Standard: UL 1973, Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications

Proposal Date: May 21, 2021
BALLOTS AND COMMETNS DUE: JULY 5, 2021

SUMMARY OF TOPICS

The following changes in requirements are being proposed:

1. Testing of Modules during the short circuit test.

2. Editorial corrections.

3. Addition of an exception to the General Performance Section for the test time for lithium ion cells or batteries.

4. Revision to Table 12.1, Note (d) for loss of primary control.

5. Addition of an Exception for the Drop Impact Test SOC.

6. Addition of an exception for outdoor use only in the Single Cell Failure Design Tolerance test.

7. Moving all lithium cell requirements into UL 1973.

8. Addition of requirements for repurposing batteries.

9. Clarification of lead acid battery requirements.

10. Addition of Vehicle Auxiliary Power System Requirements.

11. Revisions to the External Fire Test.

12. Addition of cell test method from UL 9540A for information gathering.

13. Clarification for spacings criteria and pollution degree in 7.5.

14. Addition of measurement of cell voltages during overcharge and overdischarge tests.

15. Clarification of the single cell failure design tolerance test.

16. Proposals for flowing electrolyte batteries.

17. Inclusion of mechanically recharged metal air battery requirements.

18. Functional safety updates.

19. Inclusion of EMC testing for electronic safety controls.

20. Clarification of Dielectric Voltage Withstand Test locations on sample.

21. SELV Limits for Canada.

22. Revisions to Section 7.1 to address all non-metallic materials.

23. Smart Grid Applications.

24. Clarifications for Appendix C.

25. Addition of compliance criteria P - Loss of protection controls for Drop Impact Test.

26. Inclusion of sodium ion technology batteries.

27. Expanding the wall fixture test to include other support structures.

28. Evaluation proposal for galvanic corrosion determination.

29. Revision of grounding requirement in 7.6.3.

30. aR Fuse Consideration and Module/component voltage consideration.

31. Addition of criteria for transformers.

32. Overload under discharge.

33. Addition of High Rate Charge Test.

34. Replacement of UL 60950-1 with UL 62368-1.

35. Revision of component standards in Appendix A.

Need access to the full standard or a standard this proposal references? Click here to learn more about accessing UL Standards. STP Members can find the latest copy of the standard under their My STPs tab in CSDS.

For your convenience in review, proposed additions to existing requirements are shown underlined and proposed deletions are shown ~~lined-out~~.

1. Testing of Modules during the short circuit test.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

The battery module is often the level of product submitted for UL 1973 evaluation and it is important for anyone using these modules to understand the potential short circuit current from the battery at this level.

PROPOSAL

16 Short Circuit Test

16.2A The direct short circuit test shall also be conducted on the battery module. The output of the battery module sample shall be short-circuited with a shorting device having resistance as low as practicable with a maximum total resistance of 20 mΩ.

2. Editorial Corrections.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

There were some editorial errors made in the second edition that need to be corrected.

For 18.6, the Non-compliant Test Results Table (Table 12.1) was proposed to be revised in May 2015 to be as follows for the Temperature and Operating Limits Check. The proposal achieved consensus and the revision was published, but unfortunately the requirement in 18.6 was not updated to reflect this change at the same time. Proposing to correct this oversight in 18.6 now. Other editorial changes are also being proposed.

Temperature and Operating Limits Check	E, F, C, V, S, L, R, P

PROPOSAL

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 it ~~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.

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 it ~~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.

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 or module level if determined to be equivalent to testing at the system level.

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.

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.

Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25°C ±5°C (77°F ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:

$$T \le T_{max} - (T_{ma} - T_{amb})$$

Where:

T is the temperature of the given part measured under the prescribed test.

T_{max} is the maximum temperature specified for compliance with the test.

T_{amb} is the ambient temperature during the test.

T_{ma} is the maximum ambient temperature permitted by the manufacturer's specification ~~specified~~ or 25°C (77°F), whichever is greater.

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°C ±5°C (77°F ±9°F). Temperatures on temperature sensitive components shall not exceed T_{max}.

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.

Exception No. 1: If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25°C ±5°C (77°F ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:

$$T \le T_{max} - (T_{ma} - T_{amb})$$

Where:

T is the temperature of the given part measured under the prescribed test.

T_{max} is the maximum temperature specified for compliance with the test.

T_{amb} is the ambient temperature during the test.

T_{ma} is the maximum ambient temperature permitted by the manufacturer's specification ~~specified~~ or 25°C (77°F), whichever is greater.

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°C ±5°C (77°F ±9°F). Temperatures on temperature sensitive components shall not exceed T_{max}.

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) - (h)~~(e)~~. 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)~~c)~~ S - Electric shock hazard (dielectric breakdown);

f)~~d)~~ L - Leakage (external to enclosure of DUT); and

g)~~e)~~ R - Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);

h) P - Loss of protection controls.

B2.2.1.2 The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. Each sample shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions for a total of 18 shocks unless the sample has only two axes of symmetry, in which case only two directions are tested for a total of 9. The parameters of the shock applied are as noted in the Table B.2 below. The shocks shall be applied with the sample at room temperature of 25°C ±5°C (77°F ±9°F). At the conclusion of the shock testing the sample is operated (i.e. charged/discharged) at its normal operating temperature for 1 cycle to determine if ~~its~~ it has been made hazardous as a result of the shock conditioning.

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.

3. Addition of an exception to the General Performance Section for the test time for lithium ion cells or batteries.

RATIONALE

Proposal submitted by: David Ginder, EnerSys

Lithium ion cell self-discharge is extremely low compared to other chemistries. Typically in the 1 mΩ/day. Expanding the time interval from end of charge to test from 3 hours to 36 hours will have no significant impact on test results in which temperature dependencies are not involved and provide more flexibility to group charge cells or modules for testing.

PROPOSAL

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.

Exception: For secondary lithium ion cells or batteries in which temperature is not a dependency on the test, the rest time may be extended from 3 h to 36 h, and the manufacturer’s BMS data may be used to determine the MOSOC.

4. Revision to Table 12.1, Note (d) for loss of primary control.

RATIONALE

Proposal submitted by: David Ginder, EnerSys

For breakers used in a BMS, if the breaker fails in a safe condition this is shall not be considered loss of protection controls as the BMS will need to be replaced and a reconnect into an unsafe condition cannot occur.

PROPOSAL

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Overcharge	E, F, C, V, S, L, R, P
Non-compliant Results Key: P - Loss of protection controls[d]	
[d] Loss of protection controls - Failure of software and/or electronic controls, discrete control devices or other built-in electrical protection components relied upon for safety and that remain in the circuit during the test, to operate as intended. <u>Failure of electrical components such as circuit breakers, that fail in a safe condition that does not allow the system to reconnect into an unsafe condition are acceptable.</u>	

5. Addition of an Exception for the Drop Impact Test SOC.

RATIONALE

Proposal submitted by: David Ginder, EnerSys

Batteries are not always installed at 100% SOC as the SOC needs to meet nominal SOC of the string for installation. There should be an allowance that the drop test can be performed with a fully charged battery and at the maximum SOC as indicated in the System's User Manual. This would address if there is an issue with the system and the module needs to be removed with a higher SOC stated in the manual.

Also, some flow battery systems are intended to be installed and decommissioned without electrolyte. If the manual states this, then there should be an exception for this test to be conducted without electrolyte for these systems.

PROPOSAL

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.

<u>*Exception No. 1: If the System's User Manual clearly states a lower maximum SOC below 100% allowed for removal and installation of modules, the module may be tested at both 100% SOC and the SOC listed in the system's user manual for removal.*</u>

Exception No. 2: For flow battery systems, if the system's user manual specifies that the system is to be installed and removed with no electrolyte in the system, then the test shall be conducted without electrolyte.

6. Addition of an exception for outdoor use only in the Single Cell Failure Design Tolerance test.

RATIONALE

Proposal submitted by: David Ginder, EnerSys

Section 38, Clause 38.1, has an exception for outdoor use only application shown below. Section 39 for Single Cell Failure Design Tolerance should also have this same exception and poses no more risk to personnel or facilities than that of external fire. Burden of loss of the product should be up to the owner as it is for external fire. Keeping in mind the Standard for the Installation of Stationary Energy Storage Systems, NFPA 855 process will establish the safe distances between containers, distance to other high risk structures and materials, as well as distances for emergency egress and perimeter restricted access.

> *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.*

PROPOSAL

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.

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.

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.

Exception No. 3: 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.

7. Moving all lithium cell requirements into UL 1973.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Previously, UL 1973 referenced UL 1642 for cell requirements with an alternate program in Appendix E. This proposal moves all cell criteria including the UL 1642 program to Appendix E. This is more convenient for users of UL 1973 and also allows for more flexibility to make changes that may be necessary for these applications.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE 1625, *Rechargeable Batteries for Multi-Cell Mobile Computing Devices*
IEEE 1635/ASHRAE Guideline 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*
IEEE 1725, *Rechargeable Batteries for Cellular Telephones*

6 Glossary

6.7A CELL, CYLINDRICAL - A cell format with a rigid case that has straight parallel sides and a round cross section.

6.7B CELL, POUCH - A cell format with a flexible laminate case that is typically, but not limited to a prismatic shape, and that can have its tabs on the same side or on opposite sides of each other.

6.7C CELL, PRISMATIC - A cell format with a rigid case that has a rectangular shape.

6.7D CELL, SECONDARY - A cell that is intended to be discharged and recharged many times in accordance with the manufacturer's recommendations.

6.28A LITHIUM METAL CELL– A rechargeable battery technology that employs lithium metal as the anode material, various compounds for the cathode (e.g. vanadium oxide) with a solid polymeric or ceramic electrolyte. Some types of lithium metal solid state batteries may require heating in order to be activated.

NOTE: These cells may be referred to as solid state batteries.

7.11 Cells (battery and electrochemical capacitor)

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. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal.

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.

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

Exception No. 3: The crush test shall be a bar crush test rather than a flat plate crush using a bar with a 15-cm (5.9 in) diameter 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.

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.

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.

Exception No. 6: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min

7.11.2 Secondary lithium cells shall comply with the requirements outlined in Appendix E, and be marked as required in 41.14 and 41.15. Cells shall be provided with specifications as outlined in 42.7. ~~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.~~

~~*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.*~~

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

~~*Exception No. 3: The crush test shall be a bar crush test rather than a flat plate crush using a bar with a 15-cm (5.9-in) diameter 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.*~~

~~*Exception No. 4: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min.*~~

~~*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.*~~

~~*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.*~~

7.11.2A Secondary lithium cell design shall ensure sufficient safety measures to mitigate internal short circuits and other hazardous conditions during the life of the cells. Safety measures to maintain cell safety include, but are not limited to, the following:

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

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

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

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

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

17.11.2B With reference to 17.11.2A, compliance to (a) – (e) is determined through a review of the cell construction as part of a tear down analysis, a review of documentation on the cell construction and components, and the cell tests of Appendix E.

7.11.3 Sodium-beta cells and batteries shall comply with the cell tests outlined in Appendix B. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal.

7.11.4 Flowing electrolyte stacks ~~cells~~ and battery systems shall comply with the requirements outlined in Appendix C.

MARKINGS

41 General

41.14 With reference to 7.11.2, a secondary lithium cell shall be legibly and permanently marked with:

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

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

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

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

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

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

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

41.15 With reference to 41.14, if a manufacturer produces a cell at more than one factory, each cell shall have a distinctive marking to identify it as the product of a particular factory.

INSTRUCTIONS

41 General

42.7 Cells shall be provided with a complete set of instructions that include operating region specifications for charging and discharging including current temperature range and voltages, installation instructions, storage of batteries and disposal instructions. Guidance on cell specification information that should be provided on cells can be found in the Cell Specification Sheet, Annex E of IEEE 1625.

APPENDIX E (Normative)
~~Alternative~~ Cell Test Program

E1 General

E1.1 The following ~~is an alternate program to~~ shall be used to evaluate lithium ion cells or other secondary lithium cells. ~~instead of that outlined in 7.11.2.~~

~~*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.*~~

E1.2 Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing is outlined in Table E.1. As an alternate, the lithium ion cell test program outlined in Sections E9 - E10 may be used.

E1.3 Prior to conditioning in E1.4, two samples from the total set of samples as representative samples shall be subjected to the capacity check per E1A.2 to confirm the capacity of the samples is correct.

E1.4 ~~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. During charging, a minimum of one temperature is measured on the surface of the cell centered on the cell. For prismatic cells, this would be on the largest flat surface.

Table E.1
Test samples and results criteria

Test	Section	Number of Samples Conditioned at Upper Limit Temperature per E1.4[a]	Number of Samples Conditioned at Lower Limit Temperature per E1.4[a]	Total Samples Tested	Compliance[c]
Short Circuit	E2	1	1	2	No: fire or explosion
Cell Impact	E3	1	1	2	No: fire or explosion
Drop Impact	E4	-	-	2	No: fire or explosion
Heating	E5	1	1	2	No: fire or explosion
Overcharge	E6	1	1	2	No: fire or explosion
Forced Discharge	E7	-	-	2	No: fire or explosion
Projectile	E8	-	-	2 (4)	No: projectiles in accordance with E8.2.

[a] The upper limit temperature, lower limit temperature, upper limit charging voltage, maximum charging current, discharge current and end point voltage parameters used for conditioning of cell samples are specified by the cell manufacturer.
[b] Those cells not complying with the Projectile Test of E8 can be used in batteries that comply with the Thermal Exposure for Explosion Hazards Test of Section 38.
[c] Test results for compliance criteria is defined in E11.3.

E1.5 Some lithium cells are capable of exploding when the tests described in this Appendix are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.

E1.6 As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E1.7 during the tests described in this appendix. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90°C (194°F) and not to touch the lithium cell while the surface temperature exceeds 45°C (113°F).

E1.7 In accordance with E1.6, the surface temperatures of the cell casing shall be measured as follows:

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

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

Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.

E1.8 For protection, the Projectile Test in E8 shall be conducted in a room separate from the observer or within an appropriate containment chamber.

E1A Preconditioning and Capacity Check

E1A.1 Preconditioning

E1A.1.1 The charge/discharge cycling preconditioning in E1A.1.2 shall be done before testing and conducted on secondary lithium metal (i.e. lithium metal anode) cells. Lithium ion cells need not be subjected to charge/discharge cycle preconditioning.

E1A.1.2 Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned at 25°C ±5°C (77°F ±9°F). The cells shall be continuously cycled as specified by the manufacturer. The specification shall be such that the full rated capacity of the cell is utilized and the number of cycles accumulated shall be at least equal to 25% of the advertised cycle life of the cell or cycled continuously for 90 days, whichever is shorter. Cycling shall be done either individually or in groups. Cells shall be recharged prior to testing.

E1A.2 Capacity check

E1A.2.1 Prior to conducting testing, the capacity of the lithium ion and lithium metal cells to be tested shall be checked in accordance with E1A.2.2 – E1A.2.5 by selecting two samples from the total set of samples.

E1A.2.2 For secondary lithium metal (i.e. lithium metal anode) cells, this capacity check shall be conducted on preconditioned secondary lithium metal cells per E1A.1.

Exception : For secondary lithium metal cells subjected to preconditioning per E1A.1, the capacity check may be conducted during the preconditioning of these secondary lithium metal cells by checking the discharged capacity during the first few cycles. This capacity confirmation may be done in the manufacturer shipping inspection by checking the capacity discharge curve shipped with the samples.

E1A.2.3 The cell shall be discharged at 25°C ±5°C (77°F ±9°F) at a constant current of 0.2C rate, down to a specified end of discharge voltage. The cell shall then be charged in a room ambient temperature, 25°C ±5°C (77°F ±9°F), at charging parameters specified by the manufacturer until fully charged. The cell shall then be allowed to stabilize at room ambient per 6.4.2.

E1A.2.4 With the cell in the fully charged condition, the cell shall be discharged at a constant current discharge in accordance with the cell manufacturer's specifications down to the end of discharge voltage. The duration of the discharge shall be monitored and the measured capacity of the cell shall be calculated to three significant figures.

E1A.2.5 For cells to be used for the test program outlined in this appendix, their measured capacity shall equal or exceed the rated specifications. All samples shall be subjected to the capacity check test if any representative sample does not meet this criteria. The cells not meeting this criteria shall be excluded from testing.

E2 Short Circuit

E2.1 Fully charged, conditioned cells are stored in an ambient temperature of 25°C ±5°C (77°F ~~°C~~ ±9°F) until their casing reaches ambient temperature, and then subjected to a short circuit condition using an external resistance of ≤ 20 mΩ.

E2.3 The sample and compliance criteria shall be in accordance with Table E.1. ~~As a result of the short circuit test, the cells shall not show signs of fire or explosion.~~

E3 Cell Impact

E3.1 Fully charged, conditioned cells shall be ~~are~~ subjected to an impact test as outlined in E10.4 ~~UL 1642~~. The cells shall be at an ambient temperature of 25°C ±5°C (77°F~~°C~~ ±9°F) prior to testing.

E3.2 The sample and compliance criteria shall be in accordance with Table E.1.~~As a result of the impact test, the cells shall not show signs of fire or explosion.~~

E4 Drop Impact

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°F~~°C~~ ±9°F) prior to testing.

E4.4 The sample and compliance criteria shall be in accordance with Table E.1.~~As a result of the drop impact test, the cells shall not show signs of fire or explosion.~~

E5 Heating

E5.1 Fully charged, conditioned cells shall be ~~are~~ subjected to a heating test as outlined in E10.7 ~~UL 1642~~.

E5.2 The sample and compliance criteria shall be in accordance with Table E.1.~~As a result of the heating test, the cells shall not show signs of fire or explosion.~~

E6 Overcharge

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°F~~°C~~ ±9°F) and with the cell casing at an ambient of 25°C ±5°C (77°F~~°C~~ ±9°F) at the start of the test. The voltage and temperature of the cell shall be monitored during the test.

E6.3 The sample and compliance criteria shall be in accordance with Table E.1.~~As a result of the overcharge test, the cells shall not show signs of fire or explosion.~~

E7 Forced Discharge

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°F~~°C~~ ±9°F).

E7.3 The sample and compliance criteria shall be in accordance with Table E.1.~~As a result of the forced discharge test, the cells shall not show signs of fire or explosion.~~

E8 Projectile

E8.1 Two fully charged cells shall be subjected to the projectile test criteria as outlined in E10.10. ~~Exception No. 1 of 7.11.2.~~

Alternative Test Program for Secondary Lithium Cells

E9 General

E9.1 This cell test program may be used to evaluate secondary lithium cells for use in battery systems that comply with this standard instead of the test program outlined in Sections E1 - E8. Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing shall be as outlined in Table E.2.

E9.2 Some lithium cells are capable of exploding when the tests described below are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.

E9.3 As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E9.4 during the tests described below. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90°C (194°F) and not to touch the lithium cell while the surface temperature exceeds 45°C (113°F).

E9.4 In accordance with E9.3, the surface temperatures of the cell casing shall be measured as follows:

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

b) With the measuring junction of the thermocouple held tightly against the metal casing of the cell.

Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.

E9.5 For protection, the Projectile Test in E10.10 shall be conducted in a room separate from the observer or within an appropriate containment chamber.

E9.6 Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned in accordance with E1A.1 prior to the testing.

E9.7 The capacity of the samples for all lithium chemistries shall be confirmed in accordance with E1A.2 prior to testing.

E10 Tests

E10.1 Short-circuit test

E10.1.1 Each test cell shall be short-circuited by connecting the positive and negative terminals with a resistance load of less than or equal to 20 mΩ. The temperature of the cell case shall be recorded during the test. The short circuit shall be applied until the cell case temperature has returned to ±10°C (±18°F) of ambient temperature.

E10.1.2 Tests shall be conducted at 55°C ±5°C (131°F ±9°F). The samples shall reach equilibrium at 55°C ±5°C (131°F ±9°F), as applicable, before the terminals are connected.

E10.1.3 The sample and compliance criteria shall be as noted in Table E.2.

E10.2 Overcharge test

E10.2.1 The cell shall be subjected to the overcharge test as outlined in E10.2.2.

E10.2.2 A cell shall be subjected to a constant current charge at the maximum specified charging current until the cell reaches 120% of its maximum specified charge voltage limit or it reaches 130% SOC, whichever comes first.

E10.2.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.3 Crush test

E10.3.1 A cell shall be subjected to a bar crush using a bar with a 15-cm (5.9-in) diameter. The force for the crushing shall be applied by a hydraulic ram or similar force mechanism. The force shall be applied until one of the following in (a) - (c) occurs. Once the maximum force has been obtained, the force shall be released.

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

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

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

E10.3.2 A cylindrical, pouch or prismatic cell shall be crushed with its longitudinal axis parallel to the crushing apparatus. Each sample shall be subjected to a crushing force in only one direction and the crush shall be conducted only on the wide side of a pouch or prismatic cell. Separate samples shall be used for each test. See also, E10.3.3 and E10.3.4.

E10.3.3 With reference to E10.3.2, for other than pouch cells, the crush shall be applied in the center of the cells.

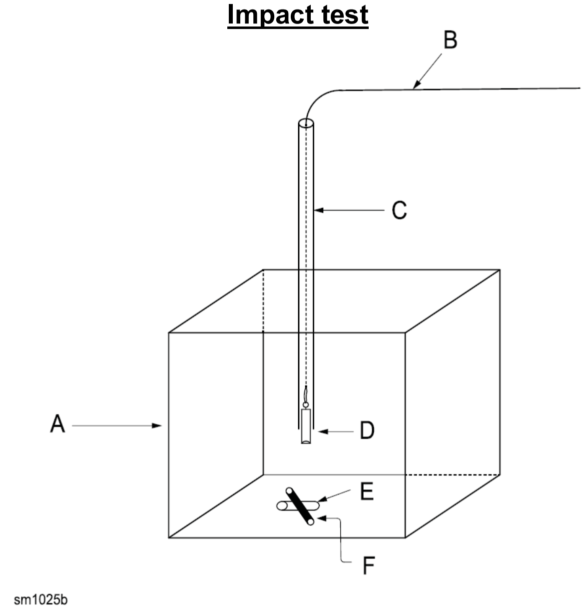
E10.3.4 With reference to E10.3.2, for pouch type cells, the crushing force shall be applied on the casing near where the cell tabs exit. If the positive and negative tabs are on opposite sides, the crush force shall be applied on the casing near where the negative tab exits.

E10.3.5 The sample and compliance criteria shall be in accordance with Table E.2.

E10.4 Impact test

E10.4.1 A cell shall be placed on a flat surface. A 15.8-mm ±0.1-mm (5/8-in ±0.004-in) diameter bar shall be placed across the center of the sample. A 9.1 ±0.46-kg (20 ±1-lb) weight shall be dropped from a height of 610 mm ±25 mm (24 in ±1 in) onto the sample. See Figure E.1.

Figure E.1
Impact test



A - Steel impact chamber (hinged door not shown)

B - Weight support rope

C - Containment tube

D - 9 kg (20 lb) weight

E - Cell

F - 16-mm (5/8-in) diameter bar

E10.4.2 The cell shall be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15.8-mm (5/8-in) diameter curved surface lying across the center of the test sample. For prismatic and pouch cells, only the wide side shall be impacted. Each sample shall be subjected to only a single impact. Separate samples shall be used for each test.

E10.4.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.5 Shock test

E10.5.1 The cell shall be secured to the testing machine by means of a rigid mount which supports all mounting surfaces of the cell. Each cell shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions unless it has only two axes of symmetry in which case only two directions shall be tested. Each shock shall be applied in a direction normal to the face of the cell.

E10.5.2 For each shock, the cell shall be accelerated in such a manner that during the initial 3 ms the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 and 175 g. Cells shall be tested at a temperature of 25°C ±5°C (77°F ±9°F).

E10.5.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.6 Vibration test

E10.6.1 A cell shall be subjected to simple harmonic motion with an amplitude of 0.8 mm (0.03 in) [1.6 mm (0.06 in) total maximum excursion].

E10.6.2 The frequency shall be varied at the rate of 1 Hz/min between 10 and 55 Hz, and return in not less than 90 nor more than 100 min. The cell shall be tested in three mutually perpendicular directions. For a cell that has only two axes of symmetry, the cell shall be tested perpendicular to each axis.

E10.6.3 At the end of the vibration conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.

E10.6.4 The sample and compliance criteria shall be in accordance with Table E.2.

E10.7 Heating test

E10.7.1 A cell shall be heated in a gravity convection or circulating air oven with an initial temperature of 25°C ±5°C (77°F ±9°F). The temperature of the oven shall be raised at a rate of 5°C ±2°C (9°F ±3.6°F) per minute to a temperature of 130°C ±2°C (266°F ±3.6°F) and remain for 10 min. For cells specified for temperatures above 100°C (212°F), the conditioning temperature shall be increased from 130°C ±2°C (266°F ±3.6°F), to 30°C ±2°C (86°F ±3.6°F) above the manufacturers maximum specified temperature.

Exception: For cells whose weight is greater than 500 g (1.1 lbs), the maximum temperature of the heating test shall be held for 30 min rather than 10 min.

E10.7.2 The sample shall return to room temperature, 25°C ±5°C (77°F ±9°F), and then be examined.

E10.7.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.8 Temperature cycling test

E10.8.1 The cells shall be placed in a test chamber and subjected to the following cycles:

a) Raising the chamber-temperature to 85°C ±2°C (185°F ±3.6°F) or T_{max} + 10°C (T_{max} is the manufacturer's maximum specified temperature) within 30 min and maintaining this temperature for 4 h;

b) Reducing the chamber temperature to 25°C ±5°C (77°F ±9°F) within 30 min and maintaining this temperature for 2 h;

c) Reducing the chamber temperature to minus 40°C ±2°C (minus 40°F ±3.6°F) within 30 min and maintaining this temperature for 4 h;

d) Raising the chamber temperature to 25°C ±5°C (77°F ±9°F) within 30 min;

e) Repeating the sequence for a further 9 cycles; and

f) After the 10th cycle, storing the cells for a minimum of 24 h, at a temperature of 25°C ±5°C (77°F ±9°F) prior to examination.

E10.8.2 At the end of the cycling, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.

E10.8.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.9 Low pressure (altitude simulation) test

E10.9.1 Sample cells shall be stored for 6 h at an absolute pressure of 11.6 kPa (1.68 psi) and a temperature of 25°C ±5°C (77°F ±9°F).

E10.9.2 At the end of the conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.

E10.9.3 The sample and compliance criteria shall be in accordance with Table E.2.

E10.10 Projectile test

E10.10.1 Each test sample cell shall be placed on a screen that covers a 102-mm (4-in) diameter hole in the center of a platform table. The screen shall be constructed of steel wire mesh having 20 openings per 25.4 mm (1 in) and a wire diameter of 0.43 mm (0.017 in).

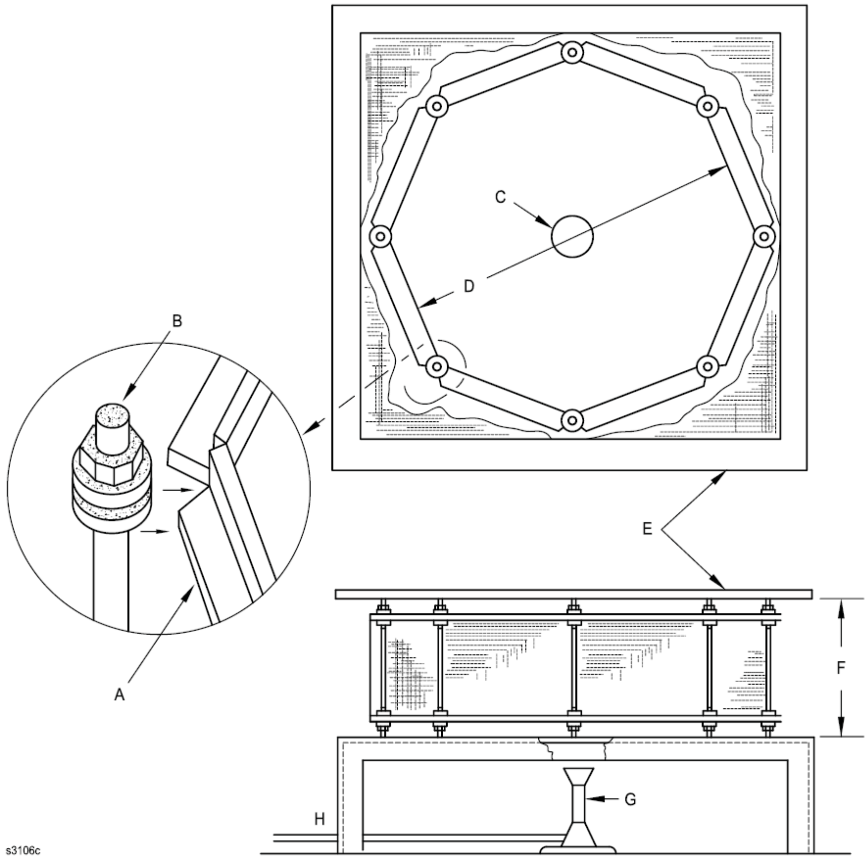
E10.10.2 The screen shall be mounted 38 mm (1-1/2 in) above a Meker type burner. The fuel and air flow rates shall be set to provide a bright blue flame that causes the supporting screen to glow a bright red.

E10.10.3 An eight-sided covered wire cage, 610-mm (12-in) across and 305-mm (12-in) high, made from metal screening shall be placed over the test sample. See Figure E.2. The metal screening shall be constructed from 0.25-mm (0.010-in) diameter aluminum wire with 16 - 18 wires per 25.4 mm (1 in) in each direction.

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

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

Figure E.2
Test apparatus for projectile test



A – 12.7 × 12.7 mm (1/2 × ½ in) angle, top and bottom

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

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

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

E – Flat screen cover

F – 305 mm (12 in)

G – Burner – Meker type burner

H – Fuel

E10.10.4 The sample shall be heated and shall remain on the screen until it explodes or the cell has ignited and burned out. It is not required to secure the sample in place unless the sample is at risk of falling off the screen before the test is completed. When required, the sample shall be secured to the screen with a single wire tied around the sample.

E10.10.5 The sample and compliance criteria shall be in accordance with Table E.2.

E11 Test Samples and Results Criteria

E11.1 The test samples and results criteria for the tests in this annex shall be in accordance with Table E.2.

Table E.2
Tests samples and results criteria

Test	Reference	Number of samples	Results Criteria for Total Samples Tested[c]
Short-Circuit	E10.1	2	No: fire or explosion
Abnormal Charging	E10.2	2	No: fire or explosion
Crush	E10.3	2	No: fire or explosion
Impact	E10.4	2	No: fire or explosion
Shock	E10.5	2	No: venting, leakage, rupture, fire, or explosion
Vibration	E10.6	2	No: venting, leakage, rupture, fire, explosion, or OCV change[a]
Heating	E10.7	2	No: fire or explosion
Temperature Cycling	E10.8	2	No: venting, leakage, rupture, fire, explosion, or OCV change[a]
Low Pressure (Altitude Simulation)	E10.9	2	No: venting, leakage, rupture, fire, explosion, or OCV change[a]
Projectile[b]	E10.10	2 (4)	No: projectiles per E10.10

[a] No "OCV" change would be a drop in the open circuit voltage after testing of less than 10% of the before test value.
[b] Those cells not complying with the Projectile Test of E10.10 can only be used in batteries that comply with the Thermal Exposure for Explosion Hazards Test of Section 38.
[c] Test results compliance criteria are defined in E11.2.

E11.2 Test results compliance criteria

E11.2.1 Venting is determined by evidence of mass loss as noted in Table E.3 below.

Table E.3
Venting and Leakage Mass Loss Criteria

Mass of cell		Maximum mass percent loss
g	(oz)	%
≤ 1.0	(≤ 0.035)	0.5
> 1.0 ≤ 5.0	(> 0.035 ≤ 0.176)	0.2
> 5.0	(> 0.176)	0.1

E11.2.2 Leakage is determined by evidence of visible liquid electrolyte on the external case of the cell or mass loss criteria as outlined in Table E.3.

E11.2.3 Rupture is determined by a tear in the cell case at a location other than at the designed vent.

E11.2.4 Fire is determine by evidence visible flames or of charging and burning of the cell and its contents.

E11.2.5 Explosion is determined by evidence of disassembly of the cell and its contents beyond a rupture of the case.

8. Addition of requirements for repurposing batteries.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Since the Standard for Evaluation of Repurposing Batteries, UL 1974 was published October 25, 2018, there should be a reference added to it in UL 1973 in order to address batteries and battery systems that are using repurposed cells and batteries.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

UL Standards

UL 1974, *Evaluation for Repurposing Batteries*

CONSTRUCTION

7 General

7.12 Repurposed cells and batteries

7.12.1 Batteries and battery systems using repurposed cells and batteries shall ensure that the repurposed parts have gone through an acceptable process for repurposing in accordance with UL 1974. See also 41.2A.

MARKINGS

41 General

41.2A Batteries and Battery systems using repurposed batteries in accordance with 7.12, shall be marked “Repurposed” or “Second Life” and “UL 1974”.

APPENDIX G (Informative)
Safety Marking Translations

Table G.1
Safety marking translations

Reference	English	French
41.2A	"Repurposed"	« Réutilisé »
41.2A	“Second Life”	« deuxième vie »
41.2A	"UL 1974"	« UL 1974 »
41.5	"Use Only ( ) Charger"	« Utiliser Uniquement ( ) Chargeur »
41.7	"caution"	« attention »
41.7	"read instruction manual"	« Lire le manuel d'instruction »
42.5	"DANGER," "WARNING," or "CAUTION."	« DANGER », « AVERTISSEMENT » ou « ATTENTION ».

9. Clarification of lead acid battery requirements.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

This proposal is intended to clarify how lead acid battery systems should be handled is the system is to be subjected to UL 1973. Lead acid batteries have a long history of use in stationary applications, they are made from fairly standardized type monobloc batteries and have more simplified controls than a lithium ion system for example that need to monitor individual cells to ensure they do not go outside their specified limits of operation.

PROPOSAL

1.3 Appendix B of this standard includes requirements specific to sodium-beta type technologies. Appendix C of this standard includes requirements specific to flowing electrolyte technologies. Appendix H of this standard includes requirements specific to vented and valve regulated lead acid and nickel cadmium batteries.

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

ASHRAE Guideline 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

CAN/CSA C22.2 No. 107.2, *Battery Chargers*
CSA C22.2 No. 60335-2-29, *Household and Similar Electrical Appliances - Safety - Part 2-29: Particular Requirements for Battery Chargers*

International Code Council (ICC)

ICC IBC, *International Building Code*

Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE 693, *Recommended Practice for Seismic Design of Substations*
IEEE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

NFPA 2, *Hydrogen Technologies Code*
NFPA 68, *Explosion Protection by Deflagration Venting*
NFPA 69, *Explosion Prevention Systems*

Telcordia

GR-63-CORE, *Network Equipment - Building System (NEBS) Requirements: Physical* Protection

UL 1012, *Power Units Other Than Class 2*
UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*
UL 2416, *Audio/Video, Information and Communication Technology Equipment Cabinet, Enclosure and Rack Systems*
UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*
UL 60335-2-29, *Household and Similar Electrical Appliances - Safety - Part 2-29: Particular Requirements for Battery Chargers*

6 Glossary

6.6 CASING - The container that directly encloses and confines the contents of a cell, monobloc battery or electrochemical capacitor.

6.35 MONOBLOC (MULTI-CELL) BATTERY - A battery design that contains series connected cells in a common ~~pressure~~ vessel construction, with a ~~single~~ vent assembly or valve assembly and shared hardware.

7.11 Cells (battery and electrochemical capacitor)

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. See Appendix H for alternative criteria for vented or valve regulated lead acid or nickel cadmium batteries. Cells and multi-cell/monobloc batteries shall be provided with specifications for use (charging and discharging), installation, storage and disposal as outlined in Appendix H.

39.3 Single cell failure design tolerance (other technologies)

39.3.1 Other technologies such as lithium metal, sodium sulfur, and 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 manufacturing defects for that technology and/or cell and battery design deficiencies that could lead to latent failures of the cell, and that would not be evident under the individual cell safety testing.

MARKINGS

41 General

41.16 Required markings for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be legibly and permanently marked in accordance with 41.1 with the following included:

a) The manufacturer's name, trade name or trademark, model designation, and month and year of manufacture;

Exception: The date of manufacture may be in the form of a code that does not repeat in 10 years.

b) The statement "Warning: Risk of fire, explosion, or burns. Do not disassemble, heat above XX°C (or °F), or incinerate." (Where XX is the cell or battery's maximum temperature specification.)

Exception: This statement may be included in the instructions provided with the cell or battery, rather than be marked on the battery.

c) Battery type (e.g. valve regulated lead-acid battery) and rated nominal voltage and capacity; and

d) Positive and negative leads or terminals indicated by (+) and (−).

INSTRUCTIONS

42 General

42.8 The installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the batteries and components of the battery systems shall be installed in accordance with Article 480 or 706 of NFPA 70 or Section 64 of CSA C22.1.

42.9 Installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the charging system for these batteries shall prevent charging outside of the battery specifications through the use of voltage (and temperature for VRLA) monitoring and controls, or both current and temperature monitoring and controls. The system may also use current monitoring to prevent out of condition specifications. The instructions shall indicate that chargers shall comply with UL 1012, UL 1741, UL 60335-2-29/CSA C22.2 No. 60335-2-29, CAN/CSA C22.2 No. 107.2, or UL 62368-1/CSA C22.2 No. 62368-1. Instructions for the battery system shall provide information on a specific charger to be used with the battery system if the charger is relied upon to maintain the battery system safety.

42.10 The instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that battery systems exceeding 60 Vdc shall be provided with a disconnecting means for all ungrounded conductors in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.

42.11 Installation instructions for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be provided with instructions indicating that service disconnects shall be provided as applicable to the end product battery system in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.

42.12 Installation instructions for vented and valve regulated lead acid and nickel cadmium multi-battery/cell systems shall include the short circuit current output from the battery system rather than the marking of 41.3.

42.13 Vented lead acid or nickel cadmium cell and battery installation instructions shall indicate the need for spill control in accordance with the building, fire and installation codes.

42.14 The instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate that ventilation to address any hydrogen off gassing shall be in accordance with the local fire and installation codes.

42.15 The instructions for open rack vented and valve regulated lead acid and nickel cadmium battery systems shall indicate that these racks shall be installed in restricted access locations or be installed within a protective enclosure that prevents access in accordance with the end use application.

42.16 Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate recommended wiring for battery connections, the minimum clearance between cells and batteries on the racks and any type of protection device.

42.17 Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall include maintenance instructions for maintaining the cells and batteries in safe operating condition through the life of the cell and battery including electrolyte maintenance if applicable, examination of terminals and casings for damage, etc.

42.18 If lead acid and nickel cadmium cells and batteries are intended for installation in an end use that utilizes protective grounding, the installation instructions shall recommend that the grounding and bonding system be checked after the completion of the assembly to ensure that the resistance is less than or equal to 0.1 Ω.

42.19 The instructions provided with lead acid and nickel cadmium cells and batteries shall indicate the maximum voltage of the end use system they can be installed in. If the voltage in the end use is exceeded, then the instructions shall recommend a repeat of the dielectric voltage withstand test of the assembly for the higher voltage.

APPENDIX G (Informative)
Safety Marking Translations

Table G.1
Safety marking translations

Reference	English	French
41.5	"Use Only ( ) Charger"	« Utiliser Uniquement ( ) Chargeur »
41.7	"caution"	« attention »
41.7	"read instruction manual"	« Lire le manuel d'instruction »
42.5	"DANGER," "WARNING," or "CAUTION."	« DANGER », « AVERTISSEMENT » ou « ATTENTION ».
41.16(b)	"Warning: Risk of fire, explosion, or burns. Do not disassemble, heat above XX°C (or °F), or incinerate." (Where XX is the cell or battery's maximum temperature specification.)	« Mise en garde : Risque d'incendie, d'explosion ou de brûlures. Ne pas démonter, chauffer à plus de XX°C (ou °F) ou incinérer. » (XX correspond à la température maximale que peut supporter une pile ou une batterie)

APPENDIX H (NORMATIVE)
Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries

H1 General

H1.1 This appendix is provided as the evaluation program for valve regulated or vented lead-acid and nickel-cadmium cells, batteries and battery systems (i.e. battery(s) with a rack and/or enclosure) for stationary applications to this Standard. This appendix considers the fact that these systems are often assembled at the stationary end product stage (e.g. ESS or UPS) using standardized lead acid or nickel-cadmium batteries that are not first assembled as battery systems and evaluated in accordance with this Standard. Therefore, the evaluation according to this appendix can be conducted to meet the battery technology requirements of this standard for these types of batteries.

H1.2 This appendix covers both single cell or multi-cell/monobloc batteries, or battery systems consisting of multiple cells or batteries connected in series and/or parallel connections with associated components that may or may not be enclosed.

H1.3 It is understood that due to the typically standardized, single cell or multi-cell (often referred to as monobloc) design of the lead acid and nickel cadmium batteries used in these systems and their general robustness, they do not require the complex controls that a chemistry such as lithium ion requires. Their charging systems typically have safety controls that monitor and control for voltage and maximum current. For VRLA batteries, remote sensing at the batteries (coupled with temperature compensation of the charge voltage) is often used to meet fire code requirements to monitor and control for potential thermal runaway. The failure mechanisms of concern for these batteries result from external abuse such as short circuiting over terminals or overcharging conditions.

H1.4 The lead acid and nickel cadmium batteries off-gas small amounts of hydrogen under ambient pressure conditions such as is the case with vented types not fitted with recombiner caps, or much less when under slight increases of pressure in the case of valve regulated. The installation of these types of batteries, whether they are in open racks within rooms or installed within enclosed containers needs to consider the potential for hydrogen off gassing and address venting of this gas in the battery system or in its installation to prevent hazardous concentrations of hydrogen gas.

H1.5 Systems using vented type batteries needs to address spill control of hazardous electrolytes in accordance with building fire code regulations for installations of these types of batteries. See 42.13.

H1.6 For families of lead-acid and nickel-cadmium cells and batteries, testing can be conducted on the representative worst case cell or battery (e.g. highest capacity) to cover the family. A family is a group of cells or batteries that have the same basic internal construction but have different capacities. When testing a cell or battery that can have casings that are molded from materials with different flame ratings, the casing with the lowest flame rating shall be used if it can impact the test.

H2 Construction

H2.1 Valve regulated or vented lead acid or nickel cadmium cells and multi-cell/monobloc batteries shall comply with the Pressure Release Test or the Flame Arrester Vent Cap Test requirements in UL 1989 as applicable to the battery type.

H2.2 With reference to H2.1, casing material for cells and batteries shall be V-2 minimum.

Exception: The casing material for vented type cells and batteries can be HB minimum if the top cover of the casing mounting the flame arrestor/vent cap assembly is V-2 minimum.

H2.3 The multi-battery battery systems consisting of multiple batteries shall also be provided with markings in accordance with Section 41 and instructions in accordance with Section 42 criteria as applicable to the system. Single cells and multi-call/monobloc batteries shall be provided with instructions that include specifications for use (charging and discharging), storage, installation and disposal.

H2.4 The construction requirements in this standard apply to a battery system consisting of multiple batteries with associated components if applicable, except for that of 7.8.

H2.5 A battery system exceeding a nominal voltage of 240 Vdc shall be provided with disconnects to disconnect the series-connected strings into segments not exceeding 240 V in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1, for servicing of the battery system.

H2.6 Nonmetallic materials that are components of a rack support system such as spacers or insulation, shall be rated V-2 minimum or HBF minimum as applicable to the material.

H3 Performance

H3.1 General

H3.1.1 Table H.1 below outlines the tests that are applied to vented and valve regulated lead acid and nickel cadmium cells, multi-call/monobloc batteries and battery systems

H3.1.2 During the tests of H3.2 – H3.5, temperatures on the casing and target DUTs of H3.5 shall be measured to determine that temperatures do not exceed the casing material's relative thermal index (RTI) with impact.

Table H.1
Test Program for Lead Acid and Nickel Cadmium Cells, Monobloc Batteries and Battery Systems

Test	Reference	Alternative test program	Sample Criteria	
			Cell/ Monobloc	Battery system
Electrical Tests				
Overcharge Test	15	H3.2.1	3	-
Short Circuit Test	16	H3.2.2	3	-
Overdischarge Protection Test	17	H3.2.3	3	-
Temperature and Operating Limits Check Test[b]	18	H3.2.4	1	-

Test	Reference	Alternative test program	Sample Criteria	
			Cell/ Monobloc	Battery system
Imbalanced Charging Test	19	N/A	-	-
Dielectric Voltage Withstand Test[c]	20	H3.2.5	1	1
Continuity Test	21	H3.2.6	-	1
Failure of Cooling/Thermal Stability System	22	N/A	-	-
Mechanical Tests				
Static Force Test	28	H3.3.1	-	1[a]
Impact Test	29	H3.3.2	-	1[a]
Drop Impact Test	30	H3.3.3	3	-
Mold Stress Test	32	H3.3.4	-	1[a]
Strength of the Support Structure Test	31	H3.3.5	-	1 [a]
Environmental Tests				
Salt Fog Test	37	H3.4.1	1	-
Thermal Exposure for Explosion Hazards Test	38	N/A	-	-
Single Cell Failure Design Tolerance				
Single cell failure design tolerance (other technologies)	39.3	H3.5.1	3	-
Cell Evaluation for Large Scale Fire Testing	39A	H3.5.1	3	-

[a] - These test apply to a multi-battery battery system that has an external enclosure for the system.
[b] - The Temperature Test is conducted on the single cell or multi-cell/monobloc battery or on the multi-battery battery system if temperatures measuring on the case during the Overcharge, Short Circuit And Overdischarge Test exceeds the relative thermal index of the case material.
[c] - The Dielectric Voltage Withstand Test is conducted on multi-battery battery systems at voltages ≥ 60 Vdc.

H3.2 Electrical tests

H3.2.1 Overcharge

H3.2.1 Single cells or multi-cell/monobloc batteries shall be subjected to an overcharge test as outlined in H3.2.1.2 – H3.2.1.3.

H3.2.1.2 During the test, temperatures on the cell or battery casings shall be measured and recorded.

H3.2.1.3 The cells/batteries shall be charged at the maximum charging current at constant current charging until the maximum voltage in (a) or (b) has been reached. The charging is then continued at constant voltage charging for 7 h.

a) 2.50 V/cell for VLA and VRLA cells and batteries; or

b) 1.67 V/cell for nickel cadmium cells and batteries.

H3.2.1.4 As a result of the test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.

H3.2.2 Short circuit

H3.2.2.1 A short circuit test in accordance with Method 1 in H3.2.2.5 or Method 2 in H3.2.2.6 on the lead acid or nickel-cadmium single cells or multi-cell/ monobloc batteries shall be conducted, and the short circuit current measured.

H3.2.2.2 The DUTs shall have, an actual capacity Ca of at least the rated capacity Cr as determined using a 3 h rate to EODV of 1.70 V/cell at a selected reference temperature.

H3.2.2.3 During the test, temperatures on the cell or battery casings shall be measured and recorded.

H3.2.2.4 Prior to applying the short circuit resistance, the DUTs shall:

a) Be fully charged; and

b) Have a temperature between 20°C (68°F) and 25°C (77°F).

H3.2.2.5 Method 1: The single cells or batteries shall be discharged for 30 s with a current equal to 3 times:

a) The 5 min rate current to EODV of 1.80 V/cell at (68°F) or 25°C (77°F); or

b) With a current equal to the maximum allowable discharge current, both as specified by the manufacturer in their published product specifications.

H3.2.2.6 Method 2: The single cells or battery shall be subjected to an external resistance of ≤ 3.5 mΩ for 30 s.

H3.2.2.7 After the completion of the discharge duration, the DUTs shall be at an open circuit voltage condition for 5 min, and their voltage measured and reported.

H3.2.2.8 The test units shall be examined, after the discharge, internally and externally for effects of high current flow and signs of melting.

H3.2.2.9 As a result of the test, there shall be no melting at the battery terminals, rupture of the battery casings, leakage of electrolyte, fire or explosion.

H3.2.3 Overdischarge

H3.2.3.1 The overdischarge test shall be conducted as outlined in H3.2.3.2 to H3.2.3.4.

H3.2.3.2 During the test, temperatures on the cell or battery casings shall be measured and recorded.

H3.2.3.3 For VLA and VRLA cells and batteries, the DUT shall be discharged at the 8-h discharge rate using the 1.75 V/cell rate down to an EODV of 1.57 V/cell. For nickel-cadmium cells and batteries, the DUT shall be discharged at the 5-h discharge rate using the 1.0 V/cell rate down to an EODV of 0.9 V/cell.

H3.2.3.4 At the conclusion of the discharge, the battery shall then be immediately recharged at the float voltage until the float current stabilizes (i.e. no more than a 10% change in float current over three successive hourly measurements).

H3.2.3.5 As a result of the test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.

H3.2.4 Temperature

H3.2.4.1 The temperature test in accordance with H3.2.4.2 shall be conducted on single cells or multi-cell batteries where the temperatures on the casing during the overcharge, short circuit and overdischarge test exceeded the relative thermal index of the casing material.

H3.2.4.2 One sample of the fully charged DUT shall be placed in a chamber at the manufacturer's specified maximum charging temperature until the temperature on the DUT casing is at the chamber temperature. The DUT is then discharged down to the EODV, while measuring temperatures on the cell case and recording the temperatures. The DUT is then allowed to sit at the chamber temperature until the temperature on the DUT case has dropped to the chamber temperature. The DUT is then charged in accordance with the manufacturer's specifications for maximum charging parameters. During this time, temperatures on the case were measured and recorded.

H3.2.4.3 The maximum temperatures recorded on the DUT casing shall not exceed the material specifications. The accessible surface temperatures do not exceed the limit in Table 18.1 and 18.2.

H3.2.5 Dielectric voltage withstand

H3.2.5.1 Multi-battery battery systems that have a voltage of 60 Vdc or greater shall be subjected to the Dielectric Voltage Withstand Test of Section 20.

H3.2.5.2 A single cell or monobloc battery intended for use in a system with a voltage greater than 60 Vdc shall be subjected to a Dielectric Voltage Withstand Test of Section 20. The test voltages shall be applied for a minimum of 1 min. The test voltage should be applied between the positive terminal or negative terminal and the accessible non-current carrying part in turn, to avoid short circuiting between the positive and negative terminals. If the case is a polymeric or similar insulating material, a sheet of foil in accordance with 20.5 shall be applied to the case and testing shall be between the terminal and the foil.

H3.2.5.3 There shall be no evidence of dielectric breakdown.

H3.2.6 Continuity

H3.2.6.1 This test shall be conducted on multi-battery battery systems that employ cells or batteries with metallic casings.

H3.2.6.2 The Continuity Test of Section 21 shall be conducted on the battery system.

H3.2.6.3 The determined (calculated or measured) resistance shall be less than or equal to 0.1 Ω.

H3.3 Mechanical tests

H3.3.1 Static force test

H3.3.1.1 This is a test for the enclosure/cabinet of a multi-battery battery system.

H3.3.1.2 The Static Force Test of Section 28, shall be conducted on the battery system enclosure. If applicable, the Dielectric Voltage Withstand Test of H3.2.5 shall be conducted.

H3.3.1.3 There shall be no damage or breakage of the enclosure that can result in access to live parts. If applicable, there shall be no evidence of dielectric breakdown.

H3.3.2 Impact test

H3.3.2.1 This is a test for the enclosure/cabinet of a multi-battery battery system.

H3.3.2.2 The Impact Test of Section 29, shall be conducted on the battery system enclosure. If applicable, the Dielectric Voltage Withstand Test of H3.2.5 shall be conducted.

H3.3.2.3 There shall be no damage or breakage of the enclosure that can result in access to live parts. If applicable, there shall be no evidence of dielectric breakdown.

H3.3.3 Drop impact test

H3.3.3.1 Samples of single cell or multi-cell/monobloc batteries shall be subjected to the Drop Impact Test in accordance with Section 30, except as outlined in H3.3.3.2 to H3.3.3.5.

H3.3.3.2 Each sample shall be subjected to a single drop, and the height for the drop shall be as follows:

a) Dropped from a height of 100 mm (3.93 in) for units weighing < 50 kg (110.2 lb);

b) Dropped from a height of 50 mm (1.97 in) for units weighing 50 kg – 100 kg (110.2 lb – 220.5 lb); and

c) Dropped from a height of 25 mm (0.98 in) for units weighing > 100 kg (220.5 lb).

H3.3.3.3 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.

H3.3.3.4 Following the drop, the samples shall be subjected to an observation period of 1 h and are not cycled beforehand.

H3.3.3.5 As a result of this test there shall be no rupture of the battery casing, leakage of electrolyte, fire or explosion.

H3.3.4 Mold stress test

H3.3.4.1 The cell or battery with a polymeric molded case shall be subjected to the mold stress test of H3.3.4.2.

H3.3.4.2 A discharged single cell or multi-call/monobloc battery shall be conditioned in an air circulating oven at 70°C (158°F) or 10°C (18°F) above the maximum temperature measured on the case during the short circuit, overcharge and discharge test or temperature test as applicable.

H3.3.4.3 There shall be no warping or damage to the case that can result in electrolyte leakage.

H3.3.5 Strength of the support structure test

H3.3.5.1 A battery system support structure such as a battery rack shall be subjected to the Strength of the Support Structure Test of H3.3.5.2.

H3.3.5.2 The support structure shall be subjected to 4 times the total anticipated weight the structure is anticipated to support applied for one minute.

Exception: A support rack that complies with UL 2416, or the seismic structural strength criteria of IEEE 693, Telcordia GR-63-CORE, or the ICC IBC need not be tested.

H3.3.5.3 As a result of the applied force, there shall be no breakage or damage to the support structure.

H3.4 Environmental tests

H3.4.1 Salt fog test

H3.4.1.1 This test shall only be conducted on those single cells or multi-cell/monobloc batteries with metallic cases that are intended for installation in a marine environment.

H3.4.1.2 The Salt Fog Test of Section 37 shall be conducted on 3 fully charged samples of the single cells or multi-cell/monobloc batteries.

H3.4.1.3 As a result of this test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.

H3.5 Single cell failure design tolerance

H3.5.1 Overcharge thermal runaway test

H3.5.1.1 This test shall be conducted on 3 samples of a single cell or multi-cell/monobloc battery and is intended to determine if the cell or battery can be driven into thermal runaway.

H3.5.1.2 During the test, the samples shall be installed in an alcove painted black and separated from the wall by the minimum separation distances recommended by the manufacturer for the end use application. The DUT under test shall be surrounded by target cells or batteries spaced to represent the minimum clearance distances between cells or batteries specified by the manufacturer. Target cells or batteries may be either discharged samples or just the external casing of the cells or batteries.

H3.5.1.3 Temperatures on the DUT case, the target cells or batteries and adjacent walls shall be measured during the test and the maximum measured temperatures shall be recorded.

H3.5.1.4 The DUTs shall be subjected to the Overcharge Test of H3.2.1 except that the charging is continued for a total of 168 h. The samples shall be draped in a single layer of cheesecloth indicator. Temperatures on the casing shall be monitored.

H3.5.1.5 The cheesecloth indicator shall be untreated cotton cloth running 26 – 28 m^2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.

H3.5.1.6 The Cell Vent Gas Composition Test of UL 9540A shall be conducted on a cell or monobloc battery driven into thermal runaway. If unable to capture the gas with the samples in the pressure vessel as noted in the Cell Vent Gas Composition Test method of UL 9540A, the gas shall be captured from the vent/valve assembly to a gas collection vessel.

Exception: Instead of the off gas testing outlined in Cell Vent Gas Composition Test of UL 9540A*, the combustible off gas composition from vented and valve regulated lead acid and Ni-Cd batteries under a thermal runaway condition may be determined through applicable calculations in accordance with IEEE 1635/ASHRAE Guideline 21 as noted in Table H.2.*

Table H.2
Battery Off Gassing Formulas

Battery Type	**Off Gassing Formulas Based upon Test Values Used**	
	Calculation using C_x (m^3/s)	**Calculation using P_{15} (m^3/s)**
VLA, lead-calcium and pure lead	$H_{2\text{-rate}} = 1.99 \times 10^{-10} \times n_c \times C_8$	$H_{2\text{-rate}} = 1.53 \times 10^{-7} \times n_c \times P_{15}$
VLA, lead-antimony, EOL	$H_{2\text{-rate}} = 3.98 \times 10^{-9} \times n_c \times C_8$	$H_{2\text{-rate}} = 1.02 \times 10^{-6} \times n_c \times P_{15}$
VLA, lead-selenium, EOL	$H_{2\text{-rate}} = 5.47 \times 10^{-10} \times n_c \times C_8$	$H_{2\text{-rate}} = 1.40 \times 10^{-7} \times n_c \times P_{15}$
VLA, lead-selenium, EOL	$AsH_{3\text{-rate}} = 8.83 \times 10^{-15} \times n_c \times C^8$	$AsH_{3\text{-rate}} = 2.25 \times 10^{-12} \times n_c \times P_{15}$
VLA, lead-selenium, EOL	$SbH_{3\text{-rate}} = 1.02 \times 10^{-13} \times n_c \times C_8$	$SbH_{3\text{-rate}} = 2.60 \times 10^{-11} \times n_c \times P_{15}$
VRLA, AGM	$H_{2\text{-rate}} = 1.54 \times 10^{-10} \times n_c \times C_8$	$H_{2\text{-rate}} = 3.86 \times 10^{-8} \times n_c \times P_{15}$

Battery Type	Off Gassing Formulas Based upon Test Values Used	
	Calculation using C_x (m^3/s)	Calculation using P_{15} (m^3/s)
VRLA, gel	$H_{2\text{-rate}} = 4.48 \times 10^{-10} \times n_c \times C_8$	$H_{2\text{-rate}} = 1.12 \times 10^{-7} \times n_c \times P_{15}$
Ni-Cd, sintered/PBE, pocket, fiber	$H_{2\text{-rate}} = 3.50 \times 10^{-9} \times n_c \times C_5$	-
Ni-Cd, foamed/PBE	$H_{2\text{-rate}} = 6.61 \times 10^{-10} \times n_c \times C_5$	-
Ni-Cd, partially recombinant	$H_{2\text{-rate}} = 1.74 \times 10^{-10} \times n_c \times C_5$	-

$H_{2\text{-rate}}$ – The hydrogen gas release rate in m^3/s at standard sea level atmospheric pressure and 25 °C

$AsH_{3\text{-rate}}$ – The arsine gas release rate in m^3/s at standard sea level atmospheric pressure and 25 °C

$SbH_{3\text{-rate}}$ – The stibine gas release rate in m^3/s at standard sea level atmospheric pressure and 25 °C

VLA – Vented lead acid

EOL – End of Life (*considered worse case off gassing stage*)

VRLA – Valve regulated lead acid

PBE – Plastic Bonded Electrode

n_c – Number of cells in device under test

P_{15} – The 15 min kW/cell rating of a lead-acid cell to 1.67 V at 25 °C

C_8 – The 8 h ampere-hour rating of a lead-acid cell to 1.75 V at 25 °C

C_5 – The 5 h ampere-hour rating of a Ni-Cd cell to 1.0 V at 20 °C

Note: Lead acid batteries may also off gas H_2S towards the end of thermal runaway, but there is no calculation for this determination. The methods of 7.4 may be used if the volume of H_2S off gassed is requested.

H3.5.1.7 The volume of hydrogen gas measured during the testing or calculated and documented. This value can be utilized in the end use to determine the suitable deflagration/explosion protection.

NOTE: The Test Concepts and Application of Test Results to Installations annex of UL 9540A outlines the approach to addressing the off gassing data to aid in determining the need for deflagration/explosion protection and to inform that design in accordance with NFPA 68 and NFPA 69. Information on explosion control addressing unique properties for hydrogen can be found in the Hydrogen Explosion Control annex of NFPA 2.

H3.5.1.8 As a result of the test, there shall be no evidence of fire (i.e. charring of the cheesecloth indicator) or explosion for any of the samples tested. The temperatures measured on the DUT and target batteries and gas information shall be documented.

NOTE: Refer to UL 9540A for information that is required to be provided for a UL 9540A report.

10. Addition of Vehicle Auxiliary Power System Requirements.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

UL 1973 includes batteries for vehicle auxiliary power batteries, which are non-traction energy sources on vehicles such as recreational vehicles. This proposal clarifies the test requirements that would apply to a battery in a vehicle application to cover vibration, shock and temperature cycling. The requirements proposed are based upon vehicle criteria.

PROPOSAL

1 Scope

1.2A These requirements are also applicable to batteries for use in vehicle auxiliary power (VAP) systems that are utilized in recreational vehicles and other vehicles to provide power for various applications such as lighting and appliances. These batteries are not used for traction power in the vehicles, since batteries for traction power are to be evaluated to UL/ULC 2580 and UL/ULC 2271 as applicable to the intended motive application.

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*
UL/ULC 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*
UL/ULC 2580, *Batteries for Use in Electric Vehicles*
~~CAN/ULC 2580, Batteries for Use in Electric Vehicles~~

7.1 Non-metallic materials

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.

Exception No. 1: Polymeric materials utilized for light electric rail (LER) enclosures for motive and VAP 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.

Exception No. 2: LER enclosure parts for motive and VAP applications may alternatively be evaluated to the 20 mm end-product flame tests in accordance with UL 746C.

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Mechanical Tests		
Vibration (LER Motive and VAP Applications)	25	1
Shock (LER Motive and VAP Applications) [c]	26	1
Crush (LER Motive and VAP Applications) [c]	27	1
Environmental Tests		
Thermal Cycling (LER Motive and VAP Applications)[c]	35	1
Material Tests		
20-mm end product flame test (LER Motive and VAP Applications)	7.1.1	[b]

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Vibration (LER Motive and VAP Applications)	E, F, C, V, S, L, R, P
Shock (LER Motive and VAP Applications)	E, F, C, V, S, L, R, P
Crush (LER Motive and VAP Applications)	E, F, C, V
Thermal Cycling (LER Motive and VAP Applications)	E, F, C, V, S, L, R, P

25 Vibration Test (LER Motive and VAP Applications)

25.1 The purpose of this test is to determine the battery system's resistance to anticipated vibration in LER motive and VAP installations and applies only to those systems intended for installation in these ~~that~~ applications.

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.)

Exception: Batteries intended for VAP applications shall be subjected to the Vibration Endurance Test of UL/ULC 2271 or UL/ULC 2580.

26 Shock Test (LER Motive and VAP Applications)

26.1 The purpose of this test is to determine the battery system's resistance to anticipated shock in LER motive and VAP installations and applies only to those systems intended for installation in these ~~that~~ applications.

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.)

Exception No. 1: This test may be conducted at the module level if it can be shown that testing shall be representative of the battery system.

Exception No. 2: Batteries intended for VAP applications shall be subjected to the Shock Test of UL/ULC 2271 or UL/ULC 2580.

27 Crush Test (LER Motive and VAP Applications)

27.1 This test is conducted on a fully charged battery system intended for LER motive and VAP 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 these ~~that~~ applications.

35 Thermal Cycling Test (LER Motive and VAP Applications)

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 and VAP applications.

11. Revisions to the External Fire Test.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

These proposals to update the external fire test include updating the title to better clarify the intent, add more details around the fuel pan and include the hose down portion of the test in the test method rather than referencing the standard.

PROPOSAL

38 Thermal Exposure for Explosion Hazards Test ~~External Fire Exposure Test~~

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~~ landing beyond the test perimeter as a result of being exposed to a hydrocarbon pool~~/brush~~ fire simulating an external fire exposure that may occur.

Exception No. 1: The battery system may be subjected to the ~~e~~External ~~f~~Fire ~~e~~Exposure ~~t~~Test in UL/ULC 2580 instead of the method outlined in 38.2.

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.

Exception No. 3: If the secondary lithium cells employed in the system comply with ~~UL 1642 or UL 2054~~ the Projectile test of E8, the system is exempted from this test. This test is not applicable to systems employing lead acid or similar monobloc aqueous electrolyte batteries.

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.

38.1A This test shall be conducted in a controlled setting free from the effects of wind or other environmental factors that may affect the test. The ambient temperature during the testing is to be within the range of 0°C to 46°C (32°F to 114.8°F).

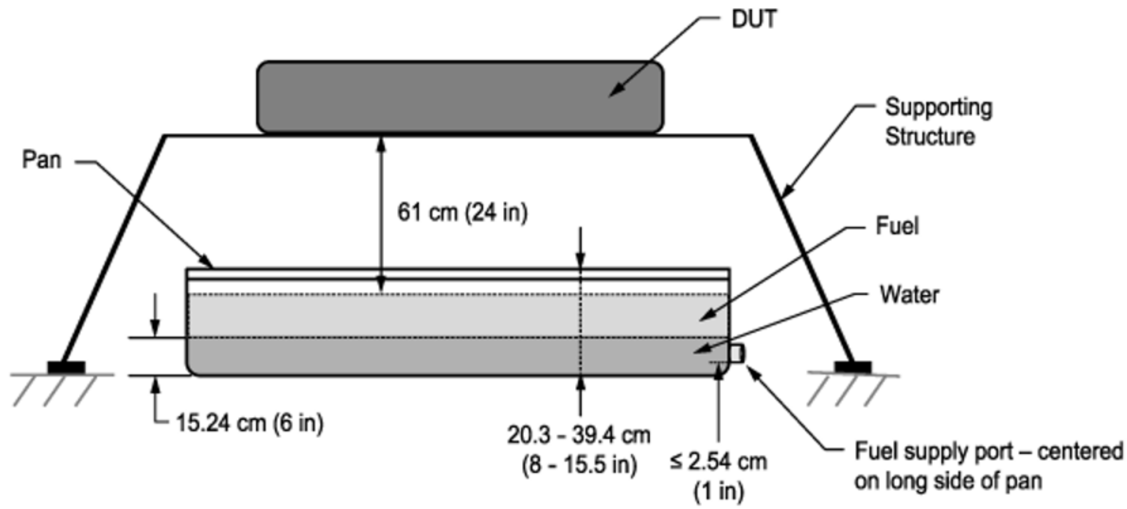
38.3 The pan, which provides the fire containment, shall be constructed of steel of sufficient thickness to prevent warping during the course of the 20-min test. ~~The upper lip shall have a steel angle welded all around or similar reinforcement to prevent warping during testing.~~ The pan shall be sized~~,~~ in relation to the DUT and ~~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. The walls of the pan shall not project more than 8 cm (3.1 in) above the level of the fuel at the start of the test. The pan dimensions shall be sized to ensure that the sides of the tested-device are exposed to the flame. The pan shall exceed the horizontal projection of the DUT by 20 to 50 cm (7.9 to 19.7 in). ~~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.~~

38.3A There should be approximately 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. The fire shall cover the whole area of the pan during whole fire exposure.

38.5 The DUT shall be fully supported and 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, and shall be of a sufficient height so that the bottom surface of the DUT is approximately 50 cm (19.7 in) from the top fuel surface in the pan. See Figure 38.1 for details of set up.

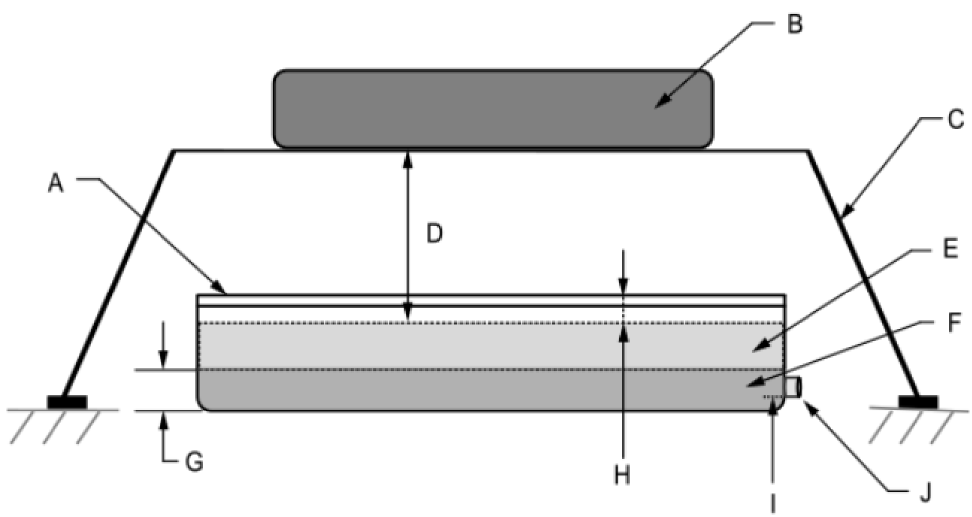
Figure 38.1
~~External Fire~~ Thermal Exposure for Explosion Hazards Test Set-Up

(CURRENT FIGURE)



su1387a

(PROPOSED FIGURE)



su1387c

A – Pan	B – DUT
C – Supporting Structure	D – 50 cm (19.7 in) ~~61 cm (24 in)~~
E – Fuel	F – Water
G – 15.24 cm (6 in)	H – 8 cm (3.1 in) ~~20.3 – 39.4 cm (8 – 15.5 in)~~
I - Fuel Port ≤ ~~2.54 cm (1 in)~~	J – Fuel supply port – centered on long side of pan

38.6 During the test, the temperature of the cells or modules within the DUT ~~shall~~ may be monitored for information purposes.

38.7 After the 20-min fire exposure the fire shall be extinguished, and the DUT ~~is~~ shall be subjected to a hose down in accordance with 38.7A ~~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. At the conclusion of the hose down, there shall be a one hour observation period in accordance with 8.5.

38.7A The battery shall be subjected to a low impact hose stream delivered through a 38 mm (1-1/2 in) fog nozzle set at a discharge angle of 30° with a nozzle pressure of 517 kPa (75 psi) and a minimum discharge of 4.7 L/s (75 gpm). The tip of the nozzle shall be a maximum of 1.5 m (5 ft) from the center of the exposed surface of the DUT. The minimum duration of the low impact hose stream test shall be 6.5 s/m^2 (0.60 s/ft^2). The outer surface of the DUT shall be identified as the exposed area, as the hose stream must traverse this area during its application. To prevent potential for exposure to projectiles, the technician conducting the hose down portion of the test shall do so behind a protective barrier.

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 wider ~~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.~~

38.8A For protection from projectiles during the test, the DUT, test set up, and inner perimeter marking shall be enclosed within a protective test chamber that can contain the projectiles or 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 walls of the test chamber or the outer perimeter shall be located a minimum of 1.5 m (4.95 ft) from the inner perimeter marking to prevent the possibility of projectiles bouncing off the walls and back into the inner perimeter.

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Environmental Tests		
Thermal Cycling (LER Motive Applications)[c]	35	1
Resistance to Moisture[c]	36	1
Salt Fog[c]	37	1
Thermal Exposure for Explosion Hazards Test[c] ~~External Fire Exposure[c]~~	38	1

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Resistance to Moisture	E, F, C, V, S, L, R, P
Salt Fog	E, F, C, V, S, L, R, P
Thermal Exposure for Explosion Hazards Test ~~External Fire Exposure~~	E
Single Cell Failure Design Tolerance[b]	E, F

12. Addition of cell test method from UL 9540A for information gathering.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

This addition of the Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, UL 9540A cell level test of the overall large scale fire testing is being proposed to be included in UL 1973 to gather this information during the cell investigation so that it can be used to inform the large scale fire testing.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

ASHRAE Guideline 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE 1635, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*

UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Tolerance To Internal Cell Failure Tests		
Single Cell Failure Design Tolerance[c]	39	1[i]
Cell Evaluation for Large Scale Fire Testing[k]	39A	[k]
[l] This test requires about 5 cells to establish thermal runaway method.		
[k] This test requires 6 cells.		

TOLERANCE TO INTERNAL CELL FAILURE TESTS

39 Single Cell Failure Design Tolerance

39.1 General

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. See also Section 39A.

39A Cell Evaluation for Large Scale Fire Testing

39A.1 Cells intended for stationary applications shall be subjected to the cell level test of UL 9540A, The temperature information and gas information obtained during this test and evaluated to determine its properties in accordance with UL 9540A shall be documented.

39A.2 Flow battery systems shall have their electrolyte evaluated in accordance with C3.6.

39A.3 Lead acid and Ni-cad batteries shall be evaluated to determine if they are capable of going into thermal runaway in accordance with H3.5.1. The potential for hydrogen off gassing under thermal runaway shall be determined in accordance with IEEE 1635/ASHRAE Guideline 21 or in accordance with the Cell Vent Gas Composition Test of UL 9540A.

C3 Materials Containing Electrolyte – Temperature Exposure

C3.6 The electrolyte(s) of the flowing electrolyte battery systems for stationary applications shall be evaluated to determine if they are flammable in accordance with 7.3.2.2 of UL 9540A. The results shall be documented.

C3.7 With reference to C3.6, for flowing electrolyte battery systems with two active electrolytes, the temperature of the electrolytes upon mixing in accordance with UL 9540A shall be measured and recorded.

C5.3 Electrolyte blockage tests

C5.3.1 Pump failure/blockage during charging

C5.3.1.2 The Overcharge test of Section 15 shall additionally consider, for flowing electrolyte type battery systems, an overcharge condition that can result from an electrolyte pump failure or other cause leading to electrolyte line blockage. During this test, the temperature of the electrolyte(s) shall be measured and recorded.

C5.3.2 Pump failure/blockage during discharging

C5.3.2.2 The overdischarge test of Section 17 shall be modified for flowing electrolyte type battery systems to consider an overdischarge condition resulting from an electrolyte pump failure or electrolyte blockage during a constant current discharge. During this test, the temperature of the electrolyte(s) shall be measured and recorded.

C5.4 Short circuit test

C5.4.1 When conducting the short circuit test of Section 16 on the system, the electrolyte flow rate shall be maintained at a constant rate during the test, until the protection operates, the system is discharged or other ultimate results occur to end the test. During this test, the temperature of the electrolyte(s) shall be measured and recorded. A short circuit at the flow battery stack level is not conducted.

13. Clarification for spacings criteria and pollution degree in 7.5.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Clarifications regarding how to determine electrical spacings with regard to equipment Category and Pollution degree have been added. This is not a new requirements, but rather a clarification. There is also a correction of the term “energy storage system” to “battery system”. This should have been included during the development of the 2nd edition.
Please note that UL 60950-1/CSA C22.2 No. 60950-1 has been replaced with UL 62368-1/CSA C22.2 No. 62368-1 so revisions have been made accordingly.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

CAN/CSA C22.2 No. 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirement*

IEC 60664-1, *Insulation Coordination for Equipment Within Low-voltage Supply Systems – Part 1: Principles, Requirements and Tests*

UL 746E, *Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards*
UL 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirements*
UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

7.5 Spacings and separation of circuits

7.5.1 General

7.5.1.1 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.

7.5.1.2 Electrical spacings in circuits shall be based upon the grade of insulation required as outlined in the Insulation Materials and Requirements, Clause 5.4 of UL 62368-1/CSA C22.2 No. 62368-1, Grade of Insulation section of UL 60950-1 /CAN/CSA-C22.2 No. 60950-1, and shall comply with the Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3, of UL 62368-1/CSA C22.2 No. 62368-1.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 f For the appropriate pollution degree of the intended environment see 7.5.2 and 7.5.3. (see the Pollution Degrees section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1).

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 battery system or subassembly under evaluation.

Exception No. 2: As an alternative to the clearance values outlined in UL 62368-1/ CSA C22.2 No. 62368-1 *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 Clearances for Insulation in Circuits Connected to an AC Mains not Exceeding 420 V peak (300 V RMS), Annex X, of UL 62368-1/*CSA C22.2 No. 62368-1*Alternative Method for Determining Minimum Clearances, Annex G, of UL 60950-1/CAN/CSA-C22.2 No. 60950-1 may be applied.*

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.

Exception No. 4: As an alternative, clearances and creepage distances per IEC 60664-1 can be applied instead.

7.5.1.3 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.

7.5.1.4 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.

7.5.1.5 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.

7.5.1.6 UL 840 shall not be used for clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable. UL 840 shall not be used for the clearance and creepage distance at field wiring terminals.

7.5.1.7 When determining the clearance for double or reinforced insulation in accordance with UL 840, the clearances of reinforced insulation shall be dimensioned corresponding to the rated impulse voltage, but choosing one step higher in the preferred series of values in the Minimum Clearances for Equipment table of UL 840 than that specified for basic insulation. If the impulse withstand voltage required for basic insulation, is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160% of the impulse withstand voltage required for basic insulation.

7.5.1.8 When determining the creepage for double or reinforced insulation in accordance with UL 840, the creepage distances for reinforced insulation shall be twice the creepage distance required for the basic insulation as determined in UL 840.

7.5.1.9 When determining the electrical spacing according to 7.5.1.1, a battery circuit that has no direct connection to a primary circuit and derives its power from a transformer or converter shall be considered a secondary circuit. The phase-to-ground rated system voltage used in the determination of mains transient voltage in UL 62368-1/CSA C22.2 No. 62368-1 or the rated impulse voltage in UL 840 shall be the rated supply voltage of the charging equipment for the battery.

7.5.1.10 For batteries intended for installation at high altitudes (i.e. 2000 m and above), see the Multiplication Factors for Clearances and Test Voltages table of UL 62368-1/CSA C22.2 No. 62368-1 or the Altitude Correction Factors for Clearance Correction table of IEC 60664-1 for multiplication factors to be applied to clearance values.

7.5.2 Overvoltage categories applied for electrical creepage and clearance determination

7.5.2.1 When determining the creepage and clearance requirements from 7.5.1.2, the overvoltage categories for the battery systems shall be determined based on how the batteries are connected to the supply mains. For equipment or circuits energized from the mains, four categories are considered:

a) Category IV applies to equipment permanently connected at the origin of an installation (upstream of the main distribution board). Examples are electricity meters, primary overcurrent protection equipment and other equipment connected directly to outdoor open lines;

b) Category III applies to equipment permanently connected in fixed installations (downstream of, and including, the main distribution board). Examples are switchgear and other equipment in an industrial installation;

c) Category II applies to equipment not permanently connected to the fixed installation. Examples are appliances, portable tools and other plug-connected equipment; and

d) Category I applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltages to a low level.

7.5.2.2 For stationary battery systems, Overvoltage Category III is applied. Overvoltage Category II may be applied for a stationary battery system that is isolated from an Overvoltage category III supply source (such as from an Overvoltage category III PCS) through an isolated transformer or protected in a manner that prevents transient overvoltage conditions. For vehicle auxiliary power batteries and on board LER batteries, Overvoltage Category II shall be applied.

7.5.3 Pollution degree for electrical creepage and clearance determination

7.5.3.1 With reference to 7.5.1.2, the following are conditions for determining the pollution degree to utilize when determining creepage and clearance distances. See also examples noted in Table 7.2.

a) Pollution Degree 1 – No pollution or only dry, non-conductive pollution. Normally, this is achieved by having components and subassemblies adequately enclosed by enveloping or hermetic sealing so as to exclude dust and moisture.

b) Pollution Degree 2 – Only non-conductive pollution that might temporarily become conductive due to occasional condensation.

c) Pollution Degree 3 – Subject to conductive pollution, or to dry non-conductive pollution which could become conductive due to expected condensation.

d) Pollution Degree 4 – Pollution that generates persistent conductivity through conductive dust or rain and snow.

Table 7.2
Examples of the Provision of Pollution Degree Environments

Pollution Degree	Method of Achievement
PD3	a) If installed outdoors, the use of an enclosure meeting IPX4 or Type 3R; or b) If indoor installed, no climate conditioning provided to prevent condensation.
Reduction of PD3 to PD2	a) Indoor installation with climate conditioning provided and where condensation is not expected; or b) Outdoor installation provided with climate conditioning, which prevents condensation and conductive dust within an enclosure rated IPX4 or Type 3R; or c) An enclosure meeting IP54 per IEC 60529 or Type 3 per UL 50E and no internally generated contamination; or d) The use of an enclosure meeting IPX7 or IPX8 per IEC 60529 or Type 6 or Type 6P per UL 50E.
Reduction of PD2 to PD1	With a PD2 environment, an enclosure subjected to an IP5X dust test of IEC 60529 or the outdoor test of UL 50E, Clause 8.4.1 and that has no internally generated contamination.
Reduction to PD1	Control of the environment at the insulation surface to allow Pollution Degree 1 can be accomplished by the methods in UL 62368-1/CSA C22.2 62368-1 (for example, encapsulation, potting or coating) or conforming coating per UL 746E.

14. Addition of measurement of cell voltages during overcharge and overdischarge tests.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

These proposals are provided for clarification that cell voltages should be monitored during the test and safe levels should not be exceeded.

PROPOSAL

15 Overcharge Test

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. Single fault conditions can be applied to both passive and active protective devices. During test, the voltage of the cells shall be measured. 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.

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.

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.

15.7 As a result of the overcharge test, the maximum charging voltage measured on the cells shall not exceed their normal operating range. 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.

17 Overdischarge Protection Test

17.1 This test shall be conducted on a fully charged sample (MOSOC per 8.1) to determine the DUTs ability to withstand an overdischarge condition and is conducted with all discharge protection circuitry for both temperature and minimum voltage connected to prevent irreparable cell damage. 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~~. During test, the voltage of the cells shall be measured.

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

17.6 As a result of the overdischarge protection test, the minimum discharge voltage measured on the cells shall not exceed their normal operating range. 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.

15. Clarification of the single cell failure design tolerance test.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Some clarification that the cell should be brought to temperature prior to initiating the thermal runaway mechanism was needed so this additional text is being added. Also a correction was needed in 22.1 to change “energy storage system” to “battery system”, along with clarifications for monitoring temperatures on the DUT in 39.2.5 and 39.3.3.

PROPOSAL

22 Failure of Cooling/Thermal Stability System

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.

Exception: Testing may be conducted at a subassembly level if that is representative of the ~~energy storage~~ battery system.

39.2 Single cell failure design tolerance (lithium ion)

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~~±10°C (~~±9~~±18°F) for cells just before inducing the mechanism to create thermal runaway. 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.

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.

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.

39.2.5 Temperatures on the failed cell and surrounding cells, external enclosure surfaces of the DUT and the supporting surface are to be monitored and reported for information purposes. The number of cells that fail due to propagation from the triggering cell shall be documented.

39.3 Single cell failure design tolerance (other technologies)

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. Temperatures on the external enclosure surfaces of the DUT and the supporting surface shall also be recorded for information purposes. 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.

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

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

39.3.5 Temperatures on the failed cell and surrounding cells, external enclosure surfaces of the DUT and the supporting surface are to be monitored and reported for information purposes. The number of cells that fail due to propagation from the triggering cell shall be documented.

16. Proposals for flowing electrolyte batteries.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

The shunt current determination test is something that is not that applicable to today's designs of flowing electrolyte batteries. What needs to be addressed is the shock hazard concerns associated with large quantities of energized and hazardous fluids flowing through them. To better address these concerns, a requirement for leakage detection is being proposed and the shunt current determination test is being replaced by an insulation resistance test.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

IEC 60364-6, *Low-Voltage Electrical Installations – Part 6: Verification*

6 Glossary

6.20 FLOWING ELECTROLYTE BATTERY – A rechargeable battery that stores its active materials, in the form of liquid aqueous electrolytes, external to the battery. The electrolytes, which serve as energy carriers, are pumped through two half cells separated by an ion-permeable separator, which provides separation of the two electrolytes while still allowing for the passage of ions during charging and discharging. Charging and discharging results in a chemical reduction reaction in one electrolyte and an oxidation reaction in the other electrolyte. Ions selectively pass through the separator membrane to complete the redox reaction. When in use the electrolytes are continuously pumped in a circuit between reactor and storage tanks. ~~Two~~ Three commercially available flowing electrolyte batteries technologies, ~~the zinc bromine,~~ two of which are zinc-based and a third, the vanadium redox types, are described below:

a) ZINC AIR – A flowing electrolyte battery technology that has one active aqueous electrolyte containing metal particles. During charging, zinc particles are generated from a zincate solution in a chemical reaction (oxygen is off gassed from the reaction), and then transported to a storage tank in a KOH solution as a charged electrolyte. During discharge the electrolyte is pumped through the reactor interface (flow battery stack) where the zinc particles combine again with oxygen from the surrounding air to form zincate.

~~a~~b) ZINC BROMINE – A flowing electrolyte battery technology that has zinc at the negative electrode and bromide at the positive electrode with an aqueous solution containing zinc bromide and other compounds contained in two separate reservoirs. During charging, energy is stored as zinc metal within the cell and polybromide in the cathode reservoir. During discharge, the zinc is oxidized to zinc oxide and the bromine is reduced to bromide.

~~b~~c) VANADIUM REDOX – A flowing electrolyte battery technology that contains vanadium salts in various stages of oxidation in a sulfuric acid, or in a mixture of sulfuric and hydrochloric acid electrolyte. Charging and discharging the battery changes the oxidation state of the vanadium in the electrolyte solutions.

7.10 Electrolyte containment parts and parts subject to pressure

7.10.8 Flowing electrolyte batteries shall be provided with a means of leak detection that shall identify when a leak occurs in the system and initiate controls to mitigate the leak condition.

C1.1 Battery systems consisting of flowing electrolyte batteries shall comply with the applicable construction and test requirements of this Standard. They shall additionally be subjected to the requirements outlined in this Appendix.

Exception: The Overdischarge Protection Test, ~~of Section 17 and~~ Imbalanced Charging Test ~~of Section 19~~, and Drop Impact Test are not conducted on flowing electrolyte systems.

C5.5 Insulation resistance ~~Shunt current determination~~

C5.5.1 Systems shall have sufficient insulation resistance to prevent hazards associated with energized electrolyte fluids traveling through the system. ~~Imbalance conditions and the potential for corrosion of the electrolyte containment parts may occur as a result of excessive shunt currents in a flowing electrolyte battery system.~~

C5.5.2 The resistance of insulation used on hazardous voltage circuits within the flowing electrolyte battery shall be greater than or equal to 1 MΩ when conducting the test of C5.5.3. ~~The flowing electrolyte battery manufacturer shall demonstrate through data that shunt currents have been mitigated as a result of the system design to a sufficient level.~~

C5.5.3 The insulation resistance shall be measured using high impedance measuring equipment (e.g. mega ohmmeter) after applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.

Exception: The insulation resistance test of IEC 60364-6, Low voltage electrical installations – Part 6: Verification, can be conducted instead. Compliance criteria is in accordance with the IEC 60364-6 when using this method.

~~A check of the data outlined in C5.5.2 shall be conducted by:~~

a) ~~Measuring the capacity of the smallest possible flow battery system at a constant current discharge based upon manufacturer's specifications; and~~
b) ~~Measuring the capacity at constant current discharge of the largest flow battery system.~~

~~C5.5.4 The anticipated current from a large system with minimal shunt current losses shall be determined by calculation using the values obtained from the small system measurements. These shall be compared with the actual measured values from the large system. Parasitic losses due to balance of plant components powered by the systems shall be excluded from these calculations.~~

~~C5.5.5 The determined losses in the large system due to shunt currents shall match the manufacturer's specifications with tolerances.~~

17. Inclusion of mechanically recharged metal-air battery requirements.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Mechanically recharged metal air batteries are a unique technology that require some modification of the current UL 1973 in order to address them sufficiently. In addition, some definitions of metal air battery and mechanically recharged battery are needed to clarify what type of technology is being addressed. These are metal air batteries that are essentially “recharged” by changing parts containing depleted active material with a fresh “recharged” part. In this manner, they somewhat resemble a primary (non-rechargeable) battery, except the majority of the battery remains in place with only the anode being the part replaced electrode replaced. The battery may have balance of plant components and quantities of electrolyte within the battery case that require some similar considerations for safety as flow batteries. The requirements are proposed for inclusion in a new normative Appendix I.

PROPOSAL

1 Scope

1.3 Appendix B of this standard includes requirements specific to sodium-beta type technologies. Appendix C of this standard includes requirements specific to flowing electrolyte technologies. Appendix I of this standard includes requirements specific to mechanically recharged metal-air batteries.

6 Glossary

6.33A METAL-AIR BATTERY – An electrochemical battery that uses an anode made from pure metal and an external cathode of ambient air, typically with an aqueous or aprotic electrolyte. Primary, reserve, electrically rechargeable, and mechanically rechargeable metal-air battery configurations have been explored and developed. The metals that have been considered for use in metal-air batteries are calcium, magnesium, lithium, aluminum, and iron.

6.33B METAL-AIR BATTERY, MECHANICALLY RECHARGEABLE – A metal-air battery designed with a means to remove and replace the discharged anodes or discharge products (such as reacted electrolyte) with new ones for recharging. The battery essentially functions as a primary battery and the air electrodes operate only in a discharge mode. During discharging of a metal-air electrochemical cell, an oxygen reduction reaction occurs in the ambient air cathode while the metal anode is oxidized. The discharged anode or discharge products can be recharged or reclaimed external to the cell. Commercially available mechanically rechargeable metal-air batteries are Zn-Air batteries and Al-Air batteries.

APPENDIX G (Informative)
Safety Marking Translations

Table G.1
Safety marking translations

Reference	English	French
41.5	“Use Only ( ) Charger”	« Utiliser Uniquement ( ) Chargeur »
41.7	“caution”	« attention »
41.7	“read instruction manual”	« Lire le manuel d’instruction »
42.5	“DANGER,” “WARNING,” or “CAUTION.”	« DANGER », « AVERTISSEMENT » ou « ATTENTION ».
I6.1	“Corrosive fluid inside, only maintained by the manufacturer”	« Fluide 45tilizer45 à l’intérieur, seul le fabricant doit s’occuper de l’entretien »
I6.2	“Indoor Use Only”	« Pour 45tilizer45on intérieure seulement »

I6.3	"No User Serviceable parts, only mechanically recharged or refueled by authorized service personnel"	« Aucune des 46tiliz ne peut être réparée par l'utilisateur; recharger mécaniquement ou ravitailler par un personnel d'entretien qualifié uniquement. »
I7.1	"Do not use a cell stack/anode metal plate if it has been dropped, as it may result in a hazardous condition."	« Ne pas 46tilizer un assemblage de cellules ou une plaque anode métallique s'ils ont été échappés, car une situation dangereuse pourrait en résulter. »

Appendix I (NORMATIVE)
Test Program for Mechanically Rechargeable Metal-Air Batteries

I1 General

I1.1 Battery systems consisting of mechanically rechargeable Al-Air batteries or mechanically rechargeable Zn-Air batteries shall comply with the applicable construction and test requirements of this standard. They shall additionally be subjected to the requirements outlined in this Appendix. This Appendix only applies to mechanically rechargeable Al-Air batteries and mechanical rechargeable Zn-Air batteries, which recharge the battery by replacing the oxidized metal electrode with a new metal electrode.

I1.2 The sample criteria for the cell stack tests is outlined in Table I.1. Samples for all cell stack tests shall be assembled with fresh anodes which are no more than 6 months from the date of production. The same sample shall be used for test I4.1 and I4.2. Test I4.2 shall be conducted after test I4.1. Samples used for the I4.2 and I4.4 test shall be subjected to the I5.2 leakage test afterwards.

Table I.1
Test Program for Cell Stack

Test	Section	Number of cell stacks tested
Vibration of cell stack	I4.1	1 fresh
Shock test on cell stack	I4.2	1, use I4.1 sample
Drop Impact test on cell stack	I4.3	1 fresh
High Temperature test on cell stack	I4.4	1 fresh
Short Circuit test on cell stack	I4.5	1 fresh
Forced Discharge test on cell stack	I4.6	1 fresh
Leakage test	I5.2	3, use I4.2 – I4.4 samples

I1.3 The sample criteria for the mechanically rechargeable metal-air battery system tests is outlined in Table I.2. Before testing, the battery sample shall be assembled with fresh anodes which are no more than 6 months after the date of production.

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. After minor repairs, samples should be assembled with fresh anodes as noted above.

I1.4 Unless otherwise indicated, the battery sample shall then be activated by pumping the electrolyte into the cell stack and be adjusted to be fully charged in accordance with the manufacturer's specifications, and submitted to the tests in Table I.2 immediately. For mechanically rechargeable metal-air batteries, there is no need to conduct charge/discharge cycle after completing the tests on the battery system in accordance with I2.2, but if the control circuit remains operational after test in Table I.2, the loss of protection controls shall be checked by a method given by manufacturer or other suitable method such as checking that the protection will activate normally when there is a value input above protection limit.

Table I.2
Test Program for Mechanically rechargeable metal-air battery systems

Test	Section	Number of samples
Electrical Tests		
Short Circuit[a]	16	1
Temperature and Operating Limits Check[a]	18	1
Dielectric Voltage Withstand	20	1, on the same sample before and after the Temperature and Operating Limits Check Test
Continuity	21	1, on the sample after the Temperature and Operating Limits Check Test
Failure of Cooling/Thermal Stability System[a]	22	1
Working Voltage Measurements[b]	23	1
Mechanical Tests		
Static Force	28	1
Impact	29	1
Wall Mount Fixture/Support Structure/Handle Test[c]	31	1 (mounting fixture or handle fixture)
Mold Stress	32	1
Environmental Tests		
Resistance to Moisture[a]	36	1
Salt Fog[a]	37	1
Additional Tests for Mechanically Rechargeable Metal-Air Systems		
Hydraulic Pressure Test	I5.1	1
Leakage Test	I5.2	1
Electrolyte/Air Pipe Blockage Tests	I5.3	1 for each fault condition
Isolation Resistance Test	I5.4	1
Spill/Leak Containment System	I5.5	1

[a] Testing may be conducted on subassemblies if determined representative of the complete battery system.

[b] This check of maximum working voltage values is needed when using the spacing criteria of Table 7.1.

[c] This test is conducted on battery system with wall-mount fixtures or handle fixtures only.

I1.5 Only the discharge condition of the temperature and operating limits check test shall be conducted for mechanically rechargeable metal-air battery systems. The voltage, current and temperature of each cell stack instead of each cell shall be measured during test. As a result of test, the measured current and temperature of the cell stack shall be compared to its operation limits, and the limits shall not be exceeded.

I1.6 When conducting the failure of the cooling/thermal stability system test of Section 22, the battery system shall be tested at ambient temperature rather than tested in an elevated ambient within a test chamber.

I1.7 The dielectric voltage test shall be conducted on the fresh battery sample before the temperature and operating limits check test, and on the discharged battery sample after the temperature and operating limits check test.

I1.8 The continuity test shall be conducted on the discharged battery sample after the temperature and operating limits check test.

1.9 The sample criteria for the electrical components and materials containing electrolyte used in mechanically rechargeable metal-air battery system tests is outlined in Table I.3.

I1.10 Unless otherwise indicated, the tests in Tables I.2 and I.3 shall be conducted in an ambient temperature of 25°C ±5°C (77°F ±9°F).

Table I.3
Test Program for Electrical Components and Materials Containing Electrolyte

Test	Section	Number of samples
Locked-Rotor Test (Low Voltage D.C. Fans/Motors/Pumps In Secondary Circuits)	24.1	1 motor or fan or pumps
Input	24.2	1, separate accessory
Leakage Current	24.3	1, separate accessories that are supplied by ac mains
Strain Relief	24.4	1, device with a non-detachable accessible cord
Push-Back Relief	24.5	1, device with a non-detachable accessible cord
Materials Containing Electrolyte – Resistance to Deterioration from Fluids	I2	3 materials
Materials Containing Electrolyte – Temperature Exposure	I3	6 materials

I2 Materials Containing Electrolyte – Resistance to Deterioration from Fluids

I2.1 Parts containing electrolyte shall be resistant to deteriorations from the fluids they contain. Compliance is determined by the testing outlined in I2.2 and I2.3. As a result of the testing, the tensile strength of tested materials shall not be less than 80% of the tensile strength of the material in the as received condition.

I2.2 Three as-received samples of materials conditioned as described in I2.3 shall be tested in accordance with ASTM D638. The tensile strength of the materials under test shall be recorded.

I2.3 The material shall be immersed in the test liquid representative of the electrolyte contained and conditioned for 7 days, 30 days and 60 days at a temperature of 50°C (122°F) in a full-draft air-circulating explosion-proof oven. Samples are evaluated from each of the exposure times with mechanical properties determined and compared with as-received values. The 60 day exposure test may be waived depending upon results of samples subjected to 30 day exposure.

I2.4 Gasket and seals in contact with electrolyte shall be subjected to the volume change and extraction, tensile strength and elongation after 70-h immersion in the electrolyte in accordance with UL 157. The tensile strength and elongation shall be a minimum of 60% of as received values and the volume change of minus 1 to plus 25% of the as received values and extraction (change in weight) no greater than 10%.

I3 Materials Containing Electrolyte – Temperature Exposure

I3.1 Parts containing electrolyte shall be suitable for intended temperature use. Compliance is determined by the testing of I3.2 and I3.3. As a result of the oven aging, the part shall not show signs of deterioration such as cracking or embrittlement. The tensile strength of the conditioned part shall not be less than 80% of the tensile strength of the as received part.

I3.2 Three as-received samples of the polymeric part and three conditioned samples of the part shall be tested in accordance with ASTM D638. The tensile strength shall be recorded.

I3.3 Three samples of each part shall be conditioned for 45 and 90 days at a temperature of 70°C (158°F) in a full-draft air-circulating oven.

Exception No. 1: As an alternative test method, the part shall be conditioned for 30 and 60 days at a temperature of 80°C (176°F) in a full-draft air-circulating oven.

Exception No. 2: As an alternative test method, the parts shall be conditioned for 15 and 30 days at a temperature of 90°C (194°F) in a full-draft air-circulating oven.

I3.4 Gasket and seals shall be subjected to the air oven aging test of UL 157 based upon anticipated exposure temperatures in the end use application. The tensile strength and elongation after oven aging shall be a minimum of 60% of the as received values.

I3.5 Gasket and seals used in electrolyte containment systems shall be subjected to the lower temperature test of UL 157 for minus 40°C (minus 40°F), or the lowest ambient temperature specified by the manufacturer but not less than 0°C (32°F), with no visible evidence cracking in accordance with the test criteria of UL 157.

I4 Mechanically Rechargeable Metal-Air Cell Stack Tests

I4.1 Vibration test of cell stack

I4.1.1 One sample of a mechanically rechargeable metal-air cell stack shall be subjected to vibration test in accordance with I4.1.2 and I4.1.3. As a result of the vibration conditioning, the cell stack shall not be damaged to the extent that results in leaks.

I4.1.2 The DUT shall mounted to a vibration text fixture and subjected to a simple harmonic motion with an amplitude of 0.76 mm (0.03 in), and a total maximum excursion of 1.52 mm (0.06 in). The frequency shall be varied at the rate of 1 Hz/min between the limits of 10 Hz and 55 Hz. The entire range of frequencies (10 Hz to 55 Hz) and return (55 Hz to 10 Hz), shall be traversed in 90 ±5 min for each mounting position (direction of vibration). The vibration shall be applied in each of three mutually perpendicular directions.

Exception: Another method of vibration representative of the transport conditions of the cell stack such as ISO 13355, or IEC 60068-2-64, etc. may be used if determined to be more suitable for the size and design of the stack.

I4.1.3 At the conclusion of the vibration test, the same DUT sample shall then be subjected to shock test in accordance with I4.2.

I4.2 Shock test on cell stack

I4.2.1 One sample of a mechanically rechargeable metal-air cell stack previously has been submitted to vibration test per I4.1, shall be subjected to the shock test in accordance with I4.2.2 and I4.2.3. As a result of the shock conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table I.1.

I4.2.2 The DUT shall be secured to a test machine by means of a rigid mounts supporting all surfaces of the cell stack. Each DUT shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions. For each shock the DUT shall be accelerated in such a manner that during the initial 3 ms, the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 g and 175 g.

I4.2.3 At the conclusion of the shock conditioning, the DUT shall be checked for leaks by subjecting it to the leakage test I5.2.

I4.3 Drop impact of cell stack or metal anode

I4.3.1 One sample of cell stack or metal anode plate which will be subjected to installation in the battery system during mechanically recharging as specified in the operation/maintenance instruction shall be subjected to a drop impact test to determine that no hazard exists as a result of an inadvertent drop during installation or removal. As a result of the drop impacts, the cell stack to be installed or the cell stack with the metal anode to be installed shall not be damaged to the extent that results in leaks.

Exception: This test can be waived if the operation/maintenance instructions of the battery system declare that the cell stack or the metal anode cannot be used if dropped.

I4.3.2 The DUT (cell stack or metal anode plate) 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 and a height most representative of what would occur during maintenance and handling/removal of the battery system during installation and servicing. The orientation and height 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 shall 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.

I4.3.3 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.

I4.3.4 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.

I4.3.5 At the conclusion of the drop impact test, the DUT shall be checked for leaks by subjecting it to the leakage test I5.2.

I4.4 High temperature test on cell stack

I4.4.1 One fully charged sample of the mechanically rechargeable metal-air cell stack shall be subjected to the high temperature test in accordance with I4.4.2 and I4.4.3. As a result of the high temperature conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table I.1.

I4.4.2 The DUT shall be conditioned for 7 h in an air circulating temperature chamber at a temperature of 10°C ±2°C (50°F ±3.6°F) below the minimum temperature rating (operating temperature or storage temperature, whichever is lower) of the cell stack. The chamber temperature shall then be adjusted to a temperature of 10°C ±2°C (50°F ±3.6°F) plus the maximum temperature rating of the cell stack or 70°C ±2°C (158°F ±3.6°F), whichever is greater, within 60 min. The DUT shall be then be maintained at that temperature for 7 h.

I4.4.3 At the conclusion of the high temperature conditioning, the DUT shall be allowed to cool to room ambient and then it shall be checked for leaks by subjecting it to the leakage test of I5.2.

I4.5 Short circuit test on cell stack

I4.5.1 A sample of cell stack shall be activated by pumping the electrolyte into the cell stack and adjusted to be fully charged in accordance with the manufacturer's specifications.

I4.5.2 Immediately after conditioning in I4.5.1, the fully charged cell stack shall be subjected to a Short Circuit Test to a total external resistance of less than or equal to 20 mΩ until the cell stack is completely discharged, or the operation of an integral protective device or other results. See Table I.1.

I4.5.3 As a result of the Short Circuit Test, there shall be no fire or explosion.

I4.6 Forced discharge test on cell stack

I4.6.1 A sample of cell stack shall be activated by pumping the electrolyte into the cell stack and adjusted to be fully charged in accordance with the manufacturer's specifications.

I4.6.2 Immediately after conditioning in I4.6.1, the fully charged cell stack shall be discharged at its maximum discharge current until it's fully discharged, the cell stack shall then be continuously discharged at the maximum discharge current for additionally 30 min. See Table I.1.

I4.6.3 As a result of the forced discharge test, there shall be no fire or explosion.

I5 Mechanically Rechargeable Metal-Air Battery System Tests

I5.1 Hydraulic pressure test

I5.1.1 Electrolyte containment vessels where there is the potential for gas pressure build up having a pressure-times-volume value greater than 200 kPa-L (7.67 psi-gal), and pressure greater than 50 kPa (7.25 psi), shall be subjected to a hydraulic pressure test as described in I5.1.2. As a result of the test, the vessel shall not burst, leak, rupture, fracture, or permanently (plastic) deform.

Exception No. 1: Where unmarked pressure vessels are not able to be hydraulically tested, compliance shall be verified by other applicable tests, such as an air pneumatic test at the same test pressure as for the hydraulic test.

Exception No. 2: Piping systems under the scope of ASME B31.3, shall be subjected to ultimate strength and leakage testing in accordance with that code.

I5.1.2 The test pressure shall be the maximum pressure specified by the manufacturer multiplied by five or 1.5 times the operating pressure of a pressure relief device, whichever is greater. A pressure-relief device which is used to limit the maximum pressure shall be inactive during the test. The pressure shall be raised gradually to the specified test value and held at that value for 1 min.

I5.2 Leakage test

I5.2.1 Leakage from fluid-containing parts shall not result in the risk of fire, electric shock, or injury to persons. As a result of the leakage test, the following in (a) – (g) are considered non-compliant results:

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);

I5.2.2 Compliance is determined by subjecting the parts to a fluid pressure of 1.5 times the maximum pressure (if testing with liquid) or 1.1 times the maximum pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks as a result.

I5.3 Electrolyte/air pipe blockage tests

I5.3.1 A pump failure or a potential electrolyte or air pipe blockage during discharge may lead to a hazardous condition in a Mechanically rechargeable metal-air battery system. The purpose of this test is to determine if the battery system can safely withstand a failure in the fluid (electrolyte and air) supply system of the battery.

I5.3.2 This test shall be conducted on fully charged samples. Each sample shall be subjected to a fault condition consisting of one of the following in (a) – (c) below which may lead to a hazardous condition. The faulted sample(s) shall then be subjected to the maximum discharging current/power specified by the manufacturer. 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.

a) An electrolyte pump failure;

b) Electrolyte piping blockage; or

c) An air pipe blockage.

I5.3.3 The test shall continue until the protection device(s) are activated, or the DUT has been discharged for an additional 30 min after it has been completed discharged, whichever comes first.

I5.3.4 If the control circuit remains operational after test, the loss of protection controls shall be checked by a method given by manufacturer or other suitable method, such as checking that the protection will activate normally when there is a value input above protection limit. An observation period per 8.5 is then conducted.

I5.3.5 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.

I5.3.6 As a result of this test, the following in (a) – (h) are considered non-compliant results:

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.

I5.4 Isolation resistance test

I5.4.1 This test is intended to determine that the insulation of the DUT provides adequate isolation of hazardous voltage circuits from accessible conductive parts of the DUT, and that the insulation is non-hygroscopic. This test shall be conducted on a battery sample after being fully discharged.

I5.4.2 A DUT with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts. 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.

I5.4.3 The insulation resistance shall be measured after a 60-s application with a high resistance voltmeter using a 500 Vdc potential applied for at least 1 min to the locations under test. For battery systems greater than 500 Vdc, a 1,000 Vdc potential shall be applied instead.

I5.4.4 The test shall be repeated on a sample subjected to a humidity conditioning for 48 h in a chamber with a relative humidity of 93% ±3% and at an air temperature maintained within 2°C (3.6°F) of any convenient value "t" within the range of 20°C to 30°C (68°F to 86°F) such that condensation does not occur. During this conditioning the DUT is not operating. Before the humidity conditioning the sample shall be brought to a temperature between t and t +4°C (t +7.2°F). After conditioning, the sample shall be removed from the chamber, and the insulation resistance measurements shall be made immediately.

Exception No. 1: Subassembly including the isolation circuits and insulation components may be subjected to the humidity condition instead of the whole system if representative of the whole system.

Exception No. 2: The insulation resistance after humidity conditioning is not conducted if insulation materials consist of non-hygroscopic materials.

I5.4.5 The measured insulation resistance between the positive terminals and accessible parts of the DUT shall be at least 50,000 Ω.

I5.5 Spill/leak containment

I5.5.1 If an external spill containment system such as containment vessels and absorption pillows are used for containment, absorption or neutralization of electrolyte spills from a mechanically rechargeable metal-air battery, the materials and parts of the system shall be subjected to the applicable tests of UL 2436.

Exception No. 1: Internal electrolyte containment material and parts shall be subjected to the tests in Section I2 and Section I3 and the Leakage test in UL 2436.

Exception No. 2: Tests involving exposure to or use of electrolyte other than sulfuric acid shall be modified from those of UL 2436 based upon the electrolyte utilized in the mechanically rechargeable metal-air battery system under test.

I6 Additional Markings for Rechargeable Metal-Air Battery System

I6.1 The battery systems shall be marked with a warning marking “Corrosive fluid inside, only maintained by the manufacturer” or equivalent.

I6.2 The battery systems for indoor use only shall be marked “Indoor Use Only” or equivalent.

I6.3 The battery systems shall be marked with a warning marking “No User Serviceable parts, only mechanically recharged or refueled by authorized service personnel” or equivalent.

I7 Additional Instructions for Rechargeable Metal-Air Battery System

I7.1 If the drop test for cell stack or anode metal plate is waived in accordance with the exception of I4.3.1, the instructions shall include the following statement or equivalent: “Do not use a cell stack/anode metal plate if it has been dropped, as it may result in a hazardous condition.”

I7.2 The battery systems shall be provided with instructions for the proper use including discharging and mechanically charging, storage, recycling and disposal. These instructions shall include temperature and current limits during operation of the battery system as well as instructions regarding the use of any controls or monitoring systems.

I7.3 The battery systems shall be provided with the instructions for the maintenance of the whole system. The instruction shall indicate the corrosive hazards of the electrolyte, the safe handling of the corrosive hazards, and the emergency contact method in case of exposure to the corrosive electrolyte.

18. Functional safety updates.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

There needs to be a clarification regarding the safety analysis section, which is intended to evaluate the functionality and robustness of the battery safety controls. Although this analysis is intended to determine that these controls maintain the battery within its safe parameters, it does not address the impact of a thermal runaway condition within a cell(s) that may be the result of internal defects or other causes. Revisions are being proposed to 7.7.3 to help clarify this.

Sections 7.7 and 7.8 of UL 1973 allow flexibility in determining appropriate functional safety requirements to apply to active protective devices including Battery Management Systems (BMSs). Because multiple options are provided, however, there is potential for inconsistencies in the application of these requirements. Revisions are proposed to these Sections to clearly delineate a minimum set of functional safety requirements. Alternate options are still provided, but are now offered as exceptions to complying with the primary functional safety requirements, and generally are more rigorous and/or require additional proof.

The primary functional safety requirements are based on single-fault tolerance, to be consistent with the other requirements of UL 1973. This is achieved by using redundant protective devices, or by showing via analysis that all potential single-fault conditions either result in the device still being fully operational or failing in a safe manner. Compliance with the component fault analysis requirements in UL 991 (with no allowance for “critical” components), CSA C22.2 No. 0.8 (Class B), UL 60730-1 (Class B), CAN/CSA-E60730-1 (Class B), or EN/IEC 60730-1 (Class B) offer similar levels of assurance that a device is single-fault tolerant.

The exceptions to 7.7.4 potentially allow for a single active protective device that is not single-fault tolerant to be relied upon for critical safety. However, these exceptions require additional rigor to demonstrate the reliability of the device through failure rate calculations and other means not considered in the primary functional safety requirements. A minimum IEC 61508 Safety Integrity Level (SIL) of “2”, a minimum ISO 13849 Performance Level (PL) of “c”, or a minimum of ISO 26262 Automotive Safety Integrity Level (ASIL) of “C” are specified to ensure a level of equivalence with the primary functional safety requirements. There is a possibility to lower these safety ratings, but only if justification is provided in the form of additional safety analysis, e.g. Layer of Protection Analysis.

The proposed requirements also generally specify the safety functions that should be considered for these types of battery applications. Once again, it is possible to rule out one or more safety functions, but only if justification is provided in the form of additional safety analysis.

References to ISO 13849 (all parts) and ISO 26262 were added as these are commonly used international functional safety standards with relevance to applications that use battery packs. Also, reference to the Standard for Remote Software Updates, UL 5500 is being added. For additional information on UL 5500, please see the files named “*Topic 18 – UL 5500 Information.pdf”* and “*Topic 18 – UL 5500 End Product Testing Matrix.pdf”* under “**Supporting Documentation**” on the **Quick View** tab which appears on the right-hand side of this UL 1973 work area in CSDS.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

CSA Group Standards

CSA C22.1, *Canadian Electrical Code, Part I Safety Standard for Electrical Installations*

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

CSA C22.2 No. 0.8, *Safety Functions Incorporating Electronic Technology*

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

CSA C22.2 No. 113, *Fans and Ventilators*

International Standards Organization (ISO) Standards

ISO 13849 (all parts), *Safety of Machinery – Safety-Related Parts of Control Systems*

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

UL Standards

UL 5500, Remote Software Updates

6 Glossary

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

6.12A CRITICAL SAFETY – Any devices or circuits provided to protect against hazardous conditions where the failure of the device results in a hazardous condition as defined in UL 991.

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

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

NOTE: This temperature is measured on the cell casing.

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

NOTE: This temperature is measured on the cell casing.

c) END OF DISCHARGE VOLTAGE – Refer to 6.17.

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

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

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

6.38A PRIMARY SAFETY PROTECTION - The safety device or circuit that is part of the safety control system intended to prevent a hazard, and which operates before any secondary or supplemental protection operates.

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

6.40 PROTECTIVE DEVICES, PASSIVE - Devices provided to prevent hazardous conditions that do not require electrical energy in order to detect the condition and operate. ~~An e~~ Examples of ~~a~~ passive protective devices would be ~~a~~ fuses, thermal snap switches and fluid level switches.

7.7 System safety analysis

7.7.1 A~~n~~ safety analysis consisting of a hazard identification, risk analysis and risk evaluation ~~of potential hazards (including an FMEA)~~ shall be conducted on the device under test. ~~to determine that events that could lead to a~~

~~hazardous condition have been identified and addressed through design or other means.~~ This safety analysis shall determine which parts of the system are safety related through an existing methodology such as outlined 7.7.2. This approach should determine the hazard scenarios and define mitigation mechanisms. This safety analysis shall identify safety circuits or software that address each hazardous condition and consider the performance of each safety circuit or software. The following conditions in (a) - (c) shall be considered unless sufficient justification (e.g. additional safety analysis) is provided by the manufacturer that these conditions are not hazardous. The following conditions in (a) - (c) shall be considered at a minimum, but are not limited to:

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

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

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

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 is validated by compliance with 7.8. The analysis shall consider the reliability of any monitoring components and systems and any communication systems providing information to the controls that can affect safety. ~~the types and levels of protection provided to mitigate the anticipated faults.~~ The analysis shall consider single fault conditions in the protection circuit in addition to single faults elsewhere that could lead to a hazardous condition. ~~/scheme as part of the anticipated faults and/or identify the safety integrity level or similar safety classification.~~

~~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.~~

~~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.~~

7.8 Protective circuit and controls

~~7.8.1 General~~

7.8.1 Active protective devices shall not be relied upon for critical safety and shall comply with one of the following in (a) – (c) and comply with 7.8.2 and 7.8.3 as applicable. 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;

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

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

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

7.8.2 Active protective devices relied upon for safety as noted in 7.8.1, shall be evaluated in accordance with:

a) The Failure-Mode and Effect Analysis (FMEA) requirements in UL 991 (Section 7);

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

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

7.8.3 With reference to 7.8.1, software relied upon for safety shall comply with:

a) Software Class 1 requirements of UL 1998;

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

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

7.8.4 Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in UL 5500.

7.8.5 ~~7.8.1.1~~ Battery systems shall be protected against all hazards identified in the safety system safety analysis of 7.7. ~~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.~~

7.8.6 With reference to 7.8.5, if relied upon for maintaining the cells within their safe operating limits, the battery management system (BMS) shall maintain cells within the specified cell voltage and current limits to protect against overcharge and over-discharge. The BMS shall also maintain cells within the specified temperature limits providing protection from overheating and under temperature operation. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.

7.8.7 ~~7.8.1.2~~ With reference to 7.8.5 and 7.8.6, if ~~the specified~~ safe operating limits are exceeded, ~~the~~ a 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~~ When a hazardous scenario occurs, as determined in 7.7.1, the system shall continue to provide the safety function or go to a safe state (SS) or risk addressed (RA) state. If the safety function has been damaged, the system shall remain in the safe state or risk addressed state until the safety function has been restored and the system has been deemed safe to operate. ~~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.

7.8.8 7.8.1.3 Solid state circuits and software controls, relied upon as the primary safety protection, shall be evaluated and tested to verify electromagnetic immunity in accordance with Section 24A.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.

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.

7.8.9 7.8.1.4 Battery systems with hazardous voltage circuits, including outputs of 50 60 V 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. The disconnect device shall consist of either a manually operated switch or circuit breaker.

Exception No. 1: A battery system having either a plug or receptacle or connector for connection to the output circuit may be provided without an additional disconnect means. The plug, receptacle and connectors used for this purpose shall be investigated in accordance with UL 1682 and rated for current interruption suitable for the circuit. The required spacing to the hazardous voltage circuits shall be maintained when the plug or receptacle or connector is disconnected.

Exception No. 2: A flow battery that can be turned off such that no circuits remain at hazardous voltage are not required to have a manual disconnect device.

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.

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

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. 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.

19. Inclusion of EMC testing for electronic safety controls.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

The electromagnetic immunity requirements in the referenced functional safety standards vary significantly with respect to test procedures and test levels. In addition, standards such as IEC 61508, ISO 13849, and ISO 26262 do not have any specific electromagnetic immunity requirements and instead only offer guidance on which electromagnetic immunity tests should be conducted and the tests levels that should be used. To ensure consistency in the application of requirements, a new Section 24A is proposed in UL 1973 to specify which electromagnetic immunity tests shall be conducted, and which test procedures and levels shall be used. The test procedures and levels chosen are a combination of levels specified in UL 60730-1 Section H.26 and IEC 61000-6-2 (EM immunity standard for industrial environments). Electromagnetic immunity test procedures and levels specified in the other standards may still be used, but only if these test procedures and levels are equivalent or more severe than the test procedures and levels specified here.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

International Electrotechnical Commission (IEC) Standards

IEC 61000-4-2, *Electromagnetic Compatibility (EMC) - Part 4-2: Testing and Measurement Techniques - Electrostatic Discharge Immunity Test*

IEC 61000-4-3, *Electromagnetic Compatibility (EMC) - Part 4-3: Testing and Measurement Techniques - Radiated, Radio-Frequency, Electromagnetic Field Immunity Test*

IEC 61000-4-4, *Electromagnetic Compatibility (EMC) - Part 4-4: Testing and Measurement Techniques - Electrical Fast Transient/Burst Immunity Test*

IEC 61000-4-5, *Electromagnetic Compatibility (EMC) - Part 4-5: Testing and Measurement Techniques - Surge Immunity Test*

IEC 61000-4-6, *Electromagnetic Compatibility (EMC) - Part 4-6: Testing and Measurement Techniques - Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields*

IEC 61000-4-8, *Electromagnetic Compatibility (EMC) - Part 4-8: Testing and Measurement Techniques - Power Frequency Magnetic Field Immunity Test*

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Push-Back Relief	24.5	[b]
Electromagnetic Immunity Tests		
Electrostatic Discharge	24A.2	[b]
Radio-Frequency Electromagnetic Field	24A.3	[b]
Fast Transient/Burst Immunity	24A.4	[b]
Surge Immunity	24A.5	[b]
Radio-Frequency Common Mode	24A.6	[b]
Power Frequency Magnetic Field	24A.7	[b]
Operational Verification	24A.8	[b, h]
Mechanical Tests		
Vibration (LER Motive Applications)	25	1
[h] Operational Verification conducted on all samples used in 24A.2 through 24A.7.		

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Failure of Cooling/Thermal Stability System	E, F, C, V, S, L, R, P
Electrostatic Discharge	E, F, C, V, S, L, R, P
Radio-Frequency Electromagnetic Field	E, F, C, V, S, L, R, P
Fast Transient/Burst Immunity	E, F, C, V, S, L, R, P
Surge Immunity	E, F, C, V, S, L, R, P
Radio-Frequency Common Mode	E, F, C, V, S, L, R, P
Power Frequency Magnetic Field	E, F, C, V, S, L, R, P
Operational Verification	E, F, C, V, S, L, R, P
Vibration (LER Motive)	E, F, C, V, S, L, R, P

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) Electrostatic Discharge;

g) Radio-Frequency Electromagnetic Field;

h) Fast Transient/Burst Immunity;

i) Surge Immunity;

j) Radio-Frequency Common Mode;

k) Power Frequency Magnetic Field;

l) Operational Verification;

~~f~~m) Vibration;

~~g~~n) Shock;

~~h~~o) Impact or Drop Impact;

~~i~~p) Static Force;

~~j~~q) Thermal Cycling;

~~k~~r) Salt Fog; and

~~l~~s) Resistance to Moisture.

NOTE: If the tests of items (f) through (l) may be done on the battery management system only and not the whole battery system.

24A Electromagnetic Immunity Tests

24A.1 General

24A.1.1 Active protective devices (e.g. battery management systems, solid state circuits, software controls, etc.) relied upon as the primary safety protection in 7.7 - 7.8 shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in 24A.2 - 24A.7. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below.

24A.1.2 Each test shall begin with an operational DUT. The DUT may consist of only the battery management system, if that is the only part of the battery system that will be impacted.

24A.1.3 During specific tests as indicated in 24A.2 - 24A.7, the DUT shall be subjected to a charge/discharge cycle in accordance with the manufacturer's specification. No non-compliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle. It is acceptable if the charge/discharge cycle is not completed at the conclusion of the test.

24A.1.4 After each test in 24A.2 - 24A.7, the DUT shall be inspected to verify that it is still operational and in compliance with Table 12.1. This may require Operational Verification (24A.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely in accordance with Table 12.1. A DUT that is no longer operational shall not be used on any remaining test.

24A.1.5 In addition, after all tests in this section have been completed, all samples used during the tests specified in 24A.2 - 24A.7 shall comply with the Operational Verification in 24A.8.

24A.2 Electrostatic discharge

24A.2.1 The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2.

24A.2.2 The following test levels shall be used:

a) ±6 kV contact discharge; and

b) ±8 kV air discharge.

24A.2.3 After the test, the DUT shall comply with 24A.1.4.

24A.3 Radio-frequency electromagnetic field

24A.3.1 The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3.

24A.3.2 The following test levels shall be used:

a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80% AM); and

b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80% AM).

24A.3.3 During the test, the DUT shall comply with 24A.1.3.

24A.3.4 After the test, the DUT shall comply with 24A.1.4.

24A.4 Fast transient/burst immunity

24A.4.1 The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4.

24A.4.2 The following test levels in (a) - (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).

a) On signal/control ports intended to be connected to cables longer than 3 m (118 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used;

b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and

c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).

24A.4.3 After the test, the DUT shall comply with 24A.1.4.

24A.5 Surge immunity

24A.5.1 The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5.

24A.5.2 The following test levels in (a) - (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).

a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (98.4 ft), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground;

b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and

c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.

24A.5.3 After the test, the DUT shall comply with 24A.1.4.

24A.6 Radio-frequency common mode

24A.6.1 The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6.

24A.6.2 The following test levels in (a) - (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).

a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM);

b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM); and

c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM).

24A.6.3 During the test, the DUT shall comply with 24A.1.3.

24A.6.4 After the test, the DUT shall comply with 24A.1.4.

24A.7 Power-frequency magnetic field

24A.7.1 The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8.

24A.7.2 The test level of 10 A/m shall be used.

24A.7.3 During the test, the DUT shall comply with 24A.1.3.

24A.7.4 After the test, the DUT shall comply with 24A.1.4.

24A.8 Operational verification

24A.8.1 After the tests in 24A.2 - 24A.7 have been completed, all samples used during these tests shall comply with the following.

24A.8.2 The manufacturer shall declare the anticipated performance of all safety functions performed by active protective devices.

24A.8.3 The manufacturer shall provide test procedures to verify that each of the safety functions performed by active protective devices is working correctly. This may include, for example, execution of a full charge/discharge cycle, or verification of correct safety function performance by simulation.

24A.8.4 The test procedures specified in 24A.8.3 shall be performed with each DUT in the following conditions:

a) Fully-charged; and

b) Fully-discharged.

24A.8.5 During the test procedures specified in 24A.8.3 - 24A.8.4, each DUT shall exhibit one of the following behaviors:

a) No loss of safety functions; or

b) Transition to an appropriate state to ensure safe operation of the DUT. This could include a DUT that has lost its ability to charge or discharge as long as safety is maintained.

24A.8.6 If redundant methods of protection are provided for a safety function to comply with 7.7.4, each method of protection shall be evaluated to determine if it functions as intended.

20. Clarification of Dielectric Voltage Withstand Test locations on sample.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

As currently written, the dielectric voltage withstand method is not clear regarding all of the locations on the sample where the potential needs to be applied. It should not only be between live parts and accessible dead metal, but also between live parts of hazardous voltage and low voltage circuits. This proposal clarifies the text method for the dielectric voltage withstand test. Clause 20.6 is revised to indicate that the testing is between the positive or negative terminal and accessible parts or low voltage circuits.

PROPOSAL

20 Dielectric Voltage Withstand Test

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 and low voltage circuits separated from hazardous voltage circuits by reinforced or double insulation.

20.6 The test voltages shall be applied for a minimum of 1 min between all the hazardous circuits of the battery and accessible parts or circuits. ~~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.

21. SELV Limits for Canada.

RATIONALE

Proposal submitted by: Steve Edley, Zinc8 Energy Solutions

The dc voltage limits for hazardous circuits in Canada is 60 Vdc and is consistent with UL limits. The Canadian Electrical Code C22.1 Sec 61-222 defines the limit for class 2 outputs as 60 V continuous for dc. CSA 60950-1 Section 2.2.2 has a 60 Vdc limit for SELV circuits. Since this limit is consistent with 60950-1 and 62368-1, the paragraph after 6.23 is redundant and has therefore been deleted in this proposal. In ANSI/CAN/UL 9540, 6.16 defines hazardous voltage as 42.4 Vpeak or 60 Vdc.

Please also note that UL 60950-1/CSA C22.2 No. 60950-1 has been replaced with UL 62368-1/CSA C22.2 No. 62368-1 so revisions are being made accordingly.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

~~CAN/CSA C22.2 No. 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirement*~~

~~UL 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirements*~~
UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

6 Glossary

6.23 HAZARDOUS VOLTAGE - ~~In the United States,~~ A sinusoidal voltage exceeding 42.4 Vpeak or 60 Vdc is considered hazardous.

~~In Canada (per C22.1 and CAN/CSA-C22.2 No. 0), voltage exceeding 20 Vrms/42.4 Vac peak or 42.4 Vdc is considered hazardous. Batteries and battery systems intended for building into equipment evaluated to Canadian standards, such as CAN/CSA-C22.2 No. 60950-1 or CAN/CSA-C22.2 No. 62368-1, will need to meet the hazardous voltage limits dictated by that standard.~~

20 Dielectric Voltage Withstand Test

20.2 Circuits exceeding 42.4 Vpeak or 60 Vdc shall be subjected to an electric strength test in accordance with UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9. ~~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.~~

Exception: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.

22. Revisions to Section 7.1 to address all non-metallic materials.

RATIONALE

Proposal submitted by: Steve Edley, Zinc8 Energy Solutions

Sec 7.1 addresses flammability requirements for enclosures and materials used to support live parts. It also addresses other requirements for enclosures and an RTI with impact for insulation materials.

The standard does not address flammability for other components in a system that could be present with technologies such as flow batteries. Examples of components that are not addressed by the standard are piping, tanks and circuit board enclosures. The requirements for this section are too narrow and specific to address new battery technologies. The proposed requirements provide exceptions for components that would contribute negligible fuel to a fire such as decorative parts, small components while including requirements on piping, containers and electrical enclosures.

Please also note that UL 60950-1/CSA C22.2 No. 60950-1 has been replaced with UL 62368-1/CSA C22.2 No. 62368-1 so revisions are being made accordingly.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

~~CAN/CSA C22.2 No. 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirement*~~

~~UL 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirements*~~
UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

6 Glossary

6.16 ENCLOSURE - The protective outer cover of the pack or battery system that provides mechanical protection to the pack/system's contents.

NOTE: A flow battery stack is not considered an enclosure if protected by the outer enclosure of the system.

7.1 Non-metallic materials

7.1.1 Polymeric materials employed for enclosures shall comply with the requirements as outlined in the Enclosure Requirements table, Table 4.1~~6.1~~, Path III, of UL 746C except as modified by this standard.

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.

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.

7.1.3 The polymeric materials employed as enclosures and insulation shall be suitable for the anticipated temperatures encountered in the intended application. 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.

7.1.5 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.

*Exception: ~~Insulation~~ Polymeric materials used as direct support for live parts that meet the ~~criteria outlined in~~ requirements for "Safeguards Against Fire Under Normal Operating Conditions and Abnormal Operating Conditions," Clause 6.3, of UL 62368-1/*CSA C22.2 No. 62368-1, *or the requirements for "Safeguards Against Fire Under Single Fault Conditions," Clause 6.4, of UL 62368-1/*CSA C22.2 No. 62368-1 *~~UL 60950-1/CAN/CSA-C22.2 No. 60950-1, Clause 4.7.3.3 "Materials for components and other parts outside of fire enclosures" or Clause 4.7.3.4 "Materials for components and parts inside of fire enclosures"~~ are considered acceptable.*

7.1.5A Polymeric materials other than enclosures and materials for use for electrical insulation or other applications shall comply with requirements for "Safeguards Against Fire Under Normal Operating Conditions and Abnormal Operating Conditions," Clause 6.3, of UL 62368-1/CSA C22.2 No. 62368-1, or the requirements for "Safeguards Against Fire Under Single Fault Conditions," Clause 6.4, of UL 62368-1/CSA C22.2 No. 62368-1.

23. Smart Grid Applications.

RATIONALE

Proposal submitted by: Steve Edley, Zinc8 Energy Solutions

UL 2744, the Standard for Smart Grid Environments, has been withdrawn with no replacement. Paragraph 7.7.6 and Section 7.8.2 refer to UL 2744 and should be deleted.

PROPOSAL

7.7 System safety analysis

~~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.~~

~~7.8.2 Smart Grid Applications~~

~~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.~~

24. Clarifications for Appendix C.

RATIONALE

Proposal submitted by: Steve Edley, Zinc8 Energy Solutions

Appendix C has several tests that do not clearly state the test conditions for referenced standards, which in some cases reference other standards. This can cause confusion during the product evaluation regarding which standards apply to some parts of the test procedure. The clarifications below are an attempt to remove ambiguity.

Since there are multiple possible interpretations of which conditioning requirements to apply prior tensile testing, different test methods could be applied for the same test.

PROPOSAL

C2 Materials Containing Electrolyte – Resistance to Deterioration from Fluids

C2.2 Three as-received samples of materials conditioned as described in C2.3 shall be tested in accordance with ASTM D638. Prior to tensile strength testing, the samples shall be conditioned at a standard lab temperature of 23°C (73.4°F), 50% humidity for 40 h. The tensile strength of the materials under test shall be recorded.

C2.3 ~~The material~~ Nine samples shall be immersed in the test liquid representative of the electrolyte contained. ~~and~~ Three samples shall be conditioned for 7 days, three for 30 days and three for 60 days at a temperature of 50°C (122°F) in a full-draft air-circulating explosion-proof oven. Following the exposure tests the samples shall be removed from the oven and from the test liquid then conditioned at a standard lab temperature of 23°C (73.4°F), 50% humidity for 40 h prior to tensile testing. Samples are evaluated from each of the exposure times ~~with~~ for ~~mechanical properties determined~~ tensile strength and compared with as-received ~~values~~ samples. The 60-day exposure test may be waived depending upon the results of samples subjected to the 30-day exposure.

C2.4 Gaskets and seals ~~in contact with~~ which contain the electrolyte shall be subjected to the volume change and extraction, tensile strength and elongation after 70 h of immersion in the electrolyte at a temperature of 50°C (122°F) in accordance with UL 157. Prior to mechanical testing, the samples shall be cooled by use of a container of the electrolyte at 23°C (73.4°F) for 30 min. The tensile strength and elongation shall be a minimum of 60% of the as received values and the volume change of minus 1 to ~~plus~~ +25% of the as received values and extraction (change in weight) no greater than 10%.

C3 Materials Containing Electrolyte – Temperature Exposure

C3.2 Three as-received samples of ~~the polymeric part~~ materials conditioned as described in C3.3 ~~and three conditioned samples of the part~~ shall be tested in accordance with ASTM D638. Prior to tensile strength testing, the samples shall be conditioned at a standard lab temperature of 23°C (73.4°F), 50% humidity for 40 h. The tensile strength of the materials under test shall be recorded.

C3.3 ~~Three~~ Six samples of ~~each part~~ materials shall be conditioned in a full-draft air-circulating oven, three for 45 days and three for 90 days at a temperature of 70°C (158°F) ~~in a full-draft air-circulating oven~~. Following the oven conditioning the samples shall be removed from the oven and then conditioned at a standard lab temperature of 23°C (73.4°F), 50% humidity for 40 h prior to tensile testing. The samples are evaluated from each of the conditioning times for tensile strength and compared with as-received samples.

Exception No. 1: As an alternative test method, the part shall be conditioned for 30 and 60 days at a temperature of 80°C (176°F) in a full-draft air-circulating oven.

Exception No. 2: As an alternative test method, the parts shall be conditioned for 15 and 30 days at a temperature of 90°C (194°F) in a full-draft air-circulating oven.

C3.4 Gaskets and ~~S~~seals which contain the electrolyte shall be subjected to the air oven aging test of UL 157. The test temperature shall be in accordance with Table 4.3 of UL 157 and based upon the anticipated exposure temperatures in the end use application. Following oven conditioning, the samples shall be conditioned at a standard lab temperature of 23°C (73.4°F), 50% humidity for 16 h prior to tensile and elongation testing. The tensile strength and elongation after oven aging shall be a minimum of 60% of the as received values.

C3.5 Gaskets and seals used in electrolyte containment systems shall be subjected to the lower temperature test of UL 157 for minus 40°C (minus 40°F), or the lowest ambient temperature specified by the manufacturer, but not ~~less~~ higher than 0°C (32°F), with no visible evidence of cracking in accordance with the test criteria of UL 157.

25. Addition of compliance criteria "P - Loss of protection controls" for Drop Impact Test.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Adding compliance criteria of "P- loss of protection controls" to reflect present practice of the Drop Impact Test. The safe operation of the DUT should be checked if it can still be charged and discharged. It may be assumed that it is still functional.

PROPOSAL

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Impact	E, F, C, V, S, L, R, P
Drop Impact	E, F, C, S, L, R, P
Thermal Cycling (LER Motive)	E, F, C, V, S, L, R, P

30 Drop Impact Test

30.8 As a result of the drop impact test, the following in (a) – (g)~~(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); and

g) P - Loss of protection controls.

26. Inclusion of sodium ion technology batteries.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

This proposal is to provide an evaluation approach for sodium ion cells such as Prussian blue. Their construction has many similarities to lithium ion cells, so that program in Appendix E is applied.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE 1625, *Rechargeable Batteries for Multi-Cell Mobile Computing Devices*

6.45A SODIUM ION CELLS – Cells that are similar in construction to lithium ion cells except they utilize sodium as the ion of transport with a positive electrode consisting of a sodium compound, and carbon or similar type anode with an aqueous or non-aqueous electrolyte and with a sodium compound salt dissolved in the electrolyte. An example of a sodium ion cell technology is a Prussian Blue cell.

7.11.7 Sodium ion cells (e.g. Prussian Blue cells) shall comply with Appendix E, and be marked as required in 41.14 and 41.15. Cells shall be provided with specifications as outlined in 42.7.

42.7 Cells shall be provided with a complete set of instructions that include operating region specifications for charging and discharging including current temperature range and voltages, installation instructions, storage of batteries and disposal instructions. Guidance on cell specification information that should be provided on cells can be found in the Cell Specification Sheet, Annex E of IEEE 1625.

27. Expanding the wall fixture test to include other support structures.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

This proposal is just meant to address other support structures besides wall mount structures and handles. Batteries are often supported by rack systems for example. They shall either be tested unless the rack system has been already evaluated to UL 2416, Standard for Audio/Video, Information and Communication Technology Equipment Cabinet, Enclosure and Rack Systems.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

UL Standards

UL 2416, Audio/Video, Information and Communication Technology Equipment Cabinet, Enclosure and Rack Systems

31 Wall Mount Fixture/Support Structure/Handle Test

31.1 A wall mounting apparatus of a wall mounted battery system, a battery support structure such as a stationary battery system rack, the support structure for a flow batteries stack(s), 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.

Exception: This test can be waived for a battery rack complying with UL 2416 and rated for the intended weight of the batteries to be supported.

31.2 The wall mounting apparatus or other support structure 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 or support structure 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.

31.3 As a result of the applied force, there shall be no damage to the mounting apparatus or support structure and the ~~its~~ securement means when testing the wall mounting fixture or supporting structure. As a result of the applied force, there shall be no damage to handles or the handle mounting/securement means of the DUT.

28. Evaluation proposal for galvanic corrosion determination.

RATIONALE

Proposal submitted by: Laurie Florence, UL LLC

Currently there is a requirement to prevent electric contacts of dissimilar metals that can result in galvanic corrosion as outlined in Appendix D. This allows for an evaluation of a connection design that falls below the line in Appendix D that employs some protection mechanisms, etc.

PROPOSAL

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

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

ISO 9227, *Corrosion Tests in Artificial Atmospheres - Salt Spray Tests*

UL 546, *Conductor Termination Compounds*

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 unless there is an evaluation that demonstrates that the potential for corrosion is negligible for the particular connection materials and design. See Appendix D.

APPENDIX D (Normative)
Metal compatibility ~~table~~

D1 General

D1.1 For combinations that fall above the line in Table D.1, an evaluation on the parts can be conducted to determine suitability. Protection methods such as coatings can be used, but will need to be evaluated.

D1.2 The evaluation method shall consist of a comparison of the part to evaluate with a similar part using construction that is below the line of Table D.1, after corrosion conditioning such as a salt fog conditioning in accordance with ASTM B117, ISO 9227 or similar method. Measurements of the properties of the connection parts (design under consideration as well as comparison design) under test shall be made before and after conditioning with a comparison of the results. Properties to measure will depend upon the part being evaluated, but could include resistance, temperatures on the part during operation, or bond/mechanical strength as applicable to the type of connection.

D1.3 The deterioration of the devices under evaluation shall not result in unacceptable properties (i.e. reduced performance that would result in malfunction of the connection) nor shall the deterioration be greater than that of the comparison design.

D1.4 As another approach, a coating with known properties, such as one evaluated to UL 546, along with sealing the area to prevent moisture exposure can be used to establish acceptable protection against galvanic corrosion without additional evaluation.

29. Revision of grounding requirement in 7.6.3.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

Proposing to delete the first sentence in 7.6.3 as it seems to apply to a dc wiring system grounding and not related to battery equipment grounding.

PROPOSAL

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.

30. aR Fuse Consideration and Module/component voltage consideration.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

An aR fuse used for short circuit protection is not acceptable without supplementary protection such as a BMS to protect for lower levels of overload current applied to the battery. This clause addresses this concern.

Modules evaluated to UL 1973 may be intended for series connection within a battery systems where they will be exposed to the higher voltages of the systems. Components used in the module and the modules spacings and insulations should be evaluated for this intended higher voltages.

PROPOSAL

7.8 Protective circuit and controls

7.8.9 Fuses provided for battery overcurrent protection including short circuit protection shall be evaluated for both short circuit and overload conditions. Fuses that are evaluated for short circuit conditions only (type aR fuses), shall be provided with supplementary protection (e.g. the BMS) to ensure protection under overcurrent conditions in ranges below those covered by these types of fuses.

7.8.10 Protective components of battery modules intended for series connection in battery systems shall be rated for the maximum voltage of the intended battery system.

31. Addition of criteria for transformers.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

These proposals are to address transformers and include a test for transformers in low voltage dc circuits. The standard has not addressed transformers specifically, although they may be located on control boards for these systems.

PROPOSAL

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

UL 1310, *Class 2 Power Units*
UL 1562, *Transformers, Distribution, Dry-Type - Over 600 Volts*

CONSTRUCTION

7.6 Insulation levels and protective grounding and bonding

7.6A Transformers

7.6A.1 Transformers shall be evaluated in accordance with UL 1562, UL 1310 or an equivalent standard for overload conditions, and shall have suitable insulation for the circuits they are connected to.

7.6A.2 Transformers in low voltage dc circuits can alternatively be evaluated in accordance with 24.6.

7.6A.3 Transformers shall be provided with overcurrent protection on the primary side of the transformer and sized in accordance with Article 450 of NFPA 70.

PERFORMANCE

8 General

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Electrical Tests		
Strain Relief	24.4	[b]
Push-Back Relief	24.5	[b]
Low Voltage DC Transformer Evaluation	24.6	[b]
[a] See Exception in 8.2 for re-use of samples for tests.		
[b] Need only evaluate parts/area under test and not complete battery system.		

24 Tests on Electrical Components

24.6 Low voltage DC transformer evaluation

24.6.1 The purpose of this test is to determine that transformers located in low voltage dc circuits do not present a fire hazard under overload conditions. Transformers complying with UL 1310 or equivalent standard and evaluated under overload conditions are considered to comply with these requirements without further testing.

24.6.2 If the tests in this section are conducted under simulated conditions on the bench, these conditions shall include any protection device that would protect the transformer in the complete equipment. Tests shall be conducted under ambient laboratory conditions. A sample of the transformer 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/m^2 (1.18 oz/yd^2).

24.6.3 If a transformer has more than one secondary winding or a tapped secondary winding, separate tests shall be conducted for each winding, or each section of a tapped winding, with the other windings loaded or unloaded as may occur in service unless it can be determined that one condition will produce the most unfavorable results.

24.6.4 A resistive load that will draw three times the normal input current or maximum obtainable output current, whichever is less, shall be connected directly to the transformer secondary winding with the transformer connected to the voltage of the circuit the transformer will be installed in. The transformer shall be operated continuously:

a) Until ultimate conditions are observed, including opening of a thermal cutoff or a similar device;

b) For 7 h if temperatures stabilize or cycling of an automatically reset protector occurs; or

c) For 50 cycles of resetting a manually reset protector.

24.6.5 As a result of the overload test, there shall be no emission of molten metal or fire as evidenced by burning or charring of the cheesecloth indicator or tissue paper.

32. Overload under discharge.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

This test is proposed to replace the soft short that was based upon trying to find some percentage of the short circuit trip point. This approach was challenging to find the correct current to have the battery overloaded for some length of time. As a replacement, that is easier to establish test limits, we are proposing an overload under discharge with a current based upon a percentage of current above the maximum specified discharge current.

PROPOSAL

PERFORMANCE

8 General

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Electrical Tests		
Short Circuit[c]	16	1
Overload Under Discharge[c]	16A	1
Overdischarge Protection[c]	17	1
[a] See Exception in 8.2 for re-use of samples for tests.		
[b] Need only evaluate parts/area under test and not complete battery system.		
[c] Testing may be conducted on subassemblies if determined representative of the complete battery system.		

12 Test Results

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Short Circuit	E, F, C, V, S, L, R, P
Overload Under Discharge	E, F, C, V, S, L, R, P
Overdischarge Protection	E, F, C, V, S, L, R, P
Non-compliant Results Key:	
E - Explosion	
F - Fire	
C - Combustible vapor concentrations	
V - Toxic vapor release[c] (in buildings or LER passenger compartments)	
S - Electric shock hazard (dielectric breakdown)	
L - Leakage (external to enclosure of DUT)	
R - Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)	
P - Loss of protection controls[d]	

ELECTRICAL TESTS

16 Short Circuit Test

~~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.~~

16A Overload Under Discharge

16A.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 overload discharge condition. DUTs with only series connections (i.e. no parallel connections of cells or modules) may be tested at the cell or module level if determined to be equivalent to testing at the system level.

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

16A.2 Condition 1 is the overload above the specified maximum discharge current of the battery, but below the BMS overcurrent protection (secondary protection) in accordance with 16A.3 – 16A.5.

16A.3 With reference to 16A.2, the positive and negative terminals of the DUT is to be connected to the external discharging equipment. The fully charged DUT shall then be discharged at a current equal to 90% of the rated overcurrent protection value of the BMS (secondary protection).

16A.4 With reference to 16A.2, the test shall be continued until:

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

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

c) A fire or explosion has occurred.

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

16A.5 With reference to 16A.2, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.

Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.8) need not be subjected to single fault conditions.

16A.6 Condition 2 is the overload above the BMS overcurrent protection (secondary protection), but below the primary overcurrent protection in accordance with 16A.7 – 16A.9.

16A7 With reference to 16A.6, the positive and negative terminals of the DUT shall be connected to the external discharging equipment. The DUT shall then be discharged at a current equal to 135% of the main fuse rating.

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

Exception No. 2: If the secondary overcurrent protection has be investigated for an overload current higher than 150% of the primary overcurrent protector rating, then the condition 2 test can be waived.

16A.8 With reference to 16A.6, the test shall be continued until:

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

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

c) A fire or explosion has occurred.

16A.9 With reference to 16A.6, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.

Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.8) need not be subjected to single fault conditions.

16A.10 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.

16A.11 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 shall then be conducted.

16A.12 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.

16A.13 As a result of the overload 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.

33. Addition of High Rate Charge Test.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

Abnormal charging of batteries includes overcharge conditions or overcurrent charging conditions. This high rate charge test is proposed to cover the hazard of charging at too high of a rate due to mismatched or missing overcurrent charging protection. This is similar to a test in IEC 62619, Secondary Cells And Batteries Containing Alkaline Or Other Non-Acid Electrolytes - Safety Requirements For Secondary Lithium Cells And Batteries, For Use In Industrial Applications.

PROPOSAL

PERFORMANCE

8 General

Table 8.1
Tests and sample requirements for battery systems and packs
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 8.1 IS SHOWN FOR EASE OF REVIEW)

Test	Section	Number of samples[a]
Electrical Tests		
Overcharge[c]	15	1
High Rate Charge[c]	15A	1
Short Circuit[c]	16	1
Overdischarge Protection[c]	17	1
[a] See Exception in 8.2 for re-use of samples for tests.		
[b] Need only evaluate parts/area under test and not complete battery system.		
[c] Testing may be conducted on subassemblies if determined representative of the complete battery system.		

12 Test Results

Table 12.1
Non-compliant test results
(NOTE FROM STP PROJECT MANAGER: ONLY PART OF TABLE 12.1 IS SHOWN FOR EASE OF REVIEW)

Tests[a]	Non-compliant results
Overcharge	E, F, C, V, S, L, R, P
High Rate Charge	E, F, C, V, S, L, R, P
Short Circuit	E, F, C, V, S, L, R, P
Overdischarge Protection	E, F, C, V, S, L, R, P
Non-compliant Results Key:	
E - Explosion	
F - Fire	
C - Combustible vapor concentrations	
V - Toxic vapor release[c] (in buildings or LER passenger compartments)	
S - Electric shock hazard (dielectric breakdown)	
L - Leakage (external to enclosure of DUT)	
R - Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)	
P - Loss of protection controls[d]	

ELECTRICAL TESTS

15A High Rate Charge

15A.1 The purpose of this test is to evaluate a battery system's ability to protect against a high rate charge condition at currents over the battery maximum charging current specification.

15A.2 A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to a high rate charge. There shall be a single fault condition on overcurrent charge protection devices or controls unless they have been evaluated for reliability (i.e. evaluated for functional safety in accordance with 7.8). During the test, the current and voltage of the cells shall be measured. The test supply equipment used for charging the DUT shall be sufficient to provide a current that is 20% greater than the maximum specified charging rate for the batteries.

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

15A.3 The high rate charging of the DUT 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:

a) The sample charging is terminated by the protective circuitry whether it is due to current, voltage or temperature controls. The DUT is monitored per 8.5 and 10.2; or

b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.

15A.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. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.

15A.5 If the DUT is operational after the high rate charge test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.

15A.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.

15A.7 As a result of the high rate charge test, the battery protection circuit (e.g. BMS) shall detect the overcharging current and shall prevent the battery from being charged over the maximum battery charging current. 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.

34. Replacement of UL 60950-1 with UL 62368-1.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

UL 60950-1/CSA C22.2 No. 60950-1 has been replaced with UL 62368-1/CSA C22.2 No. 62368-1 so revisions are being made accordingly throughout the Standard.

PROPOSALS

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

CAN/CSA C22.2 No. 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirement*

UL 60950-1, *Information Technology Equipment - Safety - Part 1: General Requirements*
UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

20 Dielectric Voltage Withstand Test

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 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.8. 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.

24.3 Leakage current

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 Protective Touch Voltage, Touch Current and Protective Conductor Current test Section of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.7. in UL 60950-1/CAN/CSA-C22.2 No. 60950-1.

MANUFACTURING AND PRODUCTION LINE TESTS

40 General

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.

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 the Electric Strength Test of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9. 5.2.2 in UL 60950-1/CAN/CSA-C22.2 No. 60950-1.

35. Revision of component standards in Appendix A.

RATIONALE

Proposal Submitted By: Laurie Florence, UL LLC

Updating the component standard list in Appendix A that is used for evaluation of components and features of products covered by this Standard, and removing the Standard references that appear in the body of UL 1973 which are already referenced in the Normative Reference, Section 5.

PROPOSAL

APPENDIX A (Normative)

A1 Standards for Components

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

CSA Group Standards

~~C22.2 No. 0.15, *Adhesive Labels*~~
~~CAN/CSA-C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*~~
~~C22.2 No. 0.2, *Insulation Coordination*~~
C22.2 No. 14, *Industrial Control Equipment*
C22.2 No. 49, *Flexible Cords and Cables*
C22.2 No. 65, *Wire Connectors*
C22.2 No. 75, *Wires and Cables, Thermoplastic-Insulated*
~~CAN/CSA-C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*~~
C22.2 No. 127, *Equipment and Lead Wires*
C22.2 No. 153, *Electrical Quick-Connect Terminals*
C22.2 No. 158, *Terminal Blocks*
C22.2 No. 182.1, *Plugs, Receptacles, and Cable Connectors, of the Pin and Sleeve Type*
C22.2 No. 182.3, *Special Use Attachment Plugs, Receptacles and Connectors*
C22.2 No. 235, *Supplementary Protectors*
C22.2 No. 248.1, *Fuses, Low Voltage - Part 1: General Requirements*
CAN/CSA-C22.2 No. 60947-4-1, *Low-Voltage Switchgear and Controlgear - Part 4-1: ~~4-1A:~~ Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters*
~~CAN/CSA-C22.2 No. 60950-1, *Information Technology Equipment Safety - Part 1: General Requirements*~~
CAN/CSA-E61131-2, *Programmable Controllers - Part 2: Equipment Requirements and Tests*

UL Standards

UL 44, *Thermoset-Insulated Wires and Cables*
~~UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*~~
UL 62, *Flexible Cords and Cables*
UL 66, *Fixture Wire*
UL 83, *Wires and Cables, Thermoplastic-Insulated*
~~UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*~~
UL 98B, *Enclosed and Dead-Front Switches for Use in Photovoltaic Systems*
~~UL 157, *Gasket and Seals*~~
UL 248-1 (and all applicable parts), *Low-Voltage Fuses - Part 1: General Requirements*
UL 248-13, *Low-Voltage Fuses - Part 13: Semiconductor Fuses*
UL 252 Compressed Gas Regulators
UL 310, *Terminals, Electrical Quick-Connect*
UL 429, *Electrically Operated Valves*
UL 444, *Communications Cables*
UL 467, *Grounding and Bonding Equipment*
UL 486A-486B, *Wire Connectors*
UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures*
UL 489F, *Molded-Case Circuit Breakers and Molded-Case Switches for Use with Battery Power Supplies*
UL 489G, *Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, 650 - 1000 Volts AC and 650 - 1500 Volts DC*
UL 498, *Attachment Plugs and Receptacles*
UL 499, *Electric Heating Appliances*
~~UL 507, *Electric Fans*~~
UL 508, *Industrial Control Equipment*
UL 508A, *Industrial Control Panels*
UL 514A, *Metallic Outlet Boxes*
~~UL 746A, *Polymeric Materials - Short Term Property Evaluations*~~
~~UL 746B, *Polymeric Materials - Long term Property Evaluations*~~

UL 746C, *Polymeric Materials - Use In Electrical Equipment Evaluations*
UL 758, *Appliance Wiring Material*
UL 778, *Motor-Operated Water Pumps*
UL 796, *Printed-Wiring Boards*
UL 796F, *Flexible Materials Interconnect Constructions*
UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*
UL 857, *Busways*
UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*
UL 969, *Marking and Labeling Systems*
UL 1004-1, *Rotating Electrical Machines - General Requirements*
UL 1012, *Power Units Other Than Class 2*
UL 1053, *Ground-Fault Sensing and Relaying Equipment*
UL 1059, *Terminal Blocks*
UL 1063, *Wires and Cables, Machine-Tool*
UL 1077, *Supplementary Protectors for Use in Electrical Equipment*
UL 1434, *Thermistor-Type Devices*
UL 1441 *Coated Electrical Sleeving*
UL 1577, *Optical Isolators*
UL 1581, *Reference Standard for Electrical Wires, Cables, and Flexible Cords*
UL 1598, *Luminaires*
UL 1642, *Lithium Batteries*
UL 1653, *Electrical Nonmetallic Tubing*
UL 1682, *Plugs, Receptacles, and Cable Connectors, of the Pin and Sleeve Type*
UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*
UL 1861, *Power-Operated Chemical Pumps*
UL 1977, *Connectors for Use in Data Signal and Power*
UL 1998, *Software in Programmable Components*
UL 2054, *Household and Commercial Batteries*
UL 2238, *Cable Assemblies and Fittings for Industrial Control and Signal Distribution*
UL 2419, *Electrically Conductive Corrosion Resistant Compounds*
UL 2580, *Batteries for Use in Electric Vehicles*
UL 2591, *Battery Cell Separators*
UL 2726, *Battery Lead Wire*
UL 2734, *Connectors and Service Plugs for Use with On-Board Electrical Vehicle (EV) Charging Systems*
UL 4127, *Low Voltage Battery Cable*
UL 4128, *Intercell and Intertier Connectors for Use in Electrochemical Battery System Applications*
UL 4248-1, *Fuseholders - Part 1: General Requirements*
UL 9703, *Distributed Generation Wiring Harnesses*
UL 60691, *Thermal-Links - Requirements and Application Guide*
UL 60730-1, *Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements*
UL 60730-2-6, *Automatic Electrical Controls for Household and Similar Use - Part 2: Particular Requirements for Automatic Electrical Pressure Sensing Controls Including Mechanical Requirements*
UL 60730-2-9, *Automatic Electrical Controls for Household and Similar Use - Part 2-9: Particular Requirements for Temperature Sensing Controls*
UL 60947-1, *Low-Voltage Switchgear and Controlgear – Part 1: General Rules*
UL 60947-4-1, *Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters*
UL 60947-5-2, *Low-Voltage Switchgear and Controlgear - Part 5-2: Control Circuit Devices and Switching Elements - Proximity Switches*
UL 60950-1, *Information Technology Equipment Safety - Part 1: General Requirements*
UL 61058-1, *Switches for Appliances - Part 1: General Requirements*
UL 61131-2, *Programmable Controllers - Part 2: Equipment Requirements and Tests*