JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 2272:2024

STANDARD FOR SAFETY

Electrical Systems for Personal E-Mobility Devices

ANSI/UL 2272-2024

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Electrical Systems for Personal E-Mobility Devices, ANSI/CAN/UL 2272

Second Edition, Dated April 19, 2024

Summary of Topics

This new Second Edition ANSI/CAN/UL 2272 dated April 19, 2024 includes the following new and/or revised requirements:

– Updated battery pack compartment requirements; 9.2.3

– Added more specific evaluation requirements of gaskets and seals; 5.2, 7.7,

– Clarified flammability requirements for nonmetallic materials; 7.8 – 7.13

– Updated charger requirements; 11.2, Section 36

– Added external output terminal marking requirement; 5.2, Markings, 47.5, Annex B

– Updated temperature requirements; 6.23, 6.24, 27.3, 27.5

– Added reference to UL 2054, UL 62133-1 / CSA C22.2 No. 62133-1, UL 62133-2 and UL 62133-2 / CSA C22.2 No. 62133-2 for rechargeable batteries providing power other than drivetrain unit; 5.2, 17.9, 17.10

– Revised post-test cycle for non-operational condition; 22.1

– Revised the Vibration Test; 5.2, 34.1 – 34.3

– Revised the Partial Immersion test to allow the DUT to drain after the test; 44.2.2

– Clarified the definition in 6.25 to exclude motorized wheelchairs including mobility scooters for medical purposes.

– Updated the Component Section and Annex A; Section 2

– Updated the component cell requirements; 5.2, 17.1, 17.2, 17.4, 17.7, 17.8

– Added UL 62368-1 as the alternative electrical spacing requirement; 14.2, 31.4

– Aligned the dielectric strength test condition; 30.2

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated November 3, 2023 and February 23, 2024.

ANSI/UL 2272-2024

APRIL 19, 2024

ANSI/CAN/UL 2272:2024

Standard for Electrical Systems for Personal E-Mobility Devices

First Edition – November, 2016

Second Edition

April 19, 2024

This ANSI/CAN/UL Safety Standard consists of the Second Edition.

The most recent designation of ANSI/UL 2272 as an American National Standard (ANSI) occurred on April 19, 2024. 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 19, 2024.

No Text on This Page

CONTENTS

ENVIRONMENTAL TESTS

MARKINGS

INSTRUCTIONS

ANNEX A (Informative) – STANDARDS FOR COMPONENTS

ANNEX B – SAFETY MARKING TRANSLATIONS (Normative for Canada and Informative for the US)

Preface (UL)

This is the Second Edition of the ANSI/CAN/UL 2272, Standard for Electrical Systems for Personal E-Mobility Devices.

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.

This ANSI/CAN/UL 2272 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) on Electrical Systems for Personal E-Mobility Devices, TC 2272.

This list represents the TC 2272 membership when the final text in this Standard was balloted. Since that time, changes in the membership may have occurred.

TC 2272 Membership

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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.

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INTRODUCTION

1 Scope

1.1 These requirements cover the electrical drive train system including the battery system, other circuitry and electrical components for electric powered scooters and other devices to be referred to as personal e-mobility devices as defined in this Standard.

1.2 This standard is intended for evaluation of the safety of the electrical drive train system and battery and charger combination for energy and electrical shock hazards and does not evaluate the performance or reliability of these devices. In addition, it does not evaluate the physical hazards that may be associated with the use of personal e-mobility devices.

2 Components

2.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard;

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

NOTE: See Annex A for a list of Standards covering components generally used in the products covered by this Standard.

2.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

b) Is superseded by a requirement in this Standard; or

c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

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

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable standard(s) that cover devices that provide those functions.

3 Units of Measurement

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

4 Undated References

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

5 Normative References

5.1 Products covered by this Standard shall comply with the reference 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 standards for all countries where it is intended to be used.

5.2 The following standards are referenced in this Standard, and portions of these referenced standards as identified in this Standard may be essential for compliance.

CSA C22.2 No. 0.15, *Adhesive Labels*

CSA C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*

CSA C22.2 No. 0.2, *Insulation Coordination*

CSA C22.2 No. 0.8, *Safety Functions Incorporating Electronic Technology*

CSA C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*

CSA C22.2 No. 100, *Motors and Generators*

CSA C22.2 No. 107.1, *Power Conversion Equipment*

CSA C22.2 No. 223, *Power Supplies with Extra-Low-Voltage Class 2 Outputs*

CSA C22.2 No. 282, *Plugs, Receptacles, and Couplers for Electric Vehicles*

CSA C22.2 No. 60529, *Degrees of Protection Provided by Enclosures (IP Code)*

CSA E60730-1, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

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

CSA C22.2 No. 62133-1, *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 1: Nickel Systems*

CSA C22.2 No. 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*

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

IEC 60068-2-64, *Environmental Testing – Part 2-64: Tests – Test Fh: Vibration, Broadband Random and Guidance*

IEC 60417, *Graphical Symbols for Use on Equipment*

IEC 60529, *Degrees of Protection Provided by Enclosures (IP Code)*

IEC 60812, *Analysis Techniques for System Reliability – Procedure for Failure Mode and Effects Analysis (FMEA)*

IEC 61025, *Fault Tree Analysis (FTA)*

IEC 61508-1, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems – Part 1: General Requirements*

ISO 6469-1, *Electrically Propelled Road Vehicles – Safety Specifications – Part 1: Rechargeable Energy Storage System (RESS)*

ISO 7010, *Graphical Symbols – Safety Colours and Safety Signs – Registered Safety Signs*

MIL-STD-1629A, *Procedures for Performing a Failure Mode, Effects, and Criticality Analysis*

SAE J1739, *Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

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

UL 157, *Gasket and Seals*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

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

UL 810A, *Electrochemical Capacitors*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment*

UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*

UL 969, *Marking and Labeling Systems*

UL 1004-1, *Rotating Electrical Machines – General Requirements*

UL 1004-2, *Impedance Protected Motors*

UL 1004-3, *Thermally Protected Motors*

UL 1004-7, *Electronically Protected Motors*

UL 1012, *Power Units other than Class 2*

UL 1310, *Class 2 Power Units*

UL 1642, *Lithium Batteries*

UL 1989, *Valve Regulated or Vented Batteries with Aqueous Electrolytes*

UL 1998, *Software in Programmable Components*

UL 2054, *Household and Commercial Batteries*

UL 2251, *Plugs, Receptacles, and Couplers for Electric Vehicles*

UL/ULC 2271, *Batteries for Use In Light Electric Vehicle (LEV) Applications*

UL/ULC 2580, *Batteries for Use in Electric Vehicles*

UL 2849, *Electrical Systems for eBikes*

UL 60730-1, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

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

UL 62133-1, *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 1: Nickel Systems*

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*

6 Glossary

6.1 For the purpose of this Standard the following definitions apply.

6.2 BATTERY – A generic term for one or more cells electrically connected in series and/or parallel with or without monitoring and protection circuitry for charging and discharging.

6.3 BATTERY PACK – Batteries that are ready for use in a personal e-mobility device, contained in a protective enclosure, with protective devices, with a battery management system, and monitoring circuitry and that may be removable by the user for charging separately from the device.

6.4 BATTERY SYSTEM – Battery system includes the battery, charger and monitoring and protection circuit for charging and discharging of the battery.

6.5 CAPACITY, RATED – The total number of ampere-hours that can be withdrawn from a fully charged battery at a specific discharge rate to a specific end-of-discharge voltage (EODV) at a specified temperature as declared by the manufacturer.

6.6 CASING – The container that directly encloses and confines the electrolyte, and electrodes of a cell.

6.7 CELL – The basic functional electrochemical unit (sometimes referred to as a battery) containing an electrode assembly, electrolyte, separators, casing, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

6.8 CHARGING – The application of electric current to battery terminals, which results in a Faradic reaction that takes place within the battery that leads to stored electro-chemical energy. For personal e-mobility devices, charging of the battery can occur through one or more of the following methods:

a) Regenerative charging which utilizes energy from regeneration through braking or acceleration (i.e. when going down a hill).

b) Off board charging which utilizes an ac to dc charger, a dc charger, or an inductive charger external to the device.

c) On board charging which utilizes a charger on the personal e-mobility device to convert the ac mains supply to dc for charging.

6.9 CHARGING, CONSTANT CURRENT (CC) – Charging mode where current is held constant while charging voltage is allowed to vary.

6.10 DUT – Device under test.

6.11 ELECTRIC SHOCK HAZARD – A potential for exposure of persons to hazardous voltage circuits through direct contact from openings in protective enclosures and/or insufficient insulation between hazardous voltage circuits and accessible parts.

6.12 ELECTRICAL DRIVE TRAIN SYSTEM – The electrical components that power the personal e-mobility device's motion and would include the battery system; the electric motor(s); the protection, balance and control systems; and the circuitry and wiring to connect them together.

6.13 ELECTRICAL SYSTEM – All of the electrical components and circuits that are provided with the personal e-mobility device and would include the electrical drive train system, the internal or external charger used to recharge the battery and auxiliary electrical systems such as lighting, communications and audio that may be provided on the device.

6.14 ELECTROLYTE LEAKAGE – A condition where liquid electrolyte escapes through an opening in a designed vent as well as through a rupture or crack or other unintended opening in the casing or enclosure of a cell or capacitor and is visible external to the DUT.

6.15 ENCLOSURE – The outer cover of a device that provides protection to its contents to prevent a potential hazard, and may have one or more specific levels of protection as noted below:

a) ELECTRICAL ENCLOSURE – Provides protection from access to hazardous voltage circuits and may serve as part of the electrical insulation.

b) FIRE ENCLOSURE – Provides protection from the spread of fire from components within.

c) MECHANICAL ENCLOSURE – Provides physical protection from damage to components and parts contained within and/or prevents access to hazardous moving parts.

d) ENVIRONMENTAL ENCLOSURE – Provides protection from ingress of materials from the environment such as water that could damage internal components or introduce hazards. A rating such as the IP code provides the level of protection given by the enclosure.

6.16 END-OF-DISCHARGE VOLTAGE (EODV) – The voltage, under load, of the cell or battery at the end of discharge. The EODV may be specified, as in the case of a voltage terminated discharge, or simply measured in the case of a time-controlled discharge.

6.17 EXPLOSION – A violent release of energy that produces projectiles or an energy wave from the DUT and results in the DUT's contents being forcibly expelled through a rupture in the enclosure or casing.

6.18 FIRE – The sustained combustion of the DUT's contents as evidenced by flame, heat and charring or other damage of materials.

6.19 FULLY CHARGED – A battery which has been charged per the manufacturer's specifications to its full state of charge (SOC).

6.20 FULLY DISCHARGED – A battery, which has been discharged, according to the manufacturer's specifications, to its specified end of discharge voltage (EODV).

6.21 HAZARDOUS VOLTAGE – Voltage exceeding 30 Vrms/42.4 Vac peak or 60 Vdc.

6.22 INSULATION LEVELS – The following are levels of electrical insulation:

a) BASIC – A single level of insulation that provides protection against electric shock. Basic insulation alone may not provide protection from electric shock in the event of a failure of the insulation.

b) DOUBLE INSULATION – Insulation comprising both basic insulation and supplementary insulation.

c) FUNCTIONAL INSULATION – Insulation that is necessary only for the correct functioning of the equipment. Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

d) REINFORCED INSULATION – Single insulation system that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this Standard. The term "insulation system" does not imply that the insulation has to be in one homogeneous piece. It may comprise several layers that cannot be tested as basic insulation and supplementary insulation.

e) SUPPLEMENTARY INSULATION – Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

6.23 MAXIMUM CONTINUOUS CHARGING TEMPERATURE – The maximum ambient temperature per the manufacturer's specifications that can continuously charge the battery at the maximum charging parameters to its full state of charge (SOC).

6.24 MAXIMUM CONTINUOUS DISCHARGING TEMPERATURE – The maximum ambient temperature per the manufacturer's specifications that can continuously discharge the battery at the maximum discharging parameters to its specified end of discharge voltage (EODV).

6.25 PERSONAL E-MOBILITY DEVICE – A consumer mobility device intended for a single rider with a rechargeable electric drive train that balances and propels the rider, and which may be provided with a handle for grasping while riding, but excludes motorized wheelchairs including mobility scooters for medical purposes. This device may or may not be self-balancing.

6.26 ROOM AMBIENT – Considered to be a temperature in the range of 25 ±5 °C (77 ±9 °F).

6.27 RUPTURE – A mechanical failure of the DUT's enclosure/casing from either internal or external causes, that results in spillage and/or exposure of internal contents of the DUT, but does not result in projectiles and violent energy release such as occurs during an explosion.

6.28 SAFETY CRITICAL CIRCUITS/COMPONENTS – Those circuits or discrete components that are relied upon for safety as identified in the safety analysis of 16.2.

6.29 SPECIFIED OPERATING REGION – That region of voltage, current and temperature within which a cell can be safely charged and discharged repetitively throughout its anticipated life. The manufacturer specifies these values, which are then used in the safety evaluation of the device and may vary as the device ages. The specified operating region may include transient values for voltage, current and temperature that are allowed under limited conditions specified by the cell manufacturer. The specified operating regions will include the following parameters for charging and discharging as specified by the manufacturer:

a) CHARGING TEMPERATURE LIMITS – The upper and lower limits of temperature, specified by the manufacturer for charging of the cell. This temperature is measured on the casing.

b) DISCHARGE TEMPERATURE LIMITS – The upper and lower limits of temperature, specified by the manufacturer for discharging the cell. This temperature is measured on the casing.

c) END OF DISCHARGE VOLTAGE – Refer to 6.14. Also, see Figure 3.1 of UL 1642.

d) MAXIMUM DISCHARGING CURRENT – The maximum discharging current rate, which is specified by the cell manufacturer.

e) MAXIMUM CHARGING CURRENT – The maximum charging current in the specified operating region, which is specified by the cell manufacturer. This value may vary with temperature.

f) UPPER LIMIT CHARGING VOLTAGE – The highest charging voltage limit in the specified operating region specified by the cell manufacturer. This value may vary with temperature.

6.30 STATE OF CHARGE (SOC) – The available capacity in a pack, module or cell expressed as a percentage of rated capacity.

CONSTRUCTION

7 Non-Metallic Materials

7.1 The materials employed for enclosures relied upon for safety per 6.15 shall comply with the applicable enclosure requirements outlined in UL 746C, Path III of the Enclosure Requirements Table or CSA C22.2 No. 0.17, except as modified by this Standard.

7.2 Polymeric materials employed for fire enclosures shall have a minimum flame rating of V-1 in accordance with UL 94, or CSA C22.2 No. 0.17.

Exception: The enclosure may alternatively be evaluated to the 20 mm end product flame test in accordance with UL 746C, or CSA C22.2 No. 0.17.

7.3 The following factors in (a) – (e) are taken into consideration when an enclosure employing nonmetallic materials is being judged. For a nonmetallic enclosure all of these factors are to be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) – (e) below may be determined by the tests of this Standard.

a) Resistance to impact;

b) Crush resistance;

c) Abnormal operations;

d) Severe conditions; and

e) Mold-Stress Relief Distortion.

7.4 The polymeric materials employed for enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. Enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80 °C (176 °F), as determined in accordance with UL 746B, or CSA C22.2 No. 0.17.

7.5 The enclosure materials intended to be directly exposed to sunlight and rain in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with UL 746C, or CSA C22.2 No. 0.17. This requirement may be waived if the personal e-mobility device is marked that it be stored indoors and user instructions also indicate that it not be left outdoors to be exposed to UV or rain. See 47.11 and Section 48.

7.6 Materials employed as electrical insulation in the assembly shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. Compliance is determined by the tests of this Standard. Materials employed for direct support of live parts at hazardous voltage, shall additionally meet the direct support insulation criteria outlined in the Material Property Considerations Table in UL 746C or CSA C22.2 No. 0.17, unless employed as part of a component that has been evaluated to a suitable component standard. Insulated wiring is subjected to the requirements outlined in Section 10, Wiring and Terminals.

7.7 Gaskets and seals relied upon for safety shall be tested in accordance with one of the following:

a) UL 157;

b) The Gasket Tests in UL 62368-1 / CSA C22.2 No. 62368-1; or

c) The Gasket Tests in UL 50E / CSA C22.2 No. 94.2.

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

Exception: Nonmetallic materials used for internal parts within the overall enclosure of PS2 circuits (power source class 2 requirements outlined in UL 62368-1 / CSA C22.2 No. 62368-1) shall comply with one of the following:

a) Be mounted on minimum V-1 class material or VTM-1 class material;

b) Be constructed of minimum V-2 class material, VTM-2 class material, or HF-2 class foamed material;

c) Have a size of less than 1750 mm^3 (0.11 in^3);

d) Have a mass of combustible material of less than 4 g (0.14 oz);

e) Be separated by at least 13 mm (0.51 in) of air from electrical parts (other than insulated wires and cables) which under fault conditions are likely to produce a temperature that could cause ignition; or

f) Be in a sealed enclosure of 0.06 m^3 (2.12 ft^3) or less, consisting totally of non-combustible material and having no ventilation openings.

7.9 Internal parts of components shall comply with the flammability requirements of the component standard in accordance with Components, Section 2.

7.10 Small parts, and gaskets, that are not located near live parts, and are located in a manner such that they cannot propagate flame from one area to another within the equipment, are not required to have a specific flame rating.

7.11 Nonmetallic materials located outside the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts do not have a specified flame rating.

7.12 Printed wiring board materials used for circuits or components at hazardous voltage or hazardous energy levels shall be rated V-1 minimum.

7.13 For the requirements outlined in 7.8 – 7.12, 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 UL 94 and CSA C22.2 No. 0.17.

8 Metallic Parts Resistance to Corrosion

8.1 Metal enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in UL 50E or in CSA C22.2 No. 94.2.

8.2 Metal enclosures may be provided with an insulating liner to prevent shorting of live parts to the enclosure. If using an insulating liner for this purpose, the insulating liner shall consist of non-moisture absorbent materials that have a temperature rating suitable for temperatures during operation including charging.

8.3 Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action.

9 Enclosures

9.1 General

9.1.1 The enclosure relied upon for safety per 6.15 shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons as determined by the requirements contained in this Standard.

9.1.2 A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the enclosure.

9.1.3 Openings in the enclosure relied upon for safety per 6.15 shall be designed to prevent inadvertent access to hazards such as hazardous voltages, hazardous moving parts or hot surfaces that could result in burns. Parts that can be removed without the use of a tool, are to be removed to determine compliance. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, of IEC 60529, or CSA C22.2 No. 60529, for a minimum IP rating of IP3X. Evaluation per IEC 60529 or CSA C22.2 No. 60529, consists of the use of the Test Rod 2.5 mm, 100 mm long, shown in Figure 9.1 of UL/ULC 2271, applied with a force of 10 N ±10 %.

9.1.4 Openings in the environmental enclosure per 6.15 shall be designed to prevent ingress of water as installed in the personal e-mobility device in accordance with intended use and IP rating in accordance with IEC 60529, or CSA C22.2 No. 60529 with a minimum rating of IPX4 and resistant to hazards associated with partial immersion. Compliance is determined by the Water Exposure Tests in Section 44.

9.2 Battery compartments

9.2.1 Cell vents shall not be obstructed in such a way as to defeat their operation if venting is relied upon for compliance with this Standard. Compliance is checked by inspection.

9.2.2 Battery compartments within enclosures shall secure the battery in place sufficiently to prevent excessive movement and stress on the battery and cells that could result in a hazard. Compliance is checked by inspection and the mechanical tests of this Standard.

9.2.3 To prevent user servicing such as cell replacement, the outer enclosure of the battery shall be designed such that it is not capable of being opened using simple tools, such as a screwdriver. The enclosure shall be ultrasonically welded or secured by equivalent means. Adhesives complying with the adhesive requirements of UL 746C, single use or tamper-proof screws are considered equivalent means.

Exception: The requirement can be replaced by any easily detectable means for a new opening, for example a broken seal. The manufacturer shall remind users not to use a product with broken seals and shall be immediately forwarded for appropriate recycling.

9.2.4 To prevent user servicing such as cell replacement when the device enclosure serves as the outer enclosure of the battery, the device enclosure shall be designed such that it is not capable of being opened using common household tools, such as a flat blade or Philips head screwdriver. The enclosure shall be ultrasonically welded or secured by equivalent means. Adhesives complying with the adhesive requirements of UL 746C, or single use or tamper-proof screws, are considered equivalent means. See 47.12 and 48.4.

10 Wiring and Terminals

10.1 Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.

10.2 Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation. In safety critical circuits, for soldered terminations, the conductor shall be positioned or fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position. Wire routing shall not result in undue stress on battery cells in fully assembled products.

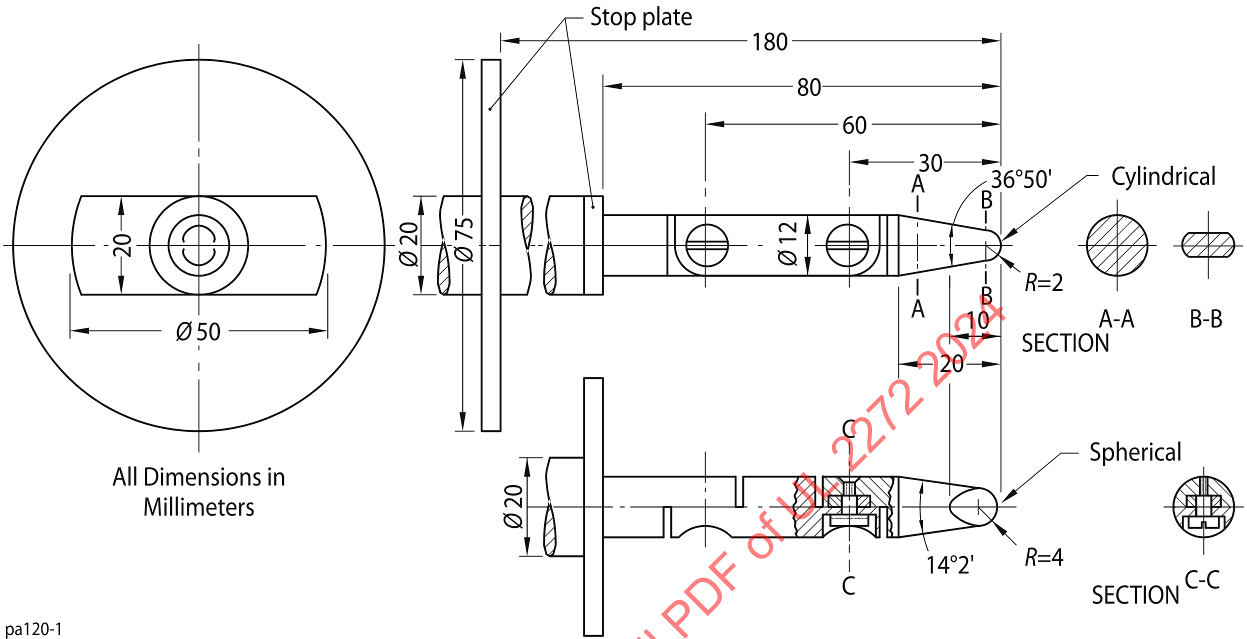
10.3 Connections to the cells shall be made in a manner that does not result in damage to the cells. For example, connections made using high heat processes such as solder shall not be used on direct connections to the cell terminals without proper processes and controls as this could result in damage to the cell as a result of heat transfer during soldering.

10.4 An external terminal shall be designed to prevent an inadvertent shorting and misalignment and a reverse polarity connection when connections are made. For battery packs that are intended for removal from the personal e-mobility device for external charging or replacement with a charged battery pack, the external terminal for discharging shall be designed to prevent inadvertent shorting, a reverse polarity connection and a misalignment.

10.5 For battery packs that are intended for removal from the personal e-mobility device for external charging or replacement with a charged battery pack by the user, the external terminal for discharging and any other external terminals with hazardous voltage shall be designed to prevent access by the user. Compliance is determined by use of the articulate test finger shown in Figure 10.1.

Figure 10.1

Articulate Probe



10.6 The external terminals of a battery pack with hazardous voltage circuits that is intended for removal from the personal e-mobility device for charging, shall be evaluated to either the no load endurance test or endurance with load test as applicable to the end use application in accordance with UL 2251, or CSA C22.2 No. 282, without being subjected to the exposure to contaminants.

10.7 A hole by which insulated wires pass through a metal wall shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.

10.8 Wiring for hazardous voltage shall be enclosed in an electrical enclosure with hazardous voltage warning labels such as ISO 7010, No. W012 (i.e. lightning bolt within triangle).

11 Chargers

11.1 Power supplies intended for charging the personal e-mobility device shall be evaluated for intrinsic safety in accordance with UL 1310, or CSA C22.2 No. 223, UL 1012, or CSA C22.2 No. 107.1, UL 60950-1 / CSA C22.2 No. 60950-1, or UL 62368-1 / CSA C22.2 No. 62368-1, and shall be determined compatible with the device's battery system. Compliance is determined by a review of data on the battery system and charger and the tests of this Standard. The charger shall be provided with a means for connection to a standard outlet if intended for connection to a mains source of electrical supply in accordance with the standards noted above.

11.2 The connector provided with the charger for connecting to the personal e-mobility device/battery terminal for charging, shall be designed to prevent misalignment, reverse polarity, or electrical mismatch. Compliance is checked by inspection of the connector design, and if necessary, the Protective Circuits and Safety Analysis requirements in Section 16.

12 Fuses

12.1 Fuses shall be acceptable for the current and voltage of the circuit they are protecting.

12.2 For user replaceable fuses, a fuse replacement marking shall be located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies, and giving the fuse ratings. Where user replaceable fuses with special fusing characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of user replaceable fuses shall also be included in the instructions.

13 Lighting

13.1 An integral lamp shall be rated for the application. If provided with user replaceable bulbs, replacement shall not impair the safety of the personal e-mobility device and there shall be no risk of electric shock. Instructions provided with the personal e-mobility device shall include information on the type and ratings of user replaceable bulbs.

14 Electrical Spacings and Separation of Circuits

14.1 Electrical circuits within the personal e-mobility device at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.

14.2 Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in one of the following:

a) Table 14.1;

b) The spacings requirements outlined in UL 60950-1 / CSA C22.2 No. 60950-1, in Clearances, Creepage Distances and Distances Through Insulation; or

c) The spacing requirements outlined in UL 62368-1 / CSA C22.2 No. 62368-1.

Exception No. 1: As an alternative to the spacing requirements of Table 14.1, the spacing requirements in UL 840, or CSA C22.2 No. 0.2, may be used. For determination of clearances, a dc source such as a battery does not have an overvoltage category as outlined in UL 840 or CSA C22.2 No. 0.2, unless charged through a source connected to a mains supply. The anticipated pollution degree is determined by the design under evaluation.

Exception No. 2: As an alternative to the clearance values outlined in UL 60950-1 / CSA C22.2 No. 60950-1, Clearances, Creepage Distances and Distances Through Insulation, the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Minimum Clearances of UL 60950-1 / CSA C22.2 No. 60950-1, may be applied.

Table 14.1
Electrical Spacings

	Voltage V	Through Air mm (in)	Over Surface mm (in)
Live parts and dead metal parts that are separated by functional or basic insulation	0 – 50[a] 51 – 130 131– 300	1.6 (1/16) 3.2 (1/8) 6.4 (1/4)	1.6 (1/16) 4.8 (3/16) 9.5 (3/8)
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only – this ordinarily is a spacing resulting from supplementary insulation	0 – 50[a] 51 – 130 131– 300	1.6 (1/16) 3.2 (1/8) 6.4 (1/4)	1.6 (1/16) 4.8 (3/16) 9.5 (3/8)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 – 50[a] 51 – 130 131– 300	3.2 (1/8) 4.8 (3/16) 12.7 (1/2)	3.2 (1/8) 6.4 (1/4) 12.7 (1/2)
[a] Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (i.e. circuits supplied by limited power sources as defined in UL 60950-1, or CSA C22.2 No. 60950-1).			

14.3 There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a component or subassembly if the distance through the insulation, at voltages above 60 Vdc or above 30 Vrms is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test, Section 30, and the Isolation Resistance Test, Section 31. There is no minimum insulation thickness requirement for insulation of circuits at or below 60 Vdc or for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.

14.4 Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacing requirements unless they are each provided with insulation acceptable for the highest voltage involved. An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different voltage.

15 Insulation Levels and Protective Grounding

15.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in 15.2 through the following:

a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation; or

b) A system of double or reinforced insulation; or

c) A combination of (a) and (b).

15.2 Safety extra low voltage (SELV) circuits (i.e. circuits at or below 60 Vdc or 48 Vrms under normal and single fault conditions) that are insulated from accessible conductive parts through functional insulation only are considered accessible.

15.3 If relying upon a protective grounding system (i.e. grounding of an accessible metal enclosure), it shall comply with 15.4 – 15.6.

15.4 Parts of a protective grounding system shall be reliably secured in accordance with 10.2 and provided with good metal-to-metal contact of the grounded parts of the personal e-mobility device. The impedance from the various bonding conductors and connections to the main ground terminal shall have a maximum resistance of 0.1 Ω. Compliance can be determined by measurement using an ohmmeter.

15.5 The main ground terminal of the protective earthing ground system shall be identified by one of the following:

a) A green-colored, not readily removable terminal screw with a hexagonal head;

b) A green-colored, hexagonal, not readily removable terminal nut;

c) A green colored pressure wire connector; or

d) The word "Ground" or the letters "G" or "GR" or the grounding symbol (IEC 60417, No. 5019 – upside down "tree" in circle) or otherwise identified by a distinctive green color. For Canada only use the grounding symbol rather than the words “Ground”, or “G” or “GR”.

15.6 Conductors, relied upon for the protective grounding and bonding system, shall be sized to handle intended fault current. If insulated, the insulation shall be green or green and yellow striped in color.

16 Protective Circuits and Safety Analysis

16.1 The personal e-mobility device's protective circuitry shall maintain the cells within their specified operating region for charging and discharging through the life of the device. If cell specified operating limits are exceeded, the protective circuitry shall limit or shut down the charging or discharging to mitigate excursions beyond specified operating limits. Compliance is determined through a review of the cell specifications and safety analysis of 16.2 and through the testing of this Standard. If applicable to the personal e-mobility device design, the analysis and testing needs to evaluate the overcharge protection control’s ability to mitigate overcharge due to regenerative charging during use.

16.2 An analysis of potential electrical and energy hazards (including an FMEA) shall be conducted on the personal e-mobility device's electrical system to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means. Documents that can be used as guidance for the safety analysis include:

a) IEC 60812;

b) IEC 61025;

c) SAE J1739; or

d) MIL-STD-1629A.

16.3 The analysis in 16.2 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the anticipated faults. The analysis shall consider single fault conditions in the protection circuit/scheme as part of the anticipated faults.

16.4 When conducting the analysis of 16.2, active devices shall not be relied upon for critical safety unless:

a) They are provided with a redundant passive protection device; or

b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection; or

c) They are determined to fail safe upon loss of power to/failure of the active circuit.

16.5 Devices relied upon for critical safety as noted in 16.4 (a) – (b) shall minimally comply with the applicable Environmental Stress Tests described in UL 991, or fully comply with appropriate functional safety requirements below. Devices solely relied upon for critical safety as noted in 16.4(c) shall fully comply with appropriate functional safety requirements in one of the following standards as appropriate to the design of the electronic and software protection scheme:

a) UL 991, or CSA C22.2 No. 0.8, and UL 1998;

b) UL 60730-1 or CSA E60730-1; and

c) IEC 61508-1, and all parts.

16.6 A personal e-mobility device containing hazardous voltage shall have a manual disconnect to prevent inadvertent access to hazardous voltage parts during servicing. The manual disconnect shall:

a) Disconnect both poles of the hazardous voltage circuit;

b) Require manual action to break the electrical connection;

c) Ensure disconnection is physically verifiable and can include actual removal of the battery system from the personal e-mobility device or unplugging the battery system connector/plug; and

d) When engaged (i.e. under disconnection), it does not create exposed conductors capable of becoming energized and is insulated to prevent a shock hazard during actuation.

16.7 If a hazardous voltage automatic disconnect device is provided to isolate accessible conductive parts from the hazardous voltage circuit of the battery system, it shall:

a) Not be able to be reset automatically although it may be able to be reset deliberately upon clearing of the fault;

b) Disconnect both poles of the hazardous voltage circuit;

c) Be capable of handling full load disconnects of the hazardous voltage circuit that it is isolating; and

d) Not result in a hazardous condition upon automatic actuation.

16.8 The personal e-mobility device shall have charger connect-interlock so that the unit cannot be activated when the charger is plugged in.

17 Cells and Batteries

17.1 Cells shall be designed to safely withstand anticipated abuse conditions for personal e-mobility devices. Compliance is determined by the requirements in 17.2 – 17.10 and by the tests of this Standard.

17.2 Lithium ion and other lithium based cells shall comply with the requirements for secondary lithium cells in UL/ULC 2580.

17.3 The temperature limits need to consider the cell manufacturer’s specified temperatures limits on the cell casing surface during charging and discharging. When evaluating the cell and battery control combination, consideration must be given to tolerances in the control circuitry for charging. If the control circuitry settings with tolerances exceed the cell charge specifications for voltage, testing of the cell needs to be repeated with the cell charged to these higher voltage values.

17.4 Nickel metal hydride cells and other nickel based cells shall comply with the nickel cell requirements in UL/ULC 2580.

17.5 Valve regulated lead acid batteries shall comply with the pressure release test of UL 1989.

17.6 Electrochemical capacitors shall comply with the capacitor requirements in UL 810A.

17.7 Sodium nickel metal chloride cells shall comply with the requirements for sodium beta battery cells outlined in the Test Program for Sodium-Beta Battery Cells Annex in UL 1973.

17.8 Sodium Ion cells shall comply with the requirements of the Cell Test Program Annex in UL 1973.

17.9 Rechargeable batteries that provide power to the drivetrain unit of personal e-mobility devices may comply with the requirements of this Standard or UL/ULC 2271. Batteries complying with UL/ULC 2271 may need not to be evaluated with the requirements of:

a) The Overcharge Test, Section 24;

b) Short Circuit Test, Section 25;

c) Overdischarge Test, Section 26; and

d) Imbalanced Charging Test, Section 29.

17.10 Rechargeable batteries that provide power to other than the drivetrain unit shall comply with UL 2054 or UL 62133-2 / CSA C22.2 No. 62133-2 or UL 62133-1 / CSA C22.2 No. 62133-1.

18 Motors

18.1 A traction motor used in a personal e-mobility device shall not be hazardous under locked rotor and overload conditions. Compliance is determined by the tests of this Standard unless previously evaluated as part of a motor and motor protector combination evaluation.

18.2 Motors shall be capable of carrying the maximum normal anticipated load without exceeding temperatures on insulation and windings as determined during the temperature test.

18.3 Motors located in hazardous voltage circuits shall comply with the requirements of UL 1004-1 or CSA C22.2 No. 100. Motors located in low voltage circuits shall comply with either UL 1004-1 or CSA C22.2 No. 100 or the requirements of this Standard.

19 Manufacturing and Production Line Testing

19.1 Personal e-mobility devices shall be subjected to 100 % production screening as described in 19.2 and 19.6 to determine the acceptability of spacing, insulation and grounding system in production.

19.2 A dielectric withstand test shall be conducted on 100 % production of personal e-mobility devices with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak ac. There shall be no evidence of breakdown as a result of the dielectric voltage withstand test.

19.3 Personal e-mobility devices with hazardous voltage circuits electrically isolated from ac mains supplied circuits shall be subjected to a production dielectric withstand voltage consisting of an dc or ac potential of twice the rated voltage. For those personal e-mobility devices with hazardous voltage circuits intended for connection to an ac mains supply or not electrically isolated from ac mains circuits, the test voltage shall be an essentially ac potential of frequency 60 Hz at 1,000 V plus twice the rated voltage. If using a dc potential to test the non-isolated circuit, the test voltage shall be 1.414 times the ac test potential value of 1,000 V plus twice the rated voltage.

19.4 The test voltages shall be applied for a minimum of 1 minute with the cells/modules disconnected in a manner to prevent inadvertent charging during application of the voltage.

Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s. If the value of the voltage noted above is increased as follows:

a) 2.4 times the circuit voltage for those circuits isolated from the ac mains supply; and

b) 1200 plus 2.4 times the circuit voltage for those circuits not isolated from the ac mains supply.

Exception No. 2: Semiconductors or similar electronic components not relied upon to protect from electric shock and liable to be damaged by application of the test voltage may be bypassed or disconnected.

Exception No. 3: The test is able to be performed on a partial or modified unit as long as it has been evaluated to be representative of a complete device.

Exception No. 4: The Isolation Resistance Test of Section 31 can be conducted in lieu of the dielectric withstand test.

19.5 The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage, which is variable and which is essentially sinusoidal if using an ac test method and dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current.

Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

19.6 A continuity check of the grounding conductors using a mega ohmmeter or other method shall be conducted on 100 % production employing protective grounding. The continuity check shall determine that the resistance of the protective grounding system does not exceed 0.1 Ω.

19.7 The manufacturer is required to have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include corrective/preventative action to address defects found affecting the key elements:

a) Supply chain control; and

b) Assembly processes.

PERFORMANCE

20 General

20.1 Unless indicated otherwise, personal e-mobility device batteries shall be fully charged in accordance with the manufacturer's specifications for conducting the tests in this Standard. After charging and prior to testing, the batteries shall be allowed to rest for a maximum period of 8 h at room ambient.

20.2 Unless otherwise indicated, fresh samples representative of production are to be used for the tests described in this Standard. The test program and number of samples to be used in each test is shown in Table 20.1.

Table 20.1
Tests and Sample Requirements

Test	Section	Number of samples[a]
Electrical Tests		
Overcharge	24	1 personal e-mobility device
Short Circuit	25	1 personal e-mobility device
Overdischarge	26	1 personal e-mobility device
Temperature	27	1 personal e-mobility device
Imbalanced Charging	29	1 personal e-mobility device
Dielectric Voltage Withstand	30	1 personal e-mobility device
Isolation Resistance	31	1 personal e-mobility device
Leakage Current	32	1 personal e-mobility device
Grounding Continuity	33	1 personal e-mobility device
Mechanical Tests		
Vibration	34	1 personal e-mobility device
Shock	35	1 personal e-mobility device
Crush	37	1 personal e-mobility device
Drop	38	1 personal e-mobility device
Mold Stress	39	1 personal e-mobility device
Handle Loading	40	1 personal e-mobility device
Strain Relief Tests (Cord Anchorages)	43	2 test specimens of the part under test or complete personal e-mobility device
Environmental Tests		
Water Exposure Tests a. IPX4 b. Partial Immersion	44	2 personal e-mobility devices
Thermal cycling	45	1 personal e-mobility device
Motor Tests		
Motor Overload	41	1 motor/personal e-mobility device
Motor Locked Rotor	42	1 motor/personal e-mobility device
Material Tests		
20-mm End Product Flame Test (Note: Not conducted if minimum V-1)	7.2	3 test specimens of the part under test (polymeric enclosure sample)
Label Permanence	46	1 test specimen of the part under test (label adhered to end use surface)

[a] Samples from different tests may be re-used for multiple tests if still intact so that its re-use does not affect the test results and the manufacturer is in agreement. Minor modifications can be made to samples such as replacement of fuses, etc. in order to reuse samples for multiple tests.

20.3 All tests, unless noted otherwise, are conducted in a room ambient 25 ±5 °C (77 ±9 °F).

20.4 Temperature shall be measured using thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG) connected to a potentiometer-type instrument. Temperature measurements are to be made with the measuring junction of the thermocouple held tightly against the component/location being measured. For those tests that require the sample to reach thermal equilibrium (also referred to as steady state conditions), thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10 % of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2 °C (±3.6 °F).

20.5 Where there is a specific reference to a single fault condition in the individual test methods, the single fault is to consist of a single failure (i.e. open, short or other failure means) of any component in the personal e-mobility devices that could occur and affect the results of the test. Faulting over two redundant components that have not been determined to be independent of each other is considered a single fault condition. This fault is implemented in conjunction with the test being conducted (i.e. overcharge, short circuit, etc.) or may be conducted as part of a verification of a protective circuit. A protective device determined to be reliable may remain in the circuit without being faulted. See Annex A and 2.1. A protective device determined to be reliable is one that has been shown to comply with an appropriate component safety standard and is used within its ratings.

20.6 The tests contained in this Standard may result in explosions, fire and emissions of flammable and/or toxic fumes as well as electric shock. It is important that personnel use extreme caution and follow local and regional worker safety regulations when conducting any of these tests and that they be protected from flying fragments, explosive force, and sudden release of heat and noise that could result from testing. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases. As an additional precaution, the temperatures on surface of at least one cell/module within the DUT are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the DUT until temperatures are falling and have returned to within ambient temperatures.

20.7 Unless noted otherwise in the individual test methods, the tests shall be followed by a minimum 1-h observation time prior to concluding the test and temperatures are to be monitored in accordance with 20.6.

20.8 Some testing may be waived for battery systems previously evaluated to UL/ULC 2271, if determined equivalent to the testing of this Standard in the personal e-mobility device system. These tests would include the following: Overcharge, Short Circuit, Overdischarge, and Imbalanced Charging. However, it must be determined through analysis that the tests conducted on the battery pack in accordance with UL/ULC 2271 are representative of testing with the system in accordance with this Standard.

21 Tolerances

21.1 Unless noted otherwise in the test methods, the overall accuracy of measured values of test specifications or results when conducting testing in accordance with this Standard, shall be within the following values of the measurement range.

a) ±1 % for voltage;

b) ±1 % for current;

c) ±2 °C (±3.6 °F) for temperature at or below 200 °C (392 °F) and ±3 % for temperatures above 200 °C (392 °F);

d) ±0.1 % for time; and

e) ±1 % for dimension.

22 Post Test Cycle

22.1 Personal e-mobility devices that are operational after the following tests shall be subjected to a minimum of one cycle of charging and discharging or if not operational, subjected to an attempt to charge only in accordance with the manufacturer’s specifications for at least 1 h to determine that there is no non-compliant results as outlined in Table 22.1 for that test:

a) Electrical Tests – Overcharge, short circuit, overdischarge protection, imbalanced charging;

b) Mechanical Tests – Vibration, shock, drop, crush; and

c) Environmental Tests – Water exposure, and thermal cycling.

Table 22.1
Noncompliant Test Results

Non-compliant results	Designation	Tests [a]
Explosion	E	All tests
Fire	F	All tests
Rupture (enclosure)	R	All tests
Electrolyte Leakage (external to enclosure)	L	All tests
Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown)	S	All tests (if hazardous voltage)

[a] For tests that evaluate one specific part of the DUT such as the mold stress, dielectric voltage withstand, isolation resistance, leakage current, grounding continuity, strain relief, and label permanence tests; only those compliance criteria noted in the tests method need be applied. See individual tests for additional compliance criteria details.

22.2 The method of discharging the batteries may vary according to the personal e-mobility device design and should be a method agreed upon by the manufacturer and organization testing the personal e-mobility device.

23 Results Criteria

23.1 See Table 22.1 for results criteria for tests outlined in this Standard and Glossary, Section 6 for definitions of the non-compliance results terms. See also individual tests methods for any additional details.

ELECTRICAL TESTS

24 Overcharge Test

24.1 This test is intended to evaluate a DUT's ability to withstand an overcharge condition under non-faulted and under a single fault in the charging control circuitry that could result in an overcharge condition.

24.2 A fully charged sample is to be discharged at a 0.2 C constant discharge rate or a higher discharge rate permitted by the cell manufacturer to the manufacturer's specified EODV. The DUT is then subjected to a constant current charging at the cell manufacturer's maximum specified charging rate and under a single fault condition in the charging protection circuitry that could lead to an overcharge condition. Protective devices that have been determined reliable may remain in the circuit as noted in 20.5. For information purposes, temperatures are to be monitored on the cell/module where temperatures may be highest. The output control circuitry of external chargers with standardized output connectors (e.g. USB connectors) that may result in the use of unspecified chargers shall not be considered as a reliable control to prevent an overcharging condition.

24.3 The test is to be continued until the voltage has reached 110 % of the specified upper limit charging voltage or the maximum obtainable charging voltage (if the 110 % of specified upper limit charging voltage cannot be reached due to remaining protection circuitry), and monitored temperatures return to ambient or steady state conditions and an additional 2 h has elapsed, or explosion/fire occur. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the cell manufacturer's maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

24.4 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning).

24.5 If a protective device in the circuit operates, the test is repeated at 90 % of the trip point of the protection device or at some percentage of the trip point that allows charging for at least 10 min. Temperatures shall be measured on the DUT for monitoring purposes.

24.6 As a result of the overcharge test, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

The voltage limits on the cells are not to exceed the specified upper limit charging voltage.

25 Short Circuit Test

25.1 This test evaluates a DUT's ability to withstand a short circuit condition.

25.2 A fully charged sample of the battery system is to be short-circuited by connecting the positive and negative terminals of the sample with a circuit load having a total resistance of less than or equal to 20 mΩ.

25.3 Samples are to be subjected to a single fault across any protective device in the load circuit. Protective devices that have been determined reliable may remain in the circuit as noted in 20.5.

25.4 The sample shall be discharged until the sample has returned to ambient temperature or fire or explosion occurs. Temperatures shall be measured on the DUT for monitoring purposes.

25.5 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

25.6 If a protective device in the circuit operates, the test is repeated at 90 % of the trip point of the protection device or at some percentage of the trip point that allows discharging for at least 10 min.

25.7 At the conclusion of the test and after cooling to near ambient, the samples that contain hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning).

25.8 As a result of the short circuit test, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

26 Overdischarge Test

26.1 This test is intended to evaluate a DUT's ability to withstand an overdischarge under protection circuitry fault condition.

26.2 The fully charged sample is to be subjected to a constant discharging current at the maximum discharging current specified by the manufacturer under a single fault condition in the discharging circuit of the DUT that could lead to an overdischarge condition. Protective devices that have been determined reliable may remain in the circuit as noted in 20.5. Temperatures shall be measured on a cell/module for monitoring purposes.

26.3 The test is to be continued until the sample is fully discharged to a near zero state or protective devices remaining in the circuit operate, and the monitored temperatures return to ambient or steady state, or explosion and/or fire occurs. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

26.4 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 31, (without humidity conditioning) or a Dielectric Voltage Withstand Test, Section 30.

26.5 As a result of the overdischarge test, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

Voltages on the cells are not to exceed the specified end of discharge voltage limits.

27 Temperature Test

27.1 This test is conducted to determine whether or not the component cells are being maintained within their specified operating limits during maximum charge and discharge conditions of the personal e-mobility device. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components and temperature sensitive materials in the personal e-mobility device are being maintained within their temperature ratings based upon the maximum operating temperature limits of the personal e-mobility device. Temperatures on accessible surfaces, which may be contacted by the user, are also monitored.

27.2 A fully discharged DUT (i.e. discharged to EODV) is to be conditioned within a chamber set to the upper limit charging temperature specifications of the personal e-mobility device manufacturer. After thermal stabilization in the chamber, the DUT is to be connected to a charging circuit input representative of anticipated maximum charging parameters provided by the specified charger. The DUT shall then be subjected to the maximum specified charging rate while monitoring voltages and currents on cells until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells, motors, etc. and on any user accessible surfaces.

Exception No. 1: The DUT can be tested at an ambient temperature of 25 ±5 °C (77 ±9 °F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:

$$T_{max} + T_{amb} - T_{ma}$$

Where:

T is the temperature of the given part measured under the prescribed test.

T_{max} is the maximum temperature specified for compliance with the test.

T_{amb} is the ambient temperature during the test.

T_{ma} is the maximum ambient temperature permitted by the manufacturer's specified or 40 °C (104 °F), whichever is greater.

Exception No. 2: If the design of the DUT and its controls result in worse case normal charging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the charge levels at elevated ambient), the test is to be conducted at ambient temperature of 25 ±5 °C (77 ±9 °F).

27.3 If the temperature protective device operates during the test in 27.2, repeat the test at maximum continuous charging temperature.

27.4 While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged DUT shall then be discharged in accordance with the manufacturer's specifications representative of the maximum continuous electrical load representative of the maximum operating load conditions while monitoring voltage and current on cells until the DUT reaches its specified EODV. The method of simulating the maximum continuous electrical load for discharging the batteries may vary according to the personal e-mobility device design and should be a method agreed upon by the manufacturer and organization testing the personal e-mobility device. The methods to simulate this loading can include the use of a dynamometer or other mechanical loading means, or manipulation of the electrical and electronic control circuit(s) to simulate loading on the motor. Factors to be considered when determining the maximum continuous electrical load during discharge include maximum weight of rider, maximum speed of movement, angle of movement and loads from auxiliary devices such as lights, audio, etc. that may be operating when the personal e-mobility device is moving. If there is a need to consider the surface impact to loading, concrete is to be used to represent typical outdoor operating surfaces. Temperatures shall be monitored on temperature sensitive safety critical components including cells, motors, etc. and on any user accessible surfaces.

Exception No. 1: The DUT can be tested at an ambient temperature of 25 ±5 °C (77 ±9 °F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:

$$T_{max} + T_{amb} - T_{ma}$$

Where:

T is the temperature of the given part measured under the prescribed test.

T_{max} is the maximum temperature specified for compliance with the test.

T_{amb} is the ambient temperature during the test.

T_{ma} is the maximum ambient temperature permitted by the manufacturer's specified or 40 °C (104 °F), whichever is greater.

Exception No. 2: If the design of the DUT and its controls result in worse case normal discharging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the charge levels at elevated ambient), the test is to be conducted at ambient temperature of 25 ±5 °C (77 ±9 °F).

27.5 If the temperature protective device operates during the test in 27.4, repeat the test at maximum continuous discharging temperature.

27.6 The manufacturer's specified limits (voltage, current and temperatures measured) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. See Table 27.1 and Table 27.2 for surface and component temperature limits.

Table 27.1
Temperatures on Components

Part	Maximum temperatures on components (T_{max}) °C (°F)
Synthetic rubber or PVC insulation of internal and external wiring	
– without temperature marking	75 (167)
– with temperature marking	Temperature marking
Components, insulation and thermoplastic materials	a
Cell casings	b
Motor Windings[c]:	
• Insulation Class A (105)	105
• Insulation Class E (120)	115
• Insulation Class B (130)	125
• Insulation Class F (155)	150

[a] The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.

[b] The internal cell case temperature shall not exceed the manufacturer's recommended maximum temperature.

[c] The temperature limits are based upon thermocouple measurements. If using the change of resistance method for measurements, refer to the Temperature Test of UL 1004-1, for method and temperature limits.

Table 27.2
Temperatures on User Accessible Surfaces

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)
Handles, knobs, grips, etc., continuously held in normal use	55 (131)	65 (149)	75 (167)
Handles, knobs, grips, etc., held or touched for short periods only	60 (140)	70 (158)	85 (185)

Table 27.2 Continued on Next Page

Table 27.2 Continued

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)
External surfaces of equipment which may be touched[b]	70 (158)	80 (176)	95 (203)
Parts inside equipment which may be touched[c]	70 (158)	80 (176)	95 (203)

[a] For each material, account shall be taken of the data from that material to determine the appropriate maximum temperature.

[b] For areas on the external surface of equipment and having no dimension exceeding 50 mm (2.0 in), and which are not likely to be touched in normal use, temperatures up to 100 °C (212 °F) are permitted.

[c] Temperatures exceeding the limits are permitted provided that the following conditions are met:

1) Unintentional contact with such a part is unlikely;

2) The part has a marking indicating that this part is hot. It is permitted to use the symbol (IEC 60417, No. 5041) to provide this information.

27.7 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 31, (without humidity conditioning) or a Dielectric Voltage Withstand Test, Section 30.

27.8 As a result of the temperature test, any of the following results in (a) – (e) below are also considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

28 Post-Discharge Charging Determination Test

28.1 At the immediate conclusion of the Temperature Test in Section 27, the supplied charger is to be plugged into the DUT to determine whether the unit allows charging above the cell manufacturer's maximum specified cell surface temperature for charging. When the charger is plugged into the DUT, the charger and DUT electrical connection shall comply with 27.4 and 27.6. Measurement of the cells by bypassing the BMS may be required to make this determination.

29 Imbalanced Charging Test

29.1 This test is to determine whether or not a DUT with series connected cells can maintain the cells within their specified operating parameters if it becomes imbalanced.

29.2 A fully charged DUT shall have all of its cells with the exception of one cell/cell block discharged to its specified fully discharged condition. The undischarged cells shall be discharged to approximately 50 % of its specified state of charge (SOC) to create an imbalanced condition prior to charging.

29.3 The DUT shall then be charged in accordance with the manufacturer's specifications using the specified charger and under a single fault condition in the charging protection circuitry. Protective devices that have been determined reliable may remain in the circuit as noted in 20.5. The voltage of the partially charged cells shall be monitored during the charging to determine if its voltage limits are exceeded. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values per Section 22, Post Test Cycle.

29.4 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 31, (without humidity conditioning) or a Dielectric Voltage Withstand Test, Section 30.

29.5 The maximum voltage limit of the cells shall not exceed the manufacturer's specifications. In addition, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

30 Dielectric Voltage Withstand Test

30.1 This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the DUT.

30.2 Circuits at 60 Vdc or 30 Vrms ac (42.4 Vpeak ac) or above and electrically isolated from ac mains supplied circuits shall be subjected to a dielectric withstand voltage consisting of a dc potential of twice the rated voltage.

Exception No. 1: An essentially sinusoidal ac potential of frequency between 40 – 70 Hz at twice rated voltage may be applied instead of the dc potential.

Exception No. 2: Semiconductors or similar electronic components not relied upon for protection from electric shock and liable to be damaged by application of the test voltage may be bypassed or disconnected.

30.3 For those circuits connected to an ac mains supply or not electrically isolated from ac mains circuits, the test voltage shall be an essentially ac potential of a frequency of 60 Hz at 1,000 V plus twice the rated voltage. If using a dc potential, the test voltage shall be 1.414 times the ac test potential value of 1,000 V plus twice the rated voltage.

Exception: Semiconductors or similar electronic components not relied upon for protection from electric shock and liable to be damaged by application of the test voltage may be bypassed or disconnected.

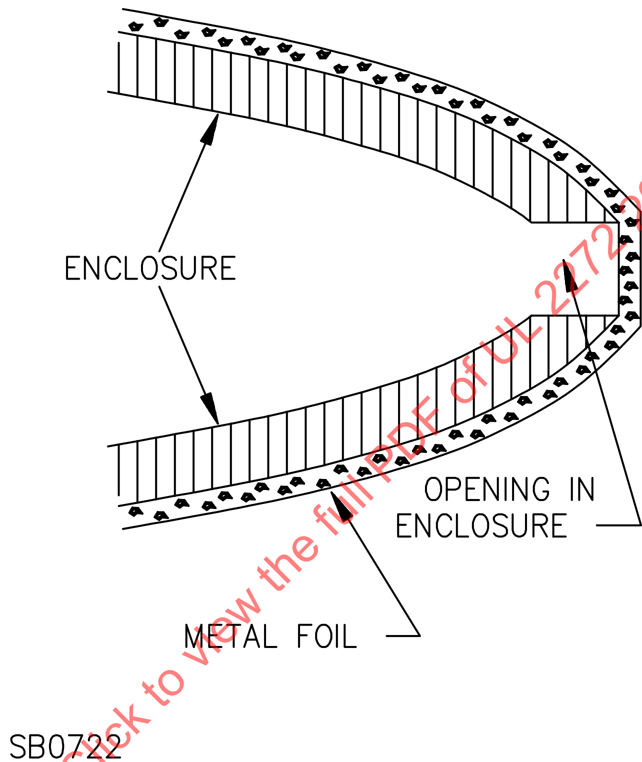
30.4 The test voltage is to be applied between the hazardous voltage circuits of the DUT and non-current carrying conductive parts that may be accessible.

30.5 The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.

30.6 If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts. The metal foil shall be wrapped tightly around and in intimate contact with the accessible part. The foil is to be drawn tightly across any opening in the enclosure or other accessible parts to form a flat plane across such opening. See Figure 30.1.

Figure 30.1

Method of covering Enclosures with Foil for Measurement and Tests



30.7 The test voltages shall be applied for a minimum of 1 minute with the cells/modules disconnected in a manner to prevent charging during application of the voltage.

30.8 The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage, which is variable and which is essentially sinusoidal if using an ac test method and dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it may not be indicative of insulation breakdown.

Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

30.9 There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacings) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as a dielectric breakdown (i.e. insulation breakdown).

31 Isolation Resistance Test

31.1 This test is intended to determine that insulation of the DUT provides adequate isolation of hazardous voltage circuits from accessible conductive parts of the DUT and that the insulation is non-hygroscopic.

31.2 A DUT with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts of a DUT. If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts as shown in 30.6 and Figure 30.1.

31.3 The insulation resistance shall be measured after a 60-s application with a high resistance voltmeter using a 500 Vdc potential applied for at least 1 min to the locations under test.

31.4 The test shall be repeated on a sample subjected to the Humidity Conditioning in accordance with UL 60950-1 / CSA C22.2 No. 60950-1, or CSA C22.2 No. 62368-1 / UL 62368-1. Measurements shall be made with the sample still in the chamber.

31.5 The measured insulation resistance between the positive terminals and accessible parts of the DUT shall be at least 50,000 Ω.

32 Leakage Current Test

32.1 This test is intended to evaluate a personal e-mobility device containing hazardous AC voltage circuits that can connect to mains AC during charging, for hazardous levels of leakage current.

32.2 The leakage current of a DUT when tested in accordance with 32.3 to 32.5 shall not be more than 0.5 milliampere.

32.3 All exposed conductive surfaces shall be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. If all accessible surfaces are bonded together and connected to the grounding conductor of the power supply cord, the leakage current may be measured between the grounding conductor and the grounded supply conductor.

32.4 If a conductive surface other than metal is used for the enclosure or a part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 centimeters (3.9 by 7.9 inches) in contact with the surface as shown in Figure 30.1. If the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface.

32.5 The circuit for the leakage current measurement is to be as illustrated in Figure 32.1. 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. The meter used need not have all the attributes of the defined instrument. The measurement instrument is to comply with the following:

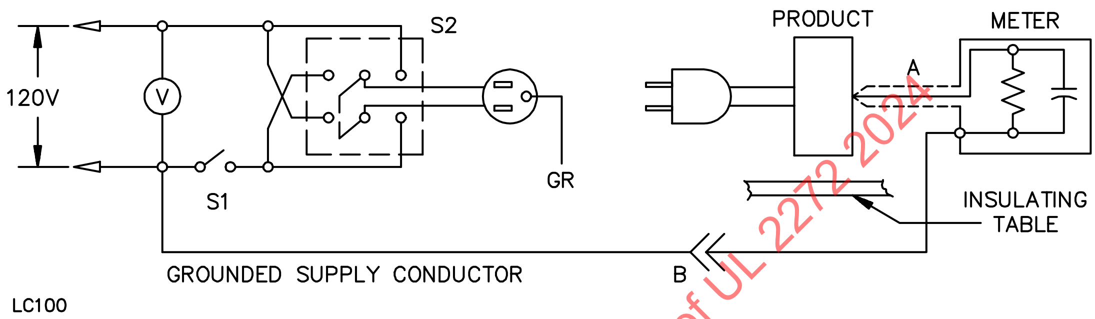
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kilohertz, the measurement circuit is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 or 0.75 milli-ampere, the measurement is not to have an error of more than 5 percent at 60 hertz.

Figure 32.1

Leakage Current Measurement Circuit



A – Probe with shielded lead

B – Separated and used as a clip when measuring currents from one part of device to another

33 Grounding Continuity Test

33.1 Personal e-mobility devices with grounding and bonding systems shall be tested to determine that the resistance of that grounding/bonding circuit does not exceed the 0.1 Ohm limit per 15.4.

33.2 The resistance of the grounding/bonding circuit can be measured between two points on the bonding connections of the grounding circuit using a milli-ohmmeter.

33.3 The measured resistance between any two bonding connections shall be less than or equal to 0.1 Ohm.

MECHANICAL TESTS

34 Vibration Test

34.1 This test evaluates the DUT's ability to withstand vibration that may occur during its anticipated use. The test shall be performed in accordance with ISO 6469-1 without temperature conditioning, or to a test profile determined by the customer and verified to the personal e-mobility device application.

34.2 The DUT is to be securely mounted to a vibration test platform in a manner similar to how it is oriented during use. The DUT is to be subjected to a random vibration sequentially along three perpendicular axes.

34.3 The DUT shall be subjected to the vibration in each axis for 21 h if testing one sample, 15 h if testing two samples or 12 h if testing 3 samples. For each axis the frequency shall be varied from 5 Hz to 200 Hz with power spectral density (PSD) for the vertical (Z) axis, the longitudinal (X) axis, and the transverse (Y) axis as outlined in ISO 6469-1.

34.4 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer’s maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

34.5 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning). The sample shall be examined with the probe of 9.1.3 to determine if it is possible to access hazardous parts if applicable.

34.6 As a result of the vibration test, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

35 Shock Test

35.1 This test is intended to determine whether or not the DUT can withstand a mechanical shock that may occur when in use.

35.2 The fully charged sample of the personal e-mobility device is to be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. Temperatures on the center cell are monitored for information purposes.

35.3 The sample is to be subjected to mechanical shock testing with parameters as shown in Table 35.1 or according to a test profile determined by the customer and verified to the personal e-mobility device application. When considering the level of shock, the weight of the DUT and maximum specified weight of the rider need to be considered. The battery can be tested first separately from the personal e-mobility device and the higher shock levels for lighter devices prior to testing the complete assembly. The shocks are to be applied in all 6 spatial directions.

Table 35.1
Shock Parameters

DUT and Maximum Allowed Rider Weight	Pulse shape	Acceleration	Duration	Number of shocks
≤ 12 kg	half-sinusoidal	50 g	11 ms	3 ⊥ directions
> 12 ≤ 100 kg	–	25 g	15 ms	3 ⊥ directions
> 100 kg[a]	–	10 g	20 ms	3 ⊥ directions

[a] Battery pack previously tested individually outside of personal e-mobility device to the appropriate higher shock level per its weight.

35.4 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer’s maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

35.5 At the conclusion of the observation period, the samples with hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning). The sample shall be examined with the probe of 9.1.3 to determine if it is possible to access hazardous parts if applicable.

35.6 As a result of the shock test, any of the following results in (a) – (e) below are considered a non-compliant result. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

36 Input Test

36.1 The input current of a product is to be measured with the unit operating while charging a fully discharged battery. The current input of the product shall not be more than 110 % of the rated current value for the DUT as assigned by the manufacturer and if an external charger is used, the measured input current shall not exceed the rated output current of the external charger.

37 Crush Test

37.1 This test is conducted to determine the DUT's ability to withstand a crush that could occur during use.

37.2 This test is conducted on a fully charged DUT.

37.3 One sample of the personal e-mobility device is to be supported on a fixed rigid supporting surface, in the position and orientation that is representative of operation of the personal e-mobility device. A crushing force is to be applied to the personal e-mobility device foot support surface by two flat applicator plates each sized 102 by 254 mm (4 by 10 inches). A force of 2 times the maximum specified rider weight is to be evenly distributed between the two applicator plates to the personal e-mobility device foot support surface. The total weight of the force applied to the personal e-mobility device foot support surfaces is to include the weight of the flat applicators.

37.4 The test force is to be held in place for a minimum of one minute. The sample shall be only subjected to one crush. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values per Section 22, Post Test Cycle. The test shall be followed by an observation period per 20.7.

37.5 At the conclusion of the observation period, samples with hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning). The sample shall be examined with the probe of 9.1.3 to determine if it is possible to access hazardous parts if applicable.

37.6 As a result of the crush test, any of the following results in (a) and (c) below are considered non-compliant results. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

38 Drop Test

38.1 This test is intended to evaluate whether a hazard exists when an DUT is subjected to an inadvertent drop during lifting or handling by the user when charging or replacement, etc.

38.2 A fully charged DUT is to be dropped three times from a height of 1.0 ±0.01 m (39.4 ±0.4 in) to strike a concrete surface in a manner most representative of what would occur during lifting or handling of the DUT by the user. The concrete surface shall be at least 76-mm (3-in) thick and shall be large enough in area to cover the DUT. If the DUT is operational after the drop, it is to be subject to a minimum of one normal charge/discharge cycle in accordance with the manufacturer's specifications.

38.3 DUTs shall be conditioned for a minimum of 3 h at 0 °C (32 °F) [or temperature specified if lower than 0 °C (32 °F)] prior to conducting the drop test, which shall be conducted immediately after removing the samples from the cold conditioning.

38.4 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 20.7 and then examined.

38.5 After the examination, the DUTs shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning) if applicable.

38.6 There shall be no damage of the enclosure that would allow hazardous voltage parts to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in Figure 9.1 of UL/ULC 2271 and the probe noted in 9.1.3.

38.7 As a result of the drop test, any of the following results in (a) – (e) below are considered non-compliant. See also Table 22.1 and Section 23, Results Criteria.

a) E – Explosion;

b) F – Fire;

c) R – Rupture (enclosure);

d) L – Electrolyte Leakage (external to enclosure); and

e) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown).

39 Mold Stress Relief Test

39.1 This test is intended to evaluate whether any shrinkage or distortion exists on a molded or formed thermoplastic enclosure due to release of internal stresses caused by the molding or forming operation and result in the exposure of hazardous parts or reduction of electrical spacings.

39.2 The sample is to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70 °C (158 °F). The samples are to remain in the oven for 7 h.

Exception: If the maximum temperature, T, recorded on the DUT thermoplastic enclosure parts, obtained during the normal Temperature Test of Section 27 exceeds 60 °C (140 °F), then the oven temperature is to be maintained at a temperature equal to T +10 °C (18 °F).

39.3 To prevent hazards from overheating energized cells, samples shall be fully discharged prior to conditioning.

39.4 After careful removal from the oven, the sample shall be allowed to cool to room temperature and then examined. After the examination, the samples shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 31, (without humidity conditioning).

39.5 There shall be no insulation breakdown during the Dielectric Voltage Withstand Test, Section 30, or the isolation resistance shall not be below the levels outlined in the Isolation Resistance Test, Section 31.

39.6 There shall be no damage of the DUT enclosure that would allow hazardous voltage parts to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in Figure 9.1 of UL/ULC 2271 and the probe in 9.1.3.

40 Handle Loading Test

40.1 This test is intended to evaluate the strength of the handle(s) on a personal e-mobility device that may be used to lift the personal e-mobility device.

40.2 A force is to be applied on the handle in the intended carrying direction uniformly over a 75-mm (2.95-in) length at the center of the handle. The applied force shall be gradually increased from zero to four times the weight of the DUT in 5 – 10 s and then maintained at the level for 1 min.

40.3 If more than one handle is provided, the test force shall be determined by the percentage of the DUT weight sustained by each handle with the DUT in the intended carrying position. If a DUT weighing less than 25 kg (55.1 lbs) is provided with more than one handle and can be carried by only one handle, each handle shall be capable of withstanding a force based on the total weight of the DUT.

40.4 There shall be no breakage of the handle, its securing means, or that part of the DUT to which the handle is attached.

41 Motor Overload Test

41.1 This test is intended to evaluate a motor's ability to safely withstand an overload condition, which may occur in the end use application. This test is waived if the motor and its overload protection has already been evaluated as part of a motor and motor protector combination evaluation per UL 1004-3, or UL 1004-7, as applicable to the method of thermal protection.

41.2 The motor is to be tested while in the personal e-mobility device and temperatures on windings are to be monitored. As an alternative, the motor can be tested outside the personal e-mobility device.

41.3 The motor is first operated under maximum normal load conditions. The load is then increased so that the current is increased in appropriate gradual steps with the motor supply voltage being maintained at its original value. When steady state temperature conditions are established the load is again increased. The load is thus progressively increased in appropriate steps until either the overload protection device operates or the motor winding becomes an open circuit.

41.4 The motor winding temperatures are determined during each steady period and the maximum temperature recorded shall not exceed the value in Table 41.1.