



# UL 1642

## STANDARD FOR SAFETY

### Lithium Batteries

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UL Standard for Safety for Lithium Batteries, UL 1642

Sixth Edition, Dated September 29, 2020

### **Summary of Topics**

***This revision of UL 1642 dated October 12, 2022 includes new test requirements for a Round Bar Crush Test instead of the Impact Test for soft-case pouch cells; [5.1.2](#), [Table 6.1](#), [Table 6.2](#), [14.2](#), and Section [14A](#).***

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 1, 2022.

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## **UL 1642**

### **Standard for Lithium Batteries**

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**September 29, 2020**

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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 primary (nonrechargeable) and secondary (rechargeable) lithium batteries for use as power sources in products. These batteries contain metallic lithium, or a lithium alloy, or a lithium ion, and may consist of a single electrochemical cell or two or more cells connected in series, parallel, or both, that convert chemical energy into electrical energy by an irreversible or reversible chemical reaction.

1.2 These requirements cover lithium batteries intended for use in technician-replaceable or user-replaceable applications.

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

1.4 These requirements are also intended to reduce the risk of injury to persons due to fire or explosion when user-replaceable lithium batteries are removed from a product and discarded.

1.5 These requirements cover technician-replaceable lithium batteries that contain 5.0 g (0.18 oz) or less of metallic lithium. A battery containing more than 5.0 g (0.18 oz) of lithium is judged on the basis of compliance with the requirements in this standard, insofar as they are applicable, and further examination and test to determine whether the battery is acceptable for its intended uses.

1.6 These requirements cover user-replaceable lithium batteries that contain 4.0 g (0.13 oz) or less of metallic lithium with not more than 1.0 g (0.04 oz) of metallic lithium in each electrochemical cell. A battery containing more than 4.0 g (0.13 oz) or a cell containing more than 1.0 g (0.04 oz) lithium may require further examination and test to determine whether the cells or batteries are acceptable for their intended uses.

1.7 These requirements do not cover the toxicity risk that may result from the ingestion of a lithium battery or its contents, nor the risk of injury to persons that may occur if a battery is cut open to provide access to the metallic lithium.

### 2 General

#### 2.1 Units of measurement

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

#### 2.2 Terminology

2.2.1 The terms "lithium battery(ies)" and "battery(ies)" refer to both user-replaceable and technician-replaceable lithium batteries.

#### 2.3 Components

2.3.1 A component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components generally used in the products covered by this standard.

2.3.2 A protective device shall be used within the ratings of the device. A protective device shall be evaluated as part of the "Whole Cell" or "Whole Battery" evaluation in accordance with the performance requirements outlined in this standard.

### 3 Glossary

3.1 For the purpose of this standard the following definitions apply.

3.2 BATTERY – General term for (1) A 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 rigid enclosure, with or without protective devices.

3.4 BATTERY, PRIMARY – A battery which can only be discharged once. It is not designed to be rechargeable 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 BATTERY, TECHNICIAN-REPLACEABLE – A battery intended for use in a product in which service and replacement of the battery will be done only by a person who has been trained to service and repair the product.

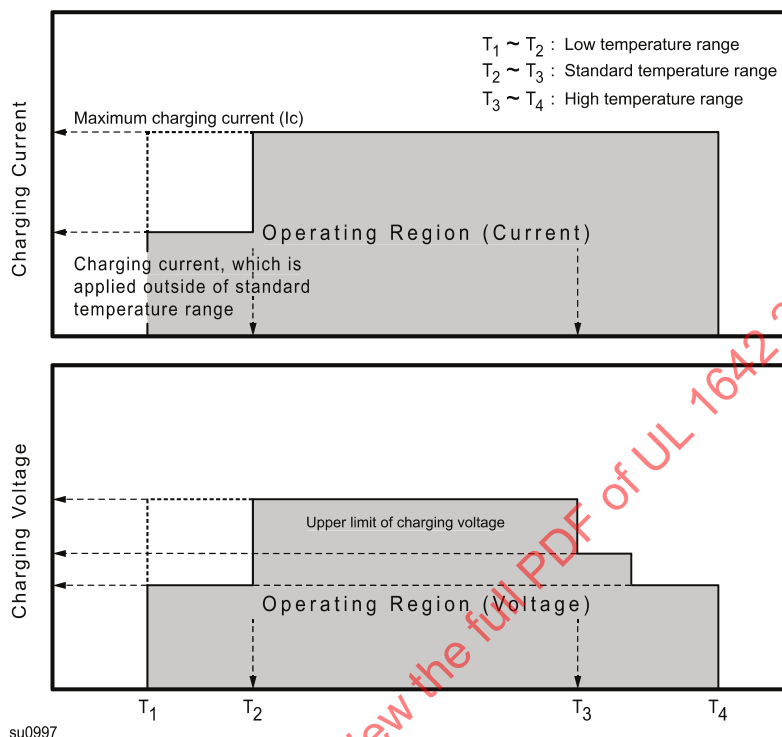
3.7 BATTERY, USER-REPLACEABLE – A battery intended for use in a product in which service and replacement of the battery may be done by the user.

3.8 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. The casing form factors noted for cells in this standard are cylindrical, prismatic, coin and pouch.

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 a component of a battery pack.

3.10 CELL OPERATING REGION (lithium ion systems) – The conditions during charging and discharging in which the cell operates within its voltage and current and temperature range as specified by the cell manufacturer. See [Figure 3.1](#) for a graphic representation of the cell operating region.

**Figure 3.1**  
**Diagram Representing an Example of a Cell Operating Region**  
**(from the Battery Association of Japan)**



**3.11 CHARGED, FULLY** – A battery is considered fully charged when the maximum amount of electrical capacity, as specified by the manufacturer, is stored in the battery.

**3.12 COMPONENT, CURRENT-LIMITING** – Any component employed to limit current during abnormal conditions. Current-limiting components include resistors, fuses, or thermal cutoffs.

**3.13 CURRENT, ABNORMAL CHARGING** – Charging current to a primary cell or battery under fault condition.

**3.14 DISCHARGED, COMPLETELY** – A primary cell or battery is considered completely discharged if the closed circuit voltage is less than 0.2 V, when connected to a 100-Ω resistive load and the short-circuit current has been reduced to less than 1 mA.

**3.15 DISCHARGE, FORCED** – Discharge of a battery by connection in series with an external power source so as to drive the battery into polarity reversal.

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

**3.17 DISCHARGED, HALF** – A battery is considered half discharged when half of the battery's rated electrical capacity has been drained from it.

**3.18 EXPLOSION** – When the cell or battery contents are forcibly expelled and the cell or battery casing is torn or split into two or more pieces.

3.19 MATERIAL, TOXIC – Any material having a toxic hazard rating of 2, moderate, in the Sax Dangerous Properties of Industrial Materials reference book or related reference guide.

3.20 MAXIMUM CHARGING CURRENT (lithium ion systems) – The maximum charging current in the cell operating region, which is specified by the cell manufacturer.

3.21 POUCH CELL – A cell which is often prismatic in shape and whose contents are enclosed within a sealed flexible pouch rather than a rigid casing.

3.22 ROOM TEMPERATURE – Approximately 23°C (73°F).

3.23 UPPER LIMIT CHARGING VOLTAGE (lithium ion systems) – The highest charging voltage 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.

3.24 VENTING – When the battery or cell electrolyte is emitted as a liquid, droplets, or vapor from a designed vent or through a seal.

## CONSTRUCTION

### 4 General

#### 4.1 Casing

4.1.1 The casing of a lithium battery shall have the strength and rigidity necessary to resist the abuses to which it may be subjected, without resulting in a risk of fire. The casing of a user-replaceable lithium battery shall have the strength and rigidity necessary to resist the abuses to which it may be subjected without resulting in a risk of injury to persons.

4.1.2 A cell of a user-replaceable battery shall be in a rigid casing of sufficient strength to prevent flexing. A tool providing the mechanical advantage of a pliers, screwdriver, or hacksaw shall be the minimum capable of opening the user-replaceable cell casing, if opening of the casing will expose metallic lithium.

*Exception: This requirement does not apply to a cell containing less than 0.02 g (0.0007 oz) of lithium metal.*

#### 4.2 Electrolyte

4.2.1 A user-replaceable battery shall not contain pressurized vapor or liquid that could spray materials into the eyes or leak more than 5 mL of liquid when the battery casing is punctured under normal laboratory conditions, 23 ±2°C (73 ±3.6°F).

#### 4.3 Use

4.3.1 A lithium battery shall be protected from abnormal charging currents during use. A battery tested and found acceptable for the charging current,  $I_C$  (see Section 11), under fault conditions specified by the manufacturer, shall be protected from larger charging currents in the end product application by:

- a) Two blocking components, such as diodes; or
- b) One blocking component and one current limiting component, such as a resistor or a fuse.

The current limiting component shall limit the charging current to one-third the value used in the Abnormal Charging Test, Section [11](#).

*Exception No. 1: Charge protection in the battery circuit is not required in end product applications where a battery cannot be subjected to a charging current, such as a battery operated device.*

*Exception No. 2: Protection components are not required for specific applications where a battery has been tested and found not to have a risk of explosion.*

*Exception No. 3: A rechargeable battery requires only a current limiting component, not a blocking component.*

## PERFORMANCE

### 5 General

#### 5.1 Technician-replaceable batteries

5.1.1 Technician-replaceable lithium cells or batteries are to be tested as described in Sections [10](#) – [20](#). Section [12](#), Forced-Discharge Test, is applicable only to cells intended to be used in series-connected multicell applications such as battery packs. For multicell installations, also see [5.3.1](#).

5.1.2 When a fire or explosion occurs as a result of the Crush Test, Section [13](#), the Impact Test, Section [14](#), or the Round Bar Crush Test, Section [14A](#), or the cell or battery ruptures to the extent that the aluminum test cage is penetrated during the Projectile Test, Section [20](#); the use of the technician replaceable cell or battery shall be restricted to applications in which it is not exposed to, or is protected from, any conditions shown to cause a fire or explosion.

5.1.3 Cells and batteries subjected to the Shock Test, Section [15](#), Vibration Test, Section [16](#), Temperature Cycling Test, Section [18](#), and Low Pressure (Altitude Simulation) Test, Section [19](#), shall also not leak or vent. For these tests, unacceptable leakage is determined to have occurred when the resulting mass loss exceeds the values shown in [Table 5.1](#), Venting and leakage mass loss criteria.

**Table 5.1**  
**Venting and Leakage Mass Loss Criteria**

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

#### 5.2 User-replaceable batteries

5.2.1 User-replaceable lithium cells or batteries are to be tested as described in Sections [10](#) – [20](#). Section [12](#), Forced-Discharge Test, is applicable only to cells intended to be used in series-connected, multicell applications such as battery packs. In addition to complying with the requirements for a technician replaceable cell or battery as specified in [5.1.1](#), a user-replaceable cell or battery shall not explode or ignite when subjected to the Crush Test, Section [13](#), or the Impact Test, Section [14](#). A user-replaceable battery shall comply with the requirements for Sections [10](#) – [20](#) and with the applicable construction requirements outlined in Section [4](#). Secondary lithium cells shall not be considered user-replaceable.

5.2.2 Sets of five specimens each are to be used for the Projectile Test, Section 20; see Table 6.1. When only one specimen from a set of five does not comply with the requirements, another set of five specimens is to be tested. All specimens from this second set shall comply with the requirements.

### 5.3 Multicell installations

5.3.1 A technician-replaceable or user-replaceable cell intended for use in multicell installations or battery packs shall also be tested as described in 10.3 and Section 12. No fire or explosion shall occur as a result of these tests. In addition, batteries subjected to the test described in 10.3 shall meet the requirements as described in 5.1.1 and 5.2.1 for a cell or battery subjected to the Short-Circuit Test, Section 10.

## 6 Samples

6.1 Fully charged primary cells or batteries and primary cells or batteries that have been conditioned by partial or complete discharge, or both, are to be used for the tests described in Sections 10 – 20. The number of samples to be used in each test for a primary cell or battery is shown in Table 6.1. When a group of cells or batteries of different sizes, but similar chemistries is involved, selected sizes representative of the range are to be tested.

**Table 6.1**  
**Number of Batteries to be Used in Each Test for Primary Batteries**

Test	Conditioning of batteries		
	Fully charged	One half discharged <sup>a</sup>	Complete discharged
<b>Electrical Tests</b>			
Short-Circuit <sup>b</sup>			
at room temperature	5	5	—
at 55°C (131°F)	5	5	—
Abnormal Charge	5	5	5
Forced-Discharge <sup>c</sup>	5	5	—
<b>Mechanical Tests</b>			
Crush	5	5	—
Impact/Round Bar Crush <sup>d</sup>	5	5	—
Shock	5	5	5
Vibration	5	5	5
<b>Environmental Tests</b>			
Heating	5	5	—
Temperature Cycling	5	5	5
Low Pressure (Altitude Simulation)	5	5	5
<b>Fire Exposure Test<sup>e</sup></b>			
Projectile	5 (10)	—	—

<sup>a</sup> Only cells with a liquid cathode, such as thionyl chloride or sulfur dioxide, are conditioned by one-half discharge.

<sup>b</sup> For multi cell use, see 10.3.

<sup>c</sup> For series use only, see 12.2 for details on samples.

<sup>d</sup> For cylindrical cells and prismatic cells, use the Impact Test, Section 14; for pouch cells use either the Impact Test, Section 14 or the Round Bar Crush Test, Section 14A.

<sup>e</sup> The projectile test may be waived on those primary cells intended for only technician replacement applications (i.e. liquid cathode types).

6.2 Fully charged secondary cells or batteries and secondary cells or batteries that have been conditioned by charge-discharge cycling are to be used for the tests described in Sections [10](#) – [20](#). The number of samples to be used in each test for a secondary cell or battery is shown in [Table 6.2](#). When a group of cells or batteries of different sizes, and similar chemistries is involved, selected sizes representative of the range are to be tested.

**Table 6.2**  
**Number of Batteries to be Used in Each Test for Secondary Batteries**

Test	Fully charged	Batteries conditioned by charge-discharge cycling
<b>Electrical Tests</b>		
Short-Circuit <sup>a</sup>		
at room temperature	5	5
at 55°C (131°F)	5	5
Abnormal Charge	5	5
Forced-Discharge <sup>b</sup>	5	5
<b>Mechanical Tests</b>		
Crush <sup>a</sup>	5	5
Impact/Round Bar Crush <sup>d</sup>	5	5
Shock	5	5
Vibration	5	5
<b>Environmental Tests</b>		
Heating	5 (10) <sup>c</sup>	5 (10) <sup>c</sup>
Temperature Cycling	5	5
Low Pressure (Altitude Simulation)	5	5
<b>Fire Exposure Test</b>		
Projectile <sup>e</sup>	5 (10)	–
<sup>a</sup> For multicell use, see <a href="#">10.3</a> . <sup>b</sup> For series use only, see <a href="#">12.2</a> for details on samples. <sup>c</sup> For lithium ion cells due to need to test cells conditioned at the operating region boundaries per <a href="#">6.3</a> – <a href="#">6.5</a> . <sup>d</sup> For cylindrical cells and prismatic cells, use the Impact Test, Section <a href="#">14</a> ; for pouch cells use either the Impact Test, Section <a href="#">14</a> or the Round Bar Crush Test, Section <a href="#">14A</a> . <sup>e</sup> Five more samples may be retested if there is a noncompliance in the first set of five tested.		

6.3 Prior to conducting the testing in Section [17](#), the lithium ion cell samples shall be pre-conditioned as outlined in [6.4](#) and [6.5](#).

6.4 For the heating test of Section [17](#), two sets of five lithium ion cell samples are to be fully discharged (i.e. to the manufacturer's specified end point voltage). The samples are then placed in a test chamber and conditioned for 1 to 4 h (5 samples at the upper temperature limit and 5 samples at the lower temperature limit of the operating region) as outlined in [Table 6.3](#).



**Table 6.3**  
**Standard Conditioning and Charging Parameters for Lithium Ion Cells**

Chemistry	Upper limit charging voltage Vdc	Maximum charging current A	Upper temperature limit <sup>a</sup> °C (°F)	Lower temperature limit <sup>b</sup> °C (°F)
Lithium cobalt oxide systems	4.25	Specified by the manufacturer	45 (113)	10 (50)
other <sup>c</sup>	Specified by the manufacturer	Specified by the manufacturer	c	d

<sup>a</sup> Shown as "T<sub>3</sub>" in [Figure 3.1](#).  
<sup>b</sup> Shown as "T<sub>2</sub>" in [Figure 3.1](#).  
<sup>c</sup> If the manufacturer's specified upper temperature limit is greater than 45°C (113°F), use the manufacturer's specified upper temperature limit plus 5°C (9°F), otherwise use 45°C (113°F).  
<sup>d</sup> If the manufacturer's specified lower temperature limit is less than 10°C (50°F), use the manufacturer's specified lower temperature limit minus 5°C (9°F), otherwise use 10°C (50°F).  
<sup>e</sup> Manufacturers that specify a higher upper limit charging voltage or charging temperatures above or below standard limits established for lithium cobalt oxide systems, are to provide data such as test results and other engineering analysis supporting the stability of the system at these other specified standard charging parameters. Ultimately compliance will be determined by the results of the heating test of Section [17](#).

6.5 While still in the test chamber set at the temperature limits, the samples are charged (5 samples at the upper temperature limit and 5 samples at lower temperature limit) at the specified maximum charging current and upper limit charging voltage per [Table 6.3](#), using a constant voltage charging method. Charging is continued until the charge current is reduced to the specified end of charge conditions (i.e. 0.05 times the charge current).

## 7 Conditioning of Samples

### 7.1 Discharge

7.1.1 Primary batteries are to be completely discharged by connecting their terminals through resistors that provide the desired level of discharge within 60 days. Batteries are to be discharged at room temperature. Cells with a liquid cathode such as thionyl chloride or sulfur dioxide, shall also be conditioned by one-half discharge.

7.1.2 For solid electrolyte and other types of primary lithium batteries that cannot be discharged within 60 days because of the small currents they inherently produce, longer discharge times plus discharge at higher temperatures may be used to obtain the desired level of discharge. The manufacturer's recommended discharge procedures are to be followed so as to obtain the required discharge level in the minimum time.

### 7.2 Charge-discharge cycling

7.2.1 Secondary cells are to be conditioned at 25°C (77°F). Cells are continuously cycled as per the manufacturer's specifications. The specification shall be such that the full rated capacity of the cell is utilized and the number of cycles accumulated shall be at least equal to 25% of the advertised cycle life of the cell or cycled continuously for 90 days, whichever is shorter. Cycling is to be done either individually or in groups. Cells are to be recharged prior to testing as indicated in [Table 6.2](#).

## 8 Important Test Considerations

8.1 Some lithium batteries are capable of exploding when the tests described in Sections [10](#) – [20](#) are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden



release of heat, and noise that results from such explosions. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases.

8.2 As an additional precaution, the temperatures on the surface of the battery casings shall be monitored during the tests described in Sections [10](#), [11](#), [12](#), [13](#), and [14](#). All personnel involved in the testing of lithium batteries are to be instructed never to approach a lithium battery while the surface temperature exceeds 90°C (194°F) and not to touch the lithium battery while the surface temperature exceeds 45°C (113°F).

8.3 For protection, the Projectile Test, Section [20](#) is to be conducted in a room separate from the observer.

## 9 Temperature Measurements

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

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

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

## TESTS FOR TECHNICIAN-REPLACEABLE AND USER-REPLACEABLE BATTERIES

### ELECTRICAL TESTS

## 10 Short-Circuit Test

10.1 Each test sample battery, 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 completely discharged state of less than 0.2 V and the battery case temperature has returned to ±10°C (±18°F) of ambient temperature. The voltage at the end of the test may not reach 0.2 V due to operation of protective devices in the circuit. The return to near ambient of the battery (cell) casing is an indication of ultimate results.

10.2 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 or 55 ±5°C, as applicable, before the terminals are connected.

10.3 A battery is to be tested individually unless the 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 batteries to be covered for each configuration.

10.4 When an overcurrent protective device activates 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. Protective devices that are relied upon to meet the compliance criteria for the short circuit test shall comply with [2.3.1](#).

10.5 The samples shall not explode or catch fire.

## 11 Abnormal Charging Test

11.1 Primary cells or batteries shall comply with [11.2](#) – [11.7](#).

11.2 Cells or batteries conditioned in accordance with [Table 6.1](#), as applicable, are to be used for this test. The batteries are to be tested in an ambient temperature of  $20 \pm 5^{\circ}\text{C}$  ( $68 \pm 9^{\circ}\text{F}$ ).

11.3 Each test sample battery is to be subjected to a charging current of three times the current  $I_c$ , specified by the manufacturer by connecting it in opposition to a dc-power supply. The specified charging current is to be obtained by connecting a resistor of the specified size and rating in series with the battery. The test charging time is to be calculated using the formula:

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

In which:

$t_c$  is the charging time in hours;

C is the capacity of the cell/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 time as 7 h.*

11.4 When a non-resettable overcurrent or protective device operates during the test, the test is to be repeated at a charge current below the level that the protective device operates. When a resettable protective device operates during the test, the protector is allowed to reset to a total of 10 cycles; or until the appropriate charging time has been completed, but not less than 7 h. Protective devices that are relied upon to meet the compliance criteria for the abnormal charging test shall comply with [2.3.1](#).

11.5 The samples shall not explode or catch fire.

11.6 Secondary cells or batteries shall comply with [11.7](#) – [11.10](#).

11.7 Cells or batteries conditioned in accordance with [Table 6.2](#), as applicable, are to be used for this test. The batteries are to be tested in an ambient temperature of  $20 \pm 5^{\circ}\text{C}$  ( $68 \pm 9^{\circ}\text{F}$ ).

11.8 Each test sample battery is to be discharged at a constant current of 0.2 C/1 h, to a manufacturer specified discharge endpoint voltage. The cell or battery is then to be charged with a constant maximum specified output voltage and a current limit of three times the maximum charging current,  $I_c$ , specified by the manufacturer. Charging duration is to be 7 h or the time required to reach the manufacturer's specified end-of-charge condition, whichever is greater.

11.9 When a non-resettable overcurrent or protective device operates during the test, the test shall be repeated at an overcharging current below the level that the protection device operates. When a resettable protective device operates during the test, the protector is to be allowed to reset to a total of 10 cycles; or until the appropriate charging time has been completed, but not less than 7 h. Protective devices that are relied upon to meet the compliance criteria for the abnormal charging test shall comply with [2.3.1](#).

11.10 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 series-connected, multicell applications, such as battery packs.

12.2 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 maximum number less one of the cells to be covered for series use. Five cells are to be fully discharged, at room temperature.

12.3 Once the fully discharged cell is connected in series with the specified number of fully charged cells the resultant battery pack is to be short circuited.

12.4 The positive and negative terminals of the sample are to be connected with a resistance load of  $80 \pm 20 \text{ m}\Omega$ . The sample is to discharge until a fire or explosion is obtained, or until it has reached a completely discharged state of less than 0.2 V and the battery case temperature has returned to  $\pm 10^\circ\text{C}$  ( $18^\circ\text{F}$ ) of ambient temperature. The voltage at the end of the test may not reach 0.2 V due to operation of protective devices in the circuit. The return to near ambient of the cell casing is an indication of ultimate results.

12.5 When an overcurrent protective device operates 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. Protective devices that are relied upon to meet the compliance criteria for the forced discharge test shall comply with [2.3.1](#).

12.6 The samples shall not explode or catch fire.

## MECHANICAL TESTS

### 13 Crush Test

13.1 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  $13 \pm 1 \text{ kN}$  ( $3000 \pm 224 \text{ lbs}$ ) is reached. Once the maximum force has been obtained it is to be released.

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

*Exception: For lithium ion systems, a cylindrical, pouch or prismatic cell is to be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. Each sample is to be subjected to a crushing force in only one direction. Test only the wide side of pouch and prismatic cells.*

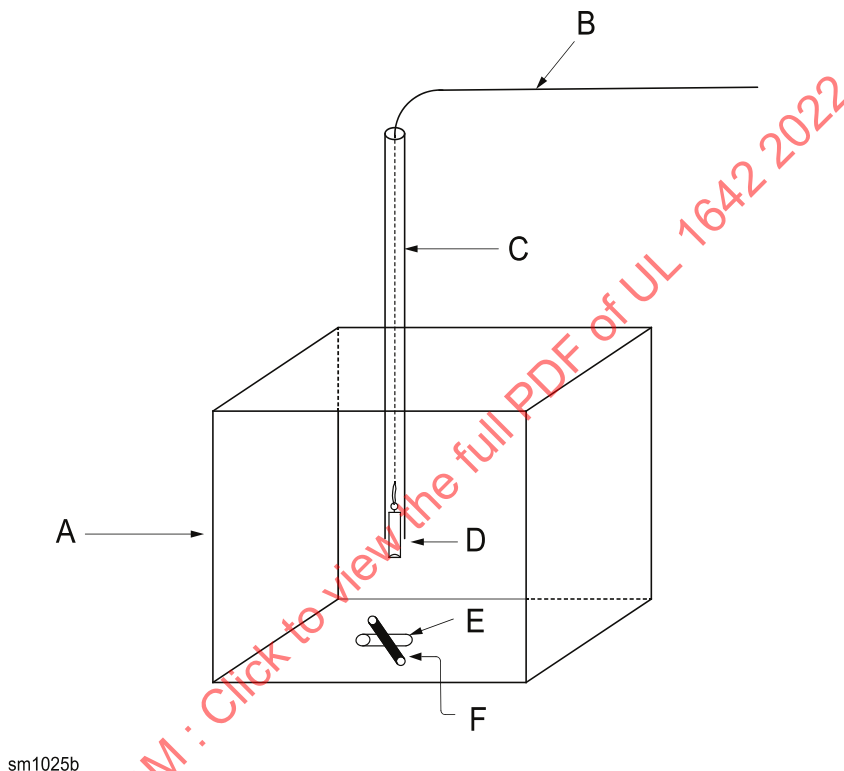
13.3 A coin or button battery is to be crushed with the flat surface of the battery parallel with the flat surfaces of the crushing apparatus.

13.4 The samples shall not explode or catch fire.

## 14 Impact Test

14.1 A test sample battery is to be placed on a flat surface. A  $15.8 \pm 0.1$ -mm ( $5/8 \pm 0.004$ -in) diameter bar is to be placed across the center of the sample. A  $9.1 \pm 0.46$ -kg ( $20 \pm 1$ -lb) weight is to be dropped from a height of  $610 \pm 25$  mm ( $24 \pm 1$  in) onto the sample. See [Figure 14.1](#).

**Figure 14.1**  
**Impact Test**



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

**Exception No. 1:** For lithium ion systems, a cylindrical, pouch or prismatic cell is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15.8-mm ( $5/8$ -in) diameter curved surface lying across the center of the test sample. Each sample is to be subjected to only a single impact. Test only the wide side of pouch and prismatic cells.

**Exception No. 2:** Pouch cells not evaluated to this test, and with a capacity greater than 300 mAh, shall comply with the Round Bar Crush Test in Section [14A](#).

14.3 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.

14.4 The samples shall not explode or catch fire.

## 14A Round Bar Crush Test

14A.1 With reference to Exception No. 2 in [14.2](#), pouch cells not evaluated with the Impact Test in Section [14](#) and with a capacity greater than 300 mAh shall be evaluated with this test.

14A.2 The sample shall be fully charged with the method recommended by the manufacturer.

14A.3 The sample shall be positioned on a flat surface with a  $25 \pm 1$  mm ( $1 \pm 0.039$  in) diameter steel round bar placed on top of the sample. The edge of the bar is to be aligned with the top edge of the cell body, with the longitudinal axis of the bar perpendicular to the tab of the cell. The bar shall extend beyond the width of the test sample on each side by at least 5 mm (0.197 in) as shown in [Figure 14A.1](#). A preload pressure of  $0.4 - 0.6$  N/cm<sup>2</sup> (0.58 – 0.87 psi) shall be applied before the sample thickness is measured in [14A.5](#) and the crush force in [14A.6](#) is applied. See [14A.4](#).

NOTE: A sample may be taped, glued or clamped to the flat surface, avoiding obstructing the round bar placement and crush plate motion, to eliminate any unevenness between the sample and the flat test surface.

14A.4 For cells with the positive tab and negative tab on opposite sides, the bar placement in [14A.3](#) and the crush force application in [14A.6](#) are applied on each side of the cell near the tabs, using a different set of samples for each side.

14A.5 After the bar placement per [14A.3](#) or [14A.4](#) and the preload pressure is applied per [14A.3](#), the thickness of the sample shall be measured allowing a tolerance of  $\pm 0.1$  mm ( $\pm 0.039$  in), using the Measuring Method of Cell Thickness in the Annex for Dimensions of the Cell with a Laminate Film Case in the Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Secondary Lithium Cells and Batteries for Portable Applications – Part 3: Prismatic and Cylindrical Lithium Secondary Cells, and Batteries Made from Them, IEC 61960-3.

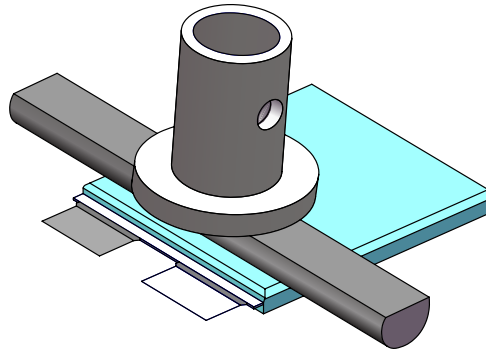
14A.6 A crush force shall be applied onto the round bar, with a crushing direction of  $90 \pm 1^\circ$  between the crushing direction and round bar and the crushing direction and test platform. The displacement in the vertical direction shall be measured. The moving speed of the crush plate is to be no greater than 0.1 mm/s (0.004 in/s). The displacement of the crush plate shall be stopped and held for 30 s once the cell deformation reaches  $13 \pm 1\%$  of the cell thickness (starting from the preload thickness measured in [14A.5](#)) or the crush force reaches the force value in [Table 14A.1](#), whichever comes first. See [Figure 14A.1](#) and [Figure 14A.2](#).

14A.7 The sample shall not explode or catch on fire.

**Table 14A.1**  
**Round Bar Crush Test Crush Force**

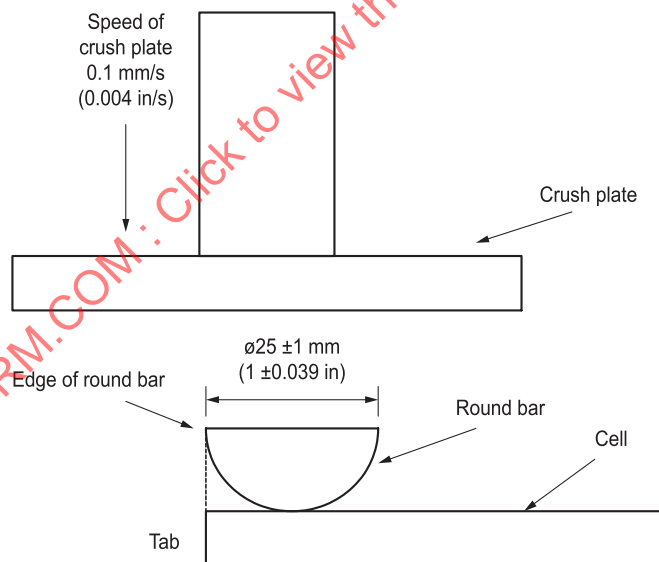
Cell width		Force	
mm	(in)	kN	(lbf)
0 ≤ 25	(0 ≤ 0.98)	1	(224.8)
> 25 ≤ 30	(> 0.98 ≤ 1.18)	3	(674.4)
> 30 ≤ 40	(> 1.18 ≤ 1.57)	4	(899.2)
> 40 ≤ 50	(> 1.57 ≤ 1.97)	5	(1124.0)
> 50 ≤ 60	(> 1.97 ≤ 2.36)	6	(1348.9)
> 60 ≤ 65	(> 2.36 ≤ 2.56)	7	(1573.7)
> 65 ≤ 70	(> 2.56 ≤ 2.76)	8	(1798.5)
> 70 ≤ 75	(> 2.76 ≤ 2.95)	10	(2248.1)
> 75	(> 2.95)	13	(2922.5)

**Figure 14A.1**  
**3D Model of Round Bar Crush Test**



su4529

**Figure 14A.2**  
**Set Up of Round Bar Crush Test**



su4530

## 15 Shock Test

15.1 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  $20 \pm 5^{\circ}\text{C}$  ( $68 \pm 9^{\circ}\text{F}$ ).

15.2 The samples shall not explode or catch fire. In addition, the sample shall not vent or leak as described in [5.1.1](#).

## 16 Vibration Test

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

16.2 The frequency is to be varied at the rate of 1 Hz/min between 10 and 55 Hz, and return in not less than 90 nor more than 100 min. The 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.

16.3 The samples shall not explode or catch fire. In addition the sample shall not vent or leak as described in [5.1.1](#).

## ENVIRONMENTAL TESTS

### 17 Heating Test

17.1 A battery is to be heated in a gravity convection or circulating air oven with an initial temperature of  $20 \pm 5^{\circ}\text{C}$  ( $68 \pm 9^{\circ}\text{F}$ ). 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 for 10 min. The sample shall return to room temperature ( $20 \pm 5^{\circ}\text{C}$ ) and then be examined. For batteries specified for temperatures above  $100^{\circ}\text{C}$  ( $212^{\circ}\text{F}$ ), the conditioning temperature shall be increased from  $130 \pm 2^{\circ}\text{C}$  ( $266 \pm 3.6^{\circ}\text{F}$ ), to  $30 \pm 2^{\circ}\text{C}$  ( $86 \pm 3.6^{\circ}\text{F}$ ) above the manufacturers maximum specified temperature. For a battery of lithium metal chemistry, the conditioning temperature shall be increased to a maximum of  $170 \pm 2^{\circ}\text{C}$  ( $338 \pm 3.6^{\circ}\text{F}$ ).

17.2 The samples shall not explode or catch fire.

### 18 Temperature Cycling Test

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

18.2 The samples shall not explode or catch fire. In addition, the samples shall not vent or leak as described in [5.1.1](#).