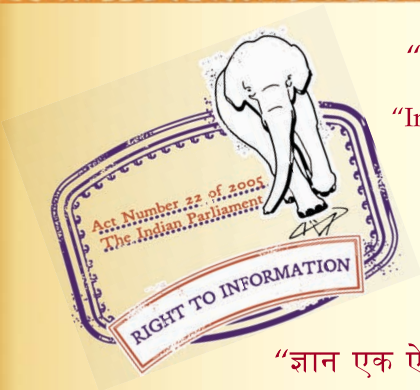
IS 6303-4 (2013): Primary Batteries, Part 4: Safety of Lithium Batteries [ETD 10: Primary Cells and Batteries]



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IS 6303 (Part 4) : 2013
IEC 60086-4 : 2007

भारतीय मानक

प्राथमिक बैटरियाँ

भाग 4 लिथियम बैटरियों की सुरक्षा

(दूसरा पुनरीक्षण)

Indian Standard

PRIMARY BATTERIES

PART 4 SAFETY OF LITHIUM BATTERIES

(Second Revision)

ICS 29.220.10

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

January 2013 **Price Group 10**

Primary Cells and Batteries Sectional Committee, ETD 10

NATIONAL FOREWORD

This Indian Standard (Part 4) (Second Revision) which is identical with IEC 60086-4 : 2007 'Primary batteries — Part 4: Safety of lithium batteries' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Primary Cells and Batteries Sectional Committee and approval of the Electrotechnical Division Council.

This standard was originally published in 1971 and was revised in 1984 to align it with the practice followed at international level. Test to determine leakage of electrolyte, continuous discharge test for determination of life and code of practice for transport, storage, use and disposal of batteries were added in this revision.

The committee has now decided to revise this standard in line with IEC Standards and adopt it in various parts. Parts 4 and 5 of this standard has been adopted under dual numbering system to align it with the latest version of IEC 60086 in various parts. Others parts in this series are:

- Part 1 General
- Part 2 Physical and electrical specifications
- Part 3 Watch batteries (*under consideration*)
- Part 5 Safety of batteries with aqueous electrolyte

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, references appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60086-1 : 1982 Primary batteries — Part 1: General	IS 6303 (Part 1) : 2012 Primary batteries: Part 1 General (*second revision*)	Technically Equivalent
IEC 60086-2 : 2007 Primary batteries — Part 2: Physical and electrical specifications	IS 6303 (Part 2) : 2012 Primary batteries: Part 2 Physical and electrical specification (*second revision*)	do

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

PRIMARY BATTERIES

PART 4 SAFETY OF LITHIUM BATTERIES

(Second Revision)

1 Scope

This part of IEC 60086 specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.

NOTE Primary lithium batteries that are standardized in IEC 60086-2 are expected to meet all applicable requirements herein. It is understood that consideration of this part of IEC 60086 might also be given to measuring and/or ensuring the safety of non-standardized primary lithium batteries. In either case, no claim or warranty is made that compliance or non-compliance with this standard will fulfil or not fulfil any of the user's particular purposes or needs.

2 Normative references

The following 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 60086-1, *Primary batteries – Part 1: General*

IEC 60086-2, *Primary batteries – Part 2: Physical and electrical specifications*

3 Terms and definitions

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

NOTE Certain definitions taken from IEC 60050-482 and IEC 60086-1 are repeated below for convenience.

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

3.2
battery
one or more cells fitted with devices necessary for use, for example case, terminals, marking and protective devices

[IEV 482-01-04:2004]

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

[IEV 482-02-40:2004]

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

[IEV 482-01-01:2004]

3.5
component cell
cell contained in a battery

3.6
cylindrical cell
cell with a cylindrical shape in which the overall height is equal to or greater than the diameter

[IEV 482-02-39:2004]

3.7
depth of discharge
percentage of rated capacity discharged from a battery

3.8
fully discharged
state of charge of a cell or battery corresponding to 100 % depth of discharge

3.9
harm
physical injury or damage to health of people, or damage to property or the environment

[ISO/IEC Guide 51:1999, 3.3]

3.10
hazard
potential source of harm

[ISO/IEC Guide 51:1999, 3.5]

3.11
intended use
use of a product, process or service in accordance with information provided by the supplier

[ISO/IEC Guide 51:1999, 3.13]

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 is more than 12 g

3.14
lithium cell
cell containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

[IEV 482-01-06:2004]

3.15
nominal voltage
suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

[IEV 482-03-31:2004]

3.16
open circuit voltage (OCV, U_{OC}, off-load voltage)
voltage across the terminals of a battery when no external current is flowing

[IEV 482-03-32:2004, modified]

3.17
prismatic
qualifies a cell or a battery having the shape of a parallelepiped whose faces are rectangular

[IEV 482-02-38:2004]

3.18
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

3.19
rated capacity
capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

[IEV 482-03-15:2004, modified]

3.20
reasonably foreseeable misuse
use of a product, process or service in a way not intended by the supplier, but which may result from readily predictable human behaviour

[ISO/IEC Guide 51:1999, 3.14]

3.21
risk
combination of the probability of occurrence of harm and the severity of that harm

[ISO/IEC Guide 51:1999, 3.2]

3.22
safety
freedom from unacceptable risk

[ISO/IEC Guide 51:1999, 3.1]

3.23
undischarged
state of charge of a primary cell or battery corresponding to 0 % depth of discharge

4 Requirements for safety

4.1 Design

Lithium batteries are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, button/coin and prismatic configurations. 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 capability and battery configuration.

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

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

b) Temperature increases in the battery shall be controlled by a design which limits current flow.

c) Lithium cells and batteries shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, intended use and reasonably foreseeable misuse.

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

4.2 Quality plan

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

5 Sampling

5.1 General

Samples should be drawn from production lots in accordance with accepted statistical methods.

5.2 Test samples

The number of test samples is given in Table 1 below. The same test cells and batteries are used for tests A to E in sequence. New test cells and batteries are required for each of tests F to M.

NOTE Test G is provided as an alternative for test F depending on which of them is more appropriate to simulate an internal short-circuit for the relevant cell design.

Table 1 – Number of test samples

<table>
<tr><th></th><th colspan="2">Cells and single cell batteries</th><th colspan="2">Multi cell batteries</th></tr>
<tr><td rowspan="2">Number of samples for tests A to E</td><td>Undischarged</td><td>Fully discharged</td><td>Undischarged</td><td>Fully discharged</td></tr>
<tr><td>10</td><td>10</td><td>4 [a]</td><td>4 [a]</td></tr>
<tr><td rowspan="2">Number of samples for tests F or G</td><td>Undischarged</td><td>Fully discharged</td><td colspan="2" rowspan="2">No battery tests required but the component cells shall have passed the test</td></tr>
<tr><td>5 (button and cylindrical)
10 (prismatic)</td><td>5 (button and cylindrical)
10 (prismatic)</td></tr>
<tr><td rowspan="2">Number of samples for test H</td><td>Undischarged</td><td>Fully discharged</td><td colspan="2" rowspan="2">No battery tests required but the component cells shall have passed the test</td></tr>
<tr><td>NA</td><td>10</td></tr>
<tr><td rowspan="2">Number of samples for tests I to K</td><td>Undischarged</td><td>Fully discharged</td><td>Undischarged</td><td>Fully discharged</td></tr>
<tr><td>5</td><td>NA</td><td>5</td><td>NA</td></tr>
<tr><td rowspan="2">Number of samples for test L</td><td>Undischarged</td><td>Fully discharged</td><td colspan="2" rowspan="2">NA</td></tr>
<tr><td>5 (+ 15) [b]</td><td>NA</td></tr>
<tr><td rowspan="2">Number of samples for test M</td><td>50 % predischarged</td><td>75 % predischarged</td><td colspan="2" rowspan="2">NA</td></tr>
<tr><td>5 (+15) [b]</td><td>5 (+15) [b]</td></tr>
<tr><td colspan="5">Key:
NA: Not applicable.</td></tr>
<tr><td colspan="5">[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] Undischarged additional cells in brackets.</td></tr>
</table>

6 Testing and requirements

6.1 General

6.1.1 Test application matrix

Applicability of test methods to test cells and batteries is shown in Table 2 below.

Table 2 – Test application matrix

Form	Applicable tests												
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	x	x	x	x	x	x	x	x	x	x	x	x [a]	x [b]
m	x	x	x	x	x	NA [c]	NA [c]	NA [c]	x	x	x	NA	NA

Test description:

Intended use tests
A: Altitude
B: Thermal cycling
C: Vibration
D: Shock

Reasonably foreseeable misuse tests
E: External short-circuit
F: Impact
G: Crush
H: Forced discharge
I: Abnormal charging
J: Free fall
K: Thermal abuse
L: Incorrect installation
M: Overdischarge

Key:

Form
s: cell or single cell battery
m: multi cell battery

Applicability
x: Applicable
NA: Not applicable

[a] Only applicable to CR17345, CR15H270 and similar type batteries of a spiral construction that could be installed incorrectly and charged.

[b] Only applicable to CR17345, CR15H270 and similar type batteries of a spiral construction that could be overdischarged.

[c] No battery tests required but the component cells shall have passed the test.

6.1.2 Safety notice

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

It has been assumed in the drafting of these tests that their execution is undertaken by appropriately qualified and experienced technicians using adequate protection.

6.1.3 Ambient temperature

Unless otherwise specified, the tests shall be carried out at 20 °C ± 5 °C.

6.1.4 Parameter measurement tolerances

The overall accuracy of controlled or measured values, relative to the specified or actual parameters, shall be within the following tolerances:

a) ± 1 % for voltage;

b) ± 1 % for current;

c) ± 2 °C for temperature;

d) ± 0,1 % for time;

e) ± 1 % for 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.

6.1.5 Predischarge

Where a test requires predischarge, the test cells or batteries shall be discharged to the respective depth of discharge with a resistive load with which the rated capacity is obtained or with a current specified by the manufacturer.

6.1.6 Additional cells

Where additional cells are required to perform a test, they shall be of the same type and, preferably, of the same production lot as the test cell.

6.2 Evaluation of test criteria

6.2.1 Short-circuit

A short-circuit is considered to have occurred during a test if the open-circuit voltage of the cell or battery 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.

6.2.2 Excessive temperature rise

An excessive temperature rise is considered to have occurred during a test if the external case temperature of the test cell or battery rises above 170 °C.

6.2.3 Leakage

Leakage is considered to have occurred during a test if electrolyte, gas or other material escapes from the test cell or battery in a manner not intended by design.

6.2.4 Mass loss

In order to quantify mass loss $\Delta m / m$, the following equation is provided:

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

where

m is the mass before a test;

m_1 is the mass after that test.

Mass loss is considered to have occurred if, during a test, the maximum values given in Table 3 are exceeded.

Table 3 – Maximum mass loss

Mass of battery m	Maximum mass loss $\Delta m / m$ %
$m \leq 1$ g	0,5
1 g < $m \leq 5$ g	0,2
$m > 5$ g	0,1

6.2.5 Venting

Venting is considered to have occurred if, during a test, an excessive build up of internal gas pressure escapes from a cell or battery through a safety feature designed for this purpose. This gas may include entrapped materials.

6.2.6 Fire

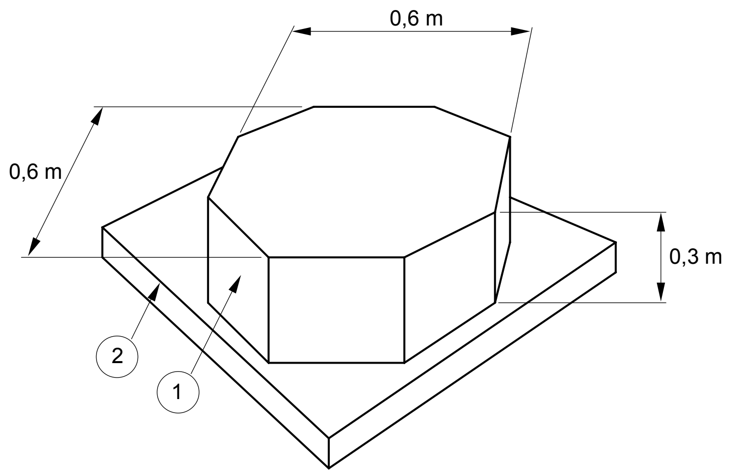
A fire is considered to have occurred if, during a test, flames are emitted from the test cell or battery.

6.2.7 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, spillage of liquids, or ejection of solid materials but no explosion.

6.2.8 Explosion

An explosion is considered to have occurred if, during a test, solid matter from any part of a cell or battery has penetrated a wire mesh screen as shown in Figure 1, centred over the cell or battery on the steel plate. The screen shall be made from annealed aluminium wire with a diameter of 0,25 mm and a grid density of 6 to 7 wires per cm.



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

Figure 1 – Mesh screen

6.3 Tests and requirements – Overview

This standard provides safety tests for intended use (tests A to D) and reasonably foreseeable misuse (tests E to M).

Table 4 contains an overview of the tests and requirements for intended use and reasonably foreseeable misuse.

Table 4 – Tests and requirements

Test number		Designation	Requirements
Intended use tests	A	Altitude	NM, NL, NV, NC, NR, NE, NF
	B	Thermal cycling	NM, NL, NV, NC, NR, NE, NF
	C	Vibration	NM, NL, NV, NC, NR, NE, NF
	D	Shock	NM, NL, NV, NC, NR, NE, NF
Reasonably foreseeable misuse tests	E	External short-circuit	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Crush	NT, NE, NF
	H	Forced discharge	NE, NF
	I	Abnormal charging	NE, NF
	J	Free fall	NV, NE, NF
	K	Thermal abuse	NE, NF
	L	Incorrect installation	NE, NF
	M	Overdischarge	NE, NF

Tests A through E shall be conducted in sequence on the same cell or battery.

Tests F and G are provided as alternatives. Only one of them shall be conducted, namely the one which is considered by the manufacturer to be more appropriate to simulate an internal short-circuit for the relevant cell design.

Key

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

See 6.2 for a detailed description of the test criteria.

6.4 Tests for intended use

6.4.1 Test A: Altitude

a) Purpose

This test simulates air transport under low pressure conditions.

b) Test procedure

Test cells and batteries shall be stored at a pressure of 11,6 kPa or less for at least 6 h at ambient temperature.

c) Requirements

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

6.4.2 Test B: Thermal cycling

a) Purpose

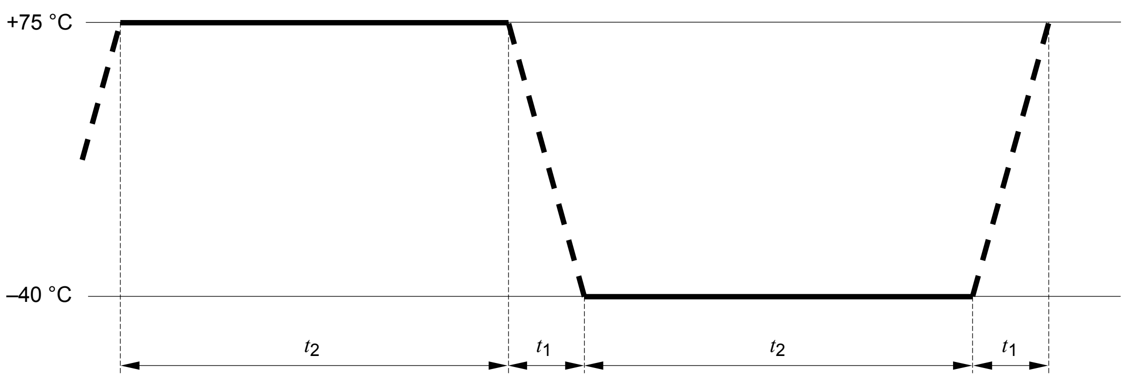
This test assesses cell and battery seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

b) Test procedure

Test cells and batteries shall be stored for at least 6 h at a test temperature of 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.



Key

t_1 ≤ 30 min

t_2 ≥ 6 h (12 h for large cells and batteries)

NOTE The figure shows one of ten cycles.

Figure 2 – Thermal cycling procedure

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 C: Vibration

a) Purpose

This test simulates vibration during transport. The test condition is based on the range of vibrations as given by ICAO [2].

b) Test procedure

Test cells and batteries shall be firmly secured to the platform of the vibration machine without distorting them and in such a manner as to faithfully transmit the vibration. Test cells and batteries shall be subjected to sinusoidal vibration according to Table 5. This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

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

Table 5 – Vibration profile (sinusoidal)

Frequency range		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
From	To				
f_1 = 7 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 = 8 g_n		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 ≈ 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 D: Shock

a) Purpose

This test simulates rough handling during transport.

b) Test procedure

Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test cell or battery. Each test cell or battery shall be subjected to 3 shocks in each direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks. For each shock, the parameters given in Table 6 shall be applied.

Table 6 – Shock parameters

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

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.

6.5 Tests for reasonably foreseeable misuse

6.5.1 Test E: External short-circuit

a) Purpose

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

b) Test procedure

The test cell or battery shall be stabilized at an external case temperature of 55 °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at

55 °C. This short-circuit condition is continued for at least 1 h after the cell or battery external case temperature has returned to 55 °C.

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

The test shall be conducted using the test samples previously subjected to the shock test.

c) Requirements

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

6.5.2 Test F: Impact

a) Purpose

This test simulates an internal short-circuit.

NOTE The impact test has been included in IEC 62281 [11] for the purpose of harmonization with the transport tests described in the UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria [17]. It has been evaluated by the IEC and found to be more appropriately described as a misuse test than a transport test. It could not be verified that it truly simulates an internal short-circuit condition. It was, however, found that for some cell designs, the crush test is more appropriate to simulate an internal short-circuit condition. Therefore, the crush test is provided as an alternative test method to simulate an internal short-circuit.

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 tests.

The test shall not be applied to cells where it does not appropriately simulate an internal short-circuit condition.

c) Requirements

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

6.5.3 Test G: Crush

a) Purpose

This test simulates an internal short-circuit.

NOTE For some cell designs, the crush test is a more appropriate simulation of an internal short-circuit than the impact test. It is therefore provided as an alternative test method for this purpose.

b) Test procedure

The cell or component cell shall be crushed between two flat surfaces. The force shall be applied by a vice or by a hydraulic ram with a round piston. The crushing shall be gradual with a speed of approximately 1,5 cm / s at the first point of contact. The crushing shall be continued until the applied force reaches approximately 13 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.

Once the maximum pressure has been obtained, the pressure shall be released.

A cylindrical cell shall be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. A prismatic cell shall be crushed by applying the force in the direction of one of the two axes perpendicular to its longitudinal axis, and, separately, by applying the force in the direction of the other one of these two axes. A button/coin cell shall be crushed by applying the force on its flat surfaces.

Each test cell or component cell shall 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 been previously subjected to other tests.

The test shall only be applied to cells where test F, Impact, does not appropriately simulate an internal short-circuit condition.

c) Requirements

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

6.5.4 Test H: Forced discharge

a) Purpose

This test evaluates the ability of a cell to withstand a forced discharge condition.

b) Test procedure

Each cell shall be force discharged at ambient temperature by connecting it in series with a 12 V direct current power supply at an initial current equal to the maximum continuous discharge current specified by the manufacturer.

The specified discharge current is obtained by connecting a resistive load of appropriate size and rating in series with the test cell and the direct current power supply. Each cell shall be force discharged for a time interval t_d equal to

$$t_d = C_r / I_i$$

where

t_d is the test duration;

C_r is the rated capacity;

I_i is the initial test current.

The test shall be conducted with fully discharged test batteries.

The test cells shall be observed for 7 days after the forced discharge condition has been discontinued.

c) Requirements

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

6.5.5 Test I: Abnormal charging

a) Purpose

This test simulates the condition when a battery is fitted within a device and is exposed to a reverse voltage from an external power supply, for example memory back-up equipment with a defective diode (see 7.1.1). The test condition is based upon UL 1642 [15].

b) Test procedure

Each test battery shall be subjected to a charging current of three times the abnormal charging current I_c specified by the battery manufacturer by connecting it in opposition to a d.c. power supply. Unless the power supply allows for setting the current, the specified charging current shall be obtained by connecting a resistor of the appropriate size and rating in series with the battery.

The test duration shall be calculated using the formula:

$$t_d = 2{,}5 \times C_n / (3 \times I_c)$$

where

t_d is the test duration. In order to expedite the test, it is permitted to adjust the test parameters such that t_d does not exceed 7 days;

C_n is the nominal capacity;

I_c is the abnormal charging current declared by the manufacturer for this test.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.6 Test J: Free fall

a) Purpose

This test simulates the situation when a battery is accidentally dropped. The test condition is based upon IEC 60068-2-32 [7].

b) Test procedure

The test batteries shall be dropped from a height of 1 m onto a concrete surface. Each test battery shall be dropped six times, a prismatic battery once from each of its six faces, a round battery twice in each of the three axes shown in Figure 3. The test batteries shall be stored for 1 h afterwards.

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

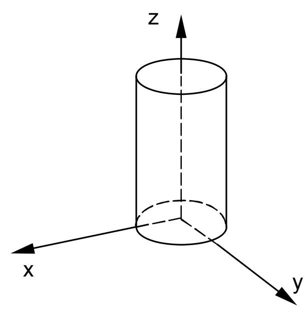


Figure 3 – Axes for free fall

c) Requirements

There shall be no venting, no explosion and no fire during this test and within the 1 h of observation.

6.5.7 Test K: Thermal abuse

a) Purpose

This test simulates the condition when a battery is exposed to an extremely high temperature.

b) Test procedure

A test battery shall be placed in an oven and the temperature raised at a rate of 5 °C/min to a temperature of 130 °C at which the battery shall remain for 10 min.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.8 Test L: Incorrect installation

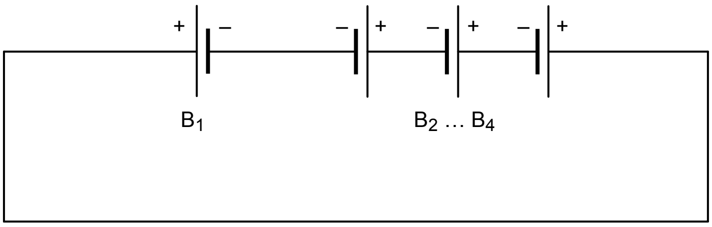
a) Purpose

This test simulates the condition when one single cell battery in a set is reversed.

b) Test procedure

A test battery is connected in series with three undischarged additional single cell batteries of the same type in such a way that the terminals of the test battery are connected in reverse. The resistance of the interconnecting circuit shall be less than or equal to 0,1 Ω.

The circuit shall be completed for 24 h or until the battery case temperature has returned to ambient.



Key

B_1 test cell

B_2...B_4 additional cells, undischarged

Figure 4 – Circuit diagram for incorrect installation

c) Requirements

There shall be no explosion and no fire during this test.

6.5.9 Test M: Overdischarge

a) Purpose

This test simulates the condition when one discharged single cell battery is connected in series with other undischarged single cell batteries. The test further simulates the use of batteries in motor powered appliances where, in general, currents over 1 A are required.

NOTE CR17345 and CR15H270 batteries are widely used in motor powered appliances where currents over 1 A are required. The current for non standardized batteries may be different.

b) Test procedure

Each test battery shall be predischarged to 50 % depth of discharge. It shall then be connected in series with three undischarged additional single cell batteries of the same type.

A resistive load R_1 is connected in series with the assembly of batteries in Figure 5 where R_1 is taken from Table 7.

The test shall be continued for 24 h or until the battery case temperature has returned to ambient.

The test shall be repeated with 75 % predischarged test batteries.

Table 7 – Resistive load for overdischarge

Battery type	Resistive load R_1 Ω
CR17345	8,20
CR15H270	8,20

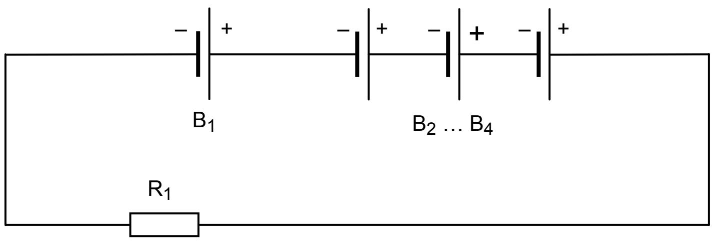
NOTE Table to be modified or expanded when additional batteries of a spiral construction are standardized.

EXAMPLE When CR17345 and CR15H270 batteries were standardized, R_1 was determined from the end voltage of the assembly in Figure 5, using the formula

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

where 2,0 V is the end voltage taken from the specification tables in IEC 60086-2; and 1 A is the test current.

R_1 was then found by rounding R to the nearest value in Table 5 of IEC 60086-1.



Key

B1 test battery, 50 % predischarged and, in separate tests, 75 % predischarged
B2… B4 additional batteries, undischarged
R1 resistive load

Figure 5 – Circuit diagram for overdischarge

c) Requirements

There shall be no explosion and no fire during this test.

6.6 Information to be given in the relevant specification

When this 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) Predischarge current specified by the manufacturer	6.1.5;
b) Declaration whether the impact test or the crush test is more appropriate to simulate an internal short-circuit condition	6.5.2 and 6.5.3;
c) Maximum continuous discharge current specified by the manufacturer for test H	6.5.4;

NOTE 1 Forced discharge of a cell can occur when it is connected in series with other cells and when it is not protected with a bypass diode. Where applicable, this should be reflected by the specification.

and

d) Abnormal charging current declared by the manufacturer for test I — 6.5.5

NOTE 2 Abnormal charging of a cell can occur when it is connected in series with other cells and one cell is reversed or when it is connected in parallel with a power supply and the protective devices do not operate correctly. Where applicable, this should be reflected by the specification.

6.7 Evaluation and report

If a report is issued, the following list of items should be considered:

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) characteristics of the test cells or batteries according to 4.1;
f) test descriptions and results, including the parameters according to 6.6;
g) a signature with name and status of the signatory.

7 Information for safety

7.1 Safety precautions during design of equipment

See also Annex B for guidelines for designers of equipment using lithium batteries.

7.1.1 Charge protection

When incorporating a primary lithium battery into a memory back-up circuit, a blocking diode and current limiting resistor or other protective devices shall be used to prevent the main power source from charging the battery (see Figure 6).

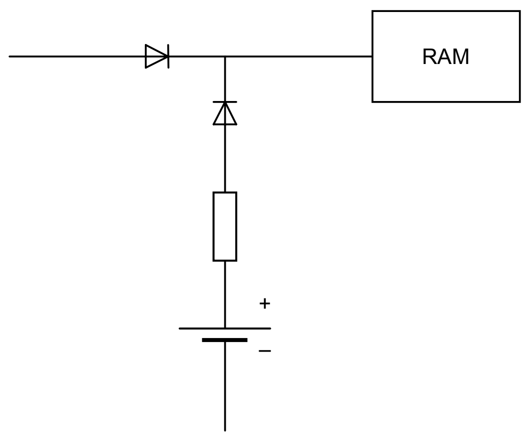


Figure 6 – Safety wiring for charge protection

7.1.2 Parallel connection

Parallel connection should be avoided when designing battery compartments. However, if required, the battery manufacturer shall be contacted for advice.

7.2 Safety precautions during handling of batteries

When used correctly, lithium batteries provide a safe and dependable source of power. However, if they are misused or abused, leakage, venting or in extreme cases, explosion and/or fire may result.

a) *Always insert batteries correctly with regard to polarity (+ and –) marked on the battery and the equipment*

When batteries are inserted in reverse they may be short-circuited or charged. This may cause overheating, leakage, venting, rupture, explosion, fire and personal injury.

b) *Do not short-circuit batteries*

When the positive (+) and negative (–) terminals of a battery are in electrical contact with each other, the battery becomes short-circuited. For example loose batteries in a pocket with keys or coins, can be short-circuited. This may result in venting, leakage, explosion, fire and personal injury.

c) *Do not charge batteries*

Attempting to charge a non-rechargeable (primary) battery may cause internal gas and/or heat generation resulting in leakage, venting, explosion, fire and personal injury.

d) *Do not force discharge batteries*

When batteries are force discharged by means of an external power source, the voltage of the battery will be forced below its design capability and gases will be generated inside the battery. This may result in leakage, venting, explosion, fire and personal injury.

e) *Do not mix old and new batteries or batteries of different types or brands*

When replacing batteries, replace all of them at the same time with new batteries of the same brand and type. When batteries of different brand or type are used together or new and old batteries are used together, some batteries may be over-discharged / force discharged due to a difference of voltage or capacity. This may result in leakage, venting, explosion and possibly fire and may cause personal injury.

f) *Exhausted batteries should be immediately removed from equipment and properly disposed*

When discharged batteries are kept in the equipment for a long time, electrolyte leakage may occur causing damage to the equipment and/or personal injury.

g) *Do not heat batteries*

When a battery is exposed to heat, leakage, venting, explosion and possibly fire may occur and cause personal injury.

h) *Do not weld or solder directly to batteries*

The heat from welding or soldering directly to a battery may cause leakage, venting, explosion and possibly fire and may cause personal injury.

i) *Do not dismantle batteries*

When a battery is dismantled or taken apart, contact with the components can be harmful and may cause personal injury or possibly fire.

j) *Do not deform batteries*

Batteries should not be crushed, punctured, or otherwise mutilated. Such abuse may result in leakage, venting, explosion, or possibly fire and cause personal injury.

k) *Do not dispose of batteries in fire*

When batteries are disposed of in fire, the heat build-up may cause explosion and/or fire and personal injury. Do not incinerate batteries except for approved disposal in a controlled incinerator.

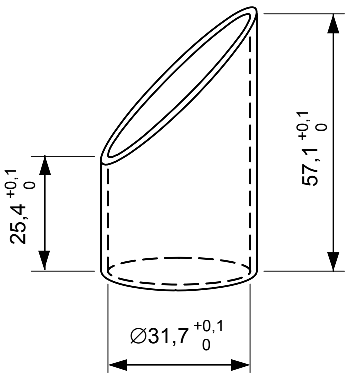
l) *A lithium battery with a damaged container should not be exposed to water*

Lithium metal in contact with water may produce hydrogen gas, fire, explosion and/or cause personal injury.

m) *Keep batteries out of the reach of children*

Especially keep batteries which are considered swallowable out of the reach of children, particularly those batteries fitting within the limits of the ingestion gauge as defined in Figure 7. In case of ingestion of a cell or battery, seek medical assistance promptly.

Dimensions in mm



NOTE This gauge defines a swallowable component and is defined in ISO 8124-1 [14].

Figure 7 – Ingestion gauge

n) *Do not allow children to replace batteries without adult supervision*

o) *Do not encapsulate and/or modify batteries*

Encapsulation or any other modification to a battery may result in blockage of the safety vent mechanism(s) and subsequent explosion and personal injury. Advice from the battery manufacturer should be sought if it is considered necessary to make any modification.

p) *Store unused batteries in their original packaging away from metal objects. If already unpacked, do not mix or jumble batteries*

Unpacked batteries could get jumbled or get mixed with metal objects. This can cause battery short-circuiting which may result in leakage, venting, explosion and possibly fire and personal injury. One of the best ways to prevent this from happening is to store unused batteries in their original packaging.

q) *Remove batteries from equipment if it is not to be used for an extended period of time unless it is for emergency purposes*

It is advantageous to remove batteries immediately from equipment which has ceased to function satisfactorily, or when a long period of disuse is anticipated (e.g. video cameras, photoflash, etc.). Although most lithium batteries on the market today are highly leak resistant, a battery that has been partially or completely exhausted may be more prone to leak than one that is unused.

7.3 Packaging

The packaging shall be adequate to avoid mechanical damage during transport, handling and stacking. The materials and packaging design shall be chosen so as to prevent the development of unintentional electrical contact, short-circuit, shifting and corrosion of the terminals, and afford some protection from the environment.

7.4 Handling of battery cartons

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

7.5 Transport

7.5.1 General

Tests and requirements for the transport of lithium cells or batteries are given in IEC 62281 [11].

Regulations concerning international transport of lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods [16].

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

7.5.2 Air transport

Regulations concerning air transport of lithium batteries are specified in the Technical Instructions for the Safe Transport of Dangerous Goods by Air published by the International Civil Aviation Organization (ICAO) [2] and in the Dangerous Goods Regulations published by the International Air Transport Association (IATA) [1].

7.5.3 Sea transport

Regulations concerning sea transport of lithium batteries are specified in the International Maritime Dangerous Goods (IMDG) Code published by the International Maritime Organization (IMO) [12].

7.5.4 Land transport

Regulations concerning road and railroad transport are specified on a national or multilateral basis. While an increasing number of regulators adopt the UN Model Regulations [16], it is recommended that country-specific transport regulations be consulted before shipping.

7.6 Display and storage

a) *Store batteries in well ventilated, dry and cool conditions*

High temperature or high humidity may cause deterioration of the battery performance and/or surface corrosion.

b) *Do not stack battery cartons on top of each other exceeding a specified height*

If too many battery cartons are stacked, batteries in the lowest cartons 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 and display batteries in their original packing*

When batteries are unpacked and mixed they may be short-circuited or damaged.

See Annex C for additional details.

7.7 Disposal

Primary batteries may be disposed via communal refuse arrangements provided no local rules to the contrary exist.

During transport, storage and handling for disposal, the following safety precautions should be considered:

a) *Do not dismantle batteries*

Some ingredients of lithium batteries can be flammable or harmful. They may cause injuries, fire, rupture or explosion.

b) *Do not dispose of batteries in fire except under conditions of approved and controlled incineration*

Lithium burns violently. Lithium batteries may explode in a fire. Combustion products from lithium batteries can be toxic and corrosive.

c) *Store collected batteries in a clean and dry environment out of direct sunlight and away from extreme heat*

Dirt and wetness may cause short-circuits and heat. Heat may cause leakage of flammable gas. This may result in fire, rupture or explosion.

d) *Store collected batteries in a well-ventilated area*

Used batteries may contain residual charge. If they are short-circuited, abnormally charged or force discharged leakage of flammable gas may be caused. This may result in fire, rupture or explosion.

e) *Do not mix collected batteries with other materials*

Used batteries may contain residual charge. If they are short-circuited, abnormally charged or force discharged the generated heat may ignite flammable wastes such as oily rags, paper or wood and cause a fire.

f) *Protect battery terminals*

Protection of terminals should be considered by providing insulation, particularly for those batteries with a high voltage. Unprotected terminals can cause short-circuits, abnormal charging and forced discharge. This may result in leakage, fire, rupture or explosion.

8 Instructions for use

a) *Always select the correct size and type of battery most suitable for the intended use. Information provided with the equipment to assist correct battery selection should be retained for reference*.
b) *Replace all batteries of a set at the same time.*
c) *Clean the battery contacts and also those of the equipment prior to battery installation.*
d) *Ensure that the batteries are installed correctly with regard to polarity (+ and –).*
e) *Remove exhausted batteries promptly.*

9 Marking

9.1 General

With the exception of small batteries (see 9.2), each battery shall be marked with the following information:

a) designation;
b) expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code;
c) polarity of terminals (when applicable);
d) nominal voltage;
e) name or trade mark of the manufacturer or supplier;
f) cautionary advice;
g) caution for ingestion of swallowable batteries (see also 7.2 m)).

9.2 Small batteries

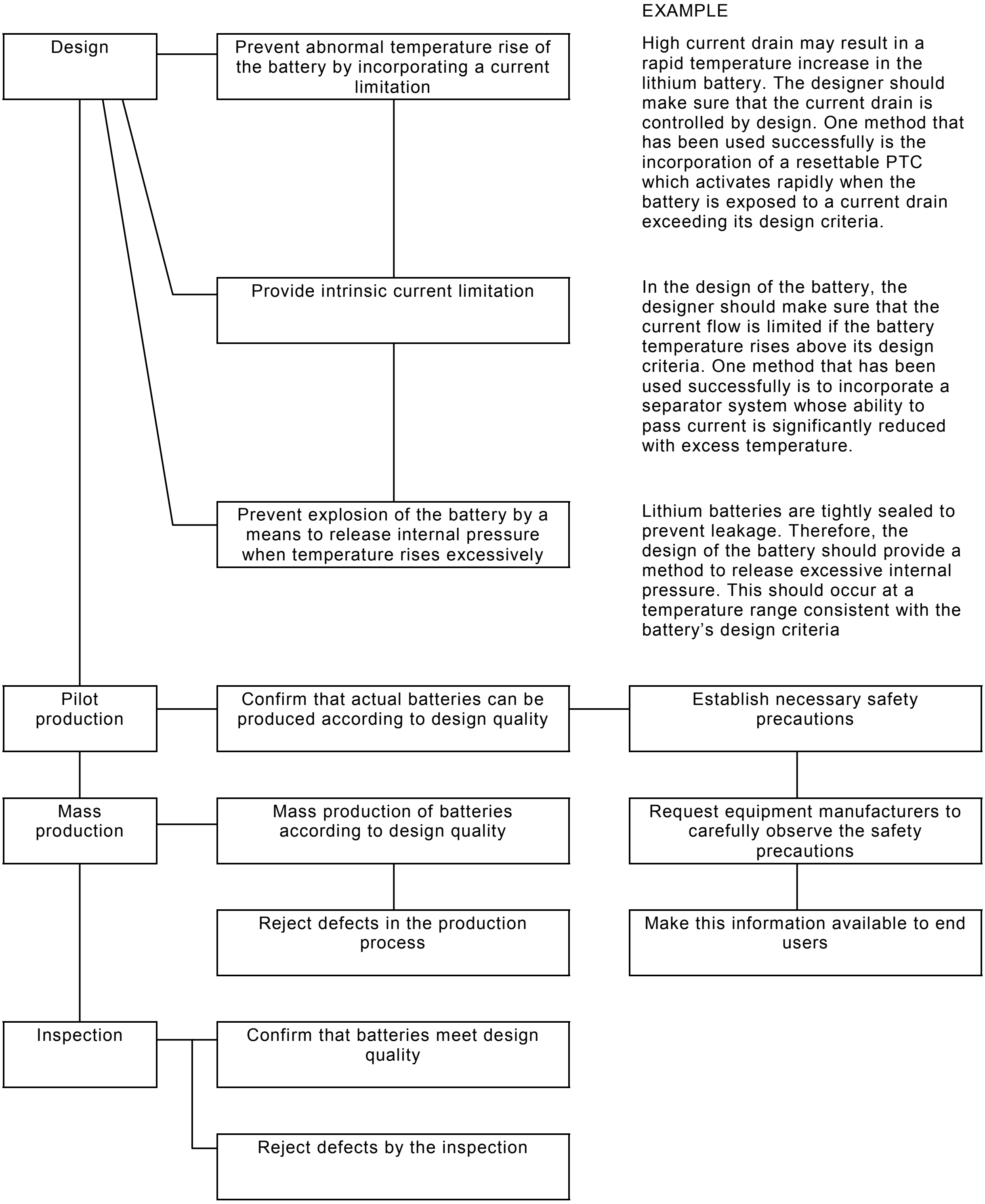
Batteries, whose external surface area is too small to accommodate the markings shown in 9.1, shall show, on the battery, the designation of 9.1 a) and polarity of 9.1 c). All other markings shown in 9.1 may be given on the immediate package instead of on the battery.

Annex A
(informative)

Guidelines for the achievement of safety of lithium batteries

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

Table A.1 – Battery design guidelines



Annex B
(informative)

Guidelines for designers of equipment using lithium batteries

Table B.1 sets out the guidelines to be used by designers of equipment which employs lithium batteries (see also IEC 60086-5:2005, Annex B [19], for guidelines for the design of battery compartments).

Table B.1 – Equipment design guidelines

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

[a] See 7.1.2

Table B.1 *(continued)*

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

Annex C
(informative)

Additional information on display and storage

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

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

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

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

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

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

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

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

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

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

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