

Subject 2849

August 24, 2018

SUMMARY OF TOPICS

The following is being proposed:

1. Proposed First Edition of the Standard for Electric Bicycles, Electrically Power Assisted Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles, UL 2849

STP BALLOTS AND ALL COMMENTS DUE: October 23, 2018

UL's goal is to have no interest category comprise more than one-third of the STP membership balance. UL is looking for participants in all categories except for Producers. Definitions for these interest categories are available on the Standards STP Internet site:

<http://ulstandards.ul.com/develop-standards/participation/interest-categories/>

If you are interested in applying for STP 2849 membership or are aware of potential candidates for this STP, please contact the STP Project Manager, patricia.a.sena@ul.com.

1. The Proposed First Edition of the Standard for Electric Bicycles, Electrically Power Assisted Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles, UL 2849

RATIONALE

Proposal submitted by: Joe Bablo, UL LLC.

The Proposed First Edition of the Standard for Electric Bicycles, Electrically Power Assisted Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles is being proposed as a Binational Standard for Canada and the United States. The requirements are largely adopted from the Third Issue of the Outline of Investigation for Electric Bicycles, Electrically Power Assisted Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles, UL 2849.

The Proposed Standard covers the electrical systems of eBikes, electric scooters, and electric motorcycles. EBikes include both Pedalec (pedal assist) and non-Pedalec types. Electric scooters and electric motorcycles are intended for over the road use. The electrical systems include onboard electrical systems, off board charging systems, and vehicle charging systems of eBikes, electric scooters, and electric motorcycles.

Benefits of a Joint Standard for US and Canada

Publishing UL 2849 as a binational US/Canadian Standard is expected to provide the following benefits:

- Greater consistency in safety of products for consumers across both countries and jurisdictions.

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- A more efficient maintenance of the standard using a single standards development process. The process uses only one standards technical committee including stakeholder representatives from both countries and will result in one document rather than two that need to be updated moving forward. This can happen quicker and result in requirements across countries remaining harmonized as technological and safety advances are made over time. This also eliminates the risk of de-harmonization over time and eliminates cost, effort and resources required to maintain two separate standards. Industry will only need to participate once rather than multiple times to maintain consistent requirements.
- Clearer guidance for manufacturers using a single Standard. One document can be used to design and evaluate products for multiple countries and across jurisdictions. This can save time and money, and can reduce potential trade barriers and enable freer flow of goods to multiple countries.
- Simpler product evaluation, compared to multiple standards.

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Annex B – French Translations (Informative)

B1 French Translations 76

PROPOSAL

INTRODUCTION

1 Scope

1.1 This Standard covers electrical systems of devices designated as eBikes, electric scooters, and electric motorcycles. EBikes include both Pedalec (pedal assist) and non-Pedalec types. Electric scooters and electric motorcycles are intended for over the road use.

1.2 Electrical systems as referenced in 1.1 include onboard electrical systems (see 1.3), off board charging systems (see 1.4), and vehicle charging systems (see 1.5) of eBikes, electric scooters, and electric motorcycles.

1.3 On board electrical systems include any electrical component or system that is located on board the device. This may include motors, motor controllers, interface/controls, battery packs, charging circuitry (which may include on board chargers), and other components or systems.

1.4 Off Board Charging Systems include individual chargers for charging batteries that are removed from the device during charging, individual chargers for charging batteries that are in place on the device during charging, supply equipment for providing AC power to the device with an on board charger, or charging systems that consist of multiple charging points such as battery swap type systems or charging rack systems.

1.5 Vehicle Charging Systems include both the on board electrical system of the device and the off board charging system.

1.6 This Standard does not cover any other electrically powered device other than eBikes, electric scooters, and electric motorcycles, as defined within this document. Electrically powered scooters that are not intended for road use and are intended for personal mobility are covered under the Standard for Electrical Systems for Personal E-Mobility Devices, CAN/UL 2272.

1.7 Requirements contained in 16 CFR Part 1512, Requirements for Bicycles, apply to eBikes. Verification of compliance with 16 CFR Part 1512 is outside the scope of this Standard.

1.8 Federal Motor Vehicle Safety Standards (FMVSS) outlined under 49 CFR Chapter V and Canadian Motor Vehicle Safety Standards (CMVSS) outlined under Consolidated Regulations of Canada, apply to electric scooters and electric motorcycles. Compliance with these FMVSS and CMVSS documents is outside the scope of this Standard.

2 Components

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

4 Undated References

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

5 Definitions

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

5.2 BATTERY SWAP STATION (SWAP STATION) – A product that is permanently connected in a public location and used to allow the user to swap a battery from their device with a fully charged battery from the swap station. The swap station will then charge the depleted battery prior to releasing it back into public use.

5.3 CHARGER – An off board or on board device that converts grid power to DC power for charging the on board battery.

5.4 CHARGING RACK – A product that is permanently connected in a public location and used to allow for public bike sharing programs for electric bicycles. The charging rack will lock and secure the eBikes in place when not in use and will charge the eBike battery while the eBike is locked in the rack.

5.5 eBIKE – A two or three wheeled electrical/mechanical device provided with pedals that includes an electric motor to either assist the rider when pedaling (pedalec versions) or provide motive power to the wheels when the rider is not pedaling.

5.6 ELECTRIC MOTORCYCLE – A two or three wheeled electric device that includes a seat for the rider. The rider is intended to straddle the device while riding. No pedals are included and the throttle controls the propulsion action. These device types are suitable for over the road use.

5.7 ELECTRIC SCOOTER – A two- or three-wheeled electric device that includes a flat section or footrests for the riders feet, a seat for the rider, and a pass-through type design for the footrest portion which is located lower than the seat. No pedals, either functional or decorative, are included and the throttle controls the propulsion action. These device types are suitable for over the road use.

5.8 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.

5.9 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.

5.10 INTERACTIVE KIOSK – An electronic terminal with custom software to allow user access to information, payment methods, and service selection aspects among other items.

5.11 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.

5.12 LOW VOLTAGE LIMITED ENERGY (LVLE) – A circuit involving a potential of not more than 30 volts alternating current (42.4 volts peak) supplied by a battery or by a standard Class 2 transformer or other suitable transforming device, or by a suitable combination of transformer and fixed impedance having output characteristics in compliance with what is required for a Class 2 transformer. A circuit obtained by connecting resistance in series with a line voltage supply circuit as a means of limiting the voltage and current is not considered to be a low voltage circuit.

5.13 MOTOR, EMERGENCY CONTROL OF – A system that allows the rider to disengage or shut-down the electric motor assist by completing one simple action that is accessible to the rider while the device is in motion.

5.14 OFF BOARD CHARGING SYSTEM – Off board device(s) that are used to charge the device's battery either when the battery remains on the device or the battery is removed from the device.

5.15 ON BOARD ELECTRICAL SYSTEM – All electrical components located on the device including, but not limited to, the motor, motor controller, interface/controls, battery pack and charging circuitry (which may include an on board charger).

5.16 PEDALEC – A version of an eBike, equipped with pedals and an auxiliary electric motor, which cannot be propelled exclusively by means of this auxiliary electric motor, except in the start-up assistance mode. The motor shall disengage its assist function when the rider stops pedaling, a maximum predetermined speed is reached, or when the user applies the brakes (if the brakes are provided with cutoff functions). Also referred to as EPAC.

5.17 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any exposed live part of a product or system if the available open-circuit potential is higher than 42.4 volts peak or 60 V dc and the available current through a 1500-ohm resistance is more than 5 milliamperes.

5.18 VEHICLE CHARGING SYSTEM – The combination of the on board electrical system (without an on board charger) and an off board charger or the connection to the power source.

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.

CSA Group Standards

CSA C22.2 No. 0.2

Insulation Coordination

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. 7

Motors With Inherent Overheating Protection

CSA C22.2 No. 18.1

Metallic Outlet Boxes

CSA C22.2 No. 18.3

Conduit, Tubing and Cable Fittings

CSA C22.2 No. 21

Cord Sets and Power Supply Cords

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. 100

Motors and Generators

CSA C22.2 No. 107.1

Power Supplies

CSA C22.2 No. 182.3

Special Use Attachment Plugs, Receptacles and Connectors

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CSA C22.2 No. 223

Power Supplies With Extra Low Voltage Class 2 Outputs - General Instruction No. 1

CSA C22.2 No. 248

Low Voltage Fuses

CSA C22.2 No. 280

Electric Vehicle Supply Equipment

CSA C22.2 No. 281.1

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements

CSA C22.2 No. 281.2

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems

CSA C22.2 No. 282

Plugs, Receptacles, and Couplers for Electric Vehicles

CSA C22.2 No. 4248

Fuseholders

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

IEC Standards

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 Standards

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

SAE Standards

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 and UL/ULC Standards**

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 101

Standard for Leakage Current for Appliances

UL 248

Low Voltage Fuses

UL 486A-486B

Wire Connectors

UL 489

Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures

UL 514A

Metallic Outlet Boxes

UL 514B

Conduit, Tubing and Cable Fittings

UL 635

Insulating Bushings

UL 746B

Polymeric Materials - Long Term Property Evaluations

UL 746C

Polymeric Materials - Use in Electrical Equipment Evaluations

UL 796

Electrical Printed-Wiring Boards

UL 817

Cord Sets and Power Supply Cords

UL 840

Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment

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

UL 1998
Software in Programmable Components

UL 2231-1
Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements

UL 2231-2
Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems

UL 2097
Double Insulation Systems for Use in Electronic Equipment

UL 2202
Electric Vehicle (EV) Charging System Equipment

UL 2251
Plugs, Receptacles, and Couplers for Electric Vehicles

UL 2271/CAN/ULC-S2271
Batteries for Use in Light Electric Vehicle (LEV) Applications

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

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UL 2594
Electric Vehicle Supply Equipment

UL 4248
Fuseholders

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

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

United States Department of Defense Military Standards

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

CONSTRUCTION

General

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 system or vehicle.

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. This would be discussed in the specific requirements for the product type.

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

7.4 Electric scooters and electric motorcycles shall not be provided with pedals, functional or otherwise, and are provided with a seat for the rider to sit on during operation. There is no maximum speed regulated for these devices. Operation is controlled through the throttle and the user is not required to act in any other manner to propel the vehicle other than manipulation of the throttle control.

7.5 For portions of the electrical system located on the vehicle, all equipment shall be evaluated as outdoor use equipment. Outdoor use equipment shall comply with all the requirements in this Standard as applicable to outdoor use equipment at a maximum altitude of 2000 m (6562 feet) and over an ambient temperature range of -10°C to 50°C (14°C to 122°C) and be subjected to ingress protection tests. For equipment located off board the vehicle, such as chargers or supply equipment, the equipment may be for indoor or outdoor use. Outdoor use is assumed unless the equipment is marked in accordance with 63.3. Indoor use only equipment shall comply with all the requirements in this Standard as applicable to indoor use equipment operating at a maximum altitude of 2000 m and over an ambient temperature range of 0°C to 40°C (32°F to 104°F) but ingress protection for water is not applicable.

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7.6 For off board equipment connected to a source of supply, the equipment may be permanently connected or cord connected to the supply source. Permanently connected equipment is fixed in place and subjected to the applicable indoor or outdoor use requirements indicated in this Standard. Cord connected equipment is considered movable, but shall be designated as indoor use only, or shall be evaluated to the outdoor use requirements in this Standard.

8 Power Levels

8.1 General

8.1.1 Regardless of product type, a specific power level will be associated with the device. This will require rated voltage and current levels to be assigned, but can also include voltages or currents that are available within the device 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 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 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.

8.3 Low Voltage Limited Energy Circuits

8.3.1 A Low-Voltage Limited Energy Circuit is considered to be a circuit involving an alternating current voltage of not more than 30 volts rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

- a) Class 2 transformer or Class 2 Power Unit,
- b) A combination of a battery source or an isolated transformer secondary winding and one or more resistors, or a regulating network complying with 8.3.3, 8.3.4, and 8.3.6, or
- c) A battery with output current limited by overcurrent protection complying with Section 19 in accordance with 8.3.5 and Table 8.1.

Table 8.1
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Current (amperes)
20 or less	5
More than 20 but not greater than 60	100/V ^a
^a V is the maximum output voltage, regardless of the load, with the primary energized.	

8.3.2 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.

8.3.3 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.

8.3.4 With reference to the voltage limit specified in 8.3.1, measurement is to be made with the product connected to the intended source of supply and with all loading circuits disconnected.

8.3.5 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.

8.3.6 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.

9 Combination of Battery/BMS and Charger

9.1 The battery/BMS is used to control battery charging and is reliant on specific reactions of the charger to maintain safe operation during charging. Tests in this Standard may have different outcomes using different chargers with the battery/BMS. Therefore, the combination of the charger and the battery/BMS is critical to the safety of the system and that combination shall be evaluated together.

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

10 User Protection While Charging

10.1 General

10.1.1 Charging of the battery may occur while the battery is installed on the vehicle, with the battery removed from the vehicle, or both options may apply based on user preference. If the battery is only intended to be charged when it is removed from the vehicle, 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 vehicle, the battery shall be considered to be charged both on board and off board the vehicle.

10.1.2 If the battery is intended to be charged while on the vehicle 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 vehicle, 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 vehicle

10.2.1 Charging of the battery on a vehicle 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 vehicle are protected and monitored during charging to prevent a shock hazard due to the charging energy supplied to the vehicle. The personnel protection system supplied shall be as indicated in 10.2.2 or 10.2.3.

10.2.2 For vehicle charging system equipment where the specifics of the installation of the on board electrical system is unknown, or is not part of the evaluation, the vehicle charging system shall be provided with a system of protection in accordance with the requirements in the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, UL 2231-1/CSA C22.2 No. 281.1 and the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems, UL 2231-2/CSA C22.2 No. 281.2.

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

10.2.4 With reference to 10.2.3, products utilizing a system of protection based on protective grounding shall comply with the requirements in 10.2.5 and products utilizing a system of protection based on double insulation shall comply with the requirements in 10.2.6.

10.2.5 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.

10.2.6 A system of double insulation provided to protect the user shall be in accordance with the requirements in the Reference Standard for Double Insulation Systems for Use in Electronic Equipment, UL 2097.

11 Battery Packs

11.1 Battery packs shall be provided with an appropriate Battery Management System (BMS), and shall be designed to safely withstand anticipated abuse conditions for the vehicle involved. The battery management system shall comply with Safety Circuits and Safety Analysis, Section 12, as applicable. A battery pack used in devices covered by this Standard shall comply with one of the following:

- a) The Standard for Batteries for Use in Electric Vehicles, UL 2580 and CAN/ULC-S2580;
- b) The Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271 and CAN/ULC-S2271; or
- c) The Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes - Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications, UL 62133 and CSA C22.2 No. 62133. See also 11.2.

11.2 A battery pack in accordance with 11.1 (c) is additionally required to comply with the requirements in Overcharging Test, Section 45.2; Short Circuit Test, Section 45.7; Imbalanced Charging Test, Section 45.8; Shock Test, Section 45.9; Vibration Test (battery method), Section 53.2; and Thermal Cycling Test, Section 45.10.

12 Safety Circuits and Safety Analysis

12.1 The system's protective circuits shall undergo a safety analysis to verify that all potential hazards associated with the design are addressed in this evaluation. A circuit is defined as a protective circuit if it contains a circuit or a component that is considered critical for mitigating a fire, shock, or explosion hazard in accordance with this Standard.

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

12.3 Protection circuits used to monitor operational parameters, such as maximum assist speed, cutoff assistance due to braking, 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 and through the tests in this Standard.

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

- a) The Standard for Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FMEA), IEC 60812;
- b) The Standard for Fault Tree Analysis (FTA), IEC 61025;
- c) The Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), SAE J1739; and
- d) The Procedures for Performing a Failure Mode, Effects, and Criticality Analysis, MIL-STD-1629A.

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

12.6 When conducting the analysis of 12.4, active devices shall not be relied upon for critical safety unless:

- a) They are provided with a redundant passive protection device;
- b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection;
- c) They are determined to fail safe upon loss of power to the active circuit; or
- d) They are part of a protective circuit that has been shown to comply with an appropriate Functional Safety standard listed in 12.7, with a safety level defined by a corresponding hazard and risk analysis.

12.7 Devices relied upon for critical safety as noted in 12.4 shall be tested for functionality in the relevant configuration and environment, in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this Standard. Functional safety criteria can be found in one of the following standards as appropriate to the design of the electronic and software protection scheme:

- a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, and the Standard for Software in Programmable Components, UL 1998, and Safety functions incorporating electronic technology, CSA C22.2 No. 0.8;
- b) The Standard for Automatic Electrical Controls for Household and Similar Use - Part 1: General Requirements, UL 60730-1 and Automatic Electric Controls – Part 1: General Requirements, CSA C22.2 E60730-1;

- c) The Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 1: General Requirements, IEC 61508-1, and all parts; and
- d) The Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 1: General Principles for Design, ISO 13849-1, and the Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 2: Validation, ISO 13849-2.

Other functional safety standards that provide equivalent analysis methods, assessment, and functional safety coordination may be used.

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 vehicle 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 The 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.

13.1.2 A device shall be provided with one or more enclosures that house all live parts that are considered hazardous. The enclosure shall protect the various parts of the device against mechanical damage from external forces. 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.

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 the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, Path III, and Evaluation of Properties of Polymeric Materials, 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 the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17.

13.2.1.3 The following factors in (a) - (e) 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) - (e) below may be determined by the tests of this Standard.

- a) Resistance to Impact;
- b) Crush Resistance;
- c) Abnormal Operations;
- d) Severe Conditions; and
- e) Mold Stress Relief Distortion.

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 the Standard for Polymeric Materials - Long Term Property Evaluations, UL 746B, and Evaluation of Properties of Polymeric Materials, 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 the Material Property Considerations in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, 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 The outdoor use enclosure materials intended to be directly exposed to sunlight and rain in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, 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 the Standard for Enclosures for Electrical Equipment, Environmental Considerations, 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 Any hazardous live parts are required to be enclosed. The enclosure that is used shall be subjected to the Impact Test, Section 46, as applicable.

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 the Standard for Degrees of Protection Provided by Enclosures (IP Code), 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 Figure 1 of the Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications, UL 2271/CAN/ULC-S2271, applied with a force of 10 N $\pm$ 10 percent.

13.5.2 Openings in an outdoor use 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 the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, with a minimum rating of IPX4 and resistant to hazards associated with partial immersion. Compliance is determined by the Ingress Protection Tests in Section 49.

14 Mounting

14.1 Components that are intended to be mounted on a vehicle shall be securely mounted to the vehicle such that they are not capable of moving and straining connections, allowing access to hazardous circuits, or increasing the risk of shock or fire. Parts shall not fall from their mounting means due to the normal vibration associated with the operation of the vehicle.

14.2 Components mounted on the vehicle shall be subjected to the Vibration Test, Section 53.

15 Printed Wiring Boards

15.1 A printed-circuit board shall comply with the requirements in the Standard for Electrical Printed-Wiring Boards, 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 vehicle electrical system at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts). 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 Table 16.1 or the spacings requirements outlined in the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, in Clearances, Creepage Distances and Distances Through Insulation.

16.3 As an alternative to the spacing requirements in 16.2, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment, UL 840, and Insulation Coordination, 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 the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, 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 the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, 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 device passes the Dielectric Strength Test, Section 41, and the Isolation Resistance Test, Section 40. 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, except magnesium shall not be used for enclosure materials.