

INTERNATIONAL STANDARD



Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications

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Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SECONDARY CELLS AND BATTERIES CONTAINING
ALKALINE OR OTHER NON-ACID ELECTROLYTES –
SAFETY REQUIREMENTS FOR SECONDARY LITHIUM CELLS
AND BATTERIES, FOR USE IN INDUSTRIAL APPLICATIONS****FOREWORD**

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This commented version (CMV) of the official standard IEC 62619:2022 edition 2.0 allows the user to identify the changes made to the previous IEC 62619:2017 edition 1.0. Furthermore, comments from IEC SC 21A experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 62619 has been prepared by subcommittee 21A: Secondary cells and batteries containing alkaline or other non-acid electrolytes, of IEC technical committee 21: Secondary cells and batteries. It is an International Standard.

This second edition cancels and replaces the first edition published in 2017. This edition constitutes a technical revision.

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

- a) new requirements for moving parts;
- b) addition of requirements for hazardous live parts;
- c) addition of requirements for battery system design;
- d) new requirements for system lock;
- e) new requirements for EMC;
- f) addition of procedure of propagation test by laser.

The text of this International Standard is based on the following documents:

Draft	Report on voting
21A/785/FDIS	21A/787/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

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SECONDARY CELLS AND BATTERIES CONTAINING ALKALINE OR OTHER NON-ACID ELECTROLYTES – SAFETY REQUIREMENTS FOR SECONDARY LITHIUM CELLS AND BATTERIES, FOR USE IN INDUSTRIAL APPLICATIONS

1 Scope

This document specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications.

When there exists an IEC International Standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this document, the former takes precedence (e.g., IEC 62660 series on road vehicles).

The following are some examples of applications that utilize cells and batteries under the scope of this document:

- Stationary applications: telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power, and similar applications.
- Motive applications: forklift truck, golf cart, automated guided vehicle (AGV), railway vehicles, and marine vehicles, with the exception of road vehicles. **1**

Since this document covers batteries for various industrial applications, it includes those requirements which are common and minimum to the various applications.

Electrical safety is included only as a part of the risk analysis of Clause 8. In regard to details for addressing electrical safety, the end use application standard requirements ~~have~~ need to be considered.

This document applies to cells and batteries. If the battery is divided into smaller units, the smaller unit can be tested as the representative of the battery. The manufacturer clearly declares the tested unit. The manufacturer ~~may~~ can add functions, which are present in the final battery to the tested unit.

This document addresses first life cells and batteries. Reuse, repurpose, second life use or similar are not taken into consideration by this document. **2**

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62133:2012, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications~~

IEC 62133-2:2017, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems

IEC 62620:2014, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 51, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

safety

freedom from unacceptable risk

3.2

risk

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

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified – deletion of Note 1 to entry.]

3.3

harm

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

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.4

hazard

potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.5

intended use

use of a product, process or service in accordance with specifications, instructions and information provided by the supplier

3.6

reasonably foreseeable misuse

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

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – "or system" has been replaced with "process or service" and notes to entry deleted.]

3.7

secondary lithium cell cell

secondary cell where electrical energy is derived from the insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode

Note 1 to entry: The cell typically has an electrolyte that consists of a lithium salt and organic solvent compound in liquid, gel or solid form and has a metal or a laminate film casing. It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

3.8 cell block

group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient device (PTC)) and monitoring circuitry

Note 1 to entry: The cell block is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

3.9 module

group of cells connected together either in a series and/or parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient device (PTC)) and monitoring circuitry

3.10 battery pack

energy storage device, which ~~is comprised of~~ comprises one or more cells or modules electrically connected and has monitoring circuitry which provides information (e.g. cell voltage) to a battery system to influence the battery's safety, performance and/or service life

~~Note 1 to entry: It has a monitoring circuitry which provides information (e.g. cell voltage) to a battery system.~~

Note 2 1 to entry: The battery pack may incorporate a protective housing and be provided with terminals or other interconnection arrangements.

3.11 battery system battery

system which comprises one or more cells, modules or battery packs and has a battery management system capable of controlling current in case of overcharge, overcurrent, overdischarge, and overheating

~~Note 1 to entry: It has a battery management system to cut off in case of overcharge, overcurrent, overdischarge, and overheating.~~

Note 1 to entry: Overdischarge cut-off is not mandatory if there is an agreement between the cell manufacturer and the customer.

Note 2 to entry: The battery system may have cooling or heating units. More than one battery system may constitute a larger battery system. The battery system is sometimes also referred to as a battery.

3.12 battery management system BMS

electronic system associated with a battery which has functions to ~~cut off~~ control current in case of overcharge, overcurrent, overdischarge, and overheating and which monitors and/or manages the battery's state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life

~~Note 1 to entry: It monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life.~~

Note 1 to entry: Overdischarge cut-off is not mandatory if there is an agreement between the cell manufacturer and the customer.

Note 2 to entry: The function of the BMS can be assigned to the battery pack or to equipment that uses the battery. (See Figure 6.)

Note 3 to entry: The BMS can be divided and it can be found partially in the battery pack and partially on the equipment that uses the battery. (See Figure 6.)

Note 4 to entry: The BMS is sometimes also referred to as a BMU (battery management unit)

3.13**leakage**

visible escape of liquid electrolyte

3.14**venting**

release of excessive internal pressure from a cell, module, battery pack, or battery system in a manner intended by design to preclude rupture or explosion

3.15**rupture**

mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

3.16**explosion**

failure that occurs when a cell container or battery case opens violently and solid components are forcibly expelled

Note 1 to entry: Liquid, gas, and smoke are ~~erupted~~ excepted.

3.17**fire**

emission of flames from a cell, module, battery pack, or battery system for more than 1 s

Note 1 to entry: Sparks and arcing are not considered as flames

3.18**rated capacity**

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

Note 1 to entry: The rated capacity is the quantity of electricity C_n Ah (ampere-hours) declared by the manufacturer which a single cell or battery can deliver during an n -hour period when charging, storing and discharging under the conditions specified in IEC 62620:2014, 6.3.1.

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – Addition of the words "cell or" in the definition and of Note 1 to entry.]

3.19**upper limit charging voltage**

<of a cell> highest charging voltage in the cell operating region specified by the cell manufacturer

3.20**lower limit discharging voltage**

<of a cell> lowest discharging voltage in the cell operating region specified by the cell manufacturer

3.21**maximum charging current**

<of a cell> ~~the maximum~~ highest charging current in the cell operating region specified by the cell manufacturer

3.22**maximum discharging current**

<of a cell> highest discharging current in the cell operating region specified by the cell manufacturer

3.23**thermal runaway**

uncontrolled intensive increase in the temperature of a cell driven by exothermic reaction

4 Parameter measurement tolerances

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

- a) $\pm 0,5$ % for voltage;
- b) ± 1 % for current;
- c) ± 2 °C for temperature;
- d) $\pm 0,1$ % for time;
- e) ± 1 % for mass;
- f) ± 1 % for dimensions.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

The details of the instrumentation used shall be provided in any report of results.

5 General safety considerations**5.1 General**

The safety of lithium secondary cells and ~~batteries~~ battery systems requires the consideration of two sets of applied conditions:

- 1) intended use;
- 2) reasonably foreseeable misuse.

Cells and ~~batteries~~ battery systems shall be designed and constructed so that they are safe under conditions of ~~both~~ intended use and reasonably foreseeable misuse. It may also be expected that cells and ~~batteries~~ battery systems subjected to intended use shall not only be safe but shall continue to be functional in all respects.

It is expected that cells or ~~batteries~~ battery systems subjected to misuse may fail to function. However, even if such a situation occurs, they shall not present any significant hazards.

Potential hazards which are the subject of this document are:

- a) fire,
- b) burst/explosion,
- c) ~~critical electrical short circuit due to~~ leakage of cell electrolyte,
- d) venting ~~which continuously vents out flammable gases~~ with continuous emission of flammable and/or toxic gas and/or smoke, **3**
- e) rupture of the casing of cell, module, battery pack, ~~and~~ or battery system with exposure of internal components.

Conformity with 5.1 a) and b) ~~to 5.6~~ is checked by the tests of Clause 6, Clause 7, and 8.2, and in accordance with the appropriate standard (see Clause 2). Conformity with 5.1 c) to e) and with 5.2 to 5.6 is checked by analysis of documents mentioned in 8.1.

Moving parts that have potential to cause human injuries shall be applied using an appropriate design and necessary measures to reduce the risk of injuries, including those injuries that may be incurred during installation, while cells or battery systems are being incorporated into equipment. **4**

5.2 Insulation and wiring

Wiring and its insulation shall be sufficient to withstand the maximum anticipated voltage, current, temperature, altitude and humidity requirements. The design of an internal wiring shall be such that adequate clearances and creepage distances are maintained between conductors and live parts at different voltages or between live parts and non-current-carrying accessible parts. Hazardous live parts of the battery system shall be protected to avoid the risk of electric shocks, including during installation. **5**

The mechanical integrity of the whole battery system (cell/module/BMS) and their connections shall be sufficient to accommodate conditions of reasonably foreseeable misuse.

5.3 Venting

The casing of a cell, module, battery pack, and battery system shall incorporate a pressure relief function that will preclude rupture or explosion. If encapsulation is used to support cells within an outer case, the type of ~~encapsulant~~ encapsulating material and the method of encapsulation shall neither cause the battery system to overheat during normal operation nor inhibit pressure relief.

5.4 Temperature/voltage/current management

The design of ~~batteries~~ battery systems shall be such that abnormal temperature-rise conditions are prevented. Battery systems shall be designed within voltage, current, and temperature limits specified by the cell manufacturer. Battery systems shall be provided with specifications and charging instructions for equipment manufacturers so that associated chargers are designed to maintain charging within the voltage, current and temperature limits specified.

~~NOTE — Where applicable, means can be provided to limit current to safe levels during charge and discharge.~~

5.5 Terminal contacts of the battery pack and/or battery system

Terminals shall have clear polarity marking(s) on the external surface of the battery pack or battery system.

~~NOTE — Exception: Battery packs with keyed external connectors designed for connection to specific end products need not be marked with polarity markings if the design of the external connector prevents reverse polarity connections.~~

The size and shape of the terminal contacts shall ensure that they can carry the maximum anticipated current. External terminal contact surfaces shall be formed from conductive materials with good mechanical strength and corrosion resistance. Terminal contacts shall be arranged so as to minimize the risk of short-circuits, for example to minimize the risk of short-circuits by metal tools. Compliance is determined through a review of the terminal specifications.

5.6 Assembly of cells, modules, or battery packs into battery systems

5.6.1 General

The assembly of cells, modules or battery packs to constitute the battery system shall respect the following rules to support adequate mitigation of risks as regard to the battery system:

- Each battery system shall have an independent control and protection method(s).

NOTE For the independent control and protection method(s), see 8.2.

- The cell manufacturer shall provide recommendations about current, voltage, temperature limits and should provide mounting advice, storage conditions, maximum number of cells in series (for cell internal protection such as a current interrupt device (CID)) **6** so that the battery system manufacturer/designer may ensure proper design and assembly.
- **Batteries** Battery systems that are designed for the selective discharging of a portion of their series connected cells shall incorporate separate circuitry to prevent the cell reversal caused by uneven discharging.
- Protective circuit components should be added as appropriate and consideration given to the end-device application.

5.6.2 Battery system design

The voltage control function of the battery system design shall ensure that the voltage of each cell or cell block shall not exceed the upper limit charging voltage specified by the manufacturer of the cells, except in the case where ~~the stationary application devices or motive application devices provide an equivalent~~ the end-devices provide the voltage control function. In such a case, the end-devices are considered as part of the battery system. Refer to Note 2 and Note 3 in 3.12.

~~The following should be considered at the battery system level and by the battery manufacturer:~~

~~For the battery system which has series-connected plural single cells, modules or battery packs, it is recommended that the voltages of any one of the single cells or cell blocks do not exceed the upper limit of the charging voltage, specified by the cell manufacturer, by monitoring the voltage of every single cell or cell block.~~

The battery shall be designed so that the maximum charging current or the maximum discharging current of the cell are not exceeded before the maximum allowed charging or discharging current of the battery is reached. **7**

5.7 Operating region of lithium cells and battery systems for safe use

The cell manufacturer shall specify the cell operating region. The battery system manufacturer shall design the battery system to comply with the cell operating region. Determination of the cell operating region is ~~explained~~ in accordance with Annex A.

5.8 System lock (or system lock function)

The battery system shall have a non-resettable function to stop operation when one or more cells in the battery system deviates from the operating region during operation. This feature shall not be user resettable or allow for automatic reset.

The function of the battery system may be returned after checking that the status of the battery system complies with the battery system manufacturer manual, i.e. the battery system maintenance manual shall clearly set out this procedure.

Depending on the application, a battery system may allow a final discharge, for example to provide emergency functions. In this case, cell limits (e.g. lower limit discharge voltage or upper temperature limit) may deviate once within the range where the cell does not cause dangerous reactions. Therefore, the cell manufacturer shall provide the second set of limits in which the cell in the battery system may accept one discharge without dangerous reactions. The cell should not be further recharged after this last discharge. **8**

5.9 Quality plan

The battery system manufacturer shall prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells, modules, battery packs, and battery systems and which covers the whole process of producing each type of cell, module,

battery pack, and battery system (e.g. ISO 9001, etc.). Manufacturers should understand their process capabilities and should institute the necessary process controls in relation to product safety.

6 Type test conditions

6.1 General

A cell in the battery system that is used outside of its operating region may exhibit hazards resulting from the cells or ~~batteries~~ battery systems. Such risks ~~have to~~ shall be taken into consideration in order to prepare a safe test plan.

The test facility should have sufficient structural integrity and a fire suppression system to sustain the conditions of overpressure and fire that may occur as a result of testing. The facility should have a ventilation system to remove and capture gas which might be produced during the tests. Consideration should be given to high voltage hazards when applicable.

Warning: THESE TESTS USE PROCEDURES WHICH MAY RESULT IN HARM IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. TESTS SHOULD ONLY BE PERFORMED BY QUALIFIED AND EXPERIENCED TECHNICIANS USING ADEQUATE PROTECTION. TO PREVENT BURNS, CAUTION SHOULD BE TAKEN FOR THOSE CELLS OR ~~BATTERIES~~ BATTERY SYSTEMS WHOSE CASINGS MAY EXCEED 75 °C AS A RESULT OF TESTING.

6.2 Test items

Tests are made with the number of cells or ~~batteries~~ battery systems specified in Table 1, using cells or ~~batteries~~ battery systems that are stored for not more than six months, under conditions specified by the cell or battery system manufacturer.

Cells or ~~batteries~~ battery systems charged in accordance with the method specified in 7.1 shall deliver the rated capacity or more according to IEC 62620:2014, 6.3.1 when they are discharged at 25 °C ± 5 °C, at a constant current of 0,2 I_t A according to IEC 62620:2014, 6.3.1, down to a specified final voltage. This capacity confirmation may be done during the cell manufacturer shipping inspection. In the case of a battery system, the capacity may be calculated on the basis of the cell capacity ~~measurements~~ as measured during the cell manufacturer shipping inspection.

Unless otherwise specified, tests are carried out in an ambient temperature of 25 °C ± 5 °C.

NOTE Test conditions are for type tests only and do not imply that intended use includes operation under these conditions. Similarly, the limit of six months is introduced for consistency and does not imply that cell and battery system safety is reduced after six months.

Table 1 – Sample size for type tests

Test items		Test unit	
Category	Test	Cell (see a)	Battery system (see b and e)
Product safety test (safety of cell and battery system)	7.2.1 External short-circuit test	R	-
	7.2.2 Impact test	R (see c)	-
	7.2.3 Drop test	R	R
	7.2.4 Thermal abuse test	R	-
	7.2.5 Overcharge test	R (see d)	-
	7.2.6 Forced discharge test	R	-
	7.3 Considerations for internal short- circuit (select one of the two options)	7.3.2 Internal short- circuit test	R*
7.3.3 Propagation test		-	R
Functional safety test (safety of battery system)	8.2.2 Overcharge control of voltage	-	R
	8.2.3 Overcharge control of current	-	R
	8.2.4 Overheating control	-	R
"R" = required (minimum of 1)			
"R*" = required. As for the sample number, refer to IEC 62133:2012, 8.3.9 IEC 62133-2:2017, 7.3.9.			
"- " = unnecessary or not applicable			
<p>a The manufacturer can use "cell block(s)" instead of "cell(s)" for any test that specifies "cell(s)" as the test unit in this document. The manufacturer clearly declares the test unit for each test.</p> <p>b If a battery system is divided into smaller units, the unit can be tested as representative of the battery system. The manufacturer can add functions which are present in the final battery system to the tested unit. The manufacturer clearly declares the tested unit.</p> <p>c Cylindrical cell or cell block: 1 direction, prismatic cell (including cell with laminate film case) or cell block: 2 directions.</p> <p>d The test is performed with the cells or cell blocks in those battery systems that are provided with only a single control or protection for charging voltage control.</p> <p>e If the positive and negative terminals of a battery are not accessible, the manufacturer is allowed to modify the sample(s) to make the terminals available, for example, in accordance with 7.2.1. The modification shall be done in a way which makes it unlikely that the test result is influenced.</p>			

7 Specific requirements and tests

7.1 Charging procedures for test purposes

Prior to charging, the cell or battery system shall be discharged in an ambient temperature of 25 °C ± 5 °C, at a constant current of 0,2 I_t A, down to a specified final voltage.

Unless otherwise stated in this document, cells or ~~batteries~~ battery systems shall be charged in an ambient temperature of 25 °C ± 5 °C, using the method specified by the manufacturer.

NOTE 1 Charging and discharging currents for the tests are based on the value of the rated capacity (C_n Ah). These currents are expressed as a multiple of I_t A, where: I_t A = C_n Ah/1 h (see IEC 61434).

NOTE 2 The battery system which cannot be discharged at a constant current of 0,2 I_t A can be discharged at the current specified by the manufacturer.

7.2 Reasonably foreseeable misuse

7.2.1 External short-circuit test (cell or cell block)

a) Requirements

Short-circuit between the positive and negative terminals shall not cause fire or explosion.

b) Test

Fully charged cells are stored in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each cell is then short-circuited by connecting the positive and negative terminals with a total external resistance of $30\text{ m}\Omega \pm 10\text{ m}\Omega$.

The cells are to remain on test for 6 h or until the case temperature declines by 80 % of the maximum temperature rise, whichever is the sooner.

c) Acceptance criteria

No fire, no explosion.

7.2.2 Impact test (cell or cell block)

a) Requirements

An impact to the cell as mentioned in 7.2.2 b) shall not cause fire or explosion.

b) Test

The cell or cell block shall be discharged at a constant current of $0,2 I_t$ A, to 50 % ~~SOC~~ capacity of the rated capacity.

The cell or cell block is placed on a flat concrete or metal floor. A type 316 stainless steel bar with a diameter of $15,8\text{ mm} \pm 0,1\text{ mm}$ and at least 60 mm in length or the longest dimension of the cell, whichever is greater, is placed across the centre of the cell or cell block. A 9,1 kg rigid mass is then dropped from a height of $610\text{ mm} \pm 25\text{ mm}$ onto the bar placed on the sample.

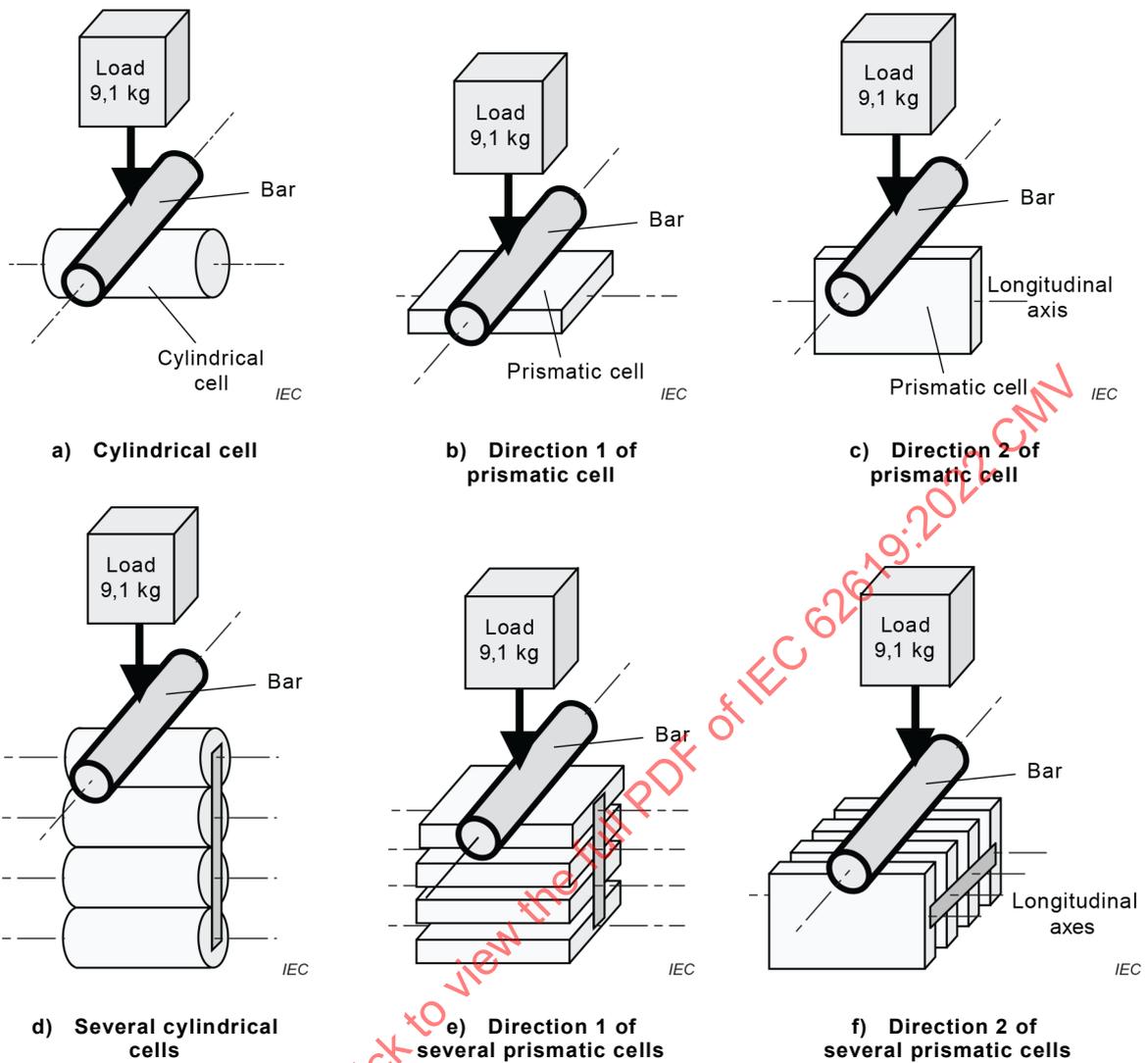
A cylindrical or prismatic cell is to be impacted with its longitudinal axis parallel to the flat concrete or metal floor and perpendicular to the longitudinal axis of the 15,8 mm diameter curved surface lying across the centre of the test sample. A prismatic cell is also to be rotated 90 degrees around its longitudinal axis so that both the wide and narrow sides will be subjected to the impact. Each sample is to be subjected to only a single impact with separate samples to be used for each impact (see Figure 1).

~~NOTE~~—In the case of a metal floor, external short circuit of the cell or ~~battery~~ cell block with the floor should be avoided by appropriate measures.

Pouch cells are tested as prismatic cells.

c) Acceptance criteria

No fire, no explosion.



NOTE The cell or cell block can be supported by some material which has no influence on the test to maintain the position.

Figure 1 – Configuration of the impact test

7.2.3 Drop test (cell or cell block, and battery system)

7.2.3.1 General

The drop test is conducted on a cell or cell block, and battery system. The test method and the height of the drop are determined by the test unit weight as shown in Table 2.

Table 2 – Drop test method and condition

Mass of the test unit	Test method	Height of drop
Less than 7 kg	Whole	1 000 mm
7 kg or more, less than 20 kg	Whole ^{a)}	100 mm
20 kg or more, less than 50 kg	Edge and corner ^{a)}	100 mm
50 kg or more, less than 100 kg	Edge and corner ^{a)}	50 mm
100 kg or more	Edge and corner ^{a)}	25 mm

NOTE—If the battery system is divided into smaller units, the unit can be tested as the representative of the battery system. The manufacturer can add functions which are present in the final battery system to the tested unit. The manufacturer clearly declares the tested unit.

^{a)} For test objects with a mass of 7 kg or more, the test shall be conducted with the bottom specified by the manufacturer facing downward.

7.2.3.2 Whole drop test (cell or cell block, and battery system)

This test is applied when the mass of the test unit is less than 20 kg.

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

Each fully charged test unit is dropped three times from a height shown in Table 2 onto a flat concrete or metal floor.

If the mass of the test unit is less than 7 kg, the test unit is dropped so as to obtain impacts in random orientations. If the mass of the test unit is 7 kg or more but less than 20 kg, the test shall be performed with the test unit dropped in the bottom down direction. The bottom surface of the test unit is specified by the manufacturer.

After the test, the test units shall be put on rest for a minimum of 1 h, and then a visual inspection shall be performed.

NOTE—If the floor of the test room is metal, external short circuit of cell or cell block, and battery system with the floor should be avoided by appropriate measures.

c) Acceptance criteria

No fire, no explosion.

7.2.3.3 Edge and corner drop test (cell or cell block, and battery system)

This test is applied when the mass of the test unit is 20 kg or more.

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

~~Each~~ A fully charged test unit is dropped two times from a height shown in Table 2 onto a flat concrete or metal floor. The drop test conditions shall ~~assure~~ ensure, with test arrangements as shown in Figure 2, Figure 3 and Figure 4, reproducible impact points for the shortest edge drop impact and the corner impacted. The two impacts, per impact type, shall be on the same corner and on the same shortest edge. For the corner and edge drops, the test unit shall be oriented in such a way that a straight line drawn through the corner/edge to be struck and the test unit geometric centre is approximately perpendicular to the impact surface. After the test, the test unit shall be put on rest for a minimum of 1 h, and then a visual inspection shall be performed.

NOTE—If the floor of the test room is metal, external short circuit of cell or cell block, and battery system with the floor should be avoided by appropriate measures.

- c) Acceptance criteria
No fire, no explosion.

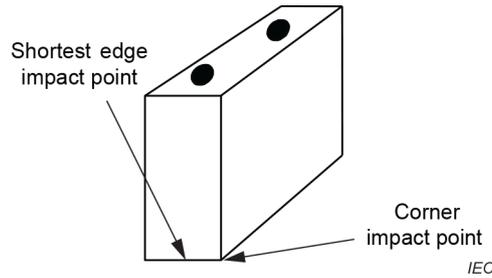


Figure 2 – Impact location

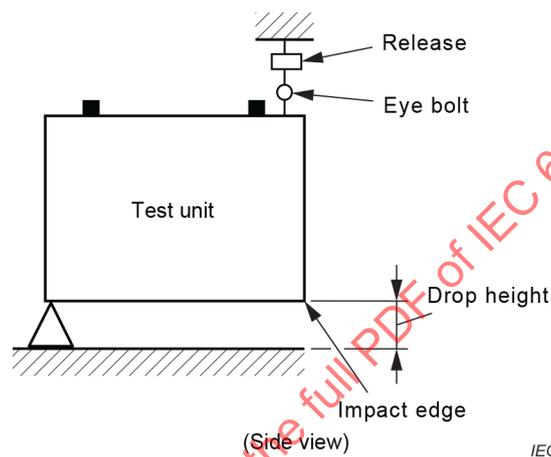
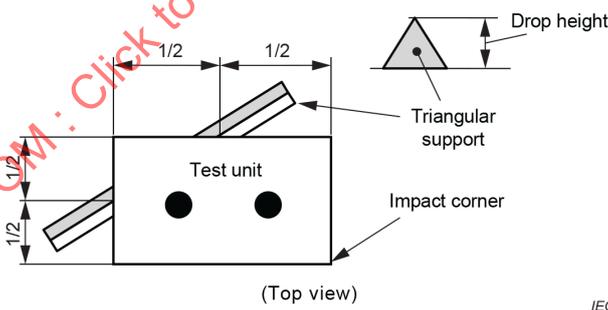


Figure 3 – Configuration for the shortest edge drop test



Smaller units can be dropped from a hand-held position. If a lifting-release device is used, it should not, on release, impart rotational or sideward forces to the unit.

Figure 4 – Configuration for the corner drop test

7.2.4 Thermal abuse test (cell or cell block)

a) Requirements

An elevated temperature exposure shall not cause fire or explosion.

b) Test

Each fully charged cell, stabilized in an ambient temperature of 25 °C ± 5 °C, is placed in a gravity or circulating air-convection oven.

The oven temperature is raised at a rate of 5 °C / min ± 2 °C / min to a temperature of 85 °C ± 5 °C.

The cell remains at this temperature for 3 h before the test is discontinued.

c) Acceptance criteria

No fire, no explosion.

7.2.5 Overcharge test (cell or cell block)

This test shall be performed for those battery systems that are provided with only a single control or protection for the charging voltage control. For those battery systems provided with two or more independent protection(s) or control(s) for the charging voltage control, this test may be waived.

NOTE An example of the two or more independent protection(s) or control(s) is as follows:

- a measurement device to monitor each cell voltage in a battery system with a function to control the charging current to prevent the highest cell voltage from exceeding the upper limit charging voltage; and
- a diagnostic monitoring system that detects the failure of the cell voltage monitoring device and functions to terminate the charging. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

a) Requirements

Charging for longer periods than specified by the cell manufacturer shall not cause fire or explosion.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each test cell shall be discharged at a constant current of $0,2 I_t$ A to a final voltage specified by the manufacturer. Sample cells shall then be charged with a constant current equal to the maximum specified charging current of the battery system until the voltage reaches the maximum voltage value that is possible under the condition where the original charging control of the battery system does not work. Then, the charging is terminated. The voltage and temperature should be monitored during the test.

Regarding the battery system with single cells connected in parallel, a cell charging current value, calculated by dividing the maximum charging current of the battery system by the number of parallel cells, is applied. **9**

NOTE "The maximum charging current of the battery system" described in this Subclause 7.2.5 b) is different from the maximum charging current of the single cell defined in 3.21.

The test shall be continued until the temperature of the cell surface reaches steady state conditions (less than 10 °C change in a 30-min period) or returns to ambient temperature.

c) Acceptance criteria

No fire, no explosion.

7.2.6 Forced discharge test (cell or cell block)

a) Requirements

A cell in a ~~multi-cell application~~ battery system shall withstand a forced discharge without causing fire or explosion.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each test cell shall be discharged at a constant current of $0,2 I_t$ A to a final voltage specified by the manufacturer. **10** A discharged cell is subjected to a forced discharge at a constant current of $1,0 I_t$ A for a test period of 90 min. At the end of the test period, a visual inspection shall be performed.

If the voltage in discharge reaches the target voltage shown below within the test period, the voltage shall be kept at the target voltage by reducing the current for the remaining test period. The target voltage is determined as follows:

- i) If the battery system is provided with two or more independent protection(s) or control(s) for discharging voltage control or the battery system has only a single cell or cell block:

Target voltage is minus the value of the upper limit charging voltage of the cell.

- ii) If the battery system is provided with only a single or no protection or control for the discharging voltage control:

Target voltage = ~~— [upper limit charging voltage of the cell × (n-1)]~~ is minus the value of (n-1) multiplied by the upper limit charging voltage of the cell,

where *n* is the number of cells connected in series in the battery system.

If the maximum discharging current of the cell is less than 1,0 *I_t* A, perform a reverse charging at the current for the test period shown below:

$$t = \frac{1I_t}{I_m} \times 90$$

where

t is the test period (min);

I_m is the maximum discharging current of the cell (A).

NOTE An example of the two or more independent protection(s) or control(s) is as follows:

- a measurement device to monitor each cell voltage in a battery system, and a function to terminate the discharging process when at least one of the cell voltages reaches the cut off voltage or the lower limit discharging voltage;
- and
- a diagnostic monitoring system which detects the failure of the cell voltage monitoring device and functions to open the discharge circuit. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

- c) Acceptance criteria

No fire, no explosion.

7.3 Considerations for internal short-circuit – Design evaluation

7.3.1 General

The purpose of the test is to determine that an internal short-circuit within a cell will not result in fire of the entire battery system or fire propagating outside the battery system. This shall be demonstrated either at the cell level according to 7.3.2 internal short-circuit test or at the battery system level according to 7.3.3 propagation test.

7.3.2 Internal short-circuit test (cell)

- a) Requirement

A forced internal short-circuit test for cylindrical cells and prismatic cells shall not cause fire. ~~Cell manufacturers shall keep a record to meet the requirements. An new design~~ evaluation of a newly designed cell shall be ~~done by the cell manufacturer after testing is~~ conducted by the cell manufacturer or a third-party test house.

- b) Test

~~Refer to 8.3.9 of IEC 62133:2012 for the test method except for the test temperature.~~ The forced internal short-circuit test is performed in a chamber according to the following procedure. All the tests are carried out in an ambient temperature of 25 °C ± 5 °C.

- 1) Charging procedure

Prior to charging, the cell shall be discharged at a constant current of 0,2 *I_t* A, down to a specified final voltage.

Then, the cell shall be charged at the upper limited charging voltage at the constant current specified by the manufacturer, continue charging at constant voltage at upper limited charge current drops to 0,05 *I_t* A.

2) Pressing the winding core with the nickel particle

A temperature-controlled chamber and special press equipment are needed for the test.

The moving part of the press equipment shall be able to move at constant speed and to be stopped immediately when an internal short-circuit is detected.

i) Preparation for the test

- The temperature of the chamber is controlled at $25\text{ °C} \pm 5\text{ °C}$. Refer to the sample preparation guidance in Clause A.5 and Clause A.6 of IEC 62133-2:2017. Put the aluminium laminated bag with the winding core and nickel particle into the chamber for $45\text{ min} \pm 15\text{ min}$.
- Remove the winding core from the sealed package and attach the terminals for voltage measurement and the thermocouple(s) for temperature measurement on the surface of the winding core. Set the winding core under the pressure equipment making sure to locate the point of placement of the nickel particle under the pressing jig.

To prevent evaporation of electrolyte, finish the work within 10 min from removing the winding core from the chamber for temperature conditioning to closing the chamber door where the equipment is located.

- Remove the insulating sheet and close the chamber door.

ii) Internal short-circuit

The bottom surface of the moving part of the press equipment (i.e. pressing jig) is made of nitrile rubber or acrylic resin, which is put on the 10 mm × 10 mm stainless steel shaft. Details of the pressing jigs are shown in Figure 5. The nitrile rubber bottom surface is for a cylindrical cell test. For a prismatic cell test, 5 mm × 5 mm (2 mm thickness) acrylic resin is put on the nitrile rubber. Put two layers of polyimide tape to the coil.

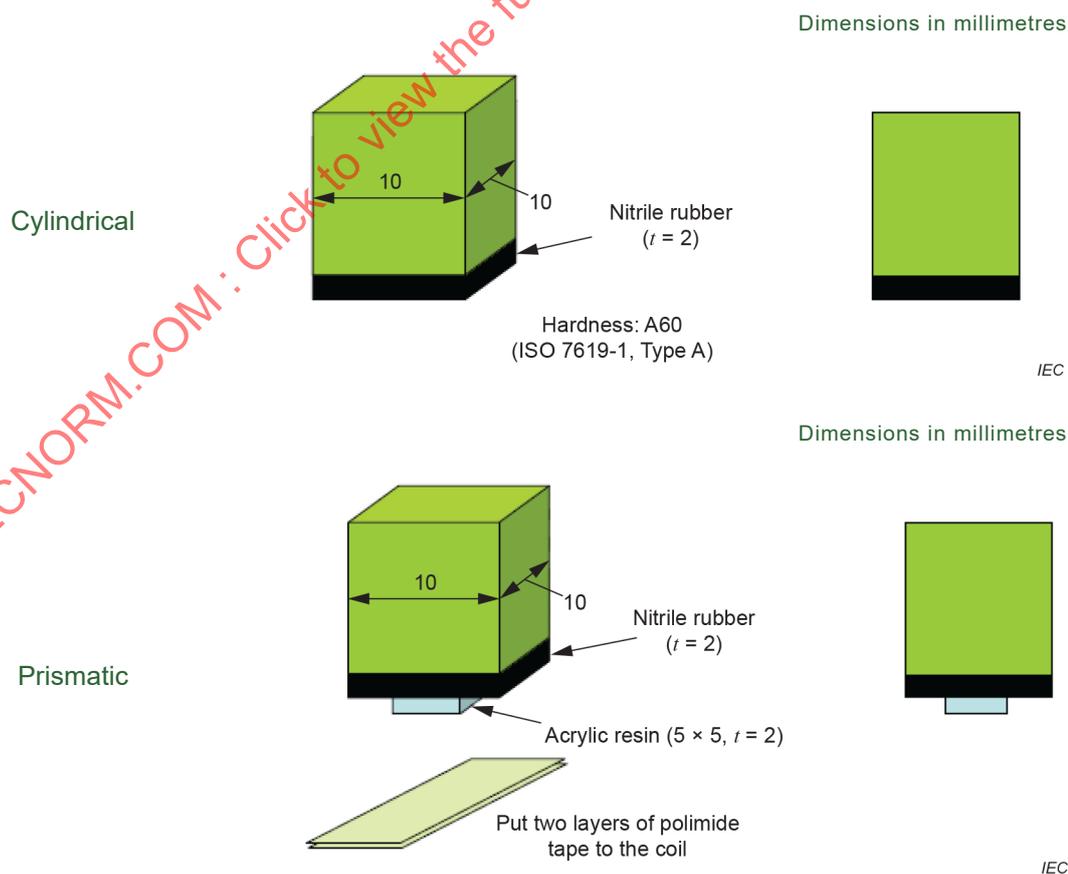


Figure 5 – Jig for pressing

The fixture is moved down at a speed of 0,1 mm/s monitoring the cell voltage. When a voltage drop caused by the internal short-circuit is detected, stop the descent immediately and keep the pressing jig in the position for 30 s, and then release the pressure. The voltage is monitored at a rate of more than 100 times per second. If the voltage drops more than 50 mV compared the initial voltage, an internal short-circuit has been determined to have occurred. If the force of the press reaches 800 N for a cylindrical cell or 400 N for a prismatic cell before the 50 mV voltage drop, stop the descent immediately.

In the case of a prismatic cell with either a stacking type or folding type electrode element, the nickel particle should be inserted at the centre of the outer end positive and negative electrode pair, and the maximum pressing pressure is 400 N. **11**

The sample preparation procedure may be changed from the procedure outlined in ~~IEC 62133 prior to performing the final pressing process with the corresponding charging procedure according to 8.3.9 of IEC 62133:2012~~ 7.3.2 2)i), it may be performed before the charging. For example:

- the nickel particle may be inserted into a discharged electrode element and then charged, or
- the nickel particle may be inserted into the electrode element before electrolyte filling and then it may be assembled, filled with electrolyte and charged. In these assemblies, a polyethylene bag and/or an aluminium-laminated bag can be used instead of the metal case for the actual cell.

~~In the case of a prismatic cell with either a stacking type or folding type electrode element, the nickel particle should be inserted at the centre of the end positive and negative electrode pair, and the maximum pressing pressure is 400 N.~~

To judge that an internal short between the positive and negative electrodes or substrate has occurred, it is acceptable to use a voltage drop of less than 50 mV if a high accuracy voltage meter with enough accuracy to detect the voltage drop is used, and the actual short-circuit location can be confirmed with an inspection of the internal short-circuit location on the sample after the test.

The applied pressure and the voltage behaviour shall be recorded, and the appearance of the short-circuit location shall be recorded by photograph or other means.

c) Acceptance criteria

No fire, ~~no explosion.~~

7.3.3 Propagation test (battery system)

a) Requirement

This test evaluates the ability of a battery system to withstand a single cell thermal runaway event so that a thermal runaway event does not result in the battery system fire.

b) Test

The battery system is fully charged and then left until the cells stabilize in an ambient temperature of 25 °C ± 5 °C. One cell in the battery system (hereafter target cell) is e.g. heated by laser until the cell enters into thermal runaway, ~~for example, using resistive heating or through thermal conductive heat transfer using an external heat source. The method used to create a thermal runaway in one cell is to be described and documented in the test report.~~ After thermal runaway in the cell is initiated, the ~~heater~~ triggering source is turned off and battery system is observed for ~~4~~ 8 h. See Annex B for an example test procedure by laser.

Other methods than ~~the examples noted above~~ the laser to initiate thermal runaway in one cell are allowed. See Annex C.

The battery system may be modified to facilitate the thermal runaway of the target cell. The modification should be minimized and it shall not affect the thermal properties of the battery system. **12**

The method used to initiate a thermal runaway in the target cell shall be described in the test report.

c) Acceptance criteria

No external fire from the battery system ~~or~~, no battery system case rupture.

If the battery system has no outer covering, the manufacturer shall specify the area for fire protection.

NOTE Fire or battery system case rupture caused by the ~~first~~ target cell is acceptable because the first thermal runaway is intentionally made for the test purpose as a trigger.

8 Battery system safety (considering functional safety)

8.1 General requirements

Reliance on electric, electronic and software controls and battery systems for critical safety shall be subjected to analysis for functional safety.

IEC 61508 (all parts), Annex H of IEC 60730-1:2013/2020, ISO 13849 (all parts) or other suitable functional safety standard for the application may be used as references.

A process hazard analysis shall be made for the cell manufacturing process as well as the battery system manufacturing process, which shall be under control with evidence documented. The manufacturer should have a way to control the manufacturing process with respect to the safety hazards of the process.

NOTE The hazard analysis of production processes refers to production faults, which effect the safety of the cell or the battery (e.g. anode-cathode alignment, damaged cells, faulty connections, safety relevant deviations from the battery characteristics and its specified construction).

~~A process hazard~~, The risk assessment and mitigation of hazards for the battery system design shall be done by the battery system manufacturers (e.g. FTA, FMEA). This process should be done in coordination with the end-use equipment manufacturer in order to fully cover the spectrum of risks. **13**

NOTE Guidance on safety analysis methods such as FMEA and FTA can be found in such documents as IEC 60812, IEC 61025, etc.

The procedure is as follows:

- a) hazard analysis;
- b) risk assessment;
- c) safety level target (e.g. safety integrity level (SIL) target).

NOTE The classification or level can also be according to the applied functional safety standard such as Class (e.g. class B or C) according to IEC 60730-1.

Examples of hazards or risks are as follows: EMC, electric shock, hot spots at electrical interfaces, moving parts, water immersion, external short-circuit, internal short-circuit, overcharge, overheating, drop, crush, overdischarge, discharge with overcurrent, charging after an overdischarge, electrolyte leakage, ignition of emission gas, fire, earthquake, seismic sea wave, etc.

8.2 Battery management system (or battery management unit)

8.2.1 Requirements for the BMS

The BMS evaluates the condition of cells and ~~batteries~~ battery systems, and it maintains cells and ~~batteries~~ battery systems within the specified cell operating region. The BMS shall be designed according to the safety integrity level (SIL) target defined in 8.1 c). Key factors of the cell operating region are voltage, temperature and current (see Figure A.1).

To evaluate the charge control that affects safety, the battery system manufacturers shall perform the tests mentioned in 8.2.2 to 8.2.4.

For these tests, the battery system includes the BMS function in the application side as well, if applicable to the design.

NOTE 1 The function of the BMS can be assigned to the battery pack or to the equipment that uses the battery system. See Figure 6.

NOTE 2 The BMS can be divided and it can be found partially in the battery pack and partially on the equipment that uses the battery system. See Figure 6.

NOTE 3 The BMS is sometimes also referred to as a BMU (battery management unit).

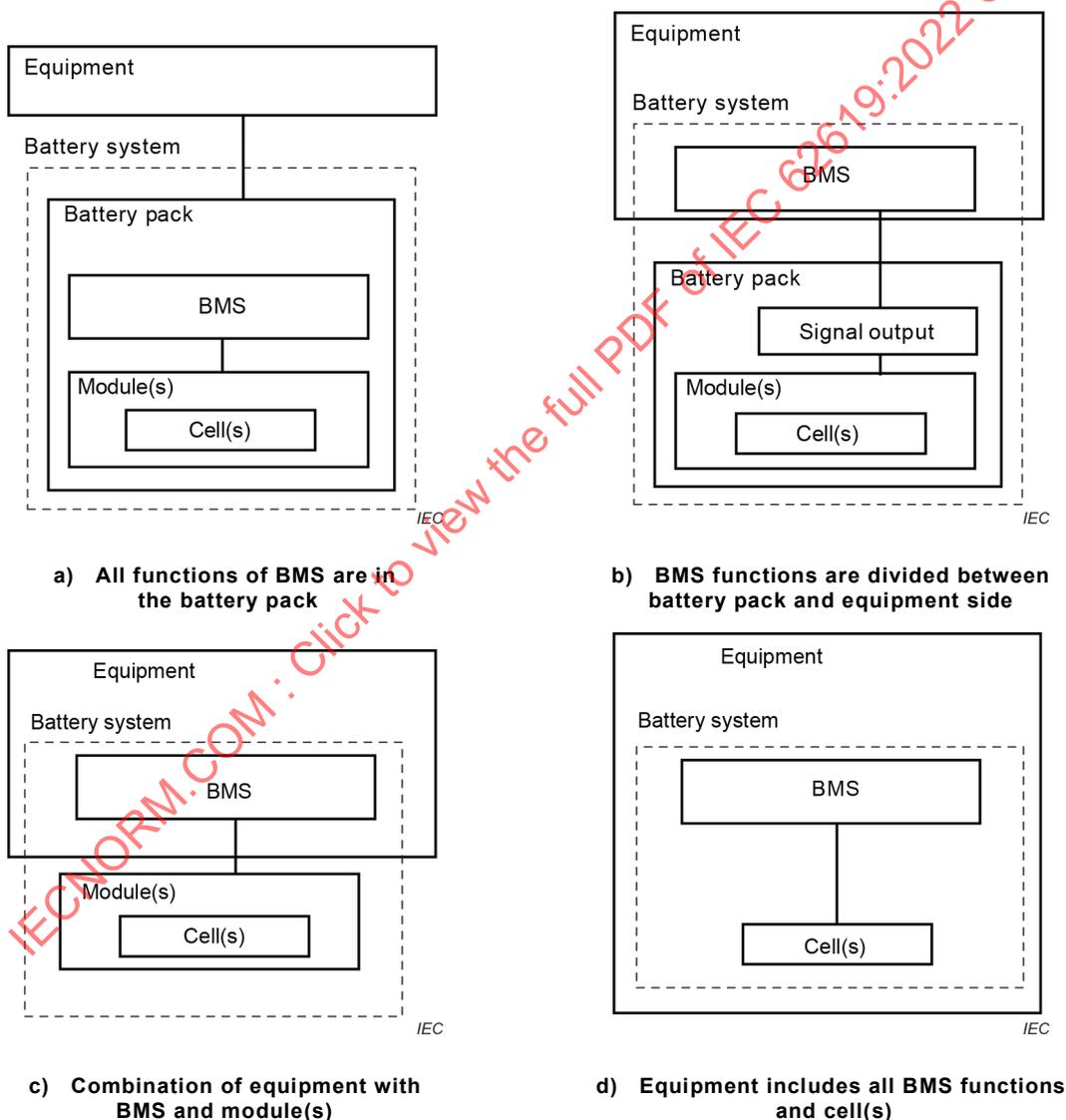


Figure 6 – Examples of BMS locations and battery system configurations

8.2.2 Overcharge control of voltage (battery system)

a) Requirement

The BMS shall control the cell voltage during charging voltage below the upper limit charging voltage of the cells.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$ and under normal operating conditions with the cooling system (if any) operating (main contactors are closed with the battery system controlled by the BMS). Each test battery system shall be discharged at a constant current of $0,2 I_t$ A, to a final voltage specified by the manufacturer. Sample ~~batteries~~ battery systems shall then be charged at the maximum current of the recommended charger with set voltage exceeding the upper limit charging voltage by 10 % for each cell in the battery.

The ~~exceeded~~ excess voltage can be applied by an additional charger if it is difficult to do so by the original charger. Also the ~~exceeded~~ excess voltage can be applied to only a part of the system such as the cell(s) in the battery system if it is difficult to do so using the whole battery system. See Figure 7.

The test shall be carried out until the BMS terminates the charging, ~~which should occur before reaching 110 % of the upper limit charging voltage~~. Data acquisition/monitoring shall be continued for 1 h after charging is stopped. During the test, all functions of the battery system shall be fully operational, as designed.

If the BMS fails to terminate the charging, the test should be stopped at the proper timing for safety reasons, for example when the cell voltage reaches 103 % of the upper limit charging voltage or 1 min after having exceeded the upper limit charging voltage, etc.

c) Acceptance criteria

BMS terminates charging before exceeding the upper limit charging voltage. No fire, no explosion.

~~The BMS shall interrupt the overcharging current by an automatic disconnect of the main contactors in order to protect the battery system against further related severe effects.~~

NOTE The BMS termination of the charging current can be achieved by contactors, relays, field effect transistor (FET), circuit breakers, electromagnetic switches, etc. in main circuit.

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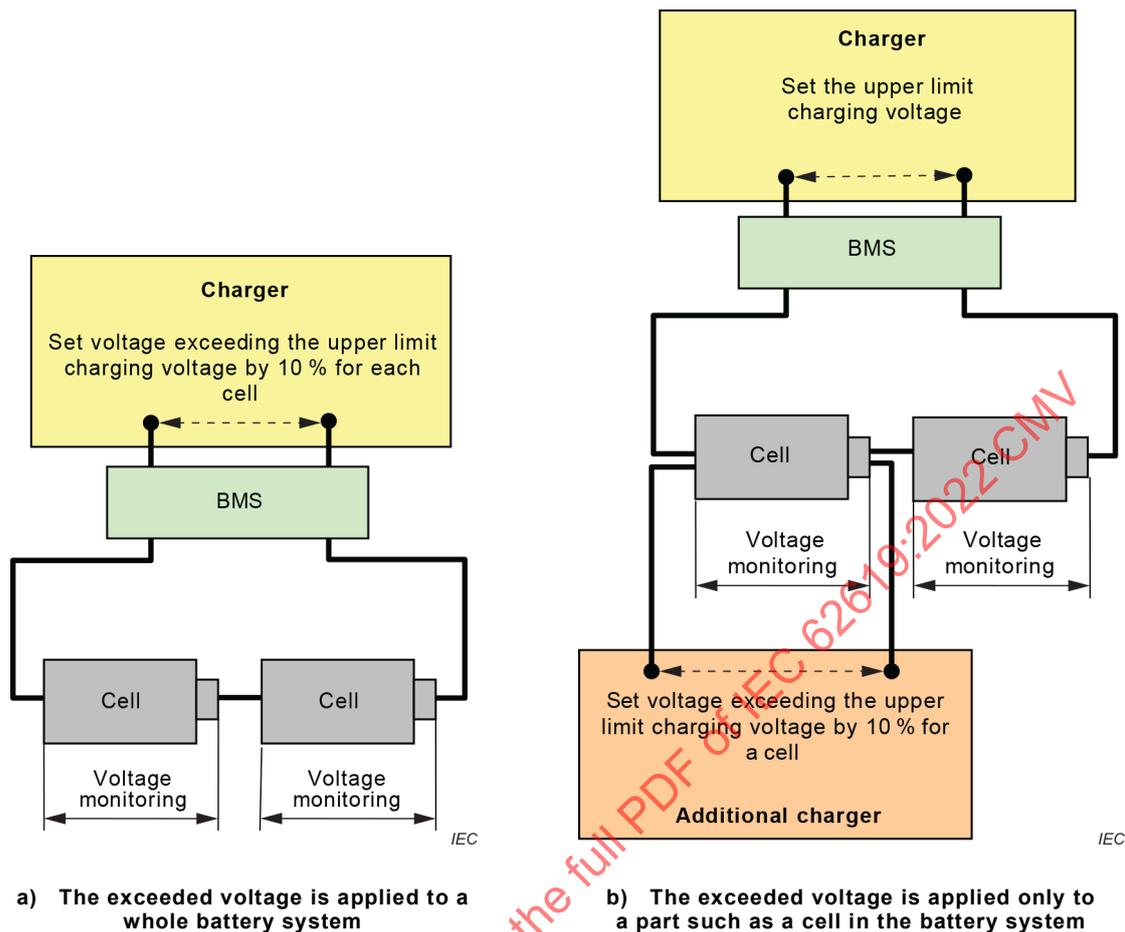


Figure 7 – Example of the circuit configuration for overcharge control of voltage

8.2.3 Overcharge control of current (battery system)

a) Requirement

~~In case the input current to the cells and batteries~~ If the charging current of the cells in the battery system exceeds the maximum charging current of the cells, the BMS shall interrupt the charging to protect the battery system from hazards related to charging currents above the specified maximum charging current of the cells.

~~NOTE~~—If the maximum ability of charging current of the upper system is lower than the maximum charging current for the battery system, this test ~~can~~ may be waived.

b) Test

The test shall be carried out in an ambient temperature of 25 °C ± 5 °C and under normal operating conditions with the cooling system (if any) operating (main contactors closed with the battery system being controlled by the BMS). ~~Each test~~ The battery system shall be discharged at a constant current of 0,2 I_t A, to a final voltage specified by the manufacturer. Sample ~~batteries~~ battery systems shall then be charged at a current exceeding the maximum charging current by 20 %. Data acquisition and/or monitoring shall be continued for 1 h after charging is stopped. During the test, all functions of the battery system shall be fully operational as designed.

c) Acceptance criteria

The BMS shall detect the overcharging current and shall control the charging below the maximum charging current ~~in order to protect the battery system against further related severe effects.~~

No fire, no explosion.

8.2.4 Overheating control (battery system)

a) Requirement

The BMS shall terminate charging when the temperature of the cells ~~and/or~~ in the battery system exceeds the upper limit that is specified by the cell manufacturer.

b) Test

The test shall be carried out at an initial ambient temperature of $25\text{ °C} \pm 5\text{ °C}$ and under normal operating conditions (main contactors are closed with battery system being controlled by the BMS) with the exception that the cooling system, if provided, shall be disconnected. Each test battery system shall be discharged at a constant current of $0,2 I_t$ A, to a final voltage specified by the manufacturer. Sample ~~batteries~~ battery systems shall then be charged at the recommended current to a 50 % ~~state-of-charge~~ capacity of the rated capacity. The temperature of the battery system shall be increased to 5 °C above the maximum operating temperature. The charging is continued at the elevated temperature until the BMS terminates the charging. Data acquisition/monitoring shall be continued for one hour after the sequence is stopped (e.g. the BMS has terminated charging).

c) Acceptance criteria

The BMS shall detect the overheat temperature and shall terminate charging ~~in order to protect the battery system against further related severe effects~~. During the test, all functions of the battery system shall be fully operational as designed.

No fire, no explosion.

9 EMC

The battery system shall fulfil EMC requirements of the end-device application such as stationary, traction, railway, etc. or the specific requirements agreed between the end-device manufacturer and the battery system manufacturer. The EMC test may be conducted on the end-device, if feasible. **14**

10 Information for safety

The use, and particularly abuse, of secondary lithium cells and ~~batteries~~ battery systems may result in the creation of hazards and may cause harm. The cell manufacturer shall provide information about current, voltage and temperature limits of their products. The battery system manufacturer shall provide information to equipment manufacturers regarding how to mitigate hazards and, in the case of direct sales, to end-users. For example, if the battery system needs the end device to provide protection devices and/or controls, the end device manufacturer shall provide details of these protection devices that need to be provided in the installation information for the battery system. **15** ~~It is the equipment manufacturer's responsibility to inform end-users of the potential hazards arising from the use of equipment containing secondary lithium cells and batteries.~~ It is the responsibility of the end-device manufacturer to inform end-users of the potential hazards arising from the use of the end-device containing the battery systems.

11 Marking and designation

Refer to Clause 5 of IEC 62620:2014.

12 Packaging and transport

Refer to Annex D.

Annex A (normative)

Operating region of cells for safe use

A.1 General

This annex explains how to determine the operating region of the cell to ensure the safe use of the cell. This region is given to ensure the safe use of the cell and is defined as the operating region. The operating region is specified by the charging conditions such as the upper limit of charging voltage and cell temperature, which ensure the safety of cells.

The cell manufacturers should stipulate the information on the operating region in the specification of cell in the safety precautions for the attention of the customers such as the manufacturers of battery packs and systems. A suitable protection device and function should also be provided in the ~~battery control system~~ BMS for possible failure of the charging control.

The limits of the operating region are specified for minimum safety, and are different from the charging voltage and temperature to optimize the performance of the cell such as cycle life.

A.2 Charging conditions for safe use

In order to ensure the safe use of cells, the cell manufacturers should set the upper limit of the voltage and the temperature of cell to be applied during charging. The cell should be charged within a predefined temperature range (standard temperature range) at a voltage not exceeding the upper limit. The cell manufacturer may also set a temperature range higher or lower than the standard temperature range, provided that the safety measures, such as lowered charging voltage, are taken. The operating region means such range of voltage and temperature where the cell can be used safely. The maximum charging current may also be set for the operating region.

The same operating region can apply to a newly developed cell, if it has the same electrode material, thickness, design, and separator as the original cell, and less than 120 % of the rated capacity of the original cell. The new cell that meets these criteria can be considered as the same product series cell.

A.3 Considerations on charging voltage

The charging voltage is applied to cells so as to promote the chemical reaction during charging. However, if the charging voltage is too high, excessive chemical reactions or side reactions occur, and the cell becomes thermally unstable. Consequently, it is most important that the charging voltage never exceeds the value specified by the cell manufacturer (i.e. the upper limit charging voltage). When a cell is charged at a higher voltage than the upper limit charging voltage, an excess amount of lithium ion is deintercalated from the positive electrode active material, and its crystalline structure tends to collapse. In these conditions, when an internal short-circuit occurs, thermal runaway can more easily occur than it does for cells charged in the predefined operating region. Consequently, the cells ~~should~~ shall never be charged at a higher voltage than the upper limit charging voltage.

The upper limit charging voltage should be set by the cell manufacturer based on the verification tests, showing the results, for example, as follows:

- test results which verify the stability of the crystalline structure of the positive material;
- test results which verify the acceptance of lithium ions into the negative electrode active material when the cell is charged at the upper limit charging voltage;

- test results which verify that the cells charged at the upper limit charging voltage are tested by the safety test in Clause 6 at the upper limit of the standard temperature range, and the acceptance criteria of each test are met.

A.4 Considerations on temperature

Charging produces a chemical reaction and is affected by temperature. The amount of side reactions or the condition of the reaction products during charging is dependent on temperature. Charging in low or high temperature ranges is considered to cause more side reactions, and is of a higher level of severity from a safety viewpoint, than in the standard temperature range where the upper limit charging voltage is safely applicable. Consequently, the charging voltage and/or the charging current should be reduced from the upper limit charging voltage and/or the maximum charging current in both the low temperature range and the high temperature range.

A.5 High temperature range

When a cell is charged at a higher temperature than the standard temperature range, the safety performance of the cell tends to decrease due to lower stability of the crystalline structure. Also, in the high temperature range, the thermal runaway tends to occur ~~by relatively~~ even with small changes in temperature.

As a result, the charging of cells in the high temperature range should be controlled as follows:

- when the surface temperature of the cell is within the high temperature range specified by the cell manufacturer, specific charging conditions, such as lower charging voltage and current, are applied;
- when the surface temperature of cell is higher than the upper limit of the high temperature range, the cell should never be charged under any charging current.

A.6 Low temperature range

When a cell is charged in the low temperature range, the mass transfer rate decreases and the lithium ion insertion rate into the negative material becomes low. Consequently, metallic lithium is easy to deposit on the ~~carbon~~ negative electrode surface. In this condition, the cell becomes thermally unstable and liable to become overheated and to cause the thermal runaway. Also, in the low temperature range, the acceptance of lithium ions is highly dependent on the temperature. In a lithium battery system that consists of multi-cells in a series connection, the lithium ion acceptability of each cell differs depending on the cell temperature, which reduces the safety of battery system.

As a result, the charging of cells in the low temperature range should be controlled as follows:

- when the surface temperature of the cell is within the low temperature range specified by the cell manufacturer, specific charging conditions, such as lower charging voltage and current, are applied;
- when the surface temperature of the cell is below the lower limit of the lower temperature range, the cell should never be charged under any charging current.

A.7 Discharging conditions for safe use

The main parameters to ensure safety during discharging are voltage, current, and temperature. Voltage should always be above the lower limit discharging voltage of the cell. Current should never exceed the maximum current defined specified by the cell manufacturer. The temperature should always be within the temperature limits (low and high limits). The cell voltage should be controlled above the lower limit discharging voltage of the cell to avoid unexpected critical failure. In addition, a cut off voltage above the lower limit discharging voltage is specified by the cell manufacturer in order to keep a proper margin for the cell operating region and to optimize performance of the cell.

A.8 Example of operating region

Figure A.1 illustrates a typical example of an operating region for charging. In a temperature range higher or lower than the standard temperature range, it is permissible to charge the cell provided that a lower charging voltage and/or current are used. The operating range can be specified with a step shape which is shown in Figure A.1, or with diagonal lines. Figure A.2 illustrates an example of an operating region for discharging.

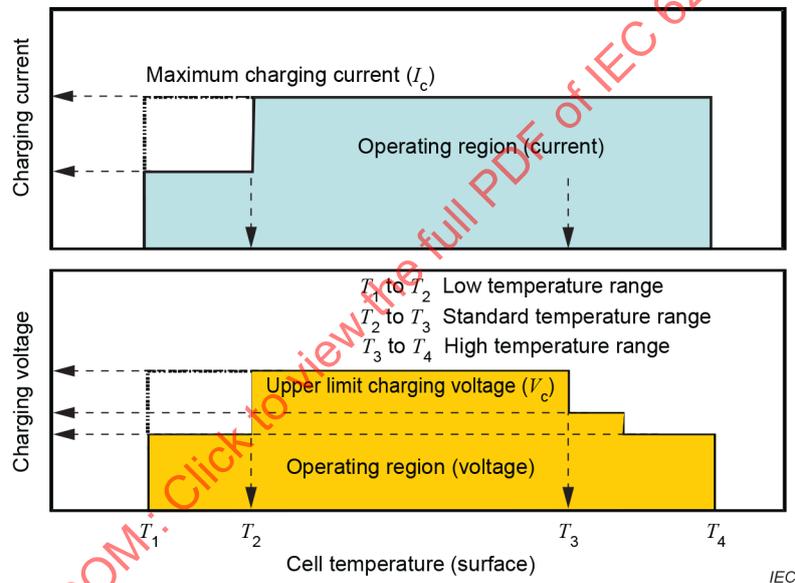


Figure A.1 – An example of operating region for charging of typical lithium ion cells

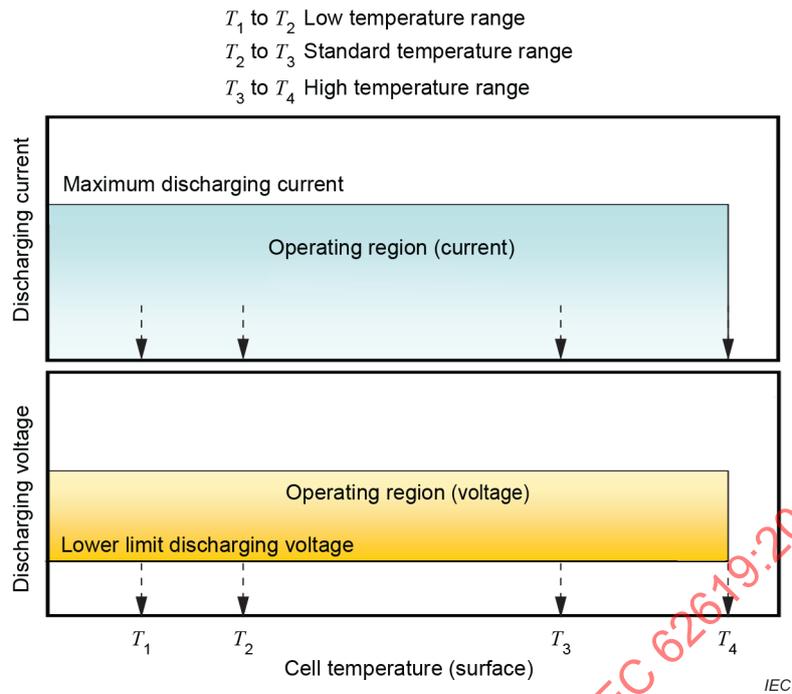


Figure A.2 – An example of operating region for discharging of typical lithium ion cells

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Annex B (informative)

Procedure of propagation test by laser irradiation (see 7.3.3)

B.1 General

This annex gives an example method for the 7.3.3 propagation test by laser. The testing entity should contact the cell or battery system manufacturer to get a detailed procedure for the cell thermal runaway.

NOTE The purpose of this test is not an evaluation of a single cell but an evaluation of propagation behaviour of the battery system. Therefore, the following methods which create thermal runaway do not simulate internal short-circuit of the cell, but a propagation trigger.

B.2 Test conditions

B.2.1 Cell test (preliminary test)

- 1) The cell is fully charged according to the manufacturer specified conditions.
- 2) Place thermocouples onto the cell to measure the surface temperature. It is better to use multiple thermocouples for redundant data acquisition.
- 3) Fix the cell onto the test bench (see Figure B.1). The irradiation point on the cell should be determined by considering the structure of the battery system supplied in the main test.
- 4) The laser irradiation program and its work should be set and confirmed. It is better to prepare covers to prevent damage to laser systems when the cell enters into thermal runaway and vent.
- 5) Prepare and set the measurement equipment for the cell temperature measurement, etc.
- 6) Set the ambient temperature at $25\text{ °C} \pm 5\text{ °C}$. The temperature controller such as air conditioning system should have the ability to maintain the ambient temperature until the cell temperature reaches the maximum temperature.
- 7) Irradiate the cell with the laser at the determined point. Measure the cell temperature continuously from the irradiation start to the observation end.
- 8) When rapid temperature increase is observed due to cell thermal runaway, the laser is turned off (see Figure B.2).
- 9) Observe the cell temperatures and appearance until the cell temperature decreases enough for safe handling.
- 10) Review the temperature profile to confirm the thermal runaway event.
- 11) The cell test should be repeated 3 times. If thermal runaway is confirmed on each test with the same conditions, go to the battery system test with the same irradiation condition.

NOTE 1 The laser type can be chosen from material process lasers such as cutting, welding or hardening. There are the CO₂ laser, YAG laser, semiconductor laser, disk laser, fibre laser, and so on.

NOTE 2 The laser parameters are set such that the cell enters the thermal runaway within 10 min because longer irradiation can cause unnecessary heat-up of surrounding cells and/or battery system.

The test should be performed in a well-ventilated environment to avoid vent gas effects from the cell.

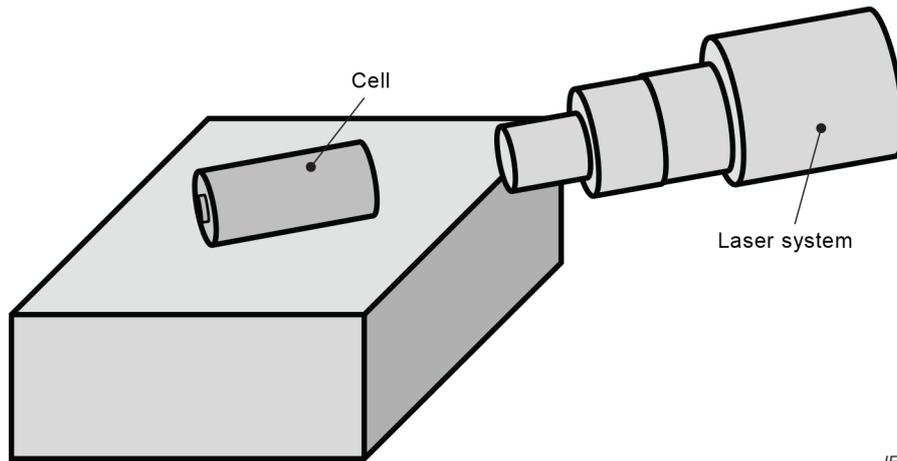


Figure B.1 – Example of the test layout

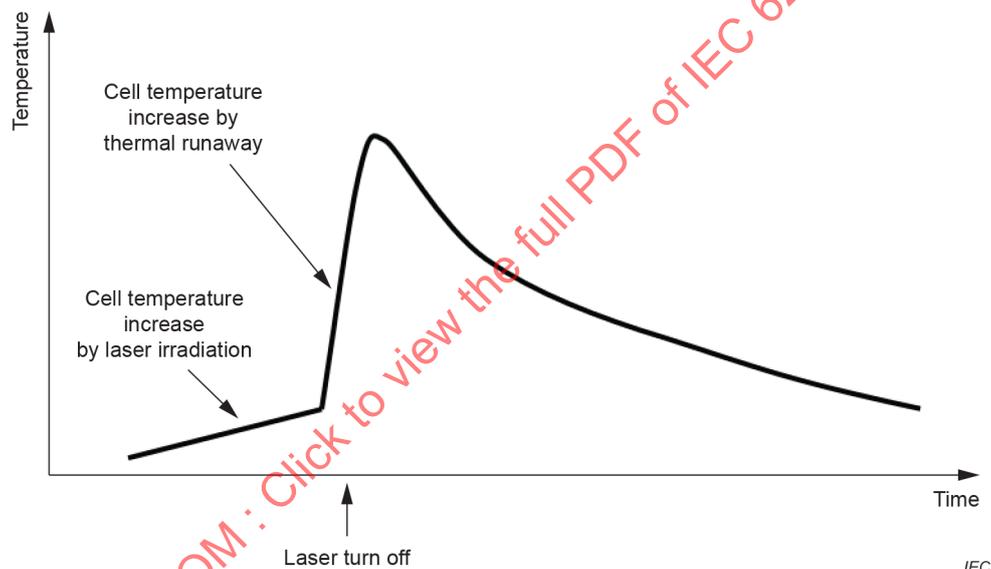


Figure B.2 – Example of typical temperature trend of the cell

B.2.2 Battery system test (main test)

- 1) The battery system is fully charged according to the manufacturer specified conditions.
- 2) Place the thermocouples onto the cells to measure the surface temperature. It is better to use multiple thermocouples for redundant data acquisition.
- 3) Fix the battery system onto the test bench. The laser path should be considered prior to testing and the irradiation point on the target cell should be the same or similar as that on the cell test.
- 4) The laser irradiation program and its work should be set and confirmed. It is better to prepare covers to prevent damage to the laser systems when the target cell enters into thermal runaway and vents.
- 5) Prepare and set the measurement equipment for cell temperature measurement, etc.
- 6) Set the ambient temperature at $25\text{ °C} \pm 5\text{ °C}$. The temperature controller such as an air conditioning system should have the ability to maintain the ambient temperature until the target cell temperature reaches the maximum temperature.

- 7) Irradiate the target cell with the laser at the determined point. Measure the cell's temperature continuously from irradiation start to observation end.
- 8) When rapid temperature increase due to cell thermal runaway is observed, the laser is turned off.
- 9) Observe the cell's temperatures and the battery system appearance for a minimum of 1 h. It is better to observe them until the cell's temperature decreases enough for safe handling.

The test should be performed in a well-ventilated environment to avoid vent gas effect from the target cell and/or the other cells.

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Annex C (informative)

Procedure of propagation test by methods other than laser (see 7.3.3)

C.1 General

The method for developing a thermal runaway of the cell is by using a laser as described in 7.3.3 and Annex B. However other methods can be chosen from ~~one of~~ the candidate methods identified in Clause C.3 below. The testing entity should contact the cell or battery system manufacturer to get a detailed procedure for the cell thermal runaway.

NOTE The purpose of this test is not an evaluation of a single cell but an evaluation of propagation behaviour inside the battery system. Therefore, the following methods which create thermal runaway do not simulate internal short-circuit of the cell, but a propagation trigger.

C.2 Test conditions

- 1) The battery system is fully charged according to the manufacturer-recommended conditions.
- 2) One cell in the battery system (hereafter called target cell) is intended to be ~~forced~~ entered into thermal runaway as a trigger of the test. When the battery system contains three or more cells, end cells in the battery system configuration may not be chosen as the target cell, i.e. the target cell has at least two other cells nearby.
- 3) This test can be carried out with a specially prepared sample, which may have a heater or a hole for nail penetration provided for ease of testing. However the special feature provided for ease of testing should not affect the heat diffusion of the battery system.

C.3 Methods for initiating the thermal runaway

Methods for initiating the thermal runaway can include the following.

1) Heating

The target cell ~~shall be~~ is heated by the following methods. Each method should heat only the target cell. The heat source should be turned off when the target cell is ~~forced~~ entered into thermal runaway.

- Heating by heater
- Heating by burner
- ~~– Heating by laser~~
- Heating by inductive heating

2) Overcharge

A The target cell is overcharged with the manufacturer-recommended conditions until the target cell is ~~forced~~ entered into thermal runaway. Any other cells in the battery system shall not be overcharged. If the cell is designed to have a current interrupt device (CID), a cell whose CID was altered to be non-functional may be used.

3) Nail penetration of the cell

A The target cell is penetrated with a nail to create a short circuit between the positive and negative electrodes. The nail may be heated prior to the test.

4) Combination of the methods in 1) to 3) above.

5) Other method(s) which are determined to be appropriate method(s) by theory and supporting data.

Annex D (informative)

Packaging and transport

The goal of packaging of secondary cells and ~~batteries~~ battery systems for transport is to prevent opportunities for short-circuit, mechanical damage and possible ingress of moisture. The materials and packaging design should be chosen so as to prevent the development of unintentional electrical conduction, corrosion of the terminals and ingress of environmental contaminants.

Lithium ion cells, modules, battery packs, and battery systems are regulated by the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), the International Maritime Organization (IMO) and other international organizations and/or government agencies.

Regulations concerning international transport of secondary lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods. Testing requirements are defined in the UN Manual of Tests and Criteria. As regulations are subject to change, the latest editions should be consulted. **16**

For reference, transportation tests are also given in IEC 62281.

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IEC 60812, ~~*Analysis techniques for system reliability – Procedure for*~~ *Failure modes and effects analysis (FMEA and FMECA)*

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IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments*

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~~IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*~~

IEC 62660 (all parts), *Secondary lithium-ion cells for the propulsion of electric road vehicles*

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IEC 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62368-1, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

ISO 9001:2015, *Quality management systems – Requirements*

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List of comments

- 1 This paragraph clarifies the vehicles covered by the standard, with the exception of road vehicles.
 - 2 The standard addresses only first life cells and batteries, as the reuse, repurpose and second life will be addressed by a new standard under development.
 - 3 The sentence has been modified to give a better description of venting.
 - 4 The 1st edition of the standard did not address the cells and batteries incorporated in moving equipment.
 - 5 It is important to emphasize the risk associated with live parts.
 - 6 The addition to the sentence gives requirements that the cell manufacturer should provide to the battery system manufacturer/designer in order to have an adequate mitigation of the risks related to the battery system.
 - 7 New text provides a clarification of the monitoring of the charging or discharging current for safety reasons.
 - 8 Subclause 5.8 provides an important addition concerning a system lock function very important for safety reasons (avoid dangerous reactions).
 - 9 New text provides clarification on the way the cell charging current is calculated when single cells are connected in parallel.
 - 10 Additional test conditions are given.
 - 11 The description of the forced internal short-circuit test for cylindrical cells and prismatic cells is described with a lot of precision as it is a major test which is not easily performed. This is an important test for the safety of the use of the cells.
 - 12 It is very important to insure that the thermal runaway of one cell does not have any effect on the entire battery system. This to insure the safety of the battery system.
 - 13 FMEA (Failure Mode and Effect Analysis) or FTA (Fault Tree Analysis) are very powerful tools to evaluate the risks associated with products.
 - 14 New Clause 9 on electromagnetic compatibility is added as it is more and more required by end-users.
 - 15 An example of a very important safety requirement is provided.
 - 16 It is very important to check the latest regulation as they are subject to change and the risks related to lithium batteries which are considered as dangerous goods.
-

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INTERNATIONAL STANDARD

NORME INTERNATIONALE



Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications

Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs au lithium pour utilisation dans des applications industrielles

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SECONDARY CELLS AND BATTERIES CONTAINING
ALKALINE OR OTHER NON-ACID ELECTROLYTES –
SAFETY REQUIREMENTS FOR SECONDARY LITHIUM CELLS
AND BATTERIES, FOR USE IN INDUSTRIAL APPLICATIONS****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62619 has been prepared by subcommittee 21A: Secondary cells and batteries containing alkaline or other non-acid electrolytes, of IEC technical committee 21: Secondary cells and batteries. It is an International Standard.

This second edition cancels and replaces the first edition published in 2017. This edition constitutes a technical revision.

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

- a) new requirements for moving parts;
- b) addition of requirements for hazardous live parts;
- c) addition of requirements for battery system design;
- d) new requirements for system lock;
- e) new requirements for EMC;

f) addition of procedure of propagation test by laser.

The text of this International Standard is based on the following documents:

Draft	Report on voting
21A/785/FDIS	21A/787/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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SECONDARY CELLS AND BATTERIES CONTAINING ALKALINE OR OTHER NON-ACID ELECTROLYTES – SAFETY REQUIREMENTS FOR SECONDARY LITHIUM CELLS AND BATTERIES, FOR USE IN INDUSTRIAL APPLICATIONS

1 Scope

This document specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications.

When there exists an IEC International Standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this document, the former takes precedence (e.g., IEC 62660 series on road vehicles).

The following are some examples of applications that utilize cells and batteries under the scope of this document:

- Stationary applications: telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power, and similar applications.
- Motive applications: forklift truck, golf cart, automated guided vehicle (AGV), railway vehicles, and marine vehicles, with the exception of road vehicles.

Since this document covers batteries for various industrial applications, it includes those requirements which are common and minimum to the various applications.

Electrical safety is included only as a part of the risk analysis of Clause 8. In regard to details for addressing electrical safety, the end use application standard requirements need to be considered.

This document applies to cells and batteries. If the battery is divided into smaller units, the smaller unit can be tested as the representative of the battery. The manufacturer clearly declares the tested unit. The manufacturer can add functions, which are present in the final battery to the tested unit.

This document addresses first life cells and batteries. Reuse, repurpose, second life use or similar are not taken into consideration by this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62133-2:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems*

IEC 62620:2014, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 51, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

safety

freedom from unacceptable risk

3.2

risk

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

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified – deletion of Note 1 to entry.]

3.3

harm

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

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.4

hazard

potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.5

intended use

use of a product, process or service in accordance with specifications, instructions and information provided by the supplier

3.6

reasonably foreseeable misuse

use of a product, process or service in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – "or system" has been replaced with "process or service" and notes to entry deleted.]

3.7

secondary lithium cell

secondary cell where electrical energy is derived from the insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode

Note 1 to entry: The cell typically has an electrolyte that consists of a lithium salt and organic solvent compound in liquid, gel or solid form and has a metal or a laminate film casing. It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

3.8 cell block

group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient device (PTC)) and monitoring circuitry

Note 1 to entry: The cell block is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

3.9 module

group of cells connected together either in a series and/or parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient device (PTC)) and monitoring circuitry

3.10 battery pack

energy storage device, which comprises one or more cells or modules electrically connected and has monitoring circuitry which provides information (e.g. cell voltage) to a battery system to influence the battery's safety, performance and/or service life

Note 1 to entry: The battery pack may incorporate a protective housing and be provided with terminals or other interconnection arrangements.

3.11 battery system battery

system which comprises one or more cells, modules or battery packs and has a battery management system capable of controlling current in case of overcharge, overcurrent, overdischarge, and overheating

Note 1 to entry: Overdischarge cut-off is not mandatory if there is an agreement between the cell manufacturer and the customer.

Note 2 to entry: The battery system may have cooling or heating units. More than one battery system may constitute a larger battery system. The battery system is sometimes also referred to as a battery.

3.12 battery management system BMS

electronic system associated with a battery which has functions to control current in case of overcharge, overcurrent, overdischarge, and overheating and which monitors and/or manages the battery's state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life

Note 1 to entry: Overdischarge cut-off is not mandatory if there is an agreement between the cell manufacturer and the customer.

Note 2 to entry: The function of the BMS can be assigned to the battery pack or to equipment that uses the battery. (See Figure 6.)

Note 3 to entry: The BMS can be divided and it can be found partially in the battery pack and partially on the equipment that uses the battery. (See Figure 6.)

Note 4 to entry: The BMS is sometimes also referred to as a BMU (battery management unit).

3.13 leakage

visible escape of liquid electrolyte

3.14 venting

release of excessive internal pressure from a cell, module, battery pack, or battery system in a manner intended by design to preclude rupture or explosion

3.15**rupture**

mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

3.16**explosion**

failure that occurs when a cell container or battery case opens violently and solid components are forcibly expelled

Note 1 to entry: Liquid, gas, and smoke are excepted.

3.17**fire**

emission of flames from a cell, module, battery pack, or battery system for more than 1 s

Note 1 to entry: Sparks and arcing are not considered as flames.

3.18**rated capacity**

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

Note 1 to entry: The rated capacity is the quantity of electricity C_n Ah (ampere-hours) declared by the manufacturer which a single cell or battery can deliver during an n -hour period when charging, storing and discharging under the conditions specified in IEC 62620:2014, 6.3.1.

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – Addition of the words "cell or" in the definition and of Note 1 to entry.]

3.19**upper limit charging voltage**

<of a cell> highest charging voltage in the cell operating region specified by the cell manufacturer

3.20**lower limit discharging voltage**

<of a cell> lowest discharging voltage in the cell operating region specified by the cell manufacturer

3.21**maximum charging current**

<of a cell> highest charging current in the cell operating region specified by the cell manufacturer

3.22**maximum discharging current**

<of a cell> highest discharging current in the cell operating region specified by the cell manufacturer

3.23**thermal runaway**

uncontrolled intensive increase in the temperature of a cell driven by exothermic reaction

4 Parameter measurement tolerances

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

- a) $\pm 0,5$ % for voltage;
- b) ± 1 % for current;
- c) ± 2 °C for temperature;
- d) $\pm 0,1$ % for time;
- e) ± 1 % for mass;
- f) ± 1 % for dimensions.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

The details of the instrumentation used shall be provided in any report of results.

5 General safety considerations

5.1 General

The safety of lithium secondary cells and battery systems requires the consideration of two sets of applied conditions:

- 1) intended use;
- 2) reasonably foreseeable misuse.

Cells and battery systems shall be designed and constructed so that they are safe under conditions of intended use and reasonably foreseeable misuse. It may also be expected that cells and battery systems subjected to intended use shall not only be safe but shall continue to be functional in all respects.

It is expected that cells or battery systems subjected to misuse may fail to function. However, even if such a situation occurs, they shall not present any significant hazards.

Potential hazards which are the subject of this document are:

- a) fire,
- b) burst/explosion,
- c) leakage of cell electrolyte,
- d) venting with continuous emission of flammable and/or toxic gas and/or smoke,
- e) rupture of the casing of cell, module, battery pack, or battery system with exposure of internal components.

Conformity with 5.1 a) and b) is checked by the tests of Clause 6, Clause 7, and 8.2, and in accordance with the appropriate standard (see Clause 2). Conformity with 5.1 c) to e) and with 5.2 to 5.6 is checked by analysis of documents mentioned in 8.1.

Moving parts that have potential to cause human injuries shall be applied using an appropriate design and necessary measures to reduce the risk of injuries, including those injuries that may be incurred during installation, while cells or battery systems are being incorporated into equipment.

5.2 Insulation and wiring

Wiring and its insulation shall be sufficient to withstand the maximum anticipated voltage, current, temperature, altitude and humidity requirements. The design of an internal wiring shall be such that adequate clearances and creepage distances are maintained between conductors and live parts at different voltages or between live parts and non-current-carrying accessible parts. Hazardous live parts of the battery system shall be protected to avoid the risk of electric shocks, including during installation.

The mechanical integrity of the whole battery system (cell/module/BMS) and their connections shall be sufficient to accommodate conditions of reasonably foreseeable misuse.

5.3 Venting

The casing of a cell, module, battery pack, and battery system shall incorporate a pressure relief function that will preclude rupture or explosion. If encapsulation is used to support cells within an outer case, the type of encapsulating material and the method of encapsulation shall neither cause the battery system to overheat during normal operation nor inhibit pressure relief.

5.4 Temperature/voltage/current management

The design of battery systems shall be such that abnormal temperature-rise conditions are prevented. Battery systems shall be designed within voltage, current, and temperature limits specified by the cell manufacturer. Battery systems shall be provided with specifications and charging instructions for equipment manufacturers so that associated chargers are designed to maintain charging within the voltage, current and temperature limits specified.

5.5 Terminal contacts of the battery pack and/or battery system

Terminals shall have clear polarity marking(s) on the external surface of the battery pack or battery system.

Battery packs with keyed external connectors designed for connection to specific end products need not be marked with polarity markings if the design of the external connector prevents reverse polarity connections.

The size and shape of the terminal contacts shall ensure that they can carry the maximum anticipated current. External terminal contact surfaces shall be formed from conductive materials with good mechanical strength and corrosion resistance. Terminal contacts shall be arranged so as to minimize the risk of short-circuits, for example to minimize the risk of short-circuits by metal tools. Compliance is determined through a review of the terminal specifications.

5.6 Assembly of cells, modules, or battery packs into battery systems

5.6.1 General

The assembly of cells, modules or battery packs to constitute the battery system shall respect the following rules to support adequate mitigation of risks as regard to the battery system:

- Each battery system shall have an independent control and protection method(s).

NOTE For the independent control and protection method(s), see 8.2.

- The cell manufacturer shall provide recommendations about current, voltage, temperature limits and should provide mounting advice, storage conditions, maximum number of cells in series (for cell internal protection such as a current interrupt device (CID)) so that the battery system manufacturer/designer may ensure proper design and assembly.
- Battery systems that are designed for the selective discharging of a portion of their series connected cells shall incorporate separate circuitry to prevent the cell reversal caused by uneven discharging.

- Protective circuit components should be added as appropriate and consideration given to the end-device application.

5.6.2 Battery system design

The voltage control function of the battery system design shall ensure that the voltage of each cell or cell block shall not exceed the upper limit charging voltage specified by the manufacturer of the cells, except in the case where the end-devices provide the voltage control function. In such a case, the end-devices are considered as part of the battery system. Refer to Note 2 and Note 3 in 3.12.

The battery shall be designed so that the maximum charging current or the maximum discharging current of the cell are not exceeded before the maximum allowed charging or discharging current of the battery is reached.

5.7 Operating region of lithium cells and battery systems for safe use

The cell manufacturer shall specify the cell operating region. The battery system manufacturer shall design the battery system to comply with the cell operating region. Determination of the cell operating region is in accordance with Annex A.

5.8 System lock (or system lock function)

The battery system shall have a non-resettable function to stop operation when one or more cells in the battery system deviates from the operating region during operation. This feature shall not be user resettable or allow for automatic reset.

The function of the battery system may be returned after checking that the status of the battery system complies with the battery system manufacturer manual, i.e. the battery system maintenance manual shall clearly set out this procedure.

Depending on the application, a battery system may allow a final discharge, for example to provide emergency functions. In this case, cell limits (e.g. lower limit discharge voltage or upper temperature limit) may deviate once within the range where the cell does not cause dangerous reactions. Therefore, the cell manufacturer shall provide the second set of limits in which the cell in the battery system may accept one discharge without dangerous reactions. The cell should not be further recharged after this last discharge.

5.9 Quality plan

The battery system manufacturer shall prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells, modules, battery packs, and battery systems and which covers the whole process of producing each type of cell, module, battery pack, and battery system (e.g. ISO 9001, etc.). Manufacturers should understand their process capabilities and should institute the necessary process controls in relation to product safety.

6 Type test conditions

6.1 General

A cell in the battery system that is used outside of its operating region may exhibit hazards resulting from the cells or battery systems. Such risks shall be taken into consideration in order to prepare a safe test plan.

The test facility should have sufficient structural integrity and a fire suppression system to sustain the conditions of overpressure and fire that may occur as a result of testing. The facility should have a ventilation system to remove and capture gas which might be produced during the tests. Consideration should be given to high voltage hazards when applicable.

Warning: THESE TESTS USE PROCEDURES WHICH MAY RESULT IN HARM IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. TESTS SHOULD ONLY BE PERFORMED BY QUALIFIED AND EXPERIENCED TECHNICIANS USING ADEQUATE PROTECTION. TO PREVENT BURNS, CAUTION SHOULD BE TAKEN FOR THOSE CELLS OR BATTERY SYSTEMS WHOSE CASINGS MAY EXCEED 75 °C AS A RESULT OF TESTING.

6.2 Test items

Tests are made with the number of cells or battery systems specified in Table 1, using cells or battery systems that are stored for not more than six months, under conditions specified by the cell or battery system manufacturer.

Cells or battery systems charged in accordance with the method specified in 7.1 shall deliver the rated capacity or more according to IEC 62620:2014, 6.3.1 when they are discharged at 25 °C ± 5 °C, at a constant current of 0,2 I_t A according to IEC 62620:2014, 6.3.1, down to a specified final voltage. This capacity confirmation may be done during the cell manufacturer shipping inspection. In the case of a battery system, the capacity may be calculated on the basis of the cell capacity as measured during the cell manufacturer shipping inspection.

Unless otherwise specified, tests are carried out in an ambient temperature of 25 °C ± 5 °C.

NOTE Test conditions are for type tests only and do not imply that intended use includes operation under these conditions. Similarly, the limit of six months is introduced for consistency and does not imply that cell and battery system safety is reduced after six months.

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Table 1 – Sample size for type tests

Test items		Test unit	
Category	Test	Cell (see a)	Battery system (see b and e)
Product safety test (safety of cell and battery system)	7.2.1 External short-circuit test	R	-
	7.2.2 Impact test	R (see c)	-
	7.2.3 Drop test	R	R
	7.2.4 Thermal abuse test	R	-
	7.2.5 Overcharge test	R (see d)	-
	7.2.6 Forced discharge test	R	-
	7.3 Considerations for internal short- circuit (select one of the two options)	7.3.2 Internal short- circuit test	R*
7.3.3 Propagation test		-	R
Functional safety test (safety of battery system)	8.2.2 Overcharge control of voltage	-	R
	8.2.3 Overcharge control of current	-	R
	8.2.4 Overheating control	-	R
"R" = required (minimum of 1) "R*" = required. As for the sample number, refer to IEC 62133-2:2017, 7.3.9. "-" = unnecessary or not applicable			
a The manufacturer can use "cell block(s)" instead of "cell(s)" for any test that specifies "cell(s)" as the test unit in this document. The manufacturer clearly declares the test unit for each test. b If a battery system is divided into smaller units, the unit can be tested as representative of the battery system. The manufacturer can add functions which are present in the final battery system to the tested unit. The manufacturer clearly declares the tested unit. c Cylindrical cell or cell block: 1 direction, prismatic cell (including cell with laminate film case) or cell block: 2 directions. d The test is performed with the cells or cell blocks in those battery systems that are provided with only a single control or protection for charging voltage control. e If the positive and negative terminals of a battery are not accessible, the manufacturer is allowed to modify the sample(s) to make the terminals available, for example, in accordance with 7.2.1. The modification shall be done in a way which makes it unlikely that the test result is influenced.			

7 Specific requirements and tests

7.1 Charging procedures for test purposes

Prior to charging, the cell or battery system shall be discharged in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$, at a constant current of $0,2 I_t$ A, down to a specified final voltage.

Unless otherwise stated in this document, cells or battery systems shall be charged in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$, using the method specified by the manufacturer.

NOTE 1 Charging and discharging currents for the tests are based on the value of the rated capacity (C_n Ah). These currents are expressed as a multiple of I_t A, where: $I_t \text{ A} = C_n \text{ Ah}/1 \text{ h}$ (see IEC 61434).

NOTE 2 The battery system which cannot be discharged at a constant current of $0,2 I_t$ A can be discharged at the current specified by the manufacturer.

7.2 Reasonably foreseeable misuse

7.2.1 External short-circuit test (cell or cell block)

a) Requirements

Short-circuit between the positive and negative terminals shall not cause fire or explosion.

b) Test

Fully charged cells are stored in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each cell is then short-circuited by connecting the positive and negative terminals with a total external resistance of $30\text{ m}\Omega \pm 10\text{ m}\Omega$.

The cells are to remain on test for 6 h or until the case temperature declines by 80 % of the maximum temperature rise, whichever is the sooner.

c) Acceptance criteria

No fire, no explosion.

7.2.2 Impact test (cell or cell block)

a) Requirements

An impact to the cell as mentioned in 7.2.2 b) shall not cause fire or explosion.

b) Test

The cell or cell block shall be discharged at a constant current of $0,2 I_t$ A, to 50 % capacity of the rated capacity.

The cell or cell block is placed on a flat concrete or metal floor. A type 316 stainless steel bar with a diameter of $15,8\text{ mm} \pm 0,1\text{ mm}$ and at least 60 mm in length or the longest dimension of the cell, whichever is greater, is placed across the centre of the cell or cell block. A 9,1 kg rigid mass is then dropped from a height of $610\text{ mm} \pm 25\text{ mm}$ onto the bar placed on the sample.

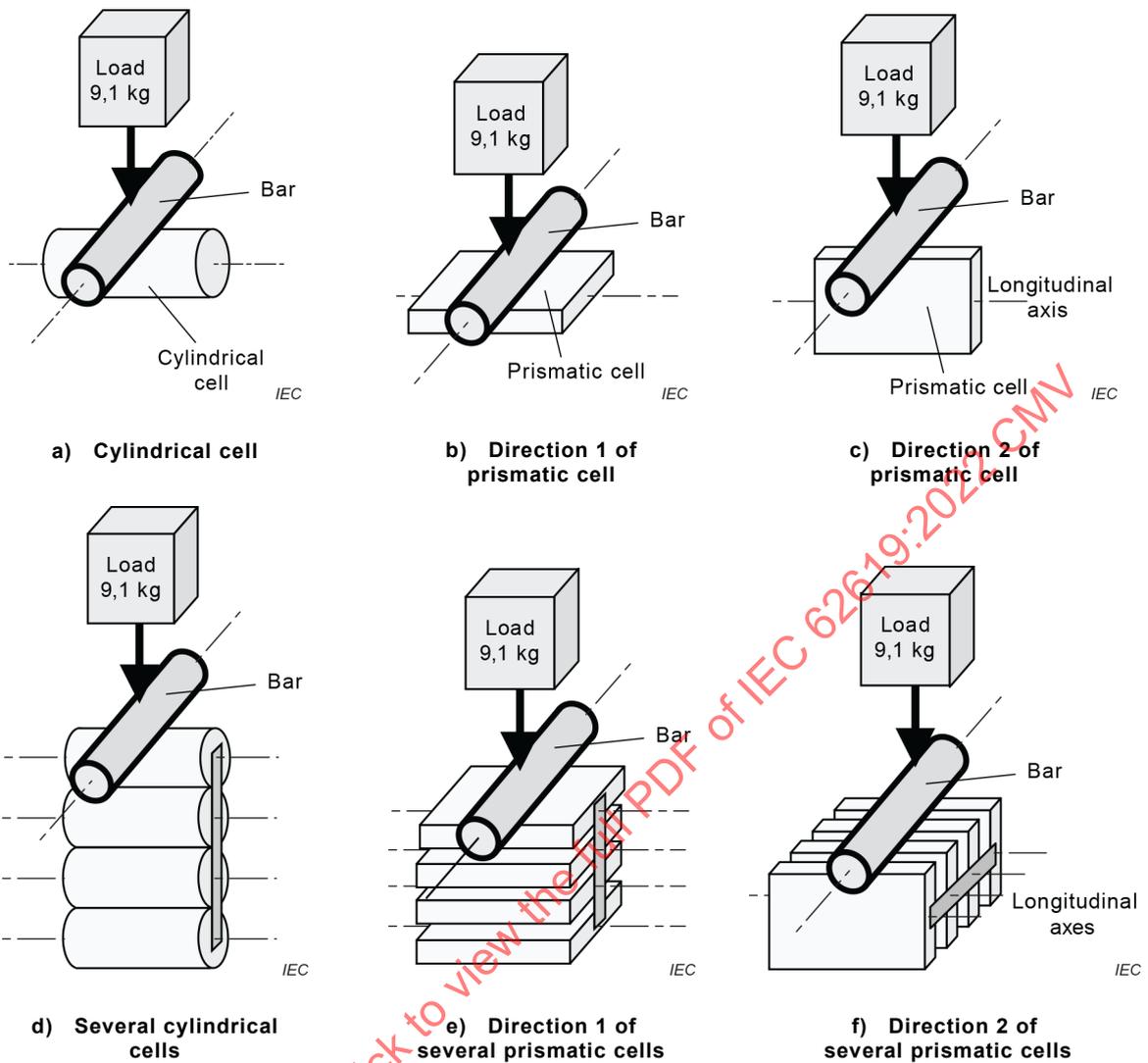
A cylindrical or prismatic cell is to be impacted with its longitudinal axis parallel to the flat concrete or metal floor and perpendicular to the longitudinal axis of the 15,8 mm diameter curved surface lying across the centre of the test sample. A prismatic cell is also to be rotated 90 degrees around its longitudinal axis so that both the wide and narrow sides will be subjected to the impact. Each sample is to be subjected to only a single impact with separate samples to be used for each impact (see Figure 1).

In the case of a metal floor, external short circuit of the cell or cell block with the floor should be avoided by appropriate measures.

Pouch cells are tested as prismatic cells.

c) Acceptance criteria

No fire, no explosion.



NOTE The cell or cell block can be supported by some material which has no influence on the test to maintain the position.

Figure 1 – Configuration of the impact test

7.2.3 Drop test (cell or cell block, and battery system)

7.2.3.1 General

The drop test is conducted on a cell or cell block, and battery system. The test method and the height of the drop are determined by the test unit weight as shown in Table 2.

Table 2 – Drop test method and condition

Mass of the test unit	Test method	Height of drop
Less than 7 kg	Whole	1 000 mm
7 kg or more, less than 20 kg	Whole ^{a)}	100 mm
20 kg or more, less than 50 kg	Edge and corner ^{a)}	100 mm
50 kg or more, less than 100 kg	Edge and corner ^{a)}	50 mm
100 kg or more	Edge and corner ^{a)}	25 mm

If the battery system is divided into smaller units, the unit can be tested as the representative of the battery system. The manufacturer can add functions which are present in the final battery system to the tested unit. The manufacturer clearly declares the tested unit.

^{a)} For test objects with a mass of 7 kg or more, the test shall be conducted with the bottom specified by the manufacturer facing downward.

7.2.3.2 Whole drop test (cell or cell block, and battery system)

This test is applied when the mass of the test unit is less than 20 kg.

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

Each fully charged test unit is dropped three times from a height shown in Table 2 onto a flat concrete or metal floor.

If the mass of the test unit is less than 7 kg, the test unit is dropped so as to obtain impacts in random orientations. If the mass of the test unit is 7 kg or more but less than 20 kg, the test shall be performed with the test unit dropped in the bottom down direction. The bottom surface of the test unit is specified by the manufacturer.

After the test, the test units shall be put on rest for a minimum of 1 h, and then a visual inspection shall be performed.

If the floor of the test room is metal, external short circuit of cell or cell block, and battery system with the floor should be avoided by appropriate measures.

c) Acceptance criteria

No fire, no explosion.

7.2.3.3 Edge and corner drop test (cell or cell block, and battery system)

This test is applied when the mass of the test unit is 20 kg or more.

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

A fully charged test unit is dropped two times from a height shown in Table 2 onto a flat concrete or metal floor. The drop test conditions shall ensure, with test arrangements as shown in Figure 2, Figure 3 and Figure 4, reproducible impact points for the shortest edge drop impact and the corner impact. The two impacts, per impact type, shall be on the same corner and on the same shortest edge. For the corner and edge drops, the test unit shall be oriented in such a way that a straight line drawn through the corner/edge to be struck and the test unit geometric centre is approximately perpendicular to the impact surface. After the test, the test unit shall be put on rest for a minimum of 1 h, and then a visual inspection shall be performed.

If the floor of the test room is metal, external short circuit of cell or cell block, and battery system with the floor should be avoided by appropriate measures.

- c) Acceptance criteria
No fire, no explosion.

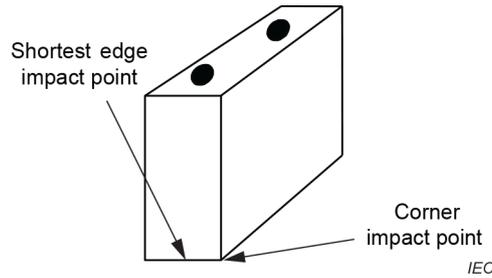


Figure 2 – Impact location

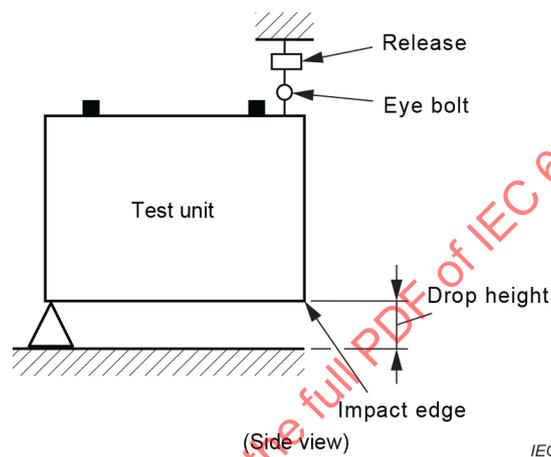
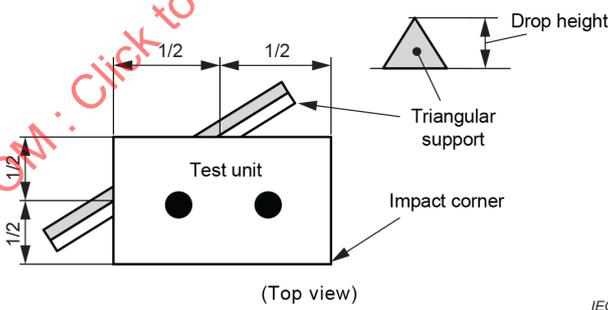


Figure 3 – Configuration for the shortest edge drop test



Smaller units can be dropped from a hand-held position. If a lifting-release device is used, it should not, on release, impart rotational or sideward forces to the unit.

Figure 4 – Configuration for the corner drop test

7.2.4 Thermal abuse test (cell or cell block)

a) Requirements

An elevated temperature exposure shall not cause fire or explosion.

b) Test

Each fully charged cell, stabilized in an ambient temperature of 25 °C ± 5 °C, is placed in a gravity or circulating air-convection oven.

The oven temperature is raised at a rate of 5 °C / min ± 2 °C / min to a temperature of 85 °C ± 5 °C.

The cell remains at this temperature for 3 h before the test is discontinued.

c) Acceptance criteria

No fire, no explosion.

7.2.5 Overcharge test (cell or cell block)

This test shall be performed for those battery systems that are provided with only a single control or protection for the charging voltage control. For those battery systems provided with two or more independent protection(s) or control(s) for the charging voltage control, this test may be waived.

NOTE An example of the two or more independent protection(s) or control(s) is as follows:

- a measurement device to monitor each cell voltage in a battery system with a function to control the charging current to prevent the highest cell voltage from exceeding the upper limit charging voltage; and
- a diagnostic monitoring system that detects the failure of the cell voltage monitoring device and functions to terminate the charging. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

a) Requirements

Charging for longer periods than specified by the cell manufacturer shall not cause fire or explosion.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each test cell shall be discharged at a constant current of $0,2 I_t$ A to a final voltage specified by the manufacturer. Sample cells shall then be charged with a constant current equal to the maximum specified charging current of the battery system until the voltage reaches the maximum voltage value that is possible under the condition where the original charging control of the battery system does not work. Then, the charging is terminated. The voltage and temperature should be monitored during the test.

Regarding the battery system with single cells connected in parallel, a cell charging current value, calculated by dividing the maximum charging current of the battery system by the number of parallel cells, is applied.

NOTE "The maximum charging current of the battery system" described in this Subclause 7.2.5 b) is different from the maximum charging current of the single cell defined in 3.21.

The test shall be continued until the temperature of the cell surface reaches steady state conditions (less than 10 °C change in a 30-min period) or returns to ambient temperature.

c) Acceptance criteria

No fire, no explosion.

7.2.6 Forced discharge test (cell or cell block)

a) Requirements

A cell in a battery system shall withstand a forced discharge without causing fire or explosion.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Each test cell shall be discharged at a constant current of $0,2 I_t$ A to a final voltage specified by the manufacturer. A discharged cell is subjected to a forced discharge at a constant current of $1,0 I_t$ A for a test period of 90 min. At the end of the test period, a visual inspection shall be performed.

If the voltage in discharge reaches the target voltage shown below within the test period, the voltage shall be kept at the target voltage by reducing the current for the remaining test period. The target voltage is determined as follows:

- i) If the battery system is provided with two or more independent protection(s) or control(s) for discharging voltage control or the battery system has only a single cell or cell block:
Target voltage is minus the value of the upper limit charging voltage of the cell.

- ii) If the battery system is provided with only a single or no protection or control for the discharging voltage control:

Target voltage is minus the value of $(n-1)$ multiplied by the upper limit charging voltage of the cell,

where n is the number of cells connected in series in the battery system.

If the maximum discharging current of the cell is less than $1,0 I_t$ A, perform a reverse charging at the current for the test period shown below:

$$t = \frac{1I_t}{I_m} \times 90$$

where

t is the test period (min);

I_m is the maximum discharging current of the cell (A).

NOTE An example of the two or more independent protection(s) or control(s) is as follows:

- a measurement device to monitor each cell voltage in a battery system, and a function to terminate the discharging process when at least one of the cell voltages reaches the cut off voltage or the lower limit discharging voltage;
- and
- a diagnostic monitoring system which detects the failure of the cell voltage monitoring device and functions to open the discharge circuit. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

- c) Acceptance criteria

No fire, no explosion.

7.3 Considerations for internal short-circuit – Design evaluation

7.3.1 General

The purpose of the test is to determine that an internal short-circuit within a cell will not result in fire of the entire battery system or fire propagating outside the battery system. This shall be demonstrated either at the cell level according to 7.3.2 internal short-circuit test or at the battery system level according to 7.3.3 propagation test.

7.3.2 Internal short-circuit test (cell)

- a) Requirement

A forced internal short-circuit test for cylindrical cells and prismatic cells shall not cause fire. An evaluation of a newly designed cell shall be conducted by the cell manufacturer or a third-party test house.

- b) Test

The forced internal short-circuit test is performed in a chamber according to the following procedure. All the tests are carried out in an ambient temperature of $25 \text{ °C} \pm 5 \text{ °C}$.

- 1) Charging procedure

Prior to charging, the cell shall be discharged at a constant current of $0,2 I_t$ A, down to a specified final voltage.

Then, the cell shall be charged at the upper limited charging voltage at the constant current specified by the manufacturer, continue charging at constant voltage at upper limited charge current drops to $0,05 I_t$ A.

2) Pressing the winding core with the nickel particle

A temperature-controlled chamber and special press equipment are needed for the test.

The moving part of the press equipment shall be able to move at constant speed and to be stopped immediately when an internal short-circuit is detected.

i) Preparation for the test

- The temperature of the chamber is controlled at $25\text{ °C} \pm 5\text{ °C}$. Refer to the sample preparation guidance in Clause A.5 and Clause A.6 of IEC 62133-2:2017. Put the aluminium laminated bag with the winding core and nickel particle into the chamber for $45\text{ min} \pm 15\text{ min}$.
- Remove the winding core from the sealed package and attach the terminals for voltage measurement and the thermocouple(s) for temperature measurement on the surface of the winding core. Set the winding core under the pressure equipment making sure to locate the point of placement of the nickel particle under the pressing jig.
To prevent evaporation of electrolyte, finish the work within 10 min from removing the winding core from the chamber for temperature conditioning to closing the chamber door where the equipment is located.
- Remove the insulating sheet and close the chamber door.

ii) Internal short-circuit

The bottom surface of the moving part of the press equipment (i.e. pressing jig) is made of nitrile rubber or acrylic resin, which is put on the 10 mm × 10 mm stainless steel shaft. Details of the pressing jigs are shown in Figure 5. The nitrile rubber bottom surface is for a cylindrical cell test. For a prismatic cell test, 5 mm × 5 mm (2 mm thickness) acrylic resin is put on the nitrile rubber.

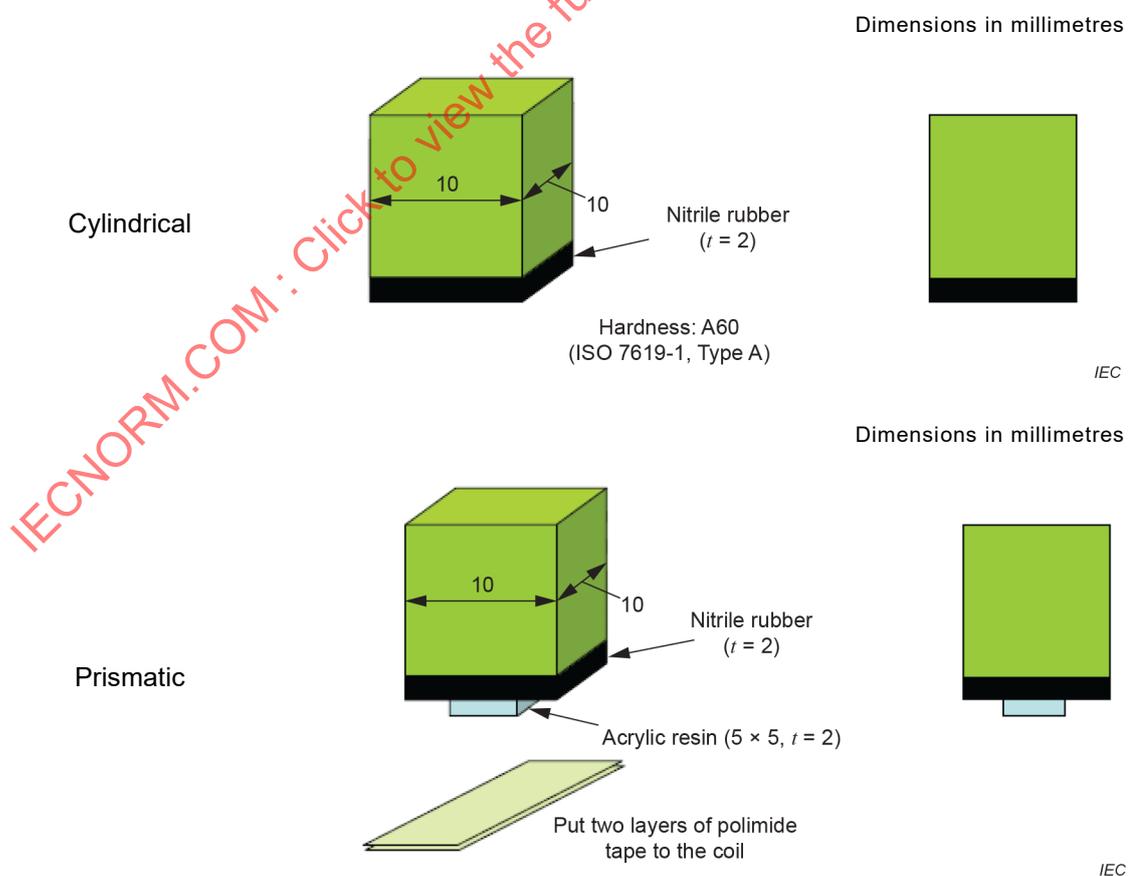


Figure 5 – Jig for pressing

The fixture is moved down at a speed of 0,1 mm/s monitoring the cell voltage. When a voltage drop caused by the internal short-circuit is detected, stop the descent immediately and keep the pressing jig in the position for 30 s, and then release the pressure. The voltage is monitored at a rate of more than 100 times per second. If the voltage drops more than 50 mV compared the initial voltage, an internal short-circuit has been determined to have occurred. If the force of the press reaches 800 N for a cylindrical cell or 400 N for a prismatic cell before the 50 mV voltage drop, stop the descent immediately.

In the case of a prismatic cell with either a stacking type or folding type electrode element, the nickel particle should be inserted at the centre of the outer end positive and negative electrode pair, and the maximum pressing pressure is 400 N.

The sample preparation procedure may be changed from the procedure outlined in 7.3.2 2)i), it may be performed before the charging. For example:

- the nickel particle may be inserted into a discharged electrode element and then charged, or
- the nickel particle may be inserted into the electrode element before electrolyte filling and then it may be assembled, filled with electrolyte and charged. In these assemblies, a polyethylene bag and/or an aluminium-laminated bag can be used instead of the metal case for the actual cell.

To judge that an internal short between the positive and negative electrodes or substrate has occurred, it is acceptable to use a voltage drop of less than 50 mV if a high accuracy voltage meter with enough accuracy to detect the voltage drop is used, and the actual short-circuit location can be confirmed with an inspection of the internal short-circuit location on the sample after the test.

The applied pressure and the voltage behaviour shall be recorded, and the appearance of the short-circuit location shall be recorded by photograph or other means.

c) Acceptance criteria

No fire.

7.3.3 Propagation test (battery system)

a) Requirement

This test evaluates the ability of a battery system to withstand a single cell thermal runaway event so that a thermal runaway event does not result in the battery system fire.

b) Test

The battery system is fully charged and then left until the cells stabilize in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. One cell in the battery system (hereafter target cell) is e.g. heated by laser until the cell enters into thermal runaway. After thermal runaway in the cell is initiated, the triggering source is turned off and battery system is observed for 8 h. See Annex B for an example test procedure by laser.

Other methods than the laser to initiate thermal runaway in one cell are allowed. See Annex C.

The battery system may be modified to facilitate the thermal runaway of the target cell. The modification should be minimized and it shall not affect the thermal properties of the battery system.

The method used to initiate a thermal runaway in the target cell shall be described in the test report.

c) Acceptance criteria

No external fire from the battery system, no battery system case rupture.

If the battery system has no outer covering, the manufacturer shall specify the area for fire protection.

NOTE Fire or battery system case rupture caused by the target cell is acceptable because the first thermal runaway is intentionally made for the test purpose as a trigger.

8 Battery system safety (considering functional safety)

8.1 General requirements

Reliance on electric, electronic and software controls and battery systems for critical safety shall be subjected to analysis for functional safety.

IEC 61508 (all parts), Annex H of IEC 60730-1:2020, ISO 13849 (all parts) or other suitable functional safety standard for the application may be used as references.

A process hazard analysis shall be made for the cell manufacturing process as well as the battery system manufacturing process, which shall be under control with evidence documented. The manufacturer should have a way to control the manufacturing process with respect to the safety hazards of the process.

NOTE The hazard analysis of production processes refers to production faults, which effect the safety of the cell or the battery (e.g. anode-cathode alignment, damaged cells, faulty connections, safety relevant deviations from the battery characteristics and its specified construction).

The risk assessment and mitigation of hazards for the battery system design shall be done by the battery system manufacturers (e.g. FTA, FMEA). This process should be done in coordination with the end-use equipment manufacturer in order to fully cover the spectrum of risks.

NOTE Guidance on safety analysis methods such as FMEA and FTA can be found in such documents as IEC 60812, IEC 61025, etc.

The procedure is as follows:

- a) hazard analysis;
- b) risk assessment;
- c) safety level target (e.g. safety integrity level (SIL) target).

NOTE The classification or level can also be according to the applied functional safety standard such as Class (e.g. class B or C) according to IEC 60730-1.

Examples of hazards or risks are as follows: EMC, electric shock, hot spots at electrical interfaces, moving parts, water immersion, external short-circuit, internal short-circuit, overcharge, overheating, drop, crush, overdischarge, discharge with overcurrent, charging after an overdischarge, electrolyte leakage, ignition of emission gas, fire, earthquake, seismic sea wave, etc.

8.2 Battery management system (or battery management unit)

8.2.1 Requirements for the BMS

The BMS evaluates the condition of cells and battery systems, and it maintains cells and battery systems within the specified cell operating region. The BMS shall be designed according to the safety integrity level (SIL) target defined in 8.1 c). Key factors of the cell operating region are voltage, temperature and current (see Figure A.1).

To evaluate the charge control that affects safety, the battery system manufacturers shall perform the tests mentioned in 8.2.2 to 8.2.4.

For these tests, the battery system includes the BMS function in the application side as well, if applicable to the design.

NOTE 1 The function of the BMS can be assigned to the battery pack or to the equipment that uses the battery system. See Figure 6.

NOTE 2 The BMS can be divided and it can be found partially in the battery pack and partially on the equipment that uses the battery system. See Figure 6.

NOTE 3 The BMS is sometimes also referred to as a BMU (battery management unit).

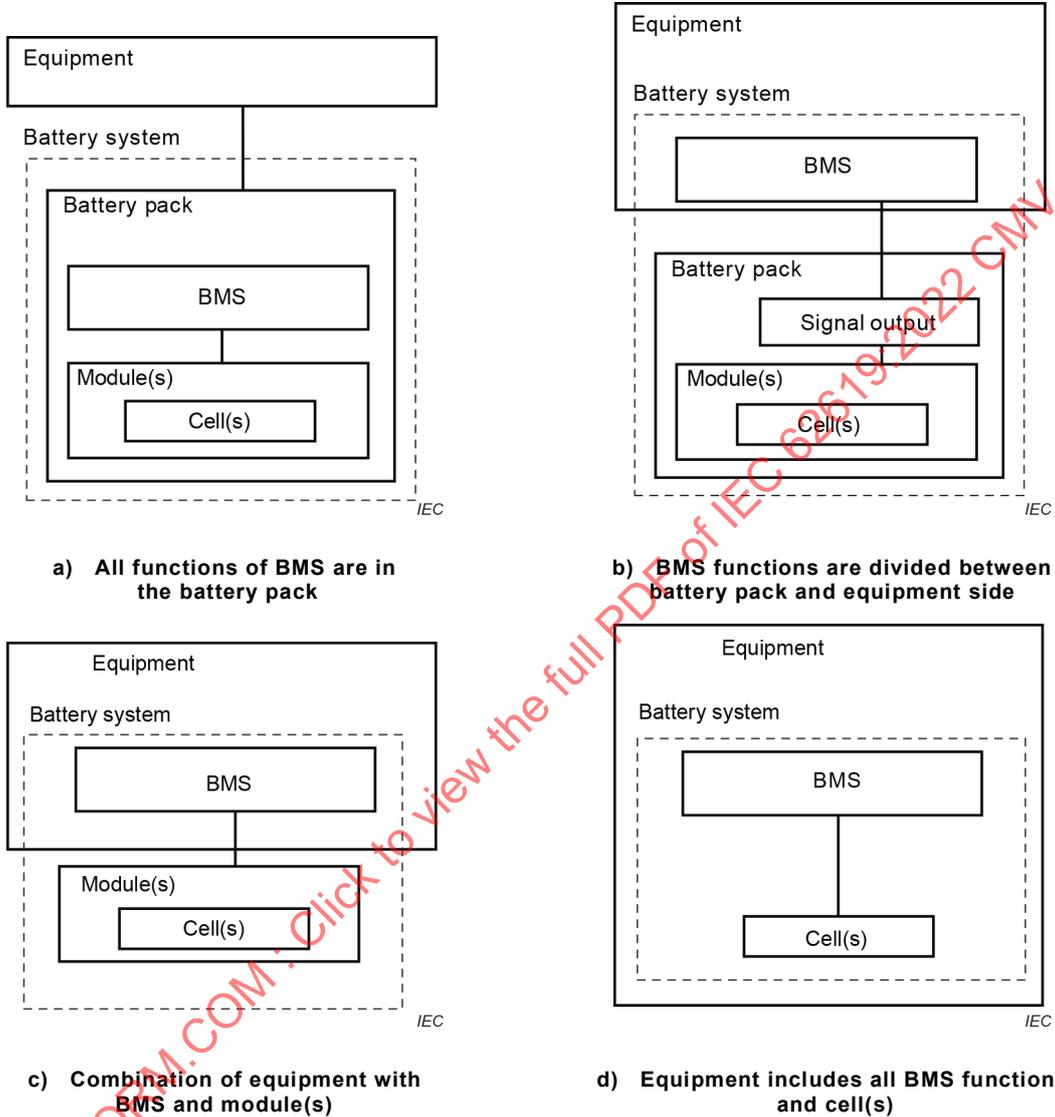


Figure 6 – Examples of BMS locations and battery system configurations

8.2.2 Overcharge control of voltage (battery system)

a) Requirement

The BMS shall control the cell voltage during charging below the upper limit charging voltage of the cells.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$ and under normal operating conditions with the cooling system (if any) operating (main contactors are closed with the battery system controlled by the BMS). Each test battery system shall be discharged at a constant current of $0,2 I_t$ A, to a final voltage specified by the manufacturer. Sample battery systems shall then be charged at the maximum current of the recommended charger with set voltage exceeding the upper limit charging voltage by 10 % for each cell in the battery system.

The excess voltage can be applied by an additional charger if it is difficult to do so by the original charger. Also the excess voltage can be applied to only a part of the system such as the cell(s) in the battery system if it is difficult to do so using the whole battery system. See Figure 7.

The test shall be carried out until the BMS terminates the charging. Data acquisition/monitoring shall be continued for 1 h after charging is stopped. During the test, all functions of the battery system shall be fully operational, as designed.

If the BMS fails to terminate the charging, the test should be stopped at the proper timing for safety reasons, for example when the cell voltage reaches 103 % of the upper limit charging voltage or 1 min after having exceeded the upper limit charging voltage, etc.

c) Acceptance criteria

BMS terminates charging before exceeding the upper limit charging voltage. No fire, no explosion.

NOTE The BMS termination of the charging current can be achieved by contactors, relays, field effect transistor (FET), circuit breakers, electromagnetic switches, etc. in main circuit.

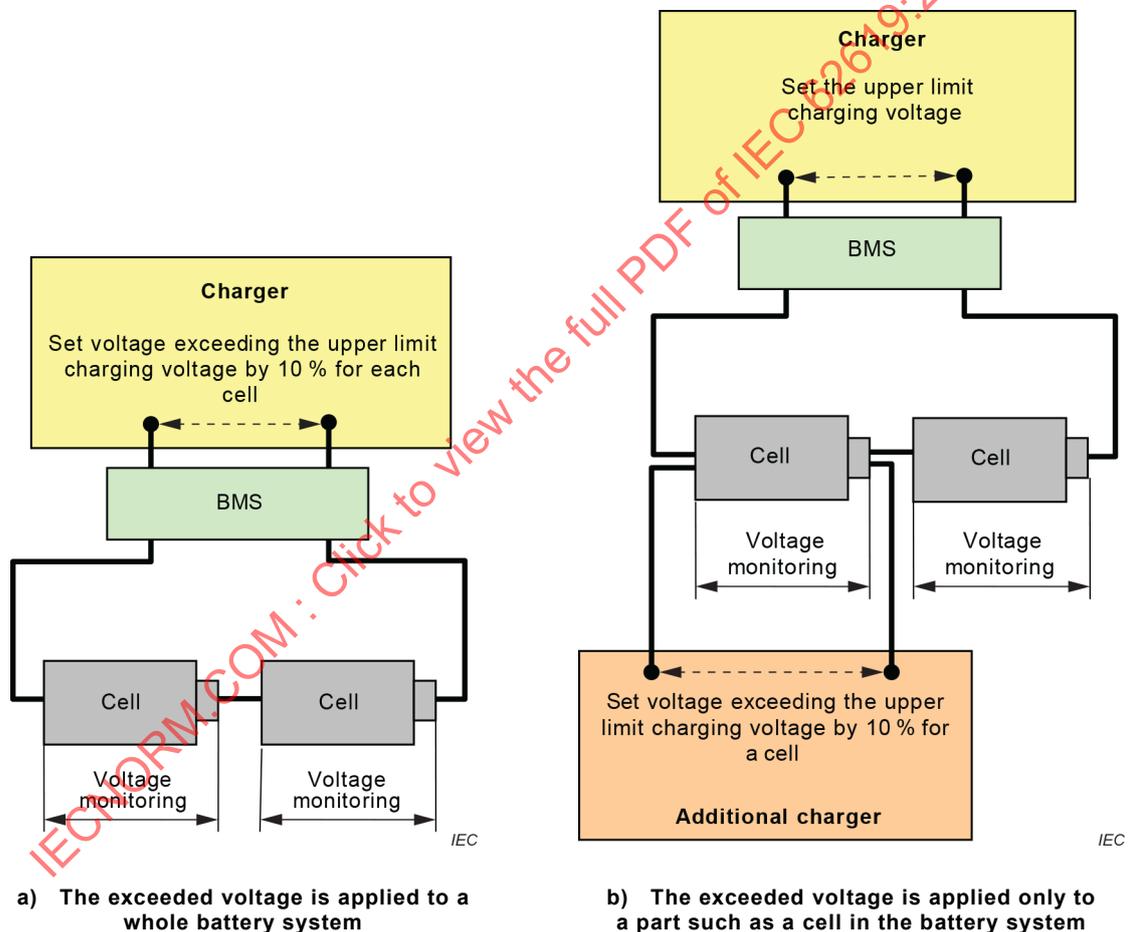


Figure 7 – Example of the circuit configuration for overcharge control of voltage

8.2.3 Overcharge control of current (battery system)

a) Requirement

If the charging current of the cells in the battery system exceeds the maximum charging current of the cells the BMS shall interrupt the charging to protect the battery system from hazards related to charging currents above the specified maximum charging current of the cells.

If the maximum ability of charging current of the upper system is lower than the maximum charging current for the battery system, this test may be waived.

b) Test

The test shall be carried out in an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$ and under normal operating conditions with the cooling system (if any) operating (main contactors closed with the battery system being controlled by the BMS). The battery system shall be discharged at a constant current of $0,2 I_t$ A, to a final voltage specified by the manufacturer. Sample battery systems shall then be charged at a current exceeding the maximum charging current by 20 %. Data acquisition and/or monitoring shall be continued for 1 h after charging is stopped. During the test, all functions of the battery system shall be fully operational as designed.

c) Acceptance criteria

The BMS shall detect the overcharging current and shall control the charging below the maximum charging current.

No fire, no explosion.

8.2.4 Overheating control (battery system)

a) Requirement

The BMS shall terminate charging when the temperature of the cells in the battery system exceeds the upper limit that is specified by the cell manufacturer.

b) Test

The test shall be carried out at an initial ambient temperature of $25\text{ °C} \pm 5\text{ °C}$ and under normal operating conditions (main contactors are closed with battery system being controlled by the BMS) with the exception that the cooling system, if provided, shall be disconnected. Each test battery system shall be discharged at a constant current of $0,2 I_t$ A, to a final voltage specified by the manufacturer. Sample battery systems shall then be charged at the recommended current to a 50 % capacity of the rated capacity. The temperature of the battery system shall be increased to 5 °C above the maximum operating temperature. The charging is continued at the elevated temperature until the BMS terminates the charging. Data acquisition/monitoring shall be continued for one hour after the sequence is stopped (e.g. the BMS has terminated charging).

c) Acceptance criteria

The BMS shall detect the overheat temperature and shall terminate charging. During the test, all functions of the battery system shall be fully operational as designed.

No fire, no explosion.

9 EMC

The battery system shall fulfil EMC requirements of the end-device application such as stationary, traction, railway, etc. or the specific requirements agreed between the end-device manufacturer and the battery system manufacturer. The EMC test may be conducted on the end-device, if feasible.

10 Information for safety

The use, and particularly abuse, of secondary lithium cells and battery systems may result in the creation of hazards and may cause harm. The cell manufacturer shall provide information about current, voltage and temperature limits of their products. The battery system manufacturer shall provide information to equipment manufacturers regarding how to mitigate hazards and, in the case of direct sales, to end-users. For example, if the battery system needs the end device to provide protection devices and/or controls, the end device manufacturer shall provide details of these protection devices that need to be provided in the installation information for the battery system. It is the responsibility of the end-device manufacturer to

inform end-users of the potential hazards arising from the use of the end-device containing the battery systems.

11 Marking and designation

Refer to Clause 5 of IEC 62620:2014.

12 Packaging and transport

Refer to Annex D.

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Annex A (normative)

Operating region of cells for safe use

A.1 General

This annex explains how to determine the operating region of the cell to ensure the safe use of the cell. This region is given to ensure the safe use of the cell and is defined as the operating region. The operating region is specified by the charging conditions such as the upper limit of charging voltage and cell temperature, which ensure the safety of cells.

The cell manufacturers should stipulate the information on the operating region in the specification of cell in the safety precautions for the attention of the customers such as the manufacturers of battery packs and systems. A suitable protection device and function should also be provided in the BMS for possible failure of the charging control.

The limits of the operating region are specified for minimum safety, and are different from the charging voltage and temperature to optimize the performance of the cell such as cycle life.

A.2 Charging conditions for safe use

In order to ensure the safe use of cells, the cell manufacturers should set the upper limit of the voltage and the temperature of cell to be applied during charging. The cell should be charged within a predefined temperature range (standard temperature range) at a voltage not exceeding the upper limit. The cell manufacturer may also set a temperature range higher or lower than the standard temperature range, provided that the safety measures, such as lowered charging voltage, are taken. The operating region means such range of voltage and temperature where the cell can be used safely. The maximum charging current may also be set for the operating region.

The same operating region can apply to a newly developed cell, if it has the same electrode material, thickness, design, and separator as the original cell, and less than 120 % of the rated capacity of the original cell. The new cell that meets these criteria can be considered as the same product series cell.

A.3 Considerations on charging voltage

The charging voltage is applied to cells so as to promote the chemical reaction during charging. However, if the charging voltage is too high, excessive chemical reactions or side reactions occur, and the cell becomes thermally unstable. Consequently, it is most important that the charging voltage never exceeds the value specified by the cell manufacturer (i.e. the upper limit charging voltage). When a cell is charged at a higher voltage than the upper limit charging voltage, an excess amount of lithium ion is deintercalated from the positive electrode active material, and its crystalline structure tends to collapse. In these conditions, when an internal short-circuit occurs, thermal runaway can more easily occur than it does for cells charged in the predefined operating region. Consequently, the cells shall never be charged at a higher voltage than the upper limit charging voltage.

The upper limit charging voltage should be set by the cell manufacturer based on the verification tests, showing the results, for example, as follows:

- test results which verify the stability of the crystalline structure of the positive material;
- test results which verify the acceptance of lithium ions into the negative electrode active material when the cell is charged at the upper limit charging voltage;

- test results which verify that the cells charged at the upper limit charging voltage are tested by the safety test in Clause 6 at the upper limit of the standard temperature range, and the acceptance criteria of each test are met.

A.4 Considerations on temperature

Charging produces a chemical reaction and is affected by temperature. The amount of side reactions or the condition of the reaction products during charging is dependent on temperature. Charging in low or high temperature ranges is considered to cause more side reactions, and is of a higher level of severity from a safety viewpoint, than in the standard temperature range where the upper limit charging voltage is safely applicable. Consequently, the charging voltage and/or the charging current should be reduced from the upper limit charging voltage and/or the maximum charging current in both the low temperature range and the high temperature range.

A.5 High temperature range

When a cell is charged at a higher temperature than the standard temperature range, the safety performance of the cell tends to decrease due to lower stability of the crystalline structure. Also, in the high temperature range, the thermal runaway tends to occur even with small changes in temperature.

As a result, the charging of cells in the high temperature range should be controlled as follows:

- when the surface temperature of the cell is within the high temperature range specified by the cell manufacturer, specific charging conditions, such as lower charging voltage and current, are applied;
- when the surface temperature of cell is higher than the upper limit of the high temperature range, the cell should never be charged under any charging current.

A.6 Low temperature range

When a cell is charged in the low temperature range, the mass transfer rate decreases and the lithium ion insertion rate into the negative material becomes low. Consequently, metallic lithium is easy to deposit on the negative electrode surface. In this condition, the cell becomes thermally unstable and liable to become overheated and to cause the thermal runaway. Also, in the low temperature range, the acceptance of lithium ions is highly dependent on the temperature. In a lithium battery system that consists of multi-cells in a series connection, the lithium ion acceptability of each cell differs depending on the cell temperature, which reduces the safety of battery system.

As a result, the charging of cells in the low temperature range should be controlled as follows:

- when the surface temperature of the cell is within the low temperature range specified by the cell manufacturer, specific charging conditions, such as lower charging voltage and current, are applied;
- when the surface temperature of the cell is below the lower limit of the lower temperature range, the cell should never be charged under any charging current.

A.7 Discharging conditions for safe use

The main parameters to ensure safety during discharging are voltage, current, and temperature. Voltage should always be above the lower limit discharging voltage of the cell. Current should never exceed the maximum current specified by the cell manufacturer. The temperature should always be within the temperature limits (low and high limits). The cell voltage should be controlled above the lower limit discharging voltage of the cell to avoid unexpected critical failure. In addition, a cut off voltage above the lower limit discharging voltage is specified by the cell manufacturer in order to keep a proper margin for the cell operating region and to optimize performance of the cell.

A.8 Example of operating region

Figure A.1 illustrates a typical example of an operating region for charging. In a temperature range higher or lower than the standard temperature range, it is permissible to charge the cell provided that a lower charging voltage and/or current are used. The operating range can be specified with a step shape which is shown in Figure A.1, or with diagonal lines. Figure A.2 illustrates an example of an operating region for discharging.

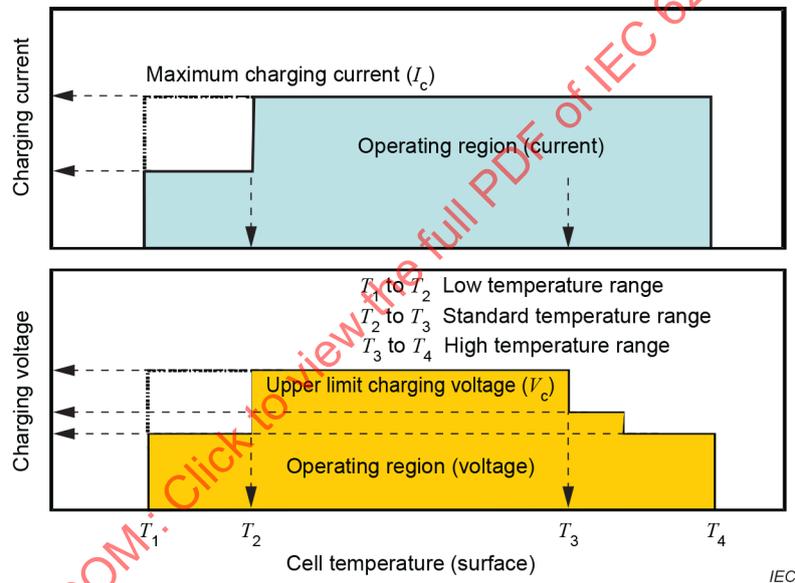


Figure A.1 – An example of operating region for charging of typical lithium ion cells

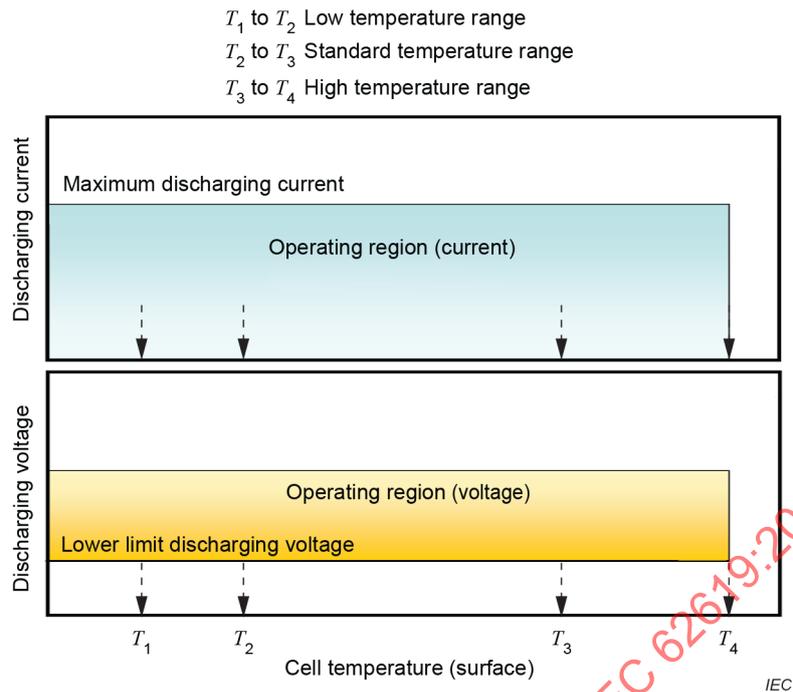


Figure A.2 – An example of operating region for discharging of typical lithium ion cells

Annex B (informative)

Procedure of propagation test by laser irradiation (see 7.3.3)

B.1 General

This annex gives an example method for the 7.3.3 propagation test by laser. The testing entity should contact the cell or battery system manufacturer to get a detailed procedure for the cell thermal runaway.

NOTE The purpose of this test is not an evaluation of a single cell but an evaluation of propagation behaviour of the battery system. Therefore, the following methods which create thermal runaway do not simulate internal short-circuit of the cell, but a propagation trigger.

B.2 Test conditions

B.2.1 Cell test (preliminary test)

- 1) The cell is fully charged according to the manufacturer specified conditions.
- 2) Place thermocouples onto the cell to measure the surface temperature. It is better to use multiple thermocouples for redundant data acquisition.
- 3) Fix the cell onto the test bench (see Figure B.1). The irradiation point on the cell should be determined by considering the structure of the battery system supplied in the main test.
- 4) The laser irradiation program and its work should be set and confirmed. It is better to prepare covers to prevent damage to laser systems when the cell enters into thermal runaway and vent.
- 5) Prepare and set the measurement equipment for the cell temperature measurement, etc.
- 6) Set the ambient temperature at $25\text{ °C} \pm 5\text{ °C}$. The temperature controller such as air conditioning system should have the ability to maintain the ambient temperature until the cell temperature reaches the maximum temperature.
- 7) Irradiate the cell with the laser at the determined point. Measure the cell temperature continuously from the irradiation start to the observation end.
- 8) When rapid temperature increase is observed due to cell thermal runaway, the laser is turned off (see Figure B.2).
- 9) Observe the cell temperatures and appearance until the cell temperature decreases enough for safe handling.
- 10) Review the temperature profile to confirm the thermal runaway event.
- 11) The cell test should be repeated 3 times. If thermal runaway is confirmed on each test with the same conditions, go to the battery system test with the same irradiation condition.

NOTE 1 The laser type can be chosen from material process lasers such as cutting, welding or hardening. There are the CO₂ laser, YAG laser, semiconductor laser, disk laser, fibre laser, and so on.

NOTE 2 The laser parameters are set such that the cell enters the thermal runaway within 10 min because longer irradiation can cause unnecessary heat-up of surrounding cells and/or battery system.

The test should be performed in a well-ventilated environment to avoid vent gas effects from the cell.

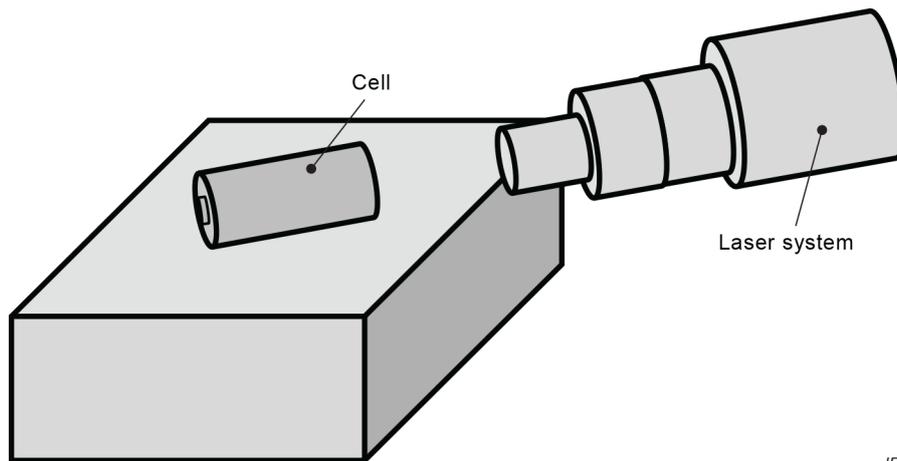


Figure B.1 – Example of the test layout

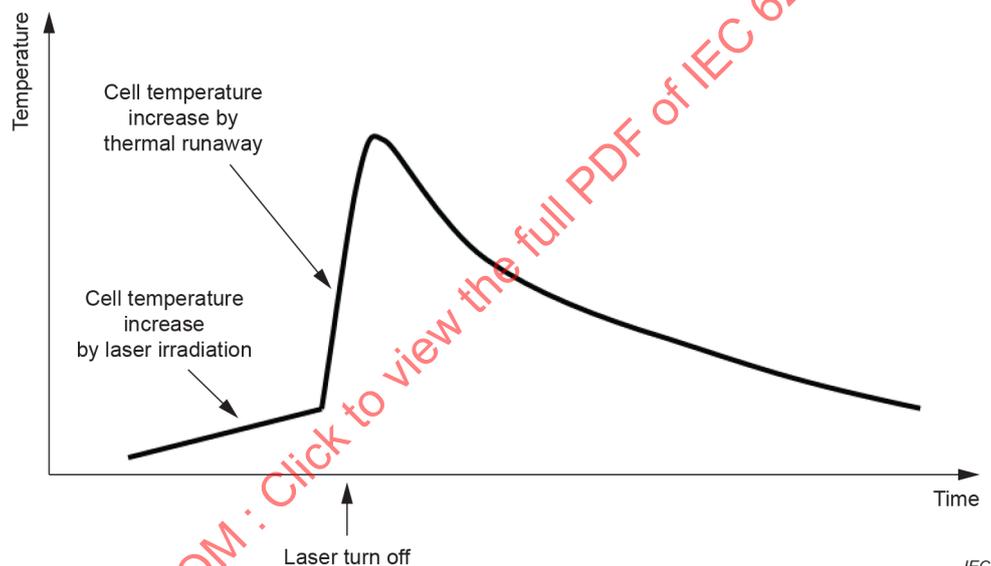


Figure B.2 – Example of typical temperature trend of the cell

B.2.2 Battery system test (main test)

- 1) The battery system is fully charged according to the manufacturer specified conditions.
- 2) Place the thermocouples onto the cells to measure the surface temperature. It is better to use multiple thermocouples for redundant data acquisition.
- 3) Fix the battery system onto the test bench. The laser path should be considered prior to testing and the irradiation point on the target cell should be the same or similar as that on the cell test.
- 4) The laser irradiation program and its work should be set and confirmed. It is better to prepare covers to prevent damage to the laser systems when the target cell enters into thermal runaway and vents.
- 5) Prepare and set the measurement equipment for cell temperature measurement, etc.
- 6) Set the ambient temperature at $25\text{ °C} \pm 5\text{ °C}$. The temperature controller such as an air conditioning system should have the ability to maintain the ambient temperature until the target cell temperature reaches the maximum temperature.

- 7) Irradiate the target cell with the laser at the determined point. Measure the cell's temperature continuously from irradiation start to observation end.
- 8) When rapid temperature increase due to cell thermal runaway is observed, the laser is turned off.
- 9) Observe the cell's temperatures and the battery system appearance for a minimum of 1 h. It is better to observe them until the cell's temperature decreases enough for safe handling.

The test should be performed in a well-ventilated environment to avoid vent gas effect from the target cell and/or the other cells.

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Annex C (informative)

Procedure of propagation test by methods other than laser (see 7.3.3)

C.1 General

The method for developing a thermal runaway of the cell is by using a laser as described in 7.3.3 and Annex B. However other methods can be chosen from the candidate methods identified in Clause C.3 below. The testing entity should contact the cell or battery system manufacturer to get a detailed procedure for the cell thermal runaway.

NOTE The purpose of this test is not an evaluation of a single cell but an evaluation of propagation behaviour inside the battery system. Therefore, the following methods which create thermal runaway do not simulate internal short-circuit of the cell, but a propagation trigger.

C.2 Test conditions

- 1) The battery system is fully charged according to the manufacturer-recommended conditions.
- 2) One cell in the battery system (hereafter called target cell) is intended to be entered into thermal runaway as a trigger of the test. When the battery system contains three or more cells, end cells in the battery system configuration may not be chosen as the target cell, i.e. the target cell has at least two other cells nearby.
- 3) This test can be carried out with a specially prepared sample, which may have a heater or a hole for nail penetration provided for ease of testing. However the special feature provided for ease of testing should not affect the heat diffusion of the battery system.

C.3 Methods for initiating the thermal runaway

Methods for initiating the thermal runaway can include the following.

1) Heating

The target cell is heated by the following methods. Each method should heat only the target cell. The heat source should be turned off when the target cell is entered into thermal runaway.

- Heating by heater
- Heating by burner
- Heating by inductive heating

2) Overcharge

The target cell is overcharged with the manufacturer-recommended conditions until the target cell is entered into thermal runaway. Any other cells in the battery system shall not be overcharged. If the cell is designed to have a current interrupt device (CID), a cell whose CID was altered to be non-functional may be used.

3) Nail penetration of the cell

The target cell is penetrated with a nail to create a short circuit between the positive and negative electrodes. The nail may be heated prior to the test.

4) Combination of the methods in 1) to 3) above.

5) Other method(s) which are determined to be appropriate method(s) by theory and supporting data.

Annex D (informative)

Packaging and transport

The goal of packaging of secondary cells and battery systems for transport is to prevent opportunities for short-circuit, mechanical damage and possible ingress of moisture. The materials and packaging design should be chosen so as to prevent the development of unintentional electrical conduction, corrosion of the terminals and ingress of environmental contaminants.

Lithium ion cells, modules, battery packs, and battery systems are regulated by the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), the International Maritime Organization (IMO) and other international organizations and/or government agencies.

Regulations concerning international transport of secondary lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods. Testing requirements are defined in the UN Manual of Tests and Criteria. As regulations are subject to change, the latest editions should be consulted.

For reference, transportation tests are also given in IEC 62281.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**ACCUMULATEURS ALCALINS ET AUTRES ACCUMULATEURS
À ÉLECTROLYTE NON ACIDE –
EXIGENCES DE SÉCURITÉ POUR LES ACCUMULATEURS AU LITHIUM
POUR UTILISATION DANS DES APPLICATIONS INDUSTRIELLES**

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La Norme internationale IEC 62619 a été établie par le sous-comité 21A: Accumulateurs alcalins et autres accumulateurs à électrolyte non acide, du comité d'études 21 de l'IEC: Accumulateurs. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2017. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) de nouvelles exigences pour les pièces mobiles;
- b) l'ajout d'exigences pour les parties actives dangereuses;
- c) l'ajout d'exigences pour la conception du système de batterie;
- d) de nouvelles exigences relatives au verrouillage système;
- e) de nouvelles exigences relatives à la CEM;
- f) l'ajout de la procédure d'essai de propagation par laser.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
21A/785/FDIS	21A/787/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Le comité a décidé que le contenu du présent document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
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ACCUMULATEURS ALCALINS ET AUTRES ACCUMULATEURS À ÉLECTROLYTE NON ACIDE – EXIGENCES DE SÉCURITÉ POUR LES ACCUMULATEURS AU LITHIUM POUR UTILISATION DANS DES APPLICATIONS INDUSTRIELLES

1 Domaine d'application

Le présent document spécifie les exigences et les essais pour le fonctionnement en toute sécurité des accumulateurs au lithium utilisés dans des applications industrielles, y compris les applications stationnaires.

Lorsqu'il existe une Norme internationale IEC qui spécifie des conditions d'essai et des exigences pour des éléments destinés à des applications particulières, et qui est en contradiction avec le présent document, la publication particulière est appliquée en priorité (par exemple, la série IEC 62660 sur les véhicules routiers).

Ci-après figurent des exemples d'applications qui emploient les éléments et les batteries inclus dans le domaine d'application du présent document :

- applications stationnaires: télécommunications, alimentation sans interruption (ASI), système de stockage d'énergie électrique, sélecteur de service, alimentation de secours et applications similaires;
- applications mobiles: chariot élévateur à fourche, voiturette de golf, véhicule à guidage automatique (AGV, automated guided vehicle), véhicules ferroviaires et marins, à l'exclusion des véhicules routiers.

Étant donné que le présent document couvre les batteries destinées à différentes applications industrielles, il inclut les exigences qui sont communes et minimales pour les différentes applications.

La sécurité électrique est incluse uniquement dans le cadre de l'analyse des risques de l'Article 8. Concernant les informations détaillées en matière de sécurité électrique, il est nécessaire de prendre en considération les exigences normalisées relatives à l'application finale.

Le présent document s'applique aux éléments et aux batteries. Si la batterie est divisée en unités plus petites, l'unité plus petite peut être soumise à l'essai pour représenter la batterie. Le fabricant déclare clairement l'unité soumise à l'essai. Il peut ajouter des fonctions, qui sont présentes dans la batterie finale, à l'unité soumise à l'essai.

Le présent document traite de la première vie des éléments et des batteries. La réutilisation, la réaffectation, l'utilisation dans le cadre d'une seconde vie ou d'autres utilisations similaires ne sont pas prises en considération dans le présent document.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 62133-2:2017, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs portables étanches, et pour les batteries qui en sont constituées, destinés à l'utilisation dans des applications portables – Partie 2: Systèmes au lithium*

IEC 62620:2014, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Éléments et batteries d'accumulateurs au lithium pour utilisation dans les applications industrielles*

Guide ISO/IEC 51, *Aspects liés à la sécurité – Principes directeurs pour les inclure dans les normes*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions du Guide ISO/IEC 51, ainsi que les suivants, s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.1

sécurité

absence de tout risque inacceptable

3.2

risque

combinaison de la probabilité de la survenue d'un dommage et de sa gravité

[SOURCE: Guide ISO/IEC 51:2014, 3.9, modifié - suppression de la Note 1 à l'article.]

3.3

dommage

blessure physique ou atteinte à la santé des personnes, ou atteinte aux biens ou à l'environnement

[SOURCE: Guide ISO/IEC 51:2014, 3.1]

3.4

danger

source potentielle de dommage

[SOURCE: Guide ISO/IEC 51:2014, 3.2]

3.5 utilisation prévue

utilisation d'un produit, procédé ou service conformément aux spécifications, aux instructions et aux informations données par le fournisseur

3.6 mauvais usage raisonnablement prévisible

utilisation d'un produit, procédé ou service dans des conditions ou à des fins non prévues par le fournisseur, mais qui peut provenir d'un comportement humain envisageable

[SOURCE: Guide ISO/IEC 51:2014, 3.7, modifié - "ou système" a été remplacé par "procédé ou service" et les notes à l'article ont été supprimées]

3.7 élément d'accumulateur au lithium élément

élément d'accumulateur dont l'énergie électrique provient des réactions d'insertion/d'extraction d'ions lithium ou des réactions d'oxydoréduction du lithium entre l'électrode négative et l'électrode positive

Note 1 à l'article: L'élément comprend généralement un électrolyte qui est généralement constitué d'un composé de sel de lithium et de solvant organique sous forme liquide, gel ou solide et possède un boîtier en métal ou en stratifié. Il est impropre à l'utilisation pour une application, car il n'est pas encore équipé de son habillage final, ni de ses bornes et de dispositif de contrôle électronique.

3.8 bloc d'éléments

groupe d'éléments connectés ensemble en parallèle avec ou sans dispositif de protection (fusible ou dispositif à coefficient de température positif (CTP), par exemple) et circuit de surveillance

Note 1 à l'article: Le bloc d'éléments est impropre à l'utilisation pour une application, car il n'est pas encore équipé de son habillage final, ni de ses bornes et de dispositif de contrôle électronique.

3.9 module

groupe d'éléments connectés ensemble en série et/ou en parallèle avec ou sans dispositif de protection (fusible ou dispositif à coefficient de température positif (CTP), par exemple) et circuit de surveillance

3.10 groupe batteries

dispositif de stockage de l'énergie, qui comprend un ou plusieurs éléments ou modules reliés électriquement et inclut des circuits de surveillance qui fournissent des informations (par exemple, la tension d'un élément) à un système de batterie pour améliorer la sécurité, les performances et la durée de vie en service de la batterie

Note 1 à l'article: Le groupe batteries peut comporter un boîtier de protection et être équipé de bornes ou autres dispositions d'interconnexion.

3.11 système de batterie batterie

système composé d'un ou plusieurs éléments, modules ou groupes batteries et inclut un système de gestion de batterie capable de contrôler le courant en cas de surcharge, de surintensité, de décharge excessive et de surchauffe

Note 1 à l'article: La coupure après décharge excessive n'est pas obligatoire en cas d'accord entre le fabricant de l'élément et le client.

Note 2 à l'article: Le système de batterie peut être équipé d'unités de refroidissement ou de chauffage. Plusieurs systèmes de batteries peuvent constituer un autre système de batterie plus important. Le système de batterie est parfois également appelé batterie.

3.12 **système de gestion de batterie** **BMS**

système électronique associé à une batterie capable de contrôler le courant en cas de surcharge, de surintensité, de décharge excessive et de surchauffe et qui surveille et/ou gère son état, calcule les données secondaires, signale ces données et/ou contrôle son environnement afin d'influencer la sécurité, les performances et/ou la durée de vie en service de la batterie

Note 1 à l'article: La coupure après décharge excessive n'est pas obligatoire en cas d'accord entre le fabricant de l'élément et le client.

Note 2 à l'article: La fonction du BMS peut être attribuée à un groupe batteries ou au matériel qui utilise la batterie. (Voir la Figure 6.)

Note 3 à l'article: Le BMS peut être divisé et peut se trouver partiellement dans le groupe batteries et sur le matériel qui utilise la batterie. (Voir la Figure 6.)

Note 4 à l'article: Le BMS est parfois également appelé BMU (battery management unit - unité de gestion de batterie).

Note 5 à l'article: L'abréviation "BMS" est dérivée du terme anglais développé correspondant "battery management system".

3.13 **fuite** perte visible d'électrolyte liquide

3.14 **échappement de gaz** libération de pression interne excessive d'un élément, d'un module, d'un groupe batteries ou d'un système de batterie conçue pour prévenir la rupture ou l'explosion

3.15 **rupture** défaillance mécanique d'un bac d'élément ou d'un boîtier de batterie induite par une cause interne ou externe, qui conduit à une exposition des matériaux ou à l'échappement de liquide, mais non à une éjection de matériaux

3.16 **explosion** défaillance qui se produit lorsqu'un bac d'élément ou un boîtier de batterie s'ouvre violemment et que les composants solides sont éjectés de manière violente

Note 1 à l'article: Du liquide, du gaz et de la fumée sont exclus.

3.17 **feu** émission de flammes d'un élément, d'un module, d'un groupe batteries ou d'un système de batterie pendant plus d'une seconde.

Note 1 à l'article: Les étincelles et la production d'arcs électriques ne sont pas considérées comme des flammes

3.18 **capacité assignée** valeur de la capacité d'un élément ou d'une batterie déterminée dans des conditions spécifiées et déclarées par le fabricant

Note 1 à l'article: La capacité assignée est la quantité d'électricité C_n Ah (ampères-heures) déclarée par le fabricant, qu'un élément individuel ou une batterie est capable de restituer en n h après charge, repos et décharge, dans les conditions spécifiées en 6.3.1 de l'IEC 62620:2014.

[SOURCE: IEC 60050-482:2004, 482-03-15, modifié – Ajout de la Note 1 à l'article.]

3.19

limite supérieure de la tension de charge

<de l'élément> tension de charge la plus élevée dans la plage de fonctionnement de l'élément, spécifiée par le fabricant de l'élément

3.20

limite inférieure de la tension de décharge

<de l'élément> tension de décharge la plus basse dans la plage de fonctionnement de l'élément, spécifiée par le fabricant de l'élément

3.21

courant de charge maximum

<de l'élément> courant de charge le plus élevé dans la plage de fonctionnement de l'élément, spécifiée par le fabricant de l'élément

3.22

courant de décharge maximum

<de l'élément> courant de décharge le plus élevé dans la plage de fonctionnement de l'élément, spécifiée par le fabricant de l'élément

3.23

emballement thermique

accroissement important et incontrôlé de la température d'un élément entraîné par une réaction exothermique

4 Tolérances de mesure relatives aux paramètres

L'exactitude globale des valeurs contrôlées ou mesurées, par rapport aux paramètres spécifiés ou réels, doit respecter les tolérances suivantes:

- a) $\pm 0,5$ % pour la tension;
- b) ± 1 % pour le courant;
- c) ± 2 °C pour la température;
- d) $\pm 0,1$ % pour le temps;
- e) ± 1 % pour la masse;
- f) ± 1 % pour les dimensions.

Ces tolérances comprennent l'exactitude combinée des appareils de mesure, des techniques de mesure utilisées et de toutes les autres sources d'erreur liées à la méthode d'essai.

Les informations détaillées relatives aux appareils utilisés doivent être fournies dans chaque rapport de résultats.

5 Considérations générales de sécurité

5.1 Généralités

La sécurité des éléments et des systèmes de batteries d'accumulateurs au lithium exige la prise en considération de deux ensembles de conditions d'utilisation:

- 1) utilisation prévue;
- 2) mauvais usage raisonnablement prévisible.

Les éléments et les systèmes de batteries doivent être conçus et construits de manière telle qu'ils soient sûrs dans les conditions d'utilisation prévue et dans les conditions de mauvais usage raisonnablement prévisible. Par ailleurs, les éléments et les systèmes de batteries utilisés dans les conditions d'utilisation prévue doivent non seulement être sûrs, mais doivent aussi continuer à être fonctionnels en tous points.

Il est admis que les éléments ou systèmes de batteries soumis à un mauvais usage puissent être défectueux. Toutefois, même si ce type de situation se produit, ils ne doivent pas présenter de dangers significatifs.

Les dangers potentiels qui font l'objet du présent document sont:

- a) le feu;
- b) l'éclatement/l'explosion;
- c) une fuite de l'électrolyte d'un élément;
- d) l'échappement de gaz qui produit en continu des gaz et/ou de la fumée inflammables et/ou toxiques;
- e) la rupture du boîtier de l'élément, du module, du groupe batteries ou du système de batterie avec exposition des composants internes.

La conformité aux spécifications de 5.1 a) et b) est vérifiée par les essais de l'Article 6, l'Article 7 et du 8.2, et conformément à la norme appropriée (voir l'Article 0). La conformité aux spécifications de 5.1 c) à e) et de 5.2 à 5.6 est vérifiée par les analyses des documents mentionnées en 8.1.

Les parties mobiles potentiellement dangereuses pour l'homme doivent bénéficier d'une conception adaptée et des mesures nécessaires afin de réduire le risque de blessures, y compris les blessures qui peuvent être subies lors de l'installation, au cours de l'intégration des éléments ou des systèmes de batteries à l'équipement.

5.2 Isolement et câblage

Le câblage interne et son isolement doivent être suffisants pour satisfaire aux exigences maximales prévisibles de tension, de courant, de température, d'altitude et d'humidité. La conception du câblage interne doit être telle que les distances adéquates d'isolement et les lignes de fuite soient maintenues entre les conducteurs et les parties actives soumises à différentes tensions ou entre les parties actives et les parties qui ne sont pas sous tension. Les parties actives dangereuses du système de batterie doivent être protégées afin d'éviter tout risque de choc électrique, y compris lors de l'installation.

L'intégrité mécanique de l'ensemble du système de batterie (élément/module/BMS) et de ses connexions doit être suffisante pour satisfaire aux conditions de mauvais usage raisonnablement prévisibles.

5.3 Échappement de gaz

Le boîtier d'un élément, d'un module, d'un groupe batteries et d'un système de batterie doit intégrer un mécanisme de libération de pression qui prévient toute rupture ou explosion. Si le surmoulage est utilisé pour maintenir les éléments dans un boîtier extérieur, le type de matériau et la méthode de surmoulage ne doivent entraîner ni une surchauffe du système de batterie en fonctionnement normal, ni le blocage du mécanisme de libération de pression.

5.4 Gestion de la température, de la tension et du courant

La conception des systèmes de batteries doit être de nature à prévenir tout échauffement anormal. Les systèmes de batteries doivent être conçus dans les limites de tension, de courant et de température spécifiées par le fabricant de l'élément. Les systèmes de batteries doivent être accompagnés de spécifications et d'instructions de charge pour les fabricants de matériel, de façon à concevoir les chargeurs associés en maintenant la charge dans les limites spécifiées de tension, de courant et de température.

5.5 Contacts des bornes du groupe batteries et/ou du système de batterie

Les bornes doivent avoir un ou des marquages clairs de polarité sur la surface externe du groupe batteries ou du système de batterie.

Les groupes batteries avec connecteurs extérieurs à détrompeur conçus pour être connectés à des produits finaux spécifiques n'ont pas besoin de porter de marquages de polarité si la conception du connecteur extérieur empêche les connexions avec inversion de polarité.

La taille et la forme des contacts des bornes doivent permettre de transporter le courant maximal prévu. Les surfaces de contact des bornes externes doivent être constituées de matériaux conducteurs, avec une bonne résistance mécanique et une bonne résistance à la corrosion. Les contacts des bornes doivent être disposés de manière à réduire le plus possible le risque de court-circuit (dû par exemple à des outils en métal). La conformité est déterminée en réalisant une revue des spécifications des bornes.

5.6 Assemblage d'éléments, de modules ou de groupes batteries dans des systèmes de batteries

5.6.1 Généralités

L'assemblage d'éléments, de modules ou de groupes batteries qui constituent un système de batterie doit respecter les règles suivantes afin d'assurer un support adéquat d'atténuation des risques dans le système de batterie:

- chaque système de batterie doit présenter une ou des méthodes de commande et de protection indépendantes;

NOTE Pour de plus amples informations sur les méthodes de commande et de protection indépendantes, voir 8.2.

- le fabricant d'éléments doit donner des recommandations concernant les limites de courant, de tension et de température. Il convient également qu'il fournisse des conseils concernant le montage, le stockage et le nombre maximal d'éléments qu'il est possible d'installer en série (pour la protection interne d'éléments, comme le dispositif d'interruption du courant (CID – current interrupt device) pour permettre au fabricant/concepteur du système de batterie d'assurer une conception et un assemblage convenables;
- les systèmes de batteries conçus pour la décharge sélective d'une partie de leurs éléments connectés en série doivent comporter des circuits séparés qui permettent d'éviter l'inversion des éléments provoquée par une décharge inégale;
- il convient d'ajouter, si nécessaire, des composants aux circuits de protection et de tenir compte de l'application du dispositif final.

5.6.2 Conception du système de batterie

La fonction de réglage de tension de la conception du système de batterie doit garantir que la tension de chaque élément ou bloc d'éléments ne doit pas dépasser la limite supérieure de la tension de charge spécifiée par le fabricant des éléments, sauf dans le cas où les dispositifs finaux assurent la fonction de réglage de tension. Dans ce cas, les dispositifs finaux sont considérés comme partie intégrante du système de batterie. Voir les Notes 2 et 3 en 3.12.

La batterie doit être conçue de sorte que le courant de charge maximum ou le courant de décharge maximum de l'élément ne soit pas dépassé avant que la batterie n'atteigne le courant de charge ou de décharge maximum admis.

5.7 Plage de fonctionnement des éléments et systèmes de batteries au lithium pour une utilisation en toute sécurité

Le fabricant de l'élément doit spécifier la plage de fonctionnement de l'élément. Le fabricant du système de batterie doit concevoir le système de batterie en fonction de la plage de fonctionnement de l'élément. La détermination de la plage de fonctionnement de l'élément est conforme à l'Annexe A.

5.8 Verrouillage système (ou fonction de verrouillage système)

Le système de batterie doit disposer d'une fonction sans réarmement pour arrêter le fonctionnement lorsqu'un ou plusieurs éléments dans le système de batterie s'écartent de la plage de fonctionnement en cours de fonctionnement. Cette fonction ne doit pas pouvoir être réalisée par l'utilisateur ou permettre une réinitialisation automatique.

La fonction du système de batterie peut être relancée après avoir vérifié que le statut du système de batterie est conforme au manuel du fabricant du système de batterie, c'est-à-dire, que le manuel d'entretien du système de batterie doit clairement mentionner cette procédure.

En fonction de l'application, un système de batterie peut permettre une décharge finale, par exemple, pour assurer des fonctions d'urgence. Dans ce cas, les limites de l'élément (par exemple, limite inférieure de la tension de décharge ou limite supérieure de température) peuvent varier dans la plage assurant que l'élément ne provoque pas de réactions dangereuses. Par conséquent, le fabricant de l'élément doit indiquer un deuxième ensemble de limites selon lequel l'élément dans le système de batterie peut accepter une décharge sans réactions dangereuses. Il convient de ne plus recharger l'élément.

5.9 Plan qualité

Le fabricant de systèmes de batteries doit préparer et mettre en œuvre un plan qualité qui définit les procédures d'examen des matériaux, des composants, des éléments, des modules, des groupes batteries et des systèmes de batteries, et qui couvre l'ensemble du processus de production de chaque type d'élément, de module, de groupe batteries et de système de batterie (par exemple, ISO 9001, etc.). Il convient que les fabricants comprennent leurs capacités de traitement et il convient qu'ils mettent en place les contrôles de processus nécessaires concernant la sécurité des produits.

6 Conditions des essais de type

6.1 Généralités

Un élément de système de batterie utilisé hors de sa plage de fonctionnement peut présenter des dangers résultant des éléments ou des systèmes de batteries. Ces risques doivent être pris en considération afin de préparer un plan d'essai sûr.

Il convient que l'installation d'essai présente une intégrité de structure suffisante et soit équipée d'un système d'extinction du feu de manière à supporter les conditions de surpression et de feu qui peuvent se produire du fait des essais. Il convient que l'installation soit équipée d'un système de ventilation qui vise à éliminer et emprisonner les gaz qui peuvent être produits pendant les essais. Il convient de tenir compte, le cas échéant, des dangers de haute tension.

Mise en garde: CES ESSAIS UTILISENT DES MÉTHODES QUI PEUVENT CONDUIRE À DES DOMMAGES SI DES PRÉCAUTIONS APPROPRIÉES NE SONT PAS PRISES. IL CONVIENT QUE LES ESSAIS NE SOIENT RÉALISÉS QUE PAR DES TECHNICIENS EXPÉRIMENTÉS ET QUALIFIÉS, UTILISANT UNE PROTECTION ADAPTÉE. POUR ÉVITER LES BRÛLURES, IL CONVIENT DE PRENDRE DES PRÉCAUTIONS, CAR LES BOÎTIERS DE CES ÉLÉMENTS OU DE CES SYSTÈMES DE BATTERIES PEUVENT DÉPASSER 75 °C DU FAIT DE L'ESSAI.

6.2 Éléments soumis à l'essai

Les essais sont effectués avec le nombre d'éléments ou de systèmes de batteries spécifié dans le Tableau 1, en utilisant des éléments ou des systèmes de batteries stockés dans des conditions spécifiées par le fabricant de l'élément ou du système de batterie depuis moins de six mois.

Les éléments ou systèmes de batterie chargés selon la méthode spécifiée en 7.1 doivent délivrer au moins la capacité assignée en cas de décharge à $25\text{ °C} \pm 5\text{ °C}$, selon l'IEC 62620:2014, 6.3.1, à un courant constant de $0,2 I_t$ A, selon l'IEC 62620:2014, 6.3.1, jusqu'à une tension finale spécifiée. Cette capacité peut être confirmée lors de l'examen d'expédition du fabricant de l'élément. Dans le cas d'un système de batterie, la capacité peut être calculée sur la base de la capacité de l'élément mesurée pendant l'examen d'expédition du fabricant de l'élément.

Sauf spécification contraire, les essais sont effectués à une température ambiante de $25\text{ °C} \pm 5\text{ °C}$.

NOTE Les conditions d'essai s'appliquent seulement aux essais de type et n'impliquent pas que l'utilisation prévue comprenne un fonctionnement dans ces conditions. De la même façon, la limite des six mois est introduite dans un souci de cohérence et n'implique pas que la sécurité de l'élément ou du système de batterie soit réduite après six mois.

Tableau 1 – Effectif d'échantillon pour les essais de type

Éléments soumis à l'essai		Unité d'essai	
Catégorie	Essai	Élément (voir a)	Système de batterie (voir b et e)
Essai de sécurité du produit (sécurité de l'élément et du système de batterie)	7.2.1 Essai de court-circuit externe	R	-
	7.2.2 Essai de choc	R (voir c)	-
	7.2.3 Essai de chute	R	R
	7.2.4 Essai de température abusive	R	-
	7.2.5 Essai de surcharge	R (voir d)	-
	7.2.6 Essai de décharge forcée	R	-
	7.3 Considérations relatives au court-circuit interne (choisir l'une des deux options)	7.3.2 Essai de court-circuit interne	R*
7.3.3 Essai de propagation		-	R
Essai de sécurité fonctionnelle (sécurité du système de batterie)	8.2.2 Contrôle de surcharge de la tension	-	R
	8.2.3 Contrôle de surcharge du courant	-	R
	8.2.4 Contrôle de surchauffe	-	R
<p>"R" = exigé (au moins 1)</p> <p>"R*" = exigé. Pour le nombre d'échantillons, voir 7.3.9 de l'IEC 62133-2:2017.</p> <p>"-" = inutile ou non applicable</p> <p>a Le fabricant peut utiliser des "blocs d'éléments" à la place des "éléments" pour tous les essais qui spécifient les "éléments" comme étant les unités d'essai dans le présent document. Le fabricant déclare clairement l'unité d'essai pour chaque essai.</p> <p>b Si le système de batterie est divisé en unités plus petites, l'unité peut être soumise à l'essai comme étant représentative du système de batterie. Le fabricant peut ajouter des fonctions, qui sont présentes dans le système de batterie final, à l'unité soumise à l'essai. Le fabricant déclare clairement l'unité soumise à l'essai.</p> <p>c Élément cylindrique ou bloc d'éléments: 1 direction, élément parallélépipédique (incluant un élément avec boîtier en stratifié) ou bloc d'éléments: 2 directions.</p> <p>d L'essai est réalisé avec des éléments ou blocs d'éléments de systèmes de batteries équipés d'une commande ou protection unique pour le réglage de la tension de charge.</p> <p>e Si les bornes positives et négatives de la batterie ne sont pas accessibles, le fabricant est autorisé à modifier l'échantillon ou les échantillons de sorte que les bornes soient disponibles (par exemple, selon 7.2.1). La modification doit être effectuée de sorte que les résultats de l'essai ne soient pas corrompus.</p>			

7 Exigences spécifiques et essais

7.1 Procédures de charge pour les besoins des essais

Avant la charge, l'élément ou le système de batterie doit être déchargé à une température ambiante de $25\text{ °C} \pm 5\text{ °C}$, à un courant constant de $0,2 I_t\text{ A}$, jusqu'à une tension finale spécifiée.

Sauf indication contraire dans le présent document, les éléments ou les systèmes de batteries doivent être chargés à une température ambiante de $25\text{ °C} \pm 5\text{ °C}$, selon la méthode spécifiée par le fabricant.

NOTE 1 Pour les essais, les courants de charge et de décharge reposent sur les valeurs de la capacité assignée ($C_n\text{ Ah}$). Ces courants sont exprimés sous la forme d'un multiple de $I_t\text{ A}$, où: $I_t\text{ A} = C_n\text{ Ah}/1\text{ h}$ (voir l'IEC 61434).

NOTE 2 Le système de batterie qui ne peut pas être déchargé à un courant constant de $0,2 I_t\text{ A}$ peut l'être au courant spécifié par le fabricant.

7.2 Mauvais usage raisonnablement prévisible

7.2.1 Essai de court-circuit externe (élément ou bloc d'éléments)

a) Exigences

Le court-circuit entre les bornes négative et positive ne doit provoquer ni feu ni explosion.

b) Essai

Les éléments totalement chargés sont stockés à une température ambiante de $25\text{ °C} \pm 5\text{ °C}$. Chaque élément est ensuite mis en court-circuit en reliant les bornes positive et négative avec une résistance externe totale de $30\text{ m}\Omega \pm 10\text{ m}\Omega$.

Les éléments doivent être soumis à l'essai en continu pendant 6 h ou jusqu'à ce que la température du boîtier s'abaisse de 80 % de l'échauffement maximal atteint, selon ce qui se produit d'abord.

c) Critères d'acceptation

Pas de feu, pas d'explosion.

7.2.2 Essai de choc (élément ou bloc d'éléments)

a) Exigences

Un impact sur l'élément tel qu'il est mentionné en 7.2.2 b) ne doit pas provoquer de feu ni d'explosion.

b) Essai

L'élément ou le bloc d'éléments doit être déchargé à un courant constant de $0,2 I_t$ A, à 50 % de la capacité assignée.

L'élément ou le bloc d'éléments est placé sur un sol plat en béton ou en métal. Une barre en acier inoxydable de type 316, de $15,8\text{ mm} \pm 0,1\text{ mm}$ de diamètre et d'au moins 60 mm de longueur ou de la dimension la plus longue de l'élément, selon la valeur la plus importante, est placée au centre de l'élément ou du bloc d'éléments. Un poids rigide de 9,1 kg est alors lâché d'une hauteur de $610\text{ mm} \pm 25\text{ mm}$ sur la barre placée sur l'échantillon.

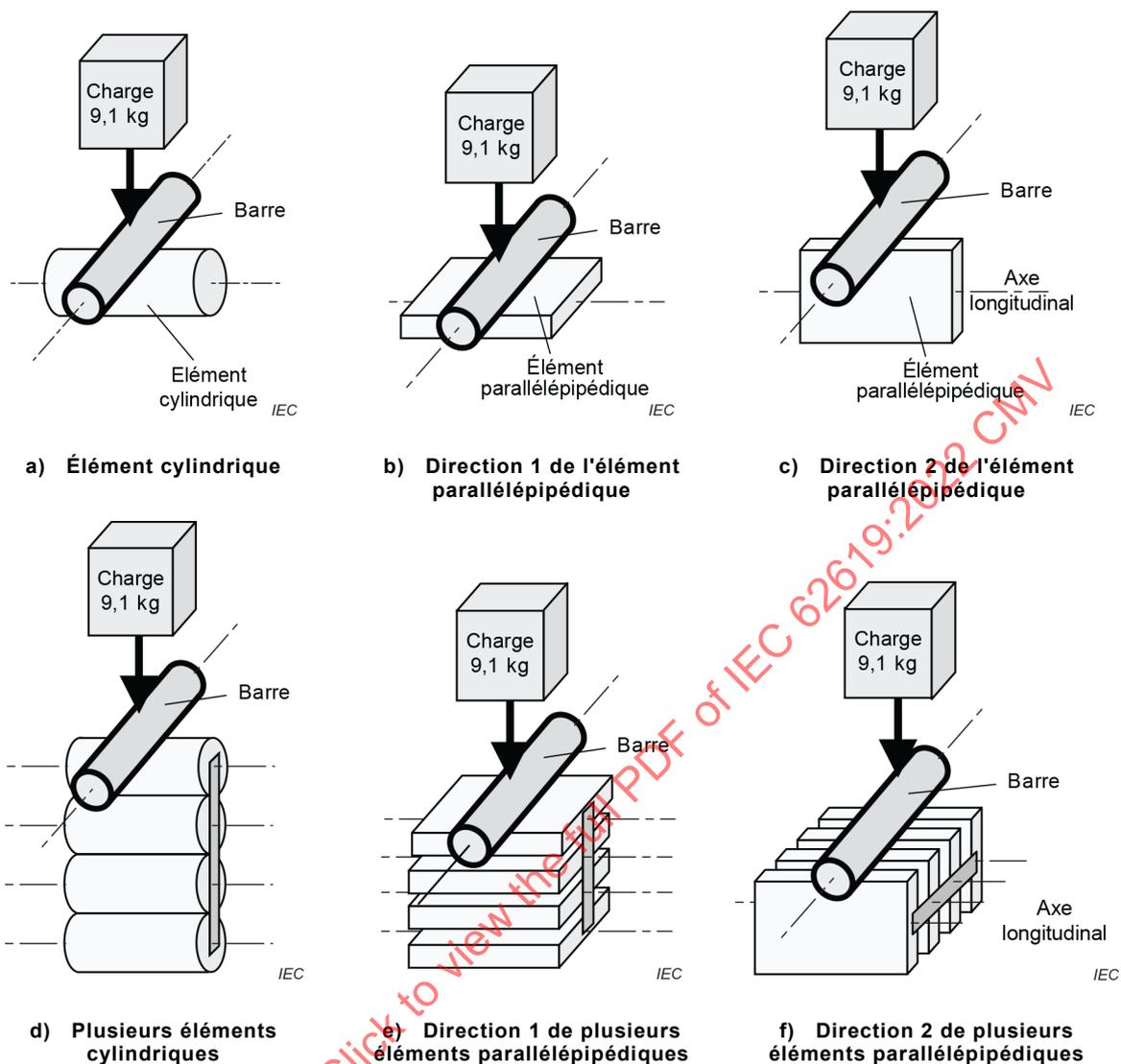
Un élément cylindrique ou parallélépipédique doit être soumis au choc, son axe longitudinal étant parallèle au sol plat en béton ou en métal et perpendiculaire à l'axe longitudinal de l'arrondi de 15,8 mm de diamètre reposant au centre de l'échantillon d'essai. Un élément parallélépipédique doit également être pivoté de 90 degrés sur son axe longitudinal, de sorte que les côtés large et étroit soient soumis au choc. Chaque échantillon doit être soumis à un seul choc, avec les échantillons séparés à utiliser pour chaque choc (voir la Figure 1).

Dans le cas d'un sol métallique, il convient d'éviter un court-circuit externe de l'élément ou du bloc d'éléments avec le sol au moyen de mesures appropriées.

Les éléments poches sont soumis à l'essai comme des éléments parallélépipédiques.

c) Critères d'acceptation

Pas de feu, pas d'explosion.



NOTE L'élément ou le bloc d'éléments peut être soutenu par un matériau qui n'a aucune influence sur l'essai pour le maintenir en position.

Figure 1 – Configuration de l'essai de choc

7.2.3 Essai de chute (élément ou bloc d'éléments et système de batterie)

7.2.3.1 Généralités

L'essai de chute est réalisé sur un élément ou un bloc d'éléments et un système de batterie. La méthode d'essai et la hauteur de chute sont déterminées par le poids de l'unité d'essai (voir le Tableau 2).