

BS EN 62281:2013



BSI Standards Publication

# Safety of primary and secondary lithium cells and batteries during transport

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**National foreword**

This British Standard is the UK implementation of EN 62281:2013. It is identical to IEC 62281:2012. It supersedes BS EN 62281:2004, which will be withdrawn on 9 January 2016.

The UK participation in its preparation was entrusted to Technical Committee CPL/35, Primary cells.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English version

**Safety of primary and secondary lithium cells and batteries  
during transport  
(IEC 62281:2012)**

Sécurité des piles et des accumulateurs  
au lithium pendant le transport  
(CEI 62281:2012)

Sicherheit von Primär- und Sekundär-  
Lithiumbatterien beim Transport  
(IEC 62281:2012)

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

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## Foreword

The text of document 35/1303/FDIS, future edition 2 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 approved by CENELEC as EN 62281:2013.

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) 2013-10-09
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2016-01-09

This document supersedes EN 62281:2004.

EN 62281:2013 includes the following significant technical changes with respect to EN 62281:2004:

- a) distinction between small and large cell or battery by gross mass rather than by lithium content or Watt-hour rating ("nominal" energy);
- b) combination of the no mass loss (NM) and no leakage (NL) criteria into one criteria (NL);
- c) extension of an acceptable mass loss of 0,2 % from 5 g to 75 g mass of a cell or battery;
- d) reduction of large batteries to be tested under tests T-1 to T-5 and T-8 from 4 to 2 samples;
- e) reduction of test samples required for small battery assemblies (5.2.2);
- f) reduction of the vibration amplitude to 2 g for large batteries in T-3 vibration test method;
- g) replacement of the impact test by the crush test for prismatic, pouch, button, and coin cells as well as cylindrical cells with no more than 20 mm in diameter.

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

## Endorsement notice

The text of the International Standard IEC 62281:2012 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 60086-4	NOTE	Harmonized as EN 60086-4.
IEC 60068-2-6	NOTE	Harmonized as EN 60068-2-6.
IEC 60068-2-27	NOTE	Harmonized as EN 60068-2-27.

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

		Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications	EN 61960	-
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	EN 62133	-
IEC 62660-1	-	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing	EN 62660-1	-

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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 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 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.

The UN Manual of Tests and Criteria [1]<sup>1</sup> 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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<sup>1</sup> 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 standard 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

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

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

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*

IEC 62660-1, *Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing*

### 3 Terms and definitions

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

#### 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 [1]. The standard was, however, carefully prepared so that the test set-up for each test is harmonized with the UN Manual.

[SOURCE: IEC 60050-482:2004 [2], 482-01-04, modified – reference to "electrically connected" has been added]

#### 3.3

##### **battery assembly**

battery comprising two or more batteries

### 3.4

#### **button (cell or battery)**

coin (cell or battery)

small round cell or battery where the overall height is less than the diameter, e.g. in the shape of a button or a coin

[SOURCE: IEC 60050-482:2004, 482-02-40, modified – the term "small round cell or battery" replaces the original "cell with a cylindrical shape"]

### 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"]

### 3.9

#### **depth of discharge**

##### **DOD**

percentage of rated capacity discharged from a battery

### 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**

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

### 3.12

#### **fully discharged**

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 notion of "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, IEC 62133, IEC 62660-1.

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – inclusion of "a cell or battery", addition of Note 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**

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 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:2011 [10], 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.

## 5.2 Battery assemblies

### 5.2.1 Secondary batteries for use in battery assemblies

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

### 5.2.2 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. For a secondary battery assembly, the assembly shall have been cycled for at least 25 cycles.

### 5.2.3 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

- 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 battery assembly,
  - preventing short-circuits and over-discharge between the batteries in the assembly, and
  - preventing any overheat or overcharge of the battery assembly.

## 5.3 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 <sup>a</sup>	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
<b>Total for all tests</b>		<b>40</b>	<b>8 batteries and 20 component cells</b>

<sup>a</sup> Single cell batteries consisting of tested component cells do not require retesting.

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

Tests	Cycles and discharge state	Cells	Single cell batteries <sup>a</sup>		Multi-cell batteries	
			Small	Large	Small	Large
Tests T-1 to T-5	At first cycle, fully charged	10	10	10	4	2
	After 25 cycles, fully charged	N/A <sup>b</sup>	N/A <sup>b</sup>	N/A <sup>b</sup>	N/A <sup>b</sup>	2
	After 50 cycles, fully charged	N/A <sup>b</sup>	N/A <sup>b</sup>	N/A <sup>b</sup>	4	N/A <sup>b</sup>
Test T-6	At first cycle, at 50 % DOD	5	5	5	5 component cells	5 component cells
Test T-7	At first cycle, fully charged	N/A <sup>b</sup>	4 <sup>c</sup>	2 <sup>c</sup>	4 <sup>c</sup>	2 <sup>c</sup>
	After 25 cycles, fully charged	N/A <sup>b</sup>	N/A <sup>b</sup>	2 <sup>c</sup>	N/A <sup>b</sup>	2 <sup>c</sup>
	After 50 cycles, fully charged	N/A <sup>b</sup>	4 <sup>c</sup>	N/A <sup>b</sup>	4 <sup>c</sup>	N/A <sup>b</sup>
Test T-8	At first cycle, fully discharged	10	10	10	10 component cells	10 component cells
	After 50 cycles, fully discharged	10	10	10	10 component cells	10 component cells
<b>Total for all tests</b>		<b>35</b>	<b>43</b>	<b>39</b>	<b>16 batteries and 25 component cells</b>	<b>8 batteries and 25 component cells</b>

<sup>a</sup> Single cell batteries consisting of tested component cells shall be subject to T7 testing only.  
<sup>b</sup> N/A = not applicable.  
<sup>c</sup> Applies only to batteries equipped with overcharge protection.

**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
--------------------------------	-------------------------------------

## 5.4 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  $20\text{ °C} \pm 5\text{ °C}$ .

### **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)  $\pm 1\%$  for voltage;
- b)  $\pm 1\%$  for current;
- c)  $\pm 2\text{ °C}$  for temperature;
- d)  $\pm 0,1\%$  for time;
- e)  $\pm 1\%$  for dimension;
- 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.

### **6.1.4 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 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  $170\text{ °C}$ .

### **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 $\Delta m / m$
$m < 1 \text{ g}$	0,5 %
$1 \text{ g} \leq m \leq 75 \text{ g}$	0,2 %
$m > 75 \text{ g}$	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, 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.

#### 6.2.9 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 5 contains an overview of the tests and requirements for transport, misuse and packaging tests.

**Table 5 – Transport and packaging tests and requirements**

Test number	Designation	Requirements	
Transport tests	T-1	Altitude	NL, NV, NC, NR, NE, NF
	T-2	Thermal cycling	NL, NV, NC, NR, NE, NF
	T-3	Vibration	NL, NV, NC, NR, NE, NF
	T-4	Shock	NL, NV, NC, NR, NE, NF
	T-5	External short-circuit	NT, NR, NE, NF
	T-6	Impact/crush	NT, NE, NF
Misuse tests	T-7	Overcharge	NE, NF
	T-8	Forced discharge	NE, NF
Packaging tests	P-1	Drop	NS, ND, NL, NV, NC, NT, NR, NE, NF
Tests T-1 through T-5 shall be conducted in sequence on the same cell or battery.			
<b>Key</b> NC: No short-circuit ND: No distortion NE: No explosion NF: No fire NL: No leakage 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 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 seal integrity of cells and batteries 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 72 °C, followed by storage for at least 6 h at a test temperature of -40 °C. The maximum time for transfer to each temperature shall be 30 min. Each test cell and battery shall undergo this procedure 10 times. This is then followed by storage for at least 24 h at ambient temperature.

For large cells and batteries the duration of exposure to the test temperatures shall be at least 12 h instead of 6 h.

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

c) Requirements

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

### 6.4.3 Test T-3: Vibration

a) Purpose

This test simulates vibration during transport.

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 6 which shows a different upper acceleration amplitude for large batteries than it shows for cells and small batteries. This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

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

**Table 6 – Vibration profile (sinusoidal)**

Frequency range		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
From	To				
$f_1 = 7$ Hz	$f_2$	$a_1 = 1 g_n$	15 min	X	12
$f_2$	$f_3$	$s = 0,8$ mm		Y	12
$f_3$	$f_4 = 200$ Hz	$a_2$		Z	12
and back to $f_1 = 7$ Hz				Total	36
NOTE Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0,8 mm corresponds to a peak-to-peak displacement of 1,6 mm.					
Key					
$f_1, f_4$	lower and upper frequency				
$f_2, f_3$	cross-over frequencies;				
	$f_2 \approx 17,62$ Hz				
	$f_3 \approx 49,84$ Hz for cells and small batteries				
	$f_3 \approx 24,92$ Hz for large batteries				
$a_1, a_2$	acceleration amplitude;				
	$a_2 = 8 g_n$ for cells and small batteries				
	$a_2 = 2 g_n$ for large batteries				
$s$	displacement amplitude				

c) Requirements

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

### 6.4.4 Test 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 3 shocks in each direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks. For each shock, the parameters given in Table 7 shall be applied:

**Table 7 – Shock parameters**

	Waveform	Peak acceleration	Pulse duration	Number of shocks per half axis
Small cells or batteries	Half sine	150 $g_n$	6 ms	3
Large cells or batteries	Half sine	50 $g_n$	11 ms	3

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

## c) Requirements

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

#### 6.4.5 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  $\Omega$  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/crush

## a) Purpose

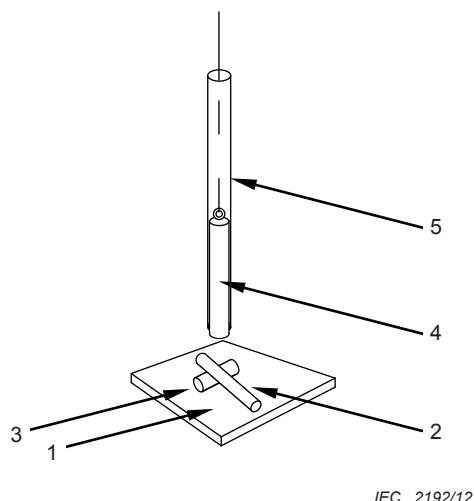
This test simulates mechanical abuse from an impact or crush that may result in an internal short-circuit.

## b) Test procedure – Impact

The impact test is applicable to cylindrical cells greater than 20 mm in diameter.

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

The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the steel bar lying across the centre of the test sample (see Figure 1).



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

**Figure 1 – Example of a test set-up for the impact test**

Each test cell or component cell shall be subjected to one impact only.

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

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

c) Test procedure – Crush

The crush test is applicable to prismatic, pouch, coin/button cells and cylindrical cells not more than 20 mm in diameter.

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

- 1) the applied force reaches  $13 \text{ kN} \pm 0,78 \text{ kN}$ ;

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

- 2) the voltage of the cell drops by at least 100 mV; or
- 3) the cell is deformed by 50 % or more of its original thickness.

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

A prismatic or pouch cell shall be crushed by applying the force to the widest side. A button/coin cell shall be crushed by applying the force on its flat surfaces. For cylindrical cells, the crush force shall be applied perpendicular to the longitudinal axis.

Each test cell or component cell is to be subjected to one crush only.

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

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

d) 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 Misuse 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 minimum 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 may be conducted using undamaged test batteries previously used in tests T-1 to T-5 for purposes of testing on cycled batteries.

#### c) Requirements

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

### 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 shall be conducted using test cells or component cells that have not previously been subjected to other tests.

#### c) Requirements

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

## 6.6 Packaging test

### 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:2011 [10], section 6.1.5. See also the regulations mentioned in 7.3.

#### 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 leakage, no venting, no short-circuit, no excessive temperature rise, no rupture, no explosion and no fire during this test.

### 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:

	Clause and/or subclause
a) (aggregate) lithium content	5.2 6.8 l)
b) nominal energy	5.1 5.2
c) Pre-discharge current or resistive load and end-point voltage specified by the manufacturer for primary cells and batteries;	6.1.4
d) Charge and discharge conditions specified by the manufacturer for optimum performance and safety of secondary (rechargeable) cells and batteries;	6.1.4
e) Manufacturer's recommended maximum continuous charge current;	6.5.1
f) Manufacturer's recommended charge voltage;	6.5.1
g) Maximum charge voltage;	6.5.1
h) Maximum continuous discharge current specified by the manufacturer;	6.5.2
i) Rated capacity specified by the manufacturer.	6.5.2

### 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 gross weight 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) type of the test sample(s): cell, component cell, battery or battery assembly;
- k) weight of the test sample(s);
- l) lithium content or nominal energy of the sample(s);
- m) a signature with name and status of the signatory;
- n) 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 4.3 and 6.6.

### **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 Goods [10].

Regulations for transport are subject to change. For the transport of lithium batteries, the latest editions of the regulations listed in 7.3.2 to 7.3.5 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) [7].

#### **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) [9].

#### **7.3.4 Land transport**

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

#### **7.3.5 Classification**

Classification of lithium cells and batteries for transport under the regulations mentioned in 7.3.2 to 7.3.4 is based on the UN Manual of Tests and Criteria, chapter 38.3, basically describing the same tests as this International Standard. Lithium cells and batteries that have not passed all required tests are generally not allowed for transport.

### **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 – 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 [3]. 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 it has to be transported fully regulated under the relevant dangerous goods 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 2 shows an example.

Documents (e.g. air waybills (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.



IEC 2193/12

NOTE 1 Delete “Metal /” or “/ Ion”, as appropriate.

NOTE 2 The example is based on ICAO Technical Instructions [8] and IATA Dangerous Goods Regulations [7]. Refer to regulations mentioned in 7.3 for marking requirements in other transport modes.

**Figure 2 – Example for the marking of packages with primary or secondary (rechargeable) lithium cells or batteries**

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- [1] United Nations: *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Fifth revised edition, Amendment 1 (2011), Section 38.3: Lithium Batteries*
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  - [6] ISO/IEC GUIDE 51, *Safety aspects – Guidelines for their inclusion in standards*
  - [7] IATA, International Air Transport Association, Quebec: *Dangerous Goods Regulations* (revised annually)
  - [8] ICAO, International Civil Aviation Organisation, Montreal: *Technical Instructions for the Safe Transport of Dangerous Goods by Air*
  - [9] IMO, International Maritime Organization, London: *International Maritime Dangerous Goods (IMDG) Code*
  - [10] United Nations:2011, *Recommendations on the Transport of Dangerous Goods, Model Regulations, Seventeenth revised edition*
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