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NATIONAL STANDARD

ANSI/CAN/UL/ULC 2580:2022

STANDARD FOR SAFETY

Batteries for Use In Electric Vehicles

ANSI/UL 2580-2022

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Batteries for Use In Electric Vehicles, ANSI/CAN/UL/ULC 2580

Third Edition, Dated March 11, 2020

Summary of Topics

This revision of ANSI/CAN/UL/ULC 2580 dated June 28, 2022 includes the following changes:

- ***Added an exception for use of orange cable or sleeving on systems of 60 Vdc or higher in 10.2.***

- ***Clarified the use and triggering method for internal short circuit trigger cells in C2.1.1 and C2.1.2.***

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated October 8, 2021 and March 25, 2022.

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ANSI/UL 2580-2022

MARCH 11, 2020
(Title Page Reprinted: June 28, 2022)

ANSI/CAN/UL/ULC 2580:2022

Standard for Batteries for Use In Electric Vehicles

First Edition – October, 2011
Second Edition – December, 2013

Third Edition

March 11, 2020

This ANSI/CAN/UL Safety Standard consists of the Third Edition including revisions through June 28, 2022.

The most recent designation of ANSI/UL 2580 as an American National Standard (ANSI) occurred on June 28, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on June 28, 2022.

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Preface

This is the Third Edition of ANSI/CAN/UL/ULC 2580, Standard for Safety for Batteries for Use In Electric Vehicles.

UL 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 2580 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 A, Annex B, Annex D, and Annex E are identified as Normative, as such, form mandatory parts of this Standard.

Annex C, identified as Informative, is for information purposes only.

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 2580 and the First Edition of CAN/ULC-S2580-13.

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

To purchase UL Standards, visit the UL Standards Sales Site at http://www.shopulstandards.com/ HowToOrder.aspx or call tollfree 1-888-853-3503 .

This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Batteries for Use in Electric Vehicles, STP 2580.

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

STP 2580 Membership

Name	Representing	Interest Category	Region
Bender, Curtis A.	Tennant Company	Supply Chain	USA
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Stankes, David	3M	Supply Chain	USA

STP 2580 Membership Continued on Next Page

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Name	Representing	Interest Category	Region
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Van Heirseele, Megan	Underwriters Laboratories Inc.	Project Manager (Non-Voting)	USA
Warner, Nicholas	Energy Storage Response Group	General Interest	USA
Weidner, Gary G.	GW Technical Services Inc.	General Interest	USA
Wong, Anthony	ATL	Producer	USA
Wu, Donald P.H.		Producer	Taiwan
Xiao, Jerry	SGS-CSTC Standards Technical Services CO LTD	Testing and Standards	China
Xu, Hongbin	Guangzhou MCM Certification and Testing CO LTD	Testing and Standards	Korea
Yun, Yonghee	Samsung SDI	Producer	Korea

International Classification for Standards (ICS): 29.220; 43.120

For further information on UL standards, please contact:

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Web site: ul.org

This Standard is intended to be used for conformity assessment.

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

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

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INTRODUCTION

1 Scope

1.1 These requirements cover electrical energy storage assemblies such as battery packs and combination battery pack-electrochemical capacitor assemblies and the subassembly/modules that make up these assemblies for use in electric-powered vehicles as defined in this standard.

1.2 This standard evaluates the electrical energy storage assembly's ability to safely withstand simulated abuse conditions and prevents any exposure of persons to hazards as a result of the abuse. This standard evaluates the electric energy storage assembly and modules based upon the manufacturer's specified charge and discharge parameters at specified temperatures. It does not evaluate the assembly's interaction with other control systems within the vehicle.

1.3 This standard does not evaluate the performance or reliability of these devices.

1.4 This standard does not include requirements for the evaluation of batteries for light electric vehicles such as electrical assist bicycles, wheel chairs, electric scooters and similar devices as defined in UL/ULC 2271.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this Standard shall comply with the requirements for that component. See Annex A for a list of Standards covering components generally used in the products covered by this Standard. A component shall comply with the Standards of CSA or UL Standards as appropriate for the country where the product is to be used.

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

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

b) Is superseded by a requirement in this standard.

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 Reference 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 Standards

ASTM D4490, *Standard Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes*
ASTM D4599, *Standard Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length-of-Stain Dosimeters*

Canada Motor Vehicle Safety Standards (CMVSS)

Document No. 305, *Motor Vehicle Safety Regulations (C.R.C., c. 1038) Electrolyte Spillage and Electrical Shock Protection (Standard 305)*

CSA Group Standards

CAN/CSA-C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*
CSA-C22.2 No. 0.2, *Insulation Coordination*
CAN/CSA-C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*
CAN/CSA-C22.2 No. 60950-1, *Information Technology Equipment Safety – Part 1: General Requirements*

Federal Motor Vehicle Safety Standards

FMVSS 49 CFR 571 305, *Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection*

IEC Standards

IEC 60068-2-27, *Environmental Testing – Part 2-27: Tests – Test Ea and Guidance: Shock*
IEC 60068-2-30, *Environmental Testing – Part 2-30: Tests – Test Db: Damp Heat, Cyclic (12 h + 12 h Cycle)*
IEC 60068-2-52, *Environmental Testing – Part 2: Tests – Test Kb: Salt Mist, Cyclic (Sodium Chloride Solution)*
IEC 60417, *Graphical Symbols for Use on Equipment*
IEC 60812, *Analysis Techniques for System Reliability – Procedure for Failure Mode and Effects Analysis (FMEA)*
IEC 61025, *Fault Tree Analysis (FTA)*
IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems (all parts)*
IEC 62061, *Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems*
IEC 62660-2, *Secondary lithium-Ion Cells for the Propulsion of Electric Road Vehicles – Part 2: Reliability and Abuse Testing*
IEC TR 62660-4, *Technical Report for Secondary Lithium-Ion Cells for the Propulsion of Electric Road Vehicles – Part 4: Candidate Alternative Test Methods for the Internal Short Circuit Test of IEC 62660-3*

IEEE Standards

IEEE 1625, Rechargeable Batteries for Multi-Cell Mobile Computing Devices
IEEE 1725, Rechargeable Batteries for Cellular Telephones

ISO Standards

ISO No. 7010, *Graphical Symbols – Safety Colours and Safety Signs – Registered Safety Signs*
ISO 6469-1, *Electrically Propelled Road Vehicles – Safety Specifications – Part 1: Rechargeable Energy Storage System (RESS)*

ISO 13849-1, *Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design*
ISO 26262, *Road Vehicles – Functional Safety (all parts)*

NEMA Standards

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

National Institute for Occupational Safety and Health (NIOSH) Standards

NIOSH Manual of Analytic Methods

NFPA Standards

NFPA 70, *National Electrical Code*

Occupational Safety and Health Administration (OSHA) Standards

OSHA Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis

SAE Standards

SAE ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
SAE J1739, *Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*
SAE J2380, *Vibration Testing of Electric Vehicle Batteries*
SAE J2464, *Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*

UL Standards

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*
UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*
UL 583, *Electric-Battery-Powered Industrial Trucks*
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 969, *Marking and Labeling Systems*
UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*
UL 1642, *Lithium Batteries*
UL 1973, *Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications*
UL 1989, *Standby Batteries*
UL 1998, *Software in Programmable Components*
UL 2054, *Household and Commercial Batteries*
UL 2251, *Plugs, Receptacles and Couplers for Electric Vehicles*
UL/ULC 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*
UL 60730, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*
UL 60950-1, *Information Technology Equipment Safety – Part 1: General Requirements*

US Department of Defense (DOD) Standards

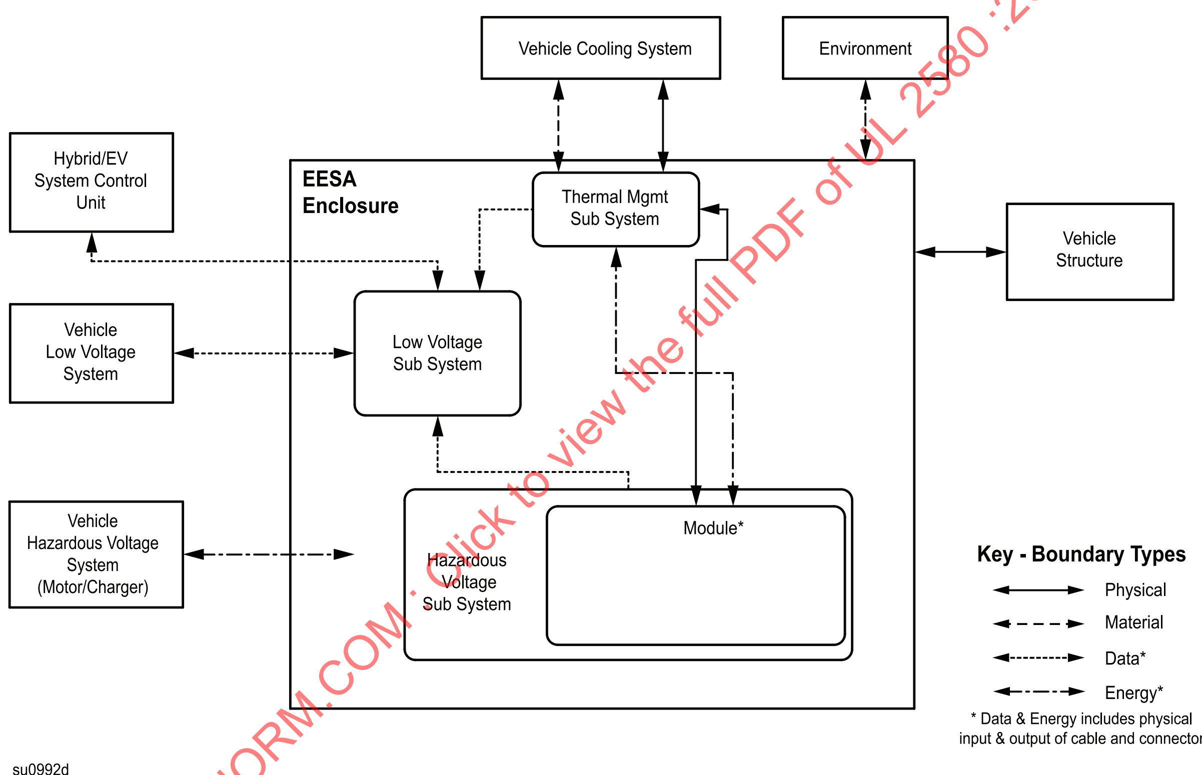
MIL-STD-1629A, *Procedures for Performing a Failure Mode, Effects, and Criticality Analysis*

6 Glossary

6.1 BATTERY PACK – Batteries that are ready for use in a electric powered vehicle, contained in a protective enclosure, with protective devices, with a battery management system, and monitoring circuitry, with or without cooling systems. See Figure 6.1.

Figure 6.1

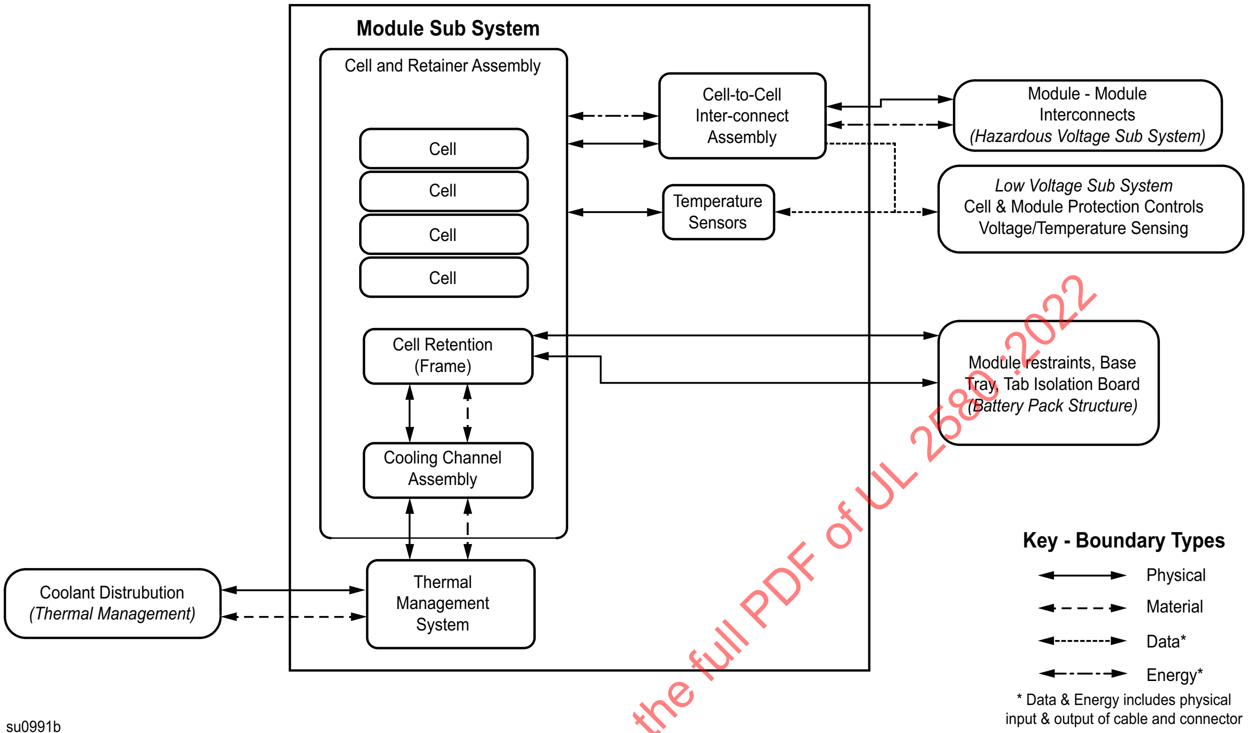
Electric energy storage assembly – system boundary diagram



6.2 CAPACITOR PACK – Electrochemical capacitors that are ready for use in a electric powered vehicle, contained in a protective enclosure, with or without protective devices, cooling systems, and monitoring circuitry. See Figure 6.2.

Figure 6.2

Module – Boundary Diagram



6.3 CAPACITY, RATED (C_n) – 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.

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

6.5 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.

6.6 CELL, CYLINDRICAL – A cell format with a rigid case that has straight parallel sides and a round cross section.

6.7 CELL, POUCH – A cell format with a flexible laminate case that is typically a prismatic shape, and that can have its tabs on the same side or on opposite sides of each other.

6.8 CELL, PRISMATIC – A cell format with a rigid case that has a rectangular shape.

6.9 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 electric vehicle applications, charging of the electric energy storage assembly 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. Charge energy can be provided external to vehicle or by an on board generator (termed Extended Range EV).

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

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

6.12 DUT – Device under test.

6.13 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. See Figure 6.1.

6.14 ELECTRIC POWERED VEHICLE – An on-road or off-road vehicle that uses electricity from batteries or other electric energy storage assemblies as a source of energy for motive power. Electric powered vehicles cover, but are not limited to, road passenger vehicles and heavy duty off road vehicles such as industrial trucks.

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 unique 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", "ultra capacitor", "electrochemical double layer capacitor" and "super capacitor".

6.16 ENCLOSURE – The protective outer cover of the electric energy storage assembly that provides mechanical protection to the assembly's contents.

6.17 END-OF-DISCHARGE VOLTAGE (EODV) (Cell) – The voltage, under a specified load, of the cell at the end of discharge. The EODV may be specified by the manufacturer, as in the case of a voltage-terminated discharge typical for lithium ion chemistries.

6.18 EODV MONITORING (Cell) – EODV monitoring is typically provided at the pack/electric energy storage assembly level by the battery management system.

6.19 EXPLOSION – A violent release of energy that produces projectiles or a pressure wave from the DUT and results in DUT 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 electric energy storage assembly, pack, module or cell which has been charged to its full state of charge (SOC) as specified by the manufacturer.

6.22 FULLY DISCHARGED – An electric energy storage assembly, pack, module or cell, which has been discharged to its end-of-discharge voltage (EODV) as specified by the manufacturer.

6.23 HAZARDOUS ENERGY – Available power level of 240 VA or more, having a duration of 60 s or more, or a stored energy level of 20 J or more, at a voltage of 2 V or more.

6.24 HAZARDOUS VOLTAGE – Voltage exceeding 30 Vrms/42.4 Vpeak or 60 V dc.

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

a) BASIC INSULATION – A single level of insulation to provide basic 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.

6.26 LEAKAGE – A condition where liquid electrolyte escapes through the opening of a designed vent as well as through a rupture or crack or other unintended opening and is visible external to the device under test.

6.27 LIMITED POWER CIRCUIT – A circuit supplied by a power source that meets SELV limits and whose power and current are further limited in accordance with UL 2054. A limited power source is equivalent to a Class 2 circuit in accordance with Article 725 of the NFPA 70. A similar concept to limited power is the term “low-voltage limited energy” (LVLE) as defined in Section 16 of UL 583.

6.28 LITHIUM ION CELL – A rechargeable cell where electrical energy is derived from the insertion/extraction reactions of lithium ions between the anode and the cathode. The lithium ion cell has an electrolyte that typically consists of a lithium salt and organic solvent compound in liquid or gel or solid form and has either a hard metal casing or a flexible polymeric pouch casing.

6.29 MANUFACTURING PRODUCTION LINE TESTING – Testing at the manufacturer's facilities used as a manufacturing check of their production. Depending upon the testing, it either can be a 100% production test, or can be a periodic check or sampling of production. This testing is sometimes referred to as routine testing.

6.30 MAXIMUM WORKING VOLTAGE – The highest voltage to which the insulation or component under consideration is or can be subjected to when the equipment is operated under conditions of normal use.

6.31 MODULE – A subassembly consisting of a group of cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry. A module is a component of an electric energy storage assembly. See Figure 6.2.

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

6.33 MOSOC – Maximum Operating State of Charge.

6.34 NICKEL CELL – A general term for a nickel cadmium or nickel metal hydride rechargeable cell that has a nickel hydroxide positive electrode and either a cadmium metal or metal hydride negative electrode and that has a liquid alkaline (i.e. KOH) electrolyte.

6.35 NORMAL OPERATING REGION – That region of voltage, current, and temperature within which a cell or electrochemical capacitor can safely be 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 region 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 6.17.

d) 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.

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

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.

6.36 PROTECTIVE COMPONENTS, 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).

6.37 PROTECTIVE COMPONENTS, PASSIVE – Devices provided to prevent hazardous conditions that do not require electrical energy in order to operate. An example of a passive protective device would be a fuse.

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

6.39 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.

6.40 SAFETY CRITICAL CIRCUITS/COMPONENTS – Those circuits or discrete components that are relied upon for safety as identified in the safety analysis of Section 13.

6.41 SODIUM NICKEL CHLORIDE CELL – A rechargeable cell that has a sodium negative electrode, a positive electrode that consists of nickel, nickel chloride and sodium chloride and a ceramic beta alumina electrolyte. The normal operation of the cell is within a temperature range of 270°C – 350°C (518°F – 662°F) so that the active materials are in a molten state and to ensure ionic conductivity.

6.42 STATE OF CHARGE (SOC) – The available capacity in an electrical energy storage assembly, pack, module or cell expressed as a percentage of rated capacity.

6.43 THERMAL RUNAWAY (CELL) – A condition where an increase in temperature of the cell results in exothermic reactions that further increases the cell temperature due to increased reactions within the cell. A thermal runaway often leads to a destructive result such as a fire or explosion when the heat cannot be safety dissipated.

6.44 TOXIC GAS RELEASE (CRASH/NONOPERATIONAL LEVELS) – A release of vapor of an identified toxic substance that is categorized as an Emergency Response Planning Guidelines (ERPG) level 2.

a) ERPG-2 defines this as: "The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action." Methods for determination of this limit are outlined in Section 23.

6.45 TOXIC GAS RELEASE (OPERATIONAL LEVELS) – A release of vapor that results in a concentration of an identified toxic substance in excess of the Occupational Safety and Health Administration (OSHA) 8-h time-weighted-average (TWA) permissible exposure limit, which corresponds to the National Institute of Safety and Health (NIOSH) 10-h per day 40-h per week permissible exposure limit. Methods for determination of this limit are outlined in Section 23. In addition, the toxic substance concentration levels should not exceed the NIOSH short term exposure limits (STELS) or ceiling limits.

6.46 VEHICLE, OFF ROAD – A motorized conveyance that is not intended for transporting persons and/or objects on public roads including the highway systems. Examples of such devices would be industrial trucks, farming equipment, construction equipment.

6.47 VEHICLE, ON ROAD – A motorized conveyance that is intended for transporting persons and objects on public roads including the highway systems. Examples of such devices would be passenger autos, trucks, buses, etc.

6.48 VENTING – A condition when the cell electrolyte and/or battery solvent is emitted as vapor, smoke or aerosol from a designed vent or through a sealing edge.

6.49 VOLTAGE, NOMINAL – A specified operating potential of a battery at its fully charged state.

CONSTRUCTION

7 Non-Metallic Materials

7.1 The materials employed for enclosures shall comply with the applicable enclosure and insulation requirements outlined in CAN/CSA-C22.2 No. 0.17 / UL 746C, Path III of the table for Enclosure Requirements, Table 4.1, 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 CAN/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 CAN/CSA-C22.2 No. 0.17 / UL 746C.

7.3 The following factors, items (a) – (e), shall be taken into consideration when an enclosure 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 distortion test.

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 shall be suitable for temperatures encountered. Enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application, but no less than 100°C (212°F), as determined in accordance with CAN/CSA-C22.2 No. 0.17 / UL 746B.

7.5 Polymeric enclosure materials intended to be exposed to sunlight in the end-use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with CAN/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 or other safety hazard. Compliance is determined by the tests of this standard. Insulated wiring is subjected to the requirements outlined in Section 10.

7.7 Gaskets and seals relied upon for safety shall be determined suitable for the temperatures they are exposed to and other conditions of use.

8 Metallic Parts Resistance to Corrosion

8.1 Metal pack enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in CAN/CSA-C22.2 No. 94.2 / UL 50E. UL 583 is the end use application standard for off road industrial truck applications, and requires that the battery enclosure be 1.35-mm (0.053-in) thick minimum.

8.2 Metallic pack enclosures may be provided with an insulating liner to prevent shorting of battery conductors. 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 enclosure during operation of the pack. The insulating liner shall meet the Dielectric Voltage Withstand Test and Isolation Resistance Test.

8.3 Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table E.1 of Annex E shall be avoided.

Exception: Dissimilar metal combinations above the line may be chosen if provided with a coating to prevent corrosion such as silver or other protective coating determined to be sufficient for this purpose.

9 Enclosures

9.1 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 NEMA 60529, for a minimum IP rating of IP2X with consideration of the device as it is installed in the vehicle. (Evaluation per NEMA 60529, Clause 12, consists of the use of the IEC articulate probe applied with a force of 10 N ±10%).

Exception: For batteries that are intended for removal from the vehicle for external charging or replacement with a charged battery 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.

9.2 The pack shall be designed to prevent inadvertent access to hazardous voltage circuits during servicing or other handling of the electric energy storage assembly.

9.3 Vent openings or ventilation systems shall be located to prevent the dispersion of gases or toxic materials into the vehicle passenger compartment during an abnormal release.

9.4 The energy storage assembly shall comply with its IP rating for ingress of fluids and other foreign materials as determined by NEMA 60529. See Section 41.

Exception: The enclosure may alternatively be evaluated in accordance with UL 50E.

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 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 background with striping), or enclosed in junction boxes with hazardous voltage warning labels such as ISO No. 7010-W012.

Exception: Batteries used in electric-battery-powered industrial trucks complying with UL 583 need not comply with this requirement.

10.3 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.

10.4 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning, shifting in position, reducing electrical spacings or creating a short circuit.

10.5 An external terminal for connection to the vehicle shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in the vehicle.

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

10.7 The external terminals of an electric energy storage assembly 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 UL 2251, without being subjected to the exposure to contaminants.

11 Spacings and Separation of Circuits

11.1 Electrical circuits within the pack 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 temperatures and maximum voltages shall be used where spacings cannot be controlled by reliable physical separation.

11.2 Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 11.1 or the spacings requirements outlined in CAN/CSA-C22.2 No. 60950-1 / UL 60950-1, the clause for Clearances, Creepage Distances and Distances Through Insulation. See also 11.5.

Exception No. 1: As an alternative to the spacing requirements of Table 11.1, the spacing requirements in CSA-C22.2 No. 0.2 / UL 840, may be used. For determination of clearances, a dc source such as a battery does not have an overvoltage category as outlined in CSA-C22.2 No. 0.2 / and the section for Components in UL 840 unless charged through a source connected to a mains supply. The anticipated pollution degree is determined by the design and application of the electrical energy storage assembly or subassembly under evaluation.

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

Exception No. 3: For electric energy storage assemblies where external leakage of electrolyte may occur, the clearance and creepage distances of Clause 6.2 of ISO 6469-1, apply.

Table 11.1
Electrical spacings

Circuit ratings V	Minimum spacings	
	Through air Between parts of opposite polarity, live and non-current carrying parts and live and ground connections mm (in)	Over surface Between parts of opposite polarity, live and non-current carrying parts and live and ground connections mm (in)
30 – 50*	1.6 (1/16)	1.6 (1/16)
51 – 150	3.2 (1/8)	6.4 (1/4)
151 – 300	6.4 (1/4)	9.5 (3/8)
301 – 660	9.5 (3/8)	12.7 (1/2)

Table 11.1 Continued on Next Page

Table 11.1 Continued

Circuit ratings	Minimum spacings	
	Through air	Over surface
	Between parts of opposite polarity, live and non-current carrying parts and live and ground connections	Between parts of opposite polarity, live and non-current carrying parts and live and ground connections
V	mm (in)	mm (in)
661 – 1000	19.1 (3/4)	19.1 (3/4)
* 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.		

11.3 Conductors of circuits operating at different voltages shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest voltage involved.

11.4 An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different voltage.

11.5 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.

12 Insulation Levels and Protective Grounding

12.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and circuits as outlined in 12.2 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).

12.2 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.

12.3 Parts of the protective grounding system shall be reliably secured in accordance with 10.3 and provided with good metal-to-metal contact. The impedance from the various bonding conductors and connections to the main ground terminal shall have a maximum resistance of 0.1 Ω as determined by the test of Section 32.

12.4 The main ground terminal of the protective grounding 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 within a circle) or otherwise identified by a distinctive green color.

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

13 System Safety Analysis

13.1 An analysis of potential hazards (including an FMEA) shall be conducted on the device under test to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means. This analysis shall include interfaces with the vehicle systems as well as access by first responders and service personnel.

13.2 Documents that can be used as guidance for the safety analysis include:

a) IEC 60812;

b) IEC 61025;

c) SAE ARP4761;

d) SAE J1739;

e) MIL-STD-1629A;

f) IEC 61508 (all parts);

g) ISO 26262 (all parts); and

h) ISO 13849-1, the Determination of Required Performance Level (PLr) annex.

13.3 The analysis of 13.1 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the anticipated faults. The analysis shall consider single fault conditions in the protection circuit/scheme as part of the anticipated faults or shall identify the appropriate level of safety and determine that the protective circuits and mechanisms meet that level of safety, depending upon the approach taken. The analysis shall address the requirement that the cells remain within their safe operating regions under normal conditions and do not present a hazard under fault conditions in accordance with Section 14, but does not address the impact of a thermal runaway condition within a cell due to a latent cell defect or other causes.

13.4 When conducting the analysis of 13.1, active devices shall not be relied upon for critical safety unless:

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

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

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

d) The protective circuit has been shown to comply with the appropriate IEC 61508 Safety Integrity Level (SIL), IEC 62061 Safety Integrity Level Claim Limit (SIL CL), ISO 26262 Automotive Safety Integrity Level (ASIL), or ISO 13849-1 Performance Level (PL) as determined by the safety analysis.

13.5 Devices relied upon for critical safety as noted in 13.4 shall be tested for functionality in accordance with appropriate functional safety requirements and evaluated through the tests of this standard.

Evaluation shall consider the effects of EMC on the electronic and programmable electronic safety system as outlined in these standards. Functional safety criteria can be found in one of the following standards as appropriate to the design of the electronic and software protection scheme:

a) UL 991 and UL 1998;

b) UL 60730, the annex for Requirements for Electronic Controls;

c) IEC 61508 (all parts);

d) IEC 62061;

e) ISO 26262 (all parts); or

f) ISO 13849-1.

14 Protective Circuits

14.1 The electric energy storage assembly protective circuits shall be designed to maintain cells or electrochemical capacitors within their normal operating region for voltage, current, and temperature during charge and discharge. Sufficient monitoring and control circuits shall be provided to prevent overcharging, overdischarging and otherwise using cells outside of their safety operating parameters. The safety analysis of these circuits per Section 13 shall consider tolerances of the control circuit operating parameters to ensure that cell operating parameters are not exceeded during operation.

14.2 If normal limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond normal operating limits. If safety limits, as determined per Section 13, are exceeded, the protective circuit shall shut down the charging or discharging to prevent excursions beyond safety limits. Compliance is determined through a review of the pack and cell or electrochemical capacitor data and through the testing of this standard.

14.3 The electric energy storage assembly that has hazardous voltage circuits shall be provided with a hazardous voltage manual disconnect for servicing or access in the event of a vehicle collision. The disconnect shall meet the following criteria:

a) Disconnects both poles of the hazardous voltage circuit or circuits if multiple packs;

b) Located in a manner to disconnect the electric energy storage assembly circuit in half or located as close as possible to the positive and negative output terminals of the electrical energy storage assembly depending upon the design/configuration of the electric energy storage assembly;

c) Require manual action to break the electrical connection;

d) Disconnection is physically verifiable;

e) When engaged, it does not create exposed conductors capable of becoming energized while exposed and is insulated to prevent shock hazard during actuation;

f) Capable of disconnecting the hazardous voltage circuit under full load conditions at least one time; and

Exception: For batteries that are intended for removal from the vehicle for external charging or replacement with a charged battery rather than being charged while installed in the vehicle, the disconnecting means shall ensure a no load condition prior to disconnecting and connecting of the hazardous voltage circuit under full load for the anticipated service life of the connector-battery without hazard.

g) Able to be accessible and to be operated without the use of a tool or other special protective equipment (i.e. flash protection) in the event of a collision.

14.4 If a hazardous voltage automatic disconnect device is provided to isolate accessible conductive parts from the hazardous voltage circuit of the electrical energy storage assembly, 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) Be located near the pack terminals;

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

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

e) Provide isolation detection of 100 Ω/V or greater.

15 Cooling/Thermal Management Systems

15.1 Battery packs that rely upon integral cooling systems shall be designed to shut down upon failure of the cooling system unless it can be demonstrated through analysis and test that the cooling system failure does not result in a hazardous situation.

15.2 Piping, hose, and tubing used to contain liquid such as coolant shall be resistant to chemical degradation from the liquid it contains. It shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses.

15.3 Piping, hose, and tubing containing liquids, shall be routed and secured to prevent leakage that could result in a fire, explosion, or shock hazard.

16 Cells (Battery and Electrochemical Capacitor)

16.1 Cells shall be designed to safely withstand anticipated abuse conditions for vehicular applications. Compliance is determined by the requirements in this section and by the tests of this standard. Cell-level protection should be verified to be valid at the battery level also.

16.2 Secondary lithium cells including lithium ion cells shall comply with 16.3, the requirements outlined in either Annex B or Annex D, and be marked as required in 44.8 and 44.9.

16.3 With reference to 16.2, secondary lithium cell design shall ensure sufficient safety measures to mitigate internal short circuits and other hazardous conditions during the life of the cells. Safety measures to maintain cell safety include, but are not limited to, the following:

a) The appropriate choice and placement of insulation. IEEE 1625 and IEEE 1725 provide guidance on placement and application of insulation within cells and general cell design safety considerations;

b) Sufficient sizing of the negative electrode active materials to cover the positive electrode active materials;

c) Proper placement of insulation and separation of parts at opposite polarity including insulation and placement of tabs to prevent inadvertent short circuits during the life of the cell;

d) The use of appropriate protection mechanisms such as separator shutdown, protective coatings and electrolyte additives, etc.; and

e) The use of separators with sufficient strength, thermal properties and that are sized to prevent short circuit between the positive and negative electrodes during charge and discharge over the life of the cells.

16.4 With reference to 16.3, compliance to (a) – (e) is determined through a review of the cell construction as part of a tear down analysis, a review of documentation on the cell construction and components, and the cell tests of Annex B or D.

Table 16.1
Cell Tests from UL 1642
Table deleted

16.5 Nickel based cells shall comply with the cell requirements in UL 2054 per Table 16.2 with modifications as outlined in Exception No. 1 – 6 below.

Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined in UL 2054 to accommodate large cells intended for EV applications but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.

Exception No. 2: The overall external resistance for the short circuit test shall be less than or equal to 20 mΩ.

Exception No. 3: The crush test shall be a bar crush test rather than a flat plate crush using a bar with a 15-cm (5.9-in) diameter. The force is to be to be applied until one of the following occurs first:

a) A voltage (OCV) drop of one-third of the original cell voltage occurs; or

b) A deformation of 15% or more (in the direction of the crush) of initial cell dimension occurs; or

c) A force of 1000 times the weight of cell is reached.

Exception No. 4: For cells whose weight is greater than 500 g (1.1 lbs), the maximum temperature of the heating test shall be held for 30 min rather than 10 min.

Exception No. 5: The sample numbers for cell testing are to be reduced from 5 samples per test to 2 samples per test.

Exception No. 6: Nickel based cells that are sealed and formed as part of a monobloc battery, need only comply with the test requirements of this standard as part of the assembled battery/module.

Table 16.2
Cell Tests from UL 2054

UL 2054 test	UL 2054 reference
Short-Circuit Test	9.1 – 9.6
Abnormal Charging Test	10.7 – 10.9
Crush Test	Section 14
Impact Test	Section 15
Shock Test	Section 16

Table 16.2 Continued on Next Page

Table 16.2 Continued

UL 2054 test	UL 2054 reference
Vibration Test	Section 17
Projectile Test	Section 22
Heating Test	Section 23
Temperature Cycling Test	Section 24

16.6 Sodium nickel metal chloride cells shall comply with the requirements for sodium beta battery cells outlined in Annex B of UL 1973.

16.7 Lead Acid batteries shall comply with the pressure release test (if provided with a pressure release valve) and the flame arrester test (if provided with a flame arrestor) of UL 1989.

16.8 *Deleted*

16.9 Electrochemical capacitor cells shall comply with the single capacitor requirements outlined in UL 810A.

17 Manufacturing and Production Line Testing and Production Quality

17.1 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.

17.2 A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test, Section 30 shall be conducted on 100% production of Assemblies/packs with circuits exceeding 60 Vdc or 30 Vrms as outlined in Section 30.

Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s with a test voltage of 2.4 times the rated voltage of the circuit if using an ac test voltage or 3.4 times the rated voltage of the circuit if using a dc test voltage.

Exception No. 2: An isolation resistance test in accordance with Section 31, in an as-received condition (without humidity conditioning) may be conducted in lieu of the Dielectric Voltage Withstand Test.

17.3 A continuity check of the grounding system using an ohmmeter or other method, shall be conducted on 100% production employing protective grounding. The continuity check shall determine that measurements made on any two points of the grounding system do not exceed 0.1 Ω.

17.4 Manufacturers of electric energy storage assemblies and electric vehicle cells 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, electric energy storage assemblies shall be at 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 samples shall be allowed to rest for a maximum period of 8 h at room ambient.

18.2 Fresh samples (i.e. not more than 6 months old) representative of production are to be used for the tests described in Sections 25 – 43. 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 for electric energy storage assemblies and component electric energy storage assemblies

Test	Section	Number of EESA samples[a)]
Electrical Tests		
Overcharge[d)]	25	1
Short Circuit[d)]	26	1
Overdischarge Protection[d)]	27	1
Temperature	28	1
Imbalanced Charging	29	1
Dielectric Voltage Withstand	30	(Use Temperature sample)
Isolation Resistance	31	(Use Temperature sample)
Continuity	32	(Use Temperature sample)
Failure of Cooling/Thermal Stability System	33	1
Mechanical Tests		
Rotation[b) c)]	34	1
Vibration Endurance[c) d)]	35	1
Shock[c) d)]	36	1
Drop[d)]	37	1
Crush[c)]	38	1
Environmental Tests		
Thermal Cycling[d)]	39	1
Salt Spray[d)]	40	1
Immersion[d)]	41	1
External Fire Exposure[d) e)]	42	1
Single Cell Failure Design Tolerance[d)]	43	1
Material Tests		
20-mm End Product Flame Test (Note: Not conducted if minimum V-1)	7.1	3 test specimens of the part under test (polymeric enclosure sample)
[a)] The same sample is used for the tests of Sections 28, 30, 31, and 32. Samples from other tests may be re-used for multiple tests if still intact so that their re-use does not affect the test outcome 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.		

Table 18.1 Continued on Next Page

Table 18.1 Continued

Test	Section	Number of EESA samples[a)]
[b)] Applicable to assemblies employed in off road vehicles not subject to Motor Vehicle Safety Regulations (C.R.C., c. 1038) Technical Standards Document No. 305 / FMVSS 305 tests.		
[c)] Test may be conducted with assembly mounted in a representative framework of vehicle.		
[d)] Testing may be conducted on a representative subassembly.		
[e)] Applicable to assemblies that contain cells that do not meet projectile test requirements of this standard.		

18.3 Unless noted otherwise in the test method, assemblies shall be tested with cooling systems and controls functioning.

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

18.5 Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures are to be monitored in accordance with 20.2.

18.6 Thermocouples are to be attached to the central component module or as near as possible to the central component module when monitoring for general conditions of the electric energy storage assembly. Temperature shall be measured using thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) (i.e. Type J special or Type K) 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.

Exception: For general safety monitoring of temperatures (i.e. monitoring for general temperature state of assembly and not for compliance data), the onboard temperature monitoring system may be utilized if not compromised from the testing.

19 Determination of Potential for Fire Hazard

19.1 In addition to visible signs of fire, non-compliant tests results for fire shall also include an evaluation for potential flammable concentrations of vapors with the use of a minimum of two continuous spark sources as described below:

a) The continuous spark sources are to provide at least two sparks per second with sufficient energy to ignite natural gas and are to be located near anticipated sources of vapor such as vent openings or at the vent duct.

Exception: A gas monitor suitable for detecting 25% of the lower flammability limit of the evolved gases measuring at a minimum of two sampling locations may be used instead of the spark sources.

19.2 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 Important Test Considerations

20.1 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 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. Test facilities shall be equipped to contain, mitigate, and exhaust toxic fumes and particulate matter that may be generated during the tests of this standard including the External Fire Exposure Test of Section 42. See also 19.2.

20.2 As an additional precaution, the temperatures on surfaces of the DUT are to be monitored during the tests per 18.6. All personnel involved in the testing of electric energy storage assemblies are to be instructed to never approach the DUT until temperatures are falling and are below 45°C (113°F). The OCV of the DUT are to be monitored also during testing if possible for information purposes.

21 Single Fault Conditions

21.1 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 electrical energy storage assembly that could occur as identified in the system safety analysis of Section 13 and that could affect the results of the test.

22 Test Results

22.1 Tests that result in one or more of the following conditions as defined in Section 6 shall be considered as non-compliant for the test as noted in Table 22.1. Details of passing results criteria are provided in the individual test methods.

Table 22.1
Noncompliant test results

Non-compliant results	Designation	Tests[a]
Explosion	E	All tests
Fire	F	All tests except external fire exposure
Combustible Concentrations	C	All tests except external fire exposure and single cell failure design tolerance
Rupture (enclosure)	R	All tests except external fire exposure, single cell failure design tolerance and crush
Leakage (external to enclosure)	L	All tests except external fire exposure, single cell failure design tolerance and crush
Venting[c]	V	All tests except crush, drop, rotation, immersion, external fire exposure, and single cell failure design tolerance: • Operational level limit if applicable (i.e. venting into passenger compartment) when using analysis methods per Section 23 for all tests. Crush, drop, and rotation tests include the following ventilation check: • Crash/Nonoperational level limit: Toxic gas release of ERPG-2 or greater when using analysis methods per Section 23.
Electric shock hazard (resistance below isolation resistance limits)	S	All tests (if hazardous voltage) except immersion, external fire exposure, and single cell failure design tolerance
Loss of protection controls[b]	P	All tests except external fire exposure, single cell failure design tolerance, crush, and immersion

Table 22.1 Continued on Next Page

Table 22.1 Continued

Non-compliant results	Designation	Tests[a]
[a] For tests that evaluate one specific part of the DUT such as the mold stress, continuity, dielectric voltage withstand, isolation resistance and material 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 during the after test cycling when operational.		
[c] Vapors from internal cell venting as a result of testing are allowed to exit the enclosure only through intended exhaust openings and not into the passenger compartment. If venting into the passenger compartment can occur, analysis per Section 23 shall be conducted. See also definitions regarding toxic gas release in 6.44 and 6.45.		

22.2 For the following tests, if the DUT is still operational after the test (a fuse may be replaced or resettable device reset), it shall be subjected to a minimum single charge/discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

a) Overcharge;

b) Short Circuit;

c) Overdischarge Protection;

d) Imbalanced Charging;

e) Failure of Cooling/Thermal Stability System;

f) Rotation;

g) Vibration Endurance;

h) Shock;

i) Drop;

j) Temperature Cycling; and

k) Salt Spray.

22.3 For those tests where rupture is identified as a non-compliant results, 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 9.1 shall be applied.

23 Determination of Toxic Emissions

23.1 Toxic emissions, as defined in 6.44 and 6.45, through openings other than exhaust openings during testing are not allowed or limited to ERPG-2 levels or OSHA TWAs, STELS and ceiling limits in those tests as identified in Table 22.1. Manufacturers shall provide analysis as outlined in Section 4.1.4 of SAE J2464 if there is potential for toxic gas release into the passenger compartment during the tests of this standard. If analysis indicates the potential for toxic gas release within the passenger compartment, monitoring during testing shall be conducted using one of the following or equivalent techniques as determined applicable in (a) – (d) below. For some toxic substances, multiple values are provided for TWAs, STELs and ceiling limits. The lowest published values shall be used for determining compliance.

a) ASTM D4490;

b) ASTM D4599; or

c) The OSHA Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis.

d) The NIOSH Manual of Analytic Methods.

Exception: No cell venting as a result of testing is considered a compliant result without additional monitoring as noted above.

23.2 To determine the concentration of toxic emissions, testing is to be conducted in a closed test chamber of known volume large enough to contain the DUT. Results obtained from sampling the emissions shall be scaled to estimate the anticipated exposure and concentration of toxic materials within the passenger compartment.

24 Tolerances

24.1 Unless noted otherwise in the test methods, the overall accuracy of controlled or measured values when conducting testing in accordance with this standard, shall be within the following tolerances:

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;

e) ±1% for dimension.

24.2 These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

ELECTRICAL TESTS

25 Overcharge Test

25.1 This test is intended to evaluate a EESA and its associated protection circuitry ability to withstand an overcharge condition.

Exception: Overcharge testing on a subassembly may be conducted instead of the complete EESA if determined to be representative of the EESA.

25.2 A fully discharged sample (i.e. discharged to the manufacturer's specified EODV) is to be subjected to the maximum specified charging rate of the battery assembly with a single fault condition in the charging circuit of the pack that could lead to an overcharge condition. See Section 21 for a description of a single fault condition. The charging parameters utilized for this test are to be based upon the maximum designed charging parameters for the intended vehicle application. See 6.9.

25.3 The test is to continue until ultimate results occur. 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 voltage or temperature controls. The DUT is monitored per 18.5 and 20.2; or

b) Where an automatic interrupt function fails to operate, or no such function for the charging is provided and the DUT is charged to 110% of its rated charge capacity or a manufacturer-specified limit. (reaching 110% of the rated charge capacity or the manufacturer-specified charging limit would be considered as a failure of the overcharge evaluation); or

c) EESA failure occurs as evidenced by explosion, fire.

25.4 During the test, a spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

25.5 At the conclusion of the test and after cooling to near ambient, the samples shall be examined for signs of damage and subjected to an "as received" isolation resistance test in accordance with 31.2(a).

25.6 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the electric energy storage assembly enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

25.7 If the DUT is operational after the overcharge test (fuses may be replaced and/or resettable devices reset), it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

26 Short Circuit Test

26.1 This test is to be conducted on fully charged samples (MOSOC per 18.1) to determine their ability to withstand an external short circuit.

Exception: Short circuit testing on a subassembly may be conducted instead of the complete EESA if determined to be representative of the EESA.

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

26.3 Testing is repeated at a load that draws a maximum current no less than 15% below the operation of the short circuit protection.

26.4 Tests are to be conducted at room ambient. The samples are to reach equilibrium temperature before the terminals are connected.

26.5 The sample is to be completely discharged (i.e. discharged until near zero state of charge/its energy is depleted), and/or the temperature on the center module has peaked or reached a steady state condition and 7 h has elapsed or a fire or explosion has occurred.

26.6 During the test, samples supplied with protective devices shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 13 for details regarding single fault conditions.

26.7 During the test, a spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

26.8 At the conclusion of the test and after cooling to near ambient, the samples shall be examined for signs of damage and subjected to the "as received" isolation resistance test in accordance with 31.2(a).

26.9 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

26.10 If the DUT is still operational after the short circuit test (fuses may be replaced and/or resettable devices reset), it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specification. The DUT shall operate as intended.

27 Overdischarge Protection Test

27.1 This test is to be conducted on a fully charged sample (MOSOC per 18.1) to determine the DUTs ability to withstand an overdischarge condition and is conducted with all discharge protection circuitry for both temperature and minimum voltage connected to prevent irreparable cell damage.

Exception: Overdischarge protection testing on a subassembly may be conducted instead of the complete EESA if determined to be representative of the EESA.

27.2 The DUT is to be subjected to a constant discharging current at the manufacturer's specified maximum discharge rate. The DUT is to be discharged until the passive protection device(s) are activated, the minimum cell voltage/maximum temperature protection is activated, or the DUT has been discharged for an additional 30 min after it has reached its specified normal discharge limits, whichever comes first.

27.3 During the test, a spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

27.4 At the conclusion of the test and after cooling to near ambient, the samples shall be examined for signs of damage and subjected to the "as received" isolation resistance test in accordance with 31.2(a).

27.5 The protection device(s) shall activate to prevent cells from going below their cut-off voltage limit. There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly enclosure except through designated ventilation systems or openings. There shall be no rupture of the enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

27.6 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the overdischarge protection test, it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

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 pack. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components in the pack including cells are being maintained within their temperature ratings based upon the maximum operating temperature limits of the pack.

28.2 A fully discharged EESA (i.e. discharged to EODV) is to be conditioned within a chamber set to the upper limit charging temperature specifications of the EESA. After being stabilized at that temperature (i.e. all cell temperatures are estimated to be within ±10°C (±18°F) of the chamber temperature for 1 h), 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 modules until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells.

28.3 While still in the conditioning chamber, and after allowing temperatures to stabilize (i.e. all cell temperatures are estimated to be within ±10°C (±18°F) of the chamber temperature for 1 h), the fully charged DUT (MOSOC per 18.1) 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 modules. Temperatures shall be monitored on temperature sensitive safety critical components including cells.

28.4 The charge and discharge cycles are then repeated for a total of 5 complete cycles of charge and discharge.

28.5 The manufacturer's specified limits (voltage, current and temperatures measured) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications.

29 Imbalanced Charging Test

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

29.2 A fully charged EESA (MOSOC per 18.1) shall have all of its modules with the exception of one discharged to its specified fully discharged condition. The undischarged module shall be discharged to approximately 50% of its specified state of charge (SOC) to create an imbalanced condition prior to charging.

29.3 The sample shall then be charged in accordance with the manufacturer’s specifications. The voltage of the partially charged module shall be monitored during the charging to determine if its voltage limits are being exceeded.

29.4 During the test, a spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

29.5 At the conclusion of the test and after cooling to near ambient, the DUT shall be examined for signs of damage and subjected to an "as received" isolation resistance test in accordance with 31.2(a).

29.6 There shall be no evidence of fire or explosion. The minimum isolation resistance of the DUT shall be 100 Ω/V. There shall be no venting of vapors external to the EESA enclosure except through designated ventilation systems or openings. There shall be no rupture of the enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

29.7 The maximum voltage limit of the module shall not be exceeded when charging an imbalanced EESA.

29.8 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the imbalanced charging test, it shall be subjected to a discharge and then a charge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

30 Dielectric Voltage Withstand Test

30.1 This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits of the electric energy storage assembly.

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

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: 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 or connected to accessible parts of a vehicle.

30.4 The test voltage is also to be applied between the hazardous voltage charging circuit and charging connections of the DUT 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.

30.6 The test voltages shall be applied for a minimum of 1 min. The test voltage should be applied between the positive terminal or negative terminal and the accessible non-current carrying part in turn, to avoid short circuiting between the positive and negative terminals.

30.7 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.

31 Isolation Resistance Test

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

31.2 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:

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.

31.3 As an exception to the method outlined in ISO 6469-1, an insulation resistance test using a dc voltage applied to the circuit under test may be conducted. For this method, the insulation resistance is to be measured using a megohmmeter after application of a dc voltage for 1 min that is higher than the circuit under test. (i.e. at least have the working voltage of the high voltage dc bus or circuit under test if higher).

31.4 The DUT is to be in the fully charged state for both (a) and (b) in 31.2.

31.5 For condition 31.2(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.

31.6 For both (a) and (b) of 31.2 and 31.3, the isolation resistance divided by the maximum working voltage of the circuit under test, shall be at least 100 Ω/V for dc and 500 Ω/V for ac or for circuits containing both ac and dc parts.

32 Continuity Test

32.1 This test evaluates the continuity of the protective grounding system of the electric energy storage assembly.

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 32.4.

32.3 The voltage drop in a protective grounding system is measured after applying a test current of 150% of the maximum 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.

33 Failure of Cooling/Thermal Stability System Test

33.1 This test attempts to evaluate the electrical energy storage assembly's ability to safely withstand a failure in the cooling/thermal stability system.

33.2 The DUT is to be fully discharged to the manufacturer's end of discharge condition EODV and then conditioned at maximum specified operating ambient for a period of 7 h. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled is to then be charged at its maximum specified charge rate until completely charged or until operation of a protective device.

33.3 The DUT is to be fully charged (MOSOC per 18.1) and then conditioned at maximum specified operating ambient for a period of 7 h. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled is to then be discharged at the maximum discharge rate until it reaches its specified end of discharge condition or until operation of a protective device.

33.4 During the test, a spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

33.5 At the conclusion of the test and after cooling to near ambient, the DUT shall be examined for signs of damage and subjected to an "as received" isolation resistance test in accordance with 31.2(a).

33.6 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

33.7 The test method of 33.2 – 33.6 shall be repeated with the DUT conditioned at the minimum specified operating ambient.

Exception: The tests at minimum ambient as outlined may be waived if it can be determined through analysis that no hazard will result in charging and discharging at minimum ambient without the cooling/thermal stability system functioning. (i.e. sodium nickel metal chloride system is not energized in cold states).

33.8 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the Failure of Cooling/Thermal Stability System Test, it shall be subjected to a discharge and then a charge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

MECHANICAL TESTS

34 Rotation Test

34.1 A sample of the electric energy storage assembly shall be subjected to a 360° rotation to simulate an overturned vehicle.

Exception No. 1: Electric energy storage assemblies intended for use in on road vehicles as defined in 6.47 subjected to a rollover test in accordance with the Motor Vehicle Safety Regulations (C.R.C., c. 1038) Electrolyte Spillage and Electrical Shock Protection (Standard 305), Document No. 305, / FMVSS 49 CFR 571 305, need not be subjected to this test.

Exception No. 2: The sample may be mounted within a mounting fixture representative of the intended end use vehicle application.

34.2 The sample charged to MOSOC of 18.1, shall be rotated at a continuous rate of 90°/15 s. Testing shall be conducted subjecting the sample to a 360° rotation in 3 mutually perpendicular different directions. DUTs with only 2 axes of symmetry, such as cylindrical designs are subjected to 2 mutually perpendicular directions of rotation. A spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample. At the conclusion of the test and after cooling to near ambient, the packs shall be examined for signs of damage and subjected to an "as received" isolation resistance test in accordance with 31.2(a).

Exception: Flooded lead acid batteries are not subjected to this test.

34.3 As a result of the rotations, there shall be no evidence of fire or explosion. There shall be no toxic gas release as defined in 6.44. The minimum isolation resistance shall be 100 Ω/V. Non-complying results are as noted in Table 22.1.

34.4 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the rotation test, it is to be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

35 Vibration Endurance Test

35.1 The test is intended to evaluate the electric energy storage assembly's ability to withstand simulated vibration that would occur over the life of the device. The sample is to be fully charged (MOSOC per 18.1) for this test.

35.2 A sample of the electric energy storage assembly is subjected to a vibration endurance test in accordance with the anticipated end application vehicle vibration profile. In the absence of this information, the vibration method outlined in SAE J2380, shall be used.

Exception No. 1: This test may be conducted at the module level for those electric energy storage assemblies intended for use in applications larger than passenger vehicles. The module level testing shall be representative of the electric energy storage assembly. The vibration profile used shall be from SAE J2380.

Exception No. 2: Electric energy storage assemblies intended for installation in off-road vehicles evaluated to UL 583 may instead be vibration tested in accordance with ISO 6469-1. The vibration shall be conducted in an ambient temperature of 25 ±5°C (77 ±9°F) throughout the test rather than varying the temperature.

35.3 During the test the OCV of the sample and temperatures on the center module shall be monitored for information purposes.

35.4 A spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

35.5 The samples shall be examined 8 – 24 h after testing. After the 8 – 24 h rest period and after cooling to near ambient, the samples shall be examined for signs of damage and subjected to an "as received" isolation resistance test in accordance with 31.2(a).

35.6 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the electric energy storage assembly enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

35.7 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the vibration test, it is to be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

36 Shock Test

36.1 This test is meant to determine whether or not the electric energy storage assembly can withstand a mechanical shock that may occur when in use in an electric vehicle.

36.2 The sample is to be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. During the test, temperatures on the center module are monitored for information purposes.

Exception: The sample may be mounted within a mounting fixture representative of the intended end use vehicle application.

36.3 A fully charged sample (MOSOC per 18.1) is to be subjected to the half sine wave shock test in accordance with IEC 60068-2-27, with the parameters as outlined in Table 36.2. The samples shall be examined for signs of damage 6 – 24 h after the shocks have been applied and after the sample has approached ambient temperature.

Exception No. 1: This test may be conducted at the module level for those electric energy storage assemblies intended for use in applications larger than passenger vehicles. The module level testing shall be representative of the electric energy storage assembly.

Exception No. 2: For electric energy storage assemblies intended for installation in off-road vehicles evaluated to UL 583, the DUT may instead be subjected to mechanical shock testing with parameters as *shown in Table 36.1. The shocks shall be applied in all 6 spatial directions for a prismatic DUT and 3 spatial directions for cylindrical DUT.*

Table 36.1
Shock parameters for off-road vehicles

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

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

Table 36.2
Shock parameters

Waveform	Peak acceleration	Pulse duration, ms	Total number of mutually perpendicular axes for test	Number of shocks in positive and negative direction of each axis	Total number of shocks per sample
Half sine wave	25 g_n	15	3	3	18

36.4 A spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

36.5 After the 6 – 24 h rest period and after cooling to near ambient, the samples shall be subjected to in isolation resistance test in accordance with 31.2(a).

36.6 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the electric energy storage assembly enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

36.7 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the shock test, it is to be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

37 Drop Test

37.1 This test is intended to evaluate whether a hazard exists when a electric energy storage assembly (EESA) is subjected to an inadvertent drop during installation or removal from the vehicle.

37.2 After being equilibrated at room temperature, an electric energy storage assembly at MOSOC per 18.1 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 EESA during servicing.

37.3 With reference to 37.2, if only one drop test is performed, it shall not be a flat drop. If the EESA is intended to be installed or removed in a horizontal direction, a drop with the DUT slanted at a 10° angle with pack edge impacted, should be considered.

37.4 With reference to 37.2, if one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.

37.5 The sample is to be dropped a minimum of one time.

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

37.7 The samples shall be examined for signs of damage within a time frame of 6 – 24 h after dropping. During the test, temperatures shall be monitored. If the sample returns to or remains near ambient, an isolation resistance test in accordance with 31.2(a) is to be conducted.

37.8 A spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample immediately after the drop and repeated in the instance of increasing temperatures.

37.9 There shall be no evidence of fire or explosion. There shall be no toxic gas release as defined in 6.44. The minimum isolation resistance shall be 100 Ω/V.

Exception: For energy storage assemblies intended for removal from the vehicle for charging and replacement, the total number of drops shall be a minimum of 3 times on a single sample. In addition to the criteria, there shall be no damage of the enclosure that would allow hazardous voltage parts to be accessed with the articulate finger evaluation of 9.2 on the DUT.

37.10 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the drop test, it is to be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended.

38 Crush Test

38.1 This test is conducted on a fully charged electric energy storage assembly to determine its ability to withstand a crush that could occur during a vehicle accident.

38.2 A sample shall be crushed between a fixed surface and a ribbed test platen in accordance with the text fixture described in SAE J2464, with the following exceptions as noted below. Packs with 3 axes of symmetry, are subjected to 3 mutually perpendicular directions of press. A different sample of the DUT may be used for each crush.

Exception No. 1: The maximum force applied to the DUT is to be 100 ±6 kN.

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

Exception No. 3: The DUT may be installed in a protective framework representative of what is provided in the vehicle.

38.3 A spark ignition source as outlined in Section 19 shall be used to detect the presence of flammable concentrations of gases within the sample.

38.4 The samples shall not explode or catch fire. There shall be no toxic gas release as defined in 6.44.

ENVIRONMENTAL TESTS

39 Thermal Cycling

39.1 This test determines the electrical energy storage assembly's ability to withstand exposure to rapidly changing environments such as when the vehicle is entering or exiting a heated garage after being in a cold environment, or during transport etc. without evidence of damage that could lead to a hazardous event.

39.2 A fully charged electrical energy storage assembly (MOSOC per 18.1) shall be subjected to the thermal shock test of SAE J2464, except that the temperature extremes are from 85 ±2°C to −40 ±2°C (185 ±3°F to −40 ±3°F).

Exception: Testing may be conducted at the module level that is representative of the energy storage assembly.

39.3 At the conclusion of the tests, the sample is returned to ambient and then subjected to a charge discharge cycled in accordance with the manufacturer's specifications if still operational (fuses may be replaced and/or resettable devices reset). The DUT shall operate as intended. The sample is examined for signs of damage and is then subjected to an as received isolation resistance test in accordance with 31.2(a).

39.4 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the electric energy storage assembly enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

40 Salt Spray Test

40.1 This test determines the electrical energy storage assembly's ability to safely withstand anticipated exposure to a salt mist conditions due to either to vehicle use near marine environments, or due to salt de-icing utilized on roads during winter months.

40.2 A fully charged electrical energy storage assembly (MOSOC per 18.1) shall be subjected to the test method per IEC 60068-2-52, with a severity level of 6.

Exception No. 1: A sample at the module level that would be representative of the electric energy storage assembly may be used for this test.

Exception No. 2: This test may be modified to a severity level of 1 for those EESAs not intended to be installed in an underbody location but may have some exposure to salt fog.

Exception No. 3: This test may be waived for those EESAs not intended to be located where they will be subject to salt exposure, such as those EESAs that are provided with an enclosure that prevents salt fog exposure (i.e. IP67) and not intended to be installed in an underbody location, or those EESAs intended for use on off-road vehicles evaluated to UL 583 that are not exposed to salted roads or marine applications.

Exception No. 4: This test may be waived on an EESA whose enclosure has been evaluated for outdoor use and resistance to corrosion (i.e. NEMA Type 4X or 6P) per UL 50E.

40.3 If the DUT is still operational (fuses may be replaced and/or resettable devices reset) after the salt spray test, it is to be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. The DUT shall operate as intended followed by an observation period.

40.4 At the conclusion of the tests, the sample is examined for signs of damage and shall be subjected to an as received isolation resistance test in accordance with 31.2(a).

40.5 There shall be no evidence of fire or explosion. The minimum isolation resistance shall be 100 Ω/V. There shall be no venting of vapors external to the electric energy storage assembly except through designated ventilation systems or openings. There shall be no rupture of the electric energy storage assembly enclosure or visible evidence of leakage of electrolyte external to the enclosure. Non-complying results are as noted in Table 22.1.

41 Immersion Test

41.1 This test is intended for those electric energy storage assemblies intended for potential immersion (i.e. underbody location). Other applications shall be evaluated based upon their environmental protection rating. See 9.4. This test is conducted on a fully charged electrical energy storage assembly (MOSOC per 18.1) and is intended to determine its resistance to temporary immersion in water from flooding of a vehicle.

41.2 With the DUT in its normal operating orientation and with switches/contactors in closed position and with the output cable connected representative of the end use vehicle application (with the opposite end of the cable outside of the water), it shall be subjected to the immersion. The DUT is to be immersed in salt water (5% by weight NaCl in H_2O) at room temperature for a minimum of 1 h or until any visible reactions have stopped. The water depth is to be sufficient to completely submerge the DUT.

Exception: Testing may be conducted at the module level that is representative of the energy storage assembly.

41.3 As a result of the immersion, there shall be no fire or explosion. Non-complying results are as noted in Table 22.1.

42 External Fire Exposure Test

42.1 The purpose of this test is to determine an electrical energy storage assembly's ability to prevent an explosion as a result of exposure to a simulated fuel or vehicle fire external to the electrical energy storage assembly.

Exception No. 1: If the cells employed in the assembly comply with the projectile test in Annex B or Annex D, the assembly is exempted from this test.

Exception No. 2: Testing may be conducted at the module level that is representative of the energy storage assembly.

Exception No. 3: The "Exposure to Fire" test of ISO 6469-1 may be conducted as an alternative to this test.

42.2 A fully charged electrical energy storage assembly (MOSOC per 18.1) shall be subjected to a uniform fire source along the length of the assembly at its bottom surface. The center of the fire source shall be placed at the center of the assembly. Any fuel may be used as the fire source as long as it provides the specified temperatures for the test as outlined in 42.4 for the duration of the test.

42.3 During the test, surface temperatures on the DUT enclosure shall be monitored. Thermocouples on the enclosure shall be placed 25 mm (1 in) from the bottom of the assembly. Metallic shielding shall be used to prevent direct flame impingement on thermocouples.

42.4 Within 5 min of ignition, at least one thermocouple shall indicate a minimum temperature of 590°C (1094°F). The test is concluded when this minimum temperature indication of 590°C (1094°F) has been maintained for 20 min.

42.5 To determine that an explosion hazard has resulted, the DUT with fire test set up, is to be centered within a circular inner perimeter area marked on the floor/supporting surface with paint or a similar marking material. The marking is to be no thicker than 12 mm (0.47 in) and the size of the circular inner perimeter area marking is to be no greater than 1.0 m (3.3 ft) from the outer edge of the longest side of the DUT. The DUT, test set up and inner perimeter markings are to be enclosed within an outer perimeter consisting of a protective barrier wall of a non-combustible material and wall thickness suitable for containing projectiles during the test. The outer perimeter is to be located approximately 1.5 m (4.9 ft) from the circular inner perimeter marking.

42.6 As a result of this test, there shall be no explosion of the DUT that results in projectiles falling outside of the circular inner perimeter described in 42.5.

TOLERANCE TO INTERNAL CELL FAILURE TESTS

43 Single Cell Failure Design Tolerance

43.1 General

43.1.1 Since there is a possibility that a cell may fail within a battery system, the battery system shall be designed to prevent a single cell failure from propagating to the extent that there is fire external to the DUT or an explosion.

43.1.2 The cell failure mechanism used for this testing shall reflect what is known or anticipated to occur in the field for a given technology. If the cell failure mechanism cannot be exactly replicated, a close simulation of what is known to occur in the field through the use of an external stress such as applied heating or mechanical force shall be utilized for the test. Examples of methods to simulate a single cell failure are outlined in Annex C. Multiple tests and possible multiple failure methods may need to be conducted as part of the analysis before a final methodology for testing is determined.

43.2 Single cell failure design tolerance (lithium ion)

43.2.1 A lithium ion battery system shall be designed to mitigate a single cell failure leading to a thermal runaway of that cell. With lithium ion batteries, it is often the effects of propagation to surrounding cells due to the heating effect of the initial cell failure that leads to hazardous events. The DUT (e.g. battery pack or module) shall be designed to prevent a single cell thermal runaway failure from creating a significant hazard as evidenced by fire propagation outside of the DUT and/or an explosion.

43.2.2 Any number of methods can be used to produce a single cell thermal runaway failure. For example, thermal runaway in cells can be achieved through the use of heaters, nail penetration, overcharge, etc. It is recommended to evaluate a candidate method first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures should be taken on the cell casings, and voltages measured for information purposes. See Annex C for guidance on several methods of inducing cell failure.

43.2.3 The details of the method used when analyzing the cell's reaction that can impact the results are to be documented. For example, if heating the cell to achieve failure: e.g. the type of heater and its dimensions, location on the cell where the heater is placed and how it is placed, maximum temperature attained including temperature ramp rate, length of time until reaction, temperatures on cell and voltage, state of charge of the cell at the beginning of the heating phase, etc. The test article shall be representative of the actual battery configuration and any modifications should not significantly impact the test results. For example, if overcharge is to be carried out, the heat conduction path between tabs shall not be hindered as that may reduce the severity of the test.

43.2.4 Once a suitable method of cell failure has been determined, the fully charged DUT (MOSOC per 18.1) shall be subjected to the single cell failure tolerance test, which consists of inducing a fault in one internal cell that is within the DUT, until cell failure resulting in thermal runaway as defined in 6.43 occurs, and determining whether or not that failure produces a significant external hazard or whether or not that failure does not cause the failure of neighboring cells. If cascading occurs, the cascading shall not propagate beyond the DUT. Prior to choosing the specific cell to fail, an analysis of the DUT design to determine the cell location considered to have the greatest potential to lead to a significant external hazard shall be conducted, taking into consideration the cell's proximity to other cells and materials that may lead to potential for propagation. If it can impact the results, the sample shall be at the maximum specified temperature during charging and operation with some tolerance as necessary for movement of the sample outside of the chamber during testing, but within ±5°C (±9°F). Once the thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 1-h observation period.

Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location represents the worst case scenario. The location of the failed cell is to be documented for each test.

Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the module in the final assembly. Temperatures on DUT external surfaces and surfaces of parts in contact with or near the DUT in the final assembly, shall be monitored to determine if excessive temperature on these adjacent parts could result in a potential for propagation within the full battery system. If there are excessive temperatures on the surfaces that may lead to potential for propagation, testing shall be repeated with all adjacent components in place of a complete battery system.

43.2.5 Temperatures on the failed cell and surrounding cells are to be monitored and reported for information purposes.

43.2.6 As a result of the testing of 43.2, there shall be no external fire propagating from the DUT or explosion of the DUT within specific time.

43.3 Single cell failure design tolerance (other technologies)

43.3.1 Other technologies such as lithium metal, sodium sulfur and sodium nickel chloride shall be subjected to a single cell failure test method similar to 43.2, except as modified as noted below. The failure mechanism for these technologies may be different than that of lithium ion and thermal runaway may or may not result from the cell failure. Similar to lithium ion, when choosing a cell failure technique, it shall be representative of what can occur in the field for the particular technology. The failure mechanism chosen shall consider failures due to potential cell manufacturing defects for that technology and/or cell and battery design deficiencies that could lead to latent failures of the cell, and that would not be evident under the individual cell safety testing.

43.3.2 For other technologies, a candidate method shall be evaluated first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures shall be taken on the cell casings, and voltages measured for information purposes. See Annex C for guidance on several methods of inducing cell failure.

43.3.3 When a suitable worse case representative method for cell failure has been determined, the DUT shall be subjected to the internal cell failure occurring in the location within the DUT considered most vulnerable to the potential for propagation. The DUT shall be in a condition that reflects its operating parameters at the worst moment such a failure could occur. For example, the DUT shall be at its nominal operating temperature. During the test, temperatures shall be monitored in critical locations such as adjoining cells during the test to record the rise in temperature due to the internal failure. If no thermal runaway occurs as a result of the single cell failure, the test is stopped when the DUT temperature has stabilized or reaches ambient room temperature, and the DUT is subjected to a 24-h observation period. If a thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 1-h observation period.

Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location tested represented the worst case scenario. The location of the failed cell is to be documented for each test.

Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the modules in the final assembly.

43.3.4 As a result of the testing per 43.3.3, there shall be no fire propagating from the DUT or explosion of the DUT.

MARKINGS

44 Markings

44.1 Required markings shall be permanent. If the markings are on adhesive labels, the labels shall either comply with the requirements of UL 969 for the surface adhered to and anticipated exposures or the labels shall comply with the Label Permanence Test of UL/ULC 2271.

44.2 Electric Energy Storage Assemblies are to be marked with the manufacturer's name, trade name, trademark, or other descriptive marking which may identify the organization responsible for the product, part number, or model number. The assemblies shall also be marked with their electrical ratings in nominal volts dc and Ah or Wh, and marked with their chemistry (i.e. lithium ion, ni-cad etc.) for battery and hybrid battery/electrochemical capacitor assemblies and marked in volts dc and farads for electrochemical capacitor assemblies.

44.3 Electric energy storage assemblies intended for off road applications such as industrial trucks that require the use of a specific charger, shall be marked with charging instructions. An example of such markings would be the following or equivalent ″Use Only (__) Charger″. The marking shall be visible to the user, including after installation, if the ESSA is not removed for charging. If applicable, the installation instructions shall indicate the need to include this charging marking on the external surface of the vehicle near the exposed charging connection. See 45.3. Additional markings are not required on the EESAs if the charger plugs and receptacles are uniquely keyed, and for vehicles that use communications between vehicle and charger or other methods to prevent charging by non-approved chargers.

44.4 Electric energy storage assemblies are to be also marked with the date of manufacture, which may be in the form of a code that does not repeat within 10 years.

44.5 All external terminals and connections shall be provided with identification and if applicable, polarity markings.

44.6 The point of connection to the charger grounding system shall be identified by the word "Ground" or the letters "G" or "GR" or the grounding symbol (IEC 60417, No. 5019) or otherwise identified by a distinctive green color.

44.7 The electric energy storage assembly that contains hazardous voltage circuits shall be marked with the following or be marked with the electric shock hazard symbol ISO 3864 No. 5036 (lightning bolt within a triangle):

In Canada:

In English: "Warning: Hazardous Voltage Circuits"; and

In French: « Attention: Circuits à tension élevée »

In the United States:

"Warning: Hazardous Voltage Circuits".

44.8 With reference to 16.2, a secondary lithium cell shall be legibly and permanently marked with:

a) The manufacturer’s or supplier's name, trade name, or trademark or other descriptive marking by which the organization responsible for the product may be identified;

b) A distinctive catalog, model or designation number or the equivalent; and

c) The date or other dating period of manufacture not exceeding any three consecutive months.

Exception No. 1: The manufacturer’s identification may be in a traceable code if the product is identified by the brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code:

a) Does not repeat in less than 10 years; and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

44.9 With reference to 44.8, if a manufacturer produces a cell at more than one factory, each cell shall have a distinctive marking to identify it as the product of a particular factory.

INSTRUCTIONS

45 Instructions

45.1 Electric energy storage assemblies shall be provided with instructions for installation and integration into the end use vehicle.

45.2 Electric energy storage assemblies shall be provided with instructions for the proper use including charging and discharging, storage, replacement, recycling, and disposal.

45.3 For electric energy storage assemblies intended for off road vehicle applications that are not removed from the vehicle for charging and are intended to be used with a specific charger per 44.3, installation instructions shall indicate that a marking per 44.3 be located near the accessible charging port of the vehicle where the marking will be visible to the user charging the vehicle.

45.4 Electric energy storage assemblies intended for removal and charging outside of the vehicle shall be provided with instructions for the safe handling including removal and insertion of assembly into the vehicle and during charging and instructions for storage of fully charged assemblies.

45.5 Electric vehicle cells shall include specifications for the safe operation of the cell in the EESA including cell operating parameters, installation requirements, etc. Guidance on cell specification information that should be provided on cells can be found in the Cell Specification Sheet, Annex E of IEEE 1625.

45.6 The instructions for an electric energy storage assembly employing vented batteries such as vented lead acid batteries, shall indicate that indoor charging facilities be provided with ventilation in accordance with the local codes.

ANNEX A (NORMATIVE)

Standards for Components

A1 Component Standards

A1.1 The CSA and UL standards listed below are used for evaluation of components and features of products covered by this standard. Components shall comply with all the applicable CSA and UL component standards. These standards shall be considered to refer to the latest edition and all revisions published to that edition.

CSA Standards

CSA-C22.2 No. 0.2, *Insulation Coordination*
CSA C22.2 No. 0.15, *Adhesive Labels*
CAN/CSA-C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*
CSA-C22.2 No. 14, *Industrial Control Equipment*
CSA C22.2 No. 49, *Flexible Cords and Cables*
CSA-C22.2 No. 65, *Wire Connectors*
CSA C22.2 No. 75, *Wires and Cables, Thermoplastic-Insulated*
CAN/CSA-C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*
CSA-C22.2 No. 127, *Equipment and Lead Wires*
CSA-C22.2 No. 153, *Electrical Quick-Connect Terminals*
CSA-C22.2 No. 158, *Terminal Blocks*
CSA-C22.2 No. 235, *Supplementary Protectors*
CSA C22.2 No. 248.1, *Fuses, Low Voltage – Part 1: General Requirements*
CAN/CSA-C22.2 No. 248.13, *Fuses, Low Voltage – Part 13: Semiconductor Fuses*
CAN/CSA-C22.2 No. 248.14, *Fuses, Low Voltage – Part 14: Supplemental Fuses*
CAN/CSA-C22.2 No. 60947-4-1, *Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters*
CAN/CSA-C22.2 No. 60950-1, *Information Technology Equipment Safety – Part 1: General Requirements*
CAN/CSA-E61131-2, *Programmable Controllers – Part 2: Equipment Requirements and Tests*

UL Standards

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*
UL 62, *Flexible Cords and Cables*
UL 66, *Fixture Wire*
UL 83, *Wires and Cables, Thermoplastic-Insulated*
UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*
UL 157, *Gaskets and Seals*
UL 248-1, *Fuses, Low Voltage – Part 1: General Requirements*
UL 248-13, *Fuses, Low Voltage – Part 13: Semiconductor Fuses*
UL 248-14, *Fuses, Low Voltage – Part 14: Supplemental Fuses*
UL 310, *Electrical Quick-Connect Terminals*
UL 486A-486B, *Wire Connectors*
UL 498, *Attachment Plugs and Receptacles*
UL 508, *Industrial Control Equipment*
UL 746A, *Polymeric Materials – Short Term Property Evaluations*
UL 746B, *Polymeric Materials – Long Term Property Evaluations*
UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*
UL 796, *Printed-Wiring Boards*
UL 796F, *Flexible Materials Interconnect Constructions*
UL 810A, *Electrochemical Capacitors*
UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*
UL 969, *Marking and Labeling Systems*
UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*
UL 1059, *Terminal Blocks*
UL 1063, *Wires and Cables, Machine-Tool*

UL 1077, *Supplementary Protectors for Use in Electrical Equipment*
UL 1434, *Thermistor-Type Devices*
UL 1577, *Optical Isolators*
UL 1642, *Lithium Batteries*
UL 1682, *Plugs, Receptacles, and Cable Connectors, of the Pin and Sleeve Type*
UL 1973, *Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications*
UL 1989, *Standby Batteries*
UL 1998, *Software in Programmable Components*
UL 2054, *Household and Commercial Batteries*
UL 2251, *Plugs, Receptacles and Couplers for Electric Vehicles*
UL 2726, *Battery Lead Wire*
UL 2733, *Surface Vehicle On-Board Cable*
UL 60947-4-1, *Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters*
UL 60947-5-2, *Low-voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches*
UL 60950-1, *Information Technology Equipment Safety – Part 1: General Requirements*
UL 61131-2, *Programmable Controllers – Part 2: Equipment Requirements and Tests*

ANNEX B (NORMATIVE)

Test Program for Secondary Lithium Cells

B1 General

B1.1 The cell test program outlined in this annex shall be used to evaluate secondary lithium cells for use in EESAs that comply with this standard. Samples used for testing shall be within 6 months of production. The number of samples used for each test and the pass/fail criteria for testing is outlined in Table B3.1. As an alternate, the Alternative Test Program for Secondary Lithium Cells outlined in Annex D may be used.

B1.1.1 Before testing, the charge/discharge cycling conditioning per Annex D shall be conducted on secondary lithium metal (i.e. lithium metal anode) cells.

B1.2 The Test Conditions of IEC 62660-2, shall be applied for the test program outlined in Section B2 below.

B1.3 The capacity of the cells shall be determined as outlined in the Capacity Check of D2.2.

B1.4 Some lithium cells are capable of exploding when the tests described in Section B2 are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.

B1.5 As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with B1.6 during the tests described in B2. All personnel involved in the testing of lithium cell shall be instructed never to approach a lithium cell while the surface temperature exceeds 90°C (194°F) and not to touch the lithium cell while the surface temperature exceeds 45°C (113°F).

B1.6 In accordance with B1.5, the surface temperatures of the cell casing shall be measured as follows:

a) By thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG) and a potentiometer-type instrument; and

b) The temperature measurements on the cells shall be made with the measuring junction of the thermocouple held tightly against the metal casing of the cell.

Exception: Placing the thermocouple with a thin piece of paper or label between the thermocouple and casing of the cell with enough pressure on the thermocouple to ensure an accurate and repeatable reading, is an acceptable practice.

B1.7 For protection, the Projectile Test in B2.10 shall be conducted in a room separate from the observer.

B2 Tests

B2.1 Vibration Test

B2.1.1 The cell shall be subjected to the Vibration, Mechanical Test as outlined in IEC 62660-2.

B2.1.2 The sample and compliance criteria is as noted in Table B3.1.

B2.2 Shock Test

B2.2.1 The cell shall be subjected to the Mechanical Shock, Mechanical Test as outlined in IEC 62660-2.

B2.2.2 The sample and compliance criteria is as noted in Table B3.1.

B2.3 Drop Test

B2.3.1 The cell shall be charged in accordance with the manufacturer's specifications as outlined in the General Charge Conditions, Electrical Measurement section of IEC 62660-2, and then subjected to a drop test as outlined in B2.3.2.

B2.3.2 The cell shall be dropped from a height of 1.0 m (3.28 ft) onto a flat concrete surface. The DUT is to be dropped three times with the orientation of the DUT in each drop varied so that it impacts the floor in a different manner for each drop. The cell is to be subjected to an observation period of 1 h and then examined to determine compliance.

B2.3.3 The sample and compliance criteria is as noted in Table B3.1.

B2.4 Crush Test

B2.4.1 The cell shall be subjected to the Crush, Mechanical Test as outlined in IEC 62660-2.

B2.4.1.1 For other than pouch cells, the crush shall be applied in the center of the cells.

B2.4.1.2 For pouch type cells, the crushing force shall be applied on the casing near where the cell tabs exit. If the positive and negative tabs are on opposite sides, the crush force is to be applied on the casing near where the negative tab exits.

B2.4.2 The sample and compliance criteria is as noted in Table B3.1.

B2.5 Heating Test

B2.5.1 The cell shall be subjected to the High Temperature Endurance, Thermal Test as outlined in IEC 62660-2.

B2.5.2 The sample and compliance criteria is as noted in Table B3.1.

B2.6 Temperature Cycling Test

B2.6.1 The cell shall be subjected to the Temperature Cycling, Thermal Test as outlined in IEC 62660-2.

B2.6.2 The sample and compliance criteria is as noted in Table B3.1.

B2.7 External Short Circuit Test

B2.7.1 The cell shall be subjected to the External Short Circuit, Electrical Test as outlined in IEC 62660-2.

B2.7.2 The sample and compliance criteria is as noted in Table B3.1.

B2.8 Overcharge Test

B2.8.1 The cell shall be subjected to the overcharge test as outlined in B2.8.1.1.

B2.8.1.1 A cell shall be subjected to a constant current charge at the maximum specified charging current until the cell reaches 120% of its maximum specified charge voltage limit or it reaches 130% SOC, whichever comes first.

B2.8.2 The sample and compliance criteria is as noted in Table B3.1.

B2.9 Forced Discharge Test

B2.9.1 The cell shall be subjected to the Forced Discharge, Electrical Test as outlined in IEC 62660-2.

Exception: This test is not required if it can be determined that overdischarge is reliably prevented by a control system meeting the requirements of 13.4 that prevents overdischarge of cells and that monitors at the cell level in the end use vehicle system.

B2.9.2 The sample and compliance criteria is as noted in Table B3.1.

B2.10 Projectile Test

B2.10.1 The cell shall be subjected to the projectile test as outlined in B2.10.2 – B2.10.6. See Table B3.1 for samples and results criteria.

B2.10.2 Each test sample cell shall be placed on a screen that covers a 102-mm (4-in) diameter hole in the center of a platform table. The screen shall be constructed of steel wire mesh having 20 openings per 25.4 mm (1 in) and a wire diameter of 0.43 mm (0.017 in).

B2.10.3 The screen shall be mounted 38-mm (1-1/2-in) above a Meker type burner. The fuel and air flow rates shall be set to provide a bright blue flame that causes the supporting screen to glow a bright red.

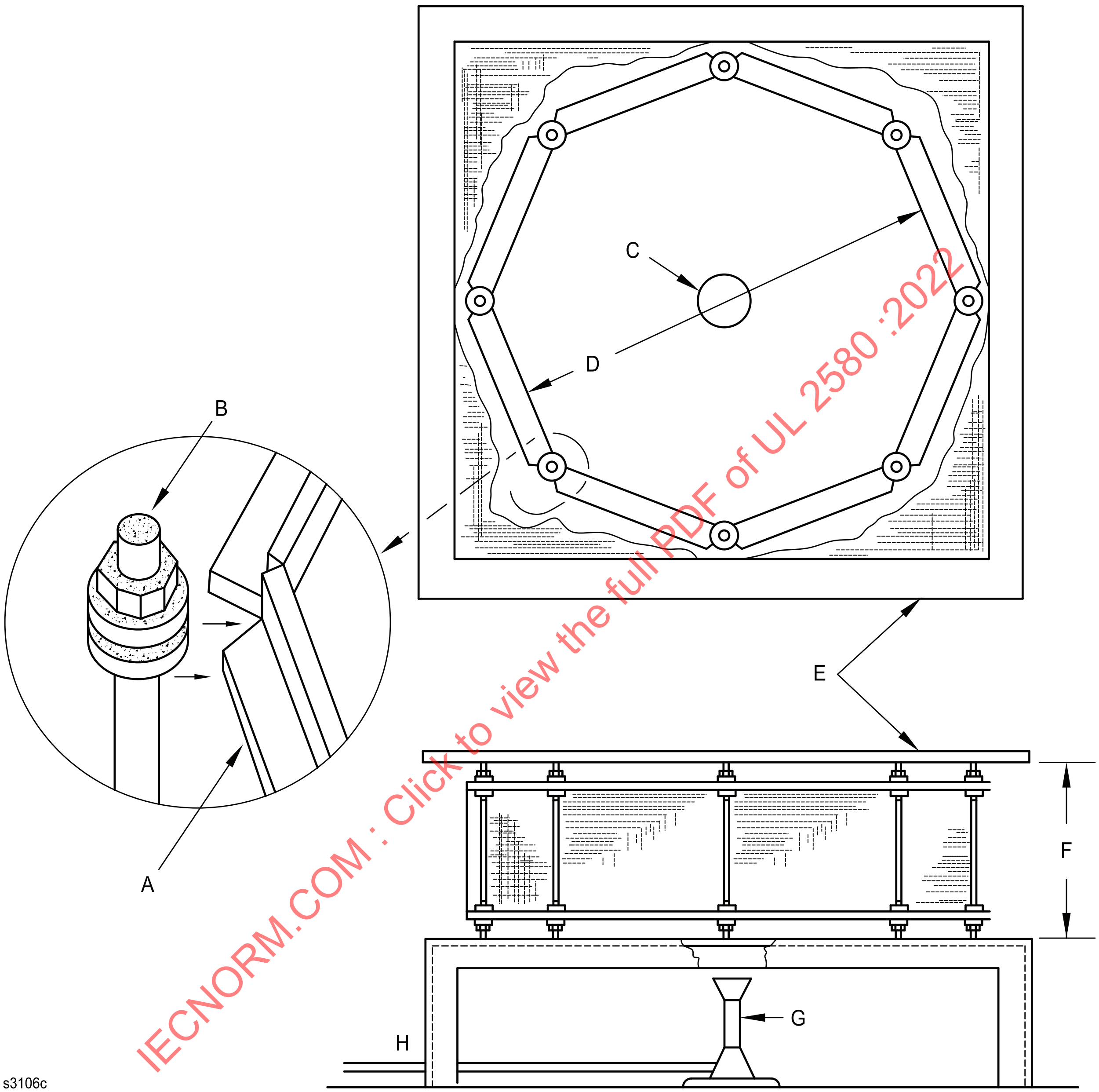
B2.10.4 An eight-sided covered wire cage, 610-mm (24-in) across and 305-mm (12-in) high, made from metal screening shall be placed over the test sample. See Figure B2.1. The metal screening shall be constructed from 0.25-mm (0.010-in) diameter aluminum wire with 16 – 18 wires per 25.4 mm (1 in) in each direction.

Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined above to accommodate large cells intended for EV applications, but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.

Exception No. 2: The projectile test cage may be replaced by a visible circular perimeter marking on the supporting surface located 0.5 m (19.7 in) from the longest side of the cell. The marking shall be no greater than 5-mm (0.2-in) thick. The test set up shall be located within a protective enclosure/room with noncombustible surfaces located a distance from the test perimeter marking where any projectiles that fall beyond the test perimeter marking can be safely contained.

Figure B2.1

Test apparatus for projectile test



A – 12.7 × 12.7-mm (1/2 × 1/2-in) angle, top and bottom

B – 6.4-mm (1/4-in) diameter rod, 305-mm (12-in) long, threaded both ends, bolted between top and bottom frames

C – 102-mm (4-in) diameter hole in table

D – 610-mm (24-in) or ≤ 305 mm (12 in) from edge of cell

E – Flat screen cover

F – 305 mm (12 in)

G – Burner – Meker type burner

H – Fuel