JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL/ULC 2271:2023

STANDARD FOR SAFETY

Batteries for Use In Light Electric Vehicle (LEV) Applications

ANSI/UL 2271-2023

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Batteries for Use In Light Electric Vehicle (LEV) Applications, ANSI/CAN/UL/ULC 2271

Third Edition, Dated September 14, 2023

Summary of Topics

This new edition of ANSI/CAN/UL/ULC 2271, Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications, dated September 14, 2023 includes the following changes:

– Modification of the normal operation conditions and cycle number during Temperature Test; 5.2, 33.1, and Table 33.1

– Clarification of the scope to better distinguish what is covered under UL/ULC 2271 versus UL/ULC 2580; 1.1, 1.4, 5.2, 6.1, 6.2, 6.14, 6.25, 6.29, 6.32, 6.40, 16.2, 16.3, and 16.8

– Updates to Functional Safety criteria; 6.34, 6.35, 6.36 and Section 15

– Additional guidance on protection of corrosion between dissimilar metals; 5.2, 8.1, 8.2, 8.4, Annex B, B1, and Table B.1

– Addition of requirements for when repurposed batteries are used; 5.2, Section 16, 16.8, Section 46, Annex C, and Table C.1

– Addition of a High Rate Charge Test that evaluates the safety when charging at a rate higher than the specified maximum level, Table 18.1, Section 21, 21.2, Table 21.1, and Section 24

– Addition of the Overload Under Discharge Test to replace the "soft short" in the Short Circuit Test; 6.32, Table 18.1, 21.1, 21.2 and Section 26

– Addition of a Single Cell Failure Design Tolerance Test for large size batteries; Table 18.1 section Table 21.1 and Section 45.

– Replaced reference to UL 60950-1 with UL 62368-1 throughout the Standard.

– Replaced reference to ISO 12405-1 with ISO 6469-1 throughout the Standard.

– Corrections to Manufacturing and Production Line Testing and inclusion of a 100% check on active controls relied upon for safety; 17.2, 17.4.

– Addition of a normal operation limit check in Overcharge and Overdischarge Test; 23.3, 23.6, 27.2 and 27.5

– Addition of a grounding continuity test; Section 14 and Section 32

– Editorial revisions throughout the Standard.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated April 7, 2023 and July 14, 2023.

ANSI/UL 2271-2023

SEPTEMBER 14, 2023

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ANSI/CAN/UL/ULC 2271:2023

Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications

First Edition – December, 2013
Second Edition – September, 2018

Third Edition

September 14, 2023

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

The most recent designation of ANSI/UL 2271 as an American National Standard (ANSI) occurred on September 14, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

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

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Preface

This is the Third Edition of ANSI/CAN/UL/ULC 2271, Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications.

ULSE is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO). ULC Standards is accredited by 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/ULC 2271 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.

Annex B, and Annex C are identified as Normative, as such, form mandatory parts of this Standard.

Annexes A and C are identified as Informative for the United States.

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.

This joint American National Standard and National Standard of Canada is based on, and now supersedes, the Second Edition of UL/ULC 2271.

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

This Edition of the Standard has been formally approved by the Technical Committee (TC) for Batteries for Use in Electric Vehicles, TC 2580.

This list represents the TC 2580 membership when the final text in this Standard was balloted. Since that time, changes in the membership may have occurred.

TC 2580 Membership

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Xu, Hongbin	Guangzhou MCM Certification and Testing Co Ltd	Testing and Standards	China
Yu, Kihoon	SK On Co Ltd / SK Battery America Inc	Producer	Korea
Yun, Yonghee	Samsung SDI	Producer	Korea
Yunzheng, Zhu	ZHEJIANG LAB/Intelligent Robot Research Center	General	China

International Classification for Standards (ICS): 29.220; 43.120

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This Standard is intended to be used for conformity assessment.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover electrical energy storage assemblies (EESAs) such as battery packs and combination battery pack-electrochemical capacitor assemblies and the subassembly/modules that make up these assemblies for use in light electric-powered vehicles (LEVs) as defined in this Standard. This Standard also covers a battery management system (BMS) that provides protection and control for the EESA.

1.2 This Standard does not evaluate the performance or reliability of these devices.

1.3 This Standard does not include requirements for the evaluation of EESAs intended for use in electric vehicles, such as on-road passenger vehicles and motorcycles intended for use on public roadways including highways, and starter batteries and heavy duty off road vehicles such as battery powered ride-on industrial trucks, earth moving or construction equipment, which are covered under the Standard for Batteries for Use in Electric Vehicles, UL/ULC 2580.

1.4 This Standard does not include requirements for evaluation of EESAs intended for use in stationary and motive auxiliary power applications, which are covered under the Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications, UL 1973.

1.5 These requirements do not cover equipment for use in hazardous locations as defined in the National Electrical Code, NFPA 70.

2 Components

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

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

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

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

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

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

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

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

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

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

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

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information. The values given in SI (metric) units shall be normative.

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 Referenced Publications

5.1 Throughout this Standard, the CSA and ULC standard references apply to products intended for use in Canada, while the UL standard references apply to products intended for use in the United States. Combined references are commonly separated by a slash (" / ").

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

ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*

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

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

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

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

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

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

IEC 60068-2-30, *Environmental Testing – Part 2-30: Tests – Test Db: Damp Heat, Cyclic (12 h + 12 h Cycle)*

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

IEC 60417, *Graphical Symbols for Use on Equipment*

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

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

IEC 61025, *Fault Tree Analysis (FTA)*

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

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

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

ISO 9227, *Corrosion Tests in Artificial Atmospheres – Salt Spray Test*

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*

ISO 26262-1, *Road Vehicles – Functional Safety (all parts)*

MIL-STD-1629A, *The 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)*

SAE J2464, *Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*

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

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

UL 546, *Conductor Termination Compounds*

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

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

UL 810A, *Electrochemical Capacitors*

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

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

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

UL 1974, *Évaluation pour la transformation des batteries*

UL 1989, *Standby Batteries*

UL 1998, *Software in Programmable Components*

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

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

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

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

6 Glossary

6.1 BATTERY MANAGEMENT SYSTEM (BMS) – A battery control circuit with active protection devices that monitors and maintains the cells within their specified operating region; and which prevents overcharge, overcurrent, overtemperature, under-temperature and overdischarge conditions of the cells.

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

6.3 CASING – The container that directly encloses and confines the electrolyte, and electrodes of a cell or electrochemical capacitor.

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

6.5 CELL BANK – One or more cells connected in parallel.

6.6 CELL STRING – One or more cells connected in series.

6.7 CHARGING – The application of electric current to battery or capacitor terminals, which results in a Faradic reaction that takes place within the battery that leads to stored electro-chemical energy or in the case of the capacitor, due to electrical charge being stored without a chemical reaction taking place. For light electric vehicle applications, charging of the EESA can occur through one or more of the following methods:

a) Regenerative braking which utilizes energy from regenerative brakes.

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

c) On board charging which utilizes a charger on the vehicle to convert the ac mains supply to dc for charging.

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

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

6.10 DUT – Device under test.

6.11 ELECTRIC ENERGY STORAGE ASSEMBLY (EESA) – A battery pack, electrochemical capacitor pack or combination battery/electrochemical capacitor pack that provides electric energy for electric vehicle motive power. This assembly can include the cooling and ventilation systems and battery management systems.

6.12 ELECTRIC MOTORCYCLE – An electric motor vehicle having a seat or saddle for the use of the rider and designed to travel on not more than three wheels in contact with the ground, but excluding a tractor. An electric motorcycle is intended for use on public roadways including highways.

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

6.14 ELECTRIC SCOOTER - A device weighing less than one hundred pounds that:

a) Has handlebars, a floorboard or a seat that can be stood or sat upon by the operator, and an electric motor;

b) Can be powered by the electric motor and/or human power; and

c) Has a maximum speed of no more than 20 mph on a paved level surface when powered solely by the electric motor.

6.15 ELECTROCHEMICAL CAPACITOR – An electric energy storage device where electrical charge is typically stored as a result of non-Faradaic reactions at the electrodes. (A subset of electrochemical capacitors referred to as an "asymmetric" type have non-Faradaic reactions at one electrode and Faradaic reactions at the other electrode.) The porous surface of the electrodes increases the surface area for holding charge resulting in much larger capacitance and energy density. Electrochemical capacitors differ from common electrolytic capacitors in that they employ a liquid rather than a solid dielectric with charge occurring at the liquid-solid interface of the electrodes when a potential is applied. Some other common names for an electrochemical capacitor are "double layer capacitor", "ultracapacitor", "electrochemical double layer capacitor" and "super capacitor".

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

6.17 ENCLOSURE – The outer cover of the EESA that provides protection to its contents.

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

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

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

6.21 FULLY CHARGED – An EESA which has been charged per the manufacturer's specifications to it full state of charge (SOC).

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

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

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

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

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

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

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

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

6.25 LIGHT ELECTRIC VEHICLE (LEV) – A light duty on-road or off-road vehicle that uses electricity as its source of energy for motive power, which is not considered suitable for use on highway systems. The following are examples of LEVs:

a) Electric bicycles;

b) Electric scooters as defined in 6.14;

c) Electric wheel chairs;

d) Golf carts;

e) All-terrain vehicles;

f) Non-ride-on industrial material handling equipment;

g) Unmanned aerial vehicles (UAVs);

h) Ride-on floor care machines; and

j) Personal e-mobility devices.

NOTE: A LEV is not limited to the examples given above. Any EESA used in an LEV that meets the above definition can be covered by this Standard unless there is a dedicated LEV standard specifying the requirements for its EESA.

6.26 MODULE – A subassembly consisting of a group of cells or cells and electrochemical capacitors connected together either in a series (cell string) and/or parallel configuration (cell bank) with or without protective devices and monitoring circuitry. A module is a component of a pack.

6.27 MONOBLOC BATTERY – A multi-cell battery design that contains a common pressure vessel construction, a single vent line assembly, and shared hardware.

6.28 MOSOC – Maximum operating state of charge. See 18.1.

6.29 MOTORCYCLE – A motor vehicle having a seat or saddle for the use of the rider and designed to travel on not more than three wheels in contact with the ground, but excluding a tractor. A motorcycle is intended for use on public roadways including highways.

6.30 NORMAL OPERATING REGION – That region of voltage, current and temperature within which a cell or electrochemical capacitor can be safely charged and discharged repetitively throughout its anticipated life. The manufacturer specifies these values, which are then used in the safety evaluation of the device and may vary as the device ages. The normal operating regions will include the following parameters for charging and discharging as specified by the manufacturer:

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

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

c) END OF DISCHARGE VOLTAGE – Refer to 6.18.

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

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

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

6.31 PACK – General term for either a battery pack or capacitor pack as defined below. A pack can also consist of a hybrid systems containing both batteries and capacitors.

a) PACK, BATTERY – Batteries that are ready for use in an LEV, contained in a protective enclosure, with protective devices, with a battery management system, and monitoring circuitry, with or without cooling systems.

b) PACK, CAPACITOR – Electrochemical capacitors that are ready for use in an LEV, contained in a protective enclosure, with or without protective devices, cooling systems, and monitoring circuitry.

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

6.33 PRIMARY OVERCURRENT PROTECTION – The safety device or circuit that is part of the safety control system intended to prevent an overcurrent hazard, and which typically operates before any secondary or supplemental protection operates, examples are fuses or circuit breakers.

6.34 PRIMARY SAFETY PROTECTION – The safety device or circuit that is part of the safety control system intended to prevent a hazard, and which operates before any secondary or supplemental protection operates.

6.35 PROTECTIVE DEVICES, ACTIVE – Devices provided to prevent hazardous conditions that require electrical energy in order to operate. An example of an active control would be a battery management system (BMS) that has monitoring and control functions.

6.36 PROTECTIVE DEVICES, PASSIVE – Devices provided to prevent hazardous conditions that do not require electrical energy in order to operate. Examples of passive protective devices would be fuses, thermal snap switches.

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

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

6.39 SAFETY CRITICAL CIRCUITS/COMPONENTS – Those circuits or discrete components that are relied upon for safety as identified in the safety analysis of 15.1.2.

6.40 SODIUM ION CELLS – Cells that are similar in construction to lithium ion cells except they utilize sodium as the ion of transport with a positive electrode consisting of a sodium compound, and carbon or similar type anode with an aqueous or non-aqueous electrolyte and with a sodium compound salt dissolved in the electrolyte.

NOTE: Examples of sodium ion cells are Prussian Blue cells or transition metal layered oxide cells.

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

CONSTRUCTION

7 Non-Metallic Materials

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

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

Exception: The enclosure may alternatively be evaluated to the 20 mm end product flame test in accordance with UL 746C.

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

a) Resistance to impact;

b) Crush resistance;

c) Abnormal operations;

d) Severe conditions; and

e) Mold-Stress Relief Distortion.

7.4 The polymeric materials employed for enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. EESA 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 CSA C22.2 No. 0.17 / UL 746B.

7.5 The enclosure materials intended to be directly exposed to sunlight and rain in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with CSA C22.2 No. 0.17 / UL 746C.

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

7.7 Gaskets and Seals of the EESA 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.

8 Metallic Parts Resistance to Corrosion

8.1 Metal EESA enclosures shall be corrosion resistant. Metal enclosures made of the following materials shall be considered to comply with the corrosion resistance requirements:

a) Copper, aluminum, or stainless steel; and

b) Bronze or brass, either of which containing at least 80 % copper.

8.2 Ferrous enclosures for indoor application shall be protected against corrosion by enameling, painting, galvanizing, or other equivalent means. Ferrous enclosures for outdoor application shall comply with the 600-hour salt spray test in CSA C22.2 No. 94.2 / UL 50E. Additional methods to achieve corrosion protection according to CSA C22.2 No. 94.2 / UL 50E can be accepted.

8.3 Metallic EESA 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 within the pack during operation.

8.4 Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table B.1 of Annex B shall be avoided unless there is an evaluation that demonstrates that the potential for corrosion is negligible for the particular connection materials and design. See Annex B.

9 Enclosures

9.1 The enclosure of an EESA 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.

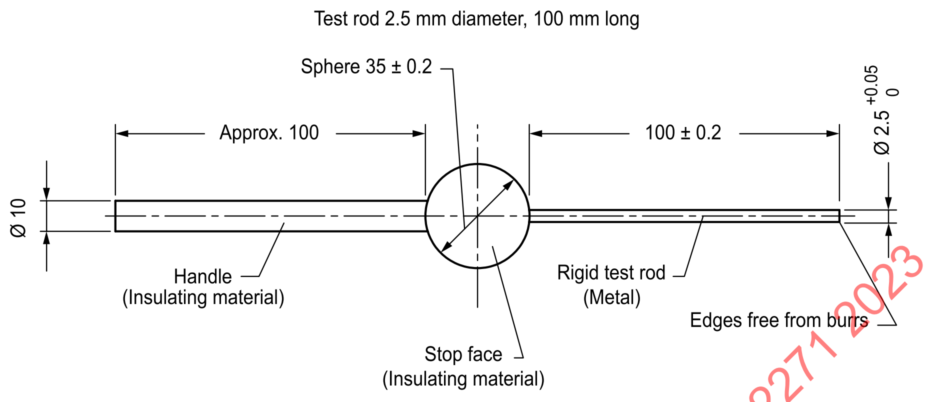
9.2 A tool providing the mechanical advantage of a pliers, screwdriver, or similar tool, shall be the minimum mechanical capability required to open the enclosure.

9.3 Openings in the enclosure of an electric energy storage assembly shall be designed to prevent inadvertent access to hazardous parts as installed in the vehicle. Compliance is determined by the "Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12" of IEC 60529, for a minimum IP rating of IP3X with consideration of the device as it is installed in the vehicle. Evaluation per IEC 60529, Clause 12, consists of the use of the 2.5 mm Test Rod, shown in Figure 9.1, applied with a force of 10 N ±10 %.

Exception: For EESAs that are intended for removal from the vehicle for external charging or replacement with a charged EESA by the user rather than being charged while installed in the vehicle, compliance is determined on the electric energy storage assembly with and without consideration of the device as it is installed in the vehicle.

Figure 9.1

IEC 2.5 mm Test Rod



Note: The handle dimensions (ø 10 and 20) are not critical.

9.4 Openings in the enclosure shall be designed to prevent ingress of water as installed in the vehicle in accordance with intended use and IP rating in accordance with Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 with a minimum rating of IPX3. Compliance is determined by the Water Exposure Test (IP code rating) in Section 42.

10 Wiring and Terminals

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

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

10.3 Connections to the cells shall be made in a manner that does not result in damage to the cells or protection assembly. For example, connections made using high heat processes, such as solder, shall not be used on direct connections to the cell terminals without proper processes and controls as this could result in damage to the cell as a result of heat transfer during soldering. To prevent damage to cells or protective devices, connections between cells and electronic protective devices should be made using the connection sequences recommended by the protective device manufacturer.

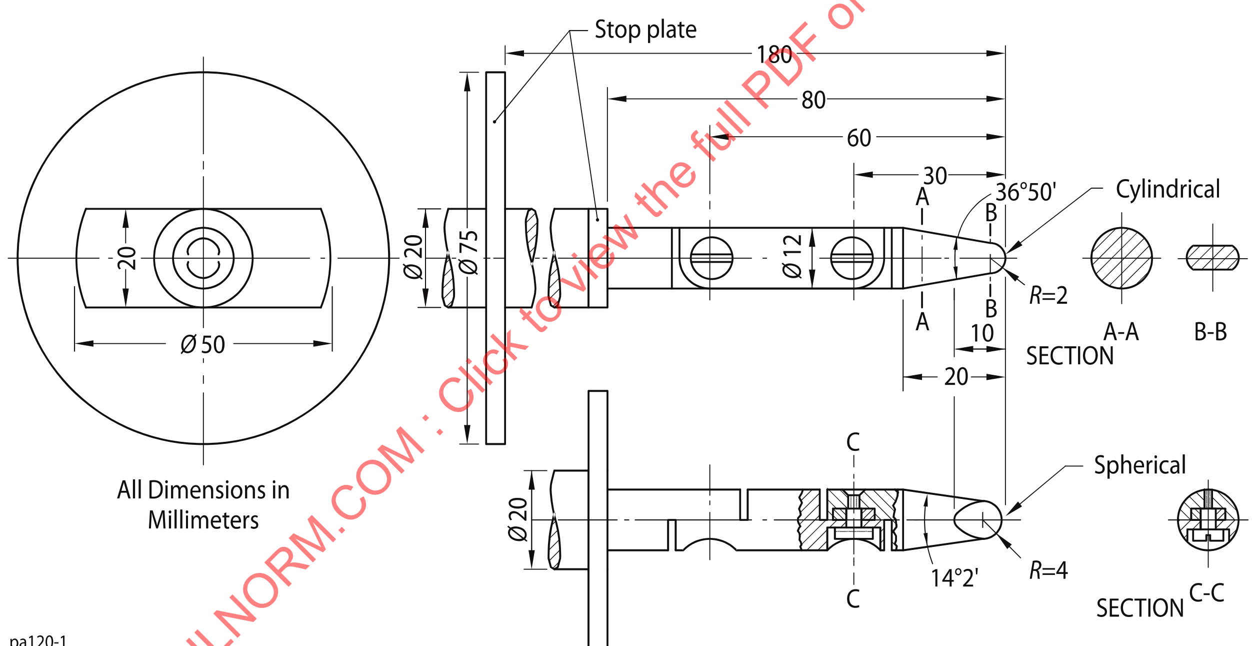
10.4 An EESA external terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in its end use vehicle.

10.5 For all EESAs, an external terminal for charging shall be designed to prevent an inadvertent shorting and misalignment and a reverse polarity connection. For EESAs that are intended for removal from the vehicle for external charging or replacement with a charged EESA, the external terminal for discharging shall be designed to prevent inadvertent shorting, a reverse polarity connection and a misalignment.

10.6 For EESAs that are intended for removal from the vehicle for external charging or replacement with a charged EESA by the user, the external terminal for discharging and any other external terminals with hazardous voltage shall be designed to prevent access by the user. Compliance is determined by use of the articulate test finger shown in Figure 10.1. The articulate test finger requirement does not apply to the manual disconnection for servicing device as outlined in 15.1.5.

Figure 10.1

Articulate Probe



10.7 The external terminals of an EESA intended for removal from the vehicle for charging, shall be evaluated to either the no load endurance test or endurance with load test as applicable to the end use application in accordance with the Standard for Plugs, Receptacles and Couplers for Electric Vehicles, UL 2251 without being subjected to the exposure to contaminants.

10.8 A hole by which insulated wires pass through an internal or external opening in the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.

10.9 Wiring for hazardous voltage shall be readily distinguishable from low voltage wiring harnesses through the use of orange colored insulation or orange wiring harness jacketing or covers. Internal wiring of hazardous voltage circuits that are not provided with orange wiring harness covers or jackets, shall also be colored primarily orange (i.e. solid orange or orange striped), or enclosed in junction boxes with hazardous voltage warning labels such as ISO No. 7010, No. W001 (i.e. lightning bolt within triangle).

11 Fuses

11.1 Fuses used in an EESA shall be acceptable for current and voltage which are likely to be subjected.

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

12 Handles

12.1 An integral handle(s) or other lifting mechanism used for picking the pack up shall be capable of supporting the weight of the pack without breakage of the handle, its securing means, or that part of the product to which the handle is attached. Compliance is determined by Section 38, Handle Loading Test.

13 Electrical Spacings and Separation of Circuits

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

13.2 Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 13.1 or the spacings requirements outlined in CSA C22.2 No. 62368-1 / UL 62368-1, the clauses for "Clearances," 5.4.2, and "Creepage Distances," 5.4.3.

Exception No. 1: As an alternative to the spacing requirements of Table 13.1, the spacing requirements in CSA C22.2 No. 0.2 or UL 840 may be used.

Exception No. 2: For electric energy storage assemblies where external leakage of liquid electrolyte may occur, the clearance and creepage distances of Clause 6.2 of ISO 6469-1 apply.

Table 13.1
Electrical Spacings

	Voltage V	Through Air mm (in)	Over Surface mm (in)
Live parts and dead metal parts that are separated by Functional or basic insulation	0 – 50[a] 51 – 130 131 – 300	1.6 (1/16) 3.2 (1/8) 6.4 (1/4)	1.6 (1/16) 4.8 (3/16) 9.5 (3/8)
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only –	0 – 50[a]	1.6 (1/16)	1.6 (1/16)

Table 13.1 Continued on Next Page

Table 13.1 Continued

	Voltage V	Through Air mm (in)	Over Surface mm (in)
this ordinarily is a spacing resulting from supplementary insulation	51 – 130 131 – 300	3.2 (1/8) 6.4 (1/4)	4.8 (3/16) 9.5 (3/8)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 – 50[a] 51 – 130 131 – 300	3.2 (1/8) 4.8 (3/16) 12.7 (1/2)	3.2 (1/8) 6.4 (1/4) 12.7 (1/2)

[a] Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (i.e. circuits supplied by limited power sources as defined in the Circuits Intended for Interconnection with Building Wiring Annex of CSA C22.2 No. 62368-1 / UL 62368-1).

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

13.4 Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacings 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.

13.5 For determination of spacing, Overvoltage category II and pollution degree 3 are applied to EESAs. Enclosures meeting IP54 or IPX7 per IEC 60529 are considered pollution degree 2. Hermetically sealed or encapsulated enclosures, or coated printing-wiring boards in compliance with the Printed Wiring Board Coating Performance Test of CSA C22.2 No. 0.2 or UL 840 are considered pollution degree 1.

13.6 CSA C22.2 No. 0.2 or UL 840 shall not be used for the clearance and creepage distance at field wiring terminals. When determining the clearance for double or reinforced insulation in accordance with CSA C22.2 No. 0.2 or UL 840, the clearances of reinforced insulation shall be dimensioned corresponding to the rated impulse voltage, but choosing one step higher in the preferred series of values in the Minimum Clearances for Equipment table of CSA C22.2 No. 0.2 or UL 840 than that specified for basic insulation. If the impulse withstand voltage required for basic insulation, is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the impulse withstand voltage required for basic insulation. When determining the creepage for double or reinforced insulation in accordance with CSA C22.2 No. 0.2 or UL 840, the creepage distances for reinforced insulation shall be twice the creepage distance required for the basic insulation as determined in CSA C22.2 No. 0.2 or UL 840.

14 Insulation Levels and Protective Grounding

14.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in 14.2 through the following:

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

b) A system of double or reinforced insulation; or

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

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

14.3 If relying upon a protective grounding system (i.e. grounding of an accessible metal enclosure), it shall comply with 14.4 – 14.6.

14.4 Parts of a protective grounding system shall be reliably secured in accordance with 10.2 and provided with good metal-to-metal contact of the grounded parts of the EESA to the vehicle. The impedance from the various bonding conductors and connections to the main ground terminal shall have a maximum resistance of 0.1 Ω. Compliance can be determined by Section 32, Grounding Continuity Test.

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

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

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

c) A green colored pressure wire connector; or

d) The word "Ground" or the letters "G" or "GR" or the grounding symbol (IEC 60417, No. 5019 – upside down "tree" in circle) or otherwise identified by a distinctive green color.

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

15 Safety Analysis

15.1 General

15.1.1 A safety analysis consisting of a hazard identification, risk analysis and risk evaluation shall be conducted on the device under test. This safety analysis shall determine which parts of the system are safety related through an existing methodology such as outlined 15.1.2. This approach shall determine the hazard scenarios and define mitigation mechanisms. This safety analysis shall identify safety circuits or software that address each hazardous condition and consider the performance of each safety circuit or software. The following conditions in (a) – (c) shall be considered unless sufficient justification (e.g. additional safety analysis) is provided by the manufacturer that these conditions are not hazardous. The following conditions in (a) – (c) shall be considered at a minimum, but are not limited to:

a) Battery cell over-voltage and under-voltage;

b) Battery over-temperature and under-temperature; and

c) Battery over-current during charge and discharge conditions.

15.1.2 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;

e) IEC 61508-1, and all parts;

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

15.1.3 The analysis of 15.1.1 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and is validated by compliance with 15.2. The analysis shall consider the reliability of any monitoring components and systems and any communication systems providing information to the controls that can affect safety. The analysis shall consider single fault conditions in the protection circuit in addition to single faults elsewhere that could lead to a hazardous condition.

15.1.4 A hazardous voltage EESA shall have a manual disconnect to prevent inadvertent access to hazardous voltage parts during servicing or during a collision. 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 EESA from the vehicle or unplugging the EESA connector/plug; and

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

15.1.5 If a hazardous voltage automatic disconnect device is provided to isolate accessible conductive parts from the hazardous voltage circuit of the EESA, 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.

15.2 Protective circuits and controls

15.2.1 Active protective devices shall not be relied upon for critical safety and shall comply with one of the following in (a) – (c) and comply with 15.2.2 and 15.2.3 as applicable. Refer to 6.35 and 6.36 for definitions of active and passive protective devices.

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

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

c) They remain fully operational or fail safe upon loss of power to, or under a single fault condition of the active circuit.

Exception : Active protective devices that comply with IEC 61508 (all parts), meeting minimum Safety Integrity Level (SIL) "2", or ISO 13849 (all parts), meeting minimum performance level (PL) "c", or ISO 26262 (all parts), minimum of Automotive Safety Integrity Level (ASIL) "C", are permitted to be relied upon for critical safety. The SIL, PL, or ASIL for a safety function may be reduced if the manufacturer provides *additional safety analysis (e.g. Layer of Protection Analysis (LOPA)) showing that the required risk reduction level has been reduced by other measures used within the battery system.*

15.2.2 Active protective devices relied upon for safety as noted in 15.2.1, shall be evaluated in accordance with:

a) The Failure-Mode and Effect Analysis (FMEA) requirements in UL 991;

b) The Protection Against Internal Faults to Ensure Functional Safety requirements in UL 60730-1 or CSA E60730-1 (Clause H.27.1.2); or

c) The Protection Against Faults to Ensure Functional Safety requirements (Class B requirements) in CSA C22.2 No. 0.8 (Section 5.5) to determine compliance and identify tests necessary to verify single fault tolerance.

15.2.3 With reference to 15.2.1, software relied upon for safety shall comply with:

a) UL 1998;

b) Software Class B requirements of CSA C22.2 No. 0.8; or

c) The Controls Using Software requirements (Software Class B requirements) in UL 60730-1 (Clause H.11.12) or CSA E60730-1.

15.2.4 Battery systems shall be protected against all hazards identified in the safety analysis of 15.1.1.

15.2.5 With reference to 15.2.4, if relied upon for maintaining the cells within their specified operating limits, the battery management system (BMS) shall maintain cells within the specified cell voltage and current limits to protect against overcharge and over-discharge. The BMS shall also maintain cells within the specified temperature limits providing protection from overheating and under temperature operation. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other devices and parts determined necessary for intended operation of the battery system that are required to be provided in the end use LEV, shall be identified in the installation instructions.

15.2.6 With reference to 15.2.4 and 15.2.5, if specified operating limits are exceeded, a protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond operating limits. When a hazardous scenario occurs, as determined in 15.1.1, the system shall continue to provide the safety function or go to a safe state (SS) or risk addressed (RA) state. If the safety function has been damaged, the system shall remain in the safe state or risk addressed state until the safety function has been restored and the system has been deemed acceptable to operate.

15.2.7 Solid state circuits and software controls, relied upon as the primary safety protection, shall be evaluated and tested to verify electromagnetic immunity in accordance with the Electromagnetic Immunity Tests of UL 1973 if not tested as part of the functional safety standard evaluation.

Exception: Solid state circuits and software need not comply if it can be demonstrated that the solid state circuits and software are not relied upon as the primary safety protection.

16 Cells, Electrochemical Capacitors, and Repurposed Cells and Batteries

16.1 Cells and electrochemical capacitors shall be designed to safely withstand anticipated abuse conditions for vehicular applications. Compliance is determined by the requirements in 16.2 – 16.8 and by the tests of this Standard.

16.2 Lithium ion and other lithium based cells shall comply with the requirements for secondary lithium cells in UL/ULC 2580, including compliance with all the performance tests for cells.

16.3 Nickel metal hydride cells and other nickel based cells shall comply with the nickel cell requirements of UL/ULC 2580, including compliance with all the performance tests for cells.

Exception: Nickel metal hydride cells and other nickel based cells that are sealed and formed as part of a monobloc battery, need only comply with the requirements of this Standard as part of the assembled battery.

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

16.5 Batteries employing re-closable pressure release valves on the external enclosure of the battery (e.g. valve regulated lead acid batteries) or flame arresters on vented batteries, shall comply with the pressure release test or the flame arrester test of UL 1989.

16.6 Electrochemical capacitors shall comply with the single capacitor requirements outlined in UL 810A.

16.7 Sodium ion cells (e.g. Prussian Blue cells or transition metal layered oxide cells) shall comply with the sodium ion cell requirements of UL/ULC 2580 (identical to the performance and marking requirement for secondary lithium cells in UL/ULC 2580), including compliance with all the performance tests for cells.

16.8 Batteries and battery systems using repurposed cells and batteries shall ensure that the repurposed parts have gone through an acceptable process for repurposing in accordance with UL 1974. See also 46.11.

17 Manufacturing and Production Line Testing

17.1 EESAs shall be subjected to 100 % production screening as described in 17.2 and 17.3 to determine the acceptability of spacing, insulation and grounding system in production.

17.2 A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test in Section 30 shall be conducted on 100 % production of EESAs with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak.

Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s. If the value of the voltage in Section 30 is increased as follows:

a) 2.4 times the circuit voltage for those circuits not connected to dc as outlined in Section 30; and

b) 1200 plus 2.4 times the circuit voltage for those circuits connected to ac as outlined in Section 30.

Exception No. 2: The isolation resistance test of Section 31 can be conducted in lieu of the dielectric withstand test.

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

17.4 Assemblies/packs shall be subjected to 100 % production screening to determine that any active controls utilized to maintain cells within normal operating parameters are functioning.

17.5 Manufacturers of EESAs shall have documented production process controls in place that continually monitor and record the following key elements of the manufacturing process that can affect safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements:

a) Supply chain control; and

b) Assembly processes.

PERFORMANCE

18 General

18.1 Unless indicated otherwise, batteries shall be fully charged to the maximum operating state of charge (MOSOC) in accordance with the manufacturer's specifications for conducting the tests in this Standard. After charging and prior to testing, the batteries shall be allowed to rest for a maximum period of 8 h at 25 ±5 °C (77 ±9 °F).

18.2 Unless otherwise indicated, fresh samples representative of production are to be used for the tests described in this Standard. The test program and number of samples to be used in each test is shown in Table 18.1.

Table 18.1
Tests and Sample Requirements

Test	Section	Number of samples[a, b]
Electrical Tests		
Overcharge	23	1 EESA
High Rate Charge	24	1 EESA
Short Circuit	25	1 EESA
Overload Under Discharge	26	1 EESA
Overdischarge	27	1 EESA
Temperature	28	1 EESA
Imbalanced Charging	29	1 EESA
Dielectric Voltage Withstand	30	1 EESA
Isolation Resistance	31	1 EESA
Mechanical Tests		
Vibration Endurance	33	1 EESA
Shock	34	1 EESA
Crush (on road)	35	1 EESA
Drop	36	1 EESA
Mold Stress	37	1 EESA
Handle Loading	38	1 EESA
Roll Over	39	1 EESA
Strain Relief Tests (Cord Anchorages)	40	2 test specimens of the part under test or complete EESA
Environmental Tests		

Table 18.1 Continued on Next Page

Table 18.1 Continued

Test	Section	Number of samples[a, b]
Immersion Test	41	1 EESA
Water Exposure Test (IP code rating)	42	1 EESA
Thermal Cycling	43	1 EESA
Material Tests		
20-mm End Product Flame Test (Note: Not conducted if minimum V-1)	7.2	3 test specimens of the part under test (polymeric enclosure sample)
Label Permanence	44	1 test specimen of the part under test (label adhered to end use surface)
Single Cell Failure Design Tolerance Test		
Single Cell Failure Design Tolerance Test	45	1 EESA

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

[b] Testing can be conducted on a subassembly of the EESA if determined to be representative.

18.3 All tests, unless noted otherwise, are conducted in a room ambient 25 ±5 °C (77 ±9 °F). Unless noted otherwise in the test method, the cooling systems or other auxiliary systems of the EESA may be allowed to operate during the test if they can affect the outcome of the test.

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

18.5 Where there is a specific reference to a single fault condition in the individual test methods, the single fault is to consist of a single failure (i.e. open, short or other failure means) of any component in the EESAs that could occur and affect the results of the test. This fault is implemented in conjunction with the test being conducted (i.e. overcharge, short circuit, etc.) or may be conducted as part of a verification of a protective circuit. A protective component determined to be reliable may remain in the circuit without being faulted. A reliable protective component is one that has been evaluated to its applicable component standard. See Annex A and 2.1. A protective circuit determined to be reliable is one that has been shown to comply with an appropriate functional safety standard per 15.1.5 with a safety level defined by a corresponding hazards and risk analysis.

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

18.7 Unless noted otherwise in the individual test methods, the tests shall be followed by a minimum 1-h observation time prior to concluding the test and temperatures are to be monitored in accordance with 18.6.

19 Combustible Concentrations

19.1 Where a system analysis indicates that venting/off gassing from cells or capacitors could result in combustible concentrations because of the system's chemistry (i.e. vented batteries) or design, the evaluation for combustible concentrations during the tests of this Standard shall be determined through the methods outlined in 19.2. If it can be determined through examination of the cells after testing that they did not vent as a result of the test, the system is in compliance with these criteria.

19.2 For detection of potential flammable concentrations that may be emitted during testing, a gas monitor suitable for detecting 25 % of the lower flammability limit of the evolved gases being measured. A minimum of two sampling locations where concentrations may occur such as at vent openings or vent ducts shall be used for taking measurements.

Exception: As an alternative to using gas detection measurement to determine if there are flammable concentrations, non-compliant tests results for fire may include an evaluation for potential flammable concentrations of vapors with the use of a minimum of two continuous spark sources. The continuous spark sources are to provide at least two sparks per second with sufficient energy to ignite natural gas (or sufficient energy to ignite the potential vapor if more energy is required for ignition than would be needed to ignite natural gas) and are to be located near anticipated sources of vapor such as vent openings or at the vent duct.

19.3 Additional precautions shall be taken during tests requiring this analysis due to the potential for flammable gas concentrations that may occur within the test room or chamber.

20 Measurement Equipment Accuracy

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

a) ±1 % for voltage;

b) ±1 % for current;

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

d) ±0.1 % for time; and

e) ±1 % for dimension.

21 Post Test Cycle

21.1 EESAs that are operational after the following tests (a fuse may be replaced or resettable device reset) 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 non-compliant results as outlined in Table 21.1 for that test:

a) Electrical Tests - Overcharge, short circuit, overdischarge protection, imbalanced charging, high rate charge;

b) Mechanical Tests – Vibration, shock, roll over, drop test for EESAs intended to be removable by the user; and

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

21.2 For those tests where rupture is identified as a non-compliant result, the DUT shall be examined at the conclusion of the test for evidence of rupture that would result in potential exposure to hazardous voltage circuits and hazards materials such as electrolyte. When determining exposure to accessible hazardous circuits or materials, the criteria outlined in 9.3 shall be applied.

Table 21.1
Noncompliant Test Results

Non-compliant results	Designation	Tests[a]
Explosion	E	All tests
Fire	F	All tests
Combustible Concentrations (if applicable to technology)	C	All tests except immersion and single cell failure design tolerance
Rupture (enclosure)	R	All tests except crush, drop test for EESAs intended for service handling only and single cell failure design tolerance
Electrolyte Leakage (external to enclosure)	L	All tests except immersion and single cell failure design tolerance
Venting	V	All tests except short circuit, crush, drop test for EESAs intended for service handling only and immersion
Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown)	S	All tests (if hazardous voltage) except single cell failure design tolerance
Loss of protection controls[b]	P	All tests except crush, drop test for EESAs intended for service handling only, and immersion, immersion, and single cell failure design tolerance

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

[b] Loss of protection controls – A failure of software and/or electronic controls, discrete control devices or other built-in electrical protection that results in a hazardous event.

NOTE: No need to verify the protection function of the single faulted protection device after test.

22 Results Criteria

22.1 See Table 21.1 for results criteria for tests outlined in this Standard and Section 6 for definitions of the non-compliance results terms. See also individual tests methods for any additional details.

ELECTRICAL TESTS

23 Overcharge Test

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

23.2 A fully charged sample is to be discharged at a 0.2 C constant discharge rate or a higher discharge rate permitted by the manufacturer to the manufacturer's specified EODV. The DUT is then subjected to a constant current charging at the manufacturer's maximum specified charging rate and under a single fault condition in the circuitry that directly controls the charging line of the DUT that could lead to an overcharge condition. Protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted as noted in 18.5. During test, the voltage of the cells shall be measured. For information purposes, temperatures are to be monitored on the cell/module where temperatures may be highest.

23.3 If BMS reduces the charging current to a lower value near the end of charging phase, the sample shall be charged continually with the reduced charging current until ultimate results in 23.4 occur.

23.4 The test is to be continued until the voltage has reached 110 % of the maximum specified voltage limit and monitored temperatures return to ambient or steady state conditions and an additional 2 h has elapsed, or explosion/fire occur. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

23.6 As a result of the overcharge test, the maximum charging voltage measured on the cells shall not exceed their normal operating region. Also, any of the following results in (a) – (h) below are considered a non-compliant results. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V – Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

24 High Rate Charge Test

24.1 The purpose of this test is to evaluate a battery system's ability to protect the cells in the battery system against a high rate charge condition at currents exceeding the maximum charging current of the cells.

24.2 A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to a high rate charge. There shall be a single fault condition on overcurrent charge protection devices or controls unless they have been evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with Section 15). During the test, the current and voltage of the cells shall be measured. The test supply equipment used for charging the DUT shall be sufficient to provide a current that is 20 % greater than the maximum specified charging rate for the battery system.

Exception 1: High rate charge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.

Exception 2: If the overcurrent protection limit for the battery system is higher than 120 % of the maximum specified charging rate for the battery system, then the test supply current used for charging the DUT shall provide a current that is 5 % greater than the overcurrent protection limit for the battery system.

24.3 The high rate charging of the DUT shall continue until ultimate results occur followed by an observation period per 18.7. Ultimate results are considered to have occurred when one of the following occurs:

a) The sample charging is terminated by the protective circuitry whether it is due to current, voltage or temperature controls. The DUT is monitored per 18.6; or

b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 21.1.

24.4 During the test, detection methods as outlined in Section 19 shall be used to detect the presence of combustible vapor concentrations if determined necessary.

24.5 If the DUT is operational after the high rate charge test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 21.1 for details regarding user resettable devices. An observation period per 18.7 is then conducted.

24.6 At the conclusion of the observation period, the samples shall be subjected to an "as received" Isolation Resistance Test in accordance with Section 31. The DUT shall be examined for signs of rupture and evidence of leakage.

24.7 As a result of the high rate charge test, the battery protection circuit (e.g. BMS) shall detect the overcharging current and shall prevent the cells inside the battery system from being charged over the maximum charging current of the cell. In addition, any of the following results in (a) – (h) below are considered a non-compliant results. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V – Venting

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls

Exception: The overcharging current may exceed the maximum charging current for a short duration (within a few seconds) which is within the delay time of the BMS detection.

25 Short Circuit Test

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

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

25.3 Samples are to be subjected to an external short under a single fault condition in the protection circuit of the DUT that could impact the external short. Protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted as noted in 18.5.

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

25.5 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

25.7 As a result of the short circuit test, any of the following results in (a) – (g) below are considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

g) P – Loss of protection controls.

26 Overload Under Discharge Test

26.1 This test shall be conducted on a fully charged DUT (MOSOC per 18.1).

Exception: Overload under discharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.

26.2 Condition 1 is the overload above the specified maximum discharge current of the battery, but below the BMS overcurrent protection in accordance with 26.3 – 26.5.

26.3 With reference to 26.2, the positive and negative terminals of the DUT are to be connected to the external discharging equipment. The fully charged DUT shall then be discharged at a current equal to 90 % of the rated overcurrent protection value of the BMS.

26.4 With reference to 26.2, the test shall be continued until:

a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted);

b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or

c) A fire or explosion has occurred.

Exception: The overload condition 1 can be waived if the maximum discharge current of the battery is equal to or higher than 90 % of the overcurrent protection value of the BMS.

26.5 With reference to 26.2, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See 18.5 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.

Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 18.5) need not be subjected to single fault conditions.

26.6 Condition 2 is the overload above the BMS overcurrent protection, but below the primary overcurrent protection (typically fuse or circuit breaker) in accordance with 26.7 – 26.9.

26.7 With reference to 26.6, the positive and negative terminals of the DUT shall be connected to the external discharging equipment. The DUT shall then be discharged at a current equal to 135 % of the main fuse or circuit breaker rating.

Exception No. 1: If the actuating device of BMS overcurrent protection is a contactor, switch or similar disconnecting device, which has been evaluated for an overload current higher than 135 % of the primary overcurrent protector (fuse or circuit breaker) rating, then the test shall be conducted at a discharge current of 150 % of the primary overcurrent protector (fuse or circuit breaker) rating.

Exception No. 2: If the actuating device of BMS overcurrent protection (such as a contactor, switch or similar disconnecting device) has been evaluated for an overload current higher than 150 % of the primary overcurrent protector (fuse or circuit breaker) rating, then the condition 2 test can be waived.

26.8 With reference to 26.6, the test shall be continued until:

a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted);

b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or

c) A fire or explosion has occurred.

26.9 With reference to 26.6, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 18.5 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.

Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 18.5) need not be subjected to single fault conditions.

26.10 If the DUT is operational after the overload under discharge test, the DUT shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 21.1 for details regarding user resettable devices. An observation period per 18.7 shall then be conducted.

26.11 At the conclusion of the observation period, the samples shall be subjected to the "as received" isolation resistance test in accordance with Section 31. The DUT shall be examined for signs of rupture and evidence of leakage.

26.12 As a result of the overload under discharge test, any of the following results in (a) - (g) below are considered a non-compliant results. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

g) P – Loss of protection controls.

27 Overdischarge Test

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

27.2 The fully charged sample is to be subjected to a constant discharging current at the maximum discharging current specified by the manufacture under a single fault condition in the discharging circuit of the DUT that could lead to an overdischarge condition. Protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted as noted in 18.5. During test, the voltage of the cells shall be measured. Temperatures shall be measured on a cell/module for monitoring purposes.

27.3 The test is to be continued until the sample is fully discharged to a near zero voltage state or protective devices remaining in the circuit operate, and the monitored temperatures return to ambient or steady state, or explosion and/or fire occurs. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

27.5 As a result of the overdischarge test, the minimum discharge voltage measured on the cells shall not exceed their normal operating range. Also, any of the following results in (a) – (h) below are considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V – Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

28 Temperature Test

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

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

Exception: If the maximum charging parameters vary with temperature, the correspondence between charging parameters and temperature shall be clearly specified in the charging instructions, and the DUT shall be charged under the most severe charging parameters.

28.3 While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged DUT shall then be discharged in accordance with the manufacturer's specifications down to the manufacturer's specified end of discharge condition while monitoring voltage and current on cells/modules until the DUT reaches its specified EODV. Temperatures shall be monitored on temperature sensitive safety critical components including cells and on any user accessible surfaces.

28.4 The charge and discharge cycles are then repeated for a minimum total of 2 complete cycles of charge and discharge, until consecutive charge and discharge cycles do not continue to increase the maximum cell temperature more than 2 °C (3.6 °F).

28.5 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.

28.6 During the temperature test in 28.2 – 28.4, thermal protection and overcurrent protection devices shall not operate, the manufacturer's specified limits for cells (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.

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

[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.

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)

[a] For each material, account shall be taken of the data for 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 (6041-1-IEC-5041) to provide this information.

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

28.8 As a result of the temperature test, any of the following results in (a) – (h) below are also considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V– Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

29 Imbalanced Charging Test

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

29.2 A fully charged DUT shall have all of its cells with the exception of one cell/cell block discharged to its specified fully discharged condition. The undischarged cells shall be discharged to approximately 50 % of its specified state of charge (SOC) to create an imbalanced condition prior to charging. For this test, protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted as noted in 18.5.

29.3 The DUT shall then be charged in accordance with the manufacturer's specifications. The voltage of the partially charged cells shall be monitored during the charging to determine if its voltage limits are exceeded. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values.

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

29.5 The maximum voltage limit of the cells shall not exceed the manufacturer's specifications. In addition, any of the following results in (a) – (h) below are considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V– Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

30 Dielectric Voltage Withstand Test

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

30.2 Circuits at 60 Vdc or higher shall be subjected to a dielectric withstand voltage consisting of a dc potential of twice the rated voltage times 1.414.

Exception No. 1: An essentially sinusoidal ac potential of 60 Hz at twice rated voltage may be applied instead of the dc potential.

Exception No. 2: For those circuits connected to an ac mains supply, the test voltage shall be an essentially ac potential of 60 Hz at 1,000 V plus twice the rated voltage. If using a dc potential, the test voltage shall be 1.414 time the ac test potential value of 1,000 V plus twice the rated voltage.

Exception No. 3: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.

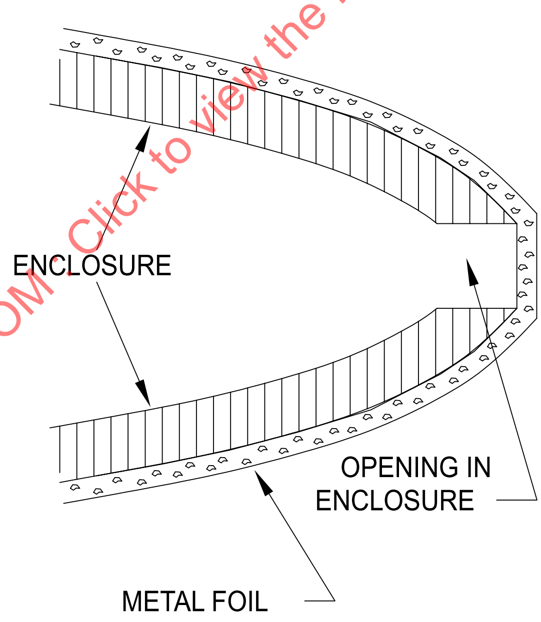
30.3 The test voltage is to be applied between the hazardous voltage circuits of the DUT and non-current carrying conductive parts that may be accessible.

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

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

Figure 30.1

Method of Covering Enclosures with Foil for Measurement and Tests



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

30.7 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 ac test method a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it may not be indicative of insulation breakdown.

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

30.8 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 an dielectric breakdown (i.e. insulation breakdown).

31 Isolation Resistance Test

31.1 Isolation resistance method for systems rated 120 V and above

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

31.1.2 The electric energy storage assembly shall be subjected to Isolation resistance test of Clause 6.1.3 of ISO 6469-1, with the following exceptions in (a) and (b). The DUT is to be in the fully charged state for both (a) and (b):

a) Testing is to be conducted with the DUT in the as-received condition (i.e. no humidity conditioning prior to measurements); and

b) Testing is to be conducted after conditioning the DUT in accordance with IEC 60068-2-30 using the following parameters:

1) Variant 1;

2) At maximum temperature of 55 ±2 °C (131 ±3 °F); and

3) 6 cycles.

31.1.3 For condition 31.1.2(b), the DUT shall be placed within the chamber so that it is oriented in the manner in which it will be installed in the vehicle. Upon completion of the 6th cycle the sample shall be subjected to a controlled recovery in accordance with Recovery, Clause 9, of IEC 60068-2-30. The isolation resistance measurements shall be made within 30 min of completion of the controlled recovery phase.

31.1.4 For both (a) and (b) of 31.1.2, the isolation resistance divided by the maximum working voltage of the circuit under test, shall be at least 100 Ω/V for dc systems and 500 Ω/V for ac systems or combined ac and dc systems.

31.2 Isolation resistance method for systems rated below 120 V (insulation resistance method)

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

31.2.2 A DUT with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts of a DUT. If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts as shown in 30.5 and Figure 30.1.

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

31.2.4 The test shall be repeated on a sample subjected to the Humidity Conditioning in accordance with CSA C22.2 No. 62368-1 / UL 62368-1, Clause 5.4.8. Measurements shall be made with the sample still in the chamber.

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

32 Grounding Continuity Test

32.1 This test applies to the electric energy storage assembly having a protective grounding system and evaluates the continuity of the protective grounding system.

32.2 The grounding system of an electric energy storage assembly shall have no more than 0.1-Ω resistance between any two parts of the system that are measured in accordance with the continuity test of 32.3 and 32.5.

32.3 The voltage drop in a protective grounding system is measured after applying a test current of 150 % of the maximum charging current of the circuit under test or 25 A, whichever is greater, for 5 s. The supply used to provide the test current is to have a no load voltage not exceeding 60 Vdc.

32.4 The voltage drop measurement is made between any two exposed conductive parts of the assembly.

32.5 The resistance shall be calculated from the measured voltage drop and current.

MECHANICAL TESTS

33 Vibration Endurance Test

33.1 This test evaluates the DUT's ability to withstand vibration that may occur from its use in an LEV. The test shall be performed in accordance with ISO 6469-1, or in accordance with a test profile specified by the manufacturer and verified to the LEV application.

Exception: The test is to be carried out at room ambient without temperature variation.

33.2 The DUT shall be securely mounted to a vibration test platform in a manner similar to how it is mounted in the end use LEV. The DUT shall be subjected to a random vibration sequentially along three perpendicular axes as defined in Table 33.1.

Table 33.1
Test Parameters for Vibration Endurance Test (Generic)

	Frequency	PSD	PSD
Axis	**Hz**	**g^2/Hz**	**$(m/s^2)^2$/Hz**
Z (vertical)	5	0.0049	0.0481
	10	0.0061	0.5774
	15	0.0392	0.3849
	200	0.00004	0.0004
	rms	**0.269 g**	**2.64 m/s^2**
Y (transverse)	5	0.0196	0.1925
	15	0.0294	0.2887
	50	0.0029	0.0289
	200	0.00004	0.0004
	rms	**0.256 g**	**2.51 m/s^2**
X (longitudinal)	5	0.0029	0.0289
	20	0.0294	0.2887
	200	0.00006	0.0006
	rms	**0.238 g**	**2.34 m/s^2**

33.3 The DUT shall be subjected to the vibration in each axis for 12 h. For each axis the frequency shall be varied from 5 Hz to 200 Hz with power spectral density (PSD) as outlined in the Table 33.1.

33.4 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

33.6 As a result of the vibration endurance test, any of the following results in (a) – (h) below are considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f)) V – Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

34 Shock Test

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

34.2 The fully charged sample 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.

Exception: For the test, the DUT may be mounted in a fixture representative of the mounting means used in the end use vehicle.

34.3 The sample is to be subjected to mechanical shock testing with parameters as shown in Table 34.1 or according to a test profile determined by the customer and verified to the LEV application. The shocks are to be applied in all 6 spatial directions for prismatic DUT and 3 spatial directions for cylindrical DUT.

Table 34.1
Shock Parameters

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

[a] Pack with separate modules previously tested individually to the appropriate higher shock level.

34.4 During the test the OCV of the sample and temperatures on the center cell(s/modules) may be monitored for information purposes.

34.5 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

34.7 As a result of the shock test, any of the following results in (a) – (h) below are considered a non-compliant result. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) V – Venting;

g) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

h) P – Loss of protection controls.

35 Crush Test

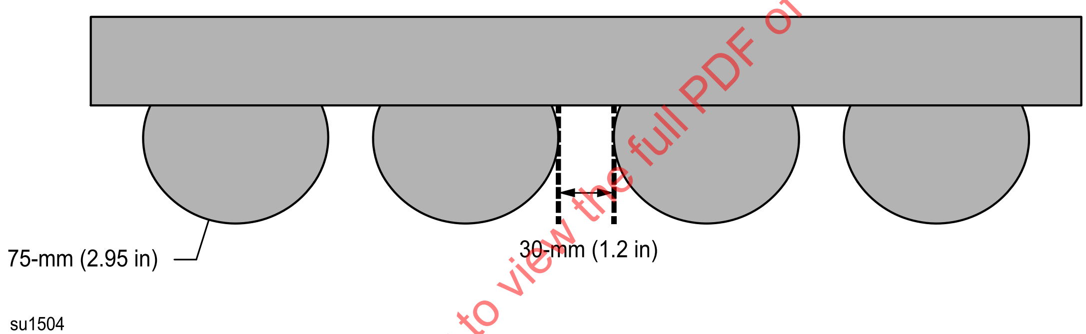
35.1 This test is conducted to determine the DUT's ability to withstand a crush that could occur during a vehicle accident. This test is only applicable to on road LEVs such as scooters and motorcycles that could be involved in a vehicle crash.

35.2 This test is conducted on a fully charged DUT.

35.3 A sample shall be crushed between a fixed surface and a ribbed test platen. The platen shall have semi-cylindrical intruders that have a 75-mm (2.95-in) radius and placed 30-mm (1.2-in) from one another across the face of the platen as shown in Figure 35.1.

Figure 35.1

Crush Test Platen



35.4 The sample is to be subjected to a crushing force that deforms the DUT by 50 % but no greater force than 1,000 times weight of the DUT or 100 kN, whichever comes first. The crushing force is to be applied at a rate of approximately 1.5 cm/s upon first contact with the sample. The crush is to be applied in each of 3 mutually perpendicular directions with the ribs centered on the sample in each direction of press.

Exception No. 1: DUTs with only 2 axes of symmetry, such as cylindrical designs are subjected to mutually perpendicular directions of press.

Exception No. 2: The DUT may be installed in a protective framework representative of what is provided in the vehicle.

35.5 Each sample shall only subject to one crush. The force shall be increase from zero to a maximum force value (i.e. 1,000 times the weight of the DUT or 100 kN) or when the maximum of 50 % deformation is achieved, whichever comes first and then it is removed. Monitoring for information purposes per 18.6 should be conducted during the test.

35.6 At the conclusion of the observation period, the samples are examined for electrolyte leakage and samples with hazardous voltage circuits shall be subjected to a Dielectric Voltage Withstand Test or Isolation Resistance Test (without humidity conditioning).

35.7 As a result of the crush test, any of the following results in (a) and (e) below are considered non-compliant results. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

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

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

36 Drop Test

36.1 Drop test for EESAs intended to be removable by the user

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

36.1.2 A fully charged DUT is to be dropped three times from a height of 1.0 ±0.01 m (39.4 ±0.4 in) to strike a flat concrete surface in a manner most representative of what would occur during lifting or handling of the DUT by the user. The concrete surface shall be at least 76-mm (3-in) thick and shall be large enough in area to cover the DUT. If the DUT is operational after the drop, it is to be subject to a minimum of one normal charge/discharge cycle in accordance with the manufacturer's specifications. The DUT shall be subjected to an observation period per 18.7 and then examined. Monitoring for information purposes per 18.6 should be conducted during the test.

Exception: DUTs employing plastic enclosures that are intended for use in 0 °C (32 °F) temperatures shall be conditioned for a minimum of 3 h at 0 °C (32 °F) [or temperature specified if lower than 0 °C (32 °F)] prior to conducting the drop test, which shall be conducted immediately after removing the samples from the cold conditioning.

36.1.3 If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 18.7.

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

36.1.5 There shall be no damage of the enclosure that would allow hazardous voltage parts to be accessed by use of the articulate test finger shown in Figure 9.1 and test pin shown in Figure 10.1.

36.1.6 As a result of the drop test, any of the following results in (a) – (g) below are considered non-compliant. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

d) R – Rupture (enclosure);

e) L – Electrolyte Leakage (external to enclosure);

f) S – Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

g) P – Loss of protection controls.

36.2 Drop test for EESAs intended for service handling only

36.2.1 This test is intended to evaluate whether a hazard exists when a DUT is subjected to an inadvertent drop during installation or removal from the vehicle.

36.2.2 After being equilibrated at room temperature, a fully charged DUT is to be dropped from a minimum height of 1.0 m (3.3 ft) to strike a flat concrete surface in the position most likely to produce the adverse results and in a manner and height most representative of what would occur during maintenance and handling/removal of the DUT during servicing.

36.2.3 If only one drop test is performed, it shall not be a flat drop, and if one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.

36.2.4 The DUT is to be dropped a minimum of one time.

36.2.5 The concrete surface is to be at least 76-mm (3-in) thick and shall be large enough in area to cover the DUT.

36.2.6 The DUT shall be examined within a time frame of 6 – 24 h after dropping. During the test, temperatures shall be monitored. If the DUT returns to or remains near ambient, a Dielectric Voltage Withstand Test or Isolation Resistance Test (without humidity conditioning) is to be conducted.

36.2.7 As a result of the drop test, any of the following results in (a) – (e) are considered non-compliant. See also Table 21.1 and Section 22.

a) E – Explosion;

b) F – Fire;

c) C – Combustible Concentrations (if applicable to technology);

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

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

37 Mold Stress Relief Test

37.1 This test is intended to evaluate whether any shrinkage or distortion exist 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.

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

Exception: If the maximum temperature, T, recorded on the DUT thermoplastic enclosure parts, obtained during the normal temperature test of Section 28 exceeds 60 °C (140 °F), then the oven temperature is to be maintained at a temperature equal to T +10 °C (18 °F).

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

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