INTERNATIONAL STANDARD

IEC 60086-4

Second edition
2000-03

Primary batteries –

Part 4:
Safety of lithium batteries

Piles électriques –

Partie 4:
Sécurité des piles au lithium

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For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV).

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to publications IEC 60027: *Letter symbols to be used in electrical technology*, IEC 60417: *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets* and IEC 60617: *Graphical symbols for diagrams*.

* See web site address on title page.

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International Electrotechnical Commission 3, rue de Varembé Geneva, Switzerland
Telefax: +41 22 919 0300 e-mail: inmail@iec.ch IEC web site http://www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60086-4 has been prepared by IEC technical committee 35: Primary cells and batteries.

This second edition cancels and replaces the first edition, published in 1996, and constitutes a technical revision.

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

FDIS	Report on voting
35/1114/FDIS	35/1125/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A, B and C are for information only.

IEC 60086 consists of the following parts, under the general title Primary batteries:

– Part 1: General
– Part 2: Specification sheets
– Part 3: Watch batteries
– Part 4: Safety of lithium batteries
– Part 5: Safety of batteries with aqueous electrolyte

The committee has decided that the contents of this publication will remain unchanged until 2002.

At this date the publication will be

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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This standard specifies requirements and tests for lithium batteries and has been prepared in accordance with ISO/IEC guidelines, taking into account all relevant national and international standards which apply.

Lithium batteries are different from conventional primary batteries using aqueous electrolyte in that they contain flammable materials.

Consequently, it is important to take safety precautions very carefully during design, production, distribution, use, and disposal of lithium batteries. Based on such special characteristics, lithium batteries for consumer applications were initially small in size and had low power output. There were also lithium batteries with high power output which were used for special industrial applications and were characterized as being "technician replaceable".

The first edition of IEC 60086-4 (1996) was drafted to accommodate the above situation.

However, from around the end of the 1980s, lithium batteries with high power output have started to be widely used in the consumer replacement market, mainly as a power source in camera applications.

Since the demand for such lithium batteries with high power output has significantly increased in recent years, various manufacturers have started to produce these types of lithium batteries. As a consequence of this situation, the safety aspects for lithium batteries with high power output have been included in this second edition of IEC 60086-4.

Safety is a balance between freedom from hazard and other requirements to be met by the product. There can be no absolute safety. Even at the highest level of safety, the product can only be relatively safe. In this respect, decision-making is based on risk evaluation and safety judgement.

As safety will pose different problems, it is impossible to provide a set of precise provisions and recommendations that will apply in every case. However, this standard, when followed on a judicious "use when applicable" basis, will provide reasonably consistent standards for safety.

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

1 Scope

This International Standard specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.

2 Normative reference

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60086-1:1996, *Primary batteries – Part 1: General*

3 Definitions

For the purpose of this part of IEC 60086, the definitions given in IEC 60086-1 (some of which are repeated below for convenience) and the following definitions apply.

3.1
battery (primary)
one or more primary cells, including case, terminals and marking

3.2
button battery
small round battery, where the overall height is less than the diameter; batteries complying with IEC 60086-1, figures 2, 3 and 4

3.3
cell (primary)
a source of electrical energy obtained by the direct conversion of chemical energy, that is not designed to be charged by any other electrical source

3.4
consumer batteries
batteries readily available in the commercial retail market and that are considered user replaceable, i.e. replaceable without the need of special tools

3.5
cylindrical battery
primary battery with cylindrical geometry where the overall height is equal to or greater than the diameter; batteries complying with IEC 60086-1, figures 1A and 1B

3.6
depth of discharge (DOD)
percentage of rated capacity discharged from a battery

3.7
distortion
any change in physical dimensions exceeding 10 %

3.8
explosion, battery (battery explosion)
an instantaneous release wherein solid matter from any part of the battery is propelled to a distance greater than 25 cm away from the battery

3.9
fire
combustion of cell/battery components with emission of flame

3.10
harm
physical injury and/or damage to health or property

3.11
hazard
a potential source of harm

3.12
high power battery
a battery that can deliver most of its energy within a short time at ambient temperature

3.13
industrial batteries
batteries not normally available to the consumer. Such batteries are often referred to as “technician replaceable” because of the skill required for their handling and installation

3.14
intended use
the use of a product, process or service under conditions or for purposes in accordance with specifications and instructions provided by the supplier, including information for publicity purposes

3.15
leakage
unplanned escape of electrolyte, gas or other material from a battery

3.16
low power battery
a battery that cannot deliver most of its energy within a short time at ambient temperature

3.17
nominal voltage
a suitable approximate value of voltage used to identify the voltage of a primary battery

3.18
open circuit voltage (OCV)
voltage across the terminals of a battery when no external current is flowing

3.19
overheating
a condition when battery temperature rises above the temperature range specified by the manufacturer

3.20
prismatic battery
primary battery with non-round geometry; batteries not complying with 4.3 of IEC 60086-1

3.21
rated capacity
capacity of a battery determined under conditions specified in the relevant standard (if applicable) and declared by the manufacturer or supplier. Also sometimes referred to as nominal capacity

3.22
reasonably foreseeable misuse
the use of a product, process or service under conditions or for purposes not intended by the supplier, but which may happen, as a result of common human behaviour

3.23
risk
the probable rate of occurrence of a hazard causing harm and the degree of severity of the harm

3.24
safety
freedom from unacceptable risk of harm

3.25
venting
the release of excessive internal pressure from a battery in a manner intended by design to preclude explosion

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 configuration. 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 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) Batteries shall be designed to relieve excessive internal pressure (not applicable to low power industrial batteries).

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

Samples shall be taken randomly from production lots in accordance with accepted quality control procedures.

NOTE 1 Many tests in this standard require preliminary conditioning of the samples such as preliminary discharge or storage at elevated temperature.

NOTE 2 Details of sample size for type approval and conditioning are found in clause 6.

6 Testing 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.

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

6.1.2 Ambient temperature

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

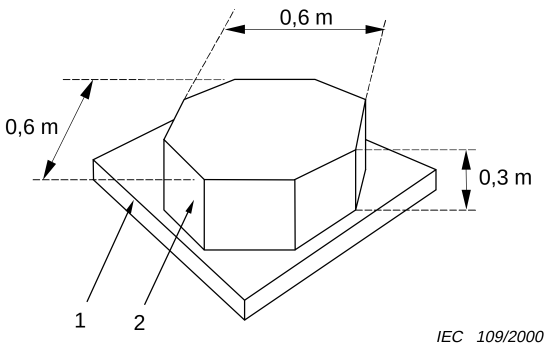
6.1.3 Explosion levels

In order to quantify the explosion as defined in 3.8, the following procedure is provided. The test battery is placed on the steel plate shown in figure 1. The mesh chamber is centred over the test battery. The test battery is then subjected to the relevant test procedure. The result shall be determined using the following two levels.

NE: battery does not explode.

NE2: battery explodes but ejected solid material does not pass through the mesh chamber specified in figure 1.

CAUTION
Avoid short-circuiting. For protection, the mesh chamber shall be in a place that is separated from the observer.



NOTE The figure shows an aluminium wire mesh chamber (2) of octagonal shape resting on a steel plate (1). The aluminium wire has a diameter of 0,25 mm. The mesh has 16 to 18 wires per 25,4 mm.

Figure 1 – Mesh chamber

6.1.4 Determination of weight loss

In order to quantify the weight loss referred to in table 2, the following procedure is provided.

$$\Delta W = \frac{W_1 - W_2}{W_1} \times 100\ \%$$

where

W_1 is the weight before the test;

W_2 is the weight after the test;

ΔW is the weight loss.

When weight loss does not exceed the values in table 1, it shall be considered as "no weight loss".

Table 1 – Weight loss limits

Weight *W* of battery	Weight loss limit
$W \leq 1$ g	0,5 %
1 g < $W \leq 5$ g	0,2 %
$W > 5$ g	0,1 %

6.1.5 Predischarge

Where a test requires predischarge (25 %, 50 %, 75 % or 100 %), the test 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 batteries

Where additional batteries are required to perform a test, they shall be of the same type as the test battery.

Where additional batteries are required to perform a test, the total number n_i of batteries in series, including the test battery, shall be determined by calculating:

$$n = 12\ \text{V}/U_n$$

and determining n_i by rounding up n to the nearest decimal integer while $n_i \geq n_{min}$ = i

where

U_n is the nominal voltage of one battery;

n_i is the total number of batteries;

n_{min} is the minimum number (2 or 3) of batteries given in the respective test description.

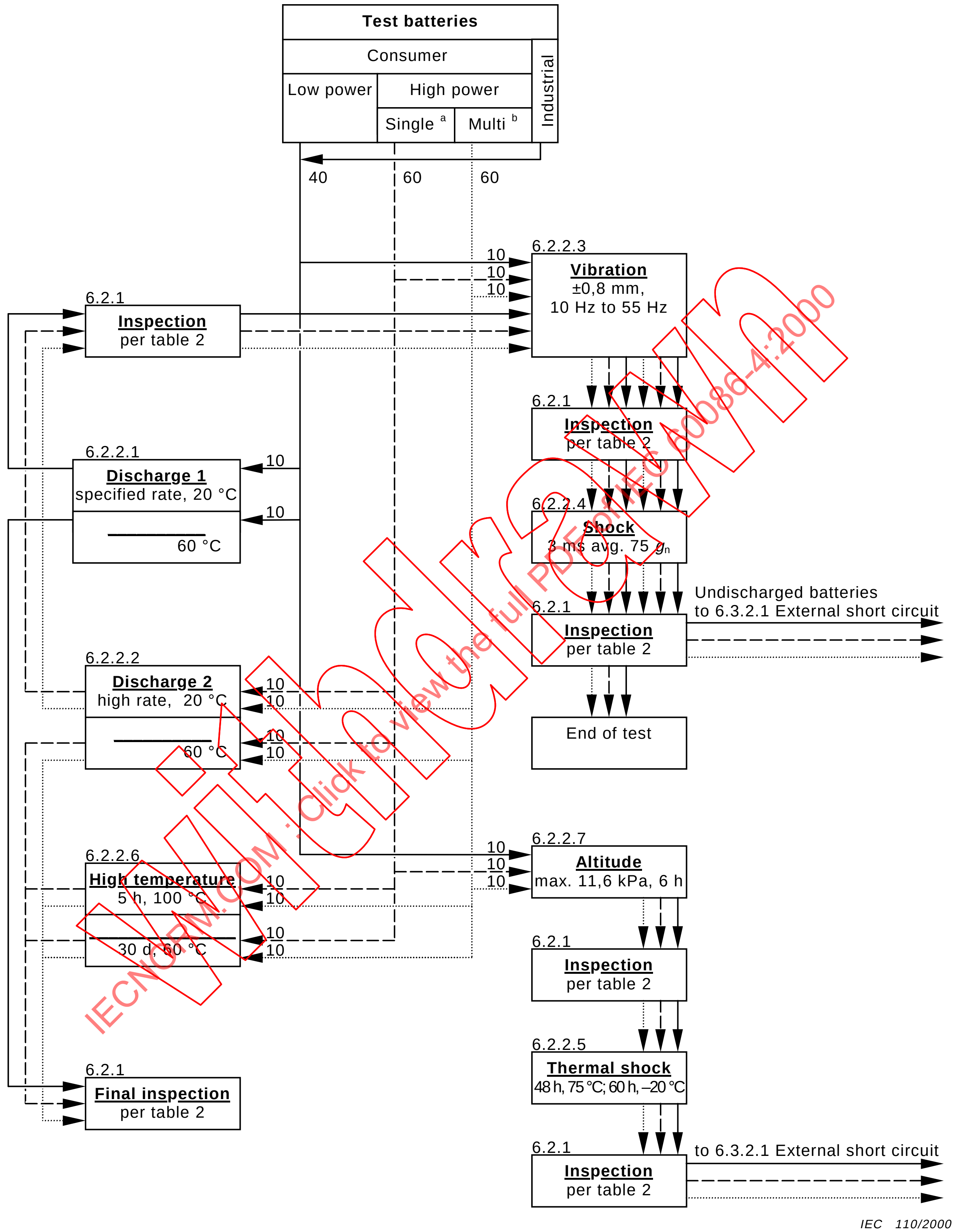
EXAMPLE 1 Let the minimum number of batteries be given as n_{min} = 2 and let the test battery have a nominal voltage U_n = 3,6 V. Calculate n = 3⅓ and determine n_2 = 4.

EXAMPLE 2 Let the minimum number of batteries be given as n_{min} = 3 and let the test battery have a nominal voltage U_n = 10 V. Calculate n = 1,2 and determine n_3 = 3.

6.2 Intended use

6.2.1 Sampling, test sequence and requirements

Figure 2 gives an overview of the test sequence and samples to be taken for intended use tests while table 2 contains the requirements.



NOTE The line type indicates the battery class.

a, b cell batteries.

Figure 2 – Sampling and sequence of intended use tests

Table 2 – Intended use tests and requirements

Test		Intended use simulation	Requirements			
			Consumer batteries			Industrial batteries
			Low power batteries	High power batteries		
				Single cell batteries	Multicell batteries	
Electrical tests	A-1	Discharge 1	NL, NV, NE, NF	*	*	NL, NV, NE, NF
	A-2	Discharge 2	*	NL, NV, NE, NF	NL, NV, NE, NF	*
Mechanical tests	B-1	Vibration	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF
	B-2	Shock	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF
Environmental tests	C-1	Thermal shock	NL, NV, NE, NF	NL, NV, NE, NF	NL, NV, NE, NF	NL, NV, NE, NF
	C-2	High temperature	*	NV, NE, NF	NV, NE, NF	*
	C-3	Altitude simulation	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF	NW, ND, NL, NV, NE, NF

Additional requirements:
Distortion: Distortion shall be reported with the cause.
Venting: If electrolyte leaks from the vent area without vent operation, it shall be considered as leakage.

*: Not applicable.
NW: No weight loss (see 6.1.4).
ND: No distortion.
NL: No leakage.
NV: No venting.
NE: No explosion.
NE2: See 6.1.3.
NF: No fire.

6.2.2 Test procedures

6.2.2.1 Electrical test A-1 – Discharge 1

a) Purpose

This test simulates the actual use of batteries. The limiting resistance value shall be specified for each battery type.

b) Test procedure

The undischarged battery is discharged, under limiting resistor R_1 for a test duration t_d:

$$t_d = C_n \times R_1 / U_n$$

where

t_d is the test duration;

C_n is the nominal capacity;

U_n is the nominal voltage;

R_1 is a resistive load selected such that the average current draw is the same as the maximum discharge current specified by the manufacturer.

The maximum discharge current specified by the manufacturer shall be such that any protective device used in the battery will not activate during the course of the test.

The test shall be carried out at (20 ± 2) °C until the battery is fully discharged and, in a separate test, at (60 ± 2) °C until the battery is fully discharged.

c) Requirements

See table 2.

6.2.2.2 Electrical test A-2 – Discharge 2

a) Purpose

This test simulates the use of batteries in cameras and similar applications. In general, a pulse discharge test of approximately 1 A is specified as the test for camera applications. However, when the film drive motor is stalled, there is a continuous current flow.

b) Test procedure

An undischarged test battery shall be continuously discharged with a resistive load R_2 taken from table 3.

Table 3 – Resistive load R_2

Battery type	Resistive load R_2 Ω
CR17345	2,00
CR-P2	3,90
2CR5	3,90
NOTE Table to be modified or expanded when additional batteries are standardized.	

The test shall be carried out at (20 ± 2) °C for 24 h and, separately, at (60 ± 2) °C for 24 h.

c) Requirements

See table 2.

6.2.2.3 Mechanical test B-1 – Vibration

a) Purpose

This test simulates vibration during transportation. The test condition is generally specified in UN (1995) [14]* and others.

b) Test procedure

The test batteries shall be subjected to simple harmonic motion with an amplitude of 0,8 mm (1,6 mm total maximum excursion). The frequency shall be varied at a rate of 1 Hz/min between 10 Hz and 55 Hz, and return in no less than 90 min and no more than 100 min. The test battery shall be tested in three mutually perpendicular directions. If a test battery has only two axes of symmetry, it shall be tested in two directions perpendicular to each axis.

The test shall be conducted with undischarged batteries and with fully discharged batteries.

c) Requirements

See table 2.

* Figures in square brackets refer to the bibliography.

6.2.2.4 Mechanical test B-2 – Shock

a) Purpose

This test simulates crash conditions or rough handling during transportation. The test condition is generally specified in UN (1995) [14] and others.

b) Test procedure

The test batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test battery. Each test battery shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular axes. Each shock shall be applied in a direction normal to a face of the test battery. For each shock, the test battery shall be accelerated in such a manner that during the first three milliseconds the minimum average acceleration is 75 g_n. The peak acceleration shall be between 125 g_n and 175 g_n.

The test shall be conducted with undischarged batteries and with fully discharged batteries.

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

c) Requirements

See table 2.

6.2.2.5 Environmental test C-1 – Thermal shock

a) Purpose

This test assesses battery seal integrity under conditions of rapid temperature changes.

b) Test procedure

Test batteries shall be stored for 48 h at a temperature of (75 ± 2) °C, followed by storage for 6 h at a temperature of (–20 ± 2) °C, followed by storage for at least 24 h at ambient temperature. The maximum time for transfer to each temperature shall be 5 min.

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

c) Requirements

See table 2.

6.2.2.6 Environmental test C-2 – High temperature

a) Purpose

This test simulates:

1) the condition wherein the overtemperature protection device does not operate properly and;
2) exposure of a battery to high temperature for a long period.

b) Test procedure

Test batteries shall be stored for 5 h at a temperature of (100 ± 2) °C, followed by storage for 8 h at (20 ± 2) °C. In a separate test, test batteries shall be stored for 30 days at a temperature of (60 ± 2) °C, followed by storage for 8 h at (20 ± 2) °C.

c) Requirements

See table 2.

6.2.2.7 Environmental test C-3 – Altitude

a) Purpose

This test simulates air transportation under low pressure conditions. The test condition is generally specified in UN (1995) [14] and others.

b) Test procedure

Test batteries shall be stored at a pressure of 11,6 kPa or less for at least 6 h and at a temperature of (20 ± 2) °C.

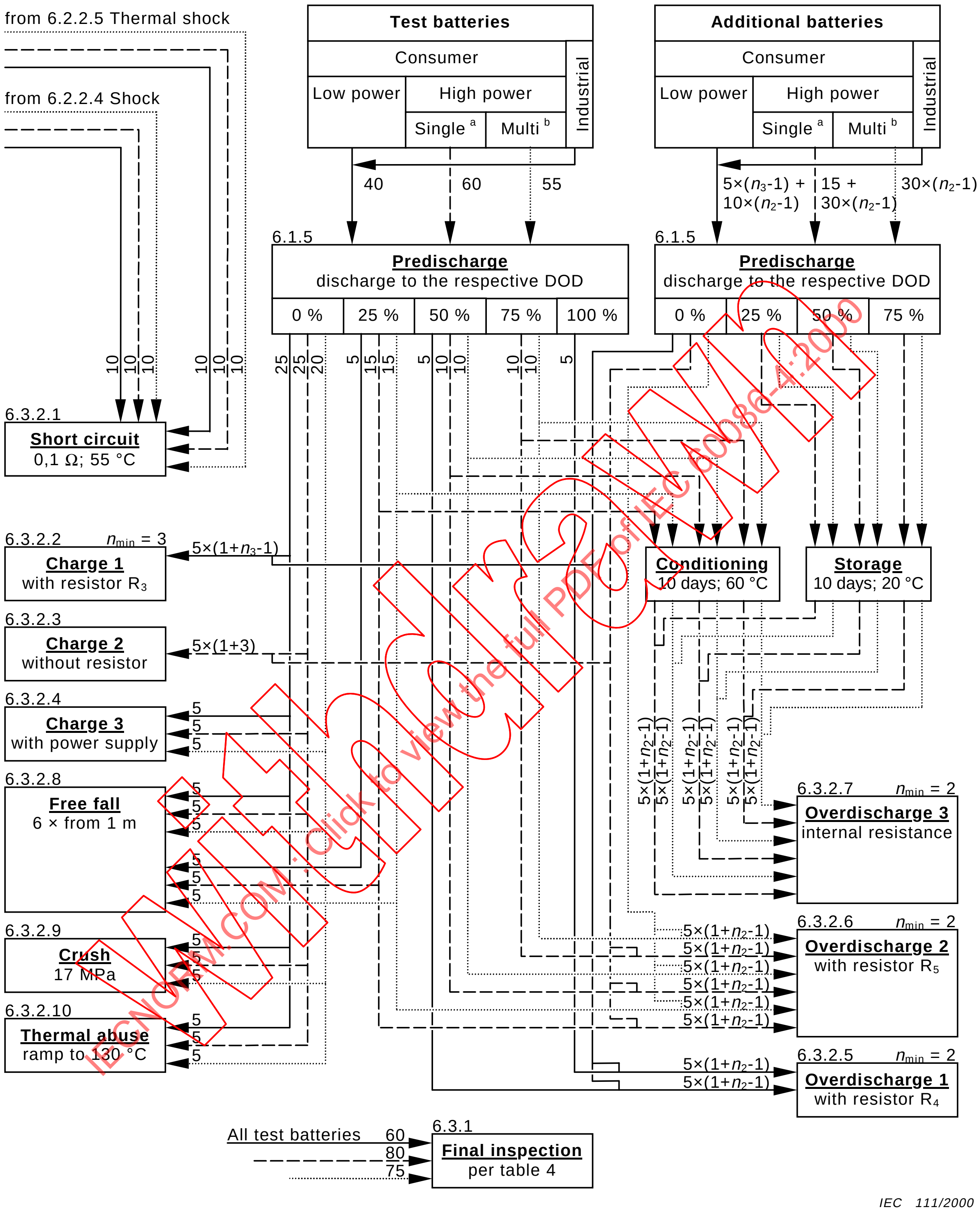
c) Requirements

See table 2.

6.3 Reasonably foreseeable misuse

6.3.1 Sampling, test sequence and requirements

Figure 3 gives an overview of the test sequence and samples to be taken for the tests simulating reasonably foreseeable misuse while table 4 contains the requirements.



NOTE 1 The line type indicates the battery class.

NOTE 2 $n_i \geq n_{min}$ = i is the total number of batteries, see 6.1.6.

[a, b] cell batteries.

Figure 3 – Sampling and sequence of tests simulating reasonably foreseeable misuse

Table 4 – Reasonably foreseeable misuse tests and requirements

Test		Misuse simulation	Requirements			
			Consumer batteries			Industrial batteries
			Low power batteries	High power batteries		
				Single cell batteries	Multicell batteries	
Electrical tests	D-1	External short circuit	NE, NF	NE, NF	NE, NF	NE2, NF
	D-2	Charge 1	NE, NF	*	*	NE2, NF
	D-3	Charge 2	*	NE, NF	*	*
	D-4	Charge 3	NE, NF	NE, NF	NE, NF	NE2, NF
	D-5	Overdischarge 1	NE, NF	*	*	NE2, NF
	D-6	Overdischarge 2	*	NE, NF	NE, NF	*
	D-7	Overdischarge 3	*	NE, NF	NE, NF	*
Mechanical tests	E-1	Free fall	NV, NE, NF	NV, NE, NF	NV, NE, NF	NE, NF
	E-2	Crush	NE, NF	NE, NF	NE, NF	NE, NF
Environmental tests	F-1	Climatic-Thermal abuse	NE2, NF	NE2, NF	NE2, NF	NF

Additional requirements:
Distortion: Distortion shall be reported with the cause.
Venting: If electrolyte leaks from the vent area without vent operation, it shall be considered as leakage.

*: Not applicable.
NW: No weight loss (see 6.1.4).
ND: No distortion.
NL: No leakage.
NV: No venting.
NE: No explosion.
NE2: See 6.1.3.
NF: No fire.

6.3.2 Test procedures

6.3.2.1 Electrical test D-1 – External short circuit

a) Purpose

This misuse may occur during handling of batteries. Resistance value and temperature are the same as those specified in UN (1995) [14] and others.

b) Test procedure

The test batteries shall be stabilized at (55 ± 2) °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at (55 ± 2) °C. This short-circuit condition is continued for at least 1 h after the battery case temperature has returned to (55 ± 2) °C.

The test shall be conducted using the batteries previously subjected to the vibration test and shock test, and, separately, using the batteries previously subjected to the altitude simulation test and the thermal shock test (see figure 3).

c) Requirements

See table 4.

6.3.2.2 Electrical test D-2 – Charge 1

a) Purpose

This test simulates the condition when one battery in a set is reversed. It is based on UN (1995) [14].

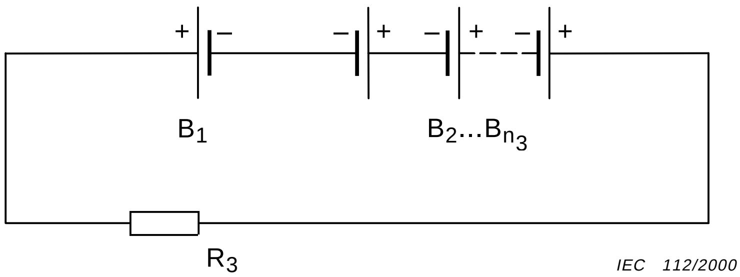
b) Test procedure

A test battery is connected in series with (n_3 – 1) undischarged additional batteries of the same type in such a way that the terminals of the test battery are connected in reverse. The total number n_3 of batteries shall be determined using the method given in 6.1.6 with n_{min} = 3.

A resistive load R_3 is connected in series to the above assembly of batteries where R_3 is selected such that the average current draw is the same as the maximum discharge current specified by the manufacturer.

The circuit shall be closed, charging the test battery. The test shall be continued until the total voltage reaches 10 % of the original open circuit voltage or for 24 h, whichever is longer.

The test shall be carried out at (20 ± 2) °C.



Key

B_1 Test battery

$B_2 \ldots B_{n_3}$ Additional batteries

R_3 Resistive load

Figure 4 – Charge 1

c) Requirements

See table 4.

6.3.2.3 Electrical test D-3 – Charge 2

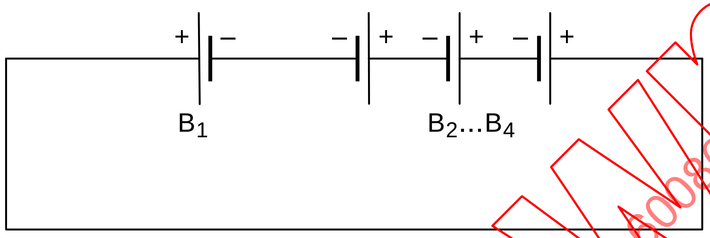
a) Purpose

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

b) Test procedure

A test battery is connected in series with three additional undischarged 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 test shall be carried out at (20 ± 2) °C for 24 h.



IEC 113/2000

Key

B_1 Test battery

$B_2 \ldots B_4$ Additional batteries, undischarged

Figure 5 – Charge 2

c) Requirements

See table 4.

6.3.2.4 Electrical test D-4 – Charge 3

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 backup equipment with a defective diode (see 7.1.1). The test condition is based upon UL 1642 [13].

b) Test procedure

Each test battery shall be subjected to a charging current of three times the 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;

C_n is the nominal capacity;

I_c is the charging current specified by the manufacturer.

The test shall be carried out at (20 ± 2) °C.

c) Requirements

See table 4.

6.3.2.5 Electrical test D-5 – Overdischarge 1

a) Purpose

This test simulates the condition when one discharged battery is connected in series with other undischarged batteries. The test condition is based upon UN (1995) [14].

b) Test procedure

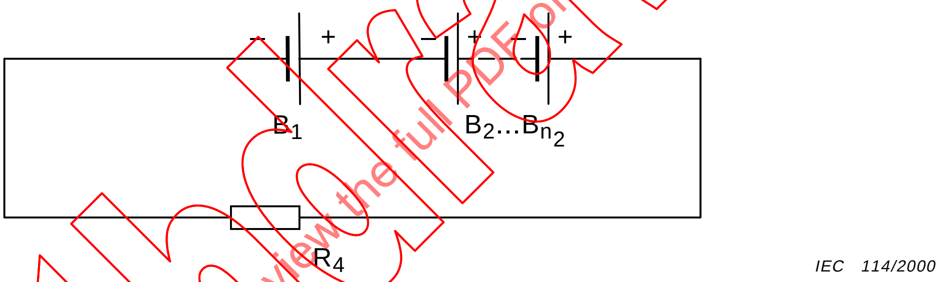
Each test battery shall be predischarged to 50 % depth of discharge. It shall then be connected in series with (n_2 – 1) undischarged additional batteries of the same type. The total number n_2 of batteries shall be determined using the method given in 6.1.6 with n_{min} = 2.

A resistive load R_4 is connected in series to the above assembly of batteries where R_4 is selected such that the average current draw is the same as the maximum discharge current specified by the manufacturer.

The test shall be carried out until the total voltage reaches 10 % of the original open circuit voltage or for 24 h, whichever is longer.

The test shall be carried out at (20 ± 2) °C.

The test shall be repeated with fully predischarged test batteries.



Key

B_1 Test battery, 50 % predischarged and, in a separate test, 100 % predischarged

B_2… B_{n_2} Additional batteries, undischarged

R_4 Resistive load

Figure 6 – Overdischarge 1

c) Requirements

See table 4.

6.3.2.6 Electrical test D-6 – Overdischarge 2

a) Purpose

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

b) Test procedure

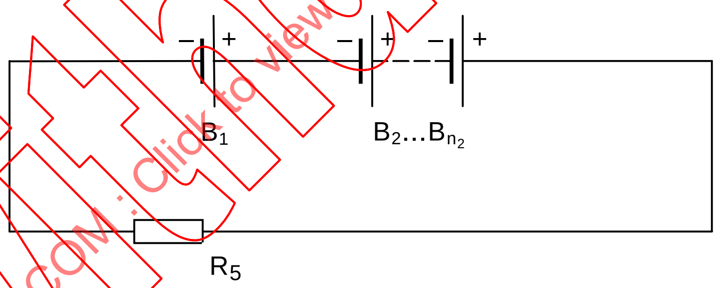
The test battery shall be predischarged to 25 % depth of discharge. It shall then be connected in series with (n_2 – 1) undischarged additional batteries of the same type and a resistive load R_5 where n_2 and R_5 are taken from table 5.

Table 5 – Total number of batteries n_2 and resistive load R_5

Battery type	Total number of batteries n_2	Resistive load R_5 Ω
CR17345	4	8,20
CR-P2	2	8,20
2CR5	2	8,20
NOTE Table to be modified or expanded when additional batteries are standardized.		

The test shall be carried out at (20 ± 2) °C for 24 h.

The test shall be repeated twice, namely with test batteries predischarged to 50 % and 75 % depth of discharge.



IEC 115/2000

Key

B_1 Test battery, 25 % predischarged and, in separate tests, 50 % and 75 % predischarged.

$B_2 \ldots B_{n_2}$ Additional batteries, undischarged

R_5 Resistive load

Figure 7 – Overdischarge 2

c) Requirements

See table 4.

6.3.2.7 Electrical test D-7 – Overdischarge 3

a) Purpose

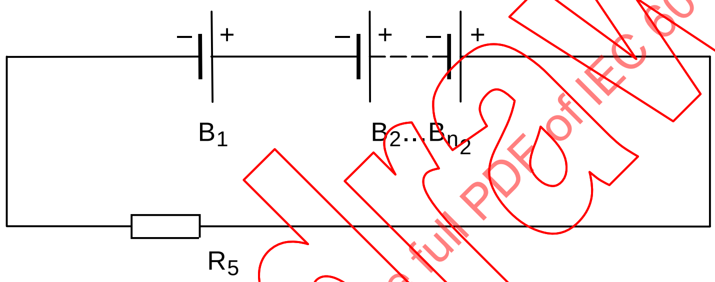
This test simulates the condition when a battery with abnormally high internal resistance is connected in series with normal batteries.

b) Test procedure

The test battery shall be predischarged to 25 % depth of discharge. It shall then be stored at (60 ± 2) °C for 10 days to increase the internal resistance. Additional batteries shall be predischarged to the same depth of discharge. They shall be stored at ambient temperature for 10 days. The preconditioned test battery shall be connected in series with (n_2 – 1) preconditioned additional batteries and a resistive load R_5 where n_2 and R_5 are taken from table 5.

The test shall be carried out at (20 ± 2) °C for 24 h.

The test shall be repeated twice, namely with test and additional batteries predischarged to 50 % and 75 % depth of discharge.



IEC 116/2000

Key

B_1	Test battery, 25 % predischarged and preconditioned at (60 ± 2) °C for 10 days and, in separate tests, 50 % and 75 % predischarged
B_2... B_{n_2}	Additional batteries, 25 % predischarged and stored at (20 ± 2) °C for 10 days and, in separate tests, 50 % and 75 % predischarged
R_5	Resistive load

Figure 8 – Overdischarge 3

c) Requirements

See table 4.

6.3.2.8 Mechanical test E-1 – 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 [6].

b) Test procedure

Undischarged 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 on each of its six faces, a round battery twice in each of the three axes shown in figure 9. The test batteries shall be stored for 1 h afterwards.

The test shall be repeated with test batteries predischarged to 25 % depth of discharge.

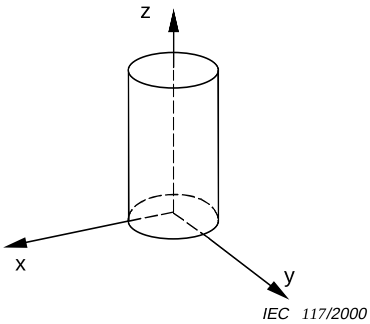


Figure 9 – Axes for free fall

c) Requirements

See table 4.

6.3.2.9 Mechanical test E-2 – Crush

a) Purpose

This test simulates the condition when a battery is exposed to forces encountered during household waste disposal, e.g. trash compaction. The test conditions are the same as those specified in UL 1642 [13].

b) Test procedure

A test battery shall be crushed between two flat surfaces. The force shall be applied by a vice or by a hydraulic ram with a 32 mm diameter piston. The crushing shall be continued until a pressure reading of 17 MPa is reached on the hydraulic ram, applied force approximately 13 kN. Once the maximum pressure has been obtained the pressure shall be released.

A cylindrical battery shall be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. A prismatic battery 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 battery shall be crushed by applying the force on its flat surfaces.

Each test battery shall only be crushed once.

c) Requirements

See table 4.

6.3.2.10 Environmental test F-1 – 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 ± 2) °C at which the battery shall remain for 10 min.

c) Requirements

See table 4.

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 10).

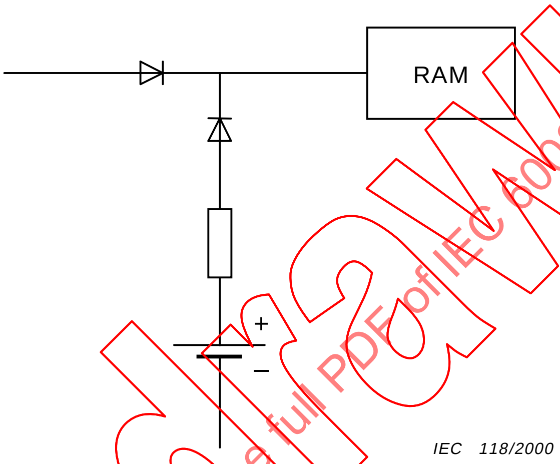


Figure 10 – Safety wiring for charge protection

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) *Do not insert batteries in reverse. Observe the + and – markings on battery and equipment.*

When batteries are inserted in reverse they may be short-circuited or charged. This may cause overheating, explosion, or fire.

b) *Do not short-circuit batteries*

When the positive (+) and negative (–) terminals of a battery are connected directly with each other, the battery becomes short-circuited. For example, batteries lying on top of each other or mixed together, can be short-circuited. This can result in venting, leakage, and possibly fire.

c) *Do not charge batteries*

Attempting to charge a primary battery may cause internal gas and/or heat generation resulting in venting, explosion and possibly fire.

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 generated inside the battery. This may result in venting, leakage, explosion and possibly fire.

e) *Do not mix batteries*

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 charged due to a difference of cell voltage or overdischarged due to a difference of capacity. This may result in venting and/or explosion.

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

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

g) *Do not overheat batteries*

When a battery is overheated, electrolyte may be released and separators may deteriorate. This may result in leakage, venting, explosion and possibly fire.

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

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

i) *Do not dismantle batteries*

When a battery is dismantled, the components may cause personal injury or fire.

j) *Do not deform batteries*

Lithium batteries should not be crushed, punctured, or otherwise mutilated. Such abuse may result in leakage, venting, explosion, or possibly fire.

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. Do not incinerate batteries except for approved disposal in a controlled incinerator.

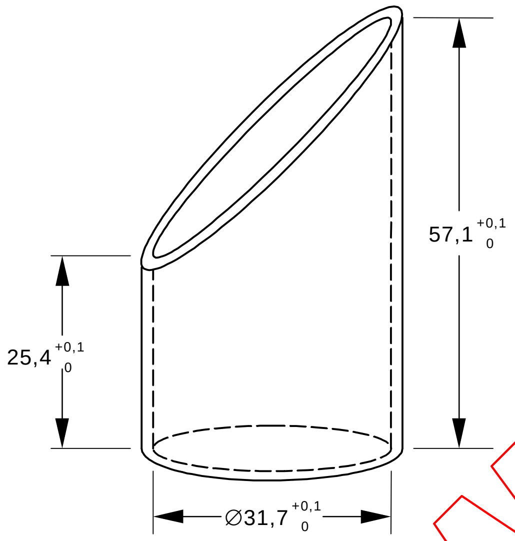
l) *A lithium battery with a damaged container should not be exposed to water*

Lithium metal in contact with water may produce fire and/or hydrogen gas.

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

n) *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 11. In case of ingestion of a cell or battery, seek medical assistance promptly.



Dimensions in millimetres

NOTE This gauge defines a swallowable component and is defined in ISO 8124-1 [12].

Figure 11 – Ingestion gauge

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. 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 and keep them away from metal objects which may short-circuit them*

One of the best ways to avoid short-circuiting is to store unused batteries in their original packaging.

q) *Remove discharged batteries from equipment*

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 Safety precautions during packaging, handling, transportation, display, storage and disposal

7.3.1 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 and corrosion of the terminals, and afford some protection from the environment.

7.3.2 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, explosion, or fire.

7.3.3 Transportation

7.3.3.1 General

Regulations concerning international transportation of lithium batteries are based on the recommendations of the United Nations Committee of Experts on the transport of dangerous goods, see UN (1995) [14].

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

7.3.3.2 Air transportation

Regulations concerning air transportation of lithium batteries are specified in Technical Instructions of the ICAO (International Civil Aviation Organization) [1]. DGR (Dangerous Goods Regulation) is specified by the regulations of ICAO (1995) [1].

7.3.3.3 Sea transportation

Regulations concerning sea transportation of lithium batteries are specified in the IMDG (International Maritime Dangerous Goods) code in IMO (International Maritime Organization) [10].

7.3.3.4 Inland transportation

There are no worldwide international regulations concerning inland transportation of lithium batteries. Specific regulations may be defined locally.

7.3.4 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 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.

7.3.5 Disposal

a) Primary lithium batteries may be disposed of via the communal refuse arrangements, provided that no local rules to the contrary exist.

b) Do not dismantle batteries.

c) Do not dispose of batteries in fire except under conditions of approved and controlled incineration.

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 batteries designated as small, each battery shall be marked with the following information:

a) electrochemical system;

b) designation;

c) year and month or week of manufacture, which may be in code, or the expiration of the guarantee period, in clear;

d) polarity of terminals (when applicable);

e) nominal voltage;

f) name or trade mark of the manufacturer or supplier;

g) cautionary advice;

h) caution for ingestion of small batteries, see also 7.2 n).

9.2 Small batteries

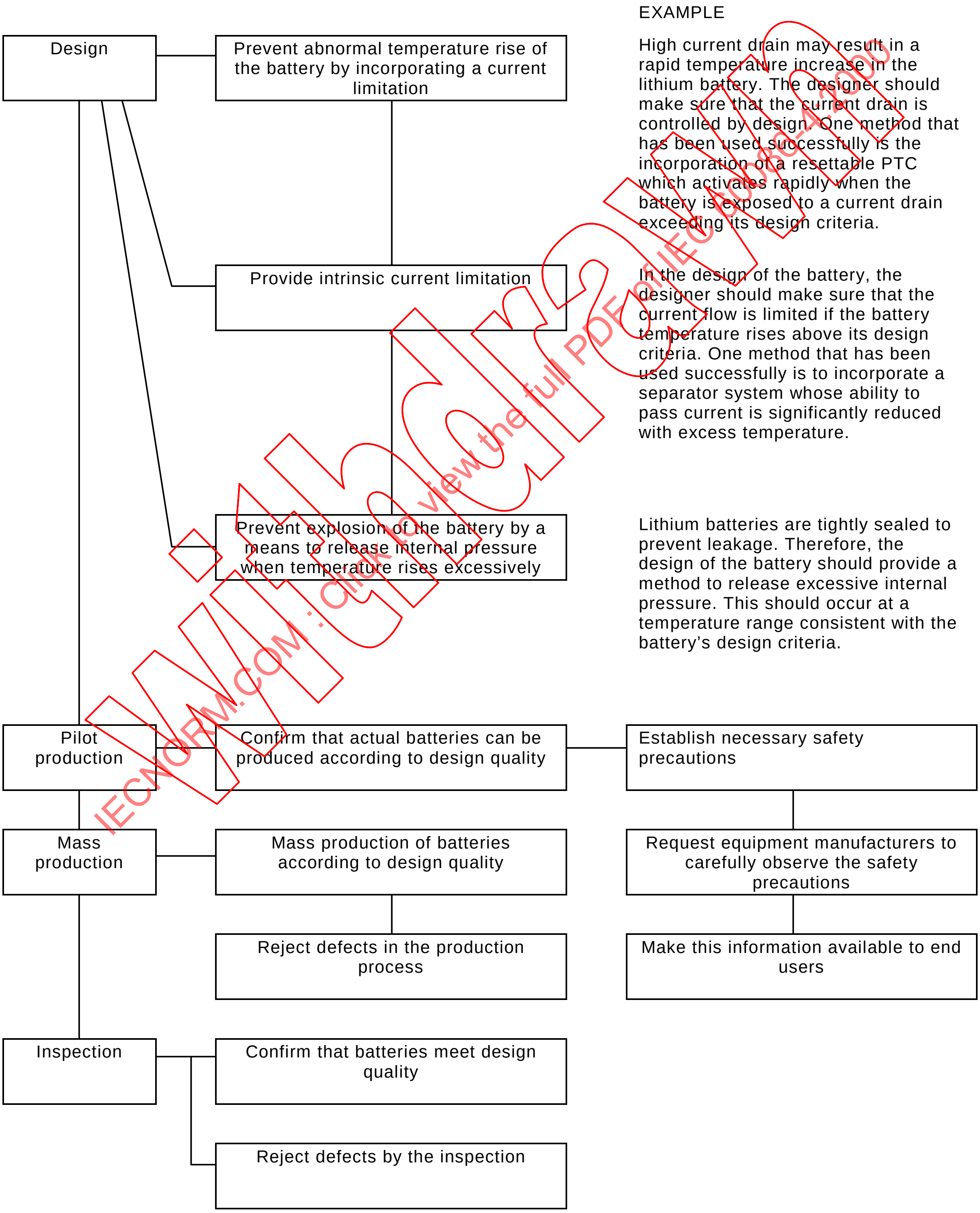
Batteries whose external surface area is too small to accommodate the markings shown in 9.1 shall show, on the battery, the designation of 9.1 b) and polarity of 9.1 d). All other markings shown in 9.1 shall be on the immediate packing.

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



IEC 120/2000

Annex B
(informative)

Guidelines for designers of equipment using lithium batteries

Table B.1 – Equipment design guidelines

Item	Sub-item	Recommendations	Possible accidents which may occur with improperly designed equipment
(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, 2CR11108 and others); one piece only	If the capacity of batteries in series connection is different, the battery with the lower capacity will become overdischarged. This may result in electrolyte leakage, overheating, explosion or fire
		b) Cylindrical batteries (CR17345, CR11108 and others); below three pieces	
		c) Button type batteries (CR2016, CR2025 and others); below 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, 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, 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, explosion or fire
(2) When a lithium battery is used as auxiliary power source	(2.1) Design of battery circuit	The battery should be used in a separate circuit so that it is not forcibly discharged or charged by the main power source	Battery may be overdischarged to reverse polarity or charged. This may result in electrolyte leakage, overheating, 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, explosion or possibly fire

[a] See 7.1.2.