

INTERNATIONAL STANDARD



**Primary batteries –
Part 4: Safety of lithium batteries**

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INTERNATIONAL STANDARD



**Primary batteries –
Part 4: Safety of lithium batteries**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 35: Primary cells and batteries.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
35/1445/DISH	35/1448/RVDISH

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

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Question 1

In looking at IEC 60086-4 Edition 5.0 2019-04, I thought it was difficult to understand all of the marking requirements for swallowable batteries as well as the purpose of those requirements. Could you provide a detailed explanation?

Answer 1

The following list of statements reflects the intention of Table 9 and presents an interpretation of certain parts of Clause 9, and Annex F:

- a) Table 9 is intended to summarize requirements that are found in the text, namely in 7.2 a), 9.1 and 9.2, and in Annex F.

- b) The structure of table 9 is similar to the list in 9.1 (items "a)" to "f)") and 9.2 (items "a)" thru "b)").
- c) From item a) in 9.2 it is not clear what exactly is required to appear on the packaging and what on the battery: the safety sign alone (Table D.1 item E, or Figure F.1) or the complete product safety label (Figure 9).

The purpose of measures to prevent accidental ingestion of batteries is to eliminate the opportunity for children to get stuck batteries in the oesophagus.

The battery that requires measures to prevent accidental ingestion is a swallowable battery size which fits within the limits of the ingestion gauge and is applied to direct sale in consumer-replaceable applications in which children have opportunity to contact swallowable batteries.

There is no description requiring the marking of Caution for ingestion on battery/cell with a diameter of 20 mm or more in the text. However, due to the consideration of measures to prevent accidental ingestion, it was determined that the marking of Caution for ingestion on a battery/cell with a diameter of 20 mm or more is needed and its requirement is shown in Table 9. Therefore, a pictogram must be engraved as a substitute of Caution for ingestion due to a battery/cell with a diameter of 20 mm or more having no space to display the marking.

The type of "caution for ingestion" that is required on the immediate packaging of swallowable batteries is one of the safety signs as shown in Figure F.1. Where there is enough space on the packaging, additional information per Figure 9 (the safety label or only its text) can be printed on the packaging or accompanying safety information about battery handling.

Table 1 of this Interpretation Sheet summarizes the requirements for marking of lithium button cells.

Table 1 – Marking requirements for swallowable batteries

Diameter	Requirement(s)
$d < 16 \text{ mm}$	Cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging.
$16 \text{ mm} \leq d < 20 \text{ mm}$	Child resistant packaging and cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging.
$d \geq 20 \text{ mm}$	Child resistant packaging, cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging, and the safety symbol E of Table D.1 on the positive side of the battery.
NOTE If applicable, the cautionary advice in the form of words should appear in one or more languages as appropriate for the market on which the cells and batteries are placed.	

Question 2

From 9.2 and in particular 9.2 a), it is not clear which kind of batteries are intended for direct sale in consumer-replaceable applications?

Answer 2

The kind of batteries that are included are those with general packaging such as blister packs sold in stores and on the internet, batteries packed with equipment and batteries which are contained in equipment and can be replaced by the consumer.

Question 3

Annex F is marked as "Informative", however "requirements" is stated in the title of Table 9. When referring to Table 9, do we have to consider Annex F as "normative" ?

Answer 3

Annex F contains supplementary material, the main text in the body of the standard takes priority over it. Therefore, even if Annex F is informative, the content listed in Table 9 has to be considered as requirements.

Question 4

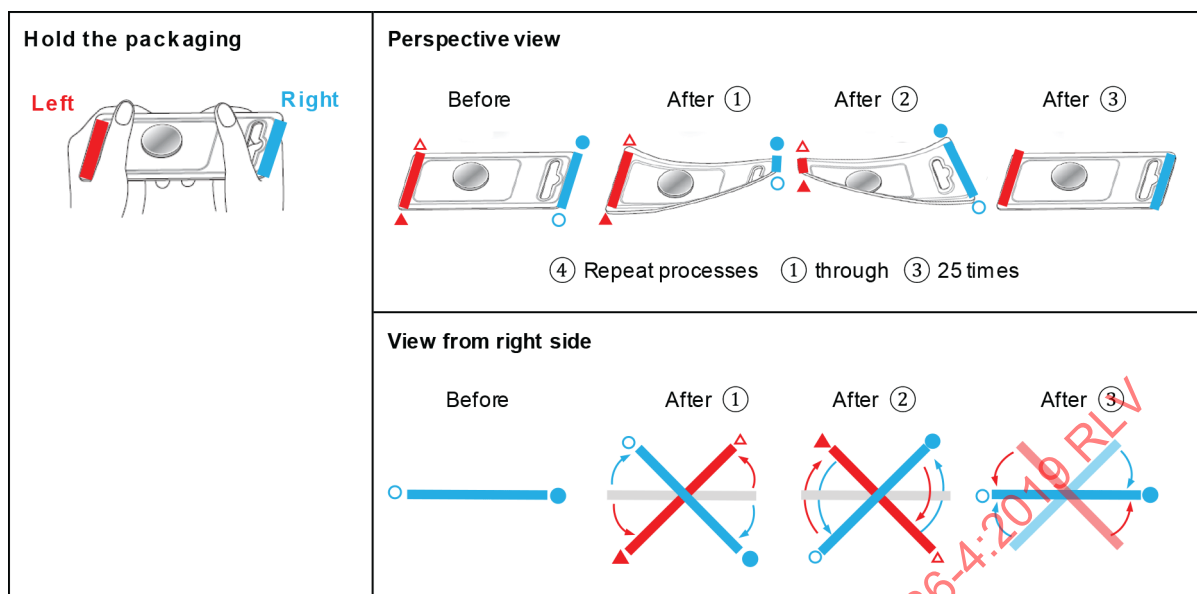
In E.3.2 b), it is difficult to understand the test method of the torsion test. It is not clear how to twist "three times in both directions".

Answer 4

Following is an explanation how and how many times to twist the packaging and in which order to proceed.

- ① First time – Hold the packaging with the fingers of one hand on each of its shorter sides from the state of 0 degrees (neutral state without torsion). Twist it diagonally with a torsion angle of 45° in opposite directions as shown in Figure E.2.
- ② Second time – Twist it diagonally 90° (45° back + 45° opposite direction) in opposite directions to the direction twisted at the first time
- ③ Third time – Return to neutral state without torsion (45° back)
- ④ Movements ①, ② and ③ are counted as 1 time (1 reciprocation) and are repeated 25 times (25 reciprocations).

Figure 1 of this Interpretation Sheet shows the movements of the torsion test. The red and blue lines represent the left and right edge of the packaging. The triangles and circles were added to keep track of the orientation during movements.



IEC

Figure 1 – Torsion test

Question 5

From 9.2 b), Table 9, and Annex E, it is not clear what the transition period is for the requirement of "Child resistant package" ?

Answer 5

The transition period is the same as Marking and packaging requirements, namely 2 years from the publication date of the fifth edition of IEC 60086-4.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

FOREWORD

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

This fifth edition cancels and replaces the fourth edition published in 2014. This edition constitutes a technical revision.

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

- a) Revised criteria for an explosion;
- b) Addition of test parameters for the overdischarge test of battery types FR14505 and FR10G445;
- c) Addition of a new subclause 5.1 Validity of Testing;
- d) revised pictogram E in Table D.1;
- e) Addition of Annex E with requirements for child resistant packaging of coin cells;
- f) Addition of Annex F with recommendations on the use of the KEEP OUT OF REACH OF CHILDREN safety sign.

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

FDIS	Report on voting
35/1420/FDIS	35/1423/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:

- 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.

The contents of the corrigendum of October 2019 and Interpretation sheet of May 2020 have been included in this copy. The contents of the corrigendum of April 2020 apply to the French version only.

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INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This document 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 document 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 document.

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 document and, for transport, IEC 62281. The fourth edition of this document 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 [23]¹.

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 document, when followed on a judicious “use when applicable” basis, will provide reasonably consistent standards for safety.

¹ Numbers in square brackets refer to the bibliography.

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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086-1:2014, *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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE Certain definitions taken from IEC 60050-482, IEC 60086-1, and ISO/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

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]

3.3

coin <cell or battery>

lithium button <cell or battery>

small round cell or battery where the overall height is less than the diameter, containing non-aqueous electrolyte.

~~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.~~

Note 1 to entry: The nominal voltage of lithium batteries is typically greater than 2 V.

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

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~~ at 100 % depth of discharge

3.8

harm

~~physical~~ injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51: ~~1999~~ 2014, ~~3.3~~ 3.1]

3.9

hazard

potential source of harm

[SOURCE: ISO/IEC Guide 51: ~~1999~~ 2014, ~~3.5, modified (removal of NOTE)~~ 3.2]

3.10

intended use

~~use of a product, process or service in accordance with information provided by the supplier~~

use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

[SOURCE: ISO/IEC Guide 51: ~~1999~~ 2014, ~~3.13~~ 3.6]

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 or 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~~ system in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:1999 2014, 3.14 3.7, modified (removal of NOTES)]

3.20

risk

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:1999 2014, 3.2 3.9, modified (removal of NOTE)]

3.21

safety

freedom from ~~unacceptable~~ risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:1999 2014, 3.1 3.14]

3.22

undischarged

state of ~~charge of~~ a primary cell or battery ~~corresponding to~~ at 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 Type testing and sampling

5.1 Validity of Testing

Lithium cells or batteries shall be subjected to the tests, as required in this standard. Testing remains valid until a design change or requirement revision has been made. Retesting is required when:

- a) a battery specification changes by more than 0,1 g or 20 % mass, whichever is greater, for the cathode, anode or electrolyte;
- b) a battery specification change would lead to a failure of any of the tests;

- c) there is an addition of new tests or requirements; or
- d) there is a requirement change that would lead to a failure of any of the tests.

5.2 Test samples

Samples should be drawn from production lots in accordance with accepted statistical methods. 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 A: Altitude B: Thermal cycling C: Vibration D: Shock			Reasonably foreseeable misuse tests E: External short-circuit F: Impact G: Crush H: Forced discharge I: Abnormal charging J: Free fall K: Thermal abuse L: Incorrect installation M: Overdischarge					Form s: cell or single cell battery m: multi cell battery					
								Applicability x: applicable n/a: not applicable					

^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 Cautionary 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 $\Delta m / m$
$m < 1 \text{ g}$	0,5 %
$1 \text{ g} \leq m \leq 75 \text{ g}$	0,2 %
$m > 75 \text{ g}$	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~~ pressure relief feature designed for this purpose. This gas may include entrapped materials.

6.2.5 Fire

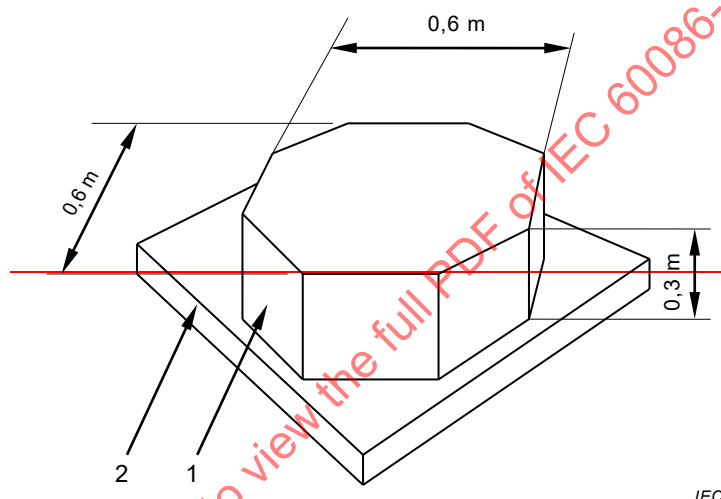
A fire is considered to have occurred if, during a test, flames are emitted from the test cell or battery.

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 or spillage of liquids, ~~or~~ but not forcible 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.~~



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

Figure 1 – Mesh screen

An explosion is considered to have occurred if a cell container or battery case opens violently and solid components are forcibly ejected.

During cell or component cell testing, ejection of internal components is acceptable. Energy of ejected components shall be limited. If required, it may be measured as follows:

- It will not penetrate a wire mesh screen (annealed aluminium wire with a diameter of 0,25 mm and grid density of 6 to 7 wires per cm) placed 25 cm away from the cell; or
- It can be measured by a method demonstrated to be equivalent to the one described in a).

6.3 Tests and requirements – Overview

This document 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

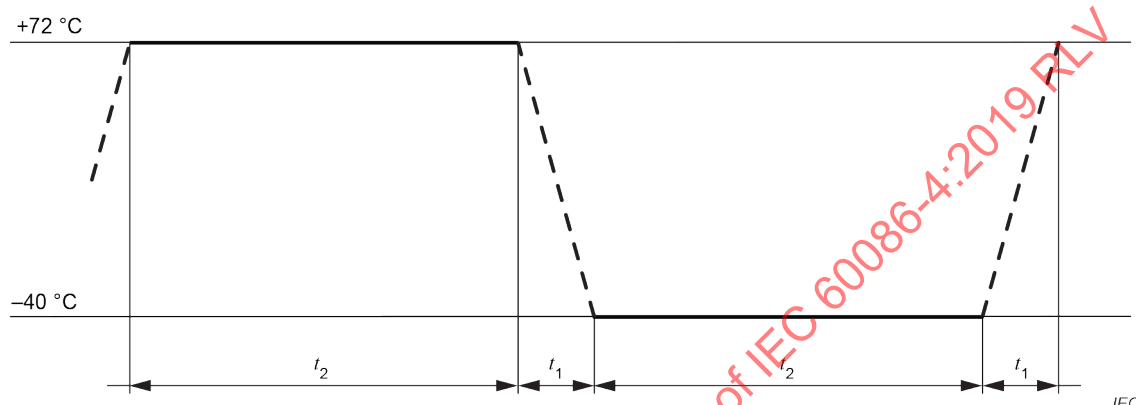
This test assesses cell and battery seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

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.

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.

**Key**

$$t_1 \leq 30 \text{ min}$$

$$t_2 \geq 6 \text{ h (12 h for large cells and batteries)}$$

NOTE The figure shows one of ten cycles

Figure 1 – Thermal cycling procedure

a) 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				
$f_1 = 7 \text{ Hz}$	f_2	$a_1 = 1 g_n$	15 min	X	12
f_2	f_3	$s = 0,8 \text{ mm}$		Y	12
f_3	$f_4 = 200 \text{ Hz}$	a_2		Z	12
and back to $f_1 = 7 \text{ Hz}$				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		$\approx 17,62 \text{ Hz}$; and			
f_3		$\approx 49,84 \text{ Hz}$, except for large batteries, where $f_3 \approx 24,92 \text{ Hz}$			
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 $g_n = 9,80665 \text{ m / s}^2$

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 $g_n = 9,80665 \text{ m / s}^2$

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-4 in IEC 62281 [12] may be used.

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.

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-5 in IEC 62281 [12] may be used.

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

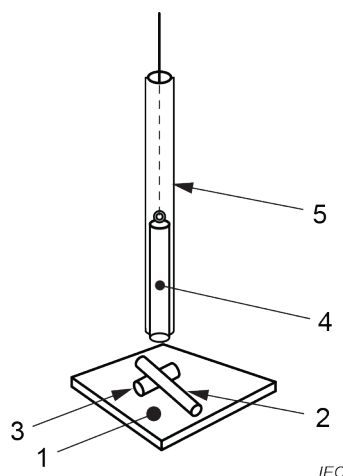
This test simulates mechanical abuse from an impact that can result in an internal short circuit.

b) Test procedure

The impact test is applicable to cylindrical cells ~~greater than 20 mm~~ not less than 18 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 $\pm$ 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 $\pm$ 0,1 kg is dropped from a height of 61 cm $\pm$ 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 2).



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).

Figure 2 – Example of a test set-up for the impact test

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, flexible², coin cells and cylindrical cells ~~not more than 20 mm~~ less than 18 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;

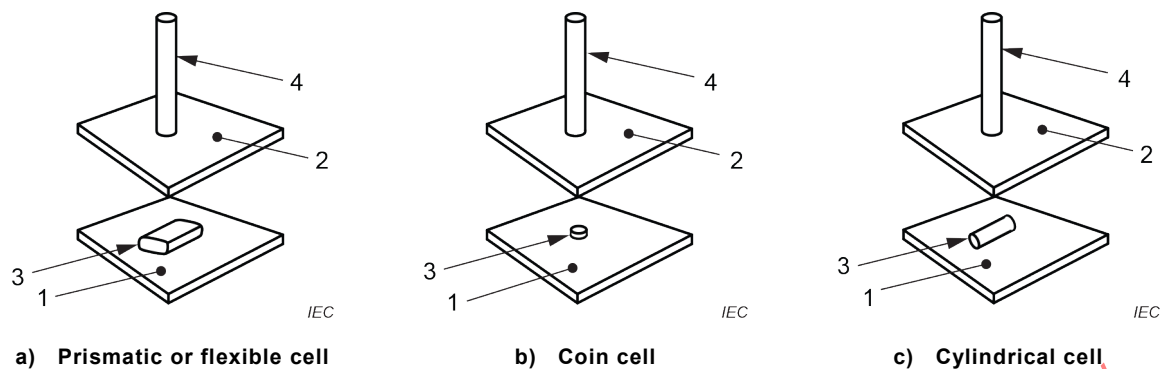
EXAMPLE: The force can be applied by a hydraulic ram with a 32 mm diameter piston until a pressure of 17 MPa is reached on the hydraulic ram.

- 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 3.

² The term "flexible cell" is used in this document in place of the term "pouch cell" which is used in [22]. It is also used in place of the terms "cell with a laminate film case" and "laminate film cell".



NOTE The figures show two flat surfaces (1 and 2) with batteries (3) of different shapes placed between them for crushing, using a piston (4).

Figure 3 – Examples of a test set-up for the crush test

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~~ (charging) current 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 [20].

b) Test procedure

Each test battery shall be subjected to a charging current of three times the abnormal charging current I_c 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 4. The test batteries shall be stored for 1 h afterwards.

The test shall be conducted with undischarged test cells and batteries.

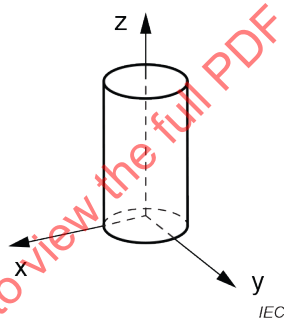


Figure 4 – Axes for free fall

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.

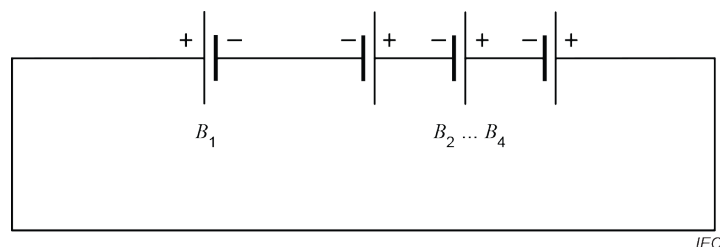
6.5.8 Test L: Incorrect installation

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 $0,1\ \Omega$. The circuit shall be completed for 24 h or until the battery case temperature has returned to ambient (see Figure 5).

**Key**

B_1 Test cell

$B_2 \dots B_4$ Additional cells, undischarged

Figure 5 – Circuit diagram for incorrect installation

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~~ might be different.

b) Test procedure

Each test battery shall be pre-discharged 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 6 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 % pre-discharged test batteries.

Table 7 – Resistive load for overdischarge

Battery type	Resistive load R_1 Ω
CR17345	8,20
CR15H270	8,20
FR14505	3,60
FR10G445	3,60

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

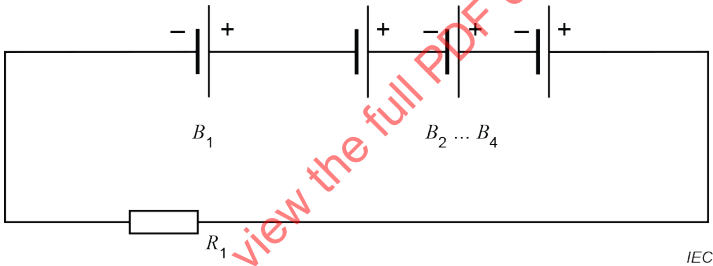
EXAMPLE When CR17345 and CR15H270 batteries were standardized, R_1 was determined from the end-voltage of the assembly in Figure 6, using the formula

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

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 4 of IEC 60086-1:2014 2015.



Key

- B_1 Test battery, 50 % predischarged and, in separate tests, 75 % predischarged.
- $B_2... B_4$ Additional batteries, undischarged
- R_1 Resistive load

Figure 6 – Circuit diagram for overdischarge

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 document 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	Subclause
a)	Predischarge current or resistive load and end-point voltage specified by the manufacturer	6.1.5
b)	Method to measure the energy of an explosion, if any.	6.2.7
c)	Shape: prismatic, flexible, coin or cylindrical; Diameter: ~~not more than 20 mm or greater than 20 mm~~ less than 18 mm or not less than 18 mm.	6.5.2 and 6.5.3
d)	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
e)	Rated capacity specified by the manufacturer for test H	6.5.4
f)	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
g)	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:

- name and address of the test facility;
- name and address of applicant (where appropriate);
- a unique test report identification;
- the date of the test report;
- design characteristics of the test cells or batteries according to 4.1;
- test descriptions and results, including the parameters according to 6.6;
- type of the test sample(s): cell, component cell, battery or battery assembly;
- weight of the test sample(s);
- lithium content of the sample(s);
- a signature with name and status of the signatory.

It is not necessary to issue a new report unless new type testing is required, see 5.1.

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 7a);
- b) two series blocking diodes (see Figure 7b);
- 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 7 – Examples of safety wiring for charge protection

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*

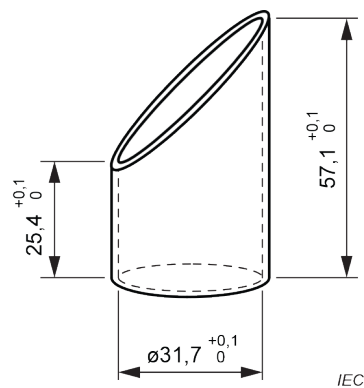
In particular, keep batteries which are considered swallowable out of the reach of children, particularly those batteries fitting within the limits of the ingestion gauge as defined in Figure 8. In case of ingestion of a cell or battery, seek medical assistance promptly. Swallowing lithium coin cells or batteries can cause chemical burns, perforation of soft tissue, and in severe cases can cause death. They ~~must~~ need to be removed immediately if swallowed. See Figure 9 for an example of appropriate warning text.

Warning text similar to Figure 9 may be used for safety information about battery handling. For cautionary advice and symbols to be printed on batteries and battery packagings refer to Clause 9.

NOTE 1 Refer to E.1 in Annex E for more details.

NOTE 2 Refer to [14] for general information on hazards from batteries.

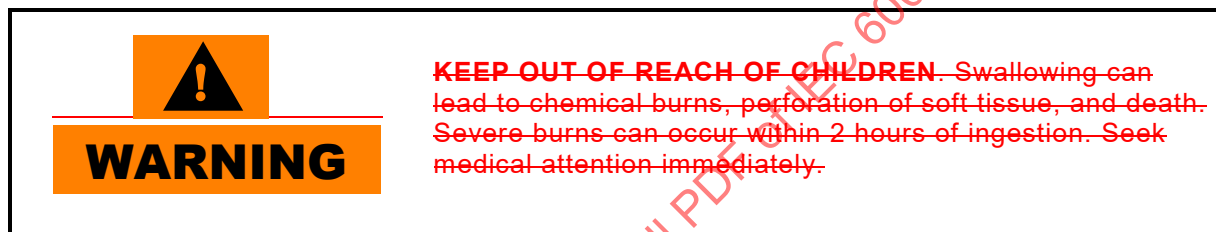
Dimensions in millimetres



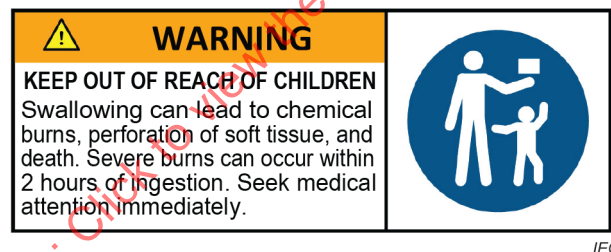
[SOURCE: ISO 8124-1 [19]]

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

Figure 8 – Ingestion gauge



IEC



IEC

NOTE This product safety label is compliant with [17].

Figure 9 – Example for warning against swallowing, particularly ~~lithium~~ coin cell batteries

- 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~~ **pressure relief** 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 **such as keys, coins, etc.** 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 [21].

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

Testing requirements are defined in the UN Manual of Tests & Criteria [22]. As regulations are subject to change, the latest editions should be consulted.

For reference, transportation tests are also given in IEC 62281 [12].

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 [21], 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 and packaging

9.1 General

With the exception of ~~small~~ swallowable 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.

See Table 9 under “General” for a summary of the marking requirements.

9.2 ~~Small~~ Swallowable batteries

For swallowable batteries i.e. those that fit entirely within the Ingestion Gauge (Figure 8) the designation 9.1 a) and the polarity 9.1 c) shall be marked on the battery, while all other markings shown in 9.1 may be given on the immediate package. However, when batteries are intended for direct sale in consumer-replaceable applications, caution for ingestion ~~9.1g)~~ shall also be marked on the immediate package:

- a) caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F.

Swallowable batteries that are intended for direct sale in consumer-replaceable applications and have a diameter of 16 mm or more shall be packaged in:

- b) child resistant packaging.

See Table 9 under “Swallowable” for a summary of the marking and packaging requirements.

9.3 Safety pictograms

Safety pictograms that could be considered for use as an alternative to written cautionary advice are provided in Annex D.

Table 9 – Marking and packaging requirements

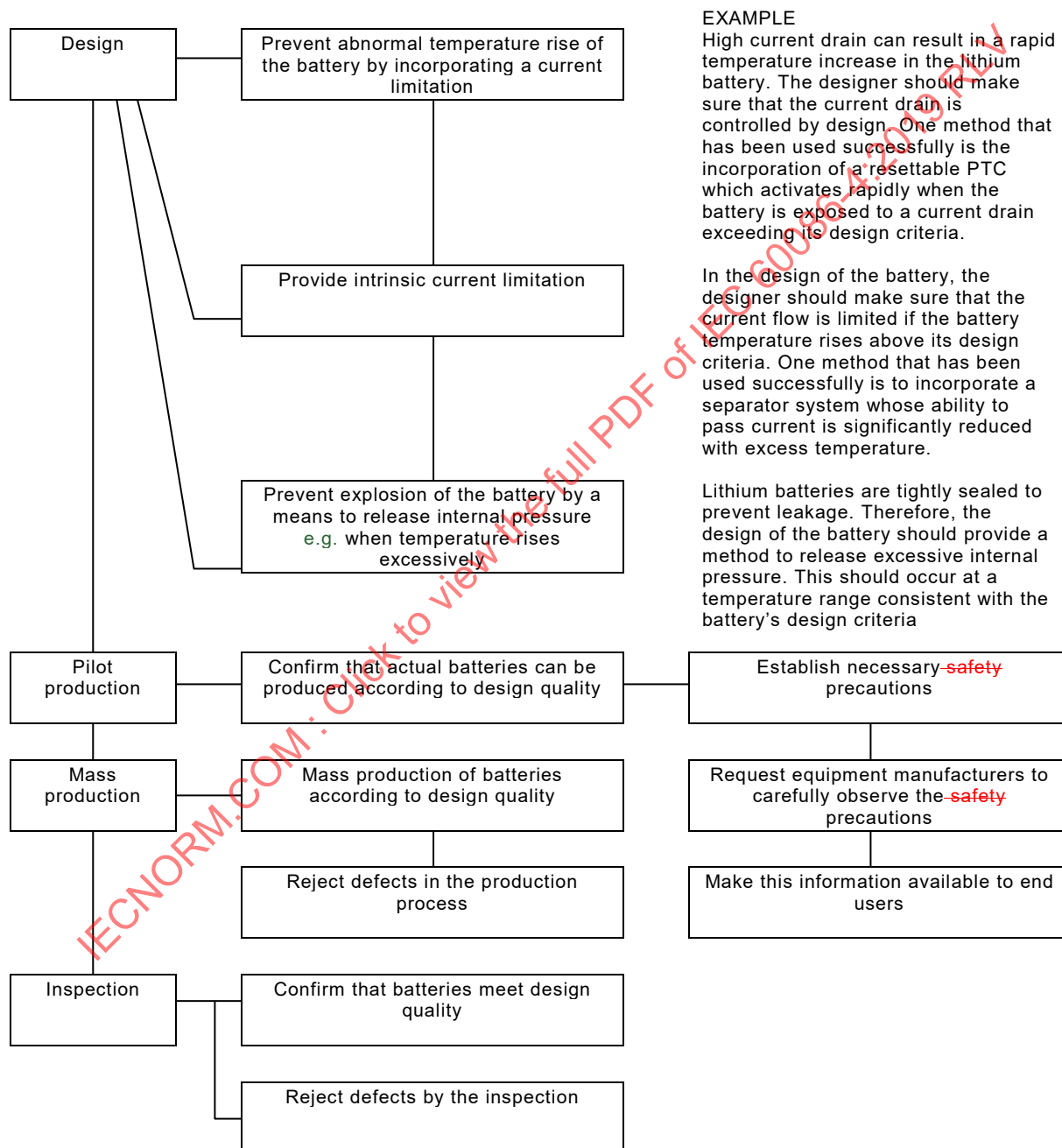
List item	General	Swallowable		
		d < 16 mm	16 mm ≤ d < 20 mm	d ≥ 20 mm
a) Designation, IEC or common	B	B	B	B
b) Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code	B			
c) Polarity of the positive (+) terminal	B	B	B	B
d) Nominal voltage	B			
e) Name or trade mark of the manufacturer or supplier	B			
f) Cautionary advice	B			
g) Caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F		P ¹⁾	P ¹⁾	B ¹⁾ + P ¹⁾
h) Child resistant packaging	n/a	n/a	B	R
¹⁾ The transition period for this requirement is 2 years from the publication date of the fifth edition of this part of IEC 60086.				
Key: d: Diameter B: Marking required on cell / battery P: Marking required on immediate packaging R: Child resistant packaging n/a: Not applicable empty: Marking may appear on (cell / battery and/or) immediate packaging				

Annex A (informative)

Guidelines for the achievement of safety of lithium batteries

The guidelines given in **Figure Table A.1** were followed during the development of high power batteries for consumer use. They are given here for information.

Figure Table A.1 – Battery design guidelines



Annex B (informative)

Guidelines for designers of equipment using lithium batteries

~~Table B.1 sets out the guidelines to be used by designers of equipment which employs lithium batteries (see also IEC 60086-5:2011 [8], Annex B, for guidelines for the design of battery compartments).~~

Table B.1 represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of primary lithium cells and batteries to equipment manufacturers and battery assemblers (see also IEC 60086-5:2016 [8], Annex B, for guidelines for the design of battery compartments).

Table B.1 – Equipment design guidelines (1 of 2)

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(1) When a lithium battery is used as main power source	(1.1) Selection of a suitable battery	Select most suitable battery for the equipment, taking note of its electrical characteristics	Battery might overheat
	(1.2) Number of batteries (series connection or parallel ^a connection) to be used and method of use	a) Multicell batteries (2CR5, CR-P2, 2CR13252 and others); one piece only	If the capacity of batteries in series connection is different, the battery with the lower capacity will be overdischarged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Cylindrical batteries (CR17345 and others); less than three pieces	
		c) Coin type batteries (CR2016, CR2025, CR11108 and others); less than three pieces	
		d) When more than one battery is used, different types should not be used in the same battery compartment	
	e) When batteries are used in parallel ^a protection against charging should be provided		If the voltages of batteries in parallel connection are different, the battery with the lower voltage will become charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(1.3) Design of battery circuit	a) Battery circuit ~~shall~~ should be isolated from any other power source	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Protective devices such as fuses ~~shall~~ should be incorporated in the circuit	Short-circuiting a battery can result in electrolyte leakage, overheating, rupture, explosion or fire
(2) When a lithium battery is used as back-up power source	(2.1) Design of battery circuit	The battery should be used in a separate circuit so that it is not force discharged or charged by the main power source	Battery might be over-discharged to reverse polarity or charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(2.2) Design of battery circuit for memory back-up application	When a battery is connected to the circuit of a main power source with the possibility of being charged, a protective circuit ~~must be provided~~ is necessary with a combination of diode and resistor. The accumulated amount of the leakage current of the diode should be below 2 % of the battery capacity during expected life time	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire

^a See 7.1.3

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(3) Battery holder and battery compartment		a) Battery compartments should be designed so that if a battery is reversed, open circuit is achieved. Battery compartments should be clearly and permanently marked to show the correct orientation of batteries	Unless protection is provided against battery reversal, damage to equipment can occur from resultant electrolyte leakage, overheating, rupture, explosion or fire
		b) Battery compartments should be designed so that batteries other than the specified size cannot be inserted and make contact	Equipment might be damaged or might not operate
		c) Battery compartments should be designed to allow generated gases to escape	Battery compartments might be damaged when internal pressure of the battery becomes too high due to gas generation
		d) Battery compartments should be designed to be water proof	
		e) Battery compartments should be designed to be explosion proof when tightly sealed	
		f) Battery compartments should be isolated from heat generated by the equipment	Battery might be deformed and leak electrolyte due to excessive heat
		g) Battery compartments should be designed so that they cannot easily be opened by children	Children might remove batteries from the compartment and swallow them
(4) Contacts and terminals		a) Material and shape of contacts and terminals should be selected so that effective electric contact is maintained	Heat might generate at the contact due to insufficient connection
		b) Auxiliary circuit should be designed to prevent reverse installation of batteries	Equipment might be damaged or might not operate
		c) Contact and terminal should be designed to prevent reverse installation of batteries	Equipment might be damaged. Battery might cause electrolyte leakage, overheating, rupture, explosion or fire
		d) Direct soldering or welding to a battery should be avoided	Battery might leak, overheat, rupture, explode or catch fire
(5) Indication of necessary precautions	(5.1) On the equipment	Orientation of batteries (polarity) should be clearly indicated at the battery compartment	When a battery is inserted reverse and charged, it can result in electrolyte leakage, overheating, rupture, explosion or fire
	(5.2) In the instruction manual	Precautions for the proper handling of batteries should be indicated	Batteries might be mishandled and cause accidents

Annex C (informative)

Additional information on display and storage

This annex provides additional details concerning display and storage of lithium batteries to those already given in 7.6.

The storage area should be clean, cool, dry, ventilated and weatherproof.

For normal storage, the temperature should be between +10 °C and +25 °C and should never exceed +30 °C. Extremes of humidity (over 95 % and below 40 % relative humidity) for sustained periods should be avoided since they are detrimental to both batteries and packings. Batteries should therefore not be stored next to radiators or boilers nor in direct sunlight.

Although the storage life of batteries at room temperature is excellent, storage is improved at lower temperatures provided that special precautions are taken. The batteries should be enclosed in special protective packing (such as sealed plastic bags or variants) which should be retained to protect the batteries from condensation during the time they are warming to ambient temperature. Accelerated warming is harmful.

Batteries which have been cold-stored may be put into use after return to ambient temperature.

Batteries may be stored fitted in equipment or packages, if determined suitable by the battery manufacturer.

The height to which batteries may be stacked is clearly dependent on the strength of the packaging. As a general rule, this height should not exceed 1,5 m for cardboard packages or 3 m for wooden cases.

The above recommendations are equally valid for storage conditions during prolonged transit. Thus, batteries should be stored away from ship engines and not left for long periods in unventilated metal box cars (containers) during summer.

Batteries ~~shall~~ **should** be dispatched promptly after manufacture and in rotation to distribution centres and on to the users. In order that stock rotation (first in, first out) can be practised, storage areas and displays should be properly designed and packs adequately marked.

Annex D (informative)

Safety pictograms

D.1 General

Cautionary advice to fulfil the marking requirements in this standard has, on a historical basis, been in the form of written text. In recent years, there has been a growing trend toward the use of pictograms as a complementary or alternative means of product safety communication.

The objectives of this annex are: (1) to establish uniform pictogram recommendations that are tied to long-used and specific written text, (2) to minimize the proliferation of safety pictogram designs, and (3) to lay the foundation for the use of safety pictograms instead of written text to communicate product safety and cautionary statements.

NOTE The design of these safety pictograms basically follows the design principles laid down in [16] and [18]. It was, however, adjusted to the limitations existing for battery marking.

D.2 Pictograms

The pictogram recommendations and cautionary advice are given in Table D.1.

Table D.1 – Safety pictograms (1 of 2)

Reference	Safety pictogram	Cautionary advice
A		DO NOT CHARGE
B		DO NOT DEFORM OR DAMAGE
C		DO NOT DISPOSE OF IN FIRE
D		DO NOT INSERT INCORRECTLY
NOTE The grey shading highlights a white margin appearing when the pictogram is printed on coloured or black background.		

Table D.1 (2 of 2)

Reference	Safety pictogram	Cautionary advice
E	 NOTE—Under consideration to replace pictogram E in IEC 60086-5:2011 [8], Table C.1 	KEEP OUT OF REACH OF CHILDREN NOTE 1 See 7.2a) for critical safety information NOTE 2 This pictogram has been submitted to ISO TC 145 for standardisation in [18] NOTE 3 See also Annex F
F		DO NOT MIX DIFFERENT TYPES OR BRANDS
G		DO NOT MIX NEW AND USED
H		DO NOT OPEN OR DISMANTLE
I		DO NOT SHORT CIRCUIT
J		INSERT CORRECTLY
NOTE The grey shading highlights a white margin appearing when the safety pictogram is printed on coloured or black background.		

D.3 Instruction for use

The following instructions are provided for use of the safety pictograms.

- Safety pictograms ~~shall~~ should be clearly legible.
- Whilst colours are permitted, they ~~shall~~ should not detract from the information displayed. If colours are used, the circle and diagonal bar of pictograms A to D and F to I should be

red and the background of pictograms E and J should be blue ~~and the circle and diagonal bar of the other pictograms should be red.~~

- c) Not all of the safety pictograms need to be used together for a particular type or brand of battery. In particular, safety pictograms D and J are meant as alternatives for a similar purpose.

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Annex E (normative)

Child resistant packaging of coin cells

E.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its voltage in excess of 2 V causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

NOTE Ingested button cells with less than 2 Volts do not exhibit the potential to cause severe chemical burns within a short time. If such cells have been ingested, established medical practice is to monitor them until they get past the oesophagus and then allow them to naturally pass through the digestive tract.

This Annex provides an approach for child resistant packaging of coin cells in order to help in preventing their accidental ingestion.

E.2 Applicability

The following applies to consumer type coin cells with a diameter of 16 mm and larger.

a) Single cell packaging

The packaging for coin cells shall meet one of the following conditions:

- i) Packaging requirements specified in any of [24], [25], or [26]; or
- ii) The packaging strength shall be such that the packaging passes the tests described in E.3.

b) Multi-cell packaging

Each cell containment in a multi-cell packaging shall be in compliance with a) even when another cell containment is removed from the packaging.

E.3 Packaging tests

E.3.1 General

The following test methods were developed based on the analysis of the behaviour of children in a test where they were required to try and open coin cell packagings within a limited time. The tests shall be conducted by an instructed person or, alternatively, if necessary, using suitable equipment.

E.3.2 Test items

a) Bending test

Hold the packaging with the fingers of one hand and hold the cell with the fingers of the other hand. Bend the packaging close to the battery until one hand touches the other hand as shown in Figure E.1. This is a guide for the bending angle: $150^\circ \pm 5^\circ$ or more.

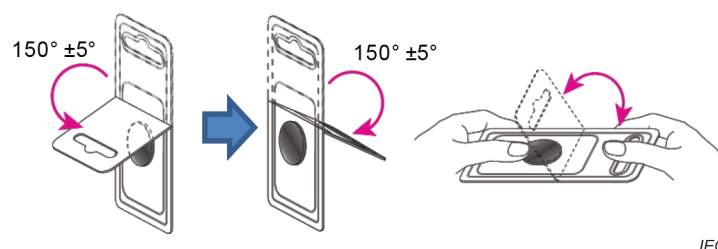


Figure E.1 – Bending test

b) Torsion test

Hold the packaging with the fingers of one hand on each of its shorter sides and twist it diagonally with a torsion angle of $45^\circ \pm 5^\circ$ in opposite directions as shown in Figure E.2, three times in both directions.

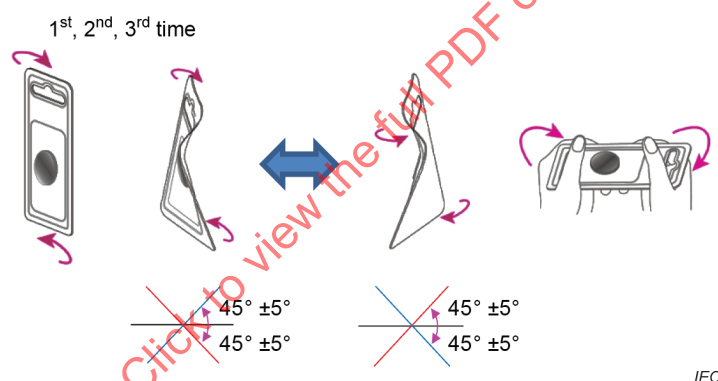


Figure E.2 – Torsion test

c) Tearing test

Try to tear the cell compartment with your fingers as shown in Figure E.3. Alternatively use suitable equipment and apply a force of at least 25 N.

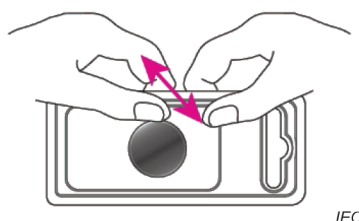


Figure E.3 – Tearing test

d) Pushing test

Try to push the cell out of the compartment with your fingers. Alternatively pull with a mass of at least 5 kg for 30 s; as shown in Figure E.4.

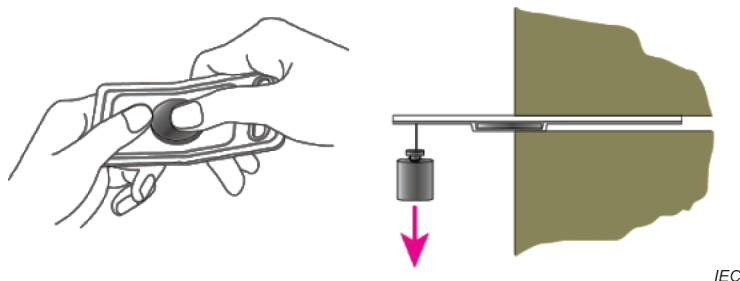


Figure E.4 – Pushing test

E.3.3 Test procedure

Sample packagings shall be tested in the condition of the packaging as sold to the consumer. The number of test samples shall be 10 packagings. Each sample shall be subjected to a series of tests in the order and frequency outlined in Table E.1.

Table E.1 – Test procedure

Order	Test item		Number of times
(1)	a)	Bending test	50
(2)	b)	Torsion test	25
(3)	c)	Tearing test	1
(4)	b)	Torsion test	25
(5)	a)	Bending test	50
(6)	c)	Tearing test	1
(7)	d)	Pushing test	1

E.3.4 Criteria

Each test sample shall meet the following criteria.

- Each cell shall be kept in its packaging until the end of the test series, and
- In order to prevent a child from pulling the cell out from its compartment, the packaging shall not open too wide. The maximum allowable size of an opening in the packaging is 6 mm diameter for a round hole and 10 mm length for a slit. See Figure E.5 for maximum packaging openings.

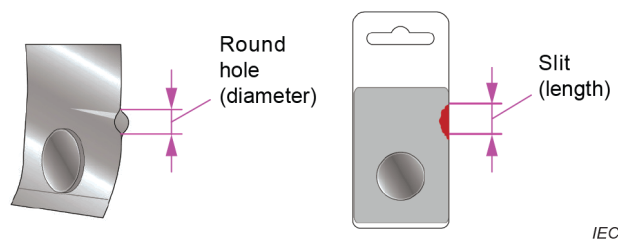


Figure E.5 – Maximum packaging opening

Annex F (informative)

Use of the KEEP OUT OF REACH OF CHILDREN safety sign

F.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the esophagus, its voltage in excess of 2 V causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

The new safety sign KEEP OUT OF REACH OF CHILDREN should give parents who have children a heads-up as a mandatory action sign even if intended products are safe in the usual sense of adults.

Therefore, purpose of the new safety sign is used to convey the message that these products should be kept out of reach of children in order to prevent accidental ingestion.

F.2 Safety sign

When a safety sign is used to convey the message that these products should be kept out of reach of children, the following best practices apply. The safety sign recommendation and cautionary advice for use on batteries and battery packagings are given in Table D.1, safety sign E while warning text for safety information about battery handling is given in Figure 9.

F.3 Best practices for marking the packaging

- a) Refer to Table 9 for marking requirements on packaging.
- b) The safety sign should be on contrasting background. The background should cover at least 50 % of the area of the pictogram.
- c) The size of the safety sign should be 6 mm in diameter or larger.
- d) If the text KEEP OUT OF REACH OF CHILDREN is used, it should contrast with the background color on which it is printed.

F.4 Best practices for marking the cell

- a) Refer to Table 9 for marking requirements on coin cells.
- b) The safety sign should be durably and indelibly marked. No colour is required. Engraving, etching, embossing or stamping are acceptable.

NOTE Recommended safety signs are shown in Figure F.1. The manufacturer can select any of the safety signs.



Type 1



Type 2



Type 3

Figure F.1 – Recommended safety signs for use on coin cells

- c) The safety sign on cells should have a diameter of 6 mm or larger.

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- [21] United Nations, New York and Geneva: *Recommendations on the Transport of Dangerous Goods, Model Regulations* (revised biennially)
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- [25] EN 862, *Packaging. Child-resistant packaging. Requirements and testing procedures for non-reclosable packages for non-pharmaceutical products*
- [26] AS 5808-2009, *Child-resistant packaging – Requirements and testing procedures for non-reclosable packages for non-pharmaceutical products*

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**Primary batteries –
Part 4: Safety of lithium batteries**

**Piles électriques –
Partie 4: Sécurité des piles au lithium**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60086-4
Edition 5.0 2019-04

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 35: Primary cells and batteries.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
35/1445/DISH	35/1448/RVDISH

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

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.

Question 1

In looking at IEC 60086-4 Edition 5.0 2019-04, I thought it was difficult to understand all of the marking requirements for swallowable batteries as well as the purpose of those requirements. Could you provide a detailed explanation?

Answer 1

The following list of statements reflects the intention of Table 9 and presents an interpretation of certain parts of Clause 9, and Annex F:

- a) Table 9 is intended to summarize requirements that are found in the text, namely in 7.2 a), 9.1 and 9.2, and in Annex F.

- b) The structure of table 9 is similar to the list in 9.1 (items "a)" to "f)") and 9.2 (items "a)" thru "b)").
- c) From item a) in 9.2 it is not clear what exactly is required to appear on the packaging and what on the battery: the safety sign alone (Table D.1 item E, or Figure F.1) or the complete product safety label (Figure 9).

The purpose of measures to prevent accidental ingestion of batteries is to eliminate the opportunity for children to get stuck batteries in the oesophagus.

The battery that requires measures to prevent accidental ingestion is a swallowable battery size which fits within the limits of the ingestion gauge and is applied to direct sale in consumer-replaceable applications in which children have opportunity to contact swallowable batteries.

There is no description requiring the marking of Caution for ingestion on battery/cell with a diameter of 20 mm or more in the text. However, due to the consideration of measures to prevent accidental ingestion, it was determined that the marking of Caution for ingestion on a battery/cell with a diameter of 20 mm or more is needed and its requirement is shown in Table 9. Therefore, a pictogram must be engraved as a substitute of Caution for ingestion due to a battery/cell with a diameter of 20 mm or more having no space to display the marking.

The type of "caution for ingestion" that is required on the immediate packaging of swallowable batteries is one of the safety signs as shown in Figure F.1. Where there is enough space on the packaging, additional information per Figure 9 (the safety label or only its text) can be printed on the packaging or accompanying safety information about battery handling.

Table 1 of this Interpretation Sheet summarizes the requirements for marking of lithium button cells.

Table 1 – Marking requirements for swallowable batteries

Diameter	Requirement(s)
$d < 16 \text{ mm}$	Cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging.
$16 \text{ mm} \leq d < 20 \text{ mm}$	Child resistant packaging and cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging.
$d \geq 20 \text{ mm}$	Child resistant packaging, cautionary advice in the form of the words KEEP OUT OF REACH OF CHILDREN or the safety symbol E of Table D.1 on the immediate packaging, and the safety symbol E of Table D.1 on the positive side of the battery.
NOTE If applicable, the cautionary advice in the form of words should appear in one or more languages as appropriate for the market on which the cells and batteries are placed.	

Question 2

From 9.2 and in particular 9.2 a), it is not clear which kind of batteries are intended for direct sale in consumer-replaceable applications?

Answer 2

The kind of batteries that are included are those with general packaging such as blister packs sold in stores and on the internet, batteries packed with equipment and batteries which are contained in equipment and can be replaced by the consumer.

Question 3

Annex F is marked as "Informative", however "requirements" is stated in the title of Table 9. When referring to Table 9, do we have to consider Annex F as "normative" ?

Answer 3

Annex F contains supplementary material, the main text in the body of the standard takes priority over it. Therefore, even if Annex F is informative, the content listed in Table 9 has to be considered as requirements.

Question 4

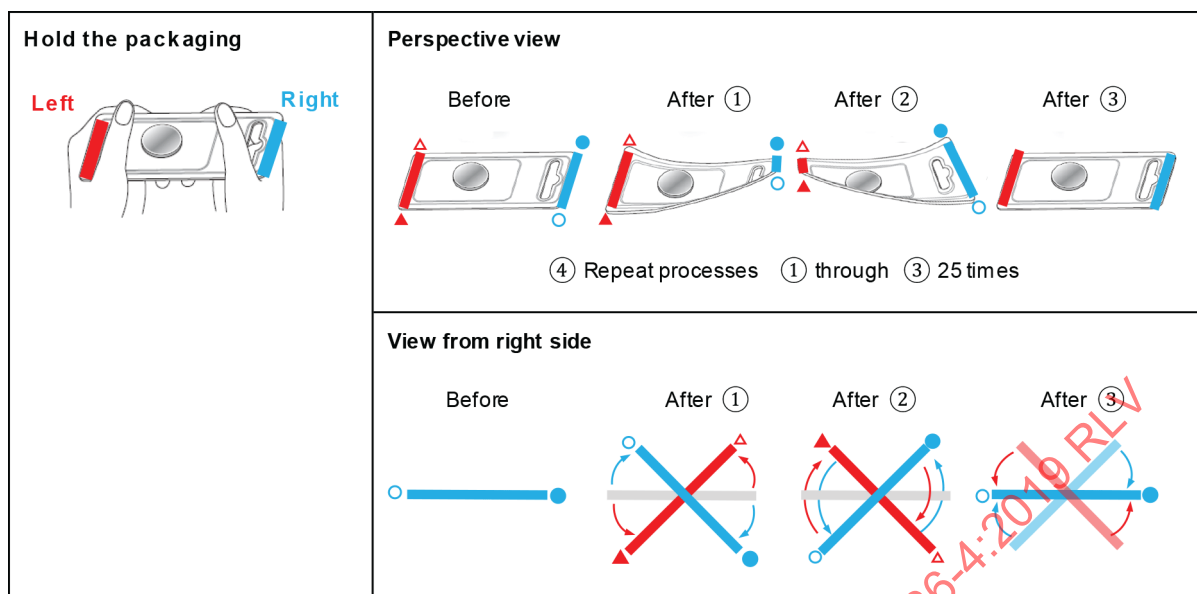
In E.3.2 b), it is difficult to understand the test method of the torsion test. It is not clear how to twist "three times in both directions".

Answer 4

Following is an explanation how and how many times to twist the packaging and in which order to proceed.

- ① First time – Hold the packaging with the fingers of one hand on each of its shorter sides from the state of 0 degrees (neutral state without torsion). Twist it diagonally with a torsion angle of 45° in opposite directions as shown in Figure E.2.
- ② Second time – Twist it diagonally 90° (45° back + 45° opposite direction) in opposite directions to the direction twisted at the first time
- ③ Third time – Return to neutral state without torsion (45° back)
- ④ Movements ①, ② and ③ are counted as 1 time (1 reciprocation) and are repeated 25 times (25 reciprocations).

Figure 1 of this Interpretation Sheet shows the movements of the torsion test. The red and blue lines represent the left and right edge of the packaging. The triangles and circles were added to keep track of the orientation during movements.



IEC

Figure 1 – Torsion test

Question 5

From 9.2 b), Table 9, and Annex E, it is not clear what the transition period is for the requirement of "Child resistant package" ?

Answer 5

The transition period is the same as Marking and packaging requirements, namely 2 years from the publication date of the fifth edition of IEC 60086-4.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRIMARY BATTERIES –**Part 4: Safety of lithium batteries****FOREWORD**

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

This fifth edition cancels and replaces the fourth edition published in 2014. This edition constitutes a technical revision.

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

- a) Revised criteria for an explosion;
- b) Addition of test parameters for the overdischarge test of battery types FR14505 and FR10G445;
- c) Addition of a new subclause 5.1 Validity of Testing;
- d) revised pictogram E in Table D.1;
- e) Addition of Annex E with requirements for child resistant packaging of coin cells;

- f) Addition of Annex F with recommendations on the use of the KEEP OUT OF REACH OF CHILDREN safety sign.

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

FDIS	Report on voting
35/1420/FDIS	35/1423/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:

- 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.

The contents of the corrigendum of October 2019 and the Interpretation sheet of May 2020 have been included in this copy. The contents of the corrigendum of April 2020 apply to the French version only.

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.

INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This document 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 document 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 document.

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 document and, for transport, IEC 62281. The fourth edition of this document 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 [23]¹.

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 document, when followed on a judicious “use when applicable” basis, will provide reasonably consistent standards for safety.

¹ Numbers in square brackets refer to the bibliography.

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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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, *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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE Certain definitions taken from IEC 60050-482, IEC 60086-1, and ISO/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**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]

3.3

coin <cell or battery>

lithium button <cell or battery>

small round cell or battery where the overall height is less than the diameter, containing non-aqueous electrolyte.

Note 1 to entry: The nominal voltage of lithium batteries is typically greater than 2 V.

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

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 a cell or battery at 100 % depth of discharge

3.8

harm

injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.9

hazard

potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.10

intended use

use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

[SOURCE: ISO/IEC Guide 51:2014, 3.6]

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 or 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 system in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified (removal of NOTES)]

3.20**risk**

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified (removal of NOTE)]

3.21**safety**

freedom from risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.22**undischarged**

state of a primary cell or battery at 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 Type testing and sampling**5.1 Validity of Testing**

Lithium cells or batteries shall be subjected to the tests, as required in this standard. Testing remains valid until a design change or requirement revision has been made. Retesting is required when:

- a) a battery specification changes by more than 0,1 g or 20 % mass, whichever is greater, for the cathode, anode or electrolyte;
- b) a battery specification change would lead to a failure of any of the tests;

- c) there is an addition of new tests or requirements; or
- d) there is a requirement change that would lead to a failure of any of the tests.

5.2 Test samples

Samples should be drawn from production lots in accordance with accepted statistical methods. 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 A: Altitude B: Thermal cycling C: Vibration D: Shock			Reasonably foreseeable misuse tests E: External short-circuit F: Impact G: Crush H: Forced discharge I: Abnormal charging J: Free fall K: Thermal abuse L: Incorrect installation M: Overdischarge					Form s: cell or single cell battery m: multi cell battery					
								Applicability x: applicable n/a: not applicable					
^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 Cautionary 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 $\Delta m / m$
$m < 1 \text{ g}$	0,5 %
$1 \text{ g} \leq m \leq 75 \text{ g}$	0,2 %
$m > 75 \text{ g}$	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 pressure relief 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 a cell container or battery case has mechanically failed, resulting in expulsion of gas or spillage of liquids but not forcible ejection of solid materials.

6.2.7 Explosion

An explosion is considered to have occurred if a cell container or battery case opens violently and solid components are forcibly ejected.

During cell or component cell testing, ejection of internal components is acceptable. Energy of ejected components shall be limited. If required, it may be measured as follows:

- a) It will not penetrate a wire mesh screen (annealed aluminium wire with a diameter of 0,25 mm and grid density of 6 to 7 wires per cm) placed 25 cm away from the cell; or
- b) It can be measured by a method demonstrated to be equivalent to the one described in a).

6.3 Tests and requirements – Overview

This document 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

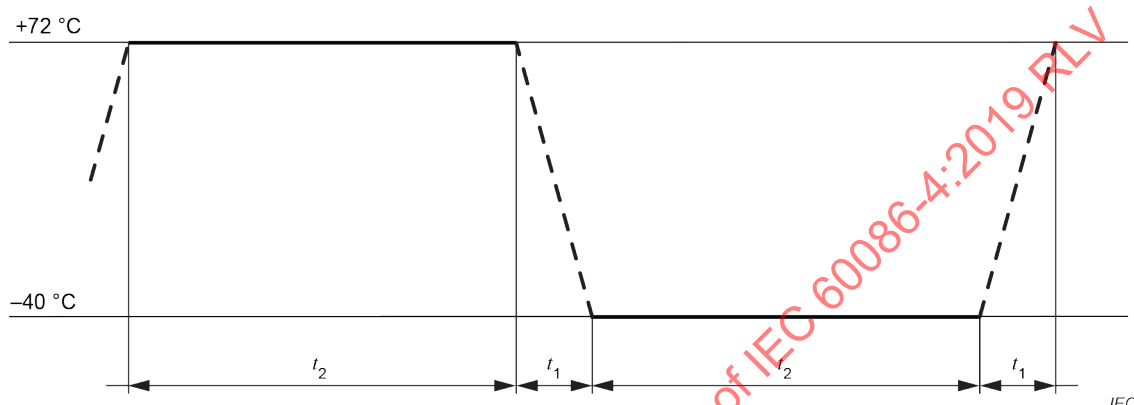
This test assesses cell and battery seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

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.

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.

**Key**

$$t_1 \leq 30 \text{ min}$$

$$t_2 \geq 6 \text{ h (12 h for large cells and batteries)}$$

NOTE The figure shows one of ten cycles

Figure 1 – Thermal cycling procedure

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				
$f_1 = 7 \text{ Hz}$	f_2	$a_1 = 1 g_n$	15 min	X	12
f_2	f_3	$s = 0,8 \text{ mm}$		Y	12
f_3	$f_4 = 200 \text{ Hz}$	a_2		Z	12
and back to $f_1 = 7 \text{ Hz}$				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		$\approx 17,62 \text{ Hz}$; and			
f_3		$\approx 49,84 \text{ Hz}$, except for large batteries, where $f_3 \approx 24,92 \text{ Hz}$			
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 $g_n = 9,80665 \text{ m / s}^2$

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 $g_n = 9,80665 \text{ m / s}^2$

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-4 in IEC 62281 [12] may be used.

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.

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-5 in IEC 62281 [12] may be used.

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

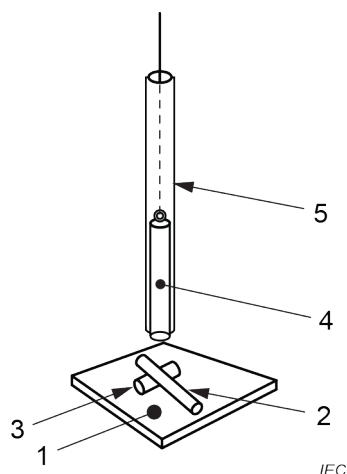
This test simulates mechanical abuse from an impact that can result in an internal short circuit.

b) Test procedure

The impact test is applicable to cylindrical cells not less than 18 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 $\pm$ 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 $\pm$ 0,1 kg is dropped from a height of 61 cm $\pm$ 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 2).



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).

Figure 2 – Example of a test set-up for the impact test

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, flexible², coin cells and cylindrical cells less than 18 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 $\pm$ 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.

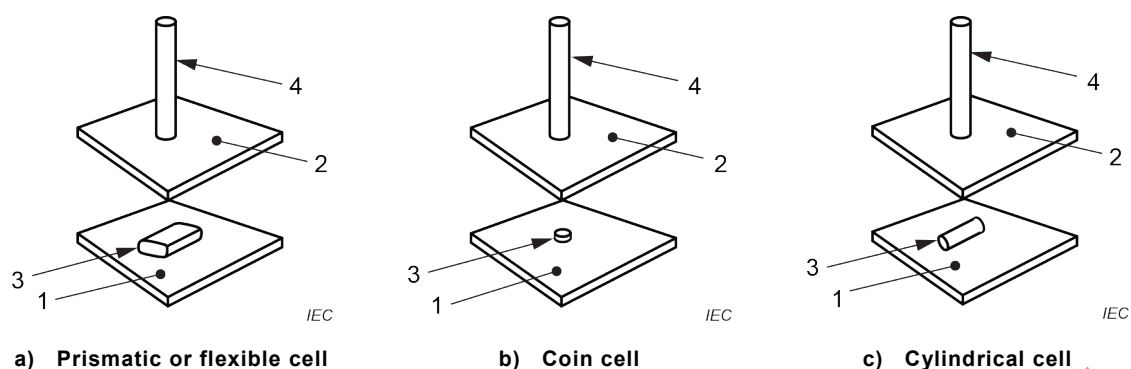
- 2) The voltage of the cell drops by at least 100 mV; or

- 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 3.

² The term "flexible cell" is used in this document in place of the term "pouch cell" which is used in [22]. It is also used in place of the terms "cell with a laminate film case" and "laminate film cell".



NOTE The figures show two flat surfaces (1 and 2) with batteries (3) of different shapes placed between them for crushing, using a piston (4).

Figure 3 – Examples of a test set-up for the crush test

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 (charging) current 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 [20].

b) Test procedure

Each test battery shall be subjected to a charging current of three times the abnormal charging current I_c 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 4. The test batteries shall be stored for 1 h afterwards.

The test shall be conducted with undischarged test cells and batteries.

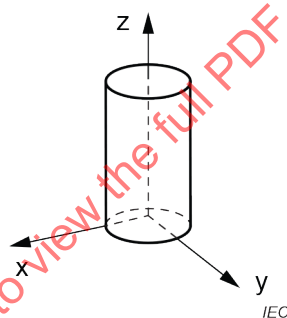


Figure 4 – Axes for free fall

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.

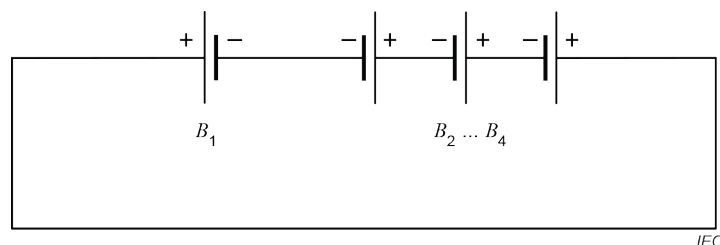
6.5.8 Test L: Incorrect installation

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 $0,1 \Omega$. The circuit shall be completed for 24 h or until the battery case temperature has returned to ambient (see Figure 5).

**Key**

B_1 Test cell

$B_2 \dots B_4$ Additional cells, undischarged

Figure 5 – Circuit diagram for incorrect installation

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 might be different.

b) Test procedure

Each test battery shall be pre-discharged 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 6 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 % pre-discharged test batteries.

Table 7 – Resistive load for overdischarge

Battery type	Resistive load R_1 Ω
CR17345	8,20
CR15H270	8,20
FR14505	3,60
FR10G445	3,60

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

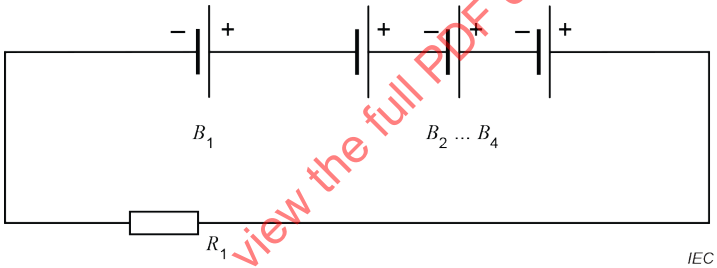
EXAMPLE When CR17345 and CR15H270 batteries were standardized, R_1 was determined from the end-voltage of the assembly in Figure 6, using the formula

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

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 4 of IEC 60086-1:2015.



Key

- B_1 Test battery, 50 % predischarged and, in separate tests, 75 % predischarged.
- $B_2 \dots B_4$ Additional batteries, undischarged
- R_1 Resistive load

Figure 6 – Circuit diagram for overdischarge

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 document 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	Subclause
a)	Predischarge current or resistive load and end-point voltage specified by the manufacturer	6.1.5
b)	Method to measure the energy of an explosion, if any.	6.2.7
c)	Shape: prismatic, flexible, coin or cylindrical; Diameter: less than 18 mm or not less than 18 mm.	6.5.2 and 6.5.3
d)	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
e)	Rated capacity specified by the manufacturer for test H	6.5.4
f)	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
g)	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:

- name and address of the test facility;
- name and address of applicant (where appropriate);
- a unique test report identification;
- the date of the test report;
- design characteristics of the test cells or batteries according to 4.1;
- test descriptions and results, including the parameters according to 6.6;
- type of the test sample(s): cell, component cell, battery or battery assembly;
- weight of the test sample(s);
- lithium content of the sample(s);
- a signature with name and status of the signatory.

It is not necessary to issue a new report unless new type testing is required, see 5.1.

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 7a);
- b) two series blocking diodes (see Figure 7b);
- 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 7 – Examples of wiring for charge protection

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 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*

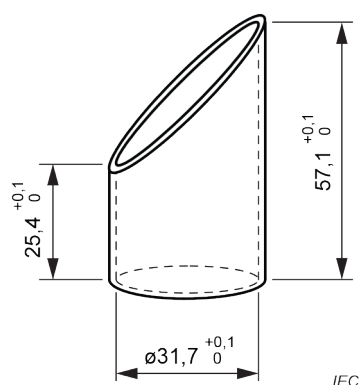
In particular, keep batteries which are considered swallowable out of the reach of children, particularly those batteries fitting within the limits of the ingestion gauge as defined in Figure 8. In case of ingestion of a cell or battery, seek medical assistance promptly. Swallowing coin cells or batteries can cause chemical burns, perforation of soft tissue, and in severe cases can cause death. They need to be removed immediately if swallowed. See Figure 9 for an example of appropriate warning text.

Warning text similar to Figure 9 may be used for safety information about battery handling. For cautionary advice and symbols to be printed on batteries and battery packagings refer to Clause 9.

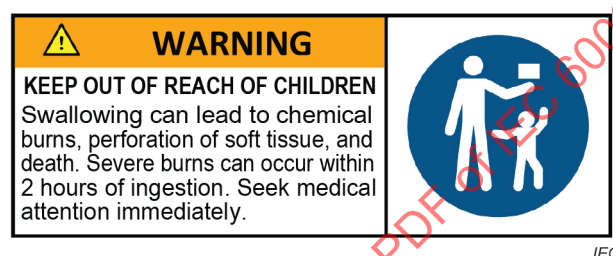
NOTE 1 Refer to E.1 in Annex E for more details.

NOTE 2 Refer to [14] for general information on hazards from batteries.

Dimensions in millimetres



[SOURCE: ISO 8124-1 [19]]

Figure 8 – Ingestion gauge

NOTE This product safety label is compliant with [17].

Figure 9 – Example for warning against swallowing, particularly coin cell batteries

- 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 pressure relief 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 such as keys, coins, etc. 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

Regulations concerning international transport of lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods [21].

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

Testing requirements are defined in the UN Manual of Tests & Criteria [22]. As regulations are subject to change, the latest editions should be consulted.

For reference, transportation tests are also given in IEC 62281 [12].

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 [21], 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 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 and packaging

9.1 General

With the exception of swallowable 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.

See Table 9 under “General” for a summary of the marking requirements.

9.2 Swallowable batteries

For swallowable batteries i.e. those that fit entirely within the Ingestion Gauge (Figure 8) the designation 9.1 a) and the polarity 9.1 c) shall be marked on the battery, while all other markings shown in 9.1 may be given on the immediate package. However, when batteries are intended for direct sale in consumer-replaceable applications, caution for ingestion shall also be marked on the immediate package:

- a) caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F.

Swallowable batteries that are intended for direct sale in consumer-replaceable applications and have a diameter of 16 mm or more shall be packaged in:

- b) child resistant packaging.

See Table 9 under “Swallowable” for a summary of the marking and packaging requirements.

9.3 Safety pictograms

Safety pictograms that could be considered for use as an alternative to written cautionary advice are provided in Annex D.

Table 9 – Marking and packaging requirements

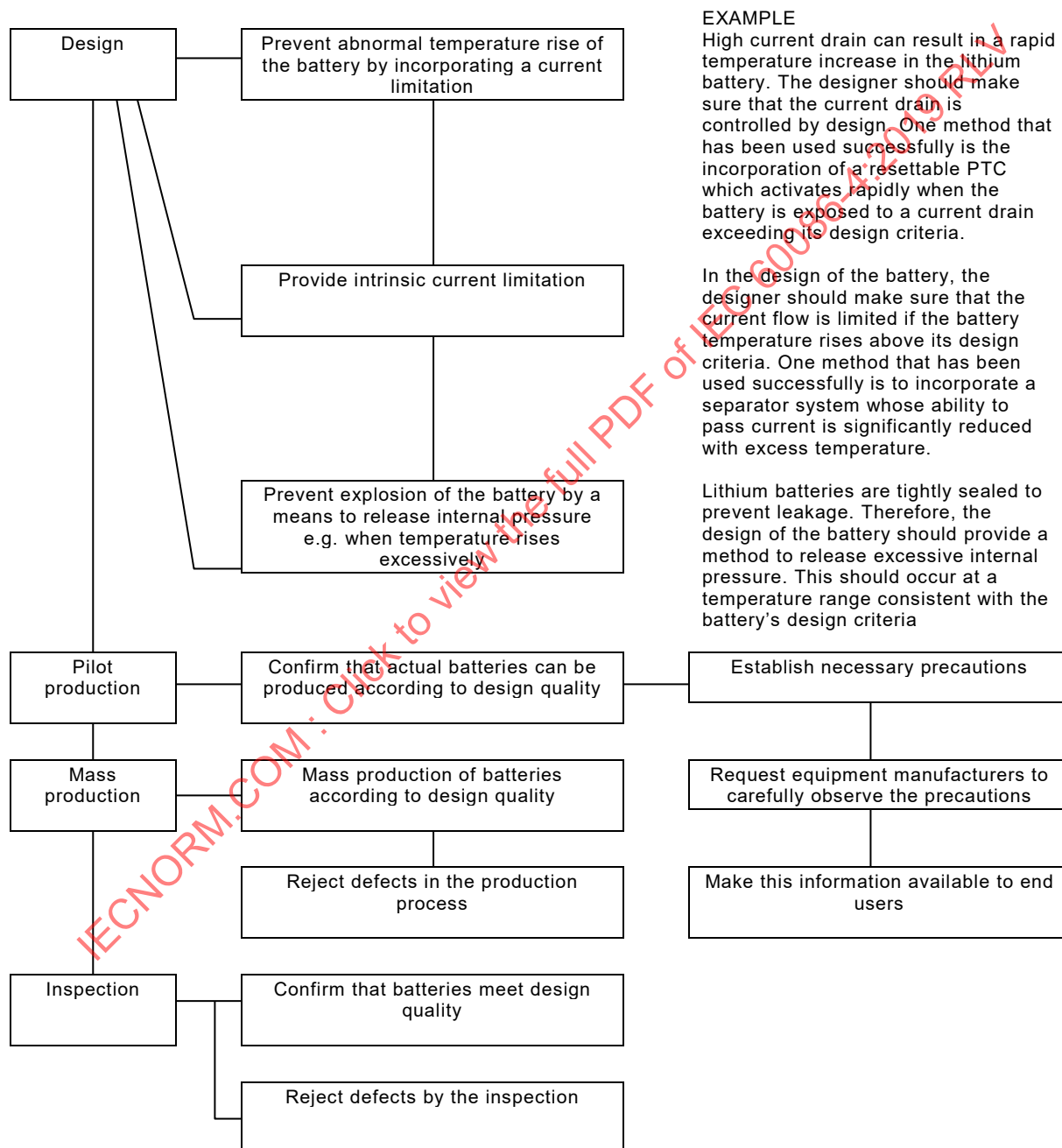
List item	General	Swallowable		
		d < 16 mm	16 mm ≤ d < 20 mm	d ≥ 20 mm
a) Designation, IEC or common	B	B	B	B
b) Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code	B			
c) Polarity of the positive (+) terminal	B	B	B	B
d) Nominal voltage	B			
e) Name or trade mark of the manufacturer or supplier	B			
f) Cautionary advice	B			
g) Caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F		P ¹⁾	P ¹⁾	B ¹⁾ + P ¹⁾
h) Child resistant packaging	n/a	n/a	R	R
¹⁾ The transition period for this requirement is 2 years from the publication date of the fifth edition of this part of IEC 60086.				
Key: d: Diameter B: Marking required on cell / battery P: Marking required on immediate packaging R: Child resistant packaging n/a: Not applicable empty: Marking may appear on (cell / battery and/or) immediate packaging				

Annex A (informative)

Guidelines for the achievement of safety of lithium batteries

The guidelines given in Table A.1 were followed during the development of high power batteries for consumer use. They are given here for information.

Table A.1 – Battery design guidelines



Annex B (informative)

Guidelines for designers of equipment using lithium batteries

Table B.1 represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of primary lithium cells and batteries to equipment manufacturers and battery assemblers (see also IEC 60086-5:2016 [8], Annex B, for guidelines for the design of battery compartments).

Table B.1 – Equipment design guidelines (1 of 2)

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(1) When a lithium battery is used as main power source	(1.1) Selection of a suitable battery	Select most suitable battery for the equipment, taking note of its electrical characteristics	Battery might overheat
	(1.2) Number of batteries (series connection or parallel ^a connection) to be used and method of use	a) Multicell batteries (2CR5, CR-P2, 2CR13252 and others); one piece only	If the capacity of batteries in series connection is different, the battery with the lower capacity will be overdischarged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Cylindrical batteries (CR17345 and others); less than three pieces	
		c) Coin type batteries (CR2016, CR2025, CR11108 and others); less than three pieces	
		d) When more than one battery is used, different types should not be used in the same battery compartment	
		e) When batteries are used in parallel ^a protection against charging should be provided	If the voltages of batteries in parallel connection are different, the battery with the lower voltage will become charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
(2) When a lithium battery is used as back-up power source	(1.3) Design of battery circuit	a) Battery circuit should be isolated from any other power source	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Protective devices such as fuses should be incorporated in the circuit	Short-circuiting a battery can result in electrolyte leakage, overheating, rupture, explosion or fire
	(2.1) Design of battery circuit	The battery should be used in a separate circuit so that it is not force discharged or charged by the main power source	Battery might be over-discharged to reverse polarity or charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(2.2) Design of battery circuit for memory back-up application	When a battery is connected to the circuit of a main power source with the possibility of being charged, a protective circuit is necessary with a combination of diode and resistor. The accumulated amount of the leakage current of the diode should be below 2 % of the battery capacity during expected life time	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
^a See 7.1.3			

Table B.1 (2 of 2)

Item	Sub-Item	Recommendations	Possible consequences if the recommendations are not observed
(3) Battery holder and battery compartment		a) Battery compartments should be designed so that if a battery is reversed, open circuit is achieved. Battery compartments should be clearly and permanently marked to show the correct orientation of batteries	Unless protection is provided against battery reversal, damage to equipment can occur from resultant electrolyte leakage, overheating, rupture, explosion or fire
		b) Battery compartments should be designed so that batteries other than the specified size cannot be inserted and make contact	Equipment might be damaged or might not operate
		c) Battery compartments should be designed to allow generated gases to escape	Battery compartments might be damaged when internal pressure of the battery becomes too high due to gas generation
		d) Battery compartments should be designed to be water proof	
		e) Battery compartments should be designed to be explosion proof when tightly sealed	
		f) Battery compartments should be isolated from heat generated by the equipment	Battery might be deformed and leak electrolyte due to excessive heat
		g) Battery compartments should be designed so that they cannot easily be opened by children	Children might remove batteries from the compartment and swallow them
(4) Contacts and terminals		a) Material and shape of contacts and terminals should be selected so that effective electric contact is maintained	Heat might generate at the contact due to insufficient connection
		b) Auxiliary circuit should be designed to prevent reverse installation of batteries	Equipment might be damaged or might not operate
		c) Contact and terminal should be designed to prevent reverse installation of batteries	Equipment might be damaged. Battery might cause electrolyte leakage, overheating, rupture, explosion or fire
		d) Direct soldering or welding to a battery should be avoided	Battery might leak, overheat, rupture, explode or catch fire
(5) Indication of necessary precautions	(5.1) On the equipment	Orientation of batteries (polarity) should be clearly indicated at the battery compartment	When a battery is inserted reverse and charged, it can result in electrolyte leakage, overheating, rupture, explosion or fire
	(5.2) In the instruction manual	Precautions for the proper handling of batteries should be indicated	Batteries might be mishandled and cause accidents

Annex C (informative)

Additional information on display and storage

This annex provides additional details concerning display and storage of lithium batteries to those already given in 7.6.

The storage area should be clean, cool, dry, ventilated and weatherproof.

For normal storage, the temperature should be between +10 °C and +25 °C and should never exceed +30 °C. Extremes of humidity (over 95 % and below 40 % relative humidity) for sustained periods should be avoided since they are detrimental to both batteries and packings. Batteries should therefore not be stored next to radiators or boilers nor in direct sunlight.

Although the storage life of batteries at room temperature is excellent, storage is improved at lower temperatures provided that special precautions are taken. The batteries should be enclosed in special protective packing (such as sealed plastic bags or variants) which should be retained to protect the batteries from condensation during the time they are warming to ambient temperature. Accelerated warming is harmful.

Batteries which have been cold-stored may be put into use after return to ambient temperature.

Batteries may be stored fitted in equipment or packages, if determined suitable by the battery manufacturer.

The height to which batteries may be stacked is clearly dependent on the strength of the packaging. As a general rule, this height should not exceed 1,5 m for cardboard packages or 3 m for wooden cases.

The above recommendations are equally valid for storage conditions during prolonged transit. Thus, batteries should be stored away from ship engines and not left for long periods in unventilated metal box cars (containers) during summer.

Batteries should be dispatched promptly after manufacture and in rotation to distribution centres and on to the users. In order that stock rotation (first in, first out) can be practised, storage areas and displays should be properly designed and packs adequately marked.

Annex D (informative)

Safety pictograms

D.1 General

Cautionary advice to fulfil the marking requirements in this standard has, on a historical basis, been in the form of written text. In recent years, there has been a growing trend toward the use of pictograms as a complementary or alternative means of product safety communication.

The objectives of this annex are: (1) to establish uniform pictogram recommendations that are tied to long-used and specific written text, (2) to minimize the proliferation of safety pictogram designs, and (3) to lay the foundation for the use of safety pictograms instead of written text to communicate product safety and cautionary statements.

NOTE The design of these safety pictograms basically follows the design principles laid down in [16] and [18]. It was, however, adjusted to the limitations existing for battery marking.

D.2 Pictograms

The pictogram recommendations and cautionary advice are given in Table D.1.

Table D.1 – Safety pictograms (1 of 2)

Reference	Safety pictogram	Cautionary advice
A		DO NOT CHARGE
B		DO NOT DEFORM OR DAMAGE
C		DO NOT DISPOSE OF IN FIRE
D		DO NOT INSERT INCORRECTLY
NOTE The grey shading highlights a white margin appearing when the pictogram is printed on coloured or black background.		

Table D.1 (2 of 2)

Reference	Safety pictogram	Cautionary advice
E		KEEP OUT OF REACH OF CHILDREN NOTE 1 See 7.2a) for critical safety information NOTE 2 This pictogram has been submitted to ISO TC 145 for standardisation in [18] NOTE 3 See also Annex F
F		DO NOT MIX DIFFERENT TYPES OR BRANDS
G		DO NOT MIX NEW AND USED
H		DO NOT OPEN OR DISMANTLE
I		DO NOT SHORT CIRCUIT
J		INSERT CORRECTLY
NOTE The grey shading highlights a white margin appearing when the safety pictogram is printed on coloured or black background.		

D.3 Instruction for use

The following instructions are provided for use of the safety pictograms.

- Safety pictograms should be clearly legible.
- Whilst colours are permitted, they should not detract from the information displayed. If colours are used, the circle and diagonal bar of pictograms A to D and F to I should be red and the background of pictograms E and J should be blue.
- Not all of the safety pictograms need to be used together for a particular type or brand of battery. In particular, safety pictograms D and J are meant as alternatives for a similar purpose.

Annex E (normative)

Child resistant packaging of coin cells

E.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its voltage in excess of 2 V causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

NOTE Ingested button cells with less than 2 Volts do not exhibit the potential to cause severe chemical burns within a short time. If such cells have been ingested, established medical practice is to monitor them until they get past the oesophagus and then allow them to naturally pass through the digestive tract.

This Annex provides an approach for child resistant packaging of coin cells in order to help in preventing their accidental ingestion.

E.2 Applicability

The following applies to consumer type coin cells with a diameter of 16 mm and larger.

a) Single cell packaging

The packaging for coin cells shall meet one of the following conditions:

- i) Packaging requirements specified in any of [24], [25], or [26]; or
- ii) The packaging strength shall be such that the packaging passes the tests described in E.3.

b) Multi-cell packaging

Each cell containment in a multi-cell packaging shall be in compliance with a) even when another cell containment is removed from the packaging.

E.3 Packaging tests

E.3.1 General

The following test methods were developed based on the analysis of the behaviour of children in a test where they were required to try and open coin cell packagings within a limited time. The tests shall be conducted by an instructed person or, alternatively, if necessary, using suitable equipment.

E.3.2 Test items

a) Bending test

Hold the packaging with the fingers of one hand and hold the cell with the fingers of the other hand. Bend the packaging close to the battery until one hand touches the other hand as shown in Figure E.1. This is a guide for the bending angle: $150^\circ \pm 5^\circ$ or more.

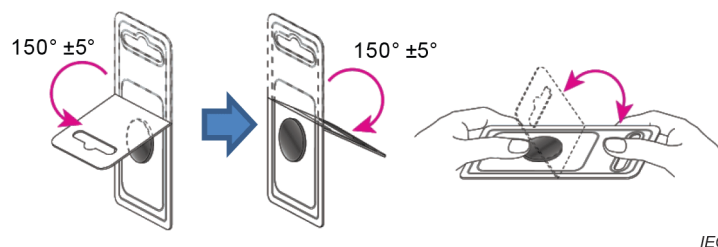


Figure E.1 – Bending test

b) Torsion test

Hold the packaging with the fingers of one hand on each of its shorter sides and twist it diagonally with a torsion angle of $45^\circ \pm 5^\circ$ in opposite directions as shown in Figure E.2, three times in both directions.

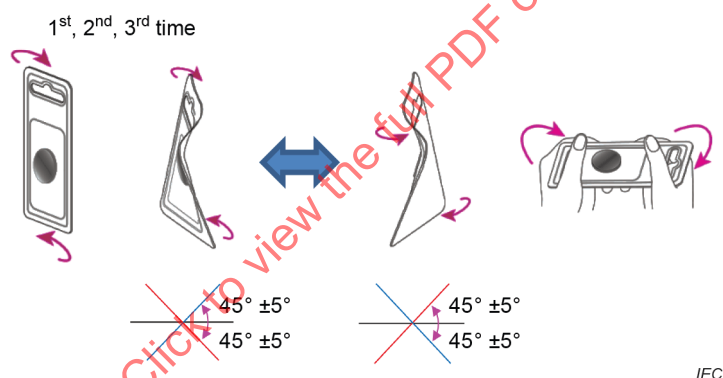


Figure E.2 – Torsion test

c) Tearing test

Try to tear the cell compartment with your fingers as shown in Figure E.3. Alternatively use suitable equipment and apply a force of at least 25 N.

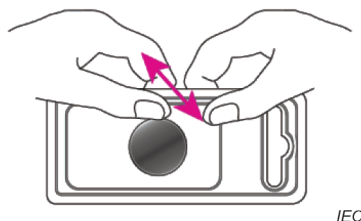


Figure E.3 – Tearing test

d) Pushing test

Try to push the cell out of the compartment with your fingers. Alternatively pull with a mass of at least 5 kg for 30 s; as shown in Figure E.4.

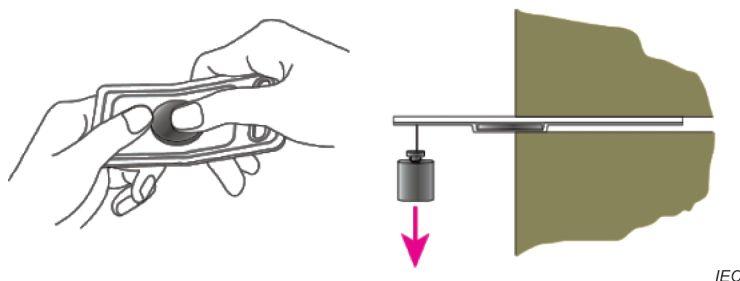


Figure E.4 – Pushing test

E.3.3 Test procedure

Sample packagings shall be tested in the condition of the packaging as sold to the consumer. The number of test samples shall be 10 packagings. Each sample shall be subjected to a series of tests in the order and frequency outlined in Table E.1.

Table E.1 – Test procedure

Order	Test item		Number of times
(1)	a)	Bending test	50
(2)	b)	Torsion test	25
(3)	c)	Tearing test	1
(4)	b)	Torsion test	25
(5)	a)	Bending test	50
(6)	c)	Tearing test	1
(7)	d)	Pushing test	1

E.3.4 Criteria

Each test sample shall meet the following criteria.

- Each cell shall be kept in its packaging until the end of the test series, and
- In order to prevent a child from pulling the cell out from its compartment, the packaging shall not open too wide. The maximum allowable size of an opening in the packaging is 6 mm diameter for a round hole and 10 mm length for a slit. See Figure E.5 for maximum packaging openings.

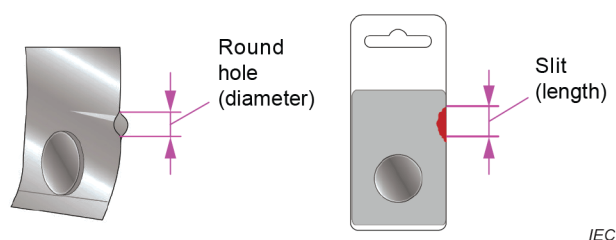


Figure E.5 – Maximum packaging opening

Annex F (informative)

Use of the KEEP OUT OF REACH OF CHILDREN safety sign

F.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the esophagus, its voltage in excess of 2 V causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

The new safety sign KEEP OUT OF REACH OF CHILDREN should give parents who have children a heads-up as a mandatory action sign even if intended products are safe in the usual sense of adults.

Therefore, purpose of the new safety sign is used to convey the message that these products should be kept out of reach of children in order to prevent accidental ingestion.

F.2 Safety sign

When a safety sign is used to convey the message that these products should be kept out of reach of children, the following best practices apply. The safety sign recommendation and cautionary advice for use on batteries and battery packagings are given in Table D.1, safety sign E while warning text for safety information about battery handling is given in Figure 9.

F.3 Best practices for marking the packaging

- a) Refer to Table 9 for marking requirements on packaging.
- b) The safety sign should be on contrasting background. The background should cover at least 50 % of the area of the pictogram.
- c) The size of the safety sign should be 6 mm in diameter or larger.
- d) If the text KEEP OUT OF REACH OF CHILDREN is used, it should contrast with the background color on which it is printed.

F.4 Best practices for marking the cell

- a) Refer to Table 9 for marking requirements on coin cells.
- b) The safety sign should be durably and indelibly marked. No colour is required. Engraving, etching, embossing or stamping are acceptable.

NOTE Recommended safety signs are shown in Figure F.1. The manufacturer can select any of the safety signs.



Type 1



Type 2



Type 3

Figure F.1 – Recommended safety signs for use on coin cells

- c) The safety sign on cells should have a diameter of 6 mm or larger.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

IEC 60086-4 Edition 5.0 2019-04

PILES ÉLECTRIQUES –

Partie 4: Sécurité des piles au lithium

FEUILLE D'INTERPRÉTATION 1

Cette feuille d'interprétation a été établie par le comité d'études 35 de l'IEC: Piles.

Le texte de cette feuille d'interprétation est issu des documents suivants:

DISH	Rapport de vote
35/1445/DISH	35/1448/RVDISH

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette feuille d'interprétation.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

Question 1

En examinant l'IEC 60086-4 Édition 5.0 2019-04, j'ai pensé qu'il était difficile de comprendre toutes les exigences de marquage pour les piles susceptibles d'être ingérées, ainsi que le but de ces exigences. Pouvez-vous fournir des explications détaillées?

Réponse 1

La liste d'énoncés suivante reflète l'objet du Tableau 9 et présente une interprétation de certaines parties de l'Article 9 et de l'Annexe F:

- a) Le Tableau 9 vise à résumer les exigences contenues dans le texte, à savoir en 7.2 a), 9.1 et 9.2, et à l'Annexe F.
- b) La structure du tableau 9 est similaire à celle de la liste figurant en 9.1 (points "a)" à "f)") et en 9.2 (points "a)" à "b)").
- c) Le point a) du 9.2 ne permet pas de savoir exactement ce qui doit figurer sur l'emballage et sur la pile : le signe de sécurité seul (Tableau D.1, point E, ou Figure F.1) ou l'étiquette de sécurité complète du produit (Figure 9).

L'objet des mesures visant à prévenir l'ingestion accidentelle de piles est d'éliminer la possibilité pour les enfants de se retrouver avec des piles coincées dans l'œsophage.

La pile exigeant des mesures pour prévenir l'ingestion accidentelle est une pile susceptible d'être ingérée, dont la taille correspond aux limites du gabarit d'ingestion et qui est appliquée à la vente directe dans des applications remplaçables par le consommateur, dans lesquelles les enfants ont la possibilité d'accéder aux piles avec risque d'ingestion.

Il ne figure pas, dans le texte, de description exigeant le marquage de Mise en garde contre l'ingestion sur la pile ou l'élément de diamètre minimal de 20 mm. Toutefois, compte tenu de l'examen des mesures visant à prévenir l'ingestion accidentelle, il a été déterminé que le marquage de "Mise en garde contre l'ingestion sur une pile ou un élément de diamètre minimal de 20 mm est nécessaire et l'exigence correspondante figure dans le Tableau 9. Par conséquent, un pictogramme doit être gravé en remplacement de la Mise en garde contre l'ingestion due à une pile ou un élément de diamètre minimal de 20 mm, qui ne dispose pas d'espace suffisant pour apposer le marquage.

Le type de "Mise en garde contre l'ingestion" qui doit figurer sur l'emballage immédiat des piles risquant d'être ingérées constitue l'un des signes de sécurité, comme le l'indique la Figure F.1. Si l'emballage dispose de suffisamment d'espace, des informations supplémentaires selon la Figure 9 (l'étiquette de sécurité ou seulement son texte) peuvent être imprimées sur l'emballage ou les informations de sécurité connexes portant sur la manipulation des piles.

Le Tableau 1 de la présente Feuille d'Interprétation résume les exigences relatives au marquage des piles boutons au lithium.

Tableau 1 – Exigences de marquage relatives aux piles susceptibles d'être ingérées

Diamètre	Exigence(s)
$d < 16 \text{ mm}$	Consigne de prudence formulée par la mention TENIR HORS DE PORTÉE DES ENFANTS ou le symbole de sécurité E du Tableau D.1 sur l'emballage immédiat.
$16 \text{ mm} \leq d < 20 \text{ mm}$	Emballage à l'épreuve des enfants et consigne de prudence formulée par la mention TENIR HORS DE PORTÉE DES ENFANTS ou le symbole de sécurité E du Tableau D.1 sur l'emballage immédiat.
$d \geq 20 \text{ mm}$	Emballage à l'épreuve des enfants, consigne de prudence formulée par la mention TENIR HORS DE PORTÉE DES ENFANTS ou le symbole de sécurité E du Tableau D.1 sur l'emballage immédiat, et le symbole de sécurité E du Tableau D.1 sur le côté positif de la pile.
NOTE Le cas échéant, il convient que la consigne de prudence sous forme rédigée apparaisse dans une ou plusieurs langues selon le marché sur lequel sont commercialisées les piles et batteries.	

Question 2

Au point 9.2 et en particulier au point 9.2 a), il n'est pas aisé de saisir clairement quels types de piles sont destinés à la vente directe dans des applications de remplacement par les consommateurs?

Réponse 2

Les piles dont il est question sont celles comportant un emballage ordinaire, tel que les blisters, en vente dans les magasins et sur Internet, les piles contenues dans l'emballage de l'équipement correspondant et les piles intégrées dans l'équipement et qui peuvent être remplacées par le consommateur.

Question 3

L'Annexe F est indiquée comme étant "Informatif"; toutefois, la mention "exigences" figure dans le titre du Tableau 9. S'agissant du Tableau 9, faut-il considérer l'Annexe F comme étant "normative"?

Réponse 3

L'annexe F contient des éléments supplémentaires; le texte principal figurant dans le corps de la norme prévaut sur ceux-ci. Par conséquent, même si l'Annexe F est informative, le contenu figurant dans le Tableau 9 doit être considéré comme étant des exigences.

Question 4

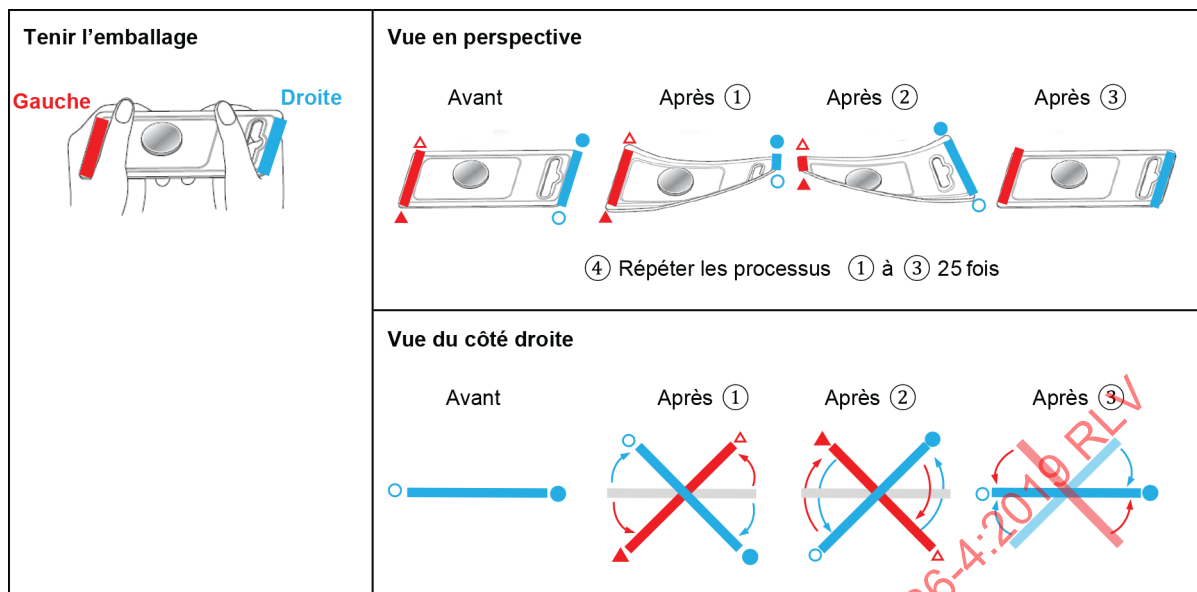
Dans l'E.3.2 b), la méthode d'essai de torsion est difficilement compréhensible. La méthode consistant à tordre l'emballage "trois fois dans les deux sens" n'est pas claire.

Réponse 4

Les instructions ci-après précisent la méthode et le nombre de torsions de l'emballage et dans quel l'ordre procéder.

- ① Première fois – Tenir l'emballage avec les doigts d'une main sur chaque côté court en partant de l'état de 0 degré (état neutre sans torsion). Tordre l'emballage suivant sa diagonale en appliquant un angle de torsion de 45° dans les sens opposés, comme cela est représenté à la Figure E.2.
- ② Deuxième fois – Tordre l'emballage suivant sa diagonale en appliquant un angle de 90° (45° vers l'arrière + 45° dans le sens opposé) dans des directions opposées à celle de la première torsion
- ③ Troisième fois - Retour à l'état neutre sans torsion (45° vers l'arrière)
- ④ Les mouvements ①, ② et ③ sont comptés comme 1 fois (1 réciprocity) et sont répétés 25 fois (25 réciprocitys).

La Figure 1 de la présente feuille d'Interprétation représente les mouvements de l'essai de torsion. Les lignes rouges et bleues représentent le bord gauche et le bord droite de l'emballage. Les triangles et les cercles ont été ajoutés pour repérer l'orientation pendant les mouvements.



IEC

Figure 1 – Essai de torsion

Question 5

D'après le 9.2 b), le Tableau 9 et l'annexe E, il n'est pas facile de déterminer quelle est la période de transition concernant l'exigence portant sur les "emballages à l'épreuve des enfants" ?

Réponse 5

La durée de transition est la même que pour les exigences portant sur le marquage et l'emballage, à savoir 2 ans à compter de la date de publication de la cinquième édition de l'IEC 60086-4.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

PILES ÉLECTRIQUES –

Partie 4: Sécurité des piles au lithium

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La Norme internationale IEC 60086-4 a été établie par le comité d'études 35 de l'IEC: Piles.

Cette cinquième édition annule et remplace la quatrième édition parue en 2014 dont elle constitue une révision technique.

La présente édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) Mise à jour des critères pour une explosion;
- b) Ajout de paramètres pour l'essai de décharge excessive des piles des types FR14505 et FR10G445;
- c) Ajout d'un nouveau paragraphe 5.1 Validité des essais;
- d) mise à jour du pictogramme E dans le Tableau D.1;

- e) Ajout de l'Annexe E avec des exigences relatives aux emballages à l'épreuve des enfants d'éléments de type bouton;
- f) Ajout de l'Annexe F avec des recommandations sur l'utilisation du signal de sécurité TENIR HORS DE PORTEE DES ENFANTS.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
35/1420/FDIS	35/1423/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

NOTE Les caractères d'imprimerie suivants sont utilisés:

- instructions/avertissements pour les consommateurs: *en caractères italiques*.

Une liste de toutes les parties de la série IEC 60086, publiées sous le titre général *Piles électriques*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

Le contenu des corrigenda d'octobre 2019 et avril 2020 et la feuille d'interprétation de mai 2020 a été pris en considération dans cet exemplaire.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

INTRODUCTION

La notion de sécurité est étroitement liée à la sauvegarde de l'intégrité des personnes et des biens. Le présent document spécifie les essais et les exigences pour les piles au lithium et elle a été établie conformément aux lignes directrices ISO/IEC, en prenant en compte toutes les normes nationales et internationales qui s'appliquent.

Les piles au lithium sont différentes des piles électriques conventionnelles utilisant un électrolyte aqueux dans la mesure où elles contiennent des matériaux inflammables.

Par conséquent, il est important de bien prendre en compte la sécurité aux étapes que sont la conception, la production, la distribution, l'utilisation et la mise au rebut des piles au lithium. Compte tenu de leurs caractéristiques spécifiques, les piles au lithium pour les applications grand public étaient à l'origine de petite taille et de faible puissance. Il existait également des piles au lithium de forte puissance qui étaient utilisées pour des applications industrielles et militaires particulières dont l'une des particularités était d'être "remplaçables par un technicien". La première édition du présent document avait été rédigée pour prendre en compte cette situation.

Cependant, depuis la fin des années 1980 environ, des piles au lithium de forte puissance ont commencé à être largement utilisées sur le marché de remplacement grand public, principalement en tant que source d'énergie dans les appareils de prise de vues. La demande pour de telles piles au lithium de forte puissance ayant augmenté de manière significative, différents fabricants ont commencé à en produire. Par conséquent, les aspects de sécurité relatifs aux piles au lithium de forte puissance ont été inclus dans la seconde édition du présent document.

Les piles au lithium, tant pour les applications grand public que pour les applications industrielles, sont des produits du marché dont la sûreté et la fiabilité sont bien établies, cela étant dû, au moins en partie, à l'existence de normes de sécurité telles que le présent document et, pour le transport, de l'IEC 62281. La quatrième édition du présent document ne reflète donc que les modifications mineures qui étaient devenues nécessaires pour qu'elle reste harmonisée avec l'IEC 62281 et pour continuer à améliorer les informations destinées à l'utilisateur touchant les questions de sécurité.

Les lignes directrices relatives aux questions de sécurité au moment de la conception des piles au lithium sont données dans l'Annexe A. L'Annexe B donne des lignes directrices relatives aux questions de sécurité au moment de la conception des matériels dans lesquels sont installées des piles au lithium. Les deux Annexes A et B reflètent l'expérience acquise avec les piles au lithium utilisées dans les applications pour les appareils de prise de vues et sont fondées sur le document de référence [22]¹.

La sécurité est l'absence de risques inacceptables. La sécurité absolue ne peut pas exister: il subsiste toujours un risque. De ce fait, un produit, un procédé ou un service ne peut être sûr que de manière relative. La sécurité est obtenue en réduisant le risque à un niveau tolérable déterminé par la recherche d'un équilibre optimal entre l'idéal de sécurité absolue et les exigences auxquelles doit répondre un produit, un procédé ou un service, et des facteurs tels que le bénéfice pour l'utilisateur, l'adéquation à l'usage prévu, la rentabilité et les conventions de la société concernée.

Dans la mesure où la sécurité pose différents problèmes, il est impossible d'établir une liste de dispositions et de recommandations précises qui s'appliquent dans tous les cas. Cependant, s'il est suivi de manière judicieuse en fonction de son applicabilité, le présent document constitue une référence raisonnable et cohérente en matière de sécurité.

¹ Les chiffres entre crochets se réfèrent à la Bibliographie.

PILES ÉLECTRIQUES –

Partie 4: Sécurité des piles au lithium

1 Domaine d'application

La présente partie de l'IEC 60086 spécifie les essais et les exigences pour les piles électriques au lithium afin d'assurer leur fonctionnement en toute sécurité dans les conditions d'utilisation prévue et en cas de mauvais usage raisonnablement prévisible.

NOTE Les piles électriques au lithium qui sont normalisées dans l'IEC 60086-2 sont prévues pour satisfaire à toutes les exigences applicables ci-dessous. Il est entendu que la présente partie de l'IEC 60086 pourrait également être prise en compte pour mesurer les piles électriques au lithium non normalisées et/ou s'assurer qu'elles sont sûres. Dans les deux cas, il n'existe aucune déclaration ou garantie que la conformité ou la non-conformité à la présente norme répondra ou ne répondra pas aux objectifs ou aux besoins particuliers de l'utilisateur.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60086-1, *Piles électriques – Partie 1: Généralités*

IEC 60086-2, *Piles électriques – Partie 2: Spécifications physiques et électriques*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

NOTE Certaines définitions tirées de l'IEC 60050-482, de l'IEC 60086-1 et du Guide ISO/IEC 51 sont répétées ci-après, dans un souci de commodité.

3.1

pile

un ou plusieurs éléments raccordés électriquement et placés dans un boîtier, avec des bornes, des marquages et des dispositifs de protection, etc., selon ce qui est nécessaire pour l'utilisation

[SOURCE: IEC 60050-482:2004, 482-01-04, modifiée ("équipés des dispositifs nécessaires pour l'emploi, par exemple boîtier" remplacé par "raccordés électriquement et placés dans un boîtier", ajout de "etc., selon ce qui est nécessaire pour l'utilisation")]

3.2

élément

unité fonctionnelle de base, consistant en un assemblage d'électrodes, d'électrolyte, de conteneur, de bornes et généralement de séparateurs, qui est une source d'énergie électrique obtenue par transformation directe d'énergie chimique

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

3.3

bouton au lithium <élément ou pile>

petit élément rond ou petite pile ronde d'une hauteur totale inférieure à son diamètre, contenant un électrolyte non aqueux

Note 1 à l'article: Typiquement, la tension nominale des piles au lithium est supérieure à 2 V.

[SOURCE: IEC 60050-482:2004 482-02-40, modifiée (termes modifiés, NOTE "En pratique, le terme élément bouton est utilisé exclusivement pour les piles au lithium non aqueuses" remplacée par une nouvelle note)]

3.4

élément composant

élément contenu dans une pile

3.5

<élément ou pile> **cylindrique**

élément rond ou pile ronde dont la hauteur totale est supérieure ou égale au diamètre

[SOURCE: IEC 60050-482:2004, 482-02-39, modifiée ("élément de forme cylindrique" remplacé par "élément rond ou pile ronde")]

3.6

profondeur de décharge

DOD

pourcentage de capacité assignée déchargée d'une pile

Note 1 à l'article: L'abréviation «DOD» est dérivée du terme anglais développé correspondant «Depth Of Discharge».

3.7

complètement déchargé

état d'un élément ou d'une pile à une profondeur de décharge de 100 %

3.8

dommage

blessure physique ou atteinte à la santé des personnes, ou atteinte aux biens ou à l'environnement

[SOURCE: Guide ISO/IEC 51:2014, 3.1]

3.9

danger

source potentielle de dommage

[SOURCE: Guide ISO/IEC 51:2014, 3.2]

3.10

utilisation prévue

utilisation conforme aux informations fournies avec un produit ou un système ou, en l'absence de telles informations, conforme aux profils d'utilisation généralement entendus

[SOURCE: Guide ISO/IEC 51:2014, 3.6]

3.11

grande pile

pile dont la masse brute est supérieure à 12 kg

3.12

grand élément

élément dont la masse brute est supérieure à 500 g

3.13

élément au lithium

élément contenant un électrolyte non aqueux et dont l'électrode négative est constituée de lithium ou en contient

[SOURCE: IEC 60050-482:2004 482-01-06, modifiée (suppression de la NOTE)]

3.14

tension nominale

valeur approchée appropriée d'une tension, utilisée pour désigner ou identifier un élément, une pile, ou un système électrochimique

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

3.15

tension en circuit ouvert

OCV, U_{OC} , tension à vide

tension électrique aux bornes d'un élément ou d'une pile en l'absence de circulation de courant externe

Note 1 à l'article: L'abréviation «OCV» est dérivée du terme anglais développé correspondant «Open Circuit Voltage».

[SOURCE: IEC 60050-482:2004, 482-03-32, modifiée (termes "OCV, U_{OC} , tension à vide" ajoutés, "quand le courant de décharge est nul" remplacé par "en l'absence de circulation de courant externe")]

3.16

parallélépipédique <élément ou pile>

qualifie un élément ou une batterie ayant la forme d'un parallélépipède dont les faces sont rectangulaires

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

3.17

dispositif de protection

dispositifs tels que les fusibles, les diodes ou d'autres limiteurs de courant électriques ou électroniques, conçus pour interrompre la circulation du courant, bloquer la circulation du courant dans un sens ou limiter la circulation de courant dans un circuit électrique

3.18**capacité assignée**

valeur de la capacité d'un élément ou d'une batterie déterminée dans des conditions spécifiées et déclarée par le fabricant

[SOURCE: IEC 60050-482:2004, 482-03-15, modifiée ("élément ou" ajouté)]

3.19**mauvais usage raisonnablement prévisible**

utilisation d'un produit, d'un procédé ou d'un système dans des conditions ou à des fins non prévues par le fournisseur, mais qui peut provenir d'un comportement humain envisageable

[SOURCE: Guide ISO/IEC 51:2014, 3.7, (suppression des notes)]

3.20**risque**

combinaison de la probabilité d'un dommage et de sa gravité

[SOURCE: Guide ISO/IEC 51:2014, 3.9, (suppression de la note)]

3.21**sécurité**

absence de risque intolérable

[SOURCE: Guide ISO/IEC 51:2014, 3.14]

3.22**non déchargé**

état d'un élément ou d'une pile électrique à une profondeur de décharge de 0 %

4 Exigences relatives à la sécurité**4.1 Conception**

Les piles au lithium sont classées en fonction de leur composition chimique (anode, cathode, électrolyte), de leur construction interne (bobine, spirale) et sont disponibles dans des configurations cylindriques, de type bouton, et parallélépipédiques. Il est nécessaire de prendre en compte tous les aspects de sécurité correspondants, au moment de la conception de la pile, en intégrant le fait qu'ils peuvent considérablement différer, en fonction du système au lithium mis en œuvre, de la puissance et de la configuration de la pile.

Les notions suivantes de conception pour assurer la sécurité sont communes à toutes les piles au lithium:

- a) Un échauffement anormal dépassant la valeur critique définie par le fabricant doit être évité par la conception.
- b) Les augmentations de température à l'intérieur de la pile doivent être maîtrisées par une conception qui limite la circulation du courant.
- c) Les éléments et les piles au lithium doivent être conçus pour éviter des pressions internes excessives ou pour empêcher une rupture violente pendant le transport, l'utilisation prévue et un mauvais usage raisonnablement prévisible.

Voir l'Annexe A pour les lignes directrices à suivre afin d'assurer la sécurité des piles au lithium.

4.2 Plan qualité

Le fabricant doit préparer et mettre en œuvre un plan qualité définissant les procédures pour le contrôle des matériaux, composants, éléments et piles au cours de la fabrication, devant être appliquées au processus complet de production d'un type spécifique de pile. Il convient que les fabricants comprennent leurs capacités opérationnelles de processus et il convient qu'ils engagent les contrôles de processus nécessaires dans la mesure où ils sont liés à la sécurité des produits.

5 Essais de type et échantillonnage

5.1 Validité des essais

Les éléments ou les piles au lithium doivent être soumis aux essais conformément aux exigences de la présente norme. Les essais restent valides tant que la conception ou les exigences n'ont pas été modifiées. De nouveaux essais sont exigés lorsque:

- a) une spécification de masse de pile varie de plus de 0,1 g ou 20 %, la plus grande des valeurs, pour la cathode, l'anode ou l'électrolyte;
- b) la modification d'une spécification d'une pile entraînerait un échec des essais;
- c) de nouveaux essais ou de nouvelles exigences sont ajoutés; ou
- d) la modification d'une exigence entraînerait un échec des essais.

5.2 Echantillons d'essai

Il convient de prélever des échantillons dans les lots de production conformément aux méthodes statistiques acceptées. Le nombre d'échantillons d'essai est donné dans le Tableau 1. Les mêmes éléments et piles d'essai sont utilisés pour les essais A à E successivement. Des éléments et des piles d'essai neufs sont exigés pour chacun des essais F à M.

Tableau 1 – Nombre d'échantillons d'essai

Essais	Etat de décharge	Eléments et piles comportant un seul élément ^a	Piles comportant plusieurs éléments
Essais A à E	Non déchargé	10	4
	Complètement déchargé	10	4
Essai F or G	Non déchargé	5	5 éléments composants
	Complètement déchargé	5	5 éléments composants
Essai H	Complètement déchargé	10	10 éléments composants
Essais I à K	Non déchargé	5	5
Essai L	Non déchargé	20 (voir Note 1)	n/a
Essai M	Prédéchargés à 50 %	20 (voir Note 2)	n/a
	Prédéchargés à 75 %	20 (voir Note 3)	n/a
^a Dans le cas des piles comportant un seul élément qui a été soumis à essai, de nouveaux essais ne sont pas exigés, sauf si la modification est susceptible de conduire à un échec de l'un quelconque des essais.			
Légende: n/a: non applicable			

NOTE 1 Quatre piles connectées en série avec l'une des quatre piles inversée (cinq ensembles).

NOTE 2 Quatre piles connectées en série, l'une d'elles étant prédéchargée à 50 % (cinq ensembles).

NOTE 3 Quatre piles connectées en série, l'une d'elles étant prédéchargée à 75 % (cinq ensembles).

6 Essais et exigences

6.1 Généralités

6.1.1 Matrice d'application d'essai

L'applicabilité des méthodes d'essai aux éléments et piles d'essai est présentée dans le Tableau 2.

Tableau 2 – Matrice d'application d'essai

Forme	Essais applicables.												
	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
Description d'essai.								Légende:					
Essais relatifs à l'utilisation prévue A: Altitude B: Cycles thermiques C: Vibrations D: Chocs		Essais relatifs à de mauvais usages raisonnablement prévisibles: E: Court-circuit extérieur F: Impact G: Ecrasement H: Décharge forcée I: Charge anormale J: Chute libre K: Température élevée L: Installation incorrecte M: Décharge excessive						Forme s: élément ou pile comportant un seul élément m: pile comportant des éléments multiples					
								Applicabilité x: applicable n/a: non applicable					
^a Un seul essai doit être appliqué, l'essai F ou l'essai G.													
^b Uniquement applicable aux modèles CR17345, CR15H270 et piles de type similaire de construction en spirale susceptibles d'être installées de manière incorrecte et chargées.													
^c Uniquement applicable aux modèles CR17345, CR15H270 et piles de type similaire de construction en spirale susceptibles de subir une décharge excessive.													
^d L'essai s'applique aux éléments composants.													

6.1.2 Mise en garde

AVERTISSEMENT: Ces essais exigent l'utilisation de procédures qui peuvent entraîner des blessures si des précautions appropriées ne sont pas prises.

Lors de la rédaction de ces essais, il a été pris pour hypothèse qu'ils seraient réalisés par des techniciens suffisamment qualifiés et expérimentés utilisant une protection appropriée.

6.1.3 Température ambiante

Sauf spécification contraire, les essais doivent être effectués à une température ambiante de 20 °C ± 5 °C.

6.1.4 Tolérances de mesure des paramètres

L'exactitude globale des valeurs contrôlées ou mesurées, par rapport aux paramètres spécifiés ou réels, doit se situer dans les tolérances suivantes:

- a) $\pm 1 \%$ pour la tension;
- b) $\pm 1 \%$ pour le courant;
- c) $\pm 2 \text{ }^{\circ}\text{C}$ pour la température;
- d) $\pm 0,1 \%$ pour la durée;
- e) $\pm 1 \%$ pour les dimensions;
- f) $\pm 1 \%$ pour la capacité.

Ces tolérances comprennent l'exactitude combinée des instruments de mesure, des techniques de mesure utilisées et de toute autre source d'erreur dans la procédure d'essai.

6.1.5 Prédécharge

Lorsqu'un essai exige une prédécharge, les éléments d'essai ou les piles d'essai doivent être déchargés à leur profondeur respective de décharge sur une charge résistive avec laquelle la capacité assignée est obtenue ou à un courant spécifié par le fabricant.

6.1.6 Éléments supplémentaires

Si des éléments supplémentaires sont exigés pour réaliser un essai, ils doivent être du même type et, de préférence, du même lot de production que l'élément d'essai.

6.2 Evaluation des critères d'essai

6.2.1 Court-circuit

Un court-circuit est considéré s'être produit pendant un essai si la tension en circuit ouvert de l'élément ou de la pile immédiatement après l'essai est inférieure à 90 % de sa valeur avant l'essai. Cette exigence n'est pas applicable aux éléments ni aux piles d'essai complètement déchargés.

6.2.2 Échauffement excessif

Un échauffement excessif est considéré s'être produit pendant un essai si la température extérieure du boîtier de l'élément ou de la pile d'essai dépasse 170 °C.

6.2.3 Fuite

Une fuite est considérée s'être produite pendant un essai si de l'électrolyte ou une autre matière s'échappe de manière visible de l'élément ou de la pile d'essai ou s'il y a une perte de matière (à l'exception du boîtier de pile, des dispositifs de manipulation ou des étiquettes) de l'élément ou de la pile d'essai correspondant à une perte de masse dépassant les limites consignées dans le Tableau 3.

L'équation suivante est donnée pour quantifier la perte de masse $\Delta m/m$:

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

où

m_1 est la masse avant un essai;

m_2 est la masse après un essai.

Tableau 3 – Limites de perte de masse

Masse de l'élément ou de la pile m	Limite de perte de masse $\Delta m / m$
$m < 1 \text{ g}$	0,5 %
$1 \text{ g} \leq m \leq 75 \text{ g}$	0,2 %
$m > 75 \text{ g}$	0,1 %

6.2.4 Echappement de gaz

Un échappement de gaz est considéré s'être produit si, au cours d'un essai, et par suite d'une augmentation excessive de la pression interne, des gaz s'échappent d'un élément ou d'une pile par un dispositif de libération de la pression conçu à cet effet. Ces gaz peuvent contenir des matériaux piégés.

6.2.5 Feu

Un feu est considéré s'être produit si, au cours d'un essai, des flammes sont produites par l'élément ou la pile d'essai.

6.2.6 Rupture

Une rupture est considérée s'être produite si le conteneur d'un élément ou le boîtier d'une pile a subi une défaillance mécanique, entraînant une expulsion de gaz ou un déversement de liquides, mais sans éjection forcée de matériaux solides.

6.2.7 Explosion

Une explosion est considérée s'être produite si le conteneur d'un élément ou le boîtier d'une pile s'ouvre avec éjection violente de composants solides.

Pendant les essais réalisés sur des éléments ou des composants, l'éjection de composants internes est acceptable. L'énergie des composants éjectés doit être limitée. Si cela est exigé, la mesure peut être réalisée comme suit:

- il n'y a pas de pénétration dans un écran grillagé (constitué de fils d'aluminium recuit d'un diamètre de 0,25 mm avec une densité de grille de six à sept fils par centimètre) placé à 25 cm de l'élément; ou
- la mesure peut être réalisée en suivant une méthode qui a été démontrée équivalente à celle décrite en a).

6.3 Essais et exigences – Vue d'ensemble

Le présent document fournit des essais de sécurité pour l'utilisation prévue (essais A à D) et les mauvais usages raisonnablement prévisibles (essais E à M).

Le Tableau 4 contient une vue d'ensemble des essais et des exigences concernant l'utilisation prévue et les mauvais usages raisonnablement prévisibles.

Tableau 4 – Essais et exigences

Numéro d'essai		Désignation	Exigences
Essais relatifs à l'utilisation prévue	A	Altitude	NL, NV, NC, NR, NE, NF
	B	Cycles thermiques	NL, NV, NC, NR, NE, NF
	C	Vibrations	NL, NV, NC, NR, NE, NF
	D	Chocs	NL, NV, NC, NR, NE, NF
Essais relatifs à de mauvais usages raisonnablement prévisibles	E	Court-circuit extérieur	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Ecrasement	NT, NE, NF
	H	Décharge forcée	NE, NF
	I	Charge anormale	NE, NF
	J	Chute libre	NV, NE, NF
	K	Température élevée	NE, NF
	L	Installation incorrecte	NE, NF
	M	Décharge excessive	NE, NF
Les essais A à E doivent être exécutés les uns après les autres sur le même élément ou la même pile. Les essais F et G sont des variantes. Seul l'un d'entre eux doit être exécuté.			
Légende NC: Pas de court-circuit NE: Pas d'explosion NF: Pas de feu NL: Pas de fuite NR: Pas de rupture NT: Pas d'échauffement excessif NV: Pas d'échappement de gaz Voir 6.2 pour une description détaillée des critères d'essai.			

6.4 Essais relatifs à l'utilisation prévue

6.4.1 Essai A: Altitude

a) Objet

Cet essai simule les conditions de basse pression propres au transport aérien.

b) Procédure d'essai

Les éléments et piles d'essai doivent être stockés à une pression de 11,6 kPa ou inférieure pendant au moins 6 h à température ambiante.

c) Exigences

Il ne doit y avoir ni fuite, ni échappement de gaz, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.4.2 Essai B: Cycles thermiques

a) Objet

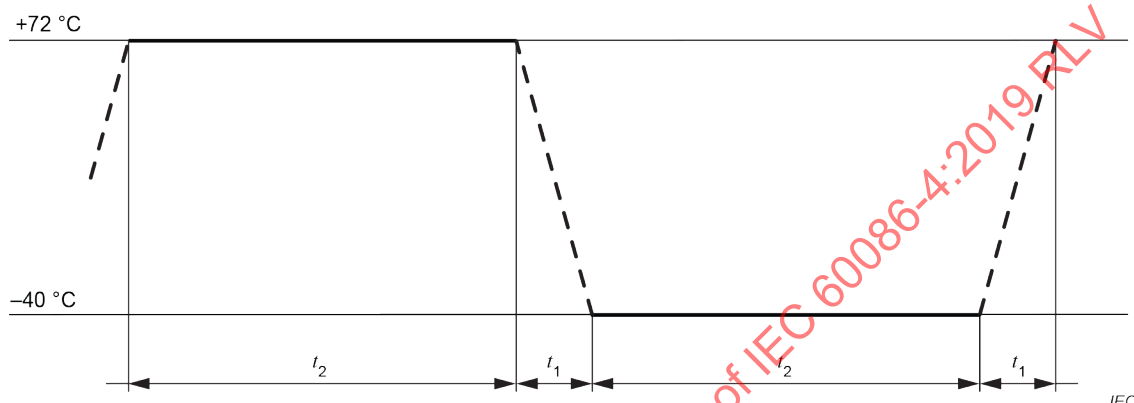
Cet essai évalue l'intégrité de l'étanchéité des éléments et des piles et celle de leurs connexions électriques internes. L'essai est exécuté en appliquant des cycles de température.

b) Procédure d'essai

Les éléments et piles d'essai doivent être stockés pendant au moins 6 h à une température d'essai de 72 °C, puis pendant au moins 6 h à une température d'essai de –40 °C. La durée maximale de transition entre les températures doit être de 30 min. Chaque élément ou pile d'essai doit être soumis à cette procédure à 10 reprises. Celle-ci est suivie par un stockage pendant au moins 24 h à température ambiante.

Pour les grands éléments et les grandes piles, la durée d'exposition aux températures d'essai doit être d'au moins 12 h au lieu de 6 h.

L'essai doit être réalisé en utilisant les éléments et les piles d'essai précédemment soumis à l'essai d'altitude.

**Légende**

$t_1 \leq 30 \text{ min}$

$t_2 \geq 6 \text{ h}$ (12 h pour les grands éléments et les grandes piles)

NOTE La figure représente un des dix cycles.

Figure 1 – Procédure pour les cycles thermiques

c) Exigences

Il ne doit y avoir ni fuite, ni échappement de gaz, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.4.3 Essai C: Vibrations

a) Objet

Cet essai simule des vibrations survenant pendant le transport. Les conditions d'essai sont fondées sur la gamme de vibrations fournie par l'OACI [2].

b) Procédure d'essai

Les éléments et les piles d'essai doivent être solidement fixés à la plate-forme du générateur de vibrations, sans déformation et de manière à transmettre fidèlement les vibrations. Les éléments et les piles d'essai doivent être soumis à des vibrations sinusoïdales selon le Tableau 5 qui montre une amplitude d'accélération supérieure différente pour les grandes piles. Ce cycle doit être répété 12 fois pendant 3 h au total pour chacune des trois positions de montage perpendiculaires les unes par rapport aux autres. Une des directions doit être perpendiculaire à la face des bornes.

L'essai doit être réalisé en utilisant les éléments et les piles d'essai précédemment soumis à l'essai de cycles thermiques.