UL 60086-4

STANDARD FOR SAFETY

Primary Batteries – Part 4: Safety of Lithium Batteries

UL Standard for Safety for Primary Batteries – Part 4: Safety of Lithium Batteries, UL 60086-4

First Edition, Dated May 22, 2015

Summary of Topics

The adoption of IEC 60086-4, the Standard for Primary Batteries – Part 4: Safety of Lithium Batteries (fourth edition, issued by the IEC September 2014) as a new IEC-based UL standard, UL 60086-4.

The effective date for UL LLC will be announced through Industry File Review – Announcement Letter.

The new requirements are substantially in accordance with Proposal(s) on this subject dated February 13, 2015.

No Text on This Page

UL 60086-4

Standard For Safety For Primary Batteries – Part 4: Safety Of Lithium Batteries

First Edition

May 22, 2015

This UL Standard for Safety consists of the First Edition.

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 http://csds.ul.com.

No Text on This Page

CONTENTS

No Text on This Page

Preface (UL)

This UL Standard is based on IEC Publication 60086-4: fourth edition Primary Batteries – Part 4: Safety of Lithium Batteries issued September 2014. IEC 60086-4 is copyrighted by the IEC.

The text, figures and tables of IEC Publication Primary Batteries – Part 4: Safety of Lithium Batteries, IEC 60086-4 copyright September 2014 are used in this Standard with the consent of the IEC and the American National Standards Institute (ANSI). The IEC copyrighted material has been reproduced with permission from ANSI. ANSI should be contacted regarding the reproduction of any portion of the IEC material. The IEC Foreword and Introduction are not a part of the requirements of this Standard but are included for information purposes only. Copies of IEC Publication IEC 60086-4 may be purchased from ANSI, 11 West 42nd Street, New York, New York, 10036, (212) 642-4900.

Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

UL Effective Date

The effective date for UL LLC will be announced through Industry File Review – Announcement Letter.

NATIONAL DIFFERENCES

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are national differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRIMARY BATTERIES – PART 4: SAFETY OF LITHIUM BATTERIES

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and nongovernmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60086-4 has been prepared by technical committee 35: Primary cells and batteries.

This fourth edition cancels and replaces the third edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Harmonization with the second edition of IEC 62281 [12][1];

b) Alternative protective circuits in 7.1.1;

c) More information regarding risks of swallowing lithium batteries in (former) 7.2.m) and promotion of this item to 7.2a);

d) A new Annex D with pictograms for some of the safety precautions in 7.2.

[1]Numbers in square brackets refer to the Bibliography.

The text of this standard is based on the following documents:

FDIS	Report on voting
35/1324/FDIS	35/1332/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

NOTE The following print types are used:

– requirements: in roman type;

– instructions/warnings for consumers: *in italic type*.

A list of all parts in the IEC 60086 series, under the general title Primary batteries, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under ″http://webstore.iec.ch″ in the data related to the specific publication. At this date, the publication will be

• reconfirmed

• withdrawn

• replaced by a revised edition, or

• amended.

IMPORTANT – The ’colour inside’ logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

DV.1 DE *Addition of the following:*

– The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

DV.2 DE *Addition of the following:*

– Words in SMALL CAPITALS in the text are defined in Clause 3.

INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This standard specifies tests and requirements for lithium batteries and has been prepared in accordance with ISO/IEC guidelines, taking into account all relevant national and international standards which apply.

Lithium batteries are different from conventional primary batteries using aqueous electrolyte in that they contain flammable materials.

Consequently, it is important to carefully consider safety during design, production, distribution, use, and disposal of lithium batteries. Based on such special characteristics, lithium batteries for consumer applications were initially small in size and had low power output. There were also lithium batteries with high power output which were used for special industrial and military applications and were characterized as being “technician replaceable”. The first edition of this standard was drafted to accommodate this situation.

However, from around the end of the 1980s, lithium batteries with high power output started to be widely used in the consumer replacement market, mainly as a power source in camera applications. Since the demand for such lithium batteries with high power output significantly increased, various manufacturers started to produce these types of lithium batteries. As a consequence of this situation, the safety aspects for lithium batteries with high power output were included in the second edition of this standard.

Primary lithium batteries both for consumer and industrial applications are well-established safe and reliable products in the market, which is at least partly due to the existence of safety standards such as this standard and, for transport, IEC 62281. The fourth edition of this standard therefore reflects only minor changes which became necessary in order to keep it harmonized with IEC 62281 and to continuously improve the user information about safety related matters.

Guidelines addressing safety issues during the design of lithium batteries are provided in Annex A. Annex B provides guidelines addressing safety issues during the design of equipment where lithium batteries are installed. Both Annex A and B reflect experience with lithium batteries used in camera applications and are based on [20].

Safety is freedom from unacceptable risk. There can be no absolute safety: some risk will remain. Therefore a product, process or service can only be relatively safe. Safety is achieved by reducing risk to a tolerable level determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service, and factors such as benefit to the user, suitability for purpose, cost effectiveness, and conventions of the society concerned.

As safety will pose different problems, it is impossible to provide a set of precise provisions and recommendations that will apply in every case. However, this standard, when followed on a judicious ″use when applicable″ basis, will provide reasonably consistent standards for safety.

PRIMARY BATTERIES – Part 4: SAFETY OF LITHIUM BATTERIES

1 Scope

This Part of IEC 60086 specifies tests and requirements for primary lithium BATTERIES to ensure their safe operation under INTENDED USE and REASONABLY FORESEEABLE MISUSE.

NOTE Primary lithium BATTERIES that are standardized in IEC 60086-2 are expected to meet all applicable requirements herein. It is understood that consideration of this part of IEC 60086 might also be given to measuring and/or ensuring the SAFETY of non-standardized primary lithium BATTERIES. In either case, no claim or warranty is made that compliance or non-compliance with this standard will fulfil or not fulfil any of the user's particular purposes or needs.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086-1:2011,
Primary batteries – Part 1: General

IEC 60086-2,
Primary batteries – Part 2: Physical and electrical specifications

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Certain definitions taken from IEC 60050-482, IEC 60086-1, and IEC Guide 51 are repeated below for convenience.

3.1 **BATTERY**: one or more cells electrically connected and fitted in a case, with terminals, markings and PROTECTIVE DEVICES etc., as necessary for use

[SOURCE: IEC 60050-482:2004, 482-01-04, modified (″fitted with devices necessary for use, for example case″ replaced by ″electrically connected and fitted in a case″, addition of ″etc., as necessary for use″)]

3.2 **COIN CELL, COIN BATTERY**: small round cell or BATTERY where the overall height is less than the diameter

Note 1 to entry: In English, the term ″coin (CELL or BATTERY)″ is used for lithium BATTERIES only while the term ″button (CELL or BATTERY)″ is only used for non-lithium BATTERIES. In languages other than English, the terms ″coin″ and ″button″ are often used interchangeably, regardless of the electrochemical system.

[SOURCE: IEC 60050-482:2004, 482-02-40, modified (term ″button″ deleted, NOTE ″In practice terms, the term coin is used exclusively for non-aqueous lithium cells.″ replaced with a different note)]

3.3 **CELL**: basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

[SOURCE: IEC 60050-482:2004, 482-01-01]

3.4 **COMPONENT CELL**: CELL contained in a BATTERY

3.5 **CYLINDRICAL (CELL or BATTERY)**: round CELL or BATTERY in which the overall height is equal to or greater than the diameter

[SOURCE: IEC 60050-482:2004, 482-02-39, modified (″CELL with a cylindrical shape″ replaced by ″round CELL or BATTERY″)]

3.6 **DEPTH OF DISCHARGE, DOD**: percentage of RATED CAPACITY discharged from a BATTERY

3.7 **FULLY DISCHARGED**: state of charge of a CELL or BATTERY corresponding to 100 % DEPTH OF DISCHARGE

3.8 **HARM**: physical injury or damage to health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:1999, 3.3]

3.9 **HAZARD**: potential source of HARM

[SOURCE: ISO/IEC Guide 51:1999, 3.5, modified (removal of NOTE)]

3.10 **INTENDED USE**: use of a product, process or service in accordance with information provided by the supplier

[SOURCE: ISO/IEC Guide 51:1999, 3.13]

3.11 **LARGE BATTERY**: BATTERY with a gross mass of more than 12 kg

3.12 **LARGE CELL**: CELL with a gross mass of more than 500 g

3.13 **LITHIUM CELL**: CELL containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

[SOURCE: IEC 60050-482:2004 482-01-06, modified (removal of NOTE)]

3.14 **NOMINAL VOLTAGE**: suitable approximate value of the voltage used to designate or identify a CELL, a BATTERY or an electrochemical system

[SOURCE: IEC 60050-482:2004, 482-03-31]

3.15 **OPEN CIRCUIT VOLTAGE, OCV, U_{OC}, OFF-LOAD VOLTAGE**: voltage across the terminals of a CELL or BATTERY when no external current is flowing

[SOURCE: IEC 60050-482:2004, 482-03-32, modified (alternative terms ″OCV, U_{OC}, OFF-LOAD VOLTAGE″ added, ″across the terminals″ added, ″when the discharge current is zero″ replaced with ″when no external current is flowing″)]

3.16 **PRISMATIC CELL, PRISMATIC BATTERY**: qualifies a CELL or a BATTERY having the shape of a parallelepiped whose faces are rectangular

[SOURCE: IEC 60050-482:2004, 482-02-38]

3.17 **PROTECTIVE DEVICES**: devices such as fuses, diodes or other electric or electronic current limiters designed to interrupt the current flow, block the current flow in one direction or limit the current flow in an electrical circuit

3.18 **RATED CAPACITY**: capacity value of a CELL or BATTERY determined under specified conditions and declared by the manufacturer

[SOURCE: IEC 60050-482:2004, 482-03-15, modified (″CELL or″ added)]

3.19 **REASONABLY FORESEEABLE MISUSE**: use of a product, process or service in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:1999, 3.14]

3.20 **RISK**: combination of the probability of occurrence of HARM and the severity of that HARM

[SOURCE: ISO/IEC Guide 51:1999, 3.2]

3.21 **SAFETY**: freedom from unacceptable RISK

[SOURCE: ISO/IEC Guide 51:1999, 3.1]

3.22 **UNDISCHARGED**: state of charge of a primary CELL or BATTERY corresponding to 0 % DEPTH OF DISCHARGE

4 Requirements for SAFETY

4.1 Design

Lithium BATTERIES are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, coin and prismatic configurations. It is necessary to consider all relevant SAFETY aspects at the BATTERY design stage, recognizing the fact that they can differ considerably, depending on the specific lithium system, power capability and BATTERY configuration.

The following design concepts for SAFETY are common to all lithium BATTERIES:

a) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.

b) Temperature increases in the BATTERY shall be controlled by a design which limits current flow.

c) LITHIUM CELLS and BATTERIES shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, INTENDED USE and REASONABLY FORESEEABLE MISUSE.

See Annex A for guidelines for the achievement of SAFETY of lithium BATTERIES.

4.2 Quality plan

The manufacturer shall prepare and implement a quality plan defining the procedures for the inspection of materials, components, CELLS and BATTERIES during the course of manufacture, to be applied to the total process of producing a specific type of BATTERY. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product SAFETY.

5 Sampling

5.1 General

Samples should be drawn from production lots in accordance with accepted statistical methods.

5.2 Test samples

The number of test samples is given in Table 1. The same test CELLS and BATTERIES are used for tests A to E in sequence. New test CELLS and BATTERIES are required for each of tests F to M.

Table 1 – Number of test samples

Tests	Discharge state	CELLS and single cell batteries[a]	Multi-cell batteries
Tests A to E	UNDISCHARGED	10	4
	FULLY DISCHARGED	10	4
Test F or G	UNDISCHARGED	5	5 COMPONENT CELLS
	FULLY DISCHARGED	5	5 COMPONENT CELLS
Test H	FULLY DISCHARGED	10	10 COMPONENT CELLS
Tests I to K	UNDISCHARGED	5	5
Test L	UNDISCHARGED	20 (see Note 1)	n/a
Test M	50 % predischarged	20 (see Note 2)	n/a
	75 % predischarged	20 (see Note 3)	n/a

[a] single cell batteries containing one tested COMPONENT CELL do not require re-testing unless the change could result in a failure of any of the tests.

Key:
n/a: not applicable

NOTE 1 Four BATTERIES connected in series with one of the four batteries reversed (5 sets).
NOTE 2 Four BATTERIES connected in series, one of which is 50 % predischarged (5 sets).
NOTE 3 Four BATTERIES connected in series, one of which is 75 % predischarged (5 sets).

6 Testing and requirements

6.1 General

6.1.1 Test application matrix

Applicability of test methods to test CELLS and BATTERIES is shown in Table 2.

Table 2 – Test application matrix

Form	Applicable tests												
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	x	x	x	x	x	x [a]	x [a]	x	x	x	x	x [b]	x [c]
m	x	x	x	x	x	x [a, d]	x [a, d]	x [d]	x	x	x	n/a	n/a

Test description:		Key:
INTENDED USE tests	REASONABLY FORESEEABLE MISUSE tests	Form
A: Altitude	E: External short-circuit	s: CELL or single cell BATTERY
B: Thermal cycling	F: Impact	m: multi CELL BATTERY
C: Vibration	G: Crush	Applicability
D: Shock	H: Forced discharge	x: applicable
	I: Abnormal charging	n/a: not applicable
	J: Free fall	
	K: Thermal abuse	
	L: Incorrect installation	
	M: Overdischarge	

[a] Only one test shall be applied, test F or test G.

[b] Only applicable to CR17345, CR15H270 and similar type BATTERIES of a spiral construction that could be installed incorrectly and charged.

[c] Only applicable to CR17345, CR15H270 and similar type BATTERIES of a spiral construction that could be overdischarged.

[d] Test applies to the COMPONENT CELLS.

6.1.2 SAFETY notice

WARNING:	**These tests call for the use of procedures which can result in injury if adequate precautions are not taken.** **It has been assumed in the drafting of these tests that their execution is undertaken by appropriately qualified and experienced technicians using adequate protection.**

6.1.3 Ambient temperature

Unless otherwise specified, the tests shall be carried out at an ambient temperature of 20 °C ± 5 °C.

6.1.4 Parameter measurement tolerances

The overall accuracy of controlled or measured values, relative to the specified or actual parameters, shall be within the following tolerances:

a) ± 1 % for voltage;

b) ± 1 % for current;

c) ± 2 °C for temperature;

d) ± 0,1 % for time;

e) ± 1 % for dimensions;

f) ± 1 % for capacity.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

6.1.5 Predischarge

Where a test requires predischarge, the test CELLS or BATTERIES shall be discharged to the respective DEPTH OF DISCHARGE on a resistive load with which the RATED CAPACITY is obtained or at a current specified by the manufacturer.

6.1.6 Additional CELLS

Where additional CELLS are required to perform a test, they shall be of the same type and, preferably, from the same production lot as the test CELL.

6.2 Evaluation of test criteria

6.2.1 Short-circuit

A short-circuit is considered to have occurred during a test if the open-circuit voltage of the CELL or BATTERY immediately after the test is less than 90 % of its voltage prior to the test. This requirement is not applicable to test CELLS and BATTERIES in FULLY DISCHARGED states.

6.2.2 Excessive temperature rise

An excessive temperature rise is considered to have occurred during a test if the external case temperature of the test CELL or BATTERY rises above 170 °C.

6.2.3 Leakage

Leakage is considered to have occurred during a test if there is visible escape of electrolyte or other material from the test CELL or BATTERY, or the loss of material (except BATTERY casing, handling devices or labels) from the test CELL or BATTERY such that the mass loss exceeds the limits in Table 3.

In order to quantify mass loss $\Delta m / m$, the following equation is provided:

$$\Delta m / m = \frac{m_1 - m_2}{m_1} \times 100\%$$

Where

m_1 is the mass before a test;

m_2 is the mass after that test.

Table 3 – Mass loss limits

Mass of CELL or BATTERY *m*	**Mass loss limit** $\Delta m / m$
$m < 1$ g	0,5 %
1 g $\leq m \leq$ 75 g	0,2 %
$m > 75$ g	0,1 %

6.2.4 Venting

Venting is considered to have occurred if, during a test, an excessive build up of internal gas pressure escapes from a CELL or BATTERY through a SAFETY feature designed for this purpose. This gas may include entrapped materials.

6.2.5 Fire

A fire is considered to have occurred if, during a test, flames are emitted from the test CELL or BATTERY.

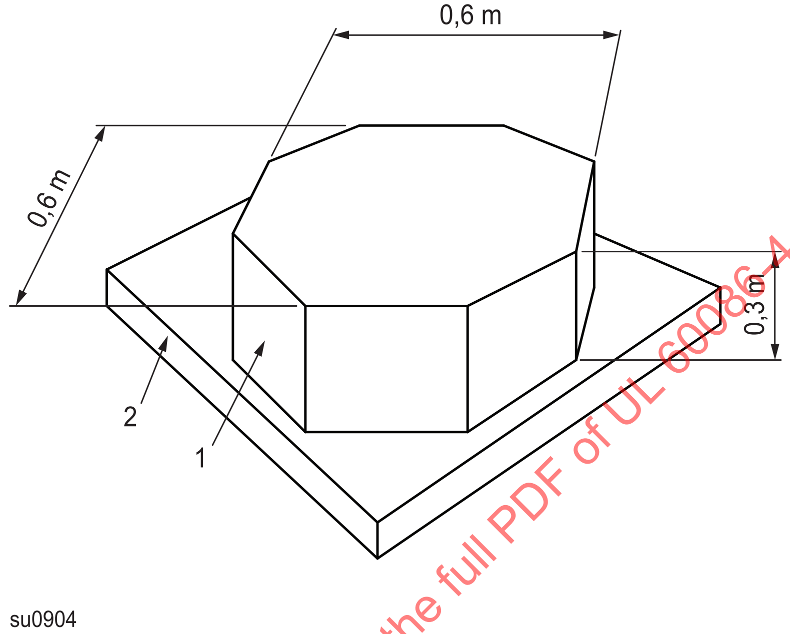
6.2.6 Rupture

A rupture is considered to have occurred if, during a test, a CELL container or BATTERY case has mechanically failed, resulting in expulsion of gas, spillage of liquids, or ejection of solid materials but no explosion.

6.2.7 Explosion

An explosion is considered to have occurred if, during a test, solid matter from any part of a CELL or BATTERY has penetrated a wire mesh screen as shown in Figure 1, centred over the CELL or BATTERY on the steel plate. The screen shall be made from annealed aluminium wire with a diameter of 0,25 mm and a grid density of 6 to 7 wires per cm.

Figure 1 – Mesh screen



NOTE The figure shows an aluminium wire mesh screen (1) of octagonal shape resting on a steel plate (2).

6.3 Tests and requirements – Overview

This standard provides SAFETY tests for INTENDED USE (tests A to D) and REASONABLY FORESEEABLE MISUSE (tests E to M).

Table 4 contains an overview of the tests and requirements for INTENDED USE and REASONABLY FORESEEABLE MISUSE.

Table 4 – Tests and requirements

Test number		Designation	Requirements
INTENDED USE tests	A	Altitude	NL, NV, NC, NR, NE, NF
	B	Thermal cycling	NL, NV, NC, NR, NE, NF
	C	Vibration	NL, NV, NC, NR, NE, NF
	D	Shock	NL, NV, NC, NR, NE, NF
REASONABLY FORESEEABLE MISUSE tests	E	External short-circuit	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Crush	NT, NE, NF
	H	Forced discharge	NE, NF
	I	Abnormal charging	NE, NF
	J	Free fall	NV, NE, NF
	K	Thermal abuse	NE, NF
	L	Incorrect installation	NE, NF
	M	Overdischarge	NE, NF
Tests A through E shall be conducted in sequence on the same CELL or BATTERY. Tests F and G are provided as alternatives. Only one of them shall be conducted.			
Key NC: No short-circuit NE: No explosion NF: No fire NL: No leakage NR: No rupture NT: No excessive temperature rise NV: No venting See 6.2 for a detailed description of the test criteria.			

6.4 Tests for INTENDED USE

6.4.1 Test A: Altitude

a) Purpose

This test simulates air transport under low pressure conditions.

b) Test procedure

Test CELLS and BATTERIES shall be stored at a pressure of 11,6 kPa or less for at least 6 h at ambient temperature.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.2 Test B: Thermal cycling

a) Purpose

This test assesses CELL and BATTERY seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

b) Test procedure

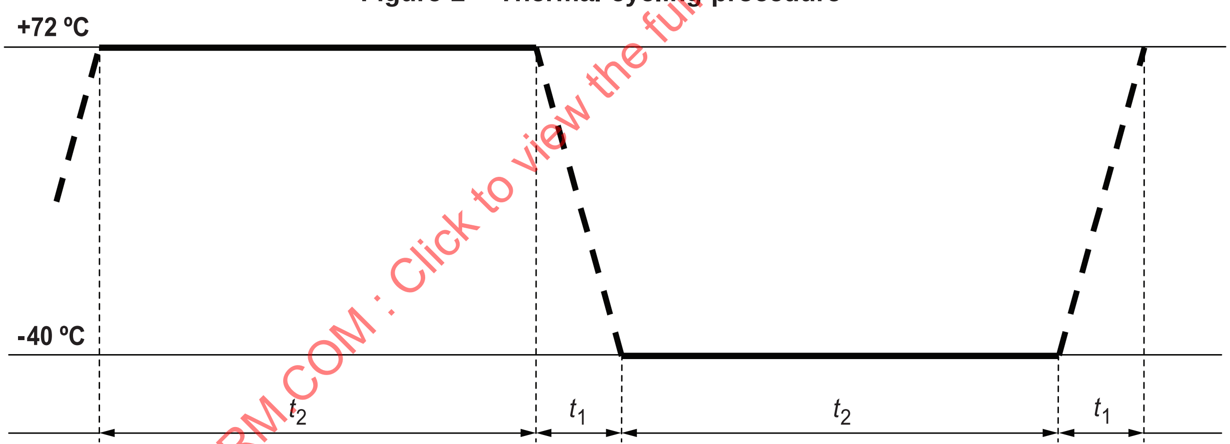
Test CELLS and BATTERIES shall be stored for at least 6 h at a test temperature of 72 °C, followed by storage for at least 6 h at a test temperature of –40 °C. The maximum time for transfer to each temperature shall be 30 min. Each test CELL and BATTERY shall undergo this procedure 10 times. This is then followed by storage for at least 24 h at ambient temperature.

NOTE Figure 2 shows one of ten cycles.

For LARGE CELLS and BATTERIES the duration of exposure to the test temperatures shall be at least 12 h instead of 6 h.

The test shall be conducted using the test CELLS and BATTERIES previously subjected to the altitude test.

Figure 2 – Thermal cycling procedure



su0905

Key

$t_1 \leq 30$ min

$t_2 \geq 6$ h (12 h for LARGE CELLS and BATTERIES)

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.3 Test C: Vibration

a) Purpose

This test simulates vibration during transport. The test condition is based on the range of vibrations as given by ICAO [2].

b) Test procedure

Test CELLS and BATTERIES shall be firmly secured to the platform of the vibration machine without distorting them and in such a manner as to faithfully transmit the vibration. Test CELLS and BATTERIES shall be subjected to sinusoidal vibration according to Table 5 which shows a different upper acceleration amplitude for large BATTERIES. This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

The test shall be conducted using the test CELLS and BATTERIES previously subjected to the thermal cycling test.

Table 5 – Vibration profile (sinusoidal)

Frequency range		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
From	**To**				
f_1 = 7 Hz	f_2	a_1 = 1 g_n	15 min	X	12
f_2	f_3	s = 0,8 mm		Y	12
f_3	f_4 = 200 Hz	a_2		Z	12
and back to f_1 = 7 Hz				Total	36

NOTE Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0,8 mm corresponds to a peak-to-peak displacement of 1,6 mm.

Key

f_1, f_4	lower and upper frequency
f_2, f_3	cross-over frequencies;
f_2	≈ 17,62 Hz; and
f_3	≈ 49,84 Hz, except for large BATTERIES, where f_3 ≈ 24,92 Hz
a_1, a_2	acceleration amplitude
a_2 = 8 g_n	except for large BATTERIES, where a_2 = 2 g_n
s	displacement amplitude

NOTE g_n = 9,80665 m / s^2

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.4 Test D: Shock

a) Purpose

This test simulates rough handling during transport.

b) Test procedure

Test CELLS and BATTERIES shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test CELL or BATTERY. Each test CELL or BATTERY shall be subjected to 3 shocks in each direction of three mutually perpendicular mounting positions of the CELL or BATTERY for a total of 18 shocks. For each shock, the parameters given in Table 6 shall be applied.

Table 6 – Shock parameters

	Waveform	Peak acceleration	Pulse duration	Number of shocks per half axis
CELLS or BATTERIES except large ones	Half sine	150 g_n	6 ms	3
LARGE CELLS or BATTERIES	Half sine	50 g_n	11 ms	3
NOTE g_n = 9,80665 m / s^2				

The test shall be conducted using the test CELLS and BATTERIES previously subjected to the vibration test.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.5 Tests for REASONABLY FORESEEABLE MISUSE

6.5.1 Test E: External short-circuit

a) Purpose

This test simulates conditions resulting in an external short-circuit.

b) Test procedure

The test CELL or BATTERY shall be stabilized at an external case temperature of 55 °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at 55 °C. This short-circuit condition is continued for at least 1 h after the CELL or BATTERY external case temperature has returned to 55 °C.

The test sample shall be observed for a further 6 h.

The test shall be conducted using the test samples previously subjected to the shock test.

c) Requirements

There shall be no excessive temperature rise, no rupture, no explosion and no fire during this test and within the 6 h of observation.

6.5.2 Test F: Impact

a) Purpose

This test simulates mechanical abuse from an impact that can result in an internal short circuit.

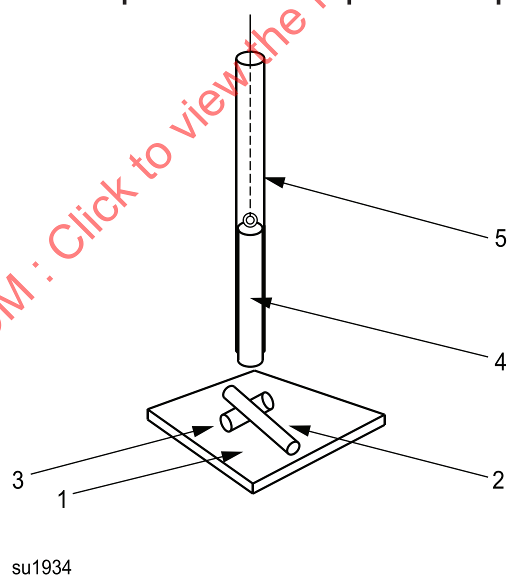
b) Test procedure

The impact test is applicable to CYLINDRICAL CELLS greater than 20 mm in diameter.

The test CELL or COMPONENT CELL is placed on a flat smooth surface. A stainless steel bar (type 316 or equivalent) with a diameter of 15,8 mm ± 0,1 mm and a length of at least 60 mm or of the longest dimension of the CELL, whichever is greater, is placed across the centre of the test sample. A mass of 9,1 kg ± 0,1 kg is dropped from a height of 61 cm ± 2,5 cm at the intersection of the bar and the test sample in a controlled manner using a near frictionless, vertical sliding track or channel with minimal drag on the falling mass. The vertical track or channel used to guide the falling mass shall be oriented 90 degrees from the horizontal supporting surface.

The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the stainless steel bar lying across the centre of the test sample (see Figure 3).

Figure 3 – Example of a test set-up for the impact test



NOTE The figure shows a flat smooth surface (1) and a stainless steel bar (2) which is placed across the centre of the test sample (3). A mass (4) is dropped at the intersection in a controlled manner using a vertical sliding channel (5).

Each test CELL or COMPONENT CELL shall be subjected to one impact only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test CELLS or COMPONENT CELLS that have not been previously subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.3 Test G: Crush

a) Purpose

This test simulates mechanical abuse from a crush that can result in an internal short circuit.

b) Test procedure

The crush test is applicable to prismatic, flexible[2], COIN CELLS and CYLINDRICAL CELLS not more than 20 mm in diameter.

A CELL or COMPONENT CELL is to be crushed between two flat surfaces. The crushing is to be gradual with a speed of approximately 1,5 cm / s at the first point of contact. The crushing is to be continued until one of the three conditions below is reached:

1) The applied force reaches 13 kN ± 0,78 kN;

EXAMPLE: The force can be applied by a hydraulic ram with a 32 mm diameter piston until a pressure of 17 MPa is reached on the hydraulic ram.

2) The voltage of the CELL drops by at least 100 mV; or

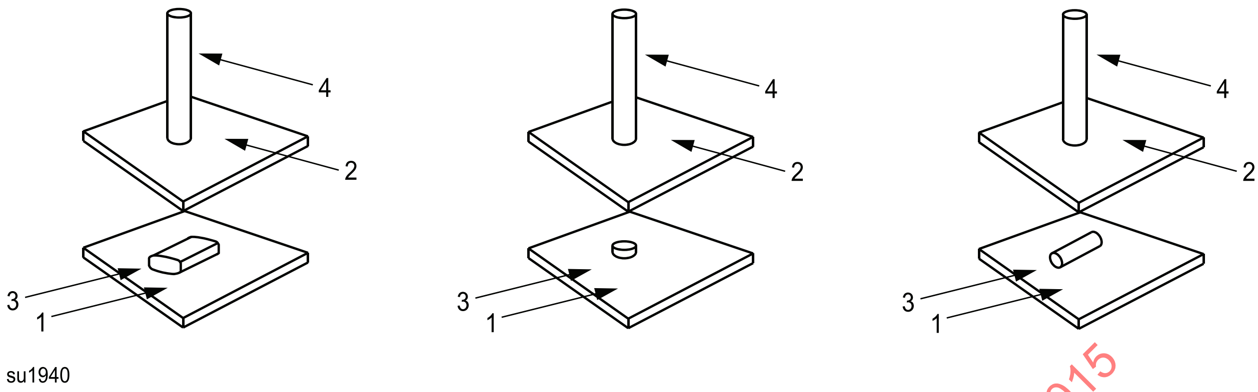
3) The CELL is deformed by 50 % or more of its original thickness.

As soon as one of the above conditions has been obtained, the pressure shall be released.

A prismatic or flexible cell shall be crushed by applying the force to the side with the largest surface area. A COIN CELL shall be crushed by applying the force on its flat surfaces. For CYLINDRICAL CELLS, the crush force shall be applied perpendicular to the longitudinal axis. See Figure 4.

[2]The term ″flexible cell″ is used in this document in place of the term ″pouch cell″ which is used in [19]. It is also used in place of the terms ″cell with a laminate film case″ and ″laminate film cell″.

Figure 4 – Examples of a test set-up for the crush test



a) PRISMATIC or flexible CELL **b) COIN CELL** **c) CYLINDRICAL CELL**

NOTE Figures 4a) to 4c) show two flat surfaces (1 and 2) with BATTERIES (3) of different shapes placed between them for crushing, using a piston (4).

Each test CELL or COMPONENT CELL is to be subjected to one crush only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test CELLS or COMPONENT CELLS that have not previously been subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.4 Test H: Forced discharge

a) Purpose

This test evaluates the ability of a CELL to withstand a forced discharge condition.

b) Test procedure

Each CELL shall be force discharged at ambient temperature by connecting it in series with a 12 V direct current power supply at an initial current equal to the maximum continuous discharge current specified by the manufacturer.

The specified discharge current is obtained by connecting a resistive load of appropriate size and rating in series with the test CELL and the direct current power supply. Each CELL shall be force discharged for a time interval equal to its RATED CAPACITY divided by the initial test current.

This test shall be conducted with FULLY DISCHARGED test CELLS or COMPONENT CELLS that have not previously been subjected to other tests.

c) Requirements

There shall be no explosion and no fire during this test and within 7 days after the test.

6.5.5 Test I: Abnormal charging

a) Purpose

This test simulates the condition when a BATTERY is fitted within a device and is exposed to a reverse voltage from an external power supply, for example memory back-up equipment with a defective diode (see 7.1.2). The test condition is based upon UL 1642 [17].

b) Test procedure

Each test BATTERY shall be subjected to a charging current of three times the abnormal charging current Ic specified by the BATTERY manufacturer by connecting it in opposition to a d.c. power supply. Unless the power supply allows for setting the current, the specified charging current shall be obtained by connecting a resistor of the appropriate size and rating in series with the BATTERY.

The test duration shall be calculated using the formula:

$$t_d = 2,5 \times C_n / (3 \times I_c)$$

where

t_d is the test duration. In order to expedite the test, it is permitted to adjust the test parameters such that t_d does not exceed 7 days;

C_n is the nominal capacity;

I_c is the abnormal charging current declared by the manufacturer for this test.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.6 Test J: Free fall

a) Purpose

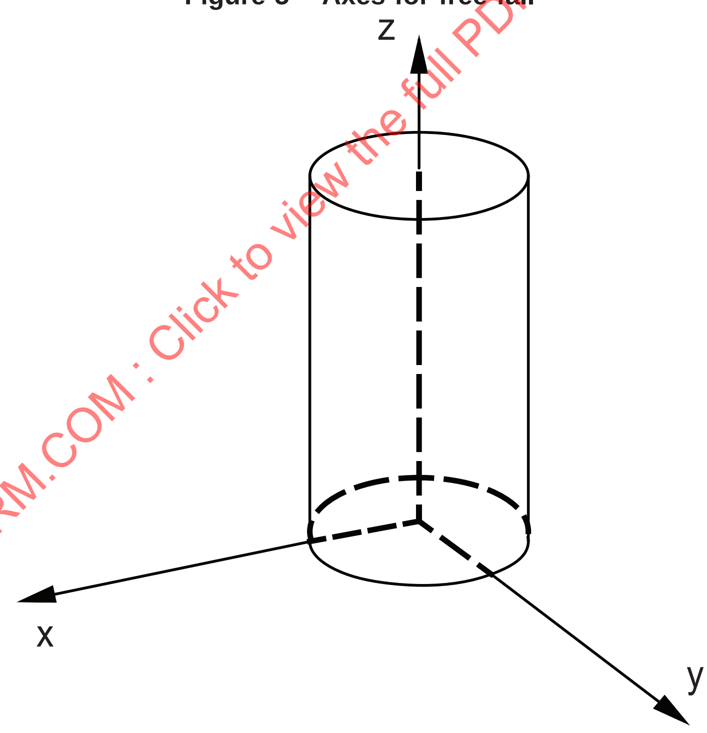
This test simulates the situation when a BATTERY is accidentally dropped. The test condition is based upon IEC 60068-2-31 [7].

b) Test procedure

The test BATTERIES shall be dropped from a height of 1 m onto a concrete surface. Each test BATTERY shall be dropped six times, a PRISMATIC BATTERY once from each of its six faces, a round BATTERY twice in each of the three axes shown in Figure 5. The test BATTERIES shall be stored for 1 h afterwards.

The test shall be conducted with UNDISCHARGED test CELLS and BATTERIES.

Figure 5 – Axes for free fall



su0906

c) Requirements

There shall be no venting, no explosion and no fire during this test and within the 1 h of observation.

6.5.7 Test K: Thermal abuse

a) Purpose

This test simulates the condition when a BATTERY is exposed to an extremely high temperature.

b) Test procedure

A test BATTERY shall be placed in an oven and the temperature raised at a rate of 5 °C/min to a temperature of 130 °C at which the BATTERY shall remain for 10 min.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.8 Test L: Incorrect installation

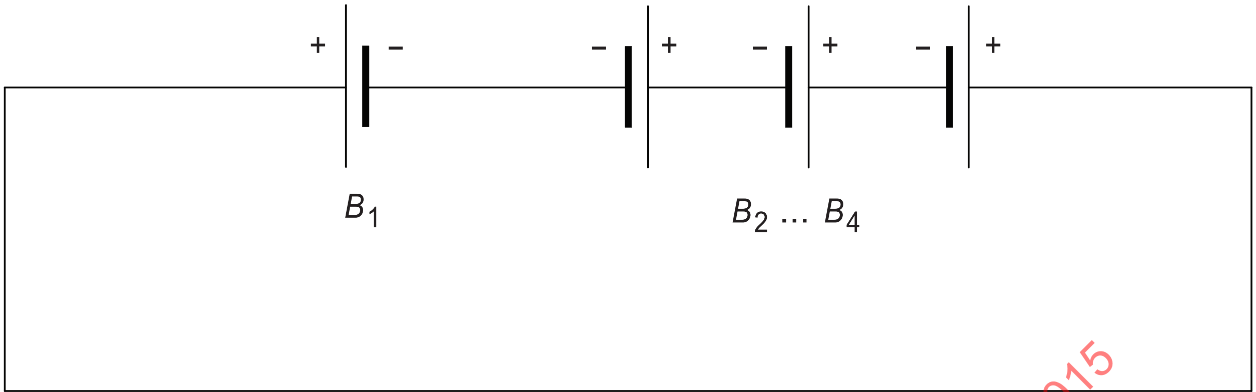
a) Purpose

This test simulates the condition when one single cell battery in a set is reversed.

b) Test procedure

A test BATTERY is connected in series with three UNDISCHARGED additional single cell batteries of the same brand and type in such a way that the terminals of the test BATTERY are connected in reverse. The resistance of the interconnecting circuit shall be no greater than 0,1 Ω. The circuit shall be completed for 24 h or until the BATTERY case temperature has returned to ambient (see Figure 6).

Figure 6 – Circuit diagram for incorrect installation



su0910

Key

B_1 Test CELL

B_2...B_4 Additional CELLS, UNDISCHARGED

c) Requirements

There shall be no explosion and no fire during this test.

6.5.9 Test M: Overdischarge

a) Purpose

This test simulates the condition when one discharged single cell battery is connected in series with other UNDISCHARGED single cell batteries. The test further simulates the use of BATTERIES in motor powered appliances where, in general, currents over 1 A are required.

NOTE CR17345 and CR15H270 BATTERIES are widely used in motor powered appliances where currents over 1 A are required. The current for non standardized BATTERIES may be different.

b) Test procedure

Each test BATTERY shall be predischarged to 50 % DEPTH OF DISCHARGE. It shall then be connected in series with three UNDISCHARGED additional single cell batteries of the same type.

A resistive load R_1 is connected in series with the assembly of BATTERIES in Figure 7 where R_1 is taken from Table 7.

The test shall be continued for 24 h or until the BATTERY case temperature has returned to ambient.

The test shall be repeated with 75 % predischarged test BATTERIES.

Table 7 – Resistive load for overdischarge

BATTERY type	**Resistive load R_1** Ω
CR17345	8,20
CR15H270	8,20

NOTE Table to be modified or expanded when additional BATTERIES of a spiral construction are standardized.

EXAMPLE When CR17345 and CR15H270 BATTERIES were standardized, R_1 was determined from the end voltage of the assembly in Figure 7, using the formula

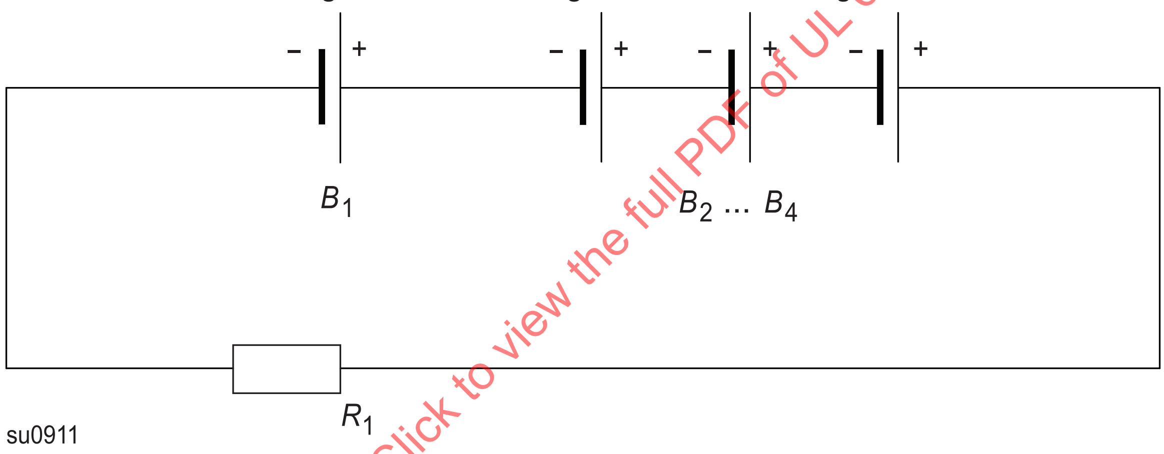
$$R = 4 \times 2{,}0\ \text{V} / 1\ \text{A}$$

where

2,0 V is the end voltage taken from the specification tables in IEC 60086-2; and 1 A is the test current.

R_1 was then found by rounding R to the nearest value in Table 6 of IEC 60086-1:2011.

Figure 7 – Circuit diagram for overdischarge



Key

B_1 Test BATTERY, 50 % predischarged and, in separate tests, 75 % predischarged.

$B_2 ... B_4$ Additional BATTERIES, UNDISCHARGED

R_1 Resistive load

c) Requirements

There shall be no explosion and no fire during this test.

6.6 Information to be given in the relevant specification

When this standard is referred to in a relevant specification, the parameters given in Table 8 shall be given in so far as they are applicable:

Table 8 – Parameters to be specified

Item	Parameters	Clause and/or subclause
a)	Predischarge current or resistive load and end-point voltage specified by the manufacturer	6.1.5
b)	Shape: prismatic, flexible, coin or cylindrical; Diameter: not more than 20 mm or greater than 20 mm.	6.5.2 and 6.5.3
c)	Maximum continuous discharge current specified by the manufacturer for test H NOTE Forced discharge of a CELL can occur when it is connected in series with other CELLS and when it is not protected with a bypass diode.	6.5.4
d)	RATED CAPACITY specified by the manufacturer for test H	6.5.4
e)	Abnormal charging current declared by the manufacturer for test I NOTE Abnormal charging of a CELL can occur when it is connected in series with other CELLS and one CELL is reversed or when it is connected in parallel with a power supply and the PROTECTIVE DEVICES do not operate correctly.	6.5.5
f)	Normal reverse current declared by the manufacturer which can be applied to the BATTERY during its operating life NOTE Normal reverse current flow through a CELL can occur when it is connected in parallel with a power supply and the PROTECTIVE DEVICES are operating properly.	7.1.2

6.7 Evaluation and report

When a report is issued, the following list of items should be considered:

a) name and address of the test facility;

b) name and address of applicant (where appropriate);

c) a unique test report identification;

d) the date of the test report;

e) design characteristics of the test CELLS or BATTERIES according to 4.1;

f) test descriptions and results, including the parameters according to 6.6;

g) type of the test sample(s): CELL, COMPONENT CELL, BATTERY or battery assembly;

h) weight of the test sample(s);

i) lithium content of the sample(s);

j) a signature with name and status of the signatory.

7 Information for SAFETY

7.1 SAFETY precautions during design of equipment

7.1.1 General

See also Annex B for guidelines for designers of equipment using lithium BATTERIES.

7.1.2 Charge protection

When incorporating a primary lithium battery into a circuit powered by an independent main power source, PROTECTIVE DEVICES shall be used in order to prevent charging the primary battery from the main power source, for example

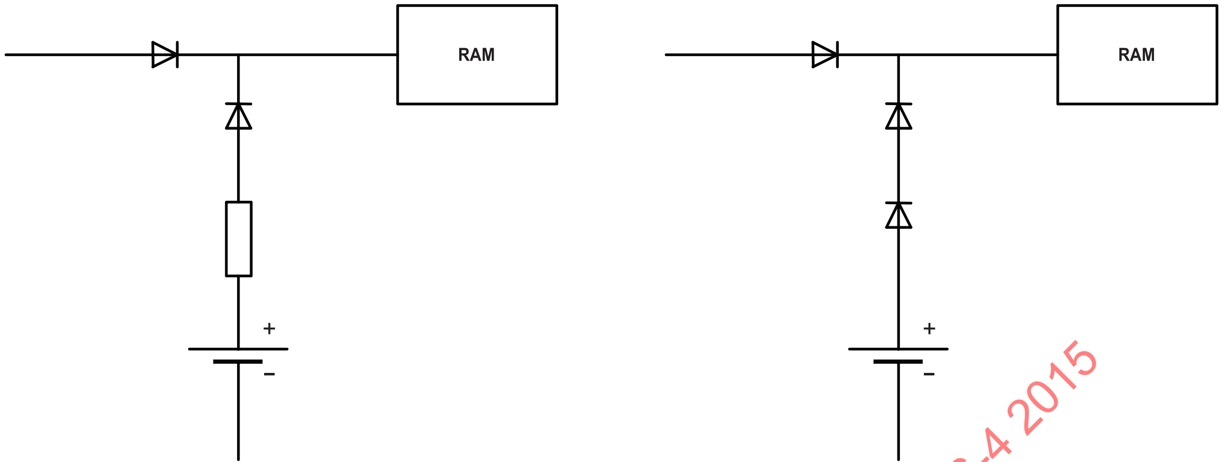
a) a blocking diode and a current limiting resistor (see Figure 8a);

b) two series blocking diodes (see Figure 8b);

c) circuits with a similar blocking function based on two or more independent PROTECTIVE DEVICES;

provided that the first protective device is capable of limiting the charging current through the lithium battery to the normal reverse current specified by the manufacturer which can be applied to the BATTERY during its operating life, while the second protective device is capable of limiting the charging current to the abnormal charging current specified by the BATTERY manufacturer and used for conduction of test I, Abnormal charging. The circuit shall be so designed that at least one of these PROTECTIVE DEVICES remains operational when any one component of the circuit fails.

Figure 8 – Examples of SAFETY wiring for charge protection



su0912

a) Diode and resistor **b) Two diodes**

7.1.3 Parallel connection

Parallel connection should be avoided when designing BATTERY compartments. However, if required, the BATTERY manufacturer shall be contacted for advice.

7.2 SAFETY precautions during handling of BATTERIES

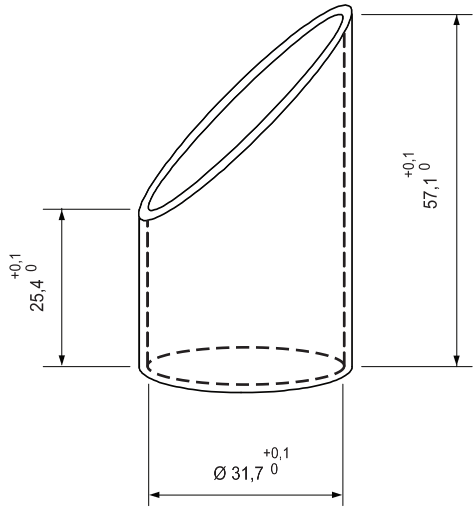
When used correctly, lithium BATTERIES provide a safe and dependable source of power. However, if they are misused or abused, leakage, venting or in extreme cases, explosion and/or fire can result.

a) *Keep BATTERIES out of the reach of children*

In particular, keep BATTERIES which are considered swallowable out of the reach of children, particularly those BATTERIES fitting within the limits of the ingestion gauge as defined in Figure 9. In case of ingestion of a CELL or BATTERY, seek medical assistance promptly. Swallowing lithium COIN CELLS or BATTERIES can cause chemical burns, perforation of soft tissue, and in severe cases can cause death. They must be removed immediately if swallowed. See Figure 10 for an example of appropriate warning text.

NOTE Refer to [14] for general information on HAZARDS from BATTERIES.

Figure 9 – Ingestion gauge

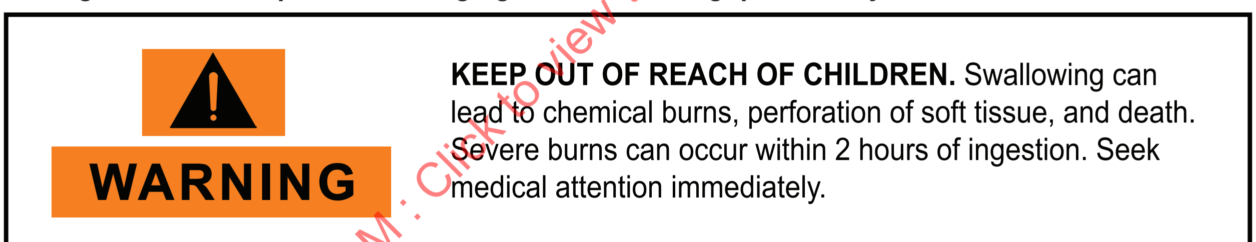


su0913

Dimensions in millimetres

NOTE This gauge defines a swallowable component and is defined in ISO 8124-1 [16].

Figure 10 – Example for warning against swallowing, particularly lithium COIN CELL BATTERIES



su1936

b) *Do not allow children to replace BATTERIES without adult supervision*

c) *Always insert BATTERIES correctly with regard to polarity (+ and –) marked on the BATTERY and the equipment*

When BATTERIES are inserted in reverse they might be short-circuited or charged. This can cause overheating, leakage, venting, rupture, explosion, fire and personal injury.

d) *Do not short-circuit BATTERIES*

When the positive (+) and negative (–) terminals of a BATTERY are in electrical contact with each other, the BATTERY becomes short-circuited. For example loose BATTERIES in a pocket with keys or coins, can be short-circuited. This can result in venting, leakage, explosion, fire and personal injury.

e) *Do not charge BATTERIES*

Attempting to charge a non-rechargeable (primary) BATTERY can cause internal gas and/or heat generation resulting in leakage, venting, explosion, fire and personal injury.

f) *Do not force discharge BATTERIES*

When BATTERIES are force discharged by means of an external power source, the voltage of the BATTERY will be forced below its design capability and gases will be generated inside the BATTERY. This can result in leakage, venting, explosion, fire and personal injury.

g) *Do not mix new and used BATTERIES or BATTERIES of different types or brands*

When replacing BATTERIES, replace all of them at the same time with new BATTERIES of the same brand and type. When BATTERIES of different brand or type are used together or new and used BATTERIES are used together, some BATTERIES might be over-discharged / force discharged due to a difference of voltage or capacity. This can result in leakage, venting, explosion or fire, and can cause personal injury.

h) *Exhausted BATTERIES should be immediately removed from equipment and properly disposed of*

When discharged BATTERIES are kept in the equipment for a long time, electrolyte leakage can occur causing damage to the equipment and/or personal injury.

i) *Do not heat BATTERIES*

When a BATTERY is exposed to heat, leakage, venting, explosion or fire can occur and cause personal injury.

j) *Do not weld or solder directly to BATTERIES*

The heat from welding or soldering directly to a BATTERY can cause leakage, venting, explosion or fire, and can cause personal injury.

k) *Do not dismantle BATTERIES*

When a BATTERY is dismantled or taken apart, contact with the components can be harmful and can cause personal injury or fire.

l) *Do not deform BATTERIES*

BATTERIES should not be crushed, punctured, or otherwise mutilated. Such abuse can cause leakage, venting, explosion or fire, and can cause personal injury.

m) *Do not dispose of BATTERIES in fire*

When BATTERIES are disposed of in fire, the heat build-up can cause explosion and/or fire and personal injury. Do not incinerate BATTERIES except for approved disposal in a controlled incinerator.

n) *A lithium BATTERY with a damaged container should not be exposed to water*

Lithium metal in contact with water can produce hydrogen gas, fire, explosion and/or cause personal injury.

o) *Do not encapsulate and/or modify BATTERIES*

Encapsulation or any other modification to a BATTERY can result in blockage of the SAFETY vent mechanism(s) and subsequent explosion and personal injury. Advice from the BATTERY manufacturer should be sought if it is considered necessary to make any modification.

p) *Store unused BATTERIES in their original packaging away from metal objects. If already unpacked, do not mix or jumble BATTERIES*

Unpacked BATTERIES could get jumbled or get mixed with metal objects. This can cause BATTERY short-circuiting which can result in leakage, venting, explosion or fire, and personal injury. One of the best ways to prevent this from happening is to store unused BATTERIES in their original packaging.

q) *Remove BATTERIES from equipment if it is not to be used for an extended period of time unless it is for emergency purposes*

It is advantageous to remove BATTERIES immediately from equipment which has ceased to function satisfactorily, or when a long period of disuse is anticipated (e.g. camcorders, digital cameras, photoflash, etc.). Although most lithium BATTERIES on the market today are highly leak resistant, a BATTERY that has been partially or completely exhausted might be more prone to leak than one that is unused.

7.3 Packaging

The packaging shall be adequate to avoid mechanical damage during transport, handling and stacking. The materials and packaging design shall be chosen so as to prevent the development of unintentional electrical contact, short-circuit, shifting and corrosion of the terminals, and afford some protection from the environment.

7.4 Handling of BATTERY cartons

BATTERY cartons should be handled with care. Rough handling might result in BATTERIES being short-circuited or damaged. This can cause leakage, explosion, or fire.

7.5 Transport

7.5.1 General

Tests and requirements for the transport of LITHIUM CELLS or BATTERIES are given in IEC 62281 [12].

Regulations concerning international transport of lithium BATTERIES are based on the UN Recommendations on the Transport of Dangerous Goods[18].

Regulations for transport are subject to change. For the transport of lithium BATTERIES, the latest editions of the following regulations should be consulted.

7.5.2 Air transport

Regulations concerning air transport of lithium BATTERIES are specified in the Technical Instructions for the Safe Transport of Dangerous Goods by Air published by the International Civil Aviation Organization (ICAO) [2] and in the Dangerous Goods Regulations published by the International Air Transport Association (IATA) [1].

7.5.3 Sea transport

Regulations concerning sea transport of lithium BATTERIES are specified in the International Maritime Dangerous Goods (IMDG) Code published by the International Maritime Organization (IMO) [13].

7.5.4 Land transport

Regulations concerning road and railroad transport are specified on a national or multilateral basis. While an increasing number of regulators adopt the UN Model Regulations [18], it is recommended that country-specific transport regulations be consulted before shipping.

7.6 Display and storage

a) *Store BATTERIES in well ventilated, dry and cool conditions*

High temperature or high humidity can cause deterioration of the BATTERY performance and/or surface corrosion.

b) *Do not stack BATTERY cartons on top of each other exceeding a specified height*

If too many BATTERY cartons are stacked, BATTERIES in the lowest cartons might be deformed and electrolyte leakage can occur.

c) *Avoid storing or displaying BATTERIES in direct sun or in places where they get exposed to rain*

When BATTERIES get wet, their insulation resistance might be impaired and self-discharge and corrosion can occur. Heat can cause deterioration.

d) *Store and display BATTERIES in their original packing*

When BATTERIES are unpacked and mixed they can be short-circuited or damaged.

See Annex C for additional details.

7.7 Disposal

BATTERIES may be disposed of via communal refuse arrangements provided no local rules to the contrary exist.

During transport, storage and handling for disposal, the following SAFETY precautions should be considered:

a) *Do not dismantle BATTERIES*

Some ingredients of lithium batteries might be flammable or harmful. They can cause injuries, fire, rupture or explosion.

b) *Do not dispose of BATTERIES in fire except under conditions of approved and controlled incineration*

Lithium burns violently. Lithium BATTERIES can explode in a fire. Combustion products from lithium BATTERIES can be toxic and corrosive.

c) *Store collected BATTERIES in a clean and dry environment out of direct sunlight and away from extreme heat*

Dirt and wetness might cause short-circuits and heat. Heat might cause leakage of flammable gas. This can result in fire, rupture or explosion.

d) *Store collected BATTERIES in a well-ventilated area*

Used BATTERIES might contain a residual charge. If they are short-circuited, abnormally charged or force discharged, leakage of flammable gas might be caused. This can result in fire, rupture or explosion.

e) *Do not mix collected BATTERIES with other materials*

Used BATTERIES might contain residual charge. If they are short-circuited, abnormally charged or force discharged, the generated heat can ignite flammable wastes such as oily rags, paper or wood and cause a fire.

f) *Protect BATTERY terminals*

Protection of terminals should be considered by providing insulation, particularly for those BATTERIES with a high voltage. Unprotected terminals might cause short-circuits, abnormal charging and forced discharge. This can result in leakage, fire, rupture or explosion.

8 Instructions for use

a) *Always select the correct size and type of BATTERY most suitable for the INTENDED USE. Information provided with the equipment to assist correct BATTERY selection should be retained for reference.*

b) *Replace all BATTERIES of a set at the same time.*

c) *Clean the BATTERY contacts and also those of the equipment prior to BATTERY installation.*

d) *Ensure that the BATTERIES are installed correctly with regard to polarity (+ and –).*

e) *Remove exhausted BATTERIES promptly.*

9 Marking

9.1 General

With the exception of small BATTERIES (see 9.2), each BATTERY shall be marked with the following information:

a) designation, IEC or common;

b) expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code;

c) polarity of the positive (+) terminal;

d) NOMINAL VOLTAGE;

e) name or trade mark of the manufacturer or supplier;

f) cautionary advice;

g) caution for ingestion of swallowable batteries, see also 7.2 a).