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Safety of primary and secondary lithium cells and batteries during transport (IEC 62281:2019)

Sécurité des piles et des accumulateurs au lithium pendant le transport
(IEC 62281:2019)

Sicherheit von Primär- und Sekundär-Lithiumzellen und -batterien beim Transport
(IEC 62281:2019)

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

The text of document 35/1416/FDIS, future edition 4 of IEC 62281, prepared by IEC/TC 35 "Primary cells and batteries" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62281:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-02-15
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-05-15

This document supersedes EN 62281:2017.

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

Endorsement notice

The text of the International Standard IEC 62281:2019 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-2-6	NOTE	Harmonized as EN 60068-2-6
IEC 60068-2-27	NOTE	Harmonized as EN 60068-2-27
IEC 60086-4	NOTE	Harmonized as EN 60086-4
IEC 61960-3	NOTE	Harmonized as EN 61960-3
IEC 62133-2	NOTE	Harmonized as EN 62133-2
IEC 62660-1	NOTE	Harmonized as EN IEC 62660-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SAFETY OF PRIMARY AND SECONDARY LITHIUM CELLS AND BATTERIES DURING TRANSPORT

FOREWORD

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International Standard IEC 62281 has been prepared jointly by IEC technical committee 35: Primary cells and batteries and subcommittee 21A: Secondary cells and batteries containing alkaline or other non-acid electrolytes, of IEC technical committee 21: Secondary cells and batteries.

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

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

a) button cell definition revised, moved to coin (cell or battery);
b) addition of provisions for batteries forming an integral part of equipment (5.4);
c) all tests for secondary cells and batteries now also contain a requirement for 25 charge and recharge cycles prior to the test;
d) addition of alternative tables for Table 1 and Table 2 in Annex B;

e) addition of "forcible" to the rupture criteria;

f) test report 6.8 merged with test certificate 6.9 and replaced with the items listed in [12];

g) addition of an informative Annex B with important deviations from the UN Manual of Tests and Criteria, Chapter 38.3.

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

FDIS	Report on voting
35/1416/FDIS	35/1422/RVD

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

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

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

Primary lithium cells and batteries were first introduced in military applications in the 1970s. At that time, little commercial interest and no industrial standards existed. Consequently, the United Nations (UN) Committee of Experts on the Transport of Dangerous Goods, although usually referring to industrial standards for testing and criteria, introduced a sub-section in the Manual of tests and criteria concerning safety tests relevant to transport of primary lithium cells and batteries. Meanwhile, commercial interest in primary and secondary (rechargeable) lithium cells and batteries has grown and several industrial standards exist. However, the existing IEC standards are manifold, not completely harmonized, and not necessarily relevant to transport. They are not suitable to be used as a source of reference in the UN Model Regulations. Therefore this group safety standard has been prepared to harmonize the tests and requirements relevant to transport.

This document applies to primary and secondary (rechargeable) lithium cells and batteries containing lithium in any chemical form: lithium metal, lithium alloy or lithium-ion. Lithium-metal and lithium alloy primary electrochemical systems use metallic lithium and lithium alloy, respectively, as the negative electrode. Lithium-ion secondary electrochemical systems use intercalation compounds (intercalated lithium exists in an ionic or quasi-atomic form within the lattice of the electrode material) in the positive and in the negative electrodes.

This document also applies to lithium polymer cells and batteries, which are considered either as primary lithium-metal cells and batteries or as secondary lithium-ion cells and batteries, depending on the nature of the material used in the negative electrode.

The history of transporting primary and secondary lithium cells and batteries is worth noting. Since the 1970s, over ten billion primary lithium cells and batteries have been transported, and since the early 1990s, over one billion secondary (rechargeable) lithium cells and batteries utilizing a lithium-ion system have been transported. As the number of primary and secondary lithium cells and batteries to be transported is increasing, it is appropriate to also include in this document the safety testing of packaging used for the transportation of these products.

This document specifically addresses the safety of primary and secondary lithium cells and batteries during transport and also the safety of the packaging used.

The UN Manual of Tests and Criteria [12][1] distinguishes between lithium metal and lithium alloy cells and batteries on the one hand, and lithium ion and lithium polymer cells and batteries on the other hand. While it defines that lithium metal and lithium alloy cells and batteries can be either primary (non-rechargeable) or rechargeable, it always considers lithium ion cells and batteries as rechargeable. However, test methods in the UN Manual of Tests and Criteria are the same for both secondary lithium metal and lithium alloy cells and batteries and lithium ion and lithium polymer cells and batteries. The concept is only needed to distinguish between small and large battery assemblies. Battery assemblies assembled from (primary or secondary) lithium metal and lithium alloy batteries are distinguished by the aggregate lithium content of all anodes (measured in grams), while battery assemblies assembled from lithium ion or lithium polymer batteries are distinguished by their "nominal" energy (measured in Watt-hours).

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1 Numbers in square brackets refer to the Bibliography.

SAFETY OF PRIMARY AND SECONDARY LITHIUM CELLS AND BATTERIES DURING TRANSPORT

1 Scope

This International Standard specifies test methods and requirements for primary and secondary (rechargeable) lithium cells and batteries to ensure their safety during transport other than for recycling or disposal. Requirements specified in this document do not apply in those cases where special provisions given in the relevant regulations, listed in 7.3, provide exemptions.

NOTE Different standards may apply for lithium-ion traction battery systems used for electrically propelled road vehicles.

2 Normative references

There are no normative references in this document.

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

3.1
aggregate lithium content
total lithium content of the cells comprising a battery

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

Note 1 to entry: This definition is different from the definition used in the UN Manual of Tests and Criteria [12]. This document was, however, carefully prepared so that the test set-up for each test is harmonized with the UN Manual.

Note 2 to entry: A cell used in equipment where the equipment is providing the functions of a case, terminals, markings and protective devices etc., as necessary for use in the equipment, is, for the purposes of this document, considered to be a battery.

[SOURCE: IEC 60050-482:2004 [1], 482-01-04, modified – Reference to "electrically connected" has been added.]

3.3
battery assembly
battery comprising two or more batteries

3.4
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 – The definition "small round cell or battery" replaces the original "cell with a cylindrical shape", "containing non-aqueous electrolyte" was added, the term "lithium button" was added]

3.5
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]

3.6
component cell
cell contained in a battery

3.7
cycle
<of a secondary (rechargeable) cell or battery> set of operations that is carried out on a secondary (rechargeable) cell or battery and is repeated regularly in the same sequence

Note 1 to entry: These operations may consist of a sequence of a discharge followed by a charge or a charge followed by a discharge under specified conditions. This sequence may include rest periods.

[SOURCE: IEC 60050-482:2004, 482-05-28, modified – The words "secondary (rechargeable)" have been added.]

3.8
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 – The words "round cell or battery" replace the original "cell with a cylindrical shape", the term "cylindrical battery" has been added.]

3.9
depth of discharge
DOD
percentage of rated capacity discharged from a battery

Note 1 to entry: This note applies to the French language only.

3.10
first cycle
initial cycle of a secondary (rechargeable) cell or battery following completion of all manufacturing, formation and quality control processes

3.11
fully charged, adj
state of charge of a secondary (rechargeable) cell or battery corresponding to 0 % depth of discharge

3.12
fully discharged, adj
state of charge of a cell or battery corresponding to 100 % depth of discharge

3.13
large battery
battery with a gross mass of more than 12 kg

3.14
large cell
cell with a gross mass of more than 500 g

3.15
lithium cell
<primary or secondary (rechargeable)> cell containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

Note 1 to entry: Depending on the design features chosen, a lithium cell may be primary or secondary (rechargeable).

[SOURCE: IEC 60050-482:2004, 482-01-06, modified – The domain "primary or secondary (rechargeable)" has been added.]

3.16
lithium content
mass of lithium in the negative electrode of a lithium metal or lithium alloy cell or battery in the undischarged or fully charged state

3.17
lithium ion cell or battery
rechargeable non-aqueous cell or battery in which the positive and negative electrodes are both intercalation compounds constructed with no metallic lithium in either electrode

Note 1 to entry: Intercalated lithium exists in an ionic or quasi-atomic form with the lattice of the electrode material.

Note 2 to entry: A lithium polymer cell or battery that uses lithium ion chemistries, as described herein, is considered as a lithium ion cell or battery.

3.18
nominal energy
energy value of a cell or battery determined under specified conditions and declared by the manufacturer

Note 1 to entry: The nominal energy is calculated by multiplying the nominal voltage by rated capacity.

Note 2 to entry: The term "rated energy" could be more appropriate.

3.19
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]

3.20
open-circuit 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 – "when no external current is flowing" replaces "when the discharge current is zero".]

3.21
primary cell or battery
cell or battery that is not designed to be electrically recharged

[SOURCE: IEC 60050-482:2004, 482-01-02, modified – Addition of "or battery".]

3.22
prismatic cell or battery
cell or battery having rectangular sides and bases

[SOURCE: IEC 60050-482:2004, 482-02-38, modified – Omission of "having the shape of a parallelepiped".]

3.23
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

3.24
rated capacity
capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

Note 1 to entry: The following IEC standards provide guidance and methodology for determining the rated capacity: IEC 61960-3 [5], IEC 62133-2 [6], IEC 62660-1 [7].

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – Inclusion of "a cell or battery", addition of Note 1 to entry.]

3.25
secondary (rechargeable) cell or battery
cell or battery which is designed to be electrically recharged

[SOURCE: IEC 60050-482:2004, 482-01-03, modified – Addition of "rechargeable" and "or battery".]

3.26
small battery
battery with a gross mass of not more than 12 kg

3.27
small cell
cell with a gross mass of not more than 500 g

3.28
type
<for cells or batteries> particular electrochemical system and physical design of cells or batteries

3.29
undischarged, adj
state of charge of a primary cell or battery corresponding to 0 % depth of discharge

4 Requirements for safety

4.1 General considerations

Lithium cells and batteries are categorized by their chemical composition (electrodes, electrolyte) and internal construction (bobbin, spiral, stacked). They are available in various shapes. It is necessary to consider all relevant safety aspects at the battery design stage, recognizing the fact that they may differ considerably, depending on the specific lithium system, power output and battery configuration.

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

a) To prevent by design an abnormal temperature rise above the critical value defined by the manufacturer.

b) To control by design temperature increases in the cell or battery e.g. by limiting the current flow or by adequate thermal management.

c) To design lithium cells and batteries so as to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport.

d) To design lithium cells and batteries so as to prevent a short-circuit under normal conditions of transport and intended use.

e) To equip primary lithium batteries containing cells or strings of cells connected in parallel with effective means, as may be necessary, to prevent dangerous reverse current flow (e.g. diodes, fuses, etc.).

4.2 Quality plan

The manufacturer shall implement a documented quality plan (i.e. quality reports, inspection records, management structure) 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 and reliability.

4.3 Packaging

Lithium cells and batteries shall be packaged so as to prevent an external short-circuit under normal transport conditions.

NOTE Additional requirements for packaging of dangerous goods are given in UN Model Regulations:2017 [13], section 6.1. See also regulations mentioned in 7.3.

5 Type testing, sampling and re-testing

5.1 Type testing

Lithium metal and lithium ion cells or batteries which differ from a tested type by

a) for primary cells and batteries, a change of more than 0,1 g or 20 % by mass, whichever is greater, to the electrodes or to the electrolyte, or

b) for rechargeable cells and batteries, a change in nominal energy (in Wh) of more than 20 % or an increase in nominal voltage of more than 20 %, or

c) a change that would lead to failure of any of the tests,

shall be considered a different type and shall be subject to the required tests.

NOTE The type of change that might be considered to differ from a tested type, such that it might lead to failure of any of the test results, may include, but is not limited to

1) a change in the material of the anode, the cathode, the separator or the electrolyte,

2) a change of protective devices, including hardware and software,
3) a change of safety design in cells or batteries, such as a venting valve,
4) a change in the number of component cells, and
5) a change in connecting mode of component cells, and,
6) for batteries which are to be tested according to test T-4 with a peak acceleration less than 150 g_n, a change in the mass which could adversely impact the result of the T-4 test and lead to a failure.

5.2 Overcharge protection

Secondary batteries not equipped with battery overcharge protection that are designed for use only in a battery assembly or in equipment, which affords such protection, are not subject to the requirements of test T-7.

5.3 Battery assemblies

5.3.1 General

Generally, battery assemblies, including battery packs, battery modules, and other units that may be assembled from batteries, are tested like batteries.

5.3.2 Small battery assemblies

When testing a battery assembly in which the aggregate lithium content of all anodes, when fully charged, is not more than 500 g, or in the case of a lithium ion battery, with a nominal energy of not more than 6 200 Wh, assembled from batteries that have passed all applicable tests, one battery assembly in a fully charged state shall be tested under tests T-3, T-4 and T-5, and, in addition, test T-7 in the case of a secondary battery assembly.

NOTE The term "fully charged" is used in [12] although it applies only to secondary battery assemblies. For primary battery assemblies, the term "undischarged" would be more appropriate.

5.3.3 Large battery assemblies

A battery assembly with an aggregate lithium content of more than 500 g, or in the case of a lithium ion battery, with a nominal energy of more than 6 200 Wh, does not need to be tested if it is of a type that has been verified as preventing:

- overcharge, and
- short circuits; and
- over discharge between the batteries.

5.4 Batteries forming an integral part of equipment

Cells or batteries that are an integral part of the equipment they are intended to power, and which are transported only when installed in the equipment, may be tested in accordance with the applicable tests when installed in the equipment.

5.5 Sampling

Each different type shall be tested by taking random samples. The number of samples for testing primary cells and batteries is given in Table 1. The number of samples for testing secondary cells and batteries is given in Table 2. The number of samples for testing packages of primary and secondary cells and batteries is given in Table 3.

Table 1 – Number of primary test cells and batteries for type testing

Tests	Discharge state	Cells or single-cell batteries [a]	Multi-cell batteries
Tests T-1 to T-5	Undischarged	10	4
	Fully discharged	10	4
Test T-6	Undischarged	5	5 component cells
	Fully discharged	5	5 component cells
Test T-8	Fully discharged	10	10 component cells
Total for all tests		**40**	**8 batteries and 20 component cells**

[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.

See also Clause B.2 in Annex B.

Table 2 – Number of secondary test cells and batteries for type testing

Tests	Cycles and discharge state	Cells	Single-cell batteries [a]		Multi-cell batteries	
			Small	Large	Small	Large
Tests T-1 to T-5	At first cycle, fully charged	5	5	5	4	2
	After 25 cycles, fully charged	5	5	5	4	2
Test T-6	At first cycle, at 50 % DOD	5	5	5	5 component cells	5 component cells
	After 25 cycles, at 50 % DOD	5	5	5	5 component cells	5 component cells
Test T-7	At first cycle, fully charged	N/A [b]	4 [c]	2 [c]	4 [c]	2 [c]
	After 25 cycles, fully charged	N/A [b]	4 [c]	2 [c]	4 [c]	2 [c]
Test T-8	At first cycle, fully discharged	10	10	10	10 component cells [d]	10 component cells [d]
	After 25 cycles, fully discharged	10	10	10	10 component cells [d]	10 component cells [d]
Total for all tests		**40**	**48**	**44**	**16 batteries and 30 component cells**	**8 batteries and 30 component cells**

[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, except for test T-7 where only batteries are tested.

[b] N/A = not applicable.

[c] See 5.2.

[d] Multi-cell batteries are considered to be protected against overdischarge of their component cells. Otherwise they would have to be tested as well.

See also Clause B.3 in Annex B.

Table 3 – Number of packages with primary or secondary test cells and batteries

Number of samples for test P-1	1 package as supplied for transport

5.6 Re-testing

In the event that a primary or secondary lithium cell or battery type does not meet the test requirements, steps shall be taken to correct the deficiency or deficiencies that caused the failure before such a cell or battery type is re-tested.

6 Test methods and requirements

6.1 General

6.1.1 Cautionary notice

WARNING – These tests call for the use of procedures which may result in injury if adequate precautions are not taken.

The execution of these tests shall only be conducted by appropriately qualified and experienced technicians using adequate protection.

6.1.2 Ambient temperature

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

6.1.3 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 dimension;

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.

6.1.4 Pre-discharge and pre-cycling

Where, prior to testing, it is required to discharge primary test cells or test batteries, they shall be discharged to their respective depth of discharge on a resistive load with which the rated capacity is obtained, or at a constant current specified by the manufacturer.

Where, prior to testing, it is required to cycle secondary (rechargeable) test cells or test batteries, they shall be cycled using the charge and discharge conditions specified by the manufacturer for optimum performance and safety.

6.2 Evaluation of test criteria

6.2.1 Shifting

Shifting is considered to have occurred during a test if one or more test cells or batteries are released from the packaging, do not retain their original orientation, or are affected in such a way that the occurrence of an external short-circuit or crushing cannot be excluded.

6.2.2 Distortion

Distortion is considered to have occurred if a physical dimension changes by more than 10 %.

6.2.3 Short-circuit

A short-circuit is considered to have occurred during a test if the open circuit voltage of the cell or battery directly after the test is less than 90 % of its voltage immediately prior to the test. This requirement is not applicable to test cells and batteries at fully discharged states.

6.2.4 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.

6.2.5 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 4.

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 4 – Mass loss limits

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

6.2.6 Venting

Venting is considered to have occurred during a test if gas has escaped from a cell or battery through a feature designed for this purpose, in order to relieve excessive internal pressure. This gas may include entrapped materials.

6.2.7 Fire

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

6.2.8 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.

6.2.9 Explosion

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