UL 2054

STANDARD FOR SAFETY

Household and Commercial Batteries

UL Standard for Safety for Household and Commercial Batteries, UL 2054

Third Edition, Dated November 17, 2021

Summary of Topics

This revision of UL 2054 dated March 10, 2022 includes editorial corrections to the equations in 16.8, 17.8 and Figure 19.1. No other changes have been made.

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

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UL 2054

Standard for Household and Commercial Batteries

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This UL Standard for Safety consists of the Third Edition including revisions through March 10, 2022.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover portable primary (nonrechargeable) and secondary (rechargeable) batteries for use as power sources in products. These batteries consist of either a single electrochemical cell or two or more cells connected in series, parallel, or both, that convert chemical energy into electrical energy by chemical reaction.

1.2 These requirements are intended to reduce the risk of fire or explosion when batteries are used in a product. The proper use of these batteries in a particular application is dependent on their use in a complete product that complies with the requirements applicable to such a product.

1.3 These requirements are intended to cover batteries for general use and do not include the combination of the battery and the host product which are covered by requirements in the host product standard.

1.4 These requirements are also intended to reduce the risk of injury to persons due to fire or explosion when batteries are removed from a product to be transported, stored, or discarded.

1.5 These requirements do not cover the toxicity risk that results from the ingestion of a battery or its contents, nor the risk of injury to persons that occurs if a battery is cut open to provide access to its contents.

2 Units of Measurement

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

3 Components

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

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

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

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

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

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

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

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

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

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

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

4 Referenced Publications

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

4.2 The following publications are referenced in this Standard:

UL 248-14, Low-Voltage Fuses – Part 14, Supplemental Fuses

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

UL 796, Printed-Wiring Boards

UL 969, Marking and Labeling Systems

UL 1434, Thermistor-Type Devices

UL 1642, Lithium Batteries

UL 60691, Thermal-Links – Requirements and Application Guide

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

5 Glossary

5.1 For the purpose of these requirements the following definitions apply.

5.2 BATTERY – General term for (1) any single cell, or (2) a group of cells connected together either in a series and/or parallel configuration. May be ready for use or may be an installed component.

NOTE: The term “battery(ies)” refers to single or multicell batteries.

5.3 BATTERY PACK – A battery which is ready for use, contained in a supplemental rigid enclosure, with or without protective devices.

5.4 BATTERY, PRIMARY – A battery that can only be discharged once. It is not designed to be electrically recharged and must be protected from a charging current.

5.5 BATTERY, SECONDARY – A battery that is intended to be discharged and recharged many times in accordance with the manufacturer's recommendations.

5.6 C_5 AMP RATE – The current, in amperes, that a cell or battery can be discharged at for 5 h to the voltage cutoff point specified by the manufacturer.

5.7 CAPACITY, RATED – The capacity, in ampere-hours, of a cell or battery determined under specified load, temperature and voltage conditions and declared by the manufacturer.

5.8 CASING – The outer rigid can or flexible pouch of an individual cell or of a single cell standardized (i.e. AA, C, D, etc.) battery that contains the internal components of that cell or single cell standardized battery.

5.9 CELL, COMPONENT – The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, container, terminals, and usually separators, that is a source of electrical energy by direct conversion of chemical energy. May be ready for use or may be provided as component of battery pack.

5.10 CELL OPERATING REGION (lithium ion systems) – The range of voltage, current, and temperature in which the cell operates during charging or discharging as specified by the cell manufacturer.

5.11 COMPONENT, CURRENT-LIMITING – Any component employed to limit current during abnormal conditions. Current-limiting components include resistors, fuses, or PTC thermistor type devices.

5.12 COMPONENT, TEMPERATURE-LIMITING – Any component used to limit temperature during abnormal conditions. Temperature-Limiting Components include thermal protectors and thermal cutoffs.

5.13 CURRENT, ABNORMAL CHARGING – Also called overcharge current for secondary cells; maximum rated charging current to a cell or battery under fault condition.

5.14 DISCHARGE, FORCED – Subsequent discharge of one fully discharged cell in each parallel string by connecting in series with fresh cells of the same kind so as to drive the cell into polarity reversal.

5.15 DISCHARGED, FULLY – A condition of battery energy potential representing depletion of 100 % of its rated capacity (for primary cell or battery) or depletion to its end-point-voltage as specified by the manufacturer (for a secondary cell or battery).

5.16 ENCLOSURE – The outer housing of a battery pack that provides mechanical protection and a level of fire protection for internal cells and components of the battery pack.

5.17 EXPLOSION – A condition that occurs when a cell container or battery case violently opens and major components are forcibly expelled.

5.18 MAXIMUM CHARGING CURRENT AT SPECIFIED TEMPERATURES (lithium ion systems) – The maximum charging current at specified temperatures in the cell operating region, which is specified by the cell manufacturer.

5.19 PORTABLE – Able to be moved or carried by hand.

5.20 UPPER LIMIT CHARGING VOLTAGE AT SPECIFIED TEMPERATURES (lithium ion systems) – The highest charging voltage at specified temperatures in the cell-operating region specified by the cell manufacturer. This value is specified by the cell manufacturer and although it is a maximum limit, it may be lower than the maximum charging voltage parameter specified for the abnormal charging test.

5.21 PROTECTIVE DEVICES – Any device such as a field effect transistor (FET), fuse, diode or current limiter which stops the current flow, blocks the current flow in one direction or limits the current flow in an electrical circuit.

5.22 SHORT CIRCUIT – A direct connection between positive and negative terminals of a cell or battery that provides a virtual zero resistance path for current flow.

5.23 VENTING – A condition that occurs when the battery or cell releases excessive internal pressure in a manner intended by design to preclude rupture, explosion or self ignition.

5.24 VOLTAGE, ABNORMAL CHARGING – Maximum specified charger output voltage applied to a cell or battery under fault condition.

CONSTRUCTION

6 General

6.1 Casing and enclosure

6.1.1 The casing of a cell or single cell battery, or the enclosure of a battery pack shall have the strength and rigidity required to resist the possible abuses, that it is exposed to during its intended use, in order to reduce the risk of fire or injury to persons.

6.1.2 The casing of a cell, or single cell battery, or the enclosure of a battery pack shall be rigid enough to prevent flexing that would result in damage to the cells or internal protective components. A tool providing the mechanical advantage of a pliers, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the cell casing or battery pack enclosure.

Exception No. 1: This requirement does not apply to a cell or a single cell battery containing electrodes with less than 0.04 g (0.0014 oz) of active mass. This requirements does not apply to a lithium ion polymer or lithium polymer cell (i.e. pouch type cells) of a battery pack, which rely upon the battery pack enclosure or end use application for mechanical protection.

Exception No. 2: This requirement does not apply to incomplete battery packs that rely upon the end use application for mechanical protection.

Exception No. 3: Single cell battery packs employing cells with rigid casings that comply with all of the cell tests of UL 1642 or Table 8.1 as applicable, may rely on the cell casing as part of the rigid enclosure requirement provided that internal connections and pack circuitry are provided with a suitable protection against damage as determined by the applicable battery enclosure tests in Sections 23 – 25.

6.1.3 For battery packs with plastic outer enclosures, the outer enclosure of the battery shall be designed such that it is not capable of being opened using simple tools, such as a screwdriver. The enclosure shall be ultrasonically welded, or secured by equivalent means. Adhesives complying with the adhesive requirements of UL 746C, single use or tamper-proof screws are considered equivalent means.

6.1.4 The outer enclosure material of the battery pack shall be classed as V-1 or less flammable in the minimum part thickness in accordance with UL 746C.

Exception: Materials are not required to be classed as V-1 or less flammable when they comply with the Enclosure Flammability – 20 mm (3/4 inch) Flame test described in UL 746C.

6.1.5 Openings in battery pack enclosures shall be minimized to prevent damage to cells, connections, and internal circuitry and shorting of electrical spacings within the pack. Enclosure openings shall not be located over cells that do not comply with the rigid casing requirements of 6.1.2 or over protective circuitry and connections where damage or shorting from debris entering the enclosure could result in a hazard.

6.2 Electrolyte

6.2.1 A cell shall not contain pressurized vapor or liquid that expels materials forcibly when the battery casing is punctured with a grinding wheel under laboratory conditions at a temperature of 23 ±2 °C (73 ±3.6 °F).

6.3 Wiring and terminals

6.3.1 Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, current, and voltage to which the wiring is likely to be subjected within the battery pack.

6.3.2 The wiring splice or connection shall be mechanically secured and shall provide electrical contact without strain on connections and terminals. Wiring shall be secured and routed away from sharp edges or other parts that may compromise wiring insulation.

6.4 External battery pack connectors

6.4.1 An external battery pack connector shall be constructed to prevent inadvertent short circuiting of its terminals unless the pack meets the limited power source requirements of the Limited Power Source Test, Section 15. Examples of methods to prevent inadvertent short-circuiting include recessing the terminals, providing circuitry that prevents inadvertent short circuiting, providing covers over the terminals, use of keyed connectors, and the like.

6.4.2 Insulating material for external battery pack connectors, outside the enclosure, shall have a V-2 minimum flame rating unless the pack meets the limited power source requirements of the Limited Power Source Test, Section 15. External connectors forming part of the fire enclosure shall be V-1 minimum.

6.5 Printed wiring boards

6.5.1 Printed wiring boards mounting battery circuit components shall be rated V-1 minimum and comply with UL 796.

6.6 Lithium Ion Systems Only

6.6.1 The voltage of each cell or each cellblock consisting of parallel-connected plural cells should not exceed the upper limit of the charging voltage specified by the cell manufacturer.

6.6.2 For the battery consisting of a single cell or a single cellblock, it should be confirmed that the charging voltage of the cell does not exceed the upper limit of the charging voltage specified by the cell manufacturer.

6.6.3 For the battery consisting of series-connected plural single cells or series-connected plural cellblocks, it should be confirmed that the voltages of any one of the single cells or single cellblocks does not exceed the upper limit of the charging voltage, specified by the cell manufacturer, by monitoring the voltage of every single cell or the single cellblocks.

6.6.4 Compliance for 6.6.1 – 6.6.3 can be achieved through analysis of the battery protection circuit or if unable to determine through analysis, than through monitoring values during the test of Section 16.

PERFORMANCE

7 General

7.1 Batteries are to be tested as described in Sections 11 – 28 and as follows:

a) Section 14, Forced-Discharge Test, is applicable only to cells intended to be used in multicell series applications, such as battery packs;

b) Section 15, Limited Power Source Test, is an optional requirement only carried out upon manufacturer's request; and

c) The Battery Enclosure Tests, Sections 22 – 25 (including the Steady Force, Mold Stress Relief, and Drop Impact Tests) are intended only for batteries that have an outer enclosure.

7.2 With the exception of the Projectile Test of Section 26, cells and/or batteries shall not explode or catch fire as a result of the tests in this standard. For the Shock Test, Section 20, Vibration Test, Section 21, Steady Force Test, Section 23, Mold Stress Relief Test, Section 24, Drop Impact Test, Section 25, and the Temperature Cycling Test, Section 28 the samples shall also not vent or leak. For these tests unacceptable leakage is deemed to have occurred when the resulting mass loss exceeds the values shown in Table 7.1, Venting and Leakage Mass Loss Criteria.

Table 7.1
Venting and Leakage Mass Loss Criteria

Mass of cell or battery	Maximum mass % loss
Not more than 1 gram	0.5
More than 1.0 gram but not more than 5.0 gram	0.2
More than 5.0 gram	0.1

7.3 Certain end product devices require that the power output of a battery be limited. The Limited Power Source Test described in Section 15 is to be used to determine whether a cell or battery is suitable in such applications where fire hazards may otherwise exist.

8 Samples

8.1 Unless otherwise indicated, fresh cells or batteries in the fully charged state are to be used for the tests described in Sections 11 – 28. The test program and number of samples to be used in each test is shown in Table 8.1 and Table 8.2, for cell testing and battery pack testing, respectively.

Exception: In lieu of the requirements outlined in Table 8.1, cells constructed of lithium metal, lithium alloy or lithium ion, that are used in batteries, shall meet the requirements in UL 1642.

8.2 When a battery pack is tested in accordance with Table 8.2, the cells comprising that battery pack shall also be tested in accordance with Table 8.1 if they have not already been.

Exception: In lieu of the requirements outlined in Table 8.1, cells constructed of lithium metal, lithium alloy or lithium ion, that are used in batteries, shall meet the requirements in UL 1642.

Table 8.1
Testing required for cells

Test	Section	Number of fully charged cells
Electrical Tests		
Short-Circuit	11	
at room temp.		5
at 55 °C (131 °F)		5
Abnormal Charging	12	5
Forced-Discharge	14	5
Mechanical Tests		
Crush	18	5
Impact	19	5
Shock	20	5
Vibration	21	5
Fire Exposure Tests		
Projectile	26	5
Environmental Tests		
Heating	27	5
Temperature Cycling	28	5

Table 8.2
Testing required for battery packs

Test	Section	Number of fully charged packs
Electrical Tests		
Short-Circuit	11	
at room temp.		5 (unsealed)
at 55 °C (131 °F)		5 (unsealed)
Abnormal Charging	12	5 (unsealed)
Abusive Overcharge	13	5 (unsealed)
Forced-Discharge[a]	14	5 (unsealed)
Limited Power Source	15	6 (unsealed)
Battery Pack Component Temperature	16	2 (unsealed)
Battery Pack Surface Temperature	17	2 (complete)
Battery Enclosure Tests		
Steady Force	23	3 (complete)
Mold Stress Relief	24	3 (complete)
Drop Impact	25	3 (complete)
Enclosure Flammability[b]	6	3 (+3, if necessary) unsealed enclosures

NOTE – Unsealed refers to batteries which do not use securement such as adhesive and/or ultrasonic welding to seal the top and bottom enclosures in order to facilitate access to the inside of the battery pack. Complete refers to a whole sample of the battery pack representative of production.

[a] Forced Discharge test is conducted only for multi-cell series configurations.

[b] Enclosure materials classified as V-1 or less flammable in the minimum part thickness do not require enclosure flammability tests.

8.3 All batteries shall be fully charged in accordance with the manufacturer's specifications prior to testing except for the samples to be subjected to the Abnormal Charging and Abusive Overcharge Tests, which shall be discharged to the manufacturer specified end point voltage using the manufacturer specified current prior to testing.

9 Important Test Considerations

9.1 As some batteries explode in the tests described in Sections 11 – 28, it is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, chemical burns, and noise results from such explosions. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases.

9.2 The temperatures on the surface of the battery casings shall be monitored during the tests described in Sections 11, 12, 13, 18, and 19. All personnel involved in the testing of batteries are to be instructed never to approach a battery until the surface temperature returns to ambient temperature.

9.3 The tests described in Section 26, Projectile Test, shall be conducted in a separate room or room equipped with an adequate safety barrier separating the test area from the observer.

10 Temperature Measurements

10.1 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2) and a potentiometer-type instrument.

10.2 The temperature measurements on the batteries are to be made with the measuring junction of the thermocouple held tightly against the outer casing of the battery.

ELECTRICAL TESTS

11 Short-Circuit Test

11.1 Cells shall comply with 11.1 – 11.6.

11.2 Each fully charged test sample cell, in turn, is to be short-circuited by connecting the positive and negative terminals of the battery with a circuit load having a resistance load of 80 ±20 mΩ. The temperature of the battery case is to be recorded during the test. The battery is to discharge until a fire or explosion is obtained, or until it has reached a discharged state of less than 0.2 V and/or the case temperature has returned to ±10 °C (±18 °F) of ambient temperature.

11.3 Tests are to be conducted at 20 ±5 °C (68 ±9 °F), and at 55 ±2 °C (131 ±4 °F). The cells are to reach equilibrium at 20 ±5 °C (68 ±9 °F) or 55 ±2 °C (131 ±4 °F) as applicable, before the terminals are connected.

11.4 A cell is to be tested individually unless the cell manufacturer indicates that it is intended for use in series or parallel. For series or parallel use, additional tests on five sets of batteries are to be conducted using the maximum number of cells to be covered for each configuration as specified by the manufacturer.

11.5 A cell is to be tested without the assistance of protective devices unless such protective devices are integral to the cell construction. When a protective device actuates during the test, the test shall be repeated with the cell connected to the maximum load that does not cause the protective device to open.

11.6 The samples shall not explode or catch fire. The temperature of the exterior cell or battery casing shall not exceed 150 °C (302 °F) for lithium chemistries.

11.7 Battery packs shall comply with 11.8 – 11.12.

Exception: Battery packs consisting of a single cell, in which the cell has already been subjected to the tests in 11.1 – 11.6 need not be subjected to the tests in 11.8 – 11.12.

11.8 Each fully charged test sample battery pack, in turn, is to be short-circuited by connecting the positive and negative terminals of the battery with a circuit load having a resistance load of 80 ±20 mΩ. The temperature of the battery case is to be recorded during the test. The battery is to discharge until a fire or explosion is obtained, or until it is completely discharged and/or the cell case temperature has returned to ±10 °C (±18 °F) of ambient temperature.

11.9 Tests are to be conducted at 20 ±5 °C (68 ±9 °F) and at 55 ±5 °C (131 ±4 °F). The batteries are to reach equilibrium at 20 ±5 °C (68 ±9 °F) or 55 ±5 °C (131 ±4 °F), as applicable, before the terminals are connected.

11.10 Battery pack constructions are to be subjected to a single fault across any protective device in the load circuit of the battery under test. When protective devices actuate during the test, the test shall be repeated with the battery pack connected to the maximum load that does not cause the protective devices to open. See 5.21.

Exception: A positive temperature coefficient device which complies with the tests specified in UL 1434, UL 60730-1, or other protective devices determined to be reliable, may remain in the circuit without being faulted. See 5.21. Other standards that may apply are UL 248-14 and UL 60691.

11.11 One of the above five test sample battery packs tested at 20 ±5 °C (68 ±9 °F) shall be evaluated with the following additional conditions in place. The terminals are to be subjected to a short circuit condition with a resistance that is capable of withstanding the short-circuit current and creating a short-circuit condition with a total external resistance of 80 ±20 mΩ. The test is to be conducted on a tissue paper covered soft wood surface and the sample battery pack and bare conductor is to be covered with a single layer of cheesecloth.

11.12 For all samples tested, the samples shall not explode or catch fire and the tests shall not result in chemical leaks caused by cracking, rupturing or bursting of the cell casing. The temperature of the internal cell casings shall not exceed 150 °C (302 °F) for lithium chemistries. For battery pack samples tested in accordance with 11.11, the cheesecloth and tissue paper shall not catch fire.

12 Abnormal Charging Test

12.1 Primary batteries (for example: cells, single cell batteries, or battery packs) shall comply with 12.2 – 12.5.

12.2 Batteries discharged to the manufacturer's rated capacity are to be used for this test. The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

12.3 Each fully discharged test sample battery is to be subjected to a constant charging current of three times the current, I_c, specified by the manufacturer by connecting it in opposition to a dc-power supply. The test time is to be calculated using the formula:

$$t_c = \frac{2.5\,C}{3(I_c)}$$

In which:

t_c is the charging time in hours,

C is the capacity of battery in ampere-hours, and

I_c is the maximum charging current, in amperes, specified by the manufacturer.

The minimum charging time is to be 7 h.

Exception: At the manufacturer's discretion, test currents greater than the specified three times rated I_c can be applied to expedite the test timeframe, with the minimum charging times as 7 h.

12.4 When a protective device that has been investigated for the purpose, actuates during the test, the test shall be repeated with the battery supply connected to the maximum load that does not cause the protective device to open. A protective device that has not been investigated for the purpose shall be short-circuited.

12.5 The samples shall not explode or catch fire. For battery pack samples, tests shall not result in chemical leaks caused by cracking, rupturing or bursting of the battery casing.

12.6 Secondary cells shall comply with 12.7 – 12.9.

12.7 The cells are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F). Each battery shall be discharged at a constant current of 0.2 C/1 h, to a manufacturer specified discharge endpoint voltage.

12.8 The cells are to be charged with a constant maximum specified charger output voltage and a current limit of three times the maximum current I_c, specified by the manufacturer. Charging duration is the time required to reach the manufacturer's specified end-of-charge condition plus seven additional hours.

12.9 A cell is to be tested without the assistance of protective devices, unless such protective devices are either integral to the cell constructions or have been investigated for the purpose. A re-settable protective device that actuates during the test shall be allowed to reset and the test shall be resumed, cycling as often as necessary to complete the test. When a protective device operates during the test (whether re-settable or not) the test is repeated with the same charging time, but with the cell connected to the maximum load that does not cause the protective devices to operate. A protective device that is not integral to the cell and that has not been investigated for the purpose is to be short-circuited.

12.10 The samples shall not explode or catch fire.

12.11 Secondary battery packs shall comply with 12.12 – 12.14.

12.12 The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F). A thermocouple is to be attached to the cells of each test sample battery. Each battery shall be discharged at a constant current of 0.2C/1 h, to a manufacturer specified discharge endpoint voltage.

12.13 Each of the test sample batteries are to be subjected to the following overcharge conditions, in sequential order.

a) The battery is to be initially charged using a constant current charging mode with a current limit of three times the maximum current I_c, specified by the manufacturer until the maximum specified charger output voltage is reached. At that point, the battery is to be charged with a constant maximum specified charger output voltage and a current limit of three times the maximum current I_c. Charging duration is the time required to reach the manufacturer's specified end-of-charge condition plus seven additional hours. The temperature on the cell casing shall be monitored. A re-settable protective device such as a PTC that actuates during the test shall be allowed to reset and

the test shall be resumed, cycling as often as necessary, but no less than 10 times, to complete the test. Automatic reset devices are allowed to cycle during the test. When an overcurrent protective device operates during the test, the test is repeated with the same charging time, but with the battery connected to the maximum load that does not cause the protective devices to operate.

b) The charge condition in accordance with (a) shall be conducted with each single component fault that is likely to occur in the charging circuit and which would result in overcharging of the battery.

Exception No. 1: A protective device determined to be reliable may remain in the circuit without being faulted. See Section 3 and 5.21.

Exception No. 2: For batteries without protective devices, the overcharge condition(s) in (b) do not apply.

12.14 The samples shall not explode or catch fire. For battery pack samples, tests shall not result in chemical leaks caused by cracking, rupturing or bursting of the cell casing.

13 Abusive Overcharge Test

13.1 The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

13.2 Sample batteries are to be subjected to a constant charging current at 10 times the C_5 amp rate, using a supply voltage sufficient to maintain the 10 times C_5 amp rate throughout the duration of the test. During the test, the temperature is to be measured on the internal cell casing of each sample. The test is to continue until the cell or battery explodes, vents, or a single operation protective device operates, and the temperature of the internal cell casing reaches steady state conditions or returns to ambient. If a PTC or other re-settable protection device operates during the test, it is to be reset a minimum of 10 times during the test. An automatic reset device is allowed to cycle during the test.

13.3 During the tests, batteries supplied with protective devices shall be subjected to a single component fault using any single fault condition which is likely to occur in the charging circuit and which would result in overcharging of the battery.

Exception: Protective devices determined to be reliable, may remain in the circuit without being faulted.

13.4 The samples shall not explode or catch fire.

13.5 At least one of the five samples shall be subjected to the test outlined in 13.2 and 13.3 with a constant current charge 5 times the C_5 rate (for example: at the C rate) with a supply voltage sufficient to maintain that rate throughout the duration of the test.

14 Forced-Discharge Test

14.1 This test is intended for cells that are to be used in multicell applications, such as battery packs. The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

14.2 For multi-cell series configurations without parallel strings a fully discharged cell is to be force-discharged by connecting it in series with fully charged cells of the same kind. The number of fully charged cells to be connected in series with the discharged cell is to equal the total number of cells in the pack less one.

14.3 For multi-cell series configurations with parallel strings, a fully discharged parallel string is to be force-discharged by connecting it in series with fully charged cells of the same kind. The number of fully

charged cells to be connected in series with the discharged parallel string is to equal the total number of cells in the pack less the number of cells in the discharged parallel string.

14.4 Each of the five battery packs shall be prepared as described in 14.2 or 14.3, as applicable.

14.5 Once the completely discharged cells (or string of cells) are connected in series with the specified number of fully charged cells, the resultant battery pack is to be short circuited.

14.6 The positive and negative terminals of the sample are to be connected with a copper wire with a resistance load of 80 ±20 mΩ. The battery is to discharge until a fire or explosion is obtained, or until it has reached a completely discharged state and the cell case temperature has returned to ±10 °C (±18 °F) of ambient temperature.

14.7 During the tests, batteries supplied with protective devices shall be subjected to a single component fault using any single fault condition which is likely to occur in the discharge circuit and which would result in excessive discharge of the battery.

Exception: A positive temperature coefficient device which complies with the applicable tests specified in UL 1434 and UL 60730-1, or other protective devices determined to be reliable, may remain in the circuit without being faulted. Other standards that may apply are UL 248-14 and UL 60691.

14.8 The samples shall not explode or catch fire.

15 Limited Power Source Test

15.1 The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

15.2 A battery intended to be a limited power source shall comply with one of the following:

a) The output is inherently limited in compliance with Table 15.1;

b) A linear or nonlinear impedance limits the output in compliance with Table 15.1. If a positive temperature coefficient device is used, it shall:

1) Comply with UL 1434;

2) Pass the tests specified in the Manufacturing Deviation and Drift Section, the Endurance Section, and the Manufacturing Deviation and Drift Section and the Endurance Section in the Annex for Requirements for Controls Using Thermistors of UL 60730-1; or

3) Meet the requirements in UL 60730-1 for a device for Type 2.AL Action;

c) A regulating network or an integrated circuit (IC) current limiter, limits the output in compliance with Table 15.1, both under normal operating conditions and after any simulated single fault in the regulating network or IC current limiter (open circuit or short circuit); or

d) An overcurrent protective device is used and the output is limited in compliance with Table 15.2.

Table 15.1
Limits for Power Sources Without an Overcurrent Protective Device

Output voltage U_{oc} [a] Vdc	Output current I_{sc} [b, d] A	Apparent power S [c, d] VA
$U_{oc} \leq 30$	≤ 8.0	≤ 100
$30 < U_{oc} \leq 60$	≤ $150/U_{oc}$	≤ 100

[a] U_{oc} – Open circuit battery voltage with all load circuits disconnected.

[b] I_{sc} – Maximum output current with any non-capacitive load, including a short circuit.

[c] S(VA) – Maximum output VA with any non-capacitive load including short circuit.

[d] Measurement of I_{sc} and S are made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device, and 60 s in other cases. If multiple protections are provided, such as combination of electronic circuit and positive temperature coefficient device, I_{sc} and S are measured 60 s after the application of the load with or without single fault condition applied.

Table 15.2
Limits for Battery Sources (With Overcurrent Protective Device)

Output voltage U_{oc} [a] Vdc	Output current I_{sc} [b, d] A	Apparent power S [c, d] VA	Current rating of overcurrent protective device [e] A
≤ 20	≤ $1000/U_{oc}$	≤ 250	≤ 5
$20 < U_{oc} \leq 30$			≤ $100/U_{oc}$
$30 < U_{oc} \leq 60$			≤ $100/U_{oc}$

[a] U_{oc} – Open circuit battery voltage with all load circuits disconnected.

[b] I_{sc} – Maximum output current with any non-capacitive load, including a short circuit, measured 60 s after application of the load.

[c] S(VA) – Maximum output VA after 60 s of operation with any non-capacitive load including short circuit.

[d] Current limiting impedances remain in the circuit during measurement, but overcurrent protective devices are bypassed.

[e] The current ratings of overcurrent protective devices are based on fuses and circuit breakers that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

NOTE – The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protective devices.

15.3 Where an overcurrent protective device is used, it shall be a fuse or a non-adjustable, nonautoreset, electromechanical device.

15.4 Batteries shall be fully charged when conducting the measurements for U_{oc}, I_{sc}, and S according to Table 15.1 and Table 15.2.

15.5 The non-capacitive load referenced in Table 15.1 and Table 15.2 shall be adjusted to develop maximum measured values of current (I_{sc}) and power (S) that can be obtained over the time limits noted in Table 15.1 and Table 15.2. Simulated faults in a regulating network required according to 15.2(c) above are applied under these load conditions.

15.6 Batteries that meet the limited power source requirements may be marked "Limited Power Source" "LPS" to indicate that they are considered to be a limited power source. Batteries that do not meet these requirements, regardless of terminal design, shall not be marked to indicate that they are a limited power source and are restricted to applications where a limited power source is not required.

16 Battery Pack Component Temperature Test

16.1 A battery pack with enclosure shall be subjected to a normal temperature test under both input (charging) and output (discharging) conditions. As a result of this testing, temperatures on temperature sensitive components shall not exceed the limits outlined in Table 16.1.

Table 16.1
Normal Temperature Limits – Component

Part	Maximum temperature (T_{max}) °C
Synthetic rubber or PVC insulation of internal and external wiring	
– without temperature marking	75
– with temperature marking	The temperature marking
Components, insulation, and thermoplastic materials	a
Cell casing	b
[a] Temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material including internal cells.	
[b] The cell casing temperature shall not exceed the manufacturer's recommended maximum temperature.	

16.2 For the output loading temperature test, a fully charged battery pack shall be subjected to a constant resistive loading across the output terminals of the pack with the output load current set to just below the operating limit of the discharging protection circuit. Temperatures are monitored until thermal stabilization or until the pack is at its specified endpoint voltage, whichever comes first.

16.3 The input loading temperature test shall be conducted on a fully discharged battery pack, discharged at a constant current of 0.2C/1 h to a manufacturer specified discharge endpoint voltage.

16.4 For the input loading temperature test, a fully discharged sample shall be subjected to a CCCV charging method with the maximum charging voltage not to exceed the manufacturer's recommended maximum charging voltage limits. During the test, the charging current shall not exceed three times the maximum charge current or the operating limit of the charging protection circuit, whichever is less, during the test. Temperatures are monitored until thermal stabilization or until the pack is at its fully charged state, whichever comes first.

16.5 Temperatures are considered to be stabilized when three successive readings taken at intervals of 10 % of the previously elapsed duration of the test, but not less than 15 min, indicate no further increase.

16.6 Protective devices within the pack shall not operate during the test.

16.7 Temperatures are monitored on surfaces of components using thermocouples. Thermocouples are to consist of 30 AWG wires. Larger size wires may be used, but they shall not exceed 24 AWG and shall not be large enough to result in a heat sink condition on the part under test.

16.8 During the normal temperature test, temperature measurement *T* shall not exceed

$$(T_{\max} + T_{\text{amb}} - T_{\text{ma}})$$

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, or 25 °C (77 °F), whichever is greater.

During the test T_{amb} should not exceed T_{ma} unless agreed by all parties involved.

17 Battery Pack Surface Temperature Test

17.1 A battery pack with enclosure shall be subjected to a normal temperature test under both input (charging) and output (discharging) conditions. As a result of this testing, temperatures on external accessible surfaces of the pack shall not exceed the limits outlined in Table 17.1.

17.2 For the output loading temperature test, a fully charged battery pack shall be subjected to a constant resistive loading across the output terminals of the pack with the output load current set to just below the operating limit of the discharging protection circuit. Temperatures are monitored until thermal stabilization or until the pack is at its specified endpoint voltage, whichever comes first.

17.3 The input loading temperature test shall be conducted on a fully discharged battery pack, discharged at a constant current of 0.2C/1 h to a manufacturer specified discharge endpoint voltage.

17.4 For the input loading temperature test, a fully discharged sample shall be subjected to a CCCV charging method with the maximum charging voltage not to exceed the manufacturer's recommended maximum charging voltage limits. During the test, the charging current shall not exceed three times the maximum charge current or the operating limit of the charging protection circuit, whichever is less, during the test. Temperatures are monitored until thermal stabilization or until the pack is at its fully charged state, whichever comes first.

17.5 Temperatures are considered to be stabilized when three successive readings taken at intervals of 10 % of the previously elapsed duration of the test, but not less than 15 min, indicate no further increase.

17.6 Protective devices within the pack shall not operate during the test.

17.7 Temperatures are monitored on the accessible surfaces of the pack enclosure using thermocouples. Thermocouples are to consists of 30 AWG wires. Larger size wires may be used, but they shall not exceed 24 AWG.

17.8 During the normal temperature test, temperature measurement T shall not exceed

$$(T_{max} + T_{amb} - T_{ma})$$

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 per Table 17.1,

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

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

During the test T_{amb} should not exceed T_{ma} unless agreed by all parties involved.

Table 17.1
Normal Temperature Limits – Surface

Accessible surfaces	Maximum temperature (T_{max}) °C	
	Metal	Plastic[a]
Accessible parts held continuously during normal use	55	75
Accessible surfaces held or touched for short periods only	60	85
Accessible surfaces which may be touched	70	95

[a] Temperatures measured on accessible plastic enclosure surfaces shall not exceed the temperature ratings of the materials.

MECHANICAL TESTS

18 Crush Test

18.1 The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

18.2 A battery is to be crushed between two flat surfaces. The force for the crushing is to be applied by a hydraulic ram or similar force mechanism. The flat surfaces are to be brought in contact with the cells and the crushing is to be continued until an applied force of 13 ±1.0 kN (3000 ±224 lbf) is reached. Once the maximum force has been obtained, it is to be released.

18.3 A cylindrical or prismatic battery is to be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. A prismatic battery is also to be rotated 90° around its longitudinal axis so that both the wide and narrow sides will be subjected to the crushing force. Each sample battery is to be subjected to a crushing force in only one direction. Separate samples are to be used for each test.

18.4 A coin or button battery is to be crushed with the flat surface of the battery parallel with the flat surfaces of the crushing apparatus.

18.5 The samples shall not explode or catch fire.

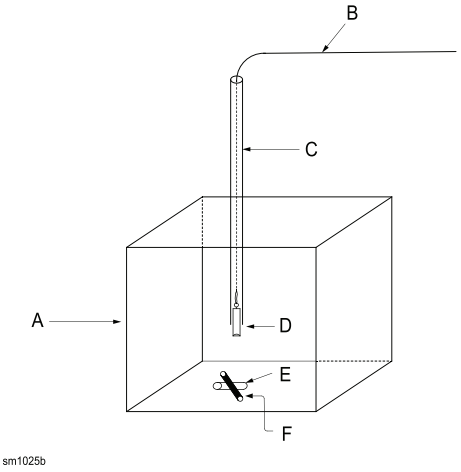
19 Impact Test

19.1 The batteries are to be tested in an ambient temperature of 20 ±5 °C (68 ±9 °F).

19.2 A test sample battery is to be placed on a flat surface. A 15.8 ±0.1 mm (5/8 ±0.004 in) diameter bar is to be placed across the center of the sample. A 9.10 ±0.46 kg (20 ±1 lb) weight is to be dropped from a height of 610 ±25 mm (24 ±1 in) onto the sample. (See Figure 19.1.)

Figure 19.1

Impact test



A – Steel impact chamber (hinged door not shown)

B – Weight support rope

C – Containment tube

D – 9.10 ±0.46 kg (20 ±1 lb) weight

E – Battery

F – 15.8-mm (5/8-in) diameter bar

19.3 A cylindrical or prismatic battery is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of a 15.8 mm (5/8 in) diameter curved surface lying across the center of the test sample. A prismatic battery is also to be rotated 90° around its longitudinal axis so that both the wide and narrow sides will be subjected to the impact. Each sample battery is to be subjected to only a single impact. Separate samples are to be used for each test.

19.4 A coin or button battery is to be impacted with the flat surface of the test sample parallel to the flat surface and the 15.8 mm (5/8 in) diameter curved surface lying across its center.

19.5 The samples shall not explode or catch fire.

20 Shock Test

20.1 The cell is to 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 are to 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 is to be applied in a direction normal to the face of the cell. For each shock the cell is to 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 20 ±5 °C (68 ±9 °F).

20.2 The samples shall not explode or catch fire.

20.3 The sample shall be examined 6 h after testing and shall not vent or leak as described in 7.2.