JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 2849:2022A

STANDARD FOR SAFETY

Electrical Systems for eBikes

ANSI/UL 2849-2022

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Electrical Systems for eBikes, ANSI/CAN/UL 2849

First Edition, Dated January 2, 2020

Summary of Topics

This revision of ANSI/CAN/UL 2849 dated December 15, 2022 includes an editorial correction to Table 8.1.

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

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ANSI/CAN/UL 2849:2022A

Standard for Electrical Systems for eBikes

First Edition

January 2, 2020

This ANSI/UL Standard for Safety consists of the First Edition including revisions through December 15, 2022.

The most recent designation of ANSI/UL 2849 as an American National Standard (ANSI) occurred on June 17, 2022. 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 June 17, 2022.

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Preface

This is the First Edition of the ANSI/CAN/UL 2849, Standard for Safety for Electrical Systems for eBikes.

UL 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 2849 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 to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Electrical Systems for eBikes, STP 2849.

This list represents the STP 2849 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

STP 2849 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.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE

INTRODUCTION

1 Scope

1.1 This Standard covers the electrical system of eBikes powered by a lithium-based, rechargeable battery. EBikes include both Electrically Power Assisted Cycle (EPAC – pedal assist) and non-pedal assist eBikes.

1.2 Electrical systems as referenced in 1.1, may include onboard components and off board components of eBikes. As a minimum, the electrical system consists of the drive unit, battery, battery management system (BMS), interconnecting wiring, and power inlet. Any additional components or systems required to demonstrate compliance are included based on the overall system application and risk.

1.3 Off board components include dedicated chargers for charging batteries that are removed from the eBike during charging or dedicated chargers for charging batteries that are in place on the eBike during charging.

1.4 This Standard does not cover the mechanical structure of the eBike unless specified otherwise.

2 Components

2.1 A critical safety component of a product covered by this Standard shall comply with the requirements for that component.

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

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

b) Is superseded by a requirement in this Standard.

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

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

3 Units of Measurement

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

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 Definitions

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

5.2 BATTERY MANAGEMENT SYSTEM (BMS) – The electrical, electronic and software monitoring and control system of a battery that is often relied upon to maintain the battery and its component cells within their specified operating region for charge and discharge, and may be source of memory of the battery operation throughout its life.

5.3 CHARGER – A device that converts grid power to DC power for charging the battery.

5.3A COMMUNICATION DEVICE – Auxiliary devices that often provide communication function such as but not limited to LTE (Long Term Evolution), EGPRS (Enhanced General Packet Radio Service), UWB (Ultra Wideband) or BLE (Bluetooth Low Energy) for location tracking or other purposes which may or may not be separated from the operator interface. These may or may not be accessible to operator/rider but can be accessible to the service personnel.

5.4 eBIKE – A two or three wheeled electrical/mechanical device provided with functional pedals that includes one or more electric motors to either assist the rider when pedaling (EPAC versions) or provide motive power to the wheels when the rider is not pedaling.

5.5 ENCLOSURE – That portion of a unit that reduces the accessibility of a part that involves a risk of fire, electric shock or injury to persons, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.6 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.

5.7 EPAC – A version of an eBike, equipped with functional pedals and one or more auxiliary electric motors, which cannot be propelled exclusively by means of the auxiliary electric motors, except in the start-up assistance mode. The motors are designed to disengage their assist function when the rider stops pedaling, when a maximum predetermined speed is reached, or when the user applies the brakes (if the brakes are provided with cutoff functions).

5.8 LIVE PART – A conductive part, such as metal, within the unit that during intended use has a potential difference with respect to earth ground or any other conductive part.

5.9 FUNCTIONAL PEDALS – Assemblies provided on eBikes that are integrally part of the drive train motive system and are used by the rider to provide motive force to the wheel or wheels.

5.10 LOW VOLTAGE LIMITED ENERGY (LVLE) – A circuit that is supplied from an isolated secondary winding of a transformer, or other appropriate means, and that complies with the requirements in 8.3.

5.10A OPERATOR INTERFACE – Auxiliary devices that often include but not limited to throttle, display, and other similar switches and human-machine-interfaces.

5.10B PASSIVE PROTECTIVE DEVICE – Device provided to prevent or detect hazardous condition(s) that does not require electrical energy in order to correctly operate. Example of passive protective devices include fuses or Thermal Cut-Outs (TCOs).

5.10C PROTECTIVE CIRCUIT – Circuit provided to prevent or detect hazardous condition(s) that requires electrical energy in order to correctly operate. Examples of protective circuits include Battery Management Systems (BMSs) and other electrical, electronic, programmable electronic, firmware, and software-based control systems that are preventing or detecting hazardous condition(s).

5.11 RISK OF ELECTRIC SHOCK – A potential for exposure of persons to hazardous voltage circuits (greater than 42.4 V peak ac or 60 V dc) through direct contact from openings in protective enclosures and/or insufficient insulation between hazardous voltage circuits and accessible parts.

6 Normative References

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

6.2 Where reference is made to any Standards, such reference shall be considered to refer to the latest editions and revisions thereto available, unless otherwise specified.

6.3 The following publications are referenced in this Standard:

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

CSA C22.2 No. 0.8, *Safety functions incorporating electronic technology*

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

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

CSA C22.2 No. 5, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures*

CSA C22.2 No. 49, *Flexible Cords and Cables*

CSA C22.2 No. 65, *Wire Connectors*

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

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

CSA C22.2 No. 107.1, *Power Supplies*

CSA C22.2 No. 107.2, *Battery Chargers*

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

CSA C22.2 No. 210, *Appliance Wiring Material Products*

CSA C22.2 No. 223, *Power Supplies With Extra Low Voltage Class 2 Outputs – General Instruction No. 1*

CSA C22.2 No. 248.1, *Low-Voltage Fuses – Part 1: General Requirements*

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

CSA C22.2 No. 4248.1, *Fuseholders – Part 1: General Requirements*

CSA C22.2 E60730-1, *Automatic Electric Controls – 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*

CAN/CSA C22.2 No. 62368-1, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

CSA LTR No. I-003, *List of Technical Requirements for Positive Temperature Coefficient (PTC) Thermistors Used as Overcurrent Protectors in Electrical and Electronic Equipment*

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

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, *The Standard for Fault Tree Analysis (FTA)*

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

ISO 12100, *Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction*

ISO 13849-1, *Safety of Machinery – Safety Related Parts of Control Systems – Part 1: General Principles for Design*

ISO 13849-2, *Safety of Machinery – Safety Related Parts of Control Systems – Part 2: Validation*

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

SAE J1739, *The 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 62, *Flexible Cords and Cables*

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

UL 248-1, *Low-Voltage Fuses – Part 1: General Requirements*

UL 486A-486B, *Wiring Connectors*

UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures*

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

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

UL 758, *Appliance Wiring Material*

UL 796, *Electrical Printed-Wiring Boards*

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

UL 969, *Marking and Labeling Systems*

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

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 1434, *Thermistor-Type Devices*

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

UL 1998, *Software in Programmable Components*

UL 2054, *Household/Commercial Batteries*

UL 2097, *Double Insulation Systems for Use in Electronic Equipment*

UL 2238, *Cable Assemblies and Fittings for Industrial Control and Signal Distribution*

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

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

UL 2580/ULC-S2580, *Batteries for Use in Electric Vehicles*

UL 4248-1, *Fuseholders – Part 1: General Requirements*

UL 60730-1, *Automatic Electrical Controls – 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*

CONSTRUCTION

7 General

7.1 The information provided in Sections 7 through 10 is essential for the proper evaluation of the products covered by this Standard. The concepts in these Sections will outline and define the evaluation path based on what is provided in the electrical system.

7.2 The concepts in Sections 7 through 10 are general in nature and could result in different methods of evaluation for each different product type dependent upon its overall design.

7.3 EBikes consist of both EPAC and non-EPAC types, but in all cases functional pedals shall be provided. For EPACs, motors shall disengage their assist function when the rider stops pedaling, when a maximum predetermined speed as specified by the manufacturer is reached, or when the user applies the brakes (if the brakes are provided with cutoff functions). For non-EPAC versions of the eBike, motors are not required to disengage when the user stops pedaling. A non-EPAC type eBike may be provided with an EPAC mode.

7.4 The electrical system located on the eBike, those subassemblies or components shall comply with all the requirements in this Standard at a maximum altitude of 2000 m (6562 feet) and over an ambient temperature range of 0°C to 40°C (32°F to 104°F) and be subjected to ingress protection tests. Equipment may be used at ambient temperature extremes for operation and battery charging that exceed the default limits above (e.g., -10 °C or +50 °C) when specified by the manufacturer and the equipment shall be provided with instructions in accordance with 46.3 (j) and (k), and 48.3.

8 Power Levels

8.1 General

8.1.1 For all products covered by this Standard, a specific power level will be associated with the eBike. This will require rated voltage and current levels to be assigned, but can also include voltages or currents that are available within the eBike being evaluated. Different approaches can be used based on the potential hazards associated with a given power level.

8.1.2 For the purposes of this Standard, different designations will be used. This includes hazardous voltage and/or hazardous current resulting in hazardous energy, and in all cases these designations indicate a voltage, current or energy level that is potentially dangerous to the user and means of protection are required. Additional designations cover Low Voltage, Limited Energy (LVLE) which indicates voltage and current levels that are not inherently hazardous to the user and the need for specific protection means may be reduced.

8.2 Hazardous Voltage and Hazardous Energy

8.2.1 Any accessible circuit or accessible part, as determined by the articulate probe in Figure 18.1, that is operating at a voltage above 42.4 volts peak or 60 V dc is considered to be operating at a hazardous voltage. In these cases, the user must be protected against contact with the part or circuit by the use of an enclosure or proper insulation. The requirements for both enclosures and insulation are included in this Standard and shall be applied as appropriate in all cases where hazardous voltages exist.

8.2.2 Hazardous energy exists in any circuit or part that is operating with a stored energy level of 20 J or more, or has an available continuous power level of 240 VA or more, at a potential of 2 volts or more. In these cases, the user shall be protected against contact with the part or circuit by the use of an enclosure or proper insulation. The requirements for both enclosures and insulation are included in this Standard and shall be applied as appropriate in all cases where hazardous energy exist.

8.3 Low Voltage Limited Energy Circuits

8.3.1 A Low-Voltage Limited Energy Circuit (LVLE) shall comply with the limits in Table 8.1.

8.3.2 The power limitations in Table 8.1 may be obtained by the use of any of the following configurations:

a) An inherently-limited transformer;

b) A non-inherently-limited transformer coupled with an overcurrent protective device in the output circuit;

c) A combination transformer and fixed impedance; or

d) An arrangement determined to be equivalent to (a), (b), or (c).

Table 8.1
Low-voltage, limited-energy circuits

	Inherently limited transformer (overcurrent protection not required)			Not-inherently-limited transformer (overcurrent protection required)			
Circuit voltage (volts)[a]	0 – 20 volts AC or DC[b]	Over 20 volts but not more than 30 volts AC or DC[b]	Over 30 volts but not more than 60 volts DC[b]	0 – 15 volts AC or DC[b]	Over 15 volts but not more than 20 volts AC or DC[b]	Over 20 volts but not more than 30 volts AC or DC[b]	Over 30 volts but not more than 60 volts DC[b]
Power limitation (volt-amperes)[c]	–	–	–	350	250	250	250
Current limitation (amperes)[d]	8	8	150/V[a]	1000/V[a]	1000/V[a]	1000/V[a]	1000/V[a]
Maximum overcurrent protection (amperes)	–	–	–	5	5	100/V[a]	100/V[a]

[a] Maximum output voltage, regardless of load, with applied rated voltage.

[b] The AC waveform shall sinusoidal.

[c] Maximum volt-ampere output regardless of load, and overcurrent protection (if provided) bypassed.

[d] Maximum output after 1 minute of operation under any noncapacitive load, including short circuit, and with overcurrent protection (if provided) bypassed.

8.3.3 A part or device, other than the battery pack, located in or supplied by an LVLE circuit need not be investigated. The secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be judged under the applicable requirements in this Standard.

8.3.4 The maximum load current is to be drawn under any condition of loading, including short circuit, using a resistor. The current is to be measured 60 seconds after the application of the load. The resistor is to be continuously readjusted during this 1 minute period to maintain maximum load current. The measured load current shall not exceed the value listed in Table 8.1.

8.3.5 With reference to the voltage limit specified in Table 8.1, measurement is to be made with the product connected to the intended source of supply and with all loading circuits disconnected.

8.3.6 The over-current protective device provided in the LVLE circuit used to limit the current shall be rated or set at not more than the values specified in Table 8.1. The device shall not be of the automatically reset type.

8.3.7 If a regulating network is used to limit the output under any conditions, the LVLE current limitation in Table 8.1 shall not be affected by malfunction of a single component, excluding resistors. The network shall comply with the value in Table 8.1 when the current is measured after 5 seconds.

9 Combination of Battery, Battery Management System, and Charger

9.1 The battery management system (BMS) is used to control battery charging and discharging. For battery packs that are provided with an integral BMS, that BMS shall be evaluated as part of the battery pack in accordance with Battery Packs, Section 11. If the BMS, or a portion of the BMS, resides in components or circuits external to the battery pack, then the combination of the external components and the battery pack is critical to safety and shall be evaluated together in accordance with 9.2.

9.2 All testing of the system shall be performed with the actual battery/BMS and charger that is recommended by the manufacturer. Any protection circuits, or other external components or systems, can remain in place provided those circuits or systems are proven to be reliable in accordance with Sections 12 and 19.

10 User Protection While Charging

10.1 General

10.1.1 Charging of the battery may occur while the battery is installed on the eBike, with the battery removed from the eBike, or both options may apply based on user preference. If the battery is only intended to be charged when it is removed from the eBike, then an inherent means shall be provided to insure that this option is the only option for charging the battery. If no inherent means are provided, and it is possible to charge the battery while on the eBike, the battery shall be considered to be charged both on board and off board the eBike.

10.1.2 If the battery is intended to be charged while on the eBike, whether by inherent construction or user preference, then the requirements in 10.2 apply. If the battery is only intended to be charged when removed from the eBike, then the requirements in 10.2 do not apply.

10.1.3 The requirements in 10.1.1 and 10.1.2 are to be used in conjunction with the requirements in Section 8. If energy levels are such that no hazard exists, then protection means may be reduced.

10.2 Charging batteries that are on the eBike

10.2.1 Charging of the battery on an eBike where voltage or energy levels exceed the lower limits for shock hazards or electric energy hazards will require that the exposed conductive surfaces of the eBike are protected and monitored during charging to prevent a shock hazard due to the charging energy supplied to the eBike. The personnel protection system supplied shall be as indicated in 10.2.2.

10.2.2 For equipment where the specifics of the installation of the on board electrical system is part of the evaluation, the eBike shall be provided with a system of protection that is considered suitable to protect the user. This may include suitable means such as double insulation systems onboard the eBike. The suitability of the protection system shall be judged based on the requirements in this Standard.

10.2.3 With reference to 10.2.2, products utilizing a system of protection based on protective grounding shall comply with the requirements in 10.2.4 and products utilizing a system of protection based on double insulation shall comply with the requirements in 10.2.5.

10.2.4 Protection systems relying on protective grounding for user protection shall comply with the applicable requirements for grounding and bonding in Section 22. The requirements shall be applied to all points where protective grounding is used as a means to protect the user.

10.2.5 A system of double insulation provided to protect the user shall be in accordance with the requirements in UL 2097.

10.2.6 The eBike shall have charger connect-interlock so that the motor cannot be activated when the charger is plugged in. If there is no interlock, there shall be a secondary means of preventing inadvertent motor activation.

11 Battery Packs

11.1 Battery packs that provide power to the motor shall be provided with an appropriate Battery Management System (BMS) either integral to the pack or as part of a system that includes components and circuits external to the pack. The BMS shall be designed to safely withstand normal and foreseeable misuse conditions for the eBike involved. For a BMS that includes components or circuits external to the battery pack, the BMS shall comply with Safety Circuits and Safety Analysis, Section 12, as applicable. A battery pack used in eBikes covered by this Standard shall comply with one of the following:

a) UL 2580/ULC-S2580;

b) UL/ULC 2271;

c) CSA C22.2 No. 62133-1/UL 62133-1 or CSA C22.2 No. 62133-2/UL 62133-2. See also 11.2; or

d) UL 2054. See also 11.2.

11.2 A battery pack in accordance with 11.1 (c) and (d) is additionally required to comply with the requirements in Overcharging Test, Section 32.2; Short Circuit Test, Section 32.7; Imbalanced Charging Test, Section 32.8; Shock Test, Section 32.9; Vibration Test (battery method), Section 38.2; and Thermal Cycling Test, Section 32.10.

11.3 For rechargeable batteries providing power to other than the motor and part of the eBike electrical system, the battery shall comply with CSA C22.2 No. 62133-1/UL 62133-1 or CSA C22.2 No. 62133-2/UL 62133-2 or UL 2054.

11.4 The charging and discharging external terminals of a battery pack intended for removal from eBike for charging, shall be evaluated to either the No-Load Endurance Test or the Endurance with Load Test, as applicable, in accordance with UL 2251 / CSA C22.2 No. 282, without being subjected to the exposure to contaminants.

Exception: Battery packs with external terminals that have been evaluated to UL 2251 as defined in UL/ULC 2271 are not repeatedly subjected to this test.

12 Safety Circuits and Safety Analysis

12.1 The electrical system of the eBike shall undergo a safety analysis as specified in 12.4 to verify that potential hazards associated with the design are addressed in this evaluation, and to identify protective circuits that prevent or detect the potential hazards.

12.2 For battery management systems, the protective circuit shall maintain the cells within their normal operating region for voltage, temperature, and current, during charging and discharging; and, if normal limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent further excursions beyond normal operating limits. Compliance is determined through a review of the battery system data including the safety analysis of 12.4 – 12.6, evaluation of functional safety in 12.7, and through the tests in this Standard.

12.3 Protective circuits used to prevent hazardous conditions related to assistance functions, such as unintentional self-start, electric motor assistance without pedaling, electric motor assistance without activation of the startup assistance mode, and the like, shall also be evaluated based on the requirements in this Section as applicable. Compliance is determined through a review of the design and overall system, including the safety analysis of 12.4 – 12.6, evaluation of functional safety in 12.7, and through the tests in this Standard.

12.4 An analysis of potential hazards shall be conducted on the electrical system of the eBike, including the charger and other circuits as applicable, to determine that events that could lead to a hazardous condition have been identified and addressed through protective circuits, passive protective devices, or other means. Documents that can be used as guidance for the safety analysis include:

a) IEC 60812;

b) IEC 61025;

c) SAE J1739;

d) MIL-STD-1629A; and

e) ISO 12100.

Other risk assessment standards that provide equivalent analysis methods, assessment means, and coordination may be used.

12.5 The analysis in 12.4 is utilized to identify anticipated faults or conditions in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the potential hazards. The manufacturer shall provide the analysis of 12.4 for review as part of the evaluation of the system. The manufacturer shall indicate potential hazards associated with the system and document the level of risk associated with each potential hazard. During the review of the analysis during this evaluation, the results associated with the analysis may change or may be modified as deemed appropriate. The analysis shall consider single fault conditions in the protective circuits/schemes as part of the anticipated faults; and faults that occur as a result of those single faults are to be included.

12.6 When conducting the analysis of 12.4, single-fault conditions of protective circuits shall not cause, or not cause a failure to detect, a hazardous condition. Protective circuits shall not be relied upon for critical safety unless:

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

b) They are provided with a redundant protective circuit that remains functional and energized upon loss of power/failure of the first protective circuit;

c) They are determined to fail safe upon loss of power to/failure of the protective circuit; or

d) They are part of a protective circuit that has been shown to comply with IEC 61508 Safety Integrity Level (SIL) 2 or ISO 13849 Performance Level (PL) c.

12.7 Protective circuits shall be tested for functionality and reliability in the relevant configuration and environment, in accordance with appropriate functional safety requirements. Functional safety criteria can be found in one of the following sets of standards as appropriate to the design of the protective circuits, with required safety level(s) defined by the safety analysis in 12.4:

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

b) UL 60730-1 and CSA C22.2 E60730-1;

c) IEC 61508-1 and all parts; or

d) ISO 13849-1 and ISO 13849-2.

12.8 Any product 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) Be accessible and able to be operated without the use of a tool in the event of a collision or during servicing;

c) Require manual action to break the electrical connection;

d) Ensure disconnection is physically verifiable and can include actual removal of the battery system from the eBike or unplugging the battery system connector/plug; and

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

12.9 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.

13 Enclosing and Insulating Hazardous Parts

13.1 General

13.1.1 An eBike shall be provided with one or more enclosures that house all live parts that are considered hazardous. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy – high current levels shall comply with the applicable enclosure requirements specified in this Standard.

Exception: For a part of the system that is in accordance with enclosure requirements of the applicable component or end product standard for the part in question, these requirements do not apply.

13.1.2 An enclosure 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.

13.2 Materials

13.2.1 Nonmetallic materials

13.2.1.1 The materials employed for enclosures shall comply with the applicable enclosure requirements outlined in UL 746C and CSA C22.2 No. 0.17, except as modified by this Standard.

13.2.1.2 Polymeric materials employed for enclosures shall have a minimum flame rating of V-1 in accordance with Flammability, Section 17, or the enclosure may alternatively be evaluated to the 20 mm end product flame test in accordance with UL 746C and CSA C22.2 No. 0.17.

Exception: Nonmetallic enclosures of rechargeable batteries that use a cell that complies with PS1 (Power source class 1) requirements outlined in UL 62368-1/CAN/CSA C22.2 No. 62368-1 are exempt from the above requirement.

13.2.1.3 The following factors in (a) – (c) shall be taken into consideration when an enclosure employing nonmetallic materials is being evaluated. For a nonmetallic enclosure all of these factors shall 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) – (c) below shall be determined by the tests of this Standard.

a) Resistance to Impact;

b) Abnormal Operations;

c) Mold Stress Relief Distortion.

13.2.1.4 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 and CSA C22.2 No. 0.17.

13.2.1.5 Materials employed as electrical insulation in the assembly shall be resistant to deterioration that would result in a risk of 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 UL 746C and 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 18, Internal Wiring and Terminals.

13.2.1.6 Gaskets and seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.

13.2.1.7 Enclosure materials intended to be directly exposed to sunlight in the end use application shall comply with the UV Resistance test in accordance with UL 746C and CSA C22.2 No. 0.17.

13.2.2 Metallic materials

13.2.2.1 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/CSA C22.2 No. 94.2.

13.2.2.2 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.

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

13.3 Strength of Enclosures

13.3.1 The enclosure shall be subjected to the Impact Test, Section 33.

13.4 Sharp Edges

13.4.1 An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use.

13.5 Ingress Protection

13.5.1 Openings in the enclosure shall be designed to inhibit inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, of IEC 60529, for a minimum IP rating of IP3X. Evaluation per IEC 60529, consists of the use of the Test Rod 2.5 mm, 100 mm long, shown in UL/ULC 2271, applied with a force of 10 N ±10 percent.

13.5.2 Openings in an enclosure shall be designed to prevent ingress of water as installed in the intended application in accordance with intended use and IP rating in accordance with IEC 60529, with a minimum rating of IPX4. Compliance is determined by the Ingress Protection Tests in Section 36.

14 Mounting

14.1 Components mounted on the eBike shall be subjected to the Vibration Test, Section 38.

15 Printed Wiring Boards

15.1 A printed-circuit board shall comply with the requirements in UL 796, and shall have a flammability rating as indicated in Section 17.

15.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.

16 Spacings and Separation of Circuits

16.1 Electrical circuits within the electrical system 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). Insulation suitable for the anticipated temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.

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

a) Table 16.1;

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/CAN/CSA C22.2 No. 62368-1.

16.3 As an alternative to the spacing requirements in 16.2, the spacing requirements in UL 840 and CSA C22.2 No. 0.2, may be used. For determination of clearances, the overvoltage category is considered Overvoltage Category II; and the pollution degree would be Pollution Degree 3 unless reduced by design in accordance with UL 840 and CSA C22.2 No. 0.2.

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

Table 16.1
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]	1.6 (1/16)	1.6 (1/16)
	51 – 130	3.2 (1/8)	4.8 (3/16)
	131 – 300	6.4 (1/4)	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]	1.6 (1/16)	1.6 (1/16)
	51 – 130	3.2 (1/8)	4.8 (3/16)
	131 – 300	6.4 (1/4)	9.5 (3/8)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 – 50[a]	3.2 (1/8)	3.2 (1/8)
	51 – 130	4.8 (3/16)	6.4(1/4)
	131– 300	12.7(1/2)	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).

16.5 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 inch) thick for supplementary or reinforced insulation, and the eBike passes the Dielectric Strength Test, Section 30, and the Isolation Resistance Test, Section 29.

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.

16.6 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.

17 Flammability

17.1 Nonmetallic materials used for enclosures shall have a minimum flammability rating of V-1 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. As an alternative, finished enclosures may be tested in accordance with the 20 mm end-product flame test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. Metallic materials used for enclosures are considered to comply without further evaluation.

Exception: Nonmetallic enclosures of rechargeable batteries that use a cell that complies with PS1 (Power source class 1) requirements outlined in UL 62368-1/CAN/CSA C22.2 No. 62368-1 are exempt from the above requirement.

17.2 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/CAN/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;

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; or

g) Not ignite during Abnormal Operations Tests, Section 32.

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

17.4 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.

17.5 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.

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

17.7 For the requirements outlined in 17.2 – 17.6, 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 CAN/CSA C22.2 No. 0.17.

18 Internal Wiring and Terminals

18.1 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.

18.2 Wiring internal to an enclosure 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.

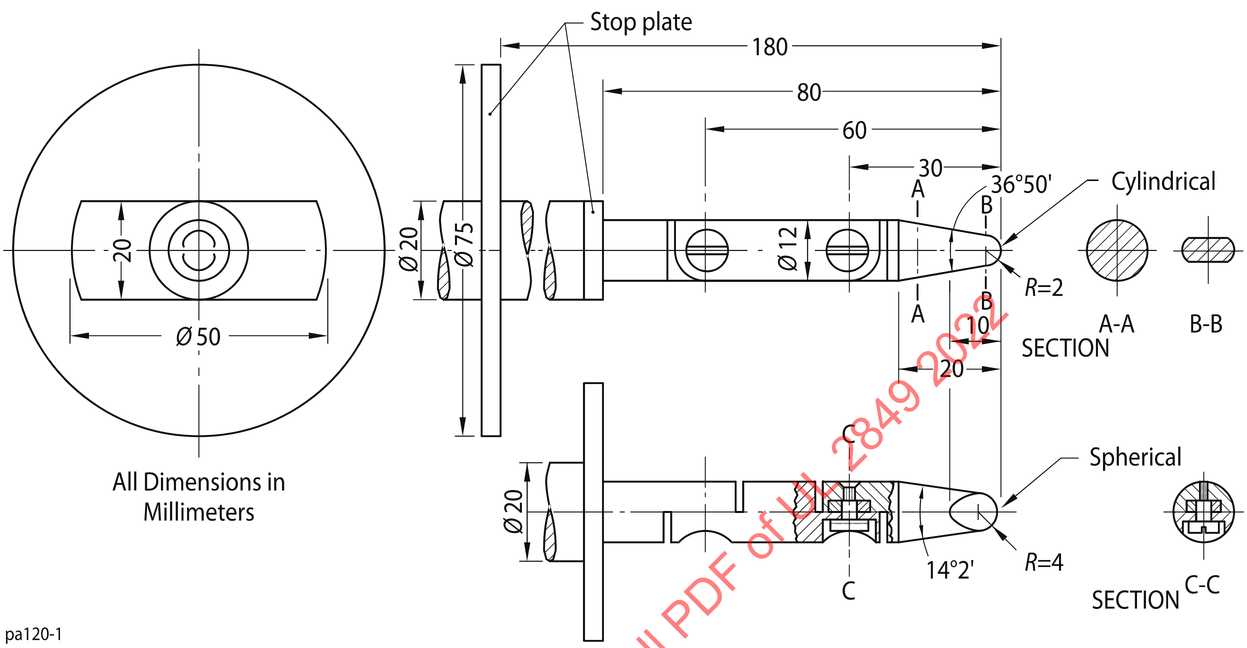
18.3 An external terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when the eBike is in use.

18.4 An external terminal for charging shall be designed to prevent an inadvertent shorting and misalignment and a reverse polarity connection when connected to the charger.

18.5 Any other external terminals with hazardous voltage shall be designed to prevent access by the user. Any external terminals with hazardous energy level as determined in accordance with 8.2.2 shall not be bridged by a metallic object. Compliance is determined by use of the articulate probe shown in Figure 18.1.

Figure 18.1

Articulate probe



18.6 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.

18.7 Wiring for hazardous voltage on board the eBike shall be enclosed in junction boxes with hazardous voltage warning labels such as ISO 7010, No. W012 (i.e. lightning bolt within triangle), or shall be protected by suitable enclosures that are not accessible to the user.

18.8 Wires that are subjected to flexing during normal operation or due to user accessibility shall be subjected to the Flexing Test, Section 35.

19 Overcurrent Protection

19.1 Power, control and auxiliary circuits shall have overcurrent protection that is sized to prevent overheating of the smallest size conductor.

19.2 The need for overcurrent protection in the power circuit to motors, whether one protective device for each motor or one device for multiple motors, is to be determined on the basis of the locked rotor and running overload tests described in Section 32.

19.3 Overcurrent devices in the control and power circuit shall be physically located the shortest distance possible from the power supply or battery.

19.4 The need for overcurrent protection in the LVLE circuits is to be determined on the basis of the requirements described in Low-Voltage Limited Energy Circuit, 8.3.

19.5 The overcurrent protective device specified in 19.4 shall be a circuit breaker, fuse or positive temperature coefficient device.

19.6 A fuse or circuit breaker shall be either:

a) Acceptable for branch circuit use; or

b) A supplementary type.

19.7 A positive temperature coefficient device shall comply with Manufacturing Deviation and Drift; Endurance; and Requirements for Controls Using Thermistors, in UL 60730-1/CSA C22.2 E60730-1 or UL 1434/CSA LTR No. I-003. The positive temperature coefficient device shall be tested and determined to comply in the actual battery configuration and environment.

19.8 Fuses shall be acceptable for the current and voltage of the circuit they are protecting and shall comply with 19.9 and 19.10. Fuses shall be tested and determined to comply in the actual battery configuration and environment.

19.9 Fuses provided for protection of circuits or outputs shall comply with CSA C22.2 No.248.1/UL 248-1 and the applicable parts of the series. Fuseholders used with these fuses shall comply with CSA C22.2 No. 4248.1/UL 4248-1 and the applicable parts of the series.

19.10 For user replaceable fuses, a fuse replacement marking in accordance with 44.3 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. 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. See Section 47.

20 Motors and Motor Controllers

20.1 A traction motor used in a eBike 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.

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

20.3 Motors located in hazardous voltage circuits shall comply with the requirements of UL 1004-1 and 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.

20.4 Sensors and controls associated with the motor control, either as a stand-alone component or system, provided to perform a safety function shall comply with the applicable requirements in the appropriate controls standard in accordance with 2.1. For eBikes and EPACs provided with a startup assistance function, the control for providing startup assistance shall require a voluntary and continuous action by the user to allow startup assistance, such as the use of a dead man switch.

20.5 In addition to the testing associated with the control of the motors in this Standard, hazards associated with the motor control shall be included in the analysis required in Safety Circuits and Safety Analysis, Section 12.

21 Operator Interface and Communication Devices

21.1 The operator interface and communication devices shall be constructed such that the user will not have access to hazardous parts. If hazardous parts exist in the operator interface, then the operator interface shall comply with the requirements for enclosing hazardous parts in Section 13. Also, the interface shall comply with 21.2.

21.2 An operator interface and communication devices with internal battery circuits and/or a touchscreen with high voltage backlights shall be evaluated as Limited Current Circuits in accordance with UL 60950-1/CSA C22.2 No. 60950-1 or UL 62368-1/CSA C22.2 No. 62368-1.

21.3 The operator interface and communication devices that comply with UL 60950-1/CSA C22.2 No. 60950-1 or UL 62368-1/CSA C22.2 No. 62368-1 are considered to comply with the requirement of this Standard.

22 Grounding and Bonding

22.1 General

22.1.1 For eBikes that are using a grounded system of protection to mitigate hazards associated with electric shock or electrical energy while charging, a means of extending the ground to the eBike through a bonding conductor shall be provided.

22.1.2 The requirement in 22.1.1 applies for both on board chargers and off board chargers.

22.2 Bonding connections

22.2.1 For grounded systems, there shall be provision for bonding all dead metal parts of an eBike to the main ground connection. This requirement applies to all dead metal parts that are exposed or that possess a risk of being contacted by a person during intended operation or adjustment and that are capable of becoming energized as a result of electrical malfunction.

22.2.2 The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455°C (850°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

22.2.3 An equipment-bonding terminal, or lead-bonding point, shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the risk of inadvertent loosening, the head of the screw or bolt shall not be accessible from outside of the enclosure.

22.2.4 An equipment-bonding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

22.2.5 An equipment-bonding point shall be located so that the risk of inadvertently removing the bonding means during servicing is reduced.

22.2.6 An equipment-bonding lead shall be the same size as the grounding lead associated with the AC power source. The surface of the insulation shall be green.

22.2.7 For eBikes that are connected to NEMA 5-20R receptacles directly, the equipment-grounding conductor of a power-supply cord shall be connected to dead metal parts within the frame or enclosure by means of a screw, or stud and nut combination, or other equivalent means, not to be removed during ordinary servicing not involving the power-supply cord. The surface of any insulation on the grounding conductor shall be green with or without one or more yellow stripes and no other conductor shall be so identified. This connection can be part of a non-detachable cord that is part of the eBike, or in the case of detachable cords, from the ground blade on the eBike side connector.

22.2.8 An equipment-grounding conductor or equipment-bonding conductor shall not be spliced, nor shall it involve a trace on a printed wiring board.

22.2.9 A soldering lug, a connection means that depends on solder only, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding or equipment-bonding.

22.2.10 The equipment-grounding terminal or equipment-bonding terminal shall be capable of securing a conductor of a size intended for the application.

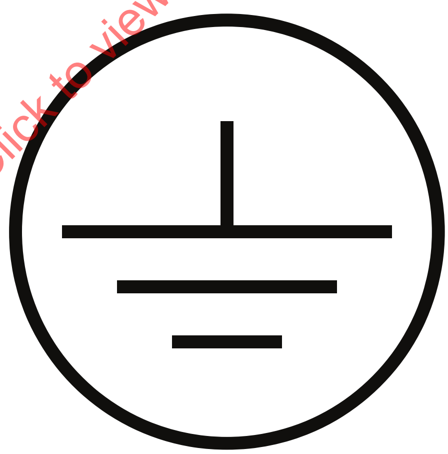
22.2.11 A terminal intended for the connection of an equipment-bonding conductor shall be identified by:

a) Being marked "G", "GR", "GND", "Ground", "Grounding", or the like; or

b) The grounding symbol illustrated in Figure 22.1 on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 22.1

Symbol for equipment bonding connection



IEC Publication 60417, Symbol 5019

23 Chargers

23.1 The charger used to recharge the battery shall comply with one of the following:

a) UL 1012 and CSA C22.2 No. 107.2;

b) UL 1310 and CSA C22.2 No. 223;

c) UL 60950-1/CSA C22.2 No. 60950-1, along with the relevant Part 2 Standard as applicable; or

d) UL 62368-1/CSA C22.2 No. 62368-1.

23.2 For chargers that comply with 23.1(b), no hazard exists at the output of the charger and requirements to mitigate a shock hazard or an energy hazard may be reduced as described in 8.3. Personnel protection in accordance with Section 10 is not required.

23.3 Chargers that comply with 23.1 (a), (c), or (d) are not necessarily limited at the output and the requirements for hazard mitigation for electrical systems connected to the output of the charger apply. Personnel protection in accordance with Section 10 shall be provided.

23.4 Chargers for lithium-ion battery systems shall have voltage, current, and temperature monitoring of the cells in the battery pack. This monitoring may be part of the battery management system integral to the battery pack. In this case, compliance with Section 11 is sufficient. If the monitoring is part of circuits or components located outside the battery pack, then those circuits or components shall be evaluated as part of the overall battery management system and shall be subjected to the risk assessment of Section 12.

24 Electrical Cables and Connectors Between the eBike and the Equipment

24.1 Cables that are used to connect the off board equipment to the eBike shall be permanently connected to the charger or connected to the charger with a connector that complies with 24.2. The cable shall comply with UL 62/CSA C22.2 No. 49 or UL 758/CSA C22.2 No. 210, and shall be suitably rated for the voltage and temperature it will be subjected to in the end use application and shall be sufficiently sized to conduct the anticipated current.

24.2 Connectors used to connect the off board equipment to the eBike or EPAC shall comply with UL 2251/CSA C22.2 No. 282, UL 486A-486B/CSA C22.2 No. 65, UL 1977/CSA C22.2 No. 182.3, or UL 2238/CSA C22.2 No. 182.3. The connectors shall be suitably rated for the application.

25 Supply Connections

25.1 For all equipment located off board the eBike and transferring power to the eBike, the connection to the supply source will be in accordance with the applicable standard for that equipment. See Chargers, Section 23.

PERFORMANCE

26 General

26.1 The performance tests are to be conducted on representative electrical systems of eBikes as appropriate.

26.2 Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).

26.3 Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.

26.4 Tests may be conducted on a test track, a bench or a test stand, which keeps the driven wheel free of the ground.

26.5 If conducted on a test track, the test track is to be level and the wind speed is to not exceed 3 m/s (6.7 mph).

26.6 In all cases, worst case conditions to simulate maximum normal load are to be selected.

26.7 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 device 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 test unit until temperatures are falling and have returned to within ambient temperatures.

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

26.9 Products that are operational after tests associated with the battery shall be subjected to a minimum of one cycle of charging and discharging in accordance with the manufacturer's specifications to determine that there is no fire, explosion, rupture, electrolyte leakage, or shock hazard associated with the stressed battery.

27 Input Test

27.1 The input current to 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 percent of the rated current value for the eBike 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.

28 Temperature Test

28.1 The Temperature test shall be conducted to determine whether or not the temperature sensitive safety critical components and temperature sensitive materials in the eBike components are being maintained within their temperature ratings and that temperatures on accessible surfaces, which may be contacted by the user, are within acceptable limits. Additionally, 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 eBike.

28.2 The test is to be performed using two methods. The battery charging circuit and battery are tested in accordance with 28.3 – 28.7, and the eBike system is tested in accordance with 28.8 – 28.9.

28.3 First, a fully discharged battery pack is to be conditioned within a chamber set to the upper limit charging temperature specifications of the eBike manufacturer. After thermal stabilization in the chamber, the battery pack is to be connected to a charging circuit input representative of anticipated maximum charging parameters provided by the specified charger. The battery pack shall then be subjected to maximum normal charging 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, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.

Exception No. 1: The battery pack with a maximum manufacturer’s recommended ambient temperature not exceeding 40°C (104°F) 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:

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

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 battery pack, with a maximum manufacturer's recommended ambient temperature not exceeding 40°C (104°F), 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).

28.4 While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged battery pack shall then be discharged in accordance with the manufacturer's specifications representative of maximum weight and operating conditions for loading down to the manufacturer's specified end of discharge condition while monitoring voltage and current on cells until the battery pack reaches its specified end of discharge voltage (EODV). Temperatures shall be monitored on temperature sensitive safety critical components including cells, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.

Exception No. 1: The battery pack with a maximum manufacturer's recommended ambient temperature not exceeding 40°C (104°F) 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:

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

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 battery pack, with a maximum manufacturer's recommended ambient temperature not exceeding 40°C (104°F), 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).

28.5 The charge and discharge cycles are then repeated for a total of 2 complete cycles of charge and discharge. The test is then repeated with the representative unit in a chamber set to the eBike system manufacturer's lowest specified operating ambient for 2 complete cycles of charge and discharge. If the battery pack will not operate at the lowest ambient rating, then a temperature as close as possible to the lower ambient rating which allows the battery pack to operate shall be used.

28.6 During the temperature test, the voltage and current during discharge and charging of the component cells is monitored to determine that they are not outside of the specified cell manufacturer's operating region.

28.7 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 28.1 and Table 28.2 for surface and component temperature limits.

28.8 The eBike shall be powered from a power source used to represent a battery pack. The eBike system is then operated at the maximum load on motors continuously until thermal stabilization. See 28.10.

28.9 Temperatures shall be monitored on all temperature sensitive components, enclosures, and user accessible surfaces. Temperatures measured on components shall not exceed their specifications. See Table 28.1 and Table 28.2 for surface and component temperature limits.

Table 28.1
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 (open motor)	105 (221)
• Insulation Class A (totally enclosed motor)	110 (230)
• Insulation Class B (open motor)	125 (257)
• Insulation Class B (totally enclosed motor)	130 (266)
• Insulation Class F (open motor)	150 (302)
• Insulation Class F (totally enclosed motor)	155 (311)

[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. Alternatively, the resistance method of the Temperature Test of UL 1004-1 is acceptable.

Table 28.2
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)
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)

Table 28.2 Continued on Next Page

Table 28.2 Continued

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)

[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.

28.10 A temperature is determined to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no increase greater than 2°C (4°F).

28.11 At the conclusion of this test, the battery pack tested under the battery method is placed back into the eBike system. Any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 29, (without humidity conditioning) or a Dielectric Strength Test, Section 30.

28.12 As a result of this test, in addition to temperatures remaining below the limits, there shall be no indication of fire, explosion, rupture, electrolyte leakage or electric shock.

29 Isolation Resistance Test

29.1 This test is intended to determine that insulation of the equipment provides adequate isolation of hazardous voltage circuits from accessible conductive parts and that the insulation is non-hygroscopic. The measured insulation resistance between the positive terminals and accessible parts of the equipment shall be at least 50,000 Ω.

29.2 Equipment with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts. If the accessible parts 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 30.4 and Figure 30.1.

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

29.4 The test shall be repeated on a representative unit subjected to humidity conditioning in accordance with Section 31. Measurements shall be made with the unit still in the chamber.

30 Dielectric Strength Test

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

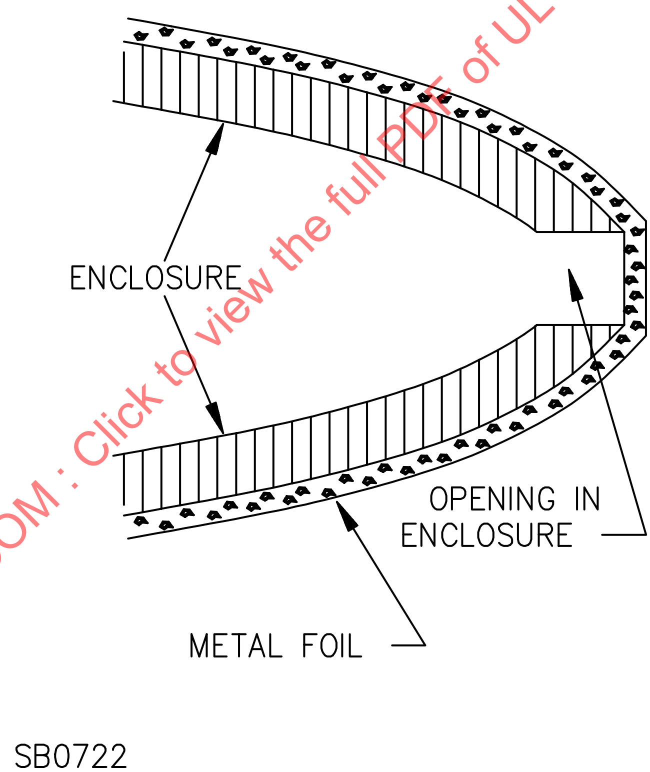
30.2 Circuits at voltages above 60 V dc or 30 Vrms ac (42.4 Vpeak ac) shall be subjected to a dielectric withstand voltage consisting of a dc potential of twice the rated dc voltage or twice the rated ac voltage times 1.414. Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.

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

30.4 If the accessible parts of the equipment 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



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

30.6 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.

31 Humidity Conditioning

31.1 A product shall comply with the requirements for the Dielectric Strength Test, Section 30, and the Isolation Resistance Test, Section 29, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).

31.2 To determine whether a unit complies with the requirement in 31.1, a representative unit is to be heated to a temperature just above 34°C (93°F) to reduce the risk of condensation of moisture during conditioning. The heated unit is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 31.1. Immediately following the conditioning, the unit is to be removed from the humidity chamber and tested as described in 31.1.

32 Abnormal Operations Tests

32.1 General

32.1.1 A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons when subjected to the tests specified in 32.2 – 32.10. Separate representative units are to be used for conducting these tests, unless requested otherwise by the manufacturer.

32.1.2 Following each test, any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 29, (without humidity conditioning) or a Dielectric Strength Test, Section 30.

32.1.3 A risk of fire, electric shock, or injury to persons exists when:

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

b) The insulation breaks down when tested in accordance with Section 30 or live parts are made accessible to the articulate probe in Figure 18.1;

c) Cracking, rupturing, or bursting of the battery case or cover, where such damage results in user contact with battery electrolyte, or electrolyte is allowed to leak outside the case or cover;

d) Explosion of the battery supply where such explosion results in a risk of injury to persons; or

e) There is a loss of protection controls associated with protecting the battery, and the battery is still allowed to charge or discharge.

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

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

32.1.6 A unit with a conductive enclosure shall have the enclosure of the unit connected directly to ground.

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

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

b) Opening of the intended branch circuit overcurrent protection device described in 32.1.5 – see 32.1.10; and

c) Opening of an internal fuse.

32.1.8 When the manually reset protector is a circuit breaker that complies with CSA C22.2 No. 5 / UL 489, it is to be operated for 3 cycles using the minimum resetting time and not faster than 10 cycles of operation per minute.

32.1.9 A manual reset protector that becomes inoperative in the open condition shall be operated between 10 cycles and 3 cycles.

32.1.10 With reference to 32.1.7(b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 46.3(i).

32.2 Overcharging test

32.2.1 This test is intended to evaluate the ability of the electrical system of the eBike to withstand an overcharge condition under a single fault in the charging control circuitry that could result in an overcharge condition. One representative system is to be tested for each fault condition applied. The same system can be used for more than one test if it remains functional after the fault is removed. For battery packs in accordance with 11.1(a) or 11.1(b), this test is not required.

32.2.2 A fully charged battery is to be discharged at a constant discharge rate of 0.2 times the manufacturer's rated capacity of the battery, or a higher discharge rate permitted by the manufacturer to the manufacturer's specified end-of-discharge voltage. The first representative system is then subjected to a constant current charging at the manufacturer's specified charging rate (i.e. based upon the maximum intended charger output current rate) 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. 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 that may result in the use of unspecified chargers shall not be considered as a reliable control to prevent an overcharging condition.

32.2.3 The test is to be continued until the voltage has reached 110 percent of the maximum specified voltage limit and/or monitored temperatures return to ambient or steady state conditions and an additional 2 hours has elapsed, or explosion/fire occurs. If the system 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 a 1-hour observation time prior to concluding the test and temperatures are to be monitored.

32.2.4 At the conclusion of the observation period, systems that contain hazardous operating voltages shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or an Isolation Resistance Test, Section 29, (without humidity conditioning).

32.2.5 If a protective device in the circuit operates, the test is repeated at 90 percent of the trip point of the protection device or at some percentage of the trip point that allows charging for at least 10 minutes. Temperatures shall be measured on the cell/module where temperatures may be highest for monitoring purposes.

32.2.6 As a result of the overcharge test, there shall be no indication of any noncompliant results as outlined in 32.1.

32.3 Component fault tests

32.3.1 A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:

a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded;

b) or electromagnetic radio frequency interference capacitors subjected to the Dielectric Strength Test across their terminals in accordance with Section 30; and

c) For resistors, transformers, inductors, and optical isolators.

32.4 Forced ventilation/blocked ventilation

32.4.1 A unit having forced ventilation is to be operated with the rotor of a blower motor or fan locked. For a unit having more than one blower motor or fan, the test is to be conducted with the rotor of each blower motor or fan locked, one at a time, unless agreeable to all for which all blower motors or fans shall be locked at the same time.

32.4.2 A unit having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 percent, then to be repeated under fully blocked condition.

32.5 Locked rotor motor test

32.5.1 This test is intended to evaluate a motor's ability to safely withstand a locked rotor condition, which may occur in the end use application. This test is waived if the motor and its locked rotor protection has already been evaluated as part of a motor and motor protector combination evaluation, in accordance with UL 1004-3 and CSA C22.2 No. 77, or UL 1004-7 and CSA C22.2 No. 77, or if relying on impedance protection in accordance with UL 1004-2 and CSA C22.2 No. 77, as applicable.

32.5.2 The motor is operated at the voltage used in the eBike application and with its rotor locked for 7 h or until steady conditions are established. The motor is to be tested while on the eBike and temperatures on windings are to be monitored. As an alternative, the motor can be tested outside of the eBike.

32.5.3 If the design or size of the motor prevents the measuring of temperatures on the windings, the test may be conducted with the motor removed from the eBike and instead of monitoring temperatures, the motor is to be supported on a surface covered with a single layer of tissue paper with the motor covered with a single layer of cheesecloth.

32.5.4 If the motor contains a hazardous voltage circuit, the motor shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 29, (without humidity conditioning).

32.5.5 If monitoring temperatures on windings during the locked rotor test, the temperatures on the windings shall not exceed the values noted in Table 32.1. If not monitoring temperatures on windings during the test, there shall be no sign of ignition of the tissue or cheesecloth at the conclusion of the test.

Table 32.1
Motor winding temperature limits during locked rotor

Thermal Class	Temperature Limits, °C (°F) Class A (105)	Class E (120)	Class B (130)	Class F (155)
Type of Protection:				
Protection by inherent or external impedance	150 (302)	165 (329)	175 (347)	200 (392)
Protection by any protective device that operates during the first hour	200 (392)	215 (419)	225 (437)	250 (482)
Protection by protective device:				
• maximum after first hour (automatic)	175 (347)	190 (374)	200 (392)	225 (437)
• maximum after first hour (thermal cutoff)	150 (302)	165 (329)	175 (347)	200 (392)
• arithmetic average during the 2nd hour and during the 72nd hour (automatic)	150 (302)	165 (329)	175 (347)	200 (392)

32.6 Running overload test

32.6.1 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 in accordance with UL 1004-3 and CSA C22.2 No. 77, or UL 1004-7 and CSA C22.2 No. 77, as applicable to the method of thermal protection.

32.6.2 The motor is to be tested while in the eBike and temperatures on windings are to be monitored. As an alternative, the motor can be tested outside the eBike.

32.6.3 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.

32.6.4 The motor winding temperatures are determined during each steady period and the maximum temperature recorded shall not exceed the value in Table 32.2.

Table 32.2
Motor winding temperature limits during overload

Thermal Class	Class A (105)	Class E (120)	Class B (130)	Class F (155)
Temperature Limit, °C (°F)	140 (284)	155 (311)	165 (329)	190 (374)

32.6.5 If the design or size of the motor prevents the measuring of temperature windings, the test may be conducted with the motor removed from the eBike and instead of monitoring temperatures, the motor is to be supported on a surface covered with a single layer of tissue paper with the motor is covered with a single layer of cheesecloth.

32.6.6 If the motor contains a hazardous voltage circuit, the motor shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or Isolation Resistance Test, Section 29, (without humidity conditioning).

32.6.7 If monitoring temperatures on windings during the overload test, the temperatures on the windings shall not exceed the values noted in Table 32.2. If not monitoring temperatures on windings during the test, there shall be no sign of ignition of the tissue or cheesecloth at the conclusion of the test.

32.7 Short circuit test

32.7.1 This test evaluates the ability of the battery pack to withstand a short circuit condition under a single fault in the discharge protection/control circuit. For battery packs in accordance with 11.1(a) or 11.1(b), this test is not required.

32.7.2 A fully charged representative battery pack is to be short-circuited by connecting the positive and negative terminals of the battery pack with a circuit load having a total resistance of less than or equal to 20 mohms.

32.7.3 Representative battery packs are to be subjected to a single fault across any protective device in the charging control circuit. Protective devices that have been determined reliable may remain in the circuit.

32.7.4 The representative battery pack shall be discharged until the battery pack has returned to ambient temperature or fire or explosion occurs. Temperatures shall be measured on the cell/module where temperatures may be highest for monitoring purposes.

32.7.5 If the electrical system of the eBike 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 a 1-hour observation time prior to concluding the test and temperatures are to be monitored.

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

32.7.7 At the conclusion of the test and after cooling to near ambient, representative battery packs that contain a hazardous operating voltage shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or an Isolation Resistance Test, Section 29, (without humidity conditioning).

32.7.8 As a result of the Short Circuit Test, there shall be no indication of any noncompliant results as outlined in 32.1.

32.8 Imbalanced charging test

32.8.1 This test is to determine whether or not the battery pack, with series connected cells, can maintain the cells within their specified operating parameters if it becomes imbalanced. For battery packs in compliance with 11.1(a) or 11.1(b), this test is not required.

32.8.2 A fully charged battery pack of an eBike 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 percent of its specified state of charge (SOC) to create an imbalanced condition prior to charging.

32.8.3 The battery pack shall then be charged in accordance with the manufacturer's specifications using the specified charger. The voltage of the partially charged cells shall be monitored during the charging to determine if its voltage limits are exceeded. If the battery pack 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 a 1-hour observation time prior to concluding the test and temperatures are to be monitored.

32.8.4 At the conclusion of the observation period, battery packs that contain hazardous operating voltages shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or an Isolation Resistance Test, Section 29 (without humidity conditioning).

32.8.5 As a result of the test, there shall be no indication of any noncompliant results as outlined in 32.1.

32.9 Shock test

32.9.1 This test is intended to determine whether or not the battery pack can withstand a mechanical shock that may occur when in use. For battery packs in compliance with 11.1(a) or 11.1(b), this test is not required.

32.9.2 The fully charged battery pack 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.

32.9.3 The battery pack is to be subjected to mechanical shock testing with parameters as shown in Table 32.3. The shocks are to be applied in all 6 spatial directions.

Exception: Battery packs found to comply with the mechanical shock testing parameters in accordance with CSA C22.2 No. 62133-2/UL 62133-2 need not comply with this requirement.

Table 32.3
Shock parameters

Maximum weight	Pulse shape	Acceleration	Duration	Number of shocks
≤ 12 kg	half-sinusoidal	50 g	11 ms	3 ⊥ directions
> 12 ≤ 25 kg	–	25 g	15 ms	3 ⊥ directions

32.9.4 If the electrical system of the device 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 a 1-hour observation time prior to concluding the test and temperatures are to be monitored.

32.9.5 At the conclusion of the observation period, devices that contain hazardous operating voltages shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or an Isolation Resistance Test, Section 29 (without humidity conditioning).

32.9.6 As a result of the test, there shall be no indication of any noncompliant results as outlined in 32.1.

32.10 Thermal cycling

32.10.1 This test determines the ability of the battery pack of the eBike to withstand exposure to rapidly changing environments such as when the eBike is entering or exiting a heated storage facility after being in a cold environment, changing temperatures during transport or storage outdoors, and the like, without evidence of damage that could lead to a hazardous event.

32.10.2 A fully charged battery shall be subjected to the thermal cycling in accordance with 32.10.3. For battery packs in compliance with 11.1(a) or 11.1(b), this test is not required.

32.10.3 For the test, the battery or battery system shall be placed in a chamber with ambient air cycling at the temperature extremes of the manufacturer's recommended ambient range. The transition period between exposure temperatures is to be 15 minutes or less. This swing of temperature variations may be performed either through the use of a fast-response chamber, or by moving the battery or battery system between two chambers at the two test temperatures. The battery or battery system shall remain at each temperature extreme for as long as required for the battery or battery system to reach a uniform temperature (±5°C) of the chamber temperature but no less than 6 hours. A total of five cycles (at the high and low temperature extremes) are to be performed.

32.10.4 If the battery pack is operational after the test, it shall be allowed to return to room ambient and then subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by a 1-hour observation time prior to concluding the test and temperatures are to be monitored.

32.10.5 At the conclusion of the observation period, battery or battery systems that contain hazardous operating voltages shall be subjected to a Dielectric Voltage Withstand Test, Section 30, or an Isolation Resistance Test, Section 29 (without humidity conditioning).

32.10.6 As a result of this test, there shall be no indication of any noncompliant results as outlined in 32.1.

33 Impact Test

33.1 unit acting as an enclosure shall be subjected to this test. The enclosure is to be subjected to an impact of 6.8 J (5 foot-pounds) on any surface that is exposed to a blow during normal use. This impact is to be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter and weighing 535 g (1.18 pounds), from a height of 1.29 m (51 inches) to produce the 6.8 J (5 foot-pound) impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 1.29 m (51 inches) to strike the surface.

33.2 A unit is to be subjected to the impact test described in 33.1 with or without any attachment specified by the manufacturer so as to result in the most severe test.

33.3 When the part under test is made of polymeric material, the impact test is to be first conducted on a representative unit or units in the as-received condition. The test is then to be repeated on a different unit or units that have been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10°C (18°F) higher than the maximum operating temperature of the material, and not less than 70°C (158°F). While being conditioned, a part is to be supported in the same manner in which it is supported on the unit.

33.4 Upon being removed from the oven mentioned in 33.3 and before being subjected to the impact test, no units shall show signs of cracking or other deleterious effects from the oven conditioning, and no unit shall be distorted so as to result in a risk of injury to persons.

33.5 After the impact test, any openings resulting from the test shall be evaluated for access to hazardous voltage parts, hazardous energy parts, hazardous moving parts and cells using the articulate probe shown in Figure 18.1.

34 Mold Stress

34.1 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.

34.2 The representative units are to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature observed on the part during the Temperature Test, Section 28, whichever is higher. The units are to remain in the oven for 7 hours.

34.3 To inhibit hazards from overheating energized cells, units shall be fully discharged prior to conditioning.

34.4 After careful removal from the oven, the units shall be allowed to cool to room temperature and then examined. After the examination, the units shall be subjected to a Dielectric Strength Test, Section 30, or Isolation Resistance Test, Section 29, (without humidity conditioning).

34.5 There shall be no damage of the eBike system enclosure that would allow hazardous voltage parts, hazardous energy parts, hazardous moving parts and cells to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in UL/ULC 2271, and the articulate probe shown in Figure 18.1.

35 Flexing Test

35.1 After wiring has been subjected to flexing as described in 35.2, the unit shall be subjected to the Dielectric Voltage-Withstand Test in Section 30 and the wiring is to be examined for damage to determine where any conductors are broken or where individual strands have penetrated the insulation.

35.2 Wiring that is subjected to movement at times other than installation and servicing is to be tested by cycling the moving part through the maximum travel intended for the construction. The duration of the test is to be 500 cycles.

36 Ingress Protection Tests

36.1 This test is intended to evaluate the ability of the eBike to withstand potential water exposure in its intended use and is conducted in accordance with the test method outlined in 36.2.

36.2 The enclosure shall be subjected to a water exposure test in accordance with the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, Tests for Protection Against Water Indicated by the Second Characteristic Numeral 4 (IPX4), unless the equipment is provided with a higher IP Code rating by the manufacturer, in which case the equipment shall be tested in accordance with its rating. During this test, the enclosure is to be mounted in the manner intended when installed on the eBike. If multiple mounting orientations are allowed, then each one is to be tested individually.

36.3 If the equipment 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 in accordance with 26.8.

36.4 At the conclusion of the observation period, the units shall be subjected to a Dielectric Strength Test, Section 30, or an Isolation Resistance Test, Section 29, (without humidity conditioning).

36.5 As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.