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Part 4: Safety of lithium batteries

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



35/1526/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER: IEC 60086-4 ED6	
DATE OF CIRCULATION: 2023-09-01	CLOSING DATE FOR COMMENTS: 2023-10-27
SUPERSEDES DOCUMENTS: 35/1516/CD, 35/1520A/CC	

IEC TC 35 : PRIMARY CELLS AND BATTERIES	
SECRETARIAT: Japan	SECRETARY: Mr Takao Uyama
OF INTEREST TO THE FOLLOWING COMMITTEES: SC 3C,TC 21,SC 21A,TC 61,TC 108	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☒ SAFETY	

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TITLE:

Primary batteries - Part 4: Safety of lithium batteries

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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 sixth edition cancels and replaces the fifth edition published in 2019. This edition constitutes a technical revision.

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

- a) Added definitions for leakage and venting, in addition to the test criteria;
- b) Revised overdischarge test;
- c) Revised marking requirements;
- d) Revised criteria for the child resistant packaging test;
- e) Added a new annex with a saline soak test for coin cells;
- f) Changed the purpose of Annex F from “informative” to “normative”

- g) Added a new annex with Additional measures against misuse of batteries that not intended for consumer replacement;
- h) Integrated the contents of Interpretation Sheet 1 (IEC 60086-4:2019/ISH1:2020);
- i) In Clause 3, terms were reordered according their functions: basic terms, electrochemical systems, battery shapes, battery sizes, electrical characteristics, specifications, safety aspects, failure modes.
- j) In 6.4.4, the exemption for the shock acceleration for lithium primary batteries was reduced from 12 kg to 4,482 kg in order to reflect the fact that this is the threshold in IEC 62281, Test T-4, where the peak acceleration decreases below 150 g.

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

FDIS	Report on voting
35/xxxx/FDIS	35/xxxx/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.

NOTE The attention of National Committees is drawn to the fact that equipment manufacturers and testing organizations may need a transitional period following publication of a new, amended or revised IEC document in which to make products in accordance with the new requirements and to equip themselves for conducting new or revised tests. It is the recommendation of the committee that the content of this document be adopted for implementation nationally not earlier than 2 years from the date of publication. The transitional period applies specifically to Table 10.

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 reflected 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 [22]¹.

The ingestion hazard of coin cell batteries has become an issue and was addressed in the fifth and sixth editions of this document by several independent measures such as the development of a new safety sign “KEEP OUT OF REACH OF CHILDREN” as well as the introduction of child resistant packaging.

A new Annex H addresses measures against misuse of cells and batteries not intended for consumer replacement.

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 [documentpart of IEC 60086standard](#) 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*

IEC 62281, *Safety of primary and secondary lithium cells and batteries during transport*

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 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]

3.2 battery

one or more cells electrically connected and fitted in a case, with terminals, markings and protective devices etc., as necessary for use

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

317 **3.3**
318 **component cell**
319 cell contained in a battery

320 **3.4**
321 **lithium cell**
322 cell containing a non-aqueous electrolyte and a negative electrode of lithium or containing
323 lithium

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

325 **3.5**
326 **coin** <cell or battery>
327 **lithium button** <cell or battery>
328 small round cell or battery where the overall height is less than the diameter, containing non-
329 aqueous electrolyte.

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

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

334 **3.6**
335 **cylindrical** <cell or battery>
336 round cell or battery in which the overall height is equal to or greater than the diameter

337 [SOURCE: IEC 60050-482:2004, 482-02-39, modified ("cell with a cylindrical shape" replaced
338 by "round cell or battery")]

339 **3.7**
340 **prismatic** <cell or battery>
341 qualifies a cell or a battery having the shape of a parallelepiped whose faces are rectangular

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

343 **3.8**
344 **large cell**
345 cell with a gross mass of more than 500 g

346 **3.9**
347 **large battery**
348 battery with a gross mass of more than 12 kg

349 **3.10**
350 **nominal voltage**
351 suitable approximate value of the voltage used to designate or identify a cell, a battery or an
352 electrochemical system

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

3.11**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”)]

3.12**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)]

3.13**depth of discharge**

DOD

percentage of rated capacity discharged from a cell or battery

3.14**undischarged**

state of a primary cell or battery at 0 % depth of discharge

3.15**fully discharged**

state of a cell or battery at 100 % depth of discharge

3.16**harm**

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

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

3.17**hazard**

potential source of harm

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

3.18**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)]

3.19**safety**

freedom from risk which is not tolerable

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

3.20**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

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

397 **3.21**

398 **reasonably foreseeable misuse**

399 use of a product, process or system in a way not intended by the supplier, but which may
400 result from readily predictable human behaviour

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

402 **3.22**

403 **protective devices**

404 devices such as fuses, diodes or other electric or electronic current limiters designed to
405 interrupt the current flow, block the current flow in one direction or limit the current flow in an
406 electrical circuit

407 **3.23**

408 **leakage**

409 unplanned escape of electrolyte, gas or other material from a cell or battery

410 Note 1 to entry: Leakage in this sense should not be confused with the test evaluation criteria for leakage
411 specified in Clause 6 of this document.

412 **3.24**

413 **venting**

414 release of excessive internal pressure from a cell or battery in a manner intended by design

415 Note 1 to entry: Venting in this sense should not be confused with the test evaluation criteria for venting specified
416 in Clause 6 of this document.

417 **4 Requirements for safety**

418 **4.1 Design**

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

424 The following design concepts for safety are common to all lithium batteries:

- 425 a) Abnormal temperature rise above the critical value defined by the manufacturer shall be
426 prevented by design.
- 427 b) Temperature increases in the battery shall be controlled by a design which limits current
428 flow.
- 429 c) Lithium cells and batteries shall be designed to relieve excessive internal pressure or to
430 preclude a violent rupture under conditions of transport, intended use and reasonably
431 foreseeable misuse.

432 If, in particular cases, this design concept cannot be implemented, alternatively, the
433 organisational requirements described in Annex H shall apply.

434 See Annex A for guidelines for the achievement of safety of lithium batteries.

435 **4.2 Quality plan**

436 The manufacturer shall prepare and implement a quality plan defining the procedures for the
437 inspection of materials, components, cells and batteries during the course of manufacture, to
438 be applied to the total process of producing a specific type of battery. Manufacturers shall

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 document. 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 or 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 ^b	n/a
Test M	50 % predischarged	CR	10 ^c	n/a
	Fully discharged	CR	10 ^d	n/a
	50 % predischarged	FR	20 ^e	n/a
	Fully discharged	FR	20 ^f	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.				
^b Four batteries connected in series with one of the four batteries reversed (5 sets).				
^c Two CR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.				
^d Two CR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.				
^e Four FR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.				
^f Four FR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.				
Key:				
n/a: not applicable				

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, FR14505, FR10G445 and similar type batteries of a spiral construction that could be installed incorrectly and charged.													
^c Only applicable to CR17345, CR15H270, FR14505, FR10G445 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) $\pm 1 \%$ 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.