Safety of primary and secondary lithium cells and batteries during transport

The European Standard EN 62281:2004 has the status of a British Standard

ICS 29.220.10
National foreword

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The UK participation in its preparation was entrusted to Technical Committee CPL/35, Primary cells and batteries, which has the responsibility to:

— aid enquirers to understand the text;
— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 24, an inside back cover and a back cover.

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Safety of primary and secondary lithium cells and batteries during transport
(IEC 62281:2004)

Sécurité des piles et des accumulateurs au lithium pendant le transport
(CEI 62281:2004)

Sicherheit von Primär- und Sekundär-Lithiumbatterien beim Transport
(IEC 62281:2004)

This European Standard was approved by CENELEC on 2004-06-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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The text of document 35/1202/FDIS, future edition 1 of IEC 62281, prepared by IEC TC 35, Primary cells and batteries, and SC 21A, Secondary cells and batteries containing alkaline or other non-acid electrolytes, of IEC TC 21, Secondary cells and batteries, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62281 on 2004-06-01.

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- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2005-03-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2007-06-01

Annex ZA has been added by CENELEC.

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**Endorsement notice**

The text of the International Standard IEC 62281:2004 was approved by CENELEC as a European Standard without any modification.

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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, dealing with 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, a new group safety standard has been prepared to harmonize the tests and requirements relevant to transport.

This International Standard 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 International Standard 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 standard the safety testing of packaging used for the transportation of these products.

This International Standard specifically addresses the safety of primary and secondary lithium cells and batteries during transport and also the safety of the packaging used. Other International Standards dealing with the safety of primary and secondary lithium cells and batteries are referenced in Clause 2 and in the bibliography of this standard. They include the safety of primary and secondary lithium cells and batteries during handling, use and disposal and also address particular aspects of primary lithium batteries (IEC 60086-4) and secondary lithium cells and batteries (IEC 62133). They also contain some test methods and acceptance criteria that are relevant to transport. Consideration may, in the future, be given to the harmonization of these standards with this standard.
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 standard do not apply in those cases where special provisions given in the relevant regulations, listed in 7.3, provide exemptions.

2 Normative references

The following referenced documents are indispensable for the application 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 60086-4, Primary batteries – Part 4: Safety of lithium batteries
IEC 61960, Secondary cells and batteries containing alkaline or other non-acid electrolyte – Secondary lithium cells and batteries for portable applications

3 Terms and definitions

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

3.1 aggregate lithium content

total lithium content or lithium equivalent content of the cells comprising a battery

3.2 battery

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

3.3 button cell

coin cell

cell with a cylindrical shape in which the overall height is less than the diameter, e.g. in the shape of a button or a coin

NOTE In practice, the term coin is used exclusively for non-aqueous lithium cells.

3.4 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
3.5 component cell
cell contained in a battery

3.6 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 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.

3.7 cylindrical cell
cell with a cylindrical shape in which the overall height is equal to or greater than the diameter

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

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

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

3.11 fully discharged
state of charge of a cell or battery corresponding to 100 % depth of discharge

3.12 large battery
battery in which the aggregate lithium content is more than 500 g

3.13 large cell
cell in which the lithium content or lithium equivalent content is more than 12 g

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

NOTE Depending on the design features chosen, a lithium cell may be primary or secondary (rechargeable).

3.15 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
3.16 **lithium equivalent content**
mass equivalent to the lithium content of a lithium-ion cell or battery

NOTE For a lithium-ion cell, the lithium equivalent content is determined by:

\[ m_e = 0.3 \text{ g} / \text{Ah} \times Q_r \]

where

- \( m_e \) is the lithium equivalent content of a lithium-ion cell;
- \( Q_r \) is the rated capacity of that cell.

For a lithium-ion battery, the lithium equivalent content is determined as the total lithium equivalent content of its component cells.

3.17 **open-circuit voltage**
voltage of a cell or battery when the discharge current is zero

3.18 **primary battery**
battery made from primary component cells

3.19 **primary cell**
cell which is not designed to be electrically recharged

3.20 **prismatic (cell or battery)**
cell or battery having rectangular sides and bases

3.21 **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

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

3.23 **secondary (rechargeable) battery**
battery made from secondary (rechargeable) component cells

3.24 **secondary (rechargeable) cell**
cell which is designed to be electrically recharged

3.25 **small battery**
battery composed of small cells, and in which the aggregate lithium content is not more than 500 g

3.26 **small cell**
cell in which the lithium content or lithium equivalent content is not more than 12 g
3.27
**type** (for cells or batteries)
particular electrochemical system and physical design of cells or batteries

3.28
**undischarged**
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). 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) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.

b) Temperature increases in the cell or battery shall be controlled by the design e.g. by limiting the 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.

d) Lithium cells and batteries shall be designed so as to prevent a short-circuit under normal conditions of transport and intended use.

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

#### 4.2 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, section 6.1.1. See also regulations mentioned in 7.3 below.

### 5 Type testing, sampling and re-testing

#### 5.1 Type testing

Lithium cells or batteries which differ from a tested type by

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

b) a change that would materially affect the test results,

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

---

1 Refer to the bibliography.
5.2 Assembly of batteries

An assembly of batteries with an aggregate lithium content of more than 500 g does not need to be tested if

a) it is formed by electrically connecting batteries that have passed all applicable tests, and

b) it is equipped with a system capable of
   - monitoring the assembly of batteries,
   - preventing short-circuits and over-discharge between the batteries in the assembly, and
   - preventing any overheat or overcharge of the assembly of batteries.

5.3 Sampling

Each different type shall be tested by randomly taking samples. The number of samples is given in Table 1 below.
#### Table 1 – Number of test cells and batteries for type testing

<table>
<thead>
<tr>
<th>Number of samples for tests T-1 to T-5</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undischarged</td>
<td>Fully discharged</td>
<td>Undischarged</td>
</tr>
<tr>
<td>10 cells</td>
<td>10 cells</td>
<td>4 batteries*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of samples for test T-6</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undischarged</td>
<td>Fully discharged</td>
<td>Undischarged</td>
</tr>
<tr>
<td>5 cells (cylindrical)</td>
<td>5 cells (cylindrical)</td>
<td>5 component cells</td>
</tr>
<tr>
<td>10 cells (prismatic)</td>
<td>10 cells (prismatic)</td>
<td>10 component cells</td>
</tr>
<tr>
<td>5 component cells (cylindrical)</td>
<td>10 component cells (prismatic)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of samples for test T-8</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undischarged</td>
<td>Fully discharged</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 cells</td>
<td>No battery tests required but the component cells shall have passed the test</td>
</tr>
</tbody>
</table>

#### Secondary cells and batteries

<table>
<thead>
<tr>
<th>Number of samples for tests T-1 to T-5</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>First cycle, fully charged</td>
<td>First cycle, fully discharged</td>
<td>First cycle, fully discharged</td>
</tr>
<tr>
<td>10 cells</td>
<td>10 cells</td>
<td>4 batteries*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of samples for test T-6</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>First cycle, 50 % DOD</td>
<td>After 50 cycles, fully discharged</td>
<td>First cycle, 50 % DOD</td>
</tr>
<tr>
<td>5 cells (cylindrical)</td>
<td>5 cells (cylindrical)</td>
<td>5 component cells</td>
</tr>
<tr>
<td>10 cells (prismatic)</td>
<td>10 cells (prismatic)</td>
<td>10 component cells</td>
</tr>
<tr>
<td>5 component cells (cylindrical)</td>
<td>10 component cells (prismatic)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of samples for test T-7</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First cycle, fully charged</td>
<td>After 50 cycles, fully charged</td>
</tr>
<tr>
<td></td>
<td>4 batteries</td>
<td>4 batteries</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of samples for test T-8</th>
<th>Cells</th>
<th>Batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>First cycle, fully discharged</td>
<td>After 50 cycles, fully discharged</td>
<td></td>
</tr>
<tr>
<td>10 cells</td>
<td>10 cells</td>
<td>No battery tests required but the component cells shall have passed the test</td>
</tr>
</tbody>
</table>

#### Packages with primary or secondary cells or batteries

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

*a* When testing batteries, unless the component cells or batteries made from them have been tested before, the number of test batteries shall be at least such that the number of component cells contained in them equals the number of test cells required for that test.

**EXAMPLE 1** If a battery with 2 component cells is tested, the number of test batteries shall be 5. If the component cells or batteries made from them have been tested before, the number of test batteries shall be 4.

**EXAMPLE 2** If a battery with 3 or more component cells is tested, the number of test batteries shall be 4.

*b* Not applicable.
5.4 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 Safety 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, during a test, 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 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 electrolyte, gas or other material escapes from the test cell or battery in a manner not intended by design.

6.2.6 Mass loss

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 the test;
- $m_2$ is the mass after the test.

Mass loss is considered to have occurred if, during a test, the maximum values given in Table 2 are exceeded.

<table>
<thead>
<tr>
<th>Mass of battery $m$</th>
<th>Maximum mass loss $\Delta m / m$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m \leq 1$ g</td>
<td>0.5</td>
</tr>
<tr>
<td>$1 \text{ g} &lt; m \leq 5$ g</td>
<td>0.2</td>
</tr>
<tr>
<td>$m &gt; 5$ g</td>
<td>0.1</td>
</tr>
</tbody>
</table>
6.2.7 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.

6.2.8 Fire

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

6.2.9 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 but not ejection of solid materials.

6.2.10 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 (annealed aluminium wire with a diameter of 0.25 mm and a grid density of 6 to 7 wires per cm) placed 25 cm away from the cell or battery.

6.3 Tests and requirements – overview

Table 3 contains an overview of the tests and requirements for transport, mis-use and packaging tests.

<table>
<thead>
<tr>
<th>Test number</th>
<th>Designation</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport tests</td>
<td>T-1</td>
<td>Altitude</td>
</tr>
<tr>
<td></td>
<td>T-2</td>
<td>Thermal cycling</td>
</tr>
<tr>
<td></td>
<td>T-3</td>
<td>Vibration</td>
</tr>
<tr>
<td></td>
<td>T-4</td>
<td>Shock</td>
</tr>
<tr>
<td></td>
<td>T-5</td>
<td>External short-circuit</td>
</tr>
<tr>
<td></td>
<td>T-6</td>
<td>Impact</td>
</tr>
<tr>
<td>Misuse tests</td>
<td>T-7</td>
<td>Overcharge</td>
</tr>
<tr>
<td></td>
<td>T-8</td>
<td>Forced discharge</td>
</tr>
<tr>
<td>Packaging tests</td>
<td>P-1</td>
<td>Drop</td>
</tr>
</tbody>
</table>

Tests T-1 through T-5 shall be conducted in sequence on the same cell or battery.

Key

NC: No short-circuit
ND: No distortion
NE: No explosion
NF: No fire
NL: No leakage
NM: No mass loss
NR: No rupture
NS: No shifting
NT: No excessive temperature rise
NV: No venting

See 6.2 for a detailed description of the test criteria.
6.4 Transport tests

6.4.1 Test T-1: 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 mass loss, no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.2 Test T-2: Thermal cycling

a) Purpose
This test assesses cells and batteries seal integrity, and 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 75 °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.

c) Requirements
There shall be no mass loss, no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.3 Test T-3: Vibration

a) Purpose
This test simulates vibration during transport in commercial aircraft. The test condition is based on the range of vibrations as given by ICAO².

b) Test procedure
Test cells and batteries shall be firmly secured to the platform of the vibration machine without distorting them in such a manner as to faithfully transmit the vibration. Test cells and batteries shall be subjected to sinusoidal vibration according to Table 4. 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.

---

² Refer to the bibliography.
Table 4 – Vibration profile (sinusoidal)

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Amplitudes</th>
<th>Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)</th>
<th>Axis</th>
<th>Number of cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_1 = 7$ Hz</td>
<td>$a_1 = 1 , g_n$</td>
<td>15 min</td>
<td>X</td>
<td>12</td>
</tr>
<tr>
<td>$f_2$</td>
<td>$s = 0.8 , mm$</td>
<td>Y</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>$f_3$</td>
<td>$a_2 = 8 , g_n$</td>
<td>Z</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>$f_4 = 200$ Hz</td>
<td></td>
<td>and back to $f_1 = 7$ Hz</td>
<td>Total</td>
<td>36</td>
</tr>
</tbody>
</table>

NOTE Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0.8 mm corresponds to a peak-to-peak displacement of 1.6 mm.

Key

- $f_1, f_4$: lower and upper frequency
- $f_2, f_3$: cross-over frequencies ($f_2 = 17.62 \, Hz$, $f_3 = 49.84 \, Hz$)
- $a_1, a_2$: acceleration amplitude
- $s$: displacement amplitude

c) Requirements

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

6.4.4 Test T-4: 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 three 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 5 shall be applied.

Table 5 – Shock parameters

<table>
<thead>
<tr>
<th>Waveform</th>
<th>Peak acceleration</th>
<th>Pulse duration</th>
<th>Number of shocks per half axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small cells or batteries</td>
<td>Half sine</td>
<td>150 $g_n$</td>
<td>6 ms</td>
</tr>
<tr>
<td>Large cells or batteries</td>
<td>Half sine</td>
<td>50 $g_n$</td>
<td>11 ms</td>
</tr>
</tbody>
</table>

The test shall be conducted using the test cells and batteries previously subjected to the vibration test.

c) Requirements

There shall be no mass loss, no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.
6.4.5 Test T-5: External short-circuit

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

b) Test procedure
   The test cell or battery shall be stabilized at an external case temperature of 55 °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at 55 °C. This short-circuit condition is continued for at least 1 h after the cell or battery external case temperature has returned to 55 °C.
   The test sample shall be observed for a further 6 h.
   The test shall be conducted using the test samples previously subjected to the shock test.

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

6.4.6 Test T-6: Impact

a) Purpose
   This test simulates an internal short-circuit.
   NOTE During previous discussions on safety tests for batteries, the IEC has evaluated the impact test. Within the context of intended use and reasonable foreseeable misuse, this test was found to be inappropriate to simulate an internal short-circuit condition. Whilst agreeing to the need for an internal short-circuit test, the IEC reserves the right to investigate a more appropriate test.

b) Test procedure
   The test cell or component cell is placed on a flat plate. A steel bar with a diameter of 15,8 mm is placed across the centre of the test sample. A mass of 9,1 kg is dropped from a height of 61 cm ± 2,5 cm onto the bar on the test sample.
   A cylindrical or prismatic cell is impacted with its longitudinal axis parallel to the flat plate and perpendicular to the longitudinal axis of the bar lying across the centre of the test sample. A prismatic cell is also rotated 90° around its longitudinal axis so that both the wide and narrow sides will be subjected to the impact. A button cell is impacted with its flat surface parallel to the flat plate and the bar lying across its centre.
   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 transport 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 Mis-use tests

6.5.1 Test T-7: Overcharge

a) Purpose
This test evaluates the ability of a secondary (rechargeable) battery to withstand an overcharge condition.

b) Test procedure
The charge current shall be twice the manufacturer’s recommended maximum continuous charge current. The minimum voltage of the test shall be as follows:

1) when the manufacturer’s recommended charge voltage is not more than 18 V, the minimum voltage of the test shall be the lesser of two times the maximum charge voltage of the battery or 22 V;

2) when the manufacturer’s recommended charge voltage is more than 18 V, the voltage of the test shall be not less than 1.2 times the maximum charge voltage.

The test shall be conducted at ambient temperature. The charging condition shall be maintained for at least 24 h. The test batteries shall be observed during 7 days after the overcharging condition has been discontinued.

c) Requirements
There shall be no explosion and no fire during this test and within the 7 days of observation.

6.5.2 Test T-8: Forced discharge

a) Purpose
This test evaluates the ability of a primary or a secondary (rechargeable) cell to withstand a forced discharge condition.

b) Test procedure
Each cell shall be forced 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 forced discharged for a time interval equal to its rated capacity divided by the initial test current. The test cells shall be observed during 7 days after the forced discharge condition has been discontinued.

c) Requirements
There shall be no explosion and no fire during this test, nor within the 7 days of observation.

6.6 Packaging test

6.6.1 Test P-1: Drop test

a) Purpose
This test assesses the ability of the packaging to prevent damage during rough handling.

NOTE Additional tests for packaging of dangerous goods are given in UN Model Regulations, section 6.1.5. See also the regulations mentioned in 7.3 below.

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3 Refer to the bibliography.
b) Test procedure

A package (typically the final outer packaging, not palletized loads) filled with cells or batteries as offered for transport shall be dropped from a height of 1.2 m onto a concrete surface in such a manner that any of its corners first touches the ground.

The test shall be conducted using test cells or batteries that have not been previously subjected to a transport test.

c) Requirements

There shall be no shifting, no distortion, no mass loss, no leakage, no venting, no short-circuit, no excessive temperature rise, no rupture, no explosion and no fire during this test.

6.6.2 Void

6.7 Information to be given in the relevant specification

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

<table>
<thead>
<tr>
<th>Clause and/or subclause</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Pre-discharge current specified by the manufacturer for primary cells and batteries; 6.1.4</td>
</tr>
<tr>
<td>b) Charge and discharge conditions specified by the manufacturer for optimum performance and safety of secondary (rechargeable) cells and batteries; 6.1.4</td>
</tr>
<tr>
<td>c) Manufacturer's recommended maximum continuous charge current; 6.5.1</td>
</tr>
<tr>
<td>d) Manufacturer's recommended charge voltage; 6.5.1</td>
</tr>
<tr>
<td>e) Maximum charge voltage; 6.5.1</td>
</tr>
<tr>
<td>f) Maximum continuous discharge current specified by the manufacturer 6.5.2</td>
</tr>
</tbody>
</table>

6.8 Evaluation and report

A report should be issued considering the following list of items:

a) name and address of the test facility;
b) name and address of applicant (where appropriate);
c) a unique test report identification;
d) the date of the test report;
e) the manufacturer of the packaging;
f) a description of the packaging design type (e.g. dimensions, materials, closures, thickness, etc.), including method of manufacture (e.g. blow molding) and which may include drawing(s) and/or photograph(s);
g) the maximum capacity of the packaging;
h) characteristics of the test cells or batteries according to 4.1;
i) test descriptions and results, including the parameters according to 6.7;
j) a signature with name and status of the signatory;
k) statements that the packaging prepared as for transport was tested in accordance with the appropriate requirements of this standard and that the use of other packaging methods or components may render it invalid.
7 Information for safety

7.1 Packaging

The purpose of the packaging is to avoid mechanical damage during transport, handling and stacking. It is particularly important that the packaging prevents crushing of the cells or batteries during rough handling, as well as the development of unintentional electrical short-circuit and corrosion of the terminals. Crushing or external short-circuit can result in leakage, venting, rupture, explosion or fire.

Whenever lithium cells or batteries are transported, it is recommended for safety reasons to use the original packaging or packaging that complies with the requirements listed in 4.2 and 6.6.1.

7.2 Handling of battery cartons

Battery cartons should be handled with care. Rough handling may result in batteries being short-circuited or damaged. This may cause leakage, rupture, explosion or fire.

7.3 Transport

7.3.1 General

Regulations concerning international transport of lithium batteries are based on the recommendations of the United Nations Committee of Experts on the Transport of Dangerous Goods4.

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

7.3.2 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) and in the Dangerous Goods Regulations published by the International Air Transport Association (IATA)5.

7.3.3 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)6.

7.3.4 Land transport

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

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4 Refer to the bibliography.
5 Refer to the bibliography.
6 Refer to the bibliography.
7.4 Display and storage

a) Store batteries in well ventilated, dry and cool conditions
   High temperature or high humidity may cause deterioration of the battery performance and/or surface corrosion.

b) Do not stack battery cartons on top of each other exceeding a height specified by the manufacturer
   If too many battery cartons are stacked, batteries in the lowest cartons may be deformed and electrolyte leakage may 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 may be impaired and self-discharge and corrosion may occur. Heat may cause deterioration.

d) Store batteries in their original packing
   When batteries are unpacked and mixed they may be short-circuited or damaged.

8 Instructions for packaging and handling during transport

8.1 Quarantine
   Packages that have been crushed, punctured or torn open to reveal contents shall not be transported. Such packages shall be isolated until the shipper has been consulted, has provided instructions and, if appropriate, has arranged to have the product inspected and repacked.

9 Marking

9.1 Marking of primary and secondary (rechargeable) cells and batteries
   The marking of primary lithium cells and batteries should comply with IEC 60086-4. The marking of secondary (rechargeable) lithium cells and batteries should comply with IEC 61960.

9.2 Marking of the packaging and shipping documents
   Each package as offered for transport – unless exempted by the relevant regulations – shall be marked with the following information:
   - that it contains lithium cells or batteries;
   - that it shall be handled with care;
   - that it shall, if damaged, be quarantined, inspected and repacked;
   - a telephone number for information.
Figure 1 shows an example.

**CAUTION!**

Lithium batteries inside
Handle with care
Flammable if damaged
If package is damaged, batteries must be quarantined, inspected and repacked.

For information, call: xyz

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**Figure 1 – Example for the marking of packages with primary or secondary (rechargeable) lithium cells or batteries**

Documents (e.g. airway bills (AWB), invoices) accompanying each shipment shall include either the shipper’s declaration, or a label attached to existing documents indicating:

- that it contains lithium cells or batteries;
- that it shall be handled with care;
- that it shall, if damaged, be quarantined, inspected and repacked;
- a telephone number for information.
Bibliography

IEC 60050-482, *International Electrotechnical Vocabulary (IEV) – Part 482: Primary and secondary cells and batteries (to be published)*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*
NOTE Harmonized as EN 60068-2-6:1995 (not modified).

NOTE Harmonized as EN 60068-2-27:1993 (not modified).

IEC 62133, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*
NOTE Harmonized as EN 62133:2003 (not modified).

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

IATA, International Air Transport Association, Quebec: *Dangerous goods regulations* (revised annually)

ICAO, International Civil Aviation Organisation, Montreal: *Technical Instructions for the Safe Transport of Dangerous Goods by Air*

IMO, International Maritime Organization, London: *International maritime dangerous goods (IMDG) code*

United Nations: *Recommendations on the transport of dangerous goods, model regulations (Twelfth revised edition; revised biennially)*

United Nations: *Recommendations on the transport of dangerous goods – Manual of tests and criteria, Amendment 1 to the third revised edition: Lithium batteries*
Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE Where an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Year</th>
<th>Title</th>
<th>EN/HD</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 60086-4</td>
<td></td>
<td>Primary batteries &lt;br&gt;Part 4: Safety standard for lithium batteries</td>
<td>EN 60086-4</td>
<td>2000</td>
</tr>
<tr>
<td>IEC 61960</td>
<td></td>
<td>Secondary cells and batteries containing alkaline or other non-acid electrolyte &lt;br&gt;Secondary lithium cells and batteries for portable applications</td>
<td>EN 61960</td>
<td>2004</td>
</tr>
<tr>
<td>IEC Guide 104</td>
<td>1997</td>
<td>The preparation of safety publications and the use of basic safety publications and group safety publications</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Undated reference.
2) Valid edition at date of issue.