Anbotek
Product Safety

Report No.: 18270BC20140301

APPLICATION FOR UL TEST REPORT

Client Name	:	Shenzhen Run Sen Sheng Trading CO.,Ltd.
Address	:	Room 2304,Tower B,Galaxy World,Bantian Yabao Road,Longgang District of Shenzhen,China
Product Name	:	Lithium Battery Pack
Date	:	Jun. 09, 2022

Shenzhen Anbotek Compliance Laboratory Limited

TEST REPORT
ANSI/CAN/UL1973: 2018
Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications

Report	
Reference No. ....:	18270BC20140301
Compiled by (+ signature)..................:	Eason Zhou/ Project Engineer ………………………
Approved by (+ signature) ....:	Dely Yang / Project Engineer ………………………
Date of issue..:	Jun. 09, 2022
Contents ....:	73 pages (including 2 pages of photos)
Testing laboratory	
Name ....:	Shenzhen Anbotek Compliance Laboratory Limited
Address...:	Zone South,1/F.,Building2,Hengchangrong High-Tech Industrial Park,Huangtian Hangcheng Street, Bao'an District, Shenzhen, Guangdong, China
Testing location ....:	Shenzhen Anbotek Compliance Laboratory Limited
Client	
Name ....:	Shenzhen Run Sen Sheng Trading CO.,Ltd.
Address...:	Room 2304,Tower B,Galaxy World,Bantian Yabao Road,Longgang District of Shenzhen,China
Test specification	
Standard ....:	ANSI/CAN/UL1973: 2018
Test procedure ....:	Compliance with ANSI/CAN/UL1973: 2018
Non-standard test method ....:	N.A.
Test item	
Description..:	Lithium Battery Pack
Trademark ....:	WEIZE
Model and/or type reference..............:	TPLI-1250AH
Manufacturer ....:	TOPAK POWER TECHNOLOGY CO.,LTD.
Address...:	Topak Industrial Park, NO.26,Yingfeng RD 1, Dalang Town, Dongguan, China
Factory...:	Same as manufacturer
Address...:	Same as manufacturer
Rating(s) ....:	12.8V, 50Ah, 640Wh

Possible test case verdicts:

Test case does not apply to the test object..............: N(/A)

Test object does meet the requirement ....: P(ass)

Test object does not meet the requirement..............: F(ail)

Testing:

Date of receipt of test item..: Dec. 25, 2021

Date(s) of performance of tests ....: Dec. 25, 2021 to Mar. 10, 2022

General remarks:

This report shall not be reproduced, except in full, without the written approval of the testing laboratory.

The test results presented in this report are only relevant to the test sample.

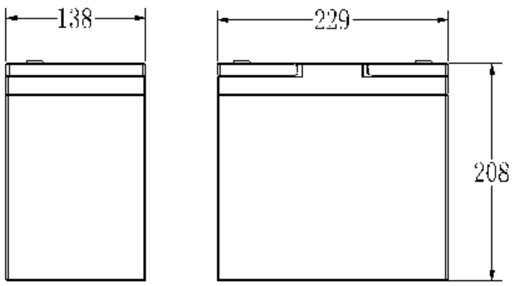
"(see remark #)" refers to a remark appended to the report.

"(see appended table)" refers to a table appended to the report.

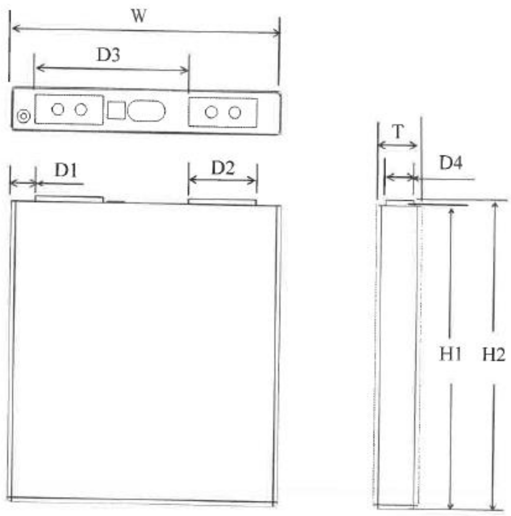
Throughout this report a point is used as the decimal separator.

As specified by the client, all the results in this report were quoted from report 18270BC10448601, test sample: Lithium Battery Pack, test model: TC1250.

Construction:



Battery(unit: mm)



Item	Parameter
W	140.2±0.5
H1	160.2±0.5
H2	163.0±0.5
T	24.0±0.5
D1	12.3±0.5
D2	35±0.5
D3	80±0.5
D4	15±0.5

Cell (unit: mm)

General product information and other remarks:

This battery is constructed with four lithium-ion cells (4S1P), and has overcharge, over-discharge, over current and short-circuits proof circuit.

The main features of the battery are shown as below:

Model	Nominal capacity	Nominal voltage	Nominal Charge Current	Nominal Discharge Current	Maximum Charge Current	Maximum Discharge Current	Maximum Charge Voltage	Final Voltage
TPLI-1250AH	50Ah	12.8V	10A	25A	50A	50A	14.6V	10.5V

The main features of the cell in the battery are shown as below:

Model	Nominal capacity	Nominal voltage	Nominal Charge Current	Nominal Discharge Current	Maximum Charge Current	Maximum Discharge Current	Maximum Charge Voltage	Final Voltage
IFP23140160-50Ah	50Ah	3.2V	25A	25A	50A	50A	3.65V	2.0V

The main features of the cell in the battery are shown as below:

Model	Upper limit charge voltage	Taper-off current	Lower charge temperature	Upper charge temperature
IFP23140160-50Ah	3.65V	2.5A	0°C	45°C

Clause	Requirement + Test	Result - Remark	Verdict
	CONSTRUCTION		**P**
7	**General**		**P**
7.1	**Non-metallic materials**		**P**
7.1.1	Polymeric materials employed for enclosures shall comply with the requirements as outlined in Table 6.1 Path III of UL 746C except as modified by this standard.		P
	Exception No. 1: Polymeric materials utilized for light electric rail (LER) enclosures for motive applications shall have a minimum flammability of V-1 or better, in accordance with UL 94 if intended for building into an enclosure or compartment within the train.		P
	Exception No. 2: LER enclosure parts for motive applications may alternatively be evaluated to the 20 mm end-product flame tests in accordance with UL 746C.		P
7.1.2	The factors taken into consideration when an enclosure is being judged are as follows. For a Non-metallic enclosure, all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief distortion test. a) Resistance to impact; b) Crush resistance; c) Abnormal operations; d) Severe conditions; and e) Mold-stress relief distortion.		P
7.1.3	The polymeric materials employed as enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application.		P
7.1.4	Pack enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80°C (176°F), as determined in accordance with UL 746B.		P
7.1.5	The pack 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 UL 746C.		P
	Polymeric materials used as direct support for live parts other than those circuits determined non-hazardous (i.e. limited power circuits) shall comply with the insulation requirements of UL 746C.		P
	Exception: Insulation materials that meet the criteria outlined in UL 60950-1/CAN/CSA-C22.2 No. 60950-1, Clause 4.7.3.3 ″Materials for components and parts outside of fire enclosures″ or Clause 4.7.3.4 ″Materials for components and parts inside of fire enclosures″ are considered acceptable.		P
7.1.6	Gaskets and Seals relied upon for safety shall be determined suitable for the temperatures they are exposed to and other conditions of use. Compliance is determined by the applicable tests of UL 157.		P

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ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
7.2	Metallic parts resistance to corrosion		N
7.2.1	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 UL 50E/C22.2 No. 94.2.		N
7.2.2	Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table D.1 of Appendix D shall be avoided.		N
7.3	Enclosures		P
7.3.1	The enclosure of a battery system shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons. Compliance is determined by the tests of this standard.		P
7.3.2	A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the enclosure.		P
7.3.3	Openings in the enclosure shall be designed to prevent inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CAN/CSA-C22.2 No. 60529, for a minimum IP rating of IP2X or IPXXB, and C22.1, the Enclosure Selection Table for Nonhazardous Locations, Table 65. (Evaluation per IEC 60529 or CAN/CSA-C22.2 No. 60529, Clause 12, consists of the use of the IEC articulate probe applied with a force of 10 N ±10%).		P
	Exception: For battery systems intended for location in restricted access locations only per 6.41, hazardous parts may be contacted with the articulate probe, but shall be located or guarded to prevent unintended contact by service or other trained personnel. Such equipment shall be provided with installation instructions in accordance with 42.3 and marked in accordance with 41.13.		P

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Clause	Requirement + Test	Result - Remark	Verdict
7.3.4	Openings in the enclosure shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25% of the LFL of hydrogen (equivalent to 1% concentration in a volume of air). Ventilation openings shall have a minimum opening area of: $A = 0.005NC_5$ (cm^2) Where: A = Total cross sectional area of ventilation holes required (cm^2) N = Number of cells in battery C_5 = Capacity of battery at the 5-h rate (Ah)		P
	Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25% of the LFL of hydrogen.		P
7.3.5	Packs intended for installation where they may be exposed to moisture either through rain, splashing water or immersion shall be evaluated for their intended resistance to ingress of moisture in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529, or as outlined in NFPA 70, Article 110, or Section 2 of C22.1 for enclosure type designation and UL 50E/C22.2 No. 94.2, or NEMA 250. See also Section 36.		P
7.4	Wiring and terminals		P
7.4.1	General		P
7.4.1.1	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.		P
7.4.1.2	A wiring splice or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals.		P
	Wiring shall be secured and routed away from sharp edges or parts exceeding insulation.		P
	Openings in compartments through which insulated wiring is routed shall be smooth and well-rounded or provided with protective insulating bushings or grommet to prevent abrasion.		P
	Wiring connections between various parts of a battery module/pack and accessories shall be routed and secured to prevent the potential for short circuit conditions to occur.		P

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Clause	Requirement + Test	Result - Remark	Verdict
7.4.1.3	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, or creating short circuit.		P
7.4.1.4	An external battery terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in its end use application.		P
7.4.1.5	External non-detachable cords and leads that are accessible in the end use installation shall be provided with strain relief that prevents strain to internal conductors under pull and push-back conditions. Compliance is determined by the tests of 24.4 and 24.5.		P
7.4.1.6	Plugs and receptacles shall be rated for the intended voltage, current, temperature, and if applicable, for disconnect under load conditions.		P
7.4.1.7	Battery system cables shall be rated for their anticipated service including voltage, current, temperature and environment. External cords for hazardous voltage circuits shall be jacketed to prevent wear to internal conductors and rated and provided with insulation suitable for the intended applications.		P
7.4.1.8	In multiway plugs and sockets, and wherever shorting could otherwise occur, means shall be provided to prevent contact between parts in SELV circuits or parts at hazardous voltage due to loosening of a terminal or breaking of a wire at a termination. Compliance is checked by inspection, by measurement and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the conductor near its termination point. The conductor shall not break away or pivot on its terminal to the extent that spacings are reduced below the values specified in 7.5.		P
7.4.1.9	Wiring compartments and wiring terminals provided for connection of the battery system to external circuits shall be constructed as outlined below:		P
	a) A field wiring compartment in which supply connections are to be made shall be located so that the connections will be accessible for inspection after the unit is installed as intended.		P
	b) A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure. The knockout shall be surrounded by a flat surface to accommodate seating of a conduit bushing or locknut of the appropriate size.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	c) An outlet box, terminal box, wiring compartment, in which field connections are made shall be free from any sharp edges including screw threads, a burr, a fin or moving part of the like that may abrade the insulation on conductor or otherwise damage wiring.		P
	d) A field wiring terminal or lead shall be rated for the connection of a conductor or conductors having a minimum ampacity rating of 125% of the rating of the unit.		P
	e) The distance between the end of the connection point of a field installed wire and the wall of the enclosure toward which the wire is to be directed, shall be in accordance with Table 312.6 (A) or (B) of NFPA 70.		P
7.4.2	Beads and ceramic insulators		N
7.4.2.1	Beads and similar ceramic insulators on conductors shall: a) Be so fixed or supported that they cannot change their position in such a way that a hazard would be created; and b) Not rest on sharp edges or sharp corners.		N
7.4.2.2	If beads are located inside flexible metal conduits, they shall be contained within an insulating sleeve, unless the conduit is mounted or secured in such a way that movement in normal use would not create a hazard. Compliance is checked by inspection and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the insulators or to the conduit. The resulting movement, if any, shall not create a hazard in the meaning of this standard.		N
7.5	Spacings and separation of circuits		N
7.5.1	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 un-insulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and maximum voltages shall be used where spacings cannot be controlled by reliable physical separation.		N
7.5.2	Electrical spacings in circuits shall be based upon the grade of insulation required as outlined in the Grade of Insulation section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1, and shall comply with the creepage and clearance requirements of the Clearances, Creepage Distances and Distances Through Insulation section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1 for the appropriate pollution degree of the intended environment (see the Pollution Degrees section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1).		N

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 1: As an alternative to these spacing requirements, the spacing requirements in 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 the section for Components of UL 840 unless charged through an ac mains connected rectifier, then the overvoltage category should be the same as that required for the rectifier unless the rectifier uses galvanic isolation. If galvanic isolation is employed, then the overvoltage category can be reduced to the next lower overvoltage category. The anticipated pollution degree is determined by the design and application of the electrical energy storage system or subassembly under evaluation.		N
	Exception No. 2: As an alternative to the clearance values outlined in UL 60950-1/CAN/CSA-C22.2 No. 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 UL 60950-1/CAN/CSA-C22.2 No. 60950-1 may be applied.		N
	Exception No. 3: As an alternative to these spacing requirements, the spacing requirements of Table 7.1 may be applied instead. When using this table, maximum working voltages of circuits can be determined through the test of Section 21. See the note in Table 7.1 regarding adjustment for spacings where double or reinforced insulation is required.		N
7.5.3	Conductors of circuits operating at different potentials shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.		N
7.5.4	An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different potential. Some examples include clamping or routing of conductors, use of separating barriers of insulating material or other means that provides permanent separation of the parts.		N
7.5.5	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 SELV levels is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test. There is no minimum insulation thickness requirement for insulation of circuits at or below SELV levels for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.		N
7.6	Insulation levels and protective grounding and bonding		P

ANSI/CAN/UL1973: 2018

Clause	Requirement + Test	Result - Remark	Verdict
7.6.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and circuits as outlined in 7.6.2 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).		P
7.6.2	Safety extra low voltage (SELV) circuits as defined in 6.44 that are insulated from accessible conductive parts through functional insulation only are considered accessible.		P
7.6.3	Article 250, Section VIII of NFPA 70 and Section 10 of C22.1 outline dc system grounding requirements including identifying types of dc circuits and systems that must be grounded. Batteries that rely upon protective grounding, shall comply with 7.6.4 through 7.6.9.		P
7.6.4	Accessible non-current carrying metal parts of a battery system with hazardous voltage circuits, that could become live in the event of an insulation fault, shall be bonded to the equipment ground terminal.		P
7.6.5	Parts of the protective grounding system shall be reliably secured in accordance with 7.4.1.2 and provided with good metal-to-metal contact. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. The resistance between the protective conductive terminal of 7.6.8 and the accessible non-current carrying conductive parts outlined in 7.6.2 shall not exceed 0.1 Ω.		P
7.6.6	With reference to 7.6.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system.		P

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
7.6.7	With reference to 7.6.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods: a) Terminal blocks; b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors; c) Exothermic welding processes; d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and e) Thread-forming machine screws that engage not less than two threads in the enclosure.		P
7.6.8	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) or otherwise identified by a distinctive green color.		P
7.6.9	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. Grounding conductors shall be sized in accordance with Article 250.122 of NFPA 70 or Rule 10-810 of C22.1.		P
7.7	System safety analysis		N
7.7.1	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.		N
7.7.2	Documents that can be used as guidance for the safety analysis include: a) IEC 60812; b) IEC 61025; c) MIL-STD-1629A; and d) IEC 61508, all parts.		N
7.7.3	The analysis of 7.7.1 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 and/or identify the safety integrity level or similar safety classification.		N

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Clause	Requirement + Test	Result - Remark	Verdict
7.7.4	When conducting the analysis of 7.7.1, active protective devices shall not be relied upon for critical safety unless they comply with the following in (a) – (c). Refer to 6.39 and 6.40 for definitions of active and passive protective devices. a) They are provided with a redundant passive protective device; or b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection; or c) They are determined to fail safe upon loss of power to the active circuit; or d) Meet the identified safety integrity level per IEC 61508 or similar safety classification.		N
7.7.5	Devices relied upon for critical safety as noted in 7.7.4 shall be tested for functionality in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this standard.		N
7.7.6	The safety system analysis for those battery systems that are identified as smart grid enabled, smart grid compatible or smart grid interactive as defined in 1.1 of UL 2744, shall include analysis of impact to safety as a result of integration of the battery system in a smart environment.		N
7.8	Protective circuit and controls		P
7.8.1	General		P

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
7.8.1.1	Battery systems shall be protected against overcharge and overdischarge, resulting from anticipated use and abuse conditions including component faults in control systems, short circuit conditions and power surges as applicable to the intended battery system application and installation as determined by the manufacturer. If relied upon for maintaining the cells within their safe operating region, the battery management system (BMS) shall maintain cells within the specified cell voltage region from over-charge and over-discharge of the cell voltage, and it shall maintain cells within the specified cell temperature region providing protection from overheating and under temperature operation. Additionally, it shall maintain batteries within the specified battery current region from over charge of current and prevent high rate discharge exceeding the cell specifications. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.		P
7.8.1.2	If the specified operating limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond these operating limits if an unsafe condition is created or the battery system will be damaged. If safety limits as determined per 7.7 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.		P
7.8.1.3	Solid state circuits and software controls, relied upon as the primary safety protection, shall be evaluated to UL 991 or C22.2 No. 0.8, UL 1998, UL 60730-1 or CAN/CSA-E60730-1, or EN/IEC 61508 series as applicable based upon the design and complexity of the controls. The required severity level, performance level, or the class of control function shall be determined by the manufacturer and the controls designed in accordance with one of the above functional safety standards.		P
	Exception: Solid state circuits and software need not comply if it can be demonstrated that the solid state circuits and software are not relied upon as the primary safety protection.		P

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
7.8.1.4	Battery systems with hazardous voltage circuits, including outputs of 50V or greater, shall either be provided with a manual disconnect device or be provided with installation instructions for the disconnect device to be provided during installation of the system. The disconnect device shall be located as near as possible to the battery system terminals and it shall be rated for the application including disconnect under load if applicable. The disconnect device shall disconnect both poles of the circuit. The manual disconnect shall not require the use of a special tool or equipment to be operated.		N
7.8.2	Smart Grid Applications		N
7.8.2.1	Those battery systems that are identified as smart grid enabled, smart grid compatible or smart grid interactive as outlined in 1.1 of UL 2744, shall be evaluated for functional safety with consideration for the environmental criteria that may affect the smart grid communication system of the battery system if there is impact to battery system safety.		N
7.9	Cooling/thermal management system		N
7.9.1	Battery systems that rely upon integral thermal management systems to prevent overheating shall be designed to shutdown upon failure of the thermal management system unless is can be demonstrated, that the thermal management system failure does not result in a hazardous situation. Compliance is determined by the Failure of the Cooling/Thermal Stability System Test of Section 22.		N
7.9.2	Piping, hose, and tubing used to contain liquid shall be resistant to chemical degradation from the liquid it contains, as well as other liquids reasonably likely to contact such parts during expected life of the equipment. It shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses. Compliance is determined as outlined in 7.10.1.		N
7.9.3	With reference to 7.9.2, piping containing fluids in accordance with the scope of ASME B31.3, shall comply with the applicable requirements of that code. ASME B31.3 applies to piping that contains toxic fluids, flammable fluids, fluids damaging to human tissue, and nonhazardous fluids at pressures greater than 15 psi (105 kPa) or temperatures lower than −29°C (−20°F) or greater than 186°C (366°F).		N
7.9.4	Piping, hose, and tubing containing liquids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.		N
7.9.5	Fans or blowers utilized for air-cooling systems shall comply with the applicable requirements in UL 507.		N
	Exception: Fans located in SELV or ELV dc circuits need not be evaluated if shown to comply with the test of 24.1.		N

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
7.9.6	Battery systems that rely on integral heaters to maintain operating temperatures of the battery system, shall be designed to shutdown upon failure of the heaters unless is can be demonstrated through fault analysis and if necessary an abnormal operation test, that the heater failure does not result in a hazardous situation.		N
7.9.7	Temperature controls for heaters used to maintain the operating temperature range of a battery system during cold ambient conditions shall be positioned such that they monitor the system temperature and are minimally affected by the outside ambient. For example, temperature controls or regulators should normally be located away from outside vents.		N
7.10	Electrolyte containment parts and parts subject to pressure		N
7.10.1	Parts that contain electrolyte, such as piping, hose, and tubing shall be resistant to chemical degradation from the electrolyte. Electrolyte containing parts shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses. Compliance is determined through review of material datasheets and where determined necessary, an immersion test (using the electrolyte as the test liquid) in accordance with the Volume Change Test after Immersion of UL 157 for elastomeric materials or the Test for Resistance of Polymeric Materials to Chemical Reagents in UL 746A for other than elastomeric materials, (same as ASMT D543, Test Method I), as applicable to the material and part being tested. Elastomeric parts in contact with electrolyte shall be subjected to the volume change and extraction test after 70-h immersion in the electrolyte in accordance with UL 157. The volume change shall be minus 1 to plus 25% and extraction (change in weight) no greater than 10%. Plastics other than elastomeric parts in contact with electrolyte shall be subjected to an immersion for 168 h at room temperature followed by a check for volume and weight change in accordance with ASTM D543, Procedure I method. The percentage of change of volume shall not be greater than 2% of the original and the change in weight shall be no not increase more than 25% or decrease more than 10% of the original value.		N
	Exception No. 1: See Appendix C for material requirements for flowing electrolyte systems.		N
	Exception No. 2: Not applicable to individual cell or capacitor casings and materials that have been evaluated to appropriate component requirements per 7.11.		N
7.10.2	Piping, hose, and tubing containing electrolyte, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.		N

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Clause	Requirement + Test	Result - Remark	Verdict
7.10.3	Parts under pressure shall be acceptable for the maximum anticipated pressure as determined by the tests of Section 33.		N
	Exception: See Appendix C for material requirements for flowing electrolyte systems.		N
7.10.4	Relief valves or rupture members relied upon to relieve overpressure conditions in a battery system shall operate in accordance with their specifications for start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure). Compliance is determined by the tests of Section 34. This requirement does not apply to relief valves or rupture members integral to a cell or monobloc battery such as a VRLA type battery.		N
	Exception: Relief valves and ruptures members stamped with the ASME approval mark for the particular device in accordance with the ASME Boiler and Pressure Vessel Code need not be subjected to the tests of Section 34.		N
7.10.5	A pressure-relief device shall have its discharge opening located and directed so that operation of the device will not deposit moisture on bare live parts or on insulation or components that could be detrimentally affected by the discharge. It shall have a start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure) rating adequate to relieve the pressure.		N
7.10.6	The fill port of the electrolyte containment of a monobloc system shall be designed to prevent overfill and spillage of electrolyte during the electrolyte filling.		N
7.10.7	Flow batteries shall be provided with a means for spill control such as a spill containment system to prevent electrolyte spills. The spill containment shall be sufficient to handle electrolyte spills for the size of the system. See Spill Containment Systems, C6, for means to determine compliance.		N
7.11	Cells (battery and electrochemical capacitor)		P
7.11.1	Sealed nickel metal hydride cells shall comply with the cell tests of the Testing Required for Cells table of UL 2054 in addition to the requirements of this standard.		P
	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 stationary and LER 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.		P
	Exception No. 2: The overall external resistance for the short circuit test shall be less than or equal to 20 mΩ.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	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 if the flat plate crush test per UL 2054 is insufficient to create a crush condition in the cell as determined by (a) – (c) below. The force shall be applied until one of the following occurs: a) A voltage (OCV) drop of one-third of the original cell voltage occurs; b) A deformation of 15% or more of initial cell dimension occurs; or c) A force of 1,000 times the weight of cell is reached.		P
	Exception No. 4: Nickel metal hydride or nickel cadmium cells that are sealed and formed as part of a monobloc battery, need only comply with the requirements of this standard as part of the assembled battery. If provided with a pressure release vent or flame arrester, the nickel battery shall comply with the requirements outlined in 7.11.5.		P
	Exception No. 5: Sample numbers tested for each test based upon UL 2054 test program may be reduced from 5 samples tested to 2 samples tested.		P
	Exception No. 6: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min.		P
7.11.2	Secondary lithium cells shall comply with the requirements of UL 1642 in addition to the requirements of this standard, except the testing shall be conducted on fresh cells only for lithium ion cells.		P
	Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined in UL 1642 to accommodate large cells intended for stationary and LER 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.		P
	Exception No. 2: The overall external resistance for the short circuit test shall be less than or equal to 20 mΩ.		P
	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 if the flat plate crush test of UL 1642 is insufficient to create a crush condition in the cell as determined by (a) – (c) below. The force shall 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 of initial cell dimension occurs; or c) A force of 1000 times the weight of cell is reached.		P
	Exception No. 4: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 5: Sample numbers tested for each test based upon the UL 1642 test program may be reduced from 5 samples tested to 2 samples tested.		P
	Exception No. 6: Secondary lithium cells may be tested using the test program outlined in Appendix E. Secondary lithium cells other than lithium ion shall be subjected to the cycling pre-conditioning requirements of UL 1642 prior to conducting the Appendix E testing.		P
7.11.3	Sodium-beta cells and batteries shall comply with the cell tests outlined in Appendix B.		P
7.11.4	Flowing electrolyte cells and battery systems shall comply with the requirements outlined in Appendix C.		P
7.11.5	Batteries employing pressure release valves or flame arrestors shall comply with the pressure release test or the flame arrester test of UL 1989 in addition to the requirements of this standard.		P
7.11.6	Electrochemical capacitor cells and modules shall comply with the requirements outlined in UL 810A in addition to the requirements of this standard.		P

	PERFORMANCE		P
8	General		P
8.1	Unless indicated otherwise the device under test (DUT) shall be at the maximum operational 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.		P
8.2	Unless otherwise indicated, fresh samples (i.e. not more than 6 months old) representative of production shall be used for the system level tests described in Sections 15 – 39. The test program and number of samples to be used in each test is shown in Table 8.1.		P
	Exception: At the agreement of the manufacturer, DUT samples may be re-used for more than one test if not damaged in a manner that would affect test results. Minor repairs can be made to samples such as replacement of fuses, etc. in order to reuse samples for multiple tests.		P
8.3	All tests, unless noted otherwise, are conducted in a room ambient 25 ±5°C (77 ±9°F). Tests shall be conducted with the DUTs heated to normal operating temperatures unless indicated otherwise in the test. For those tests that require the DUT to reach thermal equilibrium, thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10% of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2°C (3.6°F).		P

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Clause	Requirement + Test	Result - Remark	Verdict
8.4	Thermocouples shall be attached to the central component cell or module during the system level tests in Sections 15 – 39. Temperatures shall also be measured on any components affected by temperature in the control circuit during the tests of 9.1 and 9.2. Temperature shall be measured using thermocouples consisting of wires not larger than 24 AWG (0.21 mm2) and not smaller than 30 AWG (0.05mm2) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured.		P
8.5	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 shall be monitored in accordance with 10.2.		P
9	Determination of Potential for Fire Hazard		P
9.1	In addition to visible signs of fire, non-compliant test results for fire shall also include an evaluation for combustible vapor concentrations during testing if there is the potential for combustible vapor concentrations based upon the technology and design of the battery system. For detection of potential combustible vapor concentrations that may be emitted during testing, a gas monitor suitable for detecting 25% of the lower flammability limit (LFL) of the evolved gases being measured. A minimum of two sampling locations where concentrations may occur such as at vent openings or vent ducts shall be used for taking measurements.		P
	Exception: As an alternative to using gas detection measurement to determine if there are combustible vapor concentrations, non-compliant tests results for fire may include an evaluation for potential combustible vapor concentrations with the use of a minimum of two continuous spark sources. The continuous spark sources shall provide at least two sparks per second with sufficient energy to ignite natural gas and shall be located near anticipated sources of vapor such as vent openings or at the vent duct.		P
9.2	Additional precautions shall be taken during tests requiring this analysis due to the potential for combustible vapor concentrations that may occur within the test room or chamber.		P
10	Important Test Considerations		P

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Clause	Requirement + Test	Result - Remark	Verdict
10.1	The tests contained in this standard may result in explosions, fire and emissions of combustible and/or toxic vapors, leakage of hazardous chemicals 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, leaked electrolyte, explosive force, toxic vapors and chemicals and sudden release of heat and noise that could result from testing. To prevent injury, protective equipment and clothing should be utilized when handling batteries and when conducting testing. Short-circuiting can lead to very hazardous currents, and large format batteries may still be hazardous even in an uncharged condition. The test area shall be well ventilated to protect personnel from possible harmful vapors or gases and care should be taken to prevent exposure to leaked electrolyte. Test facilities shall be equipped to contain, mitigate, and exhaust toxic vapors and particulate matter, leaked electrolyte and other hazardous substances that may be generated during the tests of this standard including the External Fire Exposure Test of Section 38. See also 9.2.		P
10.2	As an additional precaution, the temperatures on surfaces of the DUT shall be monitored during the tests per 8.5. All personnel involved in the testing of battery systems shall be instructed to never approach the DUT until temperatures are falling and are at safe levels.		P
11	Single Fault Conditions		P
11.1	Where there is a specific reference to a single fault condition in the individual test methods, the single fault shall consist of a single failure (i.e. open, short or other failure means) of any component in the electrical energy storage system that could occur as identified in the system safety analysis of 7.7 and that could affect the results of the test.		P
12	Test Results		P
12.1	Tests that result in one or more of the following conditions as noted in Table 12.1 and as defined in Section 6, shall be considered as non-compliant for the test. Additional details of passing results criteria are provided in the individual test methods.		P

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Clause	Requirement + Test	Result - Remark	Verdict
12.2	For the following tests, if the DUT is still operational after the test (a user replaceable fuse may be replaced or user resettable device such as an accessible circuit breaker, etc. reset), it shall be subjected to a minimum single charge/discharge cycle in accordance with the manufacturer's specifications. No non-compliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle of a still operational DUT. a) Overcharge; b) Short Circuit; c) Overdischarge Protection; d) Imbalanced Charging; e) Failure of Cooling/Thermal Stability System; f) Vibration; g) Shock; h) Impact or Drop Impact; i) Static Force; j) Thermal Cycling; k) Salt Fog; and l) Resistance to Moisture.		P
13	Determination of Toxic Emissions		N
13.1	For those systems for which venting from cells or capacitors could result in the emission of toxic gases as determined by an analysis of the outgassed substances, the concentration of toxic gases during the destructive testing noted in Table 12.1 shall be monitored using one of the sampling methods noted below and as outlined in 13.2. Analysis of the outgassed substances can be obtained through review of MSDS sheets and/or analysis of the outgassed substances. If it can be determined through examination of the cells after testing that they did not vent as a result of the test, the system is in compliance with these criteria. a) ASTM D4490; b) ASTM D4599; c) OSHA Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis; or d) NIOSH Manual of Analytic Methods.		N

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Clause	Requirement + Test	Result - Remark	Verdict
13.2	To determine the concentration of toxic emissions, testing shall be conducted in a closed test chamber of known volume large enough to contain the DUT. Results obtained from continuous sampling the emissions during testing shall be scaled to estimate the anticipated exposure and concentration of toxic materials within either the passenger compartment of a light electric rail (LER) or the anticipated smallest room in which the system can be installed. For walk-in units, continuous monitoring shall also be conducted in the interior of the system enclosure. The results for stationary applications shall be further scaled to consider a 0.5 air changes per hour (ACH) ventilation rate. The 0.5 ACH represents allowable low ventilation rated for construction.		N
	Exception: Stationary systems intended for installation outdoors only and that are not walk-in units are exempted from this monitoring. Stationary systems and systems for LER applications are also exempted from these requirements if provided with a ventilation system or otherwise designed to prevent exposure to toxic vapor releases and vents vapors to a safe location.		N
14	Measurement Equipment Accuracy		P
14.1	Unless noted otherwise in the test methods, the overall accuracy of measured values of test specifications or results when conducting testing in accordance with this standard, shall be within the following values of the measurement range: a) ±1% for voltage; b) ±3% for current; c) ±4% for watts; d) ±2°C (±3.6°F) for temperatures at or below 200°C (392°F), and ±3% for temperatures above 200°C (392°F); e) ±0.1% for time; f) ±1% for dimension; g) ±3% for Ah; h) ±4% for Wh.		P
15	Overcharge Test		P
15.1	The purpose of this test is to evaluate a battery system's ability to withstand an overcharge condition.		P
15.2	A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to an overcharge resulting from a single fault condition in the charging protection/control circuit of the system that could lead to an overcharge condition. See Section 11 for a description of a single fault condition.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Single fault conditions can be applied to both passive and active protective devices. The test supply equipment used for charging the DUT shall be sufficient to create an overcharge of the DUT to at least 110% of the maximum specified charging voltage. The charging rate used shall be the manufacturer's specified maximum charging rate.		P
	Exception No. 1: Overcharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		N
	Exception No. 2: Components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.8.1.3) need not be subjected to single fault conditions.		P
15.3	The test shall continue until ultimate results occur followed by an observation period per 8.5. Ultimate results are considered to have occurred when one of the following occurs:		P
	a) The sample charging is terminated by the protective circuitry whether it is due to voltage or temperature controls or if the DUT reaches 110% of its maximum specified charging voltage limit. Exceeding the manufacturer's specified charging limit is considered a non-compliant result. The DUT is monitored per 8.5 and 10.2; or		P
	b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.		P
15.4	During the test, detection methods as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary.		P
	If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
15.5	If the DUT is operational after the overcharge test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
15.6	At the conclusion of the observation period, the samples shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P

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Clause	Requirement + Test	Result - Remark	Verdict
15.7	As a result of the overcharge test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L– Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 15)	P
16	Short Circuit Test		P
16.1	This test shall be conducted on a fully charged DUT (MOSOC per 8.1) with parallel connected cells or modules to determine its ability to withstand an external short circuit. DUTs with only series connections (i.e. no parallel connections of cells or modules) are tested at the cell level if determined to be equivalent to testing at the system level.		P
	Exception: Short circuit testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P
16.2	The sample shall be short-circuited by connecting the positive and negative terminals of the sample with a shorting device having resistance as low as practicable. In all cases the resistive circuit load shall have a maximum total resistance of 20 mΩ, as measured from the DUT terminals. For battery systems, the short circuit discharge profile at the terminals for current and time shall be recorded and compared with the manufacturer's specified value in 41.3.		P
16.3	Testing is repeated at a load that draws a maximum current between 85% and 100% of the protector trip rating. For the purposes of this test, the protector trip rating for a fuse is defined as 2.0 × In where In is the fuse current rating per UL 248-1.		P
16.4	Tests shall be conducted at room ambient. The samples shall reach thermal equilibrium temperature as outlined in 8.3 before the terminals are connected.		P
16.5	The sample shall be completely discharged (i.e. discharged until near zero state of charge/its energy is depleted), or protection in the circuit has operated and 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.		P

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Clause	Requirement + Test	Result - Remark	Verdict
16.6	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 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.		P
	Exception: Components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.8.1.3) need not be subjected to single fault conditions.		P
16.7	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
16.8	If the DUT is operational after the short circuit test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
16.9	At the conclusion of the observation period , the samples shall be subjected to the ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
16.10	As a result of the short circuit test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 16)	P
16.11	For battery systems, the measured maximum short circuit current and duration at that maximum value shall not be greater than the specified value of 41.3.		N
17	Over-discharge Protection Test		P

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Clause	Requirement + Test	Result - Remark	Verdict
17.1	This test shall be conducted on a fully charged sample (MOSOC per 8.1) to determine the DUTs ability to withstand an over-discharge condition and is conducted with all discharge protection circuitry for both temperature and minimum voltage connected to prevent irreparable cell damage. During the test, active protective devices shall be subjected to single fault conditions, unless the protection circuit has been tested for functionality in accordance with 7.8.1.3.		P
	Exception: Over-discharge protection testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P
17.2	The DUT shall be subjected to a constant discharging current/power that will discharge a battery at the manufacturer's specified maximum discharge rate.		P
	The test will continue until the passive protection device(s) are activated, or 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 limit, whichever comes first.		P
17.3	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
17.4	If the DUT is operational after the overdischarge protection test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
17.5	At the conclusion of the observation period, the samples shall be subjected to the ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
17.6	As a result of the overdischarge protection test, the following in (a) – (h) are considerednon-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 17)	P
18	Temperature and Operating Limits Check Test		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.1	This test is conducted to determine whether or not the cells/modules of the DUT are being maintained within their specified operating limits (including voltage and current at specified temperature) during maximum charge and discharge conditions. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components are being maintained within their temperature ratings based upon the maximum operating temperature specifications of the DUT as well as a determination that temperatures on accessible surfaces are not exceeding safe limits.		P
	Exception: Temperature and operating limits check test on a subassembly may be conducted instead of a complete battery system if determined to be representative of the battery system.		P
18.2	A fully discharged DUT (i.e. discharged to EODV) shall be conditioned within a chamber set to the upper limit charging temperature specifications of the DUT. After being stabilized at that temperature (refer to 8.3), the DUT shall 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.		P
	Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed: $T \leq T_{max} - (T_{ma} - T_{amb})$ Where: T is the temperature of the given part measured under the prescribed test. Tmax is the maximum temperature specified for compliance with the test. Tamb is the ambient temperature during the test. Tma is the maximum ambient temperature permitted by the manufacturer's specified or 25°C (77°F), whichever is greater.		P
	Exception No. 2: If the design of the DUT and its controls result in worse case normal charging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the charge levels at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed Tmax.		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.3	While still in the conditioning chamber, the chamber temperature shall be set to the upper limit discharging temperature specifications of the DUT if different from the charging temperature. The fully charged DUT (MOSOC per 6.1) shall then be discharged in accordance with the manufacturer's maximum rate of discharge 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. Temperatures on accessible surfaces are also monitored.		P
	Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed: T ≤ Tmax − (Tma − Tamb) Where: T is the temperature of the given part measured under the prescribed test. Tmax is the maximum temperature specified for compliance with the test. Tamb is the ambient temperature during the test. Tma is the maximum ambient temperature permitted by the manufacturer's specified or 25°C (77°F), whichever is greater.		P
	Exception No. 2: If the design of the DUT and its controls result in worse case normal discharging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the discharge rate at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed Tmax.		P
18.4	The charge and discharge cycles are then repeated for a minimum of two complete cycles of charge and discharge. The DUT is then subjected to an observation period per 8.5.		P
18.5	At the conclusion of the observation period, the samples shall be subjected to the ″as received″ dielectric voltage withstand test in accordance with Section 20 if it anticipated that there has been deterioration of the insulation during the temperature test. The DUT shall be examined for signs of rupture and evidence of leakage.		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.6	The manufacturer's specified operating limits for cells/modules (voltage, current at specified temperatures) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. Temperatures measured on accessible surfaces shall not exceed allowed limits. See Table 18.1 and Table 18.2 for temperature limit tables. Additional non-compliant results during the temperature test are as noted below in (a) – (e). For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) S – Electric shock hazard (dielectric breakdown); d) L – Leakage (external to enclosure of DUT); e) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	(See Table 18)	P
19	Imbalanced Charging Test		P
19.1	This test is to determine whether or not a battery system with series connected cells/modules can maintain the cells/modules within their specified operating parameters if it becomes imbalanced.		P
	Exception No. 1: Testing may be conducted at a subassembly level if that is representative of the battery system.		P
	Exception No. 2: Testing may be conducted on an alternate configuration if it can be shown to be representative for the battery system.		P
19.2	A fully charged DUT (MOSOC per 8.1) shall have all of its modules/cells with the exception of one discharged to its specified fully discharged condition. The undischarged module/cell shall be discharged to approximately 50% of its specified state of charge (SOC) to create an imbalanced condition prior to charging.		P
19.3	The sample shall then be charged in accordance with the manufacturer's maximum normal charging specifications. Charging shall continue until end of charge conditions and the DUT reaches thermal equilibrium. The voltage of the partially charged module/cell shall be monitored during the charging to determine if its voltage limits are being exceeded.		P
	During the test, active protective devices shall be subjected to single fault conditions, unless the protective circuit has been tested for functionality in accordance with 7.8.1.3.		P
19.4	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P

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Clause	Requirement + Test	Result - Remark	Verdict
19.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
19.6	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
19.7	The maximum voltage limit of the module/cell shall not be exceeded when charging an imbalanced DUT.		P
	Also, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 19)	P
20	Dielectric Voltage Withstand Test		N
20.1	This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the battery system.		N
20.2	Circuits exceeding 42.4 V peak or 60 Vdc shall be subjected to an electric strength test in accordance with UL 60950-1/CAN/CSA-C22.2 No. 60950-1, Clause 5.2. In Canada, the dc limits are 42.4 Vdc as defined in CAN/CSA-C22.2 No. 0.		N
	Exception: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.		N
20.3	The test voltage shall be applied between the hazardous voltage circuits of the DUT and non-current carrying conductive parts that may be accessible.		N
20.4	The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.		N
20.5	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.		N

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Clause	Requirement + Test	Result - Remark	Verdict
20.6	The test voltages shall be applied for a minimum of 1 min with the cells/modules disconnected to prevent charging during application of the voltage. Technologies that are required to be at an elevated operating temperature in order to be active, such as sodium-beta chemistries, shall be in a hot state prior to disconnection and applying the test potential		N
20.7	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. Corona discharge or a single momentary discharge is not regarded as an dielectric breakdown (i.e. insulation breakdown).		N
20.8	If the battery system contains hygroscopic materials that may affect spacings, this test is repeated with the DUT or with the subassembly of the DUT containing the hygroscopic materials subjected to humidity conditioning of UL 60950-1/CAN/CSA-C22.2 No. 60950-1, Clause 2.9.2. As a result of this testing, there shall be no dielectric breakdown as outlined in 20.7.		N
21	Continuity Test		N
21.1	This test evaluates the continuity of the protective grounding and bonding system of the battery system that is intended to provide an electrically conductive path from the point of a ground fault on a battery system or its representative parts or components through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.		N
21.2	An alternate test method outlined in 21.7 may be used if the construction of the protective grounding and bonding system adheres to the construction methods outlined in 7.6.5 – 7.6.7. If the connections means vary from that outlined in 7.6.6 and 7.6.7, the fault current method outlined in 21.3 – 21.6 is the default method for evaluating the suitability of the protective grounding system.		N
21.3	The grounding system of an battery system 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 21.4 and 21.5.		N

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Clause	Requirement + Test	Result - Remark	Verdict
21.4	The voltage drop in a protective grounding system is measured after applying a test current of 200% of the rating of the overcurrent protection device rating, for a duration corresponding to 200% of the time-current characteristic of the overcurrent protection device. If the duration for 200% is not given, a point closest on the time-current characteristic shall be used. The overcurrent protective device limits the fault current in the protective grounding system, and is either provided in the battery system or external to the battery system and specified in the installation instructions. The supply used to provide the test current shall have a no load voltage not exceeding 60 Vdc.		N
21.5	The voltage drop measurement is made between any two conductive parts of the grounding system.		N
21.6	The resistance shall be calculated from the measured voltage drop and current. The determined resistance shall be less than or equal to 0.1 Ω.		N
21.7	To check the continuity of the bonding connections, the resistance can be measured between two points on the bonding connections using a milli-ohmmeter. The measured resistance between any two bonding connections shall be less than or equal to 0.1 Ω.		N
22	Failure of Cooling/Thermal Stability System		N
22.1	The purpose of this test is to determine if the battery system can safely withstand a failure in the cooling/thermal stability system.		N
	Exception: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		N
22.2	The DUT shall 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 or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled shall then be charged at its maximum specified charge rate until completely charged or until operation of a protective device.		N
22.3	The DUT shall be fully charged (MOSOC per 8.1) and then conditioned at maximum specified operating ambient for a period of 7 h or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled shall then be discharged at the maximum discharge rate until it reaches its specified end of discharge condition or until operation of a protective device.		N

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Clause	Requirement + Test	Result - Remark	Verdict
22.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N
22.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		N
22.6	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test per Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		N
22.7	The test method of 22.2 – 22.6 shall be repeated with the DUT conditioned at the minimum specified operating ambient.		N
22.8	As a result of the failure of cooling/thermal stability test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.		N
23	Working Voltage Measurements		N
23.1	This test is to measure the working voltage of a battery system.		N
23.2	The working voltage between live parts of opposite polarity, live and dead metal parts, live parts and a metal enclosure, and live and ground connections under both normal charging and discharging conditions as specified by the manufacture is measured.		N
23.3	The dead metal parts and metal enclosure shall be assumed to be connected to the negative terminal of the system for testing purpose.		N
23.4	The values obtained during the measurements outlined in 23.2 shall be used to verify electrical spacings criteria per 7.5.		N
24	Tests on Electrical Components		N
24.1	Locked-rotor test for low voltage dc fans/motors in secondary circuits		N

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Clause	Requirement + Test	Result - Remark	Verdict
24.1.1	The purpose of this test is to determine if a low voltage dc fan or motor does not present a hazard in a locked rotor condition. Fans complying with UL 507 are considered to comply with this requirement without test.		N
24.1.2	A sample of the fan or motor is placed on a wooden board, which is covered with a single layer of tissue paper, and the sample in turn is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m2.		N
24.1.3	The sample is then operated at the voltage used in its application and with its rotor locked for 7 h or until steady conditions are established per 8.3, whichever is the longer.		N
24.1.4	There shall be no ignition of the tissue paper or cheesecloth.		N
24.2	Input		N
24.2.1	The input current draw of a control or accessory separate from the pack such as a mains supplied control or an accessory control evaluated independent from a system, shall be subjected to the input test of 24.2.2.		N
24.2.2	The current or watts input to an ac mains supplied unit, when connected to an ac supply adjusted to the test voltage specified in Table 24.1 shall not be more than 110% of the rated/specified value. The current or watts input draw of a dc supplied unit, when connected to a dc supply, shall not exceed the rated/specified value of the device.		N
24.3	Leakage current		N
24.3.1	For separate controls or other accessories of the system that are cord connected and supplied by ac mains circuits, the controls shall comply with the Touch current and protective conductor current test of the Touch Current and Protective Conductor Current Section in UL 60950-1/CAN/CSA-C22.2 No. 60950-1.		N
24.4	Strain relief test		P
24.4.1	The purpose of this test is to determine if the strain relief means for a non-detachable accessible cord prevents damage or displacement upon being pulled.		P

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Clause	Requirement + Test	Result - Remark	Verdict
24.4.2	The battery system or accessory provided with a strain relief shall withstand without damage to the cord or conductors and without displacement, a direct pull of 156 N (35 lbf) applied to the cord for 1 min. Supply connections within the equipment shall be disconnected from terminals or splices during the test when applicable. If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		P
24.4.3	As a result of the pull force, there was no damage or displacement of internal connectors. Inner conductors may not elongate more than 2 mm (0.08 in) from the pre-test position.	(See Table 24.4)	P
24.5	Push-back relief test		N
24.5.1	The purpose of this test is to determine if the strain relief of a non-detachable accessible cord provides adequate protection to connections and prevent hazardous displacement of internal wiring and connections as a result of push back.		N
24.5.2	A product shall be tested in accordance with 24.5.3 and 24.5.4 without occurrence of any of the following conditions: a) Subjecting the supply cord to mechanical damage; b) Exposing the supply cord to a temperature higher than that for which it is rated; c) Reducing spacings (such as to a metal strain-relief clamp) below the minimum required values; or d) Damaging internal connections or components.		N
24.5.3	The supply cord shall be held 25.4 mm (1 in) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing, which extends further than 25.4 mm (1 in) is present, the bushing shall be removed prior to the test.		N
24.5.4	When the bushing is an integral part of the cord, then the test shall be carried out by holding the bushing. The cord shall be pushed back into the product in 25.4-mm (1-in) increments until the cord buckles or the force to push the cord into the product exceeds 26.7 N (6 lbf).		N
24.5.5	The supply cord shall be manipulated to determine compliance with 24.5.1.		N
24.5.6	If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		N

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Clause	Requirement + Test	Result - Remark	Verdict
	MACHANICAL TESTS		P
25	Vibration Test (LER Motive Applications)		P
25.1	The purpose of this test is to determine the battery system's resistance to anticipated vibration in LER motive installations and applies only to those systems intended for installation in that application.		P
25.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample.		P
	Exception: The sample may be mounted within a mounting fixture representative of the intended end use application.		P
25.3	The fully charged sample (MOSOC per 8.1) shall be subjected to a vibration test in accordance with the Simulated Long Life Testing at Increased Random Vibration Levels Tests of IEC 61373, for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.)		P
25.4	The DUT shall be subjected to vibration in 3 mutually perpendicular directions. During the test the OCV of the DUT and temperatures on the center cell/module shall be monitored for information purposes.		P
25.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
25.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
25.7	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P

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Clause	Requirement + Test	Result - Remark	Verdict
25.8	As a result of the vibration test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 25)	P
26	Shock Test (LER Motive Applications)		P
26.1	The purpose of this test is to determine the battery system's resistance to anticipated shock in LER motive installations and applies only to those systems intended for installation in that application.		P
26.2	The sample shall 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.		P
	Exception: This sample may be mounted within a mounting fixture representative of the intended end-use rail application.		P
26.3	A fully charged sample (MOSOC per 8.1) shall be subjected to a shock test in accordance with IEC 61373 for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.)		P
	Exception: This test may be conducted at the module level if it can be shown that testing shall be representative of the battery system.		P
26.4	Both positive and negative direction shocks shall be applied in each of 3 mutually perpendicular directions for a total of 18 shocks.		P
26.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P

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Clause	Requirement + Test	Result - Remark	Verdict
26.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
26.7	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
26.8	As a result of the shock test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 26)	P
27	Crush Test (LER Motive Applications)		P
27.1	This test is conducted on a fully charged battery system intended for LER motive applications to determine its ability to withstand a crush that could occur during an accident and applies only to those systems intended for installation in that application.		P
27.2	A sample shall be crushed between a fixed surface and a ribbed test platen in accordance with the test 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.		P
	Exception No. 1: The maximum force applied to the DUT shall be 100 ±6 kN.		P
	Exception No. 2: Battery systems with only 2 axes of symmetry, such as cylindrical designs are subjected to 2 mutually perpendicular directions of press.		P
	Exception No. 3: The DUT may be installed in a protective framework representative of what is provided in the end use application.		P
	Exception No. 4: A subassembly may be tested instead of a complete battery system if it can be demonstrated to be equivalent to testing a complete battery system.		P

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Clause	Requirement + Test	Result - Remark	Verdict
27.3	A detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample. Venting of gases may occur, but shall not exceed ERPG-2 levels using the measurement methods outlined in Section 13. The sample shall be subjected to an observation period and the examined.		P
27.4	As a result of the crush test, the following in (a) – (d) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release;	(See Table 27)	P
28	Static Force Test		P
28.1	The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it.		P
28.2	The enclosure of a fully charged DUT (MOSOC per 8.1) shall withstand a steady force of 250 N ±10 N for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 inch) in diameter. However, this test is not applied to the bottom of an enclosure having a mass of more than 18 kg (39.7 lbs).		P
	If the DUT is operational after completion of the application of the static force, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
28.3	If deemed necessary (i.e. due to design of system and anticipation of venting of cells), one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
28.4	After the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P

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Clause	Requirement + Test	Result - Remark	Verdict
28.5	As a result of the static force test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 28)	P
29	Impact Test		P
29.1	The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the battery system contents.		P
29.2	A fully charged sample (MOSOC per 8.1) shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 29.1. A different sample may be used for each impact.		P
29.3	If the DUT is operational after the impacts it shall be subjected to a discharge and charging cycle in accordance with the manufacturer’s specifications. An observation period per 8.5 is then conducted.		P
29.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
29.5	After the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P

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Clause	Requirement + Test	Result - Remark	Verdict
29.6	As a result of the impact test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 29)	P
30	Drop Impact Test		P
30.1	Modules that are intended for field installation into rack mount or similar equipment are subjected to a drop impact test to determine that no hazard exists as a result of an inadvertent drop during installation or removal.		P
30.2	After being equilibrated at room temperature per 8.3, a fully charged module/component pack shall be dropped from a minimum height of 100 cm (39.4 in) for products weighing 7 kg (15.4 lbs) or less, 10 cm (3.9 in) for products weighing >7 kg (15.4 lbs), but less than 100 kg (220.5 lbs), and 2.5 cm (0.98 in) for products weighing > 100 kg (220.5 lbs), to strike a concrete or metal surface in the position most likely to produce adverse results and in a manner most representative of what would occur during maintenance and handling/removal of the battery system during installation and servicing. The orientation of the drop shall be determined by the testing personnel from an analysis of the installation and servicing instructions. If using a metal test surface, it should be provided with some manner of insulation such as insulating film that will prevent inadvertent short circuiting to the surface but will not affect test results.		P
30.3	The sample shall be dropped a minimum of one time. However, if only one drop test is performed, it shall not be a flat drop. If one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.		P
30.4	The concrete surface shall be at least 76-mm (3-in) thick and the concrete or metal drop surface shall be large enough in area to cover the DUT.		P

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Clause	Requirement + Test	Result - Remark	Verdict
30.5	After the drop, if the DUT is operational it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
30.6	At the conclusion of the observation period, an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
30.7	A spark ignition source or gas monitoring as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample immediately after the drop and repeated in the instance of increasing temperatures.		P
30.8	As a result of the drop impact test, the following in (a) – (f) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) S – Electric shock hazard (dielectric breakdown); e) L – Leakage (external to enclosure of DUT); f) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	(See Table 30)	P
31	Wall Mount Fixture/Handle Test		N
31.1	A wall mounting apparatus of a wall mounted battery system or a handle(s) provided for handling of a field/rack installed module/pack, shall have sufficient strength to support the battery system or allow for carrying of module/pack. Compliance is determined by the test below.		N
31.2	The wall mounting apparatus and battery system shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the battery system is additionally applied to the center of the mounting apparatus in a downward direction. The force shall be held for 1 min.For modules/packs with a carrying handle(s), the DUT shall be supported by the carrying handles and a force equal to three times the weight of the DUT is additionally applied in a downward direction. If more than one carrying handle is provided, the added weight shall be distributed between the handles.		N
31.3	As a result of the applied force, there shall be no damage to the mounting apparatus and its securement means when testing the wall mounting fixture. As a result of the applied force, there shall be no damage to handles or the handle mounting/securement means of the DUT.		N

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Clause	Requirement + Test	Result - Remark	Verdict
32	Mold Stress Test		P
32.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.		P
32.2	One complete fully discharged sample (discharged to the manufacturer's specified EODV) shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10°C (18°F) higher than the maximum temperature of the enclosure measured during the Temperature and Operating Limits Check Test in Section 18, but not less than 70°C (158°F). The sample shall remain in the oven for 7 h.		P
32.3	After removal from the oven the DUT shall be subjected to an observation period per 8.5. After the observation period, the sample shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
32.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or reducing electrical spacings or leakage of electrolyte from the enclosure.	(See Table 21)	P
33	Pressure Release Test		N
33.1	The purpose of this test is to ensure that the resettable pressure relief valve operates to prevent damage to the battery system and its electrolyte containment. This test is applicable to valve regulated technologies such as valve regulated lead acid batteries and for nickel systems with resettable relief valves.		N
33.2	A sample of the battery/cell shall be submerged in a container of mineral oil. For large batteries only the pressure relief valve needs to be submerged.		N
33.3	A charging current shall be caused to flow at an increased rate (to be specified by the manufacturer) until bubbles are observed to rise from the pressure relief valve.		N
33.4	Results are acceptable if gas is released normally and the electrolyte containment system does not rupture or leak and the DUT's casing is not ruptured.		N
34	Start-To-Discharge Test		N
34.1	The purpose of this test is to determine the average start to discharge pressure of a resettable pressure relief valve not provided with an ASME stamp and rating.		N

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Clause	Requirement + Test	Result - Remark	Verdict
34.2	A calibrated pressure gauge having a range of at least 150% of the anticipated maximum working pressure of the pressure relief valve shall be installed to indicate pressures developed within the battery system during test.		N
34.3	To determine the start-to-discharge pressure setting of a pressure-relief valve, each of three samples of the valve shall be subjected three times to a gradually increasing air pressure. The pressure at which the valve begins to open shall be recorded. The start-to-discharge pressure setting of each sample is considered to be the average value of the three trials.		N
34.4	The start-to-discharge value mentioned in 34.3 is the highest average value for the three samples tested.		N
34.5	The start-to-discharge pressure shall be in the range of 90 – 100% of its assigned start-to-discharge pressure setting.		N

	ENVIRONMENTAL TESTS		P
35	Thermal Cycling Test (LER Motive Applications)		P
35.1	This test determines the electrical energy storage system's ability to withstand temperature fluctuations that may be anticipated during the end-use application. This test is only applicable to LER motive applications.		P
35.2	A fully charged battery system (MOSOC per 8.1) shall be placed in a test chamber and subjected to the following cycles in (a) – (e). At the conclusion of the cycling, the samples shall remain at room temperature, 25 ±5°C (77 ±9°F) for 24 h. a) Raising the chamber-temperature to 75 ±2°C (167 ±3.6°F) within 30 min and maintaining this temperature for 6 h. b) Reducing the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min and maintaining this temperature for 2 h. c) Reducing the chamber temperature to minus 40 ±2°C (minus 40 ±3.6°F) within 30 min and maintaining this temperature for 6 h. d) Raising the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min. e) Repeating the sequence for a further 9 cycles.		P
	Exception No. 1: Temperatures may need to be held for longer periods for those larger systems where temperature stabilization may take longer. The time required in this case for systems that require longer exposures should be based upon the time it takes for the temperature on internal cells within the DUT to reach thermal equilibrium per 8.3 plus 1 additional hour. This time shall never be less than the exposure times noted in (a) – (d) above.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		P
35.3	If the DUT is operational after the test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
35.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
35.5	At the conclusion of the observation period, the sample is then subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
35.6	As a result of the thermal cycling test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 35)	P
36	Resistance to Moisture Test		P
36.1	The purpose of this test is to determine that the battery system can safely withstand exposure to moisture anticipated in the end use.		P
36.2	With the DUT in its normal operating orientation, it shall be subjected to a moisture resistance test based upon its IP rating in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529. The battery system shall be installed and connected as intended for this test for the end use application. For batteries located where they may be subjected to flooding conditions, the IP rating will need to minimally cover immersion. If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 1: Enclosures with Enclosure Type Ratings as identified in NFPA 70, Article 110, or Section 2 of C22.1, are subjected to the environmental testing outlined in UL 50E/C22.2 No. 94.2, rather than the IP Code.		P
	Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		P
36.3	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
36.4	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
36.5	As a result of the resistance to moisture test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 36)	P
37	Salt Fog Test		P
37.1	This test determines the electrical energy storage system’s ability to safely withstand anticipated exposure to a salt fog conditions due to use near marine environments, and would apply to those stationary systems installed near sea environments whose internal components may be exposed to deterioration from salt fog through openings in the enclosure. This test would not apply to those systems not intended to be installed near marine environments as indicated in the installation instructions or whose enclosure is designed to prevent ingress of moisture with protection against corrosion (e.g. UL/NEMA 4X).		P

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Clause	Requirement + Test	Result - Remark	Verdict
37.2	A fully charged electrical energy storage system (MOSOC per 8.1) shall be subjected to the test method per IEC 60068-2-52, with a severity level of 1 or 2 depending upon the application and location of installation.		P
	Exception: A sample at the subassembly level that would be representative of the battery system may be used for this test.		P
37.3	If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications.		P
37.4	During the cycling, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the cycling per Section 13. An observation period per 8.5 is then conducted.		P
37.5	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
37.6	As a result of the salt fog test, the following in (a) – (h) are considered non-compliant results. For additional information on non-complying results refer to Table 12.1. a) E – Explosion; b) F – Fire; c) C – Combustible vapor concentrations; d) V – Toxic vapor release; e) S – Electric shock hazard (dielectric breakdown); f) L – Leakage (external to enclosure of DUT); g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3); h) P – Loss of protection controls.	(See Table 37)	P
38	External Fire Exposure Test		N
38.1	The purpose of this test is to determine that a battery system will not explode as evidenced by projectiles breaking through the test cage as a result of being exposed to a hydrocarbon pool/brush fire.		N
	Exception No. 1: The battery system may be subjected to the external fire exposure test in UL 2580 instead of the method outlined in 38.2.		N
	Exception No. 2: Testing may be conducted on a representative subassembly rather than a complete battery system if determined that equivalent results to testing a battery system can be obtained.		N

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 3: If the cells employed in the system comply with UL 1642 or UL 2054 projectile test, the system is exempted from this test.		N
	Exception No. 4: This test does not apply to systems intended for outdoor use only that are mounted on a non-combustible surface such as a concrete pad that extends a minimum of 91.4 cm (3 ft) beyond the perimeter of the battery system.		N
38.2	A fully charged DUT at normal operating temperature is subjected to a hydrocarbon pool fire for 20 min. The fuel used shall be heptane or similar hydrocarbon fuel.		N
38.3	The pan, which provides the fire containment, shall be constructed of steel of sufficient thickness to prevent warping during the course of the 20-min test. The upper lip shall have a steel angle welded all around or similar reinforcement to prevent warping during testing. The pan shall be sized, in relation to the DUT support surface, to provide a nominal 61-cm (2-ft) above the hydrocarbon fuel surface and its height should be 20.3 – 39.4 cm (8 – 15.5 inches) in height to accommodate the fuel and water levels. A threaded fitting for the fuel supply shall be centered on the long side of the pan and be located no more than 2.54 cm (1 in) from the bottom of the pan. There should be nominally 15.24 cm (6 in) of water in the pan prior to adding the hydrocarbon fuel to protect the fuel pan and to provide for consistent flame output during the test. The fuel shall be added as needed during the test to provide sufficient fuel for the test duration.		N
38.4	A suitable means to extinguish the fire in the fuel pan within 15 s, or remove the battery from above the fire, shall be provided. This may be accomplished by drawing a cover over the pan, or by moving the DUT from over the pan or removing the pan as putting the fire out may be difficult and should not be underestimated.		N
38.5	The DUT shall be fully supported centered above the fire containment pan above the surface of the heptane. The DUT support structure shall be robust enough to withstand the weight of the DUT for the duration of the test without allowing the DUT to lean or topple. The pan shall be sized large enough to cover the dimension of the DUT. See Figure 38.1 for details of set up.		N
38.6	During the test, the temperature of the cells or modules within the DUT shall be monitored for information purposes.		N
38.7	After the 20-min fire exposure, the DUT is subjected to a hose down in accordance with the guidelines of the Conduct of Hose Stream Test of UL 263, to represent fire fighter response the system may be exposed to during a fire.		N

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Clause	Requirement + Test	Result - Remark	Verdict
38.8	To determine that an explosion hazard has resulted, the DUT with pan fire test set up shall be centered within a circular inner perimeter marked on the floor with paint or a similar marking material. The marking shall be no thicker than 12 mm (0.47 in) and the size of the circular inner perimeter area marking shall 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 marking shall be enclosed within an outer perimeter consisting of a protective barrier wall of a noncombustible material such as masonry or concrete and wall thickness suitable for containing projectiles during the test. The outer perimeter shall be located a minimum of 1.5 m (4.95 ft) from the inner perimeter marking.		N
38.9	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 38.8. See Table 12.1 for additional details.		N

	TOLERANCE TO INTERNAL CELL FAILURE TESTS		N
39	Single Cell Failure Design Tolerance		N
39.1	General		N
39.1.1	There have been field incidents with various battery technologies that have been attributed to a cell failure, which led to a hazardous event. The cell failures in these incidents were the result of either manufacturing defects or insufficient cell or battery design or a combination of both. 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.		N
39.1.2	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 Appendix F. 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.		N
39.2	Single cell failure design tolerance (lithium ion)		N

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Clause	Requirement + Test	Result - Remark	Verdict
39.2.1	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.		N
39.2.2	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. The testing agency is responsible for selecting and demonstrating an appropriate method for inducing thermal runaway. 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 Appendix F for guidance on several methods of inducing cell failure. The method chosen shall be agreed upon by the testing agency.		N
39.2.3	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.		N

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Clause	Requirement + Test	Result - Remark	Verdict
39.2.4	Once a suitable method of cell failure has been determined, the fully charged DUT (MOSOC per 8.1) 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 6.47 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 24-h observation period.		N
	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 shall be documented for each test.		N
	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.		N
39.2.5	Temperatures on the failed cell and surrounding cells are to be monitored and reported for information purposes.		N
39.2.6	As a result of the testing of 39.2, there shall be no fire propagating from the DUT or explosion of the DUT.	(See Table 39)	N
39.3	Single cell failure design tolerance (other technologies)		N

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Clause	Requirement + Test	Result - Remark	Verdict
39.3.1	Other technologies such as lithium metal, sodium sulfur, sodium nickel chloride, and lead acid where there may not be enough field data regarding their tolerance to single cell failure events, are to be subjected to a single cell failure test method similar to 39.2, 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 should be representative of what can occur in the field for the particular technology. The failure mechanism chosen shall consider failures due to potential cell anufacturing 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.		N
39.3.2	For other technologies, similarly as with lithium ion, 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 Appendix F for guidance on several methods of inducing cell failure. The method chosen shall be agreed upon by the testing agency.		N
39.3.3	When a suitable worse case representative method for cell failure has been determined, the DUT is to 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 24-h observation period.		N
	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.		N

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Clause	Requirement + Test	Result - Remark	Verdict
	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.		N
39.3.4	As a result of the testing per 39.3.3, there shall be no fire propagating from the DUT or explosion of the DUT.		N

	MANUFACTURING AND PRODUCTION LINE TESTS		N
40	General		N
40.1	Manufacturers of battery systems shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include corrective/preventative action to address defects found affecting these key elements: a) Supply chain control; and b) Assembly processes.		N
40.2	Battery systems shall be subjected to 100% production screening to determine that any active controls utilized for safety are functioning.		N
	Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.		N
40.3	An ″as received″ dielectric voltage withstand test as outlined in the Dielectric Voltage Withstand Test, Section 20 shall be conducted on 100% production of Assemblies/packs with circuits exceeding 60 Vdc or 42.4 V peak as outlined in Section 20.		N
	Exception: The time for the test may be reduced to 1 s if the test voltage values are increase by 2.4 times the values in Section 20 or as outlined in the routine test criteria of 5.2.2 in UL 60950-1/CAN/CSA-C22.2 No. 60950-1.		N
40.4	A continuity check of the grounding system using a milliohmmeter 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.		N

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Clause	Requirement + Test	Result - Remark	Verdict
40.5	Each resettable non-ASME coded pressure-relief valve shall be tested by the manufacturer for the start-to-discharge pressure by subjecting the pressure-relief valve to a gradually increasing air pressure until the valve begins to open. The start-to-discharge pressure shall be in the range of 90 – 100% of its rated start-to-discharge pressure rating.		N

	MARKINGS		P
41	General		P
	Advisory Note: In Canada, there are two official languages. Therefore, it is necessary to have CAUTION, WARNING, and DANGER instructions and markings in both English and French. Appendix G lists acceptable French translations of the CAUTION, WARNING, and DANGER instructions and markings specified in this Standard. When a product is not intended for use in Canada, instructions and markings may be provided in English only.		P
41.1	Required markings shall be permanent. Examples of permanent marking are ink stamping, engraving and if adhesive labels, compliance to UL 969 or CSA C22.2 No. 0.15 for the surface adhered and conditions of use. Markings required by this standard including nameplate markings per 41.2 and any cautionary markings shall be legible, provided in text color that contrasts with the background color and visible upon installation of the battery system.		P
41.2	Batteries shall 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, and electrical ratings in volts dc and capacity in Ampere-hours or Watt-hours and chemistry. The battery system terminals shall be marked to indicate whether they are positive (+) or negative (-). The battery shall also be marked with its IP rating.		P
41.3	Battery systems shall be marked with the maximum short circuit current and duration (at maximum short circuit current) at the system output terminals.		P
41.4	Battery systems shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 20 years.		P
41.5	A battery system intended for use with specific chargers shall be marked with the following or equivalent: "Use Only ( ) Charger".		P
41.6	A battery system evaluated for protection against ingress of moisture per 7.3.5, shall be provided with the appropriate IP Code rating.		P

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Clause	Requirement + Test	Result - Remark	Verdict
41.7	Systems shall be marked with a cautionary marking indicating to read all instructions before installation, operation and maintenance of the system. This marking may be in the form of the symbol(s) for example: ISO 7000, ″caution″ Symbol No. 434 (exclamation point inside triangle) followed by the ″read instruction manual″ Symbol No. 790 (open book). If using symbols, their meaning shall be explained in the instruction manual.		P
41.8	Systems that must be operated in a certain orientation for safe operation, shall be provided with markings indicating the correction orientation of the system.		P
41.9	Systems shall be marked with a warning marking indicating risk of electrocution near hazardous voltage battery terminals.		P
41.10	Systems with replaceable fuses, shall be marked with rating and type of fuse for replacement. The marking shall be located near the fuseholder.		P
41.11	Separable accessories and controls which are intended for connection to the mains supply shall be provided with markings that include the manufacturer's name, part number of the accessory and electrical ratings in voltage, frequency, phase if applicable, and current or watts.		P
41.12	A ground terminal shall be marked as outlined in 7.6.8.		P
41.13	Additional warning markings for battery systems located in restricted access locations such as warnings regarding hazardous moving or electrical parts, hot surfaces, etc., to alert service or other trained personnel and prevent hazards, shall be provided on the battery systems in locations where they will be visible those persons having access to the location.		P

	INSTRUCTIONS		P
42	General		P
42.1	Components of a battery system shall be provided with a complete set of instructions for proper installation and use in a battery system. These instructions shall include normal operating specifications.		P

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Clause	Requirement + Test	Result - Remark	Verdict
42.2	Systems shall be provided with complete instructions for installation in the end use application. Installation instructions shall include the following along with any other instructions necessary for the safe and correct installation of the system and its accessories in the intended end use: a) Insulated tools, insulated gloves, personal protective equipment, and clothing and other measures necessary for safe installation of the battery system; b) The necessary housing requirements for protection against ingress of moisture and debris or access by persons; c) Ventilation requirements to prevent accumulation of hydrogen greater than 25% of hydrogen LFL; d) Protective components and devices required in the end use installation such as fuses, circuit breakers, wiring, and other devices such as disconnect devices in accordance with NFPA 70 or C22.1. See 7.8.1.4; e) Circuit diagrams and instructions for proper connection of the system and any ancillary devices such as separate controllers, monitoring devices, etc.; f) Warnings and instructions regarding the battery electrolyte; g) Instructions regarding any commissioning tests and checks necessary before placing system into service; h) Table or list, etc. of symbols used and their eanings; i) The necessary information to complete an arc flash/blast analysis, including bolted fault current (IBF), 1/2 bolted fault current (1/2 IBF), protective device clearing time, and protective device current interrupt capability at a minimum, if applicable to the system; and j) If applicable, the manufacturer shall provide information on design considerations for maximum and minimum system configurations, such as number of modules installed in series, maximum resistance, and maximum inductance to prevent arc flash incident energy from exceeding the requirements of Personal Protective Equipment Category 4 per NFPA 70E or CSA Z462-15.		P
42.3	Battery systems intended for installation in a restricted access location per 6.41 shall have installation instructions indicating this with instructions defining the type of location required, its restrictions, signage and other information to be provided.		P
42.4	A system shall be provided with instructions for the proper use including charging and discharging, storage, recycling and disposal. These instructions shall include temperature limits, charging and discharging limits as well as instructions regarding the use of any controls or monitoring systems.		P

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Clause	Requirement + Test	Result - Remark	Verdict
42.5	A system shall include the following statements or equivalent: a) An attention word, such as ″DANGER,″″WARNING,″ or ″CAUTION.″ b) A brief description of possible hazards. c) A list of actions to take to avoid possible hazards regarding disposal of the system such as do not crush, disassemble, dispose of in fire, or similar actions.		P
42.6	The system shall be provided with a maintenance manual that includes a schedule for maintenance of the system and accessories including a check of wiring and connections, etc. The maintenance manual shall include necessary safety precautions regarding handling or conducting maintenance on the system and its connections and accessories.		P

	APPENDIX A (Normative)		N
	A1. Standards for component		N

	APPENDIX B (Normative)		P
	Test program for sodium-beta battery cells		P

	APPENDIX C (Normative)		N
	Test Program for flowing electrolyte batteries		N

	APPENDIX D (Normative)		N
	Metal compatibility table		N

	APPENDIX E (Normative)		P
	Alternative Cell Test Program		P
E1	General		P
E1.1	The following is an alternate program to be used to evaluate lithium ion cells or other secondary lithium cells instead of that outlined in 7.11.2.		P
	Exception: Samples of secondary lithium cells other than lithium ion shall be subjected to charge/discharge cycling as outlined in UL 1642 prior to conditioning outlined in E1.2.		P

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Clause	Requirement + Test	Result - Remark	Verdict
E1.2	Prior to testing, the samples shall be conditioned by first discharging them down to the manufacturer's specified end point voltage and then charging them to the manufacturer's specified upper limit charging voltage using the manufacturer's specified maximum charging current. Samples shall be charged at the upper temperature limit of the charging operating region and the lower limit of the charging operating region for those tests as identified in Table E.1.		P
E2	Short Circuit		P
E2.1	Fully charged, conditioned cells are stored in an ambient temperature of 25°C ±5°C (77°C ±9°F) until their casing reaches ambient temperature, and then subjected to a short circuit condition using an external resistance of ≤ 20 mΩ.		P
E2.2	The external resistance shall be applied to the cell terminals for 7 h or until temperatures on the cell cool to within ±10°C (18°F) of ambient conditions.		P
E2.3	As a result of the short circuit test, the cells shall not show signs of fire or explosion.	(See Table E2)	P
E3	Cell Impact		P
E3.1	Fully charged, conditioned cells are subjected to an impact test as outlined in UL 1642. The cells shall be at an ambient temperature of 25°C ±5°C (77°C ±9°F) prior to testing.		P
E3.2	As a result of the impact test, the cells shall not show signs of fire or explosion.	(See Table E3)	P
E4	Drop Impact		P
E4.1	Fully charged cells shall be dropped three times from a height of 1 m (3.3 ft) onto a flat concrete or metal surface. The cells shall be at an ambient temperature of 25°C ±5°C (77°C ±9°F) prior to testing.		P
E4.2	The cells shall be dropped in a manner that the impacts occur in random orientations.		P
E4.3	After completion of the impacts, the cells shall be subjected to a minimum one hour observation period before being examined.		P
E4.4	As a result of the drop impact test, the cells shall not show signs of fire or explosion.	(See Table E4)	P
E5	Heating		P
E5.1	Fully charged, conditioned cells are subjected to a heating test as outlined in UL 1642.		P
E5.2	As a result of the heating test, the cells shall not show signs of fire or explosion.	(See Table E5)	P
E6	Overcharge		P

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
E6.1	Fully charged conditioned cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25°C ±5°C (77°C ±9°F) and with the cell casing at an ambient of 25°C ±5°C (77°C ±9°F) at the start of the test. The voltage and temperature of the cell shall be monitored during the test.		P
E6.2	The cells are charged with a constant current at the maximum specified charge current until the voltage of the cell reaches 120% of the maximum specified charge voltage value or 130% State of Charge (SOC), whichever is reached first. The charge is then terminated while the cell temperature continues to be monitored. The test is concluded when the cell temperature drops and returns to ±10°C (18°F) of the test ambient.		P
E6.3	As a result of the overcharge test, the cells shall not show signs of fire or explosion.	(See Table E6)	P
E7	Forced Discharge		P
E7.1	Fully charged cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25°C ±5°C (77°C ±9°F).		P
E7.2	The discharged cells are subjected to a forced discharge at a constant current 1.0 It A for 90 min with the discharge voltage limit not to exceed the numerical value of the upper limit charging voltage specified for the cell. If the discharge voltage limit is reached before the 90 min, the cell shall be discharged at a constant voltage discharge equal to the manufacturer's determined low voltage cutoff, with the current decreasing as necessary until the 90 min time period is reached.		P
E7.3	As a result of the forced discharge test, the cells shall not show signs of fire or explosion.	(See Table E7)	P
E8	Projectile		P
E8.1	Two fully charged cells shall be subjected to the projectile test criteria as outlined in Exception No. 1 of 7.11.2.		P
E8.2	As a result of the projectile test, the cells there shall not be an explosion of the cells resulting in projectiles with sufficient force to penetrate the test cage screen.	(See Table E8)	P

	APPENDIX F (Informative)		N
	Cell Failure Methods		N
F1	General		N

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ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
F1.1	This appendix provides some recommended methods for simulating cell failure for the Single Cell Failure Design Tolerance test of Section 39. The methods below represent some known methods utilized for this type of testing and considered representative, depending upon the technology and battery design, but are not intended to be an all-inclusive list of methods to be employed.		N
F1.2	Probable cell failure techniques representative of what happens in the field are preferable for the test (e.g. contamination, separator defects or separator compromise due to internal or external fault conditions, etc.) as this would be the closest approximation of what could occur to a cell to cause it to fail. However, cells with internal defects require the use of specially constructed cells with known weaknesses built into them, and may not always be available for testing. Alternatively, the effects of a cell failure may be simulated to a realistic degree through external stresses, e.g. through heating, in a way that is representative of the failure typical effect.		N
F1.3	The following methods may be used to reproduce or simulate potential technology specific cell failures that could lead to thermal runaway and/or propagation in an end use application. The test method chosen should be based upon potential failure mechanisms due to manufacturing defects or latent defects introduced in a cell as a result of stresses from the battery system that may lead to a propagation event for the technology being evaluated. It is recommended that these failure methods be conducted at a small multi-cell or sub-module level to determine surrounding cell reaction to the internal cell failure.		N
F1.4	For this evaluation, all cells are to be in a fully charged state (> 95% MOSOC) and if necessary for the technology, heated to an active state.		N
F1.5	During the test, temperatures on the failed cell outer surface or casing, and if applicable, the outer surface or casings of the surrounding cells should be monitored. The open circuit voltage of the cell to be failed should also be monitored. The time from the start of applying the failure mechanism to the cell to observable initiation of the cell failure should be recorded. The observable results of the cell failures and impact to the surrounding cells should be recorded as well, and videotaping may be useful. The details of the test methodology should be documented including documentation of all parameters impacting the test results.		N
F2	Replicating Internal Cell Failures through Internal Defects		N

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Clause	Requirement + Test	Result - Remark	Verdict
F2.1	Single cell conductive contamination		N
F2.1.1	This method reproduces a single cell failure through the introduction of conductive contamination that connects cathode and anode in an internal short circuit. This method requires that a special cell constructed with a known defect be utilized as the failed cell. The remaining cells in the testing subassembly should be representative of production.		N
F2.1.2	The failure in the cell should be activated (e.g. through heating or other means) and the results of the failure should be recorded/documented, and temperatures and voltages measured and documented as noted above.		N
F2.2	Single cell separator defect		N
F2.2.1	This method reproduces defects such as holes or tears in a cell separator that connects cathode and anode in an internal short circuit. This method also requires the use of a special cell constructed with the known defect. The other cells in the DUT should be representative of production. The defect in the cell with the defective separator should be activated through necessary means that may include charge/discharge cycling to determine the effects of the defect on the failed and surrounding cells. Testing is continued until the defective cell failure activates in some manner and ultimate results occur.		N
F2.3	Internal heater application		N
F2.3.1	This method utilizes a special cell built with an internal heating element installed within the cell to create a single cell failure through heating of cell contents. This method requires the use of a specially built cell that contains an internal heater wire. The other cells in the cell subassembly should be representative of production. The internal heater within the cell to be failed is activated within a time frame and the temperature ramp is documented. The heating ramp should be representative of what can occur during field failure of the cell. Once the cell goes into failure, the heater should be turned off and the results of the cell failure observed and documented.		N
F3	Replicating Internal Cell Failures Through Application of External Stress		N
F3.1	External heater application		N
F3.1.1	This method utilizes an external thin film heater applied to a portion of the cell to be failed to create the failure. This method is a suitable method to represent the rapid uncontrolled heating that can occur when a cell fails as a result of an internal defect.		N

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
F3.1.2	A thin film heater should be applied to the cell to be failed in a location on the cells that does not directly affect the other cells in the assembly. The other cells should only be affected by the local effects and conduction (electrical and thermal) through the tabs of the failed cell and not the applied heater.		N
F3.1.3	The heater should have sufficient energy and the heating ramp should be of sufficient speed to replicate what occurs when a cell fails. Once the heated cell goes into failure, the heater is to be turned off and the results of the cell failure observed.		N
F3.2	External indentation without casing/surface penetration		N
F3.2.1	This method creates a single cell failure through an indentation of the cell casing with a blunt indentation mechanism that results in shorting over several layers of the cell electrode to create a single cell failure, but does not puncture the cell casing. This method can only be utilized, if it is possible to access the trigger cell to conduct this testing during the Single Cell Failure Design Tolerance test of Section 39 and the method to gain access to the cell does not affect the results of the test.		N
F3.2.2	he press equipment to be used for this test should be stepper-motor-powered press equipment with a control/monitoring system and integral conditioning chamber with the following attributes: a) Control system should provide signal to press equipment every 100 ms; b) Minimum load capacity of the press: 1,500 N (337.2 lbf) or greater as necessary to provide sufficient force on sample during the test; c) Sampling rate for the load force measurement: once per second or more frequently; d) Press speed: 0.1 ±0.01 mm/s; e) Sampling rate for the open circuit voltage (OCV) measurement: once per second or more frequently; and f) Noise limit on the OCV reading: ±5 mV or less.		N

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
F3.2.3	For the test, the cell to be failed is subjected to a force from a blunted tip indenter at the center of the cell. For cylindrical cells the force should be at the center of the length of the cell and for prismatic cells the force should be at the center of the flat face of the cell. The indenter consists of a tungsten carbide steel probe with a recommended hardness equal to SKD-11 steel or above and with the tip rounded to avoid penetration of the cell's case. The nail diameter is 3.2 mm (0.125 in) and the dimension of the tip may be varied as necessary for the form factor of the cell as noted in Figure F.1. During the test, the cell case temperature, the force applied to the cell case and displacement of the probe, and the open circuit voltage (OCV) of the cell is monitored continuously with an OCV, force and displacement sampling rate of 100 measurements/second. The monitored values of temperature, OCV drop, force and displacement should be included in the test results documentation.		N
	Exception: For cells constructed with multiple stacks or intentional gaps in electrode layers, indenter position should be adjusted to be centered on a cell stack.		N
F3.2.4	The speed of indention at the cell casing/surface should be at a rate of is 0.1 mm/s. The voltage of the cell being failed should be monitored and the indentation should be halted when there is a voltage drop of 500 mV, which is indicative of an internal short circuit through a limited number of electrode layers.		N
F3.2.5	Once the voltage drop occurs, the indentation is stopped and the results of the cell failure observed.		N
F3.3	Nail penetration through cell casing		N
F3.3.1	This method creates a single cell failure through puncture of the cell with a sharp nail moving slowing through multiple layers of the cell electrodes to create a failure. This method can only be utilized, if it is possible to access the internal cell surface to conduct this testing during the Single Cell Failure Design Tolerance test of Section 39 and the method to gain access to the cell does not affect the results. For additional details on nail penetration methodology, refer to IEC TR 62660-4.		N
F3.3.2	The press equipment used for this test is outlined in F3.2.2. During the test, the cell case temperature, the force applied to the cell case and displacement of the probe, and the open circuit voltage (OCV) of the cell is monitored continuously with an OCV, force and displacement sampling rate of 100 measurements/second. The monitored values of temperature, OCV drop, force and displacement should be included in the test results documentation.		N

ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
F3.3.3	The nail used for this test should be of a thickness that limits the area of the cell that is impacted. The recommended thickness of the indenter should be between 1 – 3 mm (0.04 – 0.12 in). The material used should have sufficient strength to prevent breaking or damage to the indenter during the test and sharp enough to be able to puncture the cell casing. For some test methods, a conductive metal nail is required for creating the short. Other methods call for the metal nail to be provided with insulation or that a ceramic nail be used so that the current does not have a path through the nail, which may affect the results. Regardless of the nail material used, it should be documented in the test results.		N
F3.3.4	The rate of indentation of the nail should be 0.1 mm/s. The voltage of the cell being failed is to be monitored and the movement of the nail through the cell should be halted when there is a voltage drop of at least 500 mV or the nail has gone through approximately half of the cell, whichever comes first. Once the voltage has dropped or the depth of penetration through half the cell has occurred, the nail penetration is stopped and the results of the cell failure is observed.		N
F3.4	Single cell short circuit		N
F3.4.1	This method simulates a single cell internal failure through a very low resistance external short circuit event to create a cell failure. This method is not recommended for cell constructions that contain internal protection devices such as PTCs or fuses, as a cell failure may not be able to be initiated.		N
F3.4.2	The cell failure should be initiated with the application of a very low resistance short circuit applied to the cell terminals. The total resistance of the short circuit as seen from the cell terminals should be as low as practicable. The external resistance should be applied until ultimate results occur. The external resistance used should be as close as possible to the cells internal resistance. The chosen external resistance should be agreed to by the test agency and manufacturer.		N
F3.5	Single cell overcharge		N
F3.5.1	This method creates a single cell failure through overcharge of the cell beyond the cell specifications to create a cell failure. This method is not recommended for cell constructions that contain internal protection devices such as PTCs or fuses, as a cell failure may not be able to be initiated. This method may not be useful for pouch type cells where excessive swelling may result from the overcharge, which may affect the ability to initiate a failure in the cell.		N

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ANSI/CAN/UL1973: 2018			
Clause	Requirement + Test	Result - Remark	Verdict
F3.5.2	The failure should be initiated through continued charging of the fully charged cell to be failed until ultimate results occur. The supply used to charge the cell should be capable of bringing the cell voltage up to the level where cell failure will be initiated (e.g. 6 Vdc for lithium ion). The charging should begin at the maximum charge voltage and be increased by 1 V and held for 1 min before increasing the voltage to the cell until ultimate results occur. The charge rate should be at 110% of the maximum specified charging rate. At that point of ultimate results, the charging may be stopped. Test voltage and current should be recorded and provided with the test results.		N
	APPENDIX G (Normative)		P
	Safety marking translations		P

	TABLE: List of critical components				P
Object/part No.	Manufacturer/ trademark	Type/model	Technical data	Standard (Edition / year)	Mark(s) of conformity[1])
Cell	Jiangxi Anchi New Energy Technology Co., Ltd.	IFP23140160-50Ah	3.2V, 50Ah	ANSI/CAN/UL 1973: 2018	Test with appliance
1) An asterisk indicates a mark which assures the agreed level of surveillance.					

15	TABLE: Overcharge Test						P
Sample No.	OCV at start of Test, Vdc	Fault Condition Imposed	Measured Maximum Charge Voltage, Vdc	Measured Maximum Charge Current, A	Max Temp Measured, °C	Dielect Voltage Break-down? Y or N?	Results
B1	11.26	S-C MOS	16.06	100	48.9	N	P
Sample No.	Charge/ Discharge Cycle at end?	Combustible Concentration		Toxic Gas Concentration			
		≥ 25% LFL?	Spark Ignition?	Potential Toxic gas	Chamber Volume, m3	Measured concentration of toxic gas, ppm	OSHA TWAs Limit Values, ppm
-	-	-	-	-	-	-	-

16	TABLE: Short Circuit Test						P
Sample No.	Initial OCV, Vdc	Meas. Max. SC Current A#/Time to operation of protection, s	Measured External Short Circuit Resistance, mΩ	Measured Maximum Temperature on sample, °C	Fault Condition Imposed	Dielectric Breakdown?, Y or N	Results
B2	13.86	/	19.6	34.6	S-C MOS	N	P
# - The maximum short circuit was measured as well as the time it took from the application of the short circuit resistance to operation of the protection device.							
[ ] See attached chart of current/time for short circuit test.							
Load at between 85% to 100% of short circuit protector trip current:							
Sample No.	Initial OCV, Vdc	Measured Maximum Short Circuit Current, A	Measured Maximum Temperature on Sample, °C	Fault Condition Imposed	Dielectric breakdown? , Y or N	Results	
-	-	-	-	-	-	-	

17	TABLE: Overdischarge Protection Test					P
Sample No.	Initial OCV, V	Voltage at End of Test, Vdc	Measured Maximum Discharge current, A	Max Temp Measured °C	Dielectric Breakdown?, Y or N	Results
B3	13.80	0	50	38.2	N	P

Sample No.	Charge/ Discharge Cycle at end?	Combustible Concentration		Toxic Gas Concentration			
		≥ 25% LFL?	Spark Ignition?	Potential Toxic gas	Chamber Volume, m3	Measured concentration of toxic gas, ppm	OSHA TWAs Limit Values, ppm
-	-	-	-	-	-	-	-

18	TABLE: Temperature And Operation Limits Check Test				P
Sample No.					
Thermocouple Location	Max Temp during charging, °C		Max Temp during discharging, °C		Max Temp Limit, °C
	Measured	Calculated	Measured	Calculated	
Chamber Ambient	23.8	-	24.2	-	25
Casing of cell	37.8	58.8	43.2	59.2	60
Module surface	38.6	78.8	41.2	79.2	80
Internal wire	48.7	198.8	50.8	199.2	200
PCB	45.6	128.8	49.2	129.2	130
MOSFET	46.2	148.8	48.6	149.2	150
Control IC	39.5	148.8	44.2	149.2	150

Location of voltage measured	Max measured Voltage on module/cell, Vdc	Min measured voltage on module/cell, Vdc	Normal Operating range of module/cell, Vdc
Cell	3.63	2.12	3.65-2.0
Module	14.57	10.63	14.6-10.5

19	TABLE: Imbalanced Charing Test						P
Sample No.	Initial OCV of partially charged module/ cell, Vdc	Measured Maximum charge voltage, Vdc	Measured Maximum charge current, A	Measured Maximum Voltage on partially charged module/cell, Vdc	Measured Maximum Temp on partially charged module/cell, °C	Dielectric Break Down?, Y or N	Results
B4	12.65	14.60	50	3.63	35.8	N	P

Sample No.	Charge/ Discharge Cycle at end?	Combustible Concentration		Toxic Gas Concentration			
		≥ 25% LFL?	Spark Ignition?	Potential Toxic gas	Chamber Volume, m3	Measured concentration of toxic gas, ppm	OSHA TWAs Limit Values, ppm
-	-	-	-	-	-	-	-

24.4	TABLE: Strain Relief Test		P
Sample No.	Test location	Applied Pull force, N	Comments
B6	Case	156	-

25	TABLE: Vibration Test(LEV Motive Applications)		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B7	13.85	13.84	-

26	TABLE: Shock Test(LEV Motive Applications)		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B8	13.84	13.83	-

27	TABLE: Crush Test(LEV Motive Applications)			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Maximum Force applied to the battery during crush,kN	Comments
B9	13.85	13.78	100	-

28	TABLE: Static Force Test			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Force Applied position	Comments
B10	13.82	13.82	Top	-
	13.80	13.80	Bottom	-
	13.81	13.80	Sides	-

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29	TABLE: Impact Test		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B11	13.81	13.80	-

30	TABLE: Drop Impact Test			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Drop Height,m	Comments
B12	13.82	13.81	0.1	-

32	TABLE: Mold Stress Test			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Maximum temperature applied to test., °C	Comments
B13	13.84	13.78	70	-

35	TABLE: Thermal Cycling Test (LEV Motive Application)		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B14	13.84	13.52	-

36	TABLE: Resistance to Moisture Test		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B15	13.82	13.77	-

37	TABLE: Salt Fog Test(outdoor use)		P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments
B16	13.84	13.78	-

E2	TABLE: Short circuit (cell)				P
Sample No.	Ambient T(°C)	Voltage at the start of test.Vdc	Resistance of circuit, (mΩ)	Maximum case temperature (°C)	Results
Charging temperature:0°C					
C1	23.5	3.32	18.5	52.1	P
Charging temperature: 45°C					
C2	23.5	3.45	18.8	53.8	P

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E3	TABLE: Cell Impact			P
Sample No.	Voltage at the start of test.Vdc	Maximum Temperature on Cell Casing, °C	Comments and Condition	
Charging temperature:0°C				
C3	3.31	24.5	-	
Charging temperature: 45°C				
C4	3.42	24.8	-	

E4	TABLE: Drop Impact			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments and Condition	
C3	3.42	3.41	-	
C4	3.43	3.42	-	

E5	TABLE: Heating			P
Sample No.	Voltage at the start of test.Vdc	Voltage at the end of test.Vdc	Comments and Condition	
Charging temperature:0°C				
C5	3.32	3.26	-	
Charging temperature: 45°C				
C6	3.43	3.34	-	

E6	TABLE: Overcharge				P
Sample No.	Measured Maximum Charging Voltage (V dc)	Initial OCV, V at	Maximum Temperature on Cell Casing, °C	Comments	
Charging temperature:0°C					
C7	4.38	2.23	38.4	-	
Charging temperature: 45°C					
C8	4.38	2.24	37.9	-	

E7	TABLE: Forced Discharge				P
Sample No.	Initial OCV, V at	Final Voltage, V	Max Discharge Current, A	Comments	
C9	2.21	0	50	-	
C10	2.24	0	50	-	

E8	TABLE: Projectile		P
Sample No.	Voltage at the start of test.Vdc	Comments	
C9	3.42	-	
C10	3.40	-	

Photo 1

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[ ] rear

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[ ] left side

[ ] top

[ ] bottom

[ ] internal

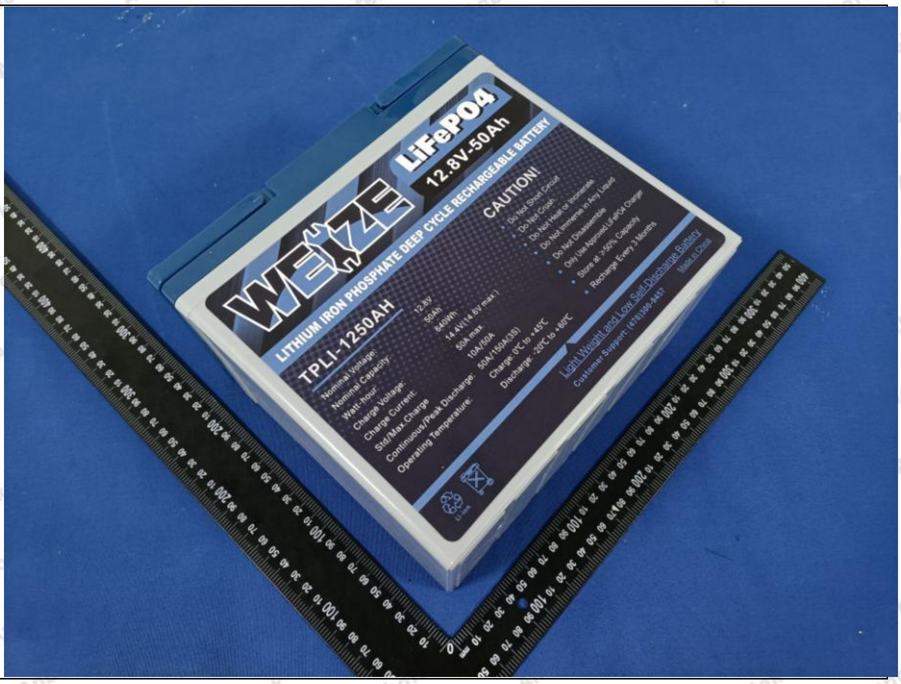

Photo 2

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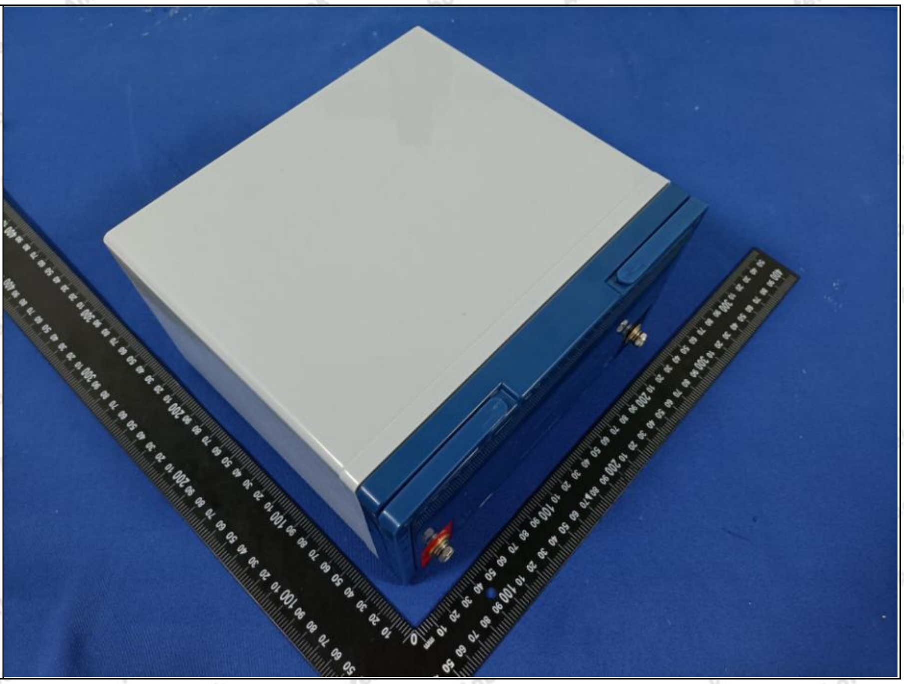
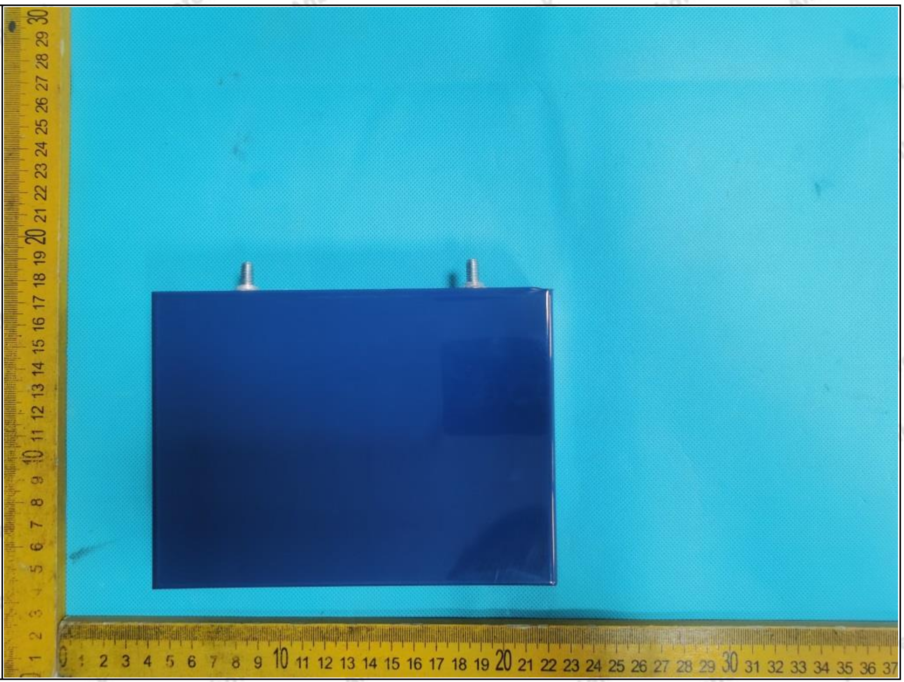
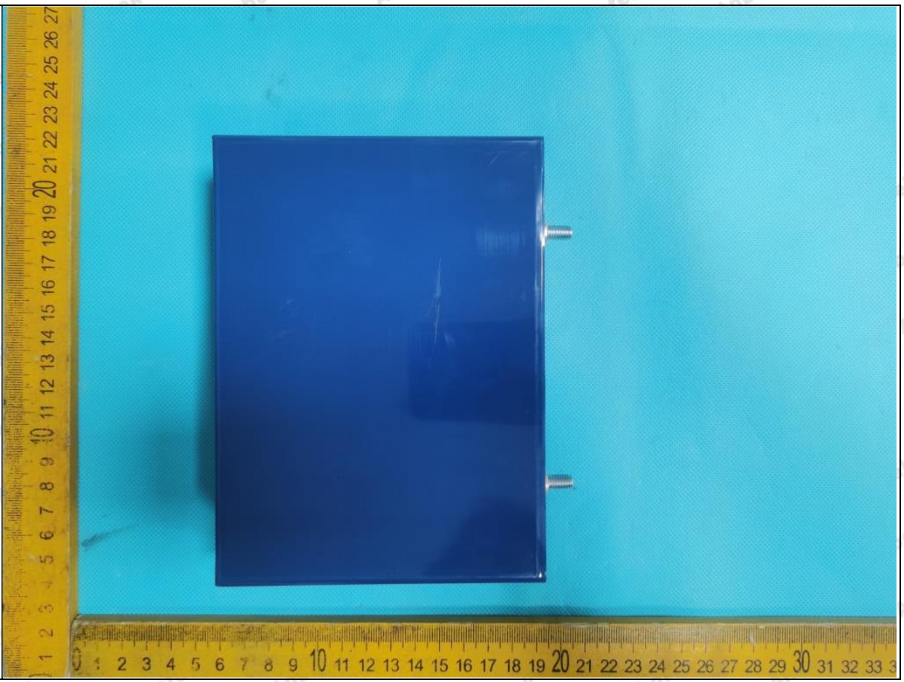


Photo 3 [√] front [ ] rear [ ] right side [ ] left side [ ] top [ ] bottom [ ] internal	
Photo 4 [ ] front [√] rear [ ] right side [ ] left side [ ] top [ ] bottom [ ] internal	

End of the report