

UL 2054

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Household and Commercial Batteries

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

Second Edition, Dated October 29,

Revisions: This Standard contains revisions through and including September 21, 2005.

Summary of Topics

The revisions dated September 21, 2005 were issued to incorporate the following:

- Changing the name of the 250 lb Crush Test to the 250 N Steady Force Test in paragraphs 5.1 and 5.2 and Table 6.2.
- Changing the temperature for the Short Circuit Test from 60°C to 55°C in paragraph 9.3.
- Changing the final temperature time in paragraph 23.3 from 30 minutes to 10 minutes.

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The following table lists the future effective dates with the corresponding item.

Future Effective Date	References
October 30, 2006	Paragraph 4.1.4, Section 13

The revised requirements are substantially in accordance with UL's Proposal(s) on this subject dated July 11, 2005.

The revisions dated September 21, 2005 include a reprinted title page (page1) for this Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing, Recognition and

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-3.....	September 21, 2005
4-7	October 29, 2004
8-10B	September 21, 2005
11-21	October 29, 2004
22	September 21, 2005
23-24	October 29, 2004
SR1-SR2.....	October 29, 2004

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OCTOBER 29, 2004

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UL 2054

Standard for Household and Commercial Batteries

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Second Edition

October 29, 2004

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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INTRODUCTION

1

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

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

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

2.1 Lithium

2.1.1 Component cells constructed of lithium metal, lithium alloy or lithium ion, that are used in batteries, shall meet the technician-replaceable or user-replaceable requirements in the Standard for Lithium

2.1.2 Component cell testing requirements in accordance with Table 6.1 are not required for lithium cells that meet the user-replaceable requirements in the Standard for Lithium Batteries, UL 1642.

2.1.3 Component cell testing requirements in accordance with Table 6.1 are limited to the Projectile Test, Section 22, for lithium cells that meet the technician-replaceable requirements in the Standard for Lithium Batteries, UL 1642.

2.2 Units of measurement

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

2.3

2.3.1 The term "battery(ies)" shall refer to single or multicell batteries.

3

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

3.2 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.

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

3.4 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.

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

3.6 C₅ AMP RATE – The current, in amperes, that a cell or battery can be discharged at for 5 hours to the voltage cutoff point specified by the manufacturer.

3.7 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.

3.8 CASING – A rigid outer protective enclosure of an individual cell or of a battery pack and any associated circuitry of the battery pack.

3.9 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.

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

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

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

3.13 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.

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3.14 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).

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

3.16 JACKET – The container for the electrolyte and terminals of an internal cell of a battery pack.

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

3.18 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.

3.19 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.

3.20 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.

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

CONSTRUCTION

4

4.1

4.1.1 The casing of a component cell or 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.

4.1.2 The casing of a battery pack shall be rigid enough to prevent flexing. A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical

Exception No. 1: This requirement does not apply to a cell or battery containing electrodes with less than 0.04 g (0.0014 ounces) of active mass.

Exception No. 2: For battery packs where repeated flexing of the case does not result in leakage as defined in Section 5 or heating of the battery to temperatures exceeding 60°C (140°F), this requirement

4.1.3 For batteries with plastic outer cases, the outer case of the battery shall be designed such that it is not capable of being opened using simple tools, such as a screwdriver. The case shall be ultrasonically welded, or sealed by equivalent means.

4.1.4 The outer case material of the battery shall be classed as V-1 or less flammable in the minimum part thickness in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment

Exception: Materials are not required to be classed as V-1 or less flammable when they comply with the enclosure flammability – 3/4 inch flame test described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.1.4 effective October 30, 2006

4.2

4.2.1 A component 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 $23 \pm 2^\circ\text{C}$ ($73 \pm 3.6^\circ\text{F}$).

PERFORMANCE

5

5.1 Batteries are to be tested as described in Sections 9 through 24. Section 12, Forced-Discharge Test, is applicable only to cells intended to be used in multicell series applications, such as battery packs. The Battery Enclosure Tests, Sections 18 – 21 (including the 250 N Steady Force, Mold Stress Relief, and Drop Impact Tests) are intended only for batteries that have a plastic outer enclosure.

5.1 revised September 21, 2005

5.2 In most cases cells and/or batteries shall not explode or catch fire as a result of the tests in this standard. For the Shock Test, Section 16, Vibration Test, Section 17, 250 N Steady Force Test, Section 19, Mold Stress Relief Test, Section 20, Drop Impact Test, Section 21, and the Temperature Cycling Test, Section 24 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 5.1, Venting and Leakage

5.2 revised September 21, 2005

Table 5.1
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

5.3 Where a cell or battery fails to meet the criteria of any of the tests in this standard it may be eligible for use in applications where it is not exposed to or protected from conditions shown to cause fire, explosion or leakage. Specific precautions must be taken for the cells and or batteries to be acceptable

5.4 Certain end product devices require that the power output of a battery be limited. The Limited Power Source Test described in Section 13 is to be used to determine whether a cell or battery is suitable in such applications where fire hazards may otherwise exist.

6

6.1 Unless otherwise indicated, fresh cells or batteries in the fully charged state are to be used for the tests described in Sections 9 – 24. The test program and number of samples to be used in each test is shown in Tables 6.1 and 6.2, for component cell testing and battery pack testing, respectively.

6.2 When a battery pack is tested in accordance with Table 6.2, the component cells comprising that

Table 6.1
Testing required for component cells

Test	Section	Number of fully charged cells
Electrical Tests		
Short-Circuit	9	
at room temp.		5
at 55°C (131°F)		5
Abnormal Charge	10	5
Forced-Discharge	12	5
Mechanical Tests		
Crush	14	5
Impact	15	5
Shock	16	5
Vibration	17	5
Fire Exposure Tests		
Projectile	22	5
Environmental Tests		
Heating	23	5
Temperature Cycling	24	5

Table 6.2
Testing required for battery packs

Table 6.2 revised September 21, 2005

Test	Section	Number of fully charged packs
Electrical Tests		
Short-Circuit	9	
at room temp.		5 (unsealed)
at 55°C (131°F)		5 (unsealed)
Abnormal Charge	10	5 (unsealed)
Abusive Overcharge	11	5 (unsealed)
Forced-Discharge ^a	12	5 (unsealed)
Limited Power Source	13	6 (unsealed)
Battery Enclosure Tests		
250 N Steady Force	19	3 (complete)
Mold Stress Relief	20	3 (complete)
Drop Impact	21	3 (complete)
Enclosure Flammability ^b	18	3 unsealed enclosures

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Table 6.2 Continued on Next Page

Table 6.2 Continued

Test	Section	Number of fully charged packs
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.		

6.3 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 Charge and Abusive Overcharge Tests, which shall be discharged to the manufacturer specified voltage and end points prior to testing.

7 Important Test Considerations

7.1 As some batteries explode in the tests described in Sections 9 – 24, 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.

7.2 The temperatures on the surface of the battery casings shall be monitored during the tests described in Sections 9, 10, 11, 14, and 15. 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.

7.3 The tests described in Section 22, Projectile Test, shall be conducted in a separate room or room equipped with an adequate safety barrier separating the test area from the observer.

8 Temperature Measurements

8.1 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG.

8.2 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

9 Short-Circuit

9.1 Component cells shall comply with 9.1 – 9.6.

9.2 Each fully charged test sample component cell, in turn, is to be short-circuited by connecting the positive and negative terminals of the battery with a circuit load having a maximum resistance load of 0.1 ohm. The battery is to discharge until a fire or explosion is obtained, or until it is completely discharged

9.3 Tests are to be conducted at $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$), and at $55 \pm 2^{\circ}\text{C}$ ($131 \pm 3.6^{\circ}\text{F}$). The component cells are to reach equilibrium at $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$) or $55 \pm 2^{\circ}\text{C}$ ($131 \pm 3.6^{\circ}\text{F}$) as applicable, before the terminals are connected.

9.3 revised September 21, 2005

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9.4 A component 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 component cells to be covered for each configuration as specified by the manufacturer.

9.5 A component 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 component cell connected to the maximum load that does not cause the protective device to open.

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

9.7 Battery packs shall comply with 9.8 – 9.12.

Exception: Battery packs consisting of a single cell, in which the cell has already been subjected to the tests in 9.1 – 9.6 need not comply.

9.8 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 maximum resistance load of 0.1 ohm. The battery is to discharge until a fire or explosion is obtained, or until it is completely discharged, or until the battery case temperature has peaked or reached a steady state condition

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

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

Exception: A positive temperature coefficient device which complies with the tests specified in Standard for Thermistor-Type Devices, UL 1434 and IEC 60730-1 may remain in the circuit without being faulted.

9.11 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 minimum length of 16 AWG (1.3 mm²) bare copper wire. 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.

9.12 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 internal cell jacket. The temperature of the battery pack casing shall not exceed 150°C (302°F). For battery pack samples tested in accordance with 9.11, the cheesecloth and tissue paper shall not catch fire.

10 Abnormal Charging Test

10.1 Primary component cells or battery packs shall comply with 10.2 – 10.5.

10.2 Cells or 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 $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

10.3 Each 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 hours.

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.

10.4 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.

10.5 The samples shall not explode or catch fire. For battery pack samples, tests shall not result in

10.6 Secondary component cells shall comply with 10.7 – 10.9.

10.7 The component cells are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$). Each battery shall be discharged at a constant current of $0.2C/1$ hour, to a manufacturer specified discharge endpoint voltage.

10.8 The component 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.

10.9 A battery/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 resettable or not) the test is repeated with the same charging time, but with the battery/cell connected to the maximum load that does not cause the protective

10.10 Secondary battery packs shall comply with 10.11 – 10.13.

10.11 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$). The room ambient temperature, T_{amb} , shall be recorded. A thermocouple is to be attached to each test sample battery. Each battery shall be discharged at a constant current of $0.2C/1$ hour, to a manufacturer specified discharge endpoint voltage.

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

a) 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 , specified by the manufacturer. Charging duration is the time required to reach the manufacturer's specified end-of-charge condition plus seven additional hours. The maximum temperature measured on the exterior cell or battery casing, T_{max} , shall be recorded.

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. Protective components which are faulted are to be documented.

Exception No. 1: A positive temperature coefficient device which complies with the tests specified in the Standard for Thermistor-Type Devices, UL 1434 and IEC 60730-1 may remain in the circuit without being faulted.

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

10.13 The samples shall not explode or catch fire. For battery pack samples, tests shall not result in

11 Abusive Overcharge Test

11.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

11.2 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. A thermocouple is to be attached to each test battery. For battery packs, the temperature is to be measured on the battery pack casing. The test is to continue until the cell or battery explodes, vents, or

11.3 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: A protective device which has been investigated for the purpose may remain in the circuit without being faulted.

11.4 The samples shall not explode or catch fire.

12 Forced-Discharge Test

12.1 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 $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

12.2 For multi-cell series configurations without parallel strings a completely 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

12.3 For multi-cell series configurations with parallel strings, a completely 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.

12.4 Each of the five battery packs shall be prepared as described in 12.2 or 12.3, as applicable.

12.5 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.

12.6 The positive and negative terminals of the sample are to be connected with a copper wire with a maximum resistance load of 0.1 ohms. The battery is to discharge until a fire or explosion is obtained, or until it has reached a completely discharged state of less than 0.2 volts (closed circuit condition) and the battery case temperature has returned to $\pm 10^{\circ}\text{C}$ ($\pm 18^{\circ}\text{F}$) of ambient temperature.

12.7 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 the Standard for Thermistor-Type Devices, UL 1434 and IEC 60730-1 may remain in the circuit without being faulted.

12.8 The samples shall not explode or catch fire.

13 Limited Power Source Test

13 effective October 30, 2006

13.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^\circ\text{C}$ ($68 \pm 9^\circ\text{F}$).

13.2 A limited power source battery shall comply with one of the following:

- a) The output is inherently limited in compliance with Table 13.1;
- b) An impedance limits the output in compliance with Table 13.1. If a positive temperature coefficient device is used, it shall pass the applicable tests specified in Annex J of IEC 60730-1;
- c) An overcurrent protective device is used and the output is limited in compliance with Table 13.2;
- d) A regulating network limits the output in compliance with Table 13.1, both under normal operating conditions and after any single fault in the regulating network (open circuit or short circuit); or
- e) A regulating network limits the output in compliance with Table 13.1 under normal operating conditions, and an overcurrent protective device limits the output in compliance with Table 13.2 after any single fault in the regulating network (open circuit or short circuit).

Table 13.1
Limits for inherently limited power sources

Output voltage U_{oc} , volts ^a	Output current I_{sc} , amperes ^b	Apparent power S , VA
V d.c.		
≤ 20	≤ 8	$\leq 5 \times U_{oc}$
$20 < U_{oc} \leq 30$	≤ 8	≤ 100
$30 < U_{oc} \leq 60$	$\leq 150/U_{oc}$	≤ 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, 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.

Table 13.2
Limits for battery sources not inherently limited (overcurrent protective device required)

Output Voltage U_{oc} , volts ^a	Output Current I_{sc} , amperes ^b	Apparent Power S, VA ^c	Current Rating of Overcurrent Protective Device, amperes ^d
V d.c.			
≤ 20	$\leq 1000/U_{oc}$	≤ 250	≤ 5
$20 < U_{oc} \leq 30$			$\leq 100/U_{oc}$
$30 < U_{oc} \leq 60$			$\leq 100/U_{oc}$

^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 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.

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

13.4 Batteries shall be fully charged when conducting the measurements for U_{oc} and I_{sc} according to

13.5 The load referenced in items 2) and 3) of Tables 13.1 and 13.2 shall include the threshold (I_{sc}) and (S) load values indicated in Tables 13.1 and 13.2 as well as a load adjusted to develop maximum current and power transfer respectively. Single faults in a regulating network are applied under all four of these load conditions.

13.6 Batteries that meet the requirements are eligible to include the Marking "LPS" to indicate that they are considered to be a limited power source. Batteries that do not meet these requirements, regardless of terminal design, are restricted to applications where a limited power source is not required.

MECHANICAL TESTS

14 Crush

14.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^\circ\text{C}$ ($68 \pm 9^\circ\text{F}$).

14.2 A battery is to be crushed between two flat surfaces. The force for the crushing is to be applied by a hydraulic ram with a 32 mm (1.25 inch) diameter piston. The crushing is to be continued until a pressure reading of 17.2 MPa (2500 psig) is reached on the hydraulic ram, resulting in an applied force of 13 kN (3000 pounds). Once the maximum pressure has been obtained it is to be released.

14.3 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 degrees 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.

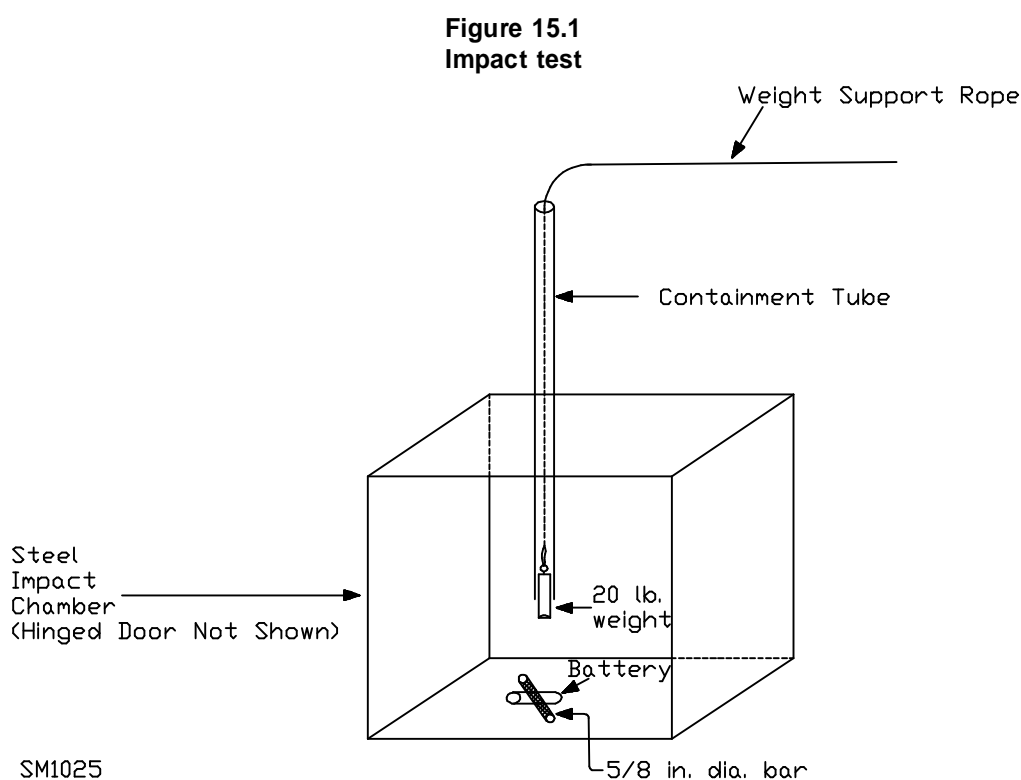
14.4 A coin or button battery is to be crushed with the flat surface of the battery parallel with the flat

14.5 The samples shall not explode or catch fire.

15 Impact

15.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

15.2 A test sample battery is to be placed on a flat surface. A 15.8 mm (5/8 inch) diameter bar is to be placed across the center of the sample. A 9.1 ± 0.46 kg (20 ± 1 pound) weight is to be dropped from a height of 610 ± 25 mm (24 ± 1 inch) onto the sample. (See Figure 15.1.)



15.3 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 inch) diameter curved surface lying across the center of the test sample. A prismatic battery is also to be rotated 90 degrees 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.

15.4 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 inch) diameter curved surface lying across its center.

15.5 The samples shall not explode or catch fire.

16 Shock

16.1 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 milliseconds 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

16.2 The samples shall not explode or catch fire.

16.3 The sample shall be examined 6 hours after testing and shall not vent or leak as described in 5.2.

17 Vibration

17.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

17.2 A battery is to be subjected to simple harmonic motion with an amplitude of 0.8 mm (0.03 inch) [1.6 mm (0.06 inch) total maximum excursion].

17.3 The frequency is to be varied at the rate of 1 hertz per minute between 10 and 55 hertz and return in not less than 90 nor more than 100 minutes. The battery is to be tested in three mutually perpendicular directions. For a battery that has only two axes of symmetry, the battery is to be tested perpendicular to each axis.

17.4 The samples shall not explode or catch fire.

17.5 The sample shall be examined 6 hours after testing and shall not vent or leak as described in 5.2.

BATTERY ENCLOSURE TESTS

18

18.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

18.2 Batteries with outer plastic enclosures shall be subjected to the tests described in Sections 19, 20, and 21.

19 250 N Steady Force Test

19.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

19.2 External enclosures of the battery pack are to be subjected to a steady force of 250 ± 10 N (56 ± 2 pounds force) for a period of 5 seconds, applied in turn to the top, bottom and sides of the battery pack enclosure by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 inches) in diameter.

19.3 The samples shall not explode or catch fire. In addition, the outer battery enclosure shall not crack to the extent that the cells or any protective devices are exposed.

19.4 The sample shall be examined 6 hours after testing and shall not vent or leak as described in 5.2.

20 Mold Stress Relief Test

20.1 Each of three samples are to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70°C (158°F). The samples are to remain in the oven for 7 hours.

Exception: If the maximum temperature, T_{max} , recorded during the Abnormal Charging Test, 10.12 a) exceeds 60°C (140°F), then the oven temperature is to be maintained at a temperature equal to $T_{\text{max}} + 10^{\circ}\text{C}$ (50°F).

20.2 After careful removal from the oven and return to room temperature, following the conditioning described in 20.1, the samples shall show no evidence of mechanical damage, such as cracking of the

20.3 The samples shall not explode or catch fire. The sample shall not vent or leak as described in 5.2. In addition, the outer battery enclosures shall not crack to the extent that the cells or any protective devices are exposed.

21 Drop Impact

21.1 The batteries are to be tested in an ambient temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

21.2 Each of three samples is to be dropped from a height of 1 m (3.28 ft) so it strikes a concrete surface in the position that is most likely to produce the adverse results in 21.3. Each sample is to be dropped three times.

21.3 The samples shall not explode or catch fire.

21.4 The sample shall be examined 6 hours after testing and shall not vent or leak as described in 5.2, and the integrity of the protective devices shall be maintained.

21.5 The outer battery enclosure shall not crack to the extent that cells or any protective devices are

FIRE EXPOSURE TESTS

22 Projectile

22.1 When subjected to the test described in 22.2 – 22.5 no part of an exploding cell or battery shall create a hole in the wire screen cage or penetrate the wire screen cage such that some or all of the cell or battery protrudes through the screen cage.

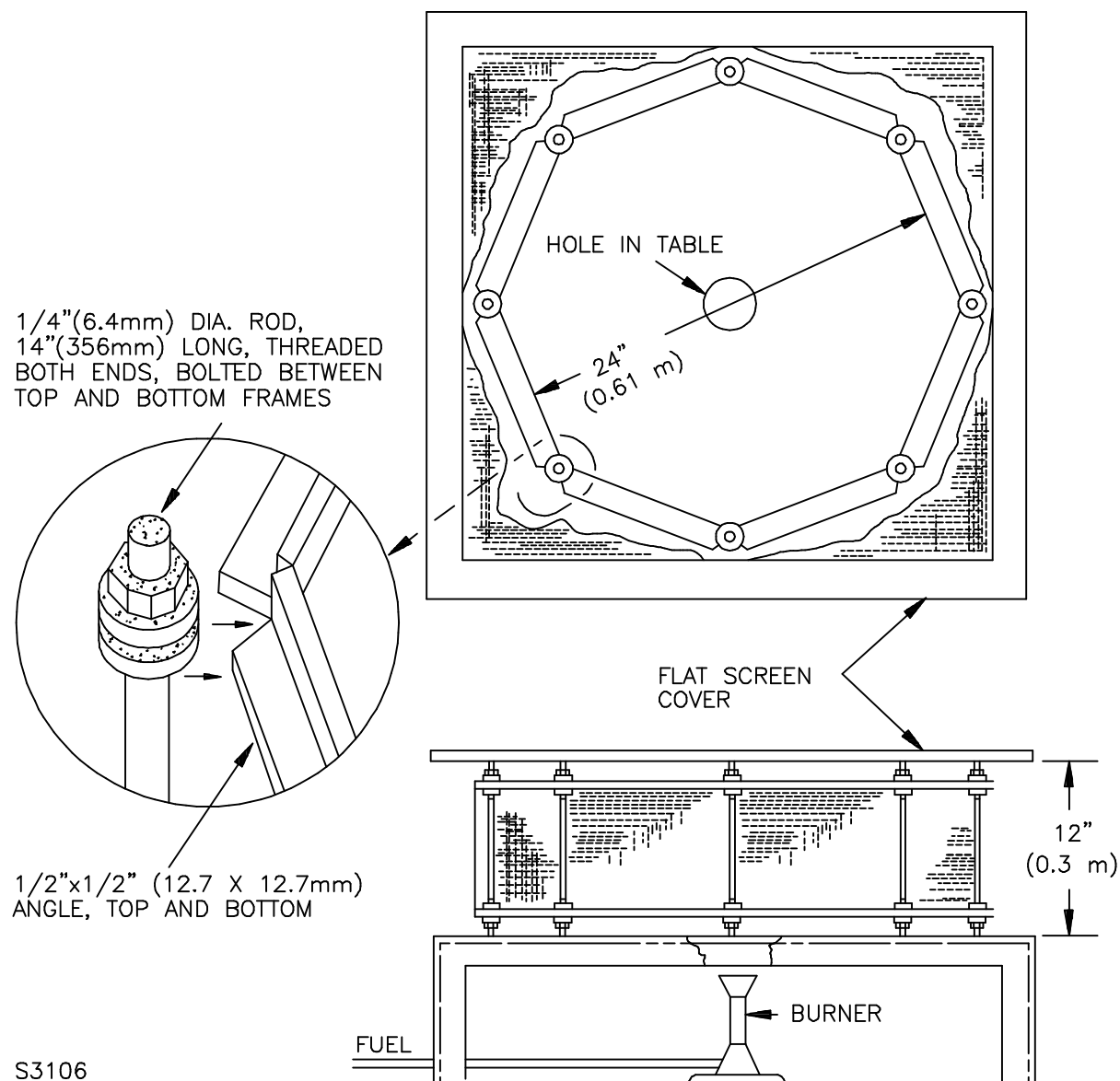
22.2 Each test sample cell or battery is to be placed on a screen that covers a 102 mm (4 inch) diameter hole in the center of a platform table. The screen is to be constructed of steel wire mesh having 20

22.3 The screen is to be mounted 38 mm (1-1/2 inch) above a burner. The fuel and air flow rates are to be set to provide a bright blue flame that causes the supporting screen to glow a bright red.

22.4 An eight-sided covered wire cage, 610 mm (2 feet) across and 305 mm (1 foot) high, made from metal screening is to be placed over the test sample. See Figure 22.1. The metal screening is to be constructed from 0.25 mm (0.010 inch) diameter aluminum wire with 16 – 18 wires per inch (25.4 mm) in each direction.

22.5 The sample is to be heated and shall remain on the screen until it explodes or the cell or battery has ignited and burned out. It is not required to secure the sample in place unless it 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.

Figure 22.1
Test apparatus for projectile test



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ENVIRONMENTAL TESTS

23 Heating

23.1 The sample shall not explode or catch fire when subjected to the test described in 23.2 – 23.4.

23.2 A battery is to be heated in a gravity convection or circulating air oven with an initial temperature of $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$).

23.3 The temperature of the oven is to be raised at a rate of $5 \pm 2^{\circ}\text{C}$ ($9 \pm 3.6^{\circ}\text{F}$) per minute to a temperature of $130 \pm 2^{\circ}\text{C}$ ($266 \pm 3.6^{\circ}\text{F}$) and remain at that temperature for 10 minutes.

23.4 The sample shall return to room temperature ($20 \pm 5^{\circ}\text{C}$) and then be examined.

24 Temperature Cycling Test

24.1 The batteries are to be placed in a test chamber and subjected to the following cycles:

- a) Raising the chamber-temperature to $70 \pm 3^{\circ}\text{C}$ ($158 \pm 5^{\circ}\text{F}$) within 30 minutes and maintaining this temperature for 4 hours.
- b) Reducing the chamber temperature to $20 \pm 3^{\circ}\text{C}$ ($68 \pm 5^{\circ}\text{F}$) within 30 minutes and maintaining this temperature for 2 hours.
- c) Reducing the chamber temperature to minus $40 \pm 3^{\circ}\text{C}$ (minus $40 \pm 5^{\circ}\text{F}$) within 30 minutes and maintaining this temperature for 4 hours.
- d) Raising the chamber temperature to $20 \pm 3^{\circ}\text{C}$ ($68 \pm 5^{\circ}\text{F}$) within 30 minutes.
- e) Repeating the sequence for a further 9 cycles.
- f) After the 10th cycle, storing the batteries for a minimum of 24 hours prior to examination.

24.2 The samples shall not explode or catch fire. In addition, the samples shall not vent or leak as

MARKING

25

25.1 A battery 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" or "model") number or the equivalent;
- c) The electrical rating; and
- d) 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

- a) Does not repeat in less than 10 years for a household product and less than 20 years for a commercial product, and
- b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

25.2 When a manufacturer produces the battery at more than one factory, each battery shall have a

25.3 A battery or the smallest unit package or instructions provided with each battery shall include the following statements or equivalent:

- a) An attention word, such as "Caution," "Warning," or "Danger."
- b) A brief description of possible hazards associated with mishandling of the battery, such as burn hazard, fire hazard, explosion hazard.
- c) A list of actions to take to avoid possible hazards, such as do not crush, disassemble, dispose of in fire, or similar actions.

25.4 The manufacturer's specified charging instructions shall be included.

25.5 A cell or battery that is less than 32 mm (1.25 inches) in diameter by 3.8 mm (0.15 in) thick shall include the following marking or equivalent on the smallest unit package or instructions provided with each cell or battery:

"Caution – Never put batteries in mouth. If swallowed, contact your physician or local poison

25.6 Batteries which meet the requirements of the Limited Power Source Test, Paragraph 13.4, may

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**Superseded requirements for
the Standard for
Household and Commercial Batteries**

UL 2054, Second Edition

The requirements shown are the current requirements that have been superseded by requirements in revisions issued for this Standard. To retain the current requirements, do not discard th

13 Limited Power Source Test

Section 13 effective until October 30, 2006

13.1 Determine the maximum power output capability, P_{MAX} , of the cell or battery, by varying the load impedance from open circuit to short circuit. Overcurrent or thermal protective devices shall be disabled or bypassed.

13.2 Three sample batteries are to be used for this test. The batteries shall be in the fully charged condition with overcurrent or thermal protective devices enabled (operational). The battery is to be loaded to the equivalent resistance load that produced P_{MAX} in 13.1 using a length of AWG 20 Nichrome wire. Two layers of cheesecloth shall be draped over the Nichrome wire in this test. The steady state circuit

13.3 When an overcurrent or thermal 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 will not cause the protective device to open. A protective device that has not been investigated for

13.4 A cell or battery shall comply with the following requirements:

- a) The maximum output current after 60 seconds shall be less than or equal to 8.0 amp, and
- b) The power output shall be less than 5 times the open circuit voltage, measured at the end of a 60-second period, and
- c) The cheesecloth shall not ignite.

Cells and batteries that meet the requirements are eligible to include the Marking "LPS" to indicate that they are considered to be a limited power source. Cells and batteries that do not meet these requirements are restricted to applications where a limited power source is not required.

Exception: Batteries designed such that they cannot be externally shorted, (such as batteries equipped with retractable leads), need not meet these requirements.

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