rated energy larger than 1 kWh shall be tested in accordance with Single Cell Failure Design Tolerance Test in the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications, UL 1973.

50.11.2 During the test, external batteries or attachments are to be installed or detached as intended which results in the most severe condition. Batteries are to be fully charged before testing.

50.11.3 As a result of testing, there shall be no fire propagating from the DUT or explosion of the DUT.

51 Vibration Test

51.1 Cells shall not catch fire nor explode during or immediately following the Vibration Test.

51.2 The Vibration Test shall consist of vibration for 4 hours at a frequency of 22 cycles per second with a displacement of 6.4 mm (1/4 inch) in a vertical plane. The unit is to be mounted as intended during the test.

52 Ground Continuity

52.1 The resistance between the point of connection of the equipment-grounding means at or within the product and any other point in the grounding circuit of the product shall not be more than 0.1Ω as determined by an ohmmeter or other equivalent means.

52.2 If unacceptable results are observed with an ohmmeter, a low voltage current source can be employed. With the low voltage current source, an alternating current of 25 A (for 15 A maximum rated products) from a power supply of 12 V or less is to be passed for one minute minimum. The current shall be passed from the point of connection of the equipment grounding means to the metal part in the grounding circuit under test. The resulting drop in potential is to be measured between the two points.

53 Overload Tests

53.1 General

53.1.1 The overload tests in 53.2 – 53.4 are required as applicable.

53.2 Overload of switches and controls test

53.2.1 Unless known to be evaluated for the application, a switch or other control device shall perform acceptably when subjected to an overload test consisting of 50 cycles of operation making and breaking the load. For this test, the load may be the actual load applied in the product, or if this is unknown, the load shall be based on the rating of the switch or control device. As a result of this overload test there shall be no electrical or mechanical breakdown of the device, undue burning or pitting of the contacts, or opening of the fuse in the grounding connections.

53.2.2 To determine whether a switch or other control device complies with the requirements in 53.2.1, the power pack is to be connected to a supply circuit of rated frequency and the maximum rated voltage (or a fully charged power pack). The load for the device under test is to be the same as that which it is intended to control in regular service. During the test, accessible dead metal parts of the power pack are to be connected to ground through a 3-ampere plug fuse. The device is to be operated at a rate of not more than 10 cycles per minute, except that a faster rate of operation may be employed if agreeable to those concerned.

53.3 Overload of protection devices

53.3.1 An overload protective device is to be cycled through 200 operations of make and break action. The device is to be connected to the voltage present in the end product and the current load is to be adjusted to be equal to the maximum load seen by the device in the end product. The device is to be cycled at 10 cycles per minute, or faster if all involved agree. At the end of the 200 cycles, the device shall be able to operate as intended.

53.4 Overload of interlocks

53.4.1 The contact of the safety interlock switch or relay is to be subjected to an overload test consisting of 50 cycles of operation at the rate of 6 to 10 cycles per minute, making and breaking 150 percent of the current imposed in the application, except that where a contact switches a motor load, the test is to be conducted with the rotor of the motor in a locked condition. After the test, the switch or relay shall still be functional.

54 Strain Relief Test

54.1 Direct-pull strain relief test

54.1.1 The strain relief means provided for a supply cord or a multi-conductor output cord where the interconnection of outputs exceeds LVLE shall withstand the force described in 54.1.3 for 1 minute with the connections within the power pack disconnected. At the point of disconnection of the conductors, there shall be no movement of the cord as to indicate that stress on the connections would have resulted from the pull force. There shall be no breakage of the cord or deformation of its anchoring surface.

54.1.2 The output wiring of a unit other than one having a multi-conductor cord as specified in 54.1.1 shall withstand the force described in 54.1.4 applied for 1 minute. The results are considered acceptable if, with the output wiring connected internally, movement of the cord does not result in:

a) A reduction of spacings to primary or dead metal parts;

b) Damage to the transformer or enclosure; or

c) Interruption of the output wiring.

54.1.3 A 15.9-kg (35-pound) weight is to be suspended from the cord and supported by the power pack so that the strain relief means is stressed from any angle the construction of the power pack permits.

54.1.4 For units employing a flexible output cord, or a multi-conductor cord where the interconnection of outputs does not exceed LVLE, a 20 pounds-force (89 N) is to be applied to the cord and supported by the unit so that the strain relief means is stressed from the most severe angle that the construction of the unit permits. For units employing output wiring consisting of separate leads, a 10 pounds-force (44 N) is to be applied to each lead.

54.2 Push-back strain relief test

54.2.1 To determine compliance with 11.2.2.3, a product shall be tested in accordance with 54.2.2 without occurrence of any of the conditions specified in 11.2.2.3 (a) – (c).

54.2.2 The supply cord or lead is to be held 25.4 mm (1 inch) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing which extends further than 25.4 mm (1 inch) 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 or lead is to be pushed back into the product in 25.4-mm (1-inch) increments until the cord buckles or the force to push the cord into the product exceed 26.7 N (6 pounds-force). The supply cord or lead within the product is to be manipulated to determine compliance with 11.2.2.3.

55 Strength of Enclosure Tests

55.1 General

55.1.1 A power pack shall be tested as described in 55.2 and 55.3. Following these tests, the power pack shall:

a) Not permit a probe, as illustrated in Figure 7.1, to contact an uninsulated live part that may involve a risk of electric shock;

b) Comply with the Dielectric Voltage Withstand Test, Section 48, with the potential applied between live parts and accessible dead metal parts; and

c) Not have a permanent distortion of a metallic enclosure that reduces spacings below the minimum values, as specified in Spacings, Section 29.

55.1.2 *Deleted*

55.2 Impact test

55.2.1 Two samples of the power pack are to be subjected to the Impact Test. The first sample is to be tested in the as-received condition. The second sample is to be conditioned in a cold chamber at 0°C (32°F), or the minimum operating temperature specified by the manufacturer if lower than 0 °C (32 °F), for

4 hours. The sample is to be removed from the cold chamber and immediately subjected to the impact described in 55.2.2. During handling of the sample, gloves are to be worn to minimize heat transfer.

55.2.2 An enclosure, guard, or cover is to be subjected to an impact of 6.78 N-m (5 foot-pounds) on any surface that may be subjected to an impact during intended use. The impact is to be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter and weighing approximately 0.535 kg (1.18 pounds), from a height of 1.30 m (51 inches). For surfaces other than the top, the steel sphere is to be suspended by a cord and allowed to swing as a pendulum dropping through a vertical distance of 1.30 m (51 inches). The impact shall be applied one time to each surface that is exposed to a blow during any condition of intended use.

55.3 Drop test

55.3.1 Two samples of the power pack are to be subjected to the Drop Test. The first sample is to be tested in the as-received condition. The second sample is to be conditioned in a cold chamber at 0°C (32°F), or the minimum operating temperature specified by the manufacturer if lower than 0 °C (32 °F), for 4 hours. The sample is to be removed from the cold chamber and immediately subjected to the impact described in 55.3.2. During handling of the sample, gloves are to be worn to minimize heat transfer. Following the test, the power pack shall be in accordance with 55.1.1 (a) – (c).

55.3.2 The sample of a portable power pack weighing equal to or less than 18 kg (39.7 pounds) is to be dropped three times from a height of 0.9 m (3 feet) to strike a concrete surface in the positions most likely to produce adverse results. The sample of a movable power pack weighing more than 18 kg (39.7 pounds) is to be dropped one time from a height of 0.9 m (3 feet) to strike a concrete surface in the position most likely to produce adverse results.

56 Mold Stress Test

56.1 One sample, consisting of the complete equipment or the complete enclosure, is to be subjected to this test.

56.2 The sample is to be placed in an air circulating oven at a temperature equal to 10 degrees higher than the maximum temperature observed on the enclosure during the temperature test, but not less than 80°C (176°F) or 70°C (158°F) if marked in accordance with 70.22. The sample is to be conditioned in the oven for 7 hours.

56.3 After the conditioning, the sample shall not show any signs of distortion, deterioration, shrinkage, warping, or softening that would allow access to hazardous live parts.

57 Strength of Handles Test

57.1 A handle used to lift or carry a power pack shall withstand a force of four times the weight of the power pack without breakage of the handle, its securing means, or that portion of the enclosure to which the handle is attached.

57.2 To determine whether a power pack complies with the requirements in 57.1, a force equal to four times the weight of the power pack is to be uniformly applied over a 76-mm (3-inch) width at the center of the handle, without clamping. The load is to be started at zero and is to be gradually increased so that the test value will be attained in 5 to 10 seconds and maintained at that value for 1 minute. If more than one handle is provided on a power pack and the power pack cannot be carried by one handle alone, the force is to be distributed between the handles. The distribution of forces is to be determined by measuring the percentage of the weight of the power pack sustained by each handle with the power pack in the normal carrying position. If a power pack is furnished with more than one handle and can be carried by one handle only, each handle shall withstand the total force.

58 Stability Test

58.1 Under conditions of normal use, a power pack shall not become physically unstable to the degree that it poses a risk of injury to persons.

58.2 A power pack shall not tip over but shall return to its normal at rest position when:

a) Tipped through an angle of 10 degrees from an at rest position on a horizontal surface; or

b) Placed on an inclined plane inclined at an angle of 10 degrees from the horizontal.

58.3 A power pack is not to be energized during this test. The test is to be conducted under conditions most likely to cause the power pack to overturn.

58.4 With reference to the requirements in 58.2, for a power pack that is constructed so that while being tipped through an angle of 10 degrees, a part or surface of the power pack not normally in contact with the horizontal supporting surface touches the supporting surface before the power pack has been tipped through an angle of 10 degrees, the tipping is to be continued until the surface or plane of the surface of the power pack originally in contact with the horizontal supporting surface is at an angle of 10 degrees from the horizontal supporting surface.

59 Hydrostatic Strength Test

59.1 A hydrostatic strength test is to be conducted by filling the pressure confining portion of the sample with water so as to exclude all air, connecting the sample to a hydraulic pump, gradually increasing the pressure to the specified test value, and holding it for a period of 1 minute. As a result of the test, the pressure confining portion of the sample shall withstand without rupture a test pressure of five times the maximum pressure developed by the system, or five times the rated pressure of the power pack's air compressor, whichever is greater.

59.2 Prior to the test, parts molded of polymeric material are to be conditioned in an air circulating oven for 7 hours at a temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature measured on the part under normal load, whichever is greater. The samples are to be removed from the oven and allowed to cool to room temperature prior to the test.

60 Rain Test

60.1 The following Rain Test shall be performed on all power packs that are designated outdoor use or temporary outdoor use.

60.2 Enclosures shall have no wetting of a hazardous voltage or hazardous energy live part nor have entrance of water above the lowest hazardous voltage or hazardous energy live part inside the enclosure at the conclusion of this test. Additionally, the power pack shall comply with the Leakage Current Test, Section 46, at the conclusion of this test.

60.2A The product may be marked "rainproof" per 69.1 if it complies with 60.2. The product may be marked "raintight" per 69.1 if no water enters the enclosure of the power pack as specified in 60.4.

NOTE: In addition to electric shock hazard, wetting of a hazardous energy live circuit of a power pack may result in a fire hazard of a battery.

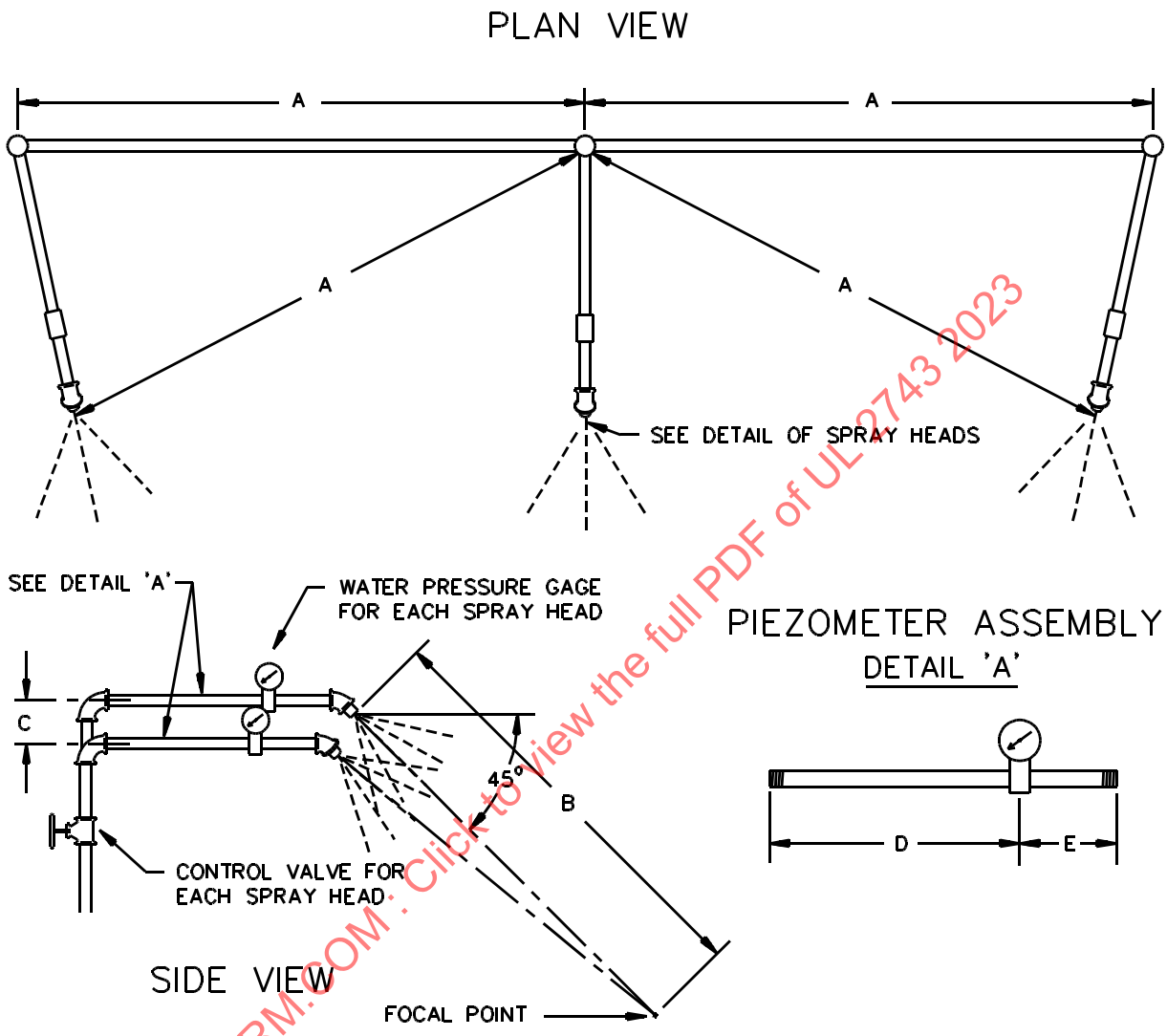
60.3 The rain test apparatus is to consist of three spray heads mounted in a water supply pipe rack as illustrated in Figure 60.1. The spray heads are to be constructed in accordance with the details illustrated in Figure 60.2. The water pressure for all tests is to be maintained at 34.5 kPa (5 psig) at each of the spray

heads. The product is to be brought into the focal area of the three spray heads in the position intended during use. The spray is to be directed at a 45 degree angle from the vertical toward the product. The total exposure is to be for 1 hour.

60.3A If fans or other means for ventilation are provided, which could affect the ingress of water, the test shall be conducted with the ventilation means both on and off unless it is evident that one of the modes of operation will produce the more onerous result.

Figure 60.1

Rain test spray head piping



Item	mm	inch
A	710	28
B	1400	55
C	55	2–1/4
D	230	9
E	75	3

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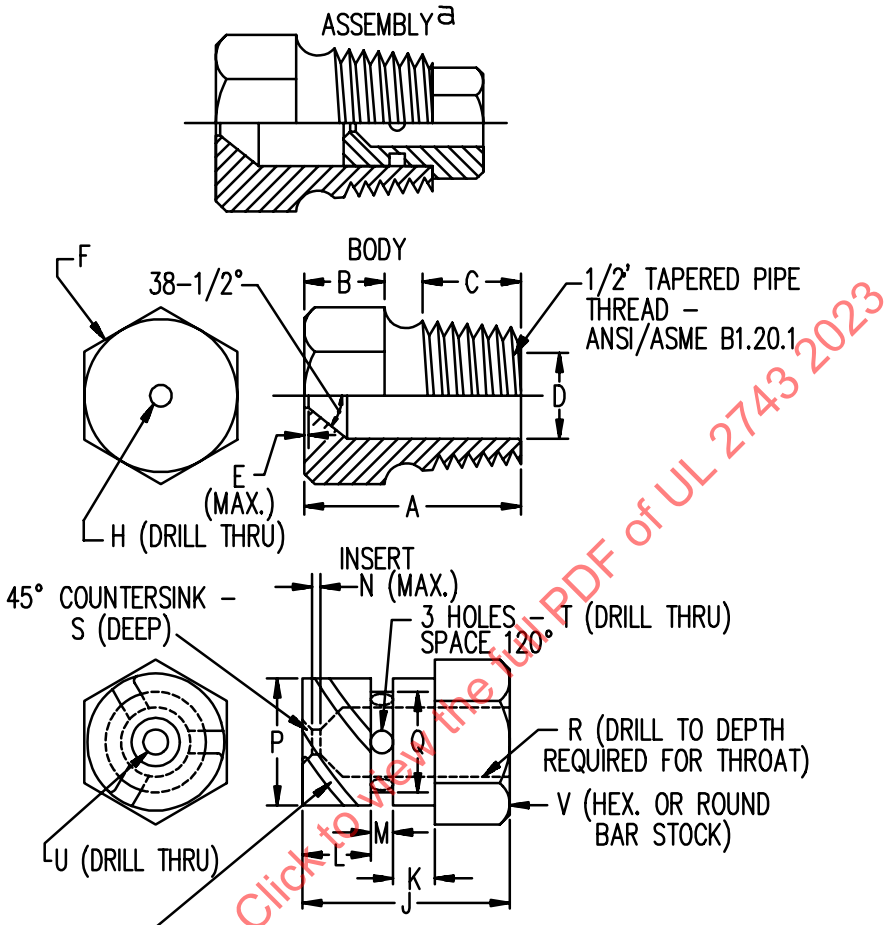
Figure 60.2

Rain test spray head



Item	mm	inch	Item	mm	inch
A	31.0	1–7/32	N	0.80	1/32
B	11.0	7/16	P	14.61	.575
C	14.0	9/16		14.63	.576
D	14.68	.578	Q	11.51	.453
	14.73	.580		11.53	.454
E	0.40	1/64	R	6.35	1/4
F	c	c	S	0.80	1/32
G	1.52	.06	T	2.80	(No. 35) [b]
H	5.0	(No.9) [b]	U	2.50	(No. 40) [b]
J	18.3	23/32	V	16.0	5/8
K	3.97	5/32	W	1.52	0.06
L	6.35	1/4			
M	2.38	3/32			

[a] Nylon Rain–Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional – To serve as a wrench grip.

RT100F