

INTERNATIONAL STANDARD



**Secondary lithium-ion cells for the propulsion of electric road vehicles –
Part 3: Safety requirements**

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INTERNATIONAL STANDARD



Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 3: Safety requirements

INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SECONDARY LITHIUM-ION CELLS FOR THE PROPULSION
OF ELECTRIC ROAD VEHICLES –****Part 3: Safety requirements****FOREWORD**

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62660-3:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62660-3 has been prepared by IEC technical committee 21: Secondary cells and batteries. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

- a) The new method for the internal short-circuit test has been added in 6.4.4.2.2 and Annex C, as an alternative option to the test in 6.4.4.2.1.
- b) The vibration test has been deleted.
- c) The test conditions of overcharge (6.4.2.2) have been partially revised.

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

Draft	Report on voting
21/1133/FDIS	21/1137/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.

A list of all parts in the IEC 62660 series, published under the general title *Secondary lithium-ion cells for the propulsion of electric road vehicles*, can be found on the IEC website.

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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INTRODUCTION

The electric road vehicles (EV) including hybrid and plug-in hybrid electric vehicles are beginning to diffuse in the global market with backing from global concerns on CO₂ reduction and energy, recent advances in technology and cost reduction. This has led to a rapidly increasing demand for high-power and high-energy density traction batteries represented by lithium-ion batteries.

For securing a basic level of quality of lithium-ion batteries for automotive applications, relevant international standards, i.e. IEC 62660-1, IEC 62660-2, ISO 12405-1 and ISO 12405-2, have been published. These standards specify the performance, reliability and abuse testing of lithium-ion battery cells, packs and systems for EV applications. Further, in the light of increasing concerns on the safety of lithium-ion batteries and demand for a referenceable international standard, safety requirements for lithium-ion battery packs and systems are defined in ISO 12405-3. Regulations, such as UN ECE R100, are also being revised that include acceptance criteria for rechargeable energy storage systems of EVs.

It is essential to specify the safety criteria at cell level in this standard, in order to secure the basic safety level of cells which differ in performance and design, and are applied to a variety of types of packs and systems. For automobile applications, it is important to note the design diversity of automobile battery packs and systems, and specific requirements for cells and batteries corresponding to each of such designs. Based on these facts, the purpose of this standard is to provide a basic level of safety test methodology and criteria with general versatility, which serves a function in common primary testing of lithium-ion cells to be used in a variety of battery systems. Specific requirements for the safety of cells differ depending on the system designs of battery packs or vehicles, and should be evaluated by the users. Final pass-fail criteria of cells are to be based on the agreement between the cell manufacturers and the customers.

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SECONDARY LITHIUM-ION CELLS FOR THE PROPULSION OF ELECTRIC ROAD VEHICLES –

Part 3: Safety requirements

1 Scope

This part of IEC 62660 specifies test procedures and acceptance criteria for safety performance of secondary lithium-ion cells and cell blocks used for propulsion of electric vehicles (EV) including battery electric vehicles (BEV) and hybrid electric vehicles (HEV).

~~NOTE 1—Cell blocks can be used as an alternative to cells according to the agreement between the manufacturer and the customer.~~

~~NOTE 2—Concerning the cell for plug-in hybrid electric vehicle (PHEV), the manufacturer can select either the test condition of the BEV application or the HEV application.~~

This document determines the basic safety performance of cells used in a battery pack and system under intended use and reasonably foreseeable misuse or incident, during the normal operation of the EV. The safety requirements of the cell in this document are based on the premise that the cells are properly used in a battery pack and system within the limits for voltage, current and temperature as specified by the cell manufacturer (cell operating region).

The evaluation of the safety of cells during transport and storage is not covered by this document.

~~NOTE 1~~ The safety performance requirements for lithium-ion battery packs and systems are defined in ~~ISO 12405-3~~ ~~ISO 6469-1~~. The specifications and safety requirements for lithium-ion battery packs and systems of electrically propelled mopeds and motorcycles are defined in ISO 18243. IEC 62619 covers the safety requirements for the lithium-ion cells and batteries for industrial applications, including, for example, forklift trucks, golf carts, and automated guided vehicles.

~~NOTE 4—Information on the cell operating region is provided in Annex A.~~

~~NOTE 2~~ Lithium cells, modules, battery packs, and battery systems are regulated by International Air Transport Association (IATA) and International Maritime Organization (IMO) for air and sea transport, and, regionally, by other authorities, mainly for land transport. Refer to IEC 62281 for additional information.

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 60050-482, International Electrotechnical Vocabulary—Part 482: Primary and secondary cells and batteries~~

~~IEC 61434, Secondary cells and batteries containing alkaline or other non-acid electrolytes—Guide to the designation of current in alkaline secondary cell and battery standards~~

IEC 62619:—¹, 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 Second edition under preparation. Stage at the time of publication: IEC FDIS 62619:2015/2021.

IEC 62660-2:2010, *Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing*

ISO/TR 8713, *Electrically propelled road vehicles – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-482 ISO/TR 8713 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

BEV

battery electric vehicle

electric vehicle with only a traction battery as power source for vehicle propulsion

3.2

cell block

group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient resistor (PTC)) and not yet fitted with its final housing, terminal arrangement and or electronic control device

3.3

cylindrical cell

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

[SOURCE: IEC 60050-482:2004, 482-02-39]

3.4

explosion

failure that occurs when a cell container, if any, opens violently and major components its solid contents are forcibly expelled

3.5

fire

emission of flames from a cell or cell block for more than 1 s

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

3.6

HEV

hybrid electric vehicle

vehicle with both a rechargeable energy storage system and a fuelled power source for propulsion

3.7

internal short-circuit

unintentional electrical connection between the negative and positive electrodes inside a cell

3.8**leakage**

visible escape of liquid electrolyte from a part, except for a vent, such as ~~casing~~ the case, sealing part, and/or terminals of the cell

3.9**nominal voltage**

suitable approximate value of the voltage used to designate or identify a cell

[SOURCE: IEC 60050-482:2004, 482-03-31, modified – Deletion of "a battery or an electrochemical system" at the end of the definition.]

3.10**pouch cell**

cell having the shape of a parallelepiped whose faces are rectangular and with a prismatic flexible laminate film case

3.11**prismatic cell**

cell having the shape of a parallelepiped whose faces are rectangular and with a prismatic hard case

[SOURCE: IEC 60050-482:2004, 482-02-38, modified – The word "cell" has been added to the term, "qualifies a cell or a battery" has been replaced with "cell" in the definition, and "and with a prismatic hard case housing" has been added.]

3.12**rated capacity**
 C_n

~~quantity of electricity C_3 Ah (ampere hours) for BEV and C_4 Ah for HEV declared by the manufacturer~~

capacity value of a cell in ampere hours (Ah) determined under specified conditions and declared by the cell manufacturer

Note 1 to entry: The subscript n in C_n is the time base in hours (h). In this document, $n = 3$ for BEV application and $n = 1$ for HEV application unless otherwise specified.

Note 2 to entry: Term and definition based on IEC 60050-482:2004, 482-03-15.

3.13**reference test current**
 I_t

reference test current in amperes (A) which is expressed as

$$I_t (A) = C_n (Ah) / n (h)$$

~~where~~

~~C_n is the rated capacity of the cell;~~

~~n in C_n is the time base (h).~~

$$I_t = C_n / 1$$

Note 1 to entry: 1 has a dimension of time in hours (h).

Note 2 to entry: See IEC 61434:1996, Clause 2.

~~3.14~~

~~room temperature~~

~~temperature of $25^{\circ}\text{C} \pm 2\text{ K}$~~

3.14

rupture

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

3.15

secondary lithium-ion cell

~~cell~~

secondary single cell whose electrical energy is derived from the insertion/extraction reactions of lithium-ions between the ~~anode~~ negative electrode and the ~~cathode~~ positive electrode

Note 1 to entry: A secondary cell is a ~~basic~~ manufactured unit providing a source of electrical energy by direct conversion of chemical energy. The cell consists of electrodes, electrolyte, container, terminals and, if any, separators. The electrode can be monopolar or bipolar; the current collector of the former has active material of single polarity and the latter has positive and negative electrode active materials. The electrolyte includes an ionic conductive liquid or solid, or a mixture of them. The cell is designed to be charged electrically.

Note 2 to entry: ~~In this standard, "cell" means the "secondary lithium-ion cell" to be used for the propulsion of electric road vehicles.~~ Where the term "cell" is used alone in this document, it refers to a secondary lithium-ion cell.

3.16

SOC

state of charge

~~available capacity in a battery expressed as a percentage of rated capacity~~

quantity of electricity stored in a cell expressed as a percentage of rated capacity

3.17

upper limit charging voltage

highest charging voltage in the cell operating region, which is specified by the cell manufacturer

Note 1 to entry: Information on the cell operating region is provided in Annex A.

[SOURCE: IEC 62133-2:2017, 3.19, modified – Note to entry added.]

3.18

venting

release of excessive internal pressure from a cell in a manner intended by design to preclude rupture or explosion.

4 Test conditions

4.1 General

Unless otherwise stated in this document, cells shall be tested at room temperature. For the purposes of this document, room temperature is $25^{\circ}\text{C} \pm 2\text{ K}$.

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

~~The cell can be tested under restraint to avoid swelling if acceptable according to the purpose of test. The restraint should refer to the battery design.~~

Cell blocks can be tested as an alternative to cells in accordance with the agreement between the cell manufacturer and the customer.

Concerning the cell for plug-in hybrid electric vehicles (PHEV), the cell manufacturer can select either the test condition of BEV application or of HEV application.

NOTE Test and measurement can be conducted in a fixture as recommended by the cell manufacturer.

4.2 Measuring instruments

4.2.1 Range of measuring devices

The instruments used shall enable the values of voltage and current to be measured. The range of these instruments and measuring methods shall be chosen so as to ensure the accuracy specified for each test.

For analogue instruments, this implies that the readings shall be taken in the last third of the graduated scale.

Any other measuring instruments may be used provided they give an equivalent accuracy.

4.2.2 Voltage measurement

The resistance of the voltmeters used shall be at least 1 M Ω /V.

4.2.3 Current measurement

The entire assembly of ammeter, shunt and leads shall be of an accuracy class of 0,5 or better.

4.2.4 Temperature measurements

The cell temperature shall be measured by use of a surface temperature measuring device capable of an equivalent scale definition and accuracy of calibration as specified in 4.2.1. The temperature should be measured at a location which most closely reflects the cell or cell block temperature. The temperature may be measured at additional appropriate locations, if necessary.

The examples for temperature measurement are shown in Figure 1. The instructions for temperature measurement specified by the cell manufacturer shall be followed.

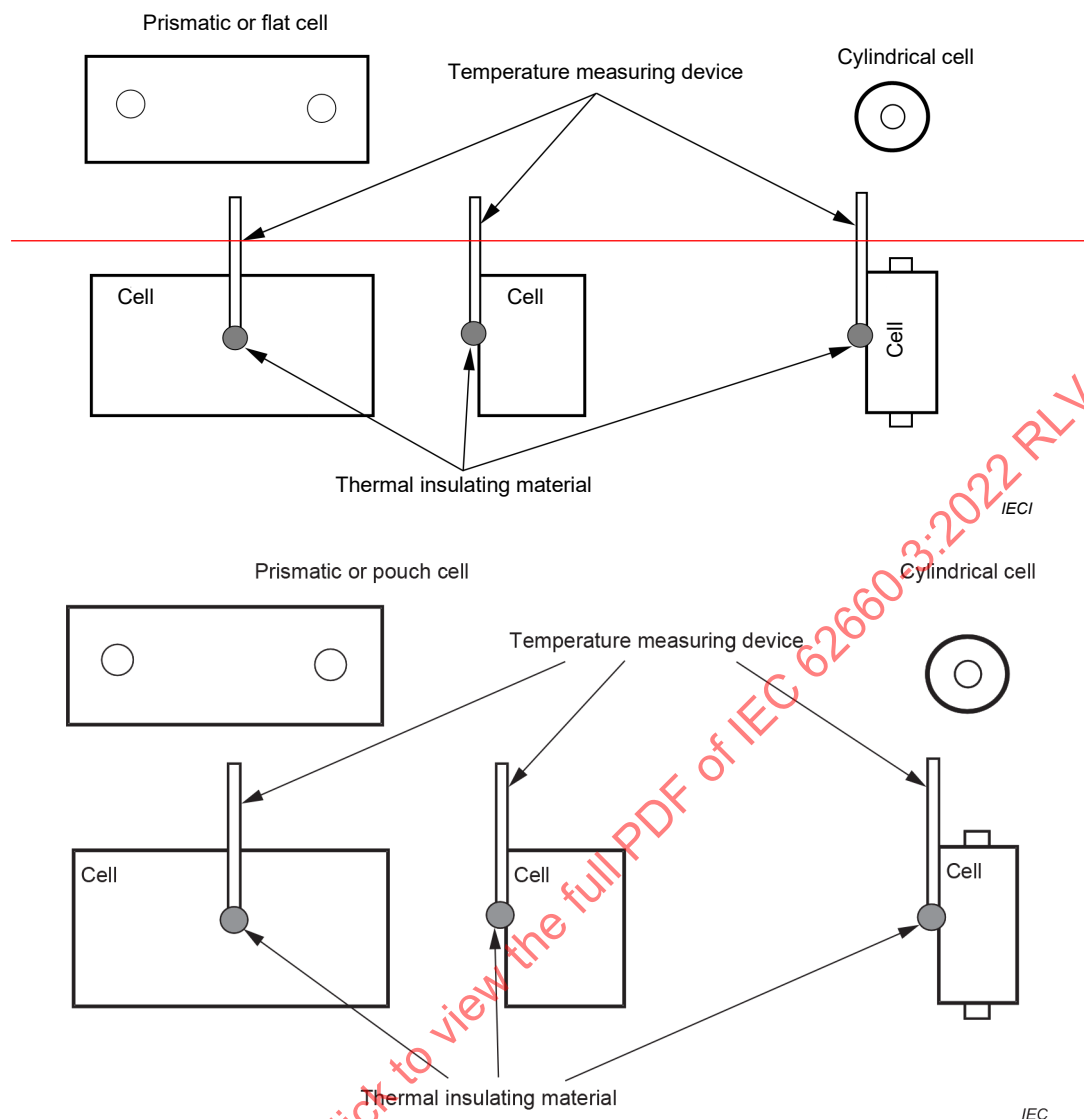


Figure 1 – Example of temperature measurement of cell

4.2.5 Other measurements

Other values ~~including capacity and power~~ may be measured by use of a measuring device, provided it complies with 4.3.

4.3 Tolerance

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

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

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

4.4 ~~Test temperature~~ Thermal stabilization

~~If not otherwise defined, before each test the cell has to be stabilized at the test~~ For the stabilization of cell temperature, the cell shall be soaked to a specified ambient temperature for a minimum of 12 h. This period ~~can~~ may be reduced if thermal ~~equilibrium~~ stabilization is reached. Thermal ~~equilibrium~~ stabilization is considered to be reached if after one interval of 1 h, the change of cell temperature is lower than 1 K.

~~Unless otherwise stated in this standard, cells shall be tested at room temperature.~~

5 Electrical measurement

5.1 General charge conditions

Unless otherwise stated in this document, prior to the electrical measurement ~~test~~, the cell shall be charged as follows.

Prior to charging, the cell shall be discharged at room temperature at a constant current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application down to an end-of-discharge voltage specified by the cell manufacturer. Then, the cell shall be charged at room temperature according to the charging method declared by the cell manufacturer.

5.2 Capacity

Before the SOC adjustment in 5.3, the capacity of the test cell shall be confirmed to be the rated value in accordance with the following phases.

- 1) Phase 1 – The cell shall be charged in accordance with 5.1. After ~~re~~charge, the cell temperature shall be stabilized in accordance with 4.4.
- 2) Phase 2 – The cell shall be discharged at room temperature at a constant current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application to the end-of-discharge voltage that is ~~provided~~ specified by the cell manufacturer.
- 3) Phase 3 – Measure the discharge ~~endurance~~ duration until the specified end-of-discharge voltage is reached, and calculate the capacity of the cell expressed in Ah up to three significant figures.

5.3 SOC adjustment

The test cells shall be charged as specified in the following list. The SOC adjustment is the procedure to be followed for preparing cells to the various SOC's for the tests in this document.

- 1) Phase 1 – The cell shall be charged in accordance with 5.1.
- 2) Phase 2 – The cell shall be left at rest at room temperature in accordance with 4.4.
- 3) Phase 3 – The cell shall be discharged at a constant current of $1/3 I_t$ (A) for BEV application and of $1 I_t$ (A) for HEV application for $(100 - n)/100 \times 3$ h for BEV application and $(100 - n)/100 \times 1$ h for HEV application, where n is SOC (%) to be adjusted for each test.

6 Safety tests

6.1 General

For all the tests specified in this Clause 6, the test installation shall be reported, including the method used for fixing and wiring of the cell. If necessary, to prevent deformation, the cell may be maintained during the test in a manner that complies with the test purpose.

The tests shall be performed on cells that are not more than six months old. The number of cells under each test can be determined according to the agreement between the cell

manufacturer and the customer. A cell block may be used for testing in place of a single cell in accordance with the agreement between the cell manufacturer and the customer.

The number and type of test samples (cell or cell block) shall be provided in a test report.

Each test shall end with the one-hour observation period, unless otherwise specified in this document.

Warning: THE 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 WHOSE ~~CASINGS~~ CASES MAY EXCEED 75 °C AS A RESULT OF TESTING.

6.2 Mechanical tests

~~6.2.1 — Vibration~~

~~6.2.1.1 — Purpose~~

~~This test is performed to simulate vibration to a cell that may occur during the normal operation of the vehicle, and to verify the safety performance of the cell under such conditions.~~

~~6.2.1.2 — Test~~

~~The test shall be performed in accordance with 6.2.1.1 of IEC 62660-2:2010.~~

~~6.2.1.3 — Acceptance criteria~~

~~During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.~~

6.2.1 Mechanical shock

6.2.1.1 Purpose

This test is performed to simulate mechanical shocks to a cell that may occur during the normal operation of the vehicle, and to verify the safety performance of the cell under such conditions.

6.2.1.2 Test

The test shall be performed in accordance with 6.2.2.2 of IEC 62660-2:2010/2018.

6.2.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.2.2 Crush

6.2.2.1 Purpose

This test is performed to simulate external load forces that may cause deformation of a cell, and to verify the safety performance of the cell under such conditions.

6.2.2.2 Test

The test shall be performed as follows:

- a) adjust the SOC of cell to 100 % for BEV application and to 80 % for HEV application in accordance with 5.3;
- b) the cell shall be placed on an insulated rigid flat supporting surface, and a force shall be applied to it with a crushing tool made of a solid material in the shape of a round or semicircular bar, or in the shape of a sphere or hemisphere with a 150 mm diameter. ~~It is recommended to use the round bar to crush a cylindrical cell, and the sphere for a prismatic cell, including a flat or pouch cell.~~ The force for the crushing shall be applied in a direction nearly perpendicular to a larger side of the layered face of the positive and negative electrodes inside the cell. The force shall be applied to the approximate centre of the cell as shown in Figure 2. The crush speed shall be less than or equal to 6 mm/min;

NOTE The round bar can be used to crush a cylindrical cell, and the sphere can be used to crush a prismatic cell or pouch cell.

- c) the force shall be released when an abrupt voltage drop of one-third of the original cell voltage occurs, or a deformation of 15 % or more of the initial cell dimension occurs, or a force of 1 000 times the weight of the cell is applied, whichever comes first. The cells shall be under observation for 24 h or until the cell temperature declines by 80 % of the maximum temperature rise, whichever occurs sooner.

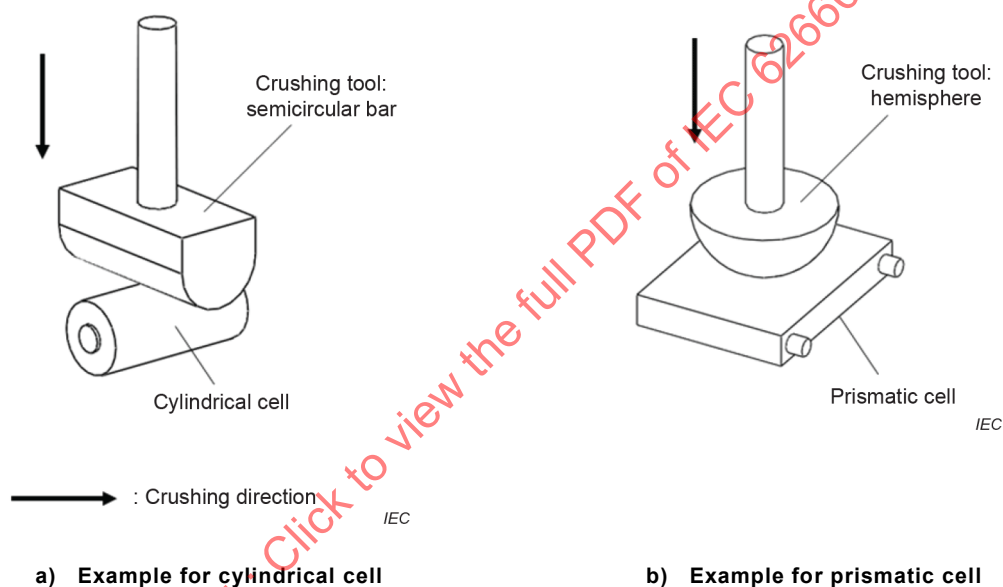


Figure 2 – Example of crush test

6.2.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.3 Thermal test

6.3.1 High temperature endurance

6.3.1.1 Purpose

This test is performed to simulate a high-temperature environment that the cell may experience during the reasonably foreseeable misuse or incident of the vehicle, and to verify the safety performance of the cell under such conditions.

6.3.1.2 Test

The test shall be performed as follows:

- a) adjust the SOC of the cell to 100 % for BEV applications, and to 80 % for HEV applications in accordance with 5.3;
- b) the cell, stabilized at room temperature, shall be placed in a gravity or circulating air convection oven. The oven temperature shall be raised at a rate of 5 K/min to 130 °C ± 2 K. The cell shall remain at this temperature for 30 min. Then, after the heater is turned off, the cell shall be observed for 1 h in the oven.

~~NOTE—If necessary, to prevent deformation, the cell can be maintained during the test in a manner that does not violate the test purpose.~~

6.3.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.3.2 Temperature cycling

6.3.2.1 Purpose

This test is performed to simulate the anticipated exposure to low and high environmental temperature variations which can result in expansion and contraction of cell components, and to verify the safety performance of the cell under such conditions.

6.3.2.2 Test

The test shall be performed in accordance with 6.3.2.2 of IEC 62660-2:2010/2018.

6.3.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.4 Electrical tests

~~If necessary, to prevent deformation, the cell can be maintained during the test in a manner that does not violate the test purpose.~~

6.4.1 External short-circuit

6.4.1.1 Purpose

This test is performed to simulate an external short-circuit of a cell, and to verify the safety performance of the cell under such conditions.

6.4.1.2 Test

The test shall be performed in accordance with 6.4.1.2 of IEC 62660-2:2010/2018.

6.4.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.4.2 Overcharge

6.4.2.1 Purpose

This test is performed to simulate an overcharge of a cell, and to verify the safety performance of the cell under such conditions.

6.4.2.2 Test

The test shall be performed as follows:

- a) adjust the SOC of the cell to 100 % in accordance with 5.3;
- b) continue charging the cell beyond the 100 % SOC with a charging current $1 I_t$ or $1/3 I_t$ for BEV application and $5 I_t$ or $1 I_t$ for HEV application at room temperature using a power supply sufficient to provide the constant charging current. The overcharge test shall be discontinued when the voltage of the cell reaches or exceeds 120 % of the maximum voltage specified by the cell manufacturer, or the quantity of electricity applied to the cell reaches or exceeds the equivalent of 130 % SOC, whichever comes first.
- c) the test conditions may be according to the agreement between the cell manufacturer and the customer.

6.4.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.4.3 Forced discharge

6.4.3.1 Purpose

This test is performed to simulate an overdischarge of a cell, and to verify the safety performance of the cell under such conditions.

6.4.3.2 Test

The test shall be performed as follows:

- a) adjust the SOC of the cell to 0 % in accordance with 5.3;
- b) continue discharging the cell beyond the 0 % SOC with a $1 I_t$ discharging current at room temperature. The forced discharge test shall be discontinued when the absolute value of the voltage of the cell reaches 25 % or less of the nominal voltage specified by the cell manufacturer, or the cell is discharged for 30 min, whichever occurs sooner.

6.4.3.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.4.4 Internal short-circuit test

6.4.4.1 Purpose

This test is performed to simulate an internal short-circuit of a cell which is caused by its contamination with a conductive particle, etc., and to verify the safety performance of the cell under such conditions.

NOTE Annex B provides the informative explanation on the internal short-circuit test.

6.4.4.2 Test

6.4.4.2.1 Forced internal short-circuit test

The test shall be performed on the cell in accordance with 7.3.2 b) of IEC 62619:—², except as follows.

When the nickel particle is placed between the positive active material coated area and the negative active material coated area, the internal short-circuit of single layer shall be confirmed. The ~~prescribed~~ specified test conditions, such as the pressing force and the shape of jig, may

² Second edition under preparation. Stage at the time of publication: IEC FDIS 62619:2015/2021.

be modified, if necessary in order to simulate the internal short-circuit of single layer. The case and electrodes of the cell shall not be crushed. ~~The~~ Any modification shall be ~~recorded~~ reported.

The nickel particle may be inserted through an incision in the cell case, without extracting the electrode core (winding, stacking or folding type) from the cell case. In such a case, the position of the nickel particle may not be the centre of cell, to the extent that the test result is not influenced.

NOTE 4 The internal short-circuit of a single layer ~~can be confirmed~~ is usually indicated by a voltage drop of a few mV.

NOTE 2 In cases where the aluminium foil of positive electrode is exposed at the outer turn, and that it faces the negative active material, the nickel particle is placed at the centre of the cell between the negative active material coated area and the positive aluminium foil which is at the end of the positive active material coated area in the winding direction. The other area where the positive aluminium foil faces the negative active material, if any, ~~can~~ may be checked by the design review, failure mode and effects analysis (FMEA), etc. according to the agreement between the cell ~~supplier~~ manufacturer and the customer.

6.4.4.2.2 Alternative internal short-circuit test

~~The other test methods to simulate the internal short circuit of cell caused by the contamination of conductive particles may be selected if the following criteria are satisfied and agreed between the customer and the supplier.~~

- ~~a) The case deformation shall not affect the short circuit event of cell thermally or electrically. The energy shall not be dispersed by any short circuit other than the interelectrode short circuit.~~
- ~~b) One layer internal short circuit between the positive electrode and the negative electrode shall be simulated (target).~~
- ~~c) Approximately the same short circuited area as that of 7.3.2 b) of IEC 62619:—³ shall be simulated.~~
- ~~d) The short circuited locations in the cell shall be the same as described in 6.4.4.2.1.~~
- ~~e) The test shall be repeatable (see Table 1 of IEC 62619:—⁴).~~

~~The detailed test conditions and parameters of an alternative test shall be adjusted before the test according to the agreement between the customer and the cell manufacturer, so that the above criteria can be satisfied. The test result shall be evaluated by the disassembly of the cell, X-ray observation, etc.~~

~~If the test result shows an internal short circuit of more than one layer, or a larger short circuited area, the test may be deemed as a valid alternative test, provided that the acceptance criteria in 6.4.4.3 are satisfied. The failure in an alternative test does not mean the failure in the test of 6.4.4.2.1, because the test condition of the alternative test may be more severe than the prescribed criteria.~~

NOTE 1 In case the internal short circuit cannot be simulated, the test is invalid and the test data are recorded.

NOTE 2 Examples of candidate alternative tests are recorded in IEC TR 62660-4 (under development).

If agreed between the cell manufacturer and the customer, the internal short-circuit test in Annex C may be conducted as an alternative to the forced internal short-circuit test in 6.4.4.2.1.

³—Under preparation. Stage at the time of publication: IEC/CDV 62619:2015

⁴—Under preparation. Stage at the time of publication: IEC/CDV 62619:2015

~~6.4.4.2.3 — Alternative to test on cell~~

~~In the particular case that the mitigation of the risk linked to the thermal runaway is obtained at a higher level than the cell level (i.e. cell block and module, battery pack and system), the internal short-circuit tests at cell level may be replaced by an alternative such as propagation test for the safety demonstration of the battery system, if agreed between the customer and the supplier. As one of the alternative methods to the internal short-circuit test, the propagation test for the cell block and module is specified in IEC 62619.~~

~~NOTE: The propagation test on the battery pack and system is under consideration for ISO 12405-3.~~

6.4.4.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

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Annex A (informative)

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. 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 the cell, as part of the guidance on safety precautions to be provided to their 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 to allow, for a possible failure of the charge control.

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

A.2 Charging conditions for safe use

A.2.1 General

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 the 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 and the lower limit of the discharging voltage may also be set for the operating region.

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

A.2.2 Consideration on charging voltage

The charging voltage is applied for 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 essential that the charging voltage never exceeds the value specified by the cell manufacturer (i.e. the upper limit of charging voltage). When a cell is charged at a higher voltage than the upper limit charging voltage, 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 occur more easily than it does for cells charged in the predefined operating region. Consequently, the cells should 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, and 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-ion into the negative active electrode 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 in accordance with 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.2.3 Consideration on temperature

A.2.3.1 General

Charging produces a chemical reaction and is affected by temperature. The number of side reactions or the condition of the reaction products during charging is dependent on temperature. Charging in the low or high temperature range is considered to cause more side reactions, and is a more severe risk from a safety viewpoint than when it is done 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.2.3.2 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 following a relatively small change 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 the cell is higher than the upper limit of the high temperature range, the cell ~~is~~ shall never ~~to~~ be charged under any charging current.

A.2.3.3 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 easily deposited on the carbon 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 the 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 ~~is~~ shall never ~~to~~ be charged under any charging current.

A.3 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.

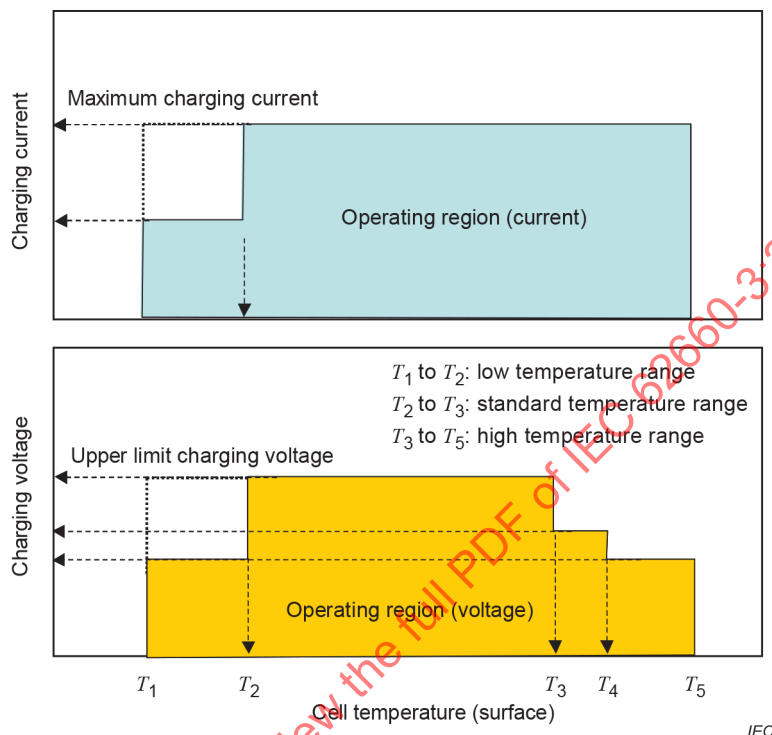


Figure A.1 – An example of operating region for charging of typical lithium-ion cells

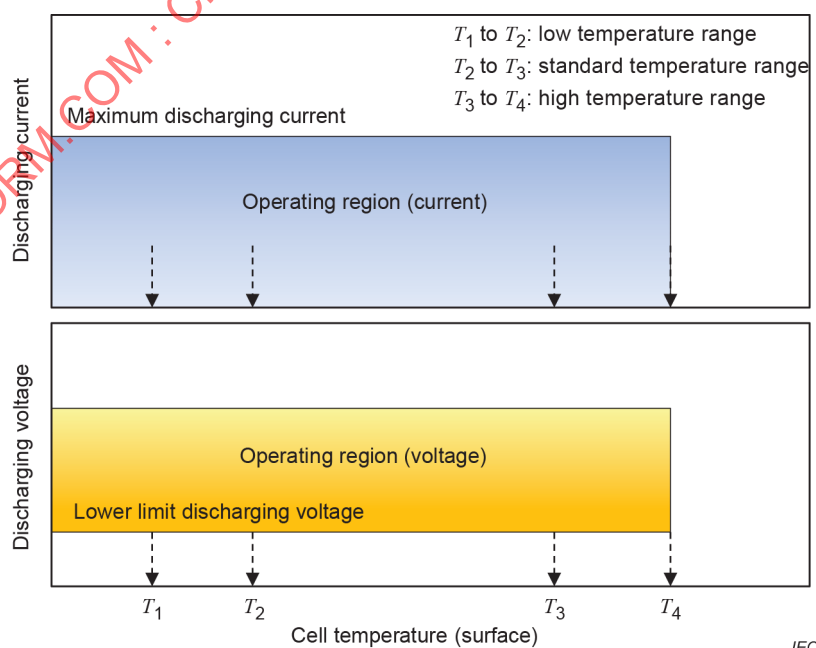


Figure A.2 – An example of operating region for discharging of typical lithium-ion cells

Annex B (informative)

Explanation for the internal short-circuit test

B.1 General concept

The internal short-circuit tests in this document verify the cell behaviour in some specific cases of the internal short-circuit. The internal short-circuit test according to 6.4.4.2.1 demonstrates the ability of the cell to withstand the presence of a particle in the cell without fire or explosion. It represents the demonstration of the risk mitigation linked to that particular case. ~~The alternative internal short-circuit tests in 6.4.4.2.2 demonstrate the ability of the cell to withstand an internal short-circuit of limited extent.~~

None of the internal short-circuit tests, however, demonstrates that the possibility of thermal runaway in the cell is reduced to zero. Accordingly, the risk linked to the thermal runaway of one cell should be mitigated in the scale-up level leading to the overall system (cell block, module, battery pack or vehicle). It is important to note that the comprehensive mitigation of the risk ~~is necessarily~~ needs to be shared between the various levels of the structure from the cell to the vehicle in order to ensure the safe use of lithium-ion technology in vehicles.

B.2 Internal short-circuit caused by the particle contamination

The internal short-circuit of the cell is likely to have various causes from the production process through to the use in the vehicle. The different safety tests in this document are intended to verify the basic safety of the cell against the various short-circuit ~~phenomena~~ causes (see Table B.1).

The internal short-circuit test in 6.4.4 is specially intended to simulate the contamination of a cell by a conductive particle, which potentially occurs during the manufacturing process. Particle contamination is especially critical, because the fire incidents of the portable lithium-ion batteries on the market are attributed in part to particle contamination.

Table B.1 – Examples of the internal short-circuit of cell

Mode	Cause	Countermeasure	Test
Excessive environmental condition	Abnormal temperature	Specify the operating condition	6.3.1 High temperature endurance
	~~Excessive vibration~~		~~6.2.1—Vibration~~
	Excessive shock (drop or impact)		6.2.1 Mechanical shock
	Crush of the cell		6.2.2 Crush
Dendrite	Improper charging conditions (low temperature or high current)	Specify the operating region	- ^a
	Overcharge		6.4.2 Overcharge
	Overdischarge		6.4.3 Forced discharge
	Improper positive/negative material balance		- ^a
Production process	Contamination with a conductive particle	Process control	6.4.4 Internal short-circuit test
	Burrs or loose metal part		- ^a
	Tear of separator		- ^a

^a The internal short-circuit test in 6.4.4 can also cover the internal short-circuit resulting from these causes because of its smaller or similar short-circuit area.

The test in 6.4.4.2.1 refers to the forced internal short-circuit (FISC) test as specified in IEC 62619. The detailed procedure of the FISC test is also defined in IEC 62133-2 ~~and IEC TR 62914~~. The FISC test is conducted with a test cell in which a nickel particle is inserted, and to simulate the worst-case condition of the internal short-circuit. The ~~prescribed~~ specified size of the nickel particle represents the largest contaminant potentially contained in a cell, and generates the maximum heat between the electrodes. The particle contamination causes ~~the single~~ a one- to two-layer internal short-circuit between the positive electrode and the negative electrode, which can be simulated ~~only by the FISC test at the time of publication~~ short-circuit test in 6.4.4.2. It is verified that the thermal, chemical and electrical conditions of the processed test cell are equivalent to ~~those~~ of the unprocessed cell, and have no influence on the test result.

NOTE 1 The thermal condition of the processed test cell is equivalent to or more severe than that of the unprocessed cell, because of the small heat conductance of the polyethylene bag to be used for the test cell. The press jig made of acrylic resin or nitrile rubber has small heat conductance, and does not affect the heat release from the test cell and the rapid heat generation at the short-circuited area.

NOTE 2 The evaporation of electrolyte during the preparation of the test cell is almost entirely prevented according to the ~~prescribed~~ specified test procedure, so that there is no influence on the test result. The processed cell has almost the same performance as it ~~has~~ in its unprocessed state in ~~terms~~ of both capacity and resistance.

Annex C (normative)

Alternative internal short-circuit test (6.4.4.2.2)

C.1 General

This annex provides the test specifications for the alternative internal short-circuit test set out in 6.4.4.2.2.

This test is applicable to prismatic and pouch cells.

The test shall be made with 5 cells. The number of cells may be changed according to the agreement between the cell manufacturer and the customer.

C.2 Test preparation and test set-up

C.2.1 Preparation of cell before the test

For a prismatic cell, the case may be thinned or removed by an appropriate method recommended by the cell manufacturer, if necessary, in order to avoid the effect of case deformation on the internal short-circuit event.

For a prismatic cell with the case connected to either the positive electrode or negative electrode, the case shall be removed by an appropriate method recommended by the cell manufacturer.

The case of a pouch cell shall not be thinned or removed.

Thinning or removal of the case should be conducted before charging and the voltage adjustment of the cell. This operation should be conducted taking all the safety measures needed.

The following is a recommended method of removing a piece of the hard case for the indenter press.

- 1) Step 1 – Thin the surface of the cell case partially up to 90 % of the case thickness. Figure C.1 shows an example of case thinning. The thinning tool shall be designed in order that the edge of cutting head enters into 90 % of the case thickness. Figure C.2 shows an example of a simplified manual thinning tool. A milling machine or other tools can also be used.

Dimensions in millimetres

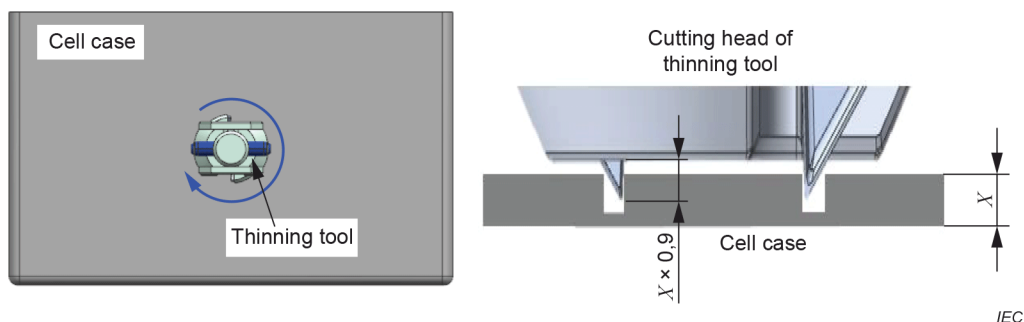


Figure C.1 – Example of case thinning

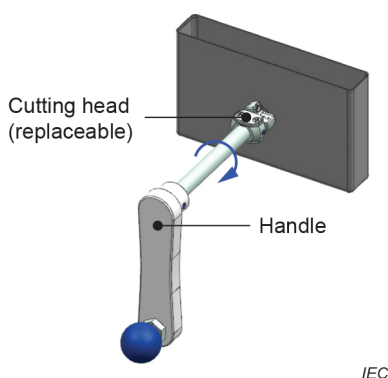


Figure C.2 – Example of thinning tool

- 2) Step 2 – Apply glue to the attachment surface of a removal pin, then attach the removal pin to the thinned part of case. The attachment surface of the removal pin shall be the same size as the thinned case hole. Glue of tensile strength above 20 MPa is recommended (for example, glue gun or epoxy glue). After glue hardening, pull the removal pin out. The hole of removed part should be sealed with insulation tape before the test. Figure C.3 shows an example of the case removal process.

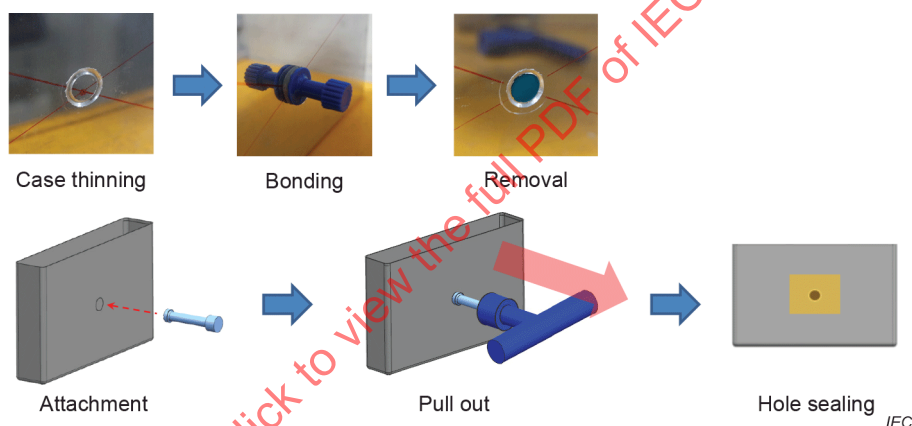


Figure C.3 – Example of removing hard case

Figure C.4 also shows an example of hard case removal during the cell manufacturing process as follows:

- 1) Step 1 – Prepare the weak area for example by welding an additional vent during the cell manufacturing process.
- 2) Step 2 – Mix the AB glue using a ratio of (1:1). Bond the pull-tab with glue on the vent piece, and wait for 10 min to ensure the glue has cured. Use the pull-tab to remove the vent piece.

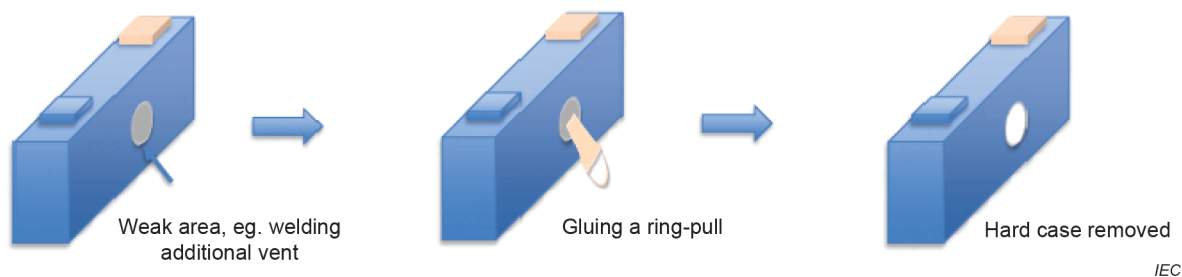


Figure C.4 – Example of hard case removal method during cell manufacturing

C.2.2 Test setup

C.2.2.1 Fixation of cell

The cell shall be held in a manner to prevent movement during the test using a fixation device. The cell shall be electrically isolated from the test bench. Figure C.5 shows an example of a fixation device.

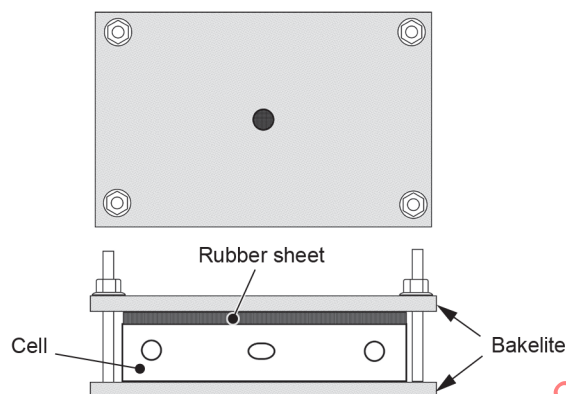


Figure C.5 – Example of fixation of cell

C.2.2.2 Voltage measurement

In order to detect the targeted internal short-circuit, the voltage shall be measured between the negative or positive terminal of the cell and an indenter according to the cell design. The voltage line shall not be connected to a terminal of the outermost electrode. Figure C.6 shows an image of the test setup.

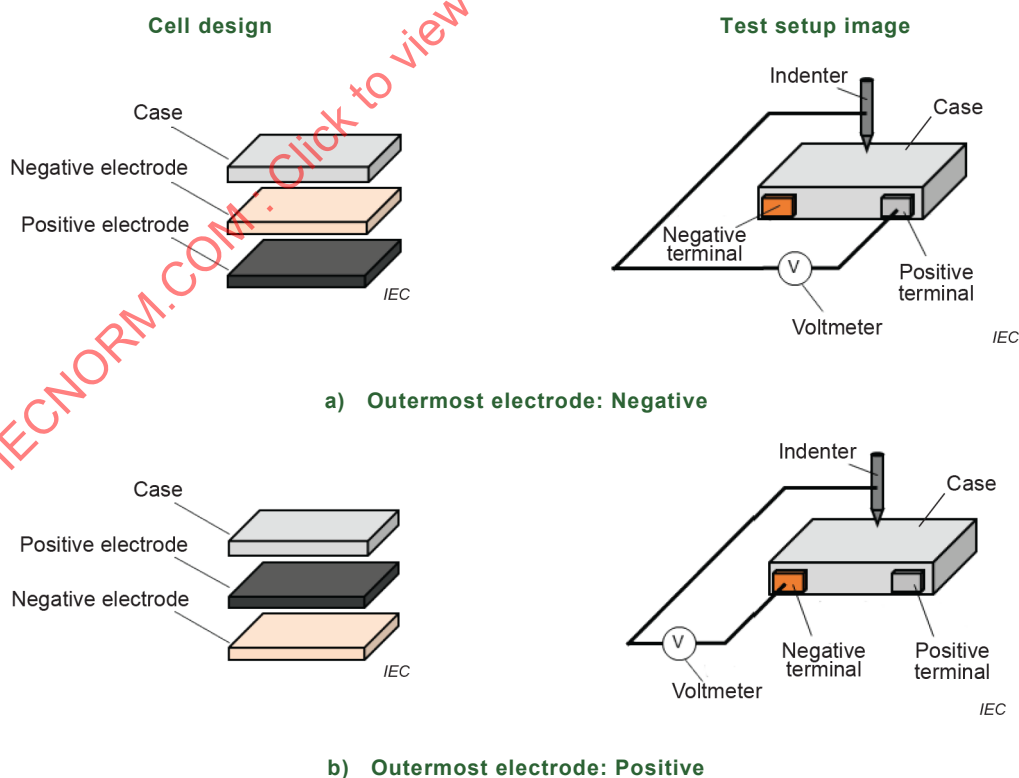


Figure C.6 – Test setup image for voltage measurement

C.2.2.3 Indenter device

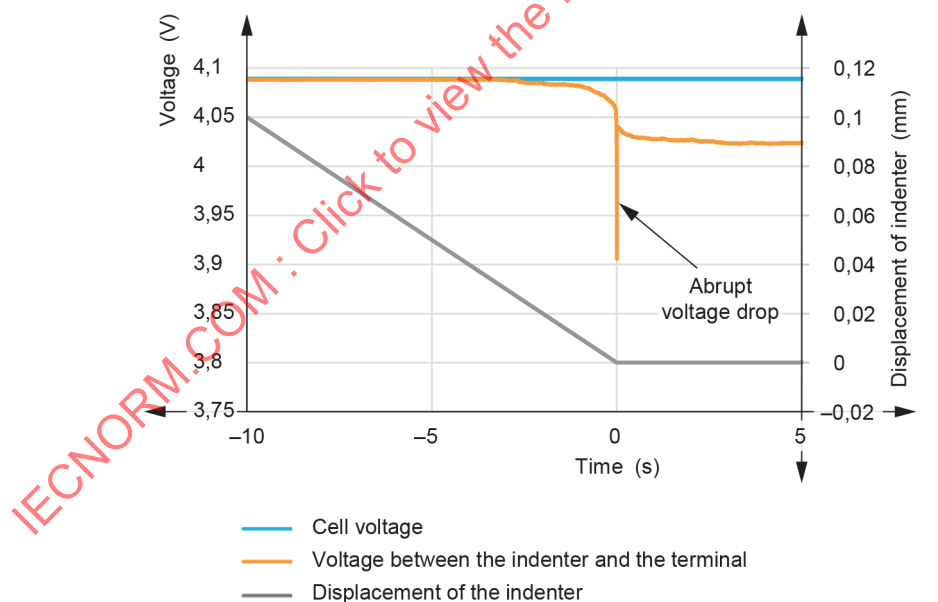
The indenter shall be a steel or SUS nail, for example, SKD-11, SUS 440C, SUS 300 series, having a diameter of between 1 mm and 3 mm.

The angle of the nail tip should be between 20° and 45°.

C.2.3 Preliminary test

The condition of the indenter stop, i.e. the value of the voltage drop, which corresponds to a one- or two-layer short-circuit of the cell under test, shall be determined before the test as follows:

- Prepare the cell in accordance with C.2.1, if applicable.
- Adjust the voltage of the cell to the upper limit charging voltage.
- Fix the cell to the test setup in accordance with C.2.2. The indenter shall be placed perpendicular to the electrode layers of the cell. The cell or the indenter shall move along this perpendicular axis. The indentation location shall be the same as that described in 6.4.4.2.1.
- The preliminary test shall be conducted at the test temperature of $25\text{ °C} \pm 5\text{ K}$. During the test, the voltage shall be recorded with sampling rate of 1 000 Hz or more.
- Press the indenter to the cell, or press the cell up to the indenter, with a constant velocity of 0,01 mm/s. The press speed may be faster than 0,01 mm/s if a one- to two-layer internal short-circuit can be achieved. The press should be stopped when a visible abrupt voltage drop is detected after the voltage between the indenter and the terminal reaches the voltage between negative and positive terminals. After the stop of the press, release the indenter from the cell within 10 s. Figure C.7 shows an example of the voltage drop.



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Figure C.7 – Example of abrupt voltage drop

- Discharge the cell to a safety voltage, and then disassemble the cell to check the number of shorted layer. Repeat steps a) to e) until a one- to two-layer internal short-circuit is achieved, and the voltage drop parameter for the indenter stop is determined. The number of short-circuit layers is equal to the number of shorted points between the positive and negative electrode. The shorted point where the indenter did not touch is not counted as shorted layer.

C.3 Test procedure

The test shall be conducted as follows:

- a) Prepare the cell in accordance with C.2.1, if applicable.
- b) Adjust the voltage of the cell to the upper limit charging voltage.
- c) Fix the cell to the test setup in accordance with C.2.2. The indenter shall be placed perpendicular to the electrode layers of the cell. The cell or the indenter shall move along this perpendicular axis. The indentation location shall be the same as described in 6.4.4.2.1.
- d) The test shall be conducted at the test temperature of $25\text{ °C} \pm 5\text{ K}$. During the test, the voltage shall be recorded with a sampling rate of 1 000 Hz or more. The temperature of the cell may be recorded with a sampling rate of 1 Hz or more. The temperature measuring device should be set on the surface of the cell, at a distance of less than 25 mm from the centre of the indentation.

NOTE After the press is stopped, the measuring frequency can be more than 1 Hz.

- e) Press the indenter to the cell, or press the cell up to the indenter, with a constant velocity of 0,01 mm/s. The press speed may be faster than 0,01 mm/s if a one- to two-layer internal short-circuit can be achieved. The press shall be stopped immediately when the voltage drop as determined in C.2.3 is detected.
- f) After stopping the press, the cell shall be observed for 1 h. The indenter shall remain in place at the stop, and be kept stable within $\pm 0,02\text{ mm}$ in the X, Y and Z directions until the end of the test including the observation period.

NOTE After the end of the observation period, the cell can be disassembled to check the number of shorted layers.

C.4 Acceptance criteria

See 6.4.4.3.

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⁵ ~~To be published.~~

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Secondary lithium-ion cells for the propulsion of electric road vehicles –
Part 3: Safety requirements**

**Éléments d'accumulateurs lithium-ion pour la propulsion des véhicules routiers
électriques –
Partie 3: Exigences de sécurité**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SECONDARY LITHIUM-ION CELLS FOR THE PROPULSION
OF ELECTRIC ROAD VEHICLES –****Part 3: Safety requirements****FOREWORD**

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IEC 62660-3 has been prepared by IEC technical committee 21: Secondary cells and batteries. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

- a) The new method for the internal short-circuit test has been added in 6.4.4.2.2 and Annex C, as an alternative option to the test in 6.4.4.2.1.
- b) The vibration test has been deleted.
- c) The test conditions of overcharge (6.4.2.2) have been partially revised.

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

Draft	Report on voting
21/1133/FDIS	21/1137/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.

A list of all parts in the IEC 62660 series, published under the general title *Secondary lithium-ion cells for the propulsion of electric road vehicles*, can be found on the IEC website.

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 LITHIUM-ION CELLS FOR THE PROPULSION OF ELECTRIC ROAD VEHICLES –

Part 3: Safety requirements

1 Scope

This part of IEC 62660 specifies test procedures and acceptance criteria for safety performance of secondary lithium-ion cells and cell blocks used for propulsion of electric vehicles (EV) including battery electric vehicles (BEV) and hybrid electric vehicles (HEV).

This document determines the basic safety performance of cells used in a battery pack and system under intended use and reasonably foreseeable misuse or incident, during the normal operation of the EV. The safety requirements of the cell in this document are based on the premise that the cells are properly used in a battery pack and system within the limits for voltage, current and temperature as specified by the cell manufacturer (cell operating region).

The evaluation of the safety of cells during transport and storage is not covered by this document.

NOTE 1 The safety performance requirements for lithium-ion battery packs and systems are defined in ISO 6469-1. The specifications and safety requirements for lithium-ion battery packs and systems of electrically propelled mopeds and motorcycles are defined in ISO 18243. IEC 62619 covers the safety requirements for the lithium-ion cells and batteries for industrial applications, including, for example, forklift trucks, golf carts, and automated guided vehicles.

NOTE 2 Lithium cells, modules, battery packs, and battery systems are regulated by International Air Transport Association (IATA) and International Maritime Organization (IMO) for air and sea transport, and, regionally, by other authorities, mainly for land transport. Refer to IEC 62281 for additional information.

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 62619:—¹, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC 62660-2:2018, *Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing*

ISO/TR 8713, *Electrically propelled road vehicles – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 8713 and the following apply.

¹ Second edition under preparation. Stage at the time of publication: IEC FDIS 62619:2021.

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

BEV

battery electric vehicle

electric vehicle with only a traction battery as power source for vehicle propulsion

3.2

cell block

group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or positive temperature coefficient resistor (PTC)) and not yet fitted with its final housing, terminal arrangement or electronic control device

3.3

cylindrical cell

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

[SOURCE: IEC 60050-482:2004, 482-02-39]

3.4

explosion

failure that occurs when a cell container opens violently and its solid contents are forcibly expelled

3.5

fire

emission of flames from a cell or cell block for more than 1 s

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

3.6

HEV

hybrid electric vehicle

vehicle with both a rechargeable energy storage system and a fuelled power source for propulsion

3.7

internal short-circuit

unintentional electrical connection between the negative and positive electrodes inside a cell

3.8

leakage

visible escape of liquid electrolyte from a part, except for a vent, such as the case, sealing part, and/or terminals of the cell

3.9

nominal voltage

suitable approximate value of the voltage used to designate or identify a cell

[SOURCE: IEC 60050-482:2004, 482-03-31, modified – Deletion of "a battery or an electrochemical system" at the end of the definition.]

3.10

pouch cell

cell having the shape of a parallelepiped whose faces are rectangular and with a prismatic flexible laminate film case

3.11

prismatic cell

cell having the shape of a parallelepiped whose faces are rectangular and with a prismatic hard case

[SOURCE: IEC 60050-482:2004, 482-02-38, modified – The word "cell" has been added to the term, "qualifies a cell or a battery" has been replaced with "cell" in the definition, and "and with a prismatic hard case housing" has been added.]

3.12

rated capacity

C_n

capacity value of a cell in ampere hours (Ah) determined under specified conditions and declared by the cell manufacturer

Note 1 to entry: The subscript n in C_n is the time base in hours (h). In this document, $n = 3$ for BEV application and $n = 1$ for HEV application unless otherwise specified.

Note 2 to entry: Term and definition based on IEC 60050-482:2004, 482-03-15.

3.13

reference test current

I_t

reference test current in amperes (A) which is expressed as

$$I_t = C_n / 1$$

Note 1 to entry: 1 has a dimension of time in hours (h).

Note 2 to entry: See IEC 61434:1996, Clause 2.

3.14

rupture

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

3.15

secondary lithium-ion cell

secondary single cell whose electrical energy is derived from the insertion/extraction reactions of lithium-ions between the negative electrode and the positive electrode

Note 1 to entry: A secondary cell is a manufactured unit providing a source of electrical energy by direct conversion of chemical energy. The cell consists of electrodes, electrolyte, container, terminals and, if any, separators. The electrode can be monopolar or bipolar; the current collector of the former has active material of single polarity and the latter has positive and negative electrode active materials. The electrolyte includes an ionic conductive liquid or solid, or a mixture of them. The cell is designed to be charged electrically.

Note 2 to entry: Where the term "cell" is used alone in this document, it refers to a secondary lithium-ion cell.

3.16

SOC

state of charge

quantity of electricity stored in a cell expressed as a percentage of rated capacity

3.17**upper limit charging voltage**

highest charging voltage in the cell operating region, which is specified by the cell manufacturer

Note 1 to entry: Information on the cell operating region is provided in Annex A.

[SOURCE: IEC 62133-2:2017, 3.19, modified – Note to entry added.]

3.18**venting**

release of excessive internal pressure from a cell in a manner intended by design to preclude rupture or explosion

4 Test conditions**4.1 General**

Unless otherwise stated in this document, cells shall be tested at room temperature. For the purposes of this document, room temperature is $25\text{ °C} \pm 2\text{ K}$.

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

Cell blocks can be tested as an alternative to cells in accordance with the agreement between the cell manufacturer and the customer.

Concerning the cell for plug-in hybrid electric vehicles (PHEV), the cell manufacturer can select either the test condition of BEV application or of HEV application.

NOTE Test and measurement can be conducted in a fixture as recommended by the cell manufacturer.

4.2 Measuring instruments**4.2.1 Range of measuring devices**

The instruments used shall enable the values of voltage and current to be measured. The range of these instruments and measuring methods shall be chosen so as to ensure the accuracy specified for each test.

For analogue instruments, this implies that the readings shall be taken in the last third of the graduated scale.

Any other measuring instruments may be used provided they give an equivalent accuracy.

4.2.2 Voltage measurement

The resistance of the voltmeters used shall be at least $1\text{ M}\Omega/\text{V}$.

4.2.3 Current measurement

The entire assembly of ammeter, shunt and leads shall be of an accuracy class of 0,5 or better.

4.2.4 Temperature measurements

The cell temperature shall be measured by use of a surface temperature measuring device capable of an equivalent scale definition and accuracy of calibration as specified in 4.2.1. The temperature should be measured at a location which most closely reflects the cell or cell block temperature. The temperature may be measured at additional appropriate locations, if necessary.

The examples for temperature measurement are shown in Figure 1. The instructions for temperature measurement specified by the cell manufacturer shall be followed.

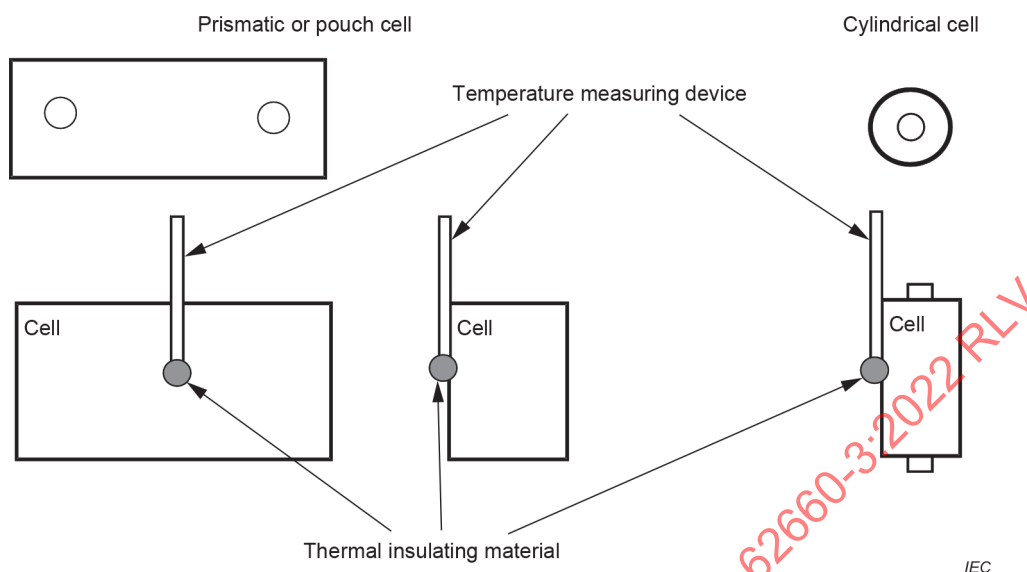


Figure 1 – Example of temperature measurement of cell

4.2.5 Other measurements

Other values may be measured by use of a measuring device, provided it complies with 4.3.

4.3 Tolerance

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

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

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

4.4 Thermal stabilization

For the stabilization of cell temperature, the cell shall be soaked to a specified ambient temperature for a minimum of 12 h. This period may be reduced if thermal stabilization is reached. Thermal stabilization is considered to be reached if after one interval of 1 h, the change of cell temperature is lower than 1 K.

5 Electrical measurement

5.1 General charge conditions

Unless otherwise stated in this document, prior to the electrical measurement, the cell shall be charged as follows.

Prior to charging, the cell shall be discharged at room temperature at a constant current of $1/3 I_t$ (A) for BEV application and $1 I_t$ (A) for HEV application down to an end-of-discharge voltage specified by the cell manufacturer. Then, the cell shall be charged at room temperature according to the charging method declared by the cell manufacturer.

5.2 Capacity

Before the SOC adjustment in 5.3, the capacity of the test cell shall be confirmed to be the rated value in accordance with the following phases.

- 1) Phase 1 – The cell shall be charged in accordance with 5.1. After charge, the cell temperature shall be stabilized in accordance with 4.4.
- 2) Phase 2 – The cell shall be discharged at room temperature at a constant current of $1/3 I_t$ (A) for BEV application and at $1 I_t$ (A) for HEV application to the end-of-discharge voltage that is specified by the cell manufacturer.
- 3) Phase 3 – Measure the discharge duration until the specified end-of-discharge voltage is reached, and calculate the capacity of the cell expressed in Ah up to three significant figures.

5.3 SOC adjustment

The test cells shall be charged as specified in the following list. The SOC adjustment is the procedure to be followed for preparing cells to the various SOC for the tests in this document.

- 1) Phase 1 – The cell shall be charged in accordance with 5.1.
- 2) Phase 2 – The cell shall be left at rest at room temperature in accordance with 4.4.
- 3) Phase 3 – The cell shall be discharged at a constant current of $1/3 I_t$ (A) for BEV application and of $1 I_t$ (A) for HEV application for $(100 - n)/100 \times 3$ h for BEV application and $(100 - n)/100 \times 1$ h for HEV application, where n is SOC (%) to be adjusted for each test.

6 Safety tests

6.1 General

For all the tests specified in this Clause 6, the test installation shall be reported, including the method used for fixing and wiring of the cell. If necessary, to prevent deformation, the cell may be maintained during the test in a manner that complies with the test purpose.

The tests shall be performed on cells that are not more than six months old. The number of cells under each test can be determined according to the agreement between the cell manufacturer and the customer. A cell block may be used for testing in place of a single cell in accordance with the agreement between the cell manufacturer and the customer.

The number and type of test samples (cell or cell block) shall be provided in a test report.

Each test shall end with the one-hour observation period, unless otherwise specified in this document.

Warning: THE 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 WHOSE CASES MAY EXCEED 75 °C AS A RESULT OF TESTING.

6.2 Mechanical tests

6.2.1 Mechanical shock

6.2.1.1 Purpose

This test is performed to simulate mechanical shocks to a cell that may occur during the normal operation of the vehicle, and to verify the safety performance of the cell under such conditions.

6.2.1.2 Test

The test shall be performed in accordance with 6.2.2.2 of IEC 62660-2:2018.

6.2.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.2.2 Crush

6.2.2.1 Purpose

This test is performed to simulate external load forces that may cause deformation of a cell, and to verify the safety performance of the cell under such conditions.

6.2.2.2 Test

The test shall be performed as follows:

- a) adjust the SOC of cell to 100 % for BEV application and to 80 % for HEV application in accordance with 5.3;
- b) the cell shall be placed on an insulated rigid flat supporting surface, and a force shall be applied to it with a crushing tool made of a solid material in the shape of a round or semicircular bar, or in the shape of a sphere or hemisphere with a 150 mm diameter. The force for the crushing shall be applied in a direction nearly perpendicular to a larger side of the layered face of the positive and negative electrodes inside the cell. The force shall be applied to the approximate centre of the cell as shown in Figure 2. The crush speed shall be less than or equal to 6 mm/min;

NOTE The round bar can be used to crush a cylindrical cell, and the sphere can be used to crush a prismatic cell or pouch cell.

- c) the force shall be released when an abrupt voltage drop of one-third of the original cell voltage occurs, or a deformation of 15 % or more of the initial cell dimension occurs, or a force of 1 000 times the weight of the cell is applied, whichever comes first. The cells shall be under observation for 24 h or until the cell temperature declines by 80 % of the maximum temperature rise, whichever occurs sooner.

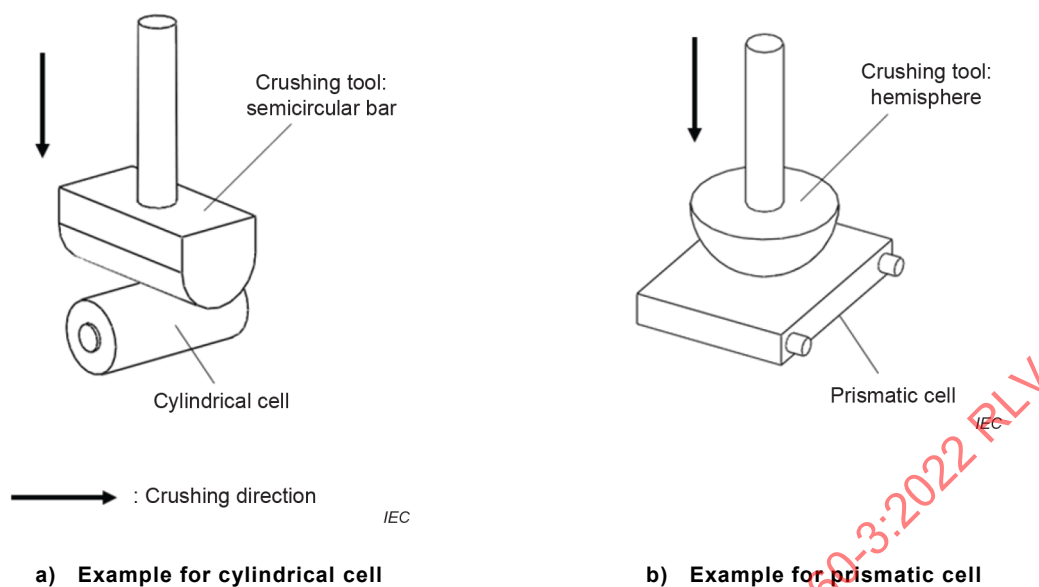


Figure 2 – Example of crush test

6.2.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.3 Thermal test

6.3.1 High temperature endurance

6.3.1.1 Purpose

This test is performed to simulate a high-temperature environment that the cell may experience during the reasonably foreseeable misuse or incident of the vehicle, and to verify the safety performance of the cell under such conditions.

6.3.1.2 Test

The test shall be performed as follows:

- adjust the SOC of the cell to 100 % for BEV applications, and to 80 % for HEV applications in accordance with 5.3;
- the cell, stabilized at room temperature, shall be placed in a gravity or circulating air convection oven. The oven temperature shall be raised at a rate of 5 K/min to $130\text{ °C} \pm 2\text{ K}$. The cell shall remain at this temperature for 30 min. Then, after the heater is turned off, the cell shall be observed for 1 h in the oven.

6.3.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.3.2 Temperature cycling

6.3.2.1 Purpose

This test is performed to simulate the anticipated exposure to low and high environmental temperature variations which can result in expansion and contraction of cell components, and to verify the safety performance of the cell under such conditions.

6.3.2.2 Test

The test shall be performed in accordance with 6.3.2.2 of IEC 62660-2:2018.

6.3.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.4 Electrical tests

6.4.1 External short-circuit

6.4.1.1 Purpose

This test is performed to simulate an external short-circuit of a cell, and to verify the safety performance of the cell under such conditions.

6.4.1.2 Test

The test shall be performed in accordance with 6.4.1.2 of IEC 62660-2:2018.

6.4.1.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.4.2 Overcharge

6.4.2.1 Purpose

This test is performed to simulate an overcharge of a cell, and to verify the safety performance of the cell under such conditions.

6.4.2.2 Test

The test shall be performed as follows:

- a) adjust the SOC of the cell to 100 % in accordance with 5.3;
- b) continue charging the cell beyond the 100 % SOC with a charging current $1 I_t$ or $1/3 I_t$ for BEV application and $5 I_t$ or $1 I_t$ for HEV application at room temperature using a power supply sufficient to provide the constant charging current. The overcharge test shall be discontinued when the voltage of the cell reaches or exceeds 120 % of the maximum voltage specified by the cell manufacturer, or the quantity of electricity applied to the cell reaches or exceeds the equivalent of 130 % SOC, whichever comes first.
- c) the test conditions may be according to the agreement between the cell manufacturer and the customer.

6.4.2.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

6.4.3 Forced discharge

6.4.3.1 Purpose

This test is performed to simulate an overdischarge of a cell, and to verify the safety performance of the cell under such conditions.

6.4.3.2 Test

The test shall be performed as follows:

- a) adjust the SOC of the cell to 0 % in accordance with 5.3;
- b) continue discharging the cell beyond the 0 % SOC with a $1 I_t$ discharging current at room temperature. The forced discharge test shall be discontinued when the absolute value of the voltage of the cell reaches 25 % or less of the nominal voltage specified by the cell manufacturer, or the cell is discharged for 30 min, whichever occurs sooner.

6.4.3.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of leakage, venting, rupture, fire or explosion.

6.4.4 Internal short-circuit test

6.4.4.1 Purpose

This test is performed to simulate an internal short-circuit of a cell which is caused by its contamination with a conductive particle, etc., and to verify the safety performance of the cell under such conditions.

NOTE Annex B provides the informative explanation on the internal short-circuit test.

6.4.4.2 Test

6.4.4.2.1 Forced internal short-circuit test

The test shall be performed on the cell in accordance with 7.3.2 b) of IEC 62619:—², except as follows.

When the nickel particle is placed between the positive active material coated area and the negative active material coated area, the internal short-circuit of single layer shall be confirmed. The specified test conditions, such as the pressing force and the shape of jig, may be modified, if necessary in order to simulate the internal short-circuit of single layer. The case and electrodes of the cell shall not be crushed. Any modification shall be reported.

The nickel particle may be inserted through an incision in the cell case, without extracting the electrode core (winding, stacking or folding type) from the cell case. In such a case, the position of the nickel particle may not be the centre of cell, to the extent that the test result is not influenced.

NOTE The internal short-circuit of a single layer is usually indicated by a voltage drop of a few mV.

In cases where the aluminium foil of positive electrode is exposed at the outer turn, and that it faces the negative active material, the nickel particle is placed at the centre of the cell between the negative active material coated area and the positive aluminium foil which is at the end of the positive active material coated area in the winding direction. The other area where the positive aluminium foil faces the negative active material, if any, may be checked by the design review, failure mode and effects analysis (FMEA), etc. according to the agreement between the cell manufacturer and the customer.

6.4.4.2.2 Alternative internal short-circuit test

If agreed between the cell manufacturer and the customer, the internal short-circuit test in Annex C may be conducted as an alternative to the forced internal short-circuit test in 6.4.4.2.1.

² Second edition under preparation. Stage at the time of publication: IEC FDIS 62619:2021.

6.4.4.3 Acceptance criteria

During the test, the cell shall exhibit no evidence of fire or explosion.

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Annex A (informative)

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. 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 the cell, as part of the guidance on safety precautions to be provided to their 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, for possible failure of the charge control.

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

A.2 Charging conditions for safe use

A.2.1 General

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 the 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 and the lower limit of the discharging voltage may also be set for the operating region.

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

A.2.2 Consideration on charging voltage

The charging voltage is applied for 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 essential that the charging voltage never exceeds the value specified by the cell manufacturer (i.e. the upper limit of charging voltage). When a cell is charged at a higher voltage than the upper limit charging voltage, 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 occur more easily than it does for cells charged in the predefined operating region. Consequently, the cells should 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, and 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-ion into the negative active electrode 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 in accordance with 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.2.3 Consideration on temperature

A.2.3.1 General

Charging produces a chemical reaction and is affected by temperature. The number of side reactions or the condition of the reaction products during charging is dependent on temperature. Charging in the low or high temperature range is considered to cause more side reactions, and is a more severe risk from a safety viewpoint than when it is done 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.2.3.2 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 following a relatively small change 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 the cell is higher than the upper limit of the high temperature range, the cell shall never be charged under any charging current.

A.2.3.3 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 easily deposited on the carbon 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 the 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 shall never be charged under any charging current.

A.3 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.

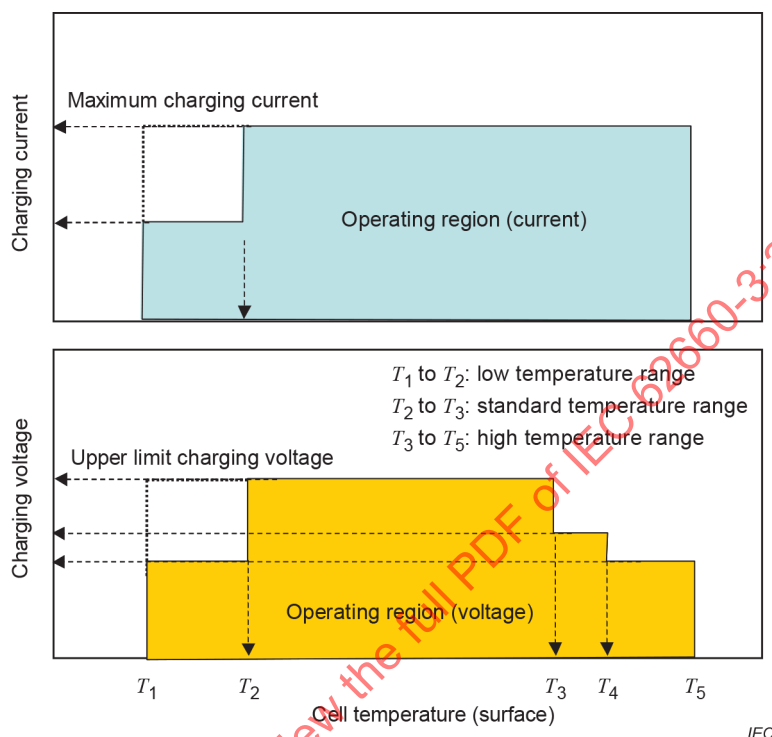


Figure A.1 – An example of operating region for charging of typical lithium-ion cells

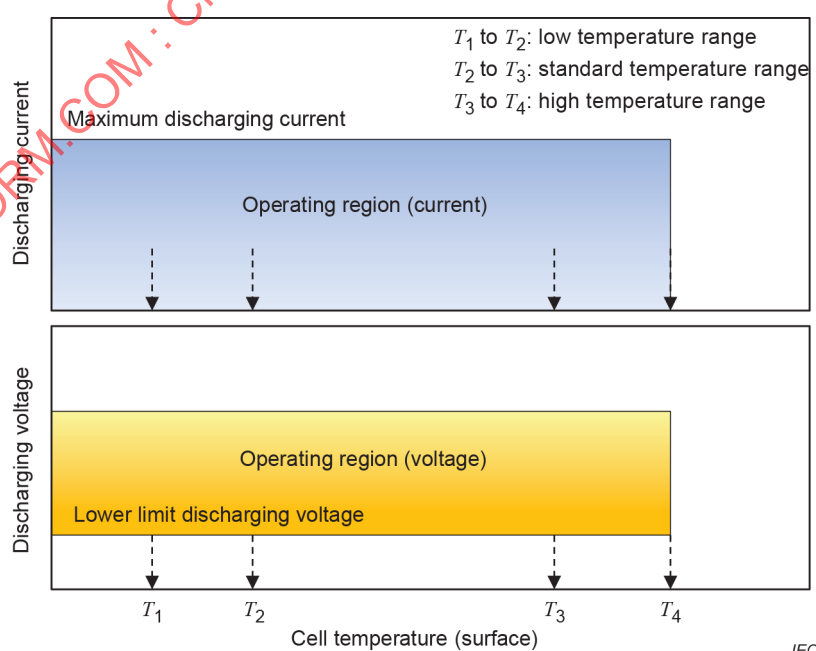


Figure A.2 – An example of operating region for discharging of typical lithium-ion cells

Annex B (informative)

Explanation for the internal short-circuit test

B.1 General concept

The internal short-circuit tests in this document verify the cell behaviour in some specific cases of the internal short-circuit. The internal short-circuit test according to 6.4.4.2.1 demonstrates the ability of the cell to withstand the presence of a particle in the cell without fire or explosion. It represents the demonstration of the risk mitigation linked to that particular case.

None of the internal short-circuit tests, however, demonstrates that the possibility of thermal runaway in the cell is reduced to zero. Accordingly, the risk linked to the thermal runaway of one cell should be mitigated in the scale-up level leading to the overall system (cell block, module, battery pack or vehicle). It is important to note that the comprehensive mitigation of the risk needs to be shared between the various levels of the structure from the cell to the vehicle in order to ensure the safe use of lithium-ion technology in vehicles.

B.2 Internal short-circuit caused by the particle contamination

The internal short-circuit of the cell is likely to have various causes from the production process through to the use in the vehicle. The different safety tests in this document are intended to verify the basic safety of the cell against the various short-circuit causes (see Table B.1).

The internal short-circuit test in 6.4.4 is specially intended to simulate the contamination of a cell by a conductive particle, which potentially occurs during the manufacturing process. Particle contamination is especially critical, because the fire incidents of the portable lithium-ion batteries on the market are attributed in part to particle contamination.

Table B.1 – Examples of the internal short-circuit of cell

Mode	Cause	Countermeasure	Test
Excessive environmental condition	Abnormal temperature	Specify the operating condition	6.3.1 High temperature endurance
	Excessive shock (drop or impact)		6.2.1 Mechanical shock
	Crush of the cell		6.2.2 Crush
Dendrite	Improper charging conditions (low temperature or high current)	Specify the operating region	- ^a
	Overcharge		6.4.2 Overcharge
	Overdischarge		6.4.3 Forced discharge
	Improper positive/negative material balance		- ^a
Production process	Contamination with a conductive particle	Process control	6.4.4 Internal short-circuit test
	Burrs or loose metal part		- ^a
	Tear of separator		- ^a

^a The internal short-circuit test in 6.4.4 can also cover the internal short-circuit resulting from these causes because of its smaller or similar short-circuit area.

The test in 6.4.4.2.1 refers to the forced internal short-circuit (FISC) test as specified in IEC 62619. The detailed procedure of the FISC test is also defined in IEC 62133-2. The FISC test is conducted with a test cell in which a nickel particle is inserted, and to simulate the worst-case condition of the internal short-circuit. The specified size of the nickel particle represents the largest contaminant potentially contained in a cell, and generates the maximum heat between the electrodes. The particle contamination causes a one- to two-layer internal short-circuit between the positive electrode and the negative electrode, which can be simulated by the short-circuit test in 6.4.4.2. It is verified that the thermal, chemical and electrical conditions of the processed test cell are equivalent to those of the unprocessed cell, and have no influence on the test result.

NOTE 1 The thermal condition of the processed test cell is equivalent to or more severe than that of the unprocessed cell, because of the small heat conductance of the polyethylene bag to be used for the test cell. The press jig made of acrylic resin or nitrile rubber has small heat conductance, and does not affect the heat release from the test cell and the rapid heat generation at the short-circuited area.

NOTE 2 The evaporation of electrolyte during the preparation of the test cell is almost entirely prevented according to the specified test procedure, so that there is no influence on the test result. The processed cell has almost the same performance as it has in its unprocessed state in terms of both capacity and resistance.

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Annex C (normative)

Alternative internal short-circuit test (6.4.4.2.2)

C.1 General

This annex provides the test specifications for the alternative internal short-circuit test set out in 6.4.4.2.2.

This test is applicable to prismatic and pouch cells.

The test shall be made with 5 cells. The number of cells may be changed according to the agreement between the cell manufacturer and the customer.

C.2 Test preparation and test set-up

C.2.1 Preparation of cell before the test

For a prismatic cell, the case may be thinned or removed by an appropriate method recommended by the cell manufacturer, if necessary, in order to avoid the effect of case deformation on the internal short-circuit event.

For a prismatic cell with the case connected to either the positive electrode or negative electrode, the case shall be removed by an appropriate method recommended by the cell manufacturer.

The case of a pouch cell shall not be thinned or removed.

Thinning or removal of the case should be conducted before charging and the voltage adjustment of the cell. This operation should be conducted taking all the safety measures needed.

The following is a recommended method of removing a piece of the hard case for the indenter press.

- 1) Step 1 – Thin the surface of the cell case partially up to 90 % of the case thickness. Figure C.1 shows an example of case thinning. The thinning tool shall be designed in order that the edge of cutting head enters into 90 % of the case thickness. Figure C.2 shows an example of a simplified manual thinning tool. A milling machine or other tools can also be used.

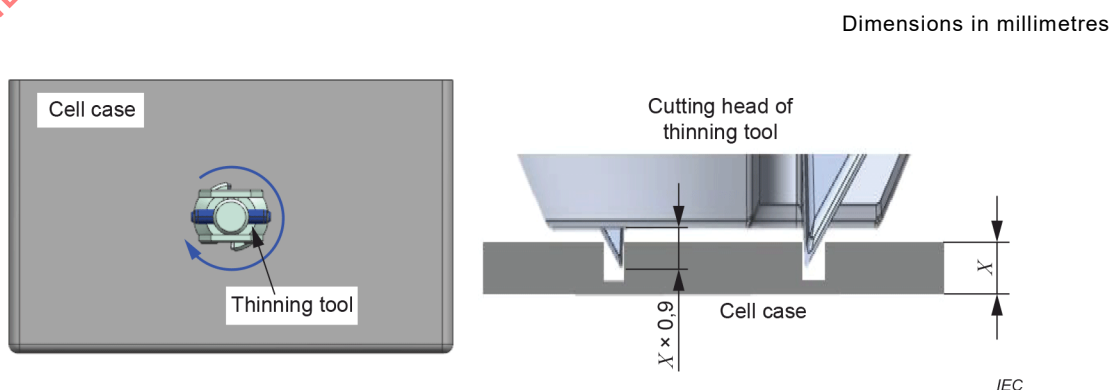


Figure C.1 – Example of case thinning

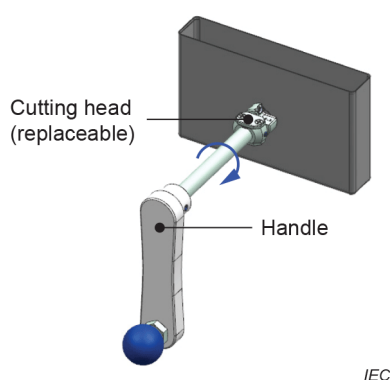


Figure C.2 – Example of thinning tool

- 2) Step 2 – Apply glue to the attachment surface of a removal pin, then attach the removal pin to the thinned part of case. The attachment surface of the removal pin shall be the same size as the thinned case hole. Glue of tensile strength above 20 MPa is recommended (for example, glue gun or epoxy glue). After glue hardening, pull the removal pin out. The hole of removed part should be sealed with insulation tape before the test. Figure C.3 shows an example of the case removal process.

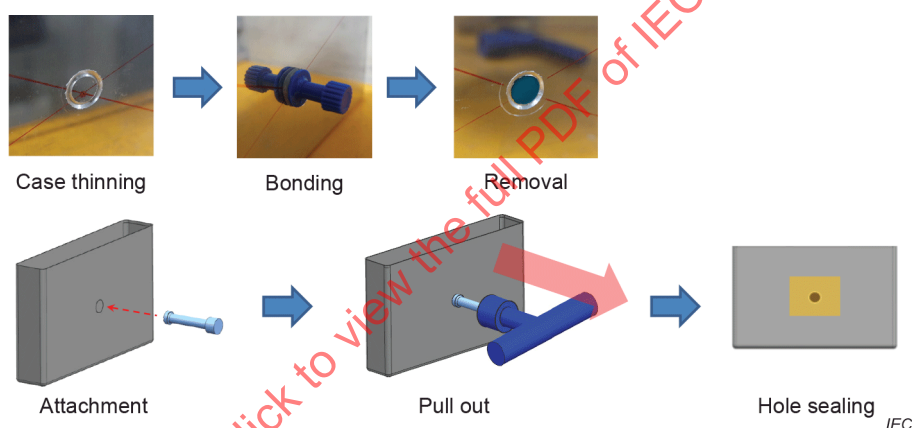


Figure C.3 – Example of removing hard case

Figure C.4 also shows an example of hard case removal during the cell manufacturing process as follows:

- 1) Step 1 – Prepare the weak area for example by welding an additional vent during the cell manufacturing process.
- 2) Step 2 – Mix the AB glue using a ratio of (1:1). Bond the pull-tab with glue on the vent piece, and wait for 10 min to ensure the glue has cured. Use the pull-tab to remove the vent piece.

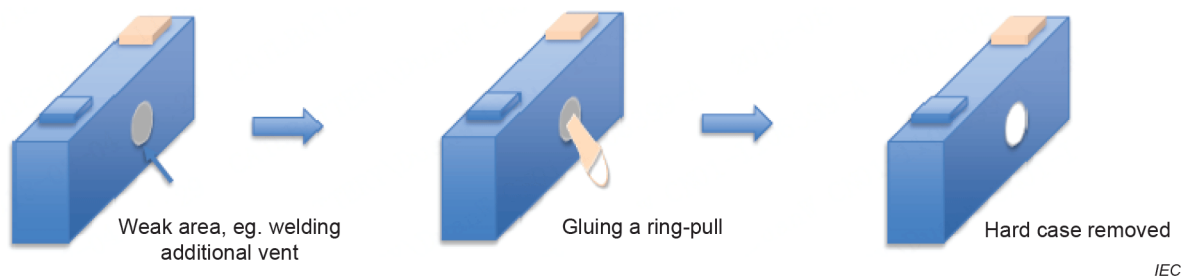


Figure C.4 – Example of hard case removal method during cell manufacturing

C.2.2 Test setup

C.2.2.1 Fixation of cell

The cell shall be held in a manner to prevent movement during the test using a fixation device. The cell shall be electrically isolated from the test bench. Figure C.5 shows an example of a fixation device.

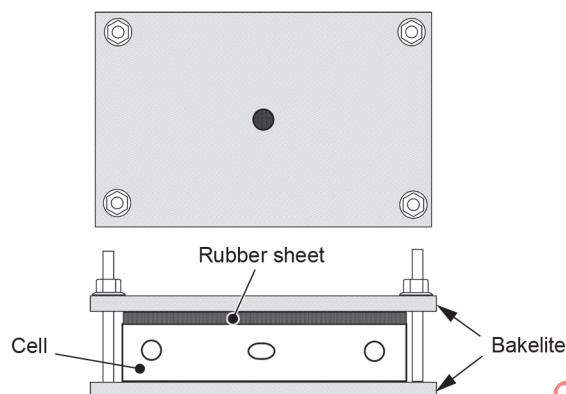


Figure C.5 – Example of fixation of cell

C.2.2.2 Voltage measurement

In order to detect the targeted internal short-circuit, the voltage shall be measured between the negative or positive terminal of the cell and an indenter according to the cell design. The voltage line shall not be connected to a terminal of the outermost electrode. Figure C.6 shows an image of the test setup.

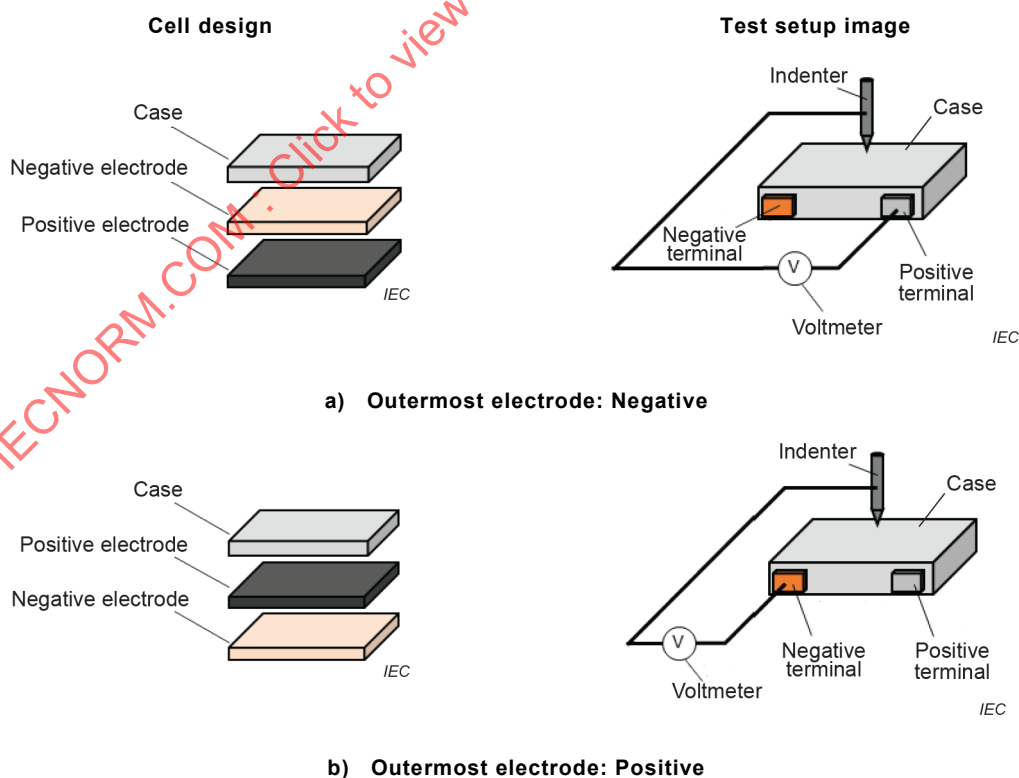


Figure C.6 – Test setup image for voltage measurement

C.2.2.3 Indenter device

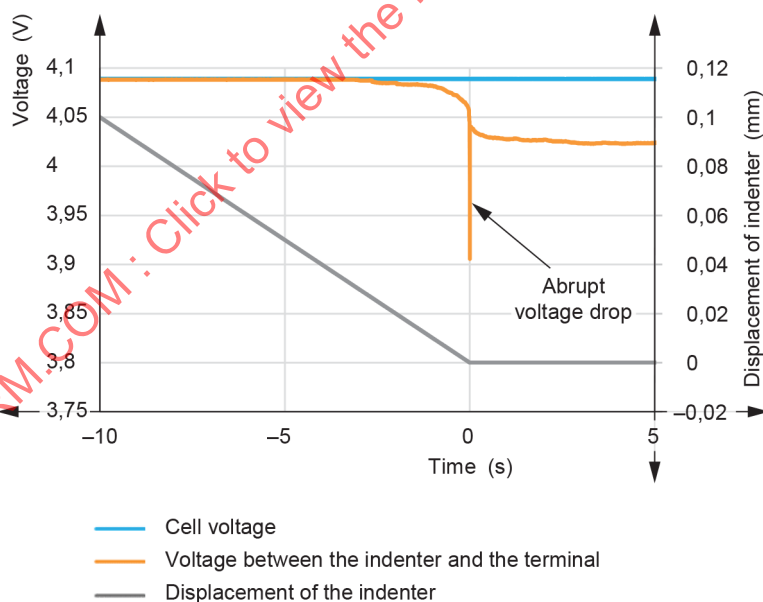
The indenter shall be a steel or SUS nail, for example, SKD-11, SUS 440C, SUS 300 series, having a diameter of between 1 mm and 3 mm.

The angle of the nail tip should be between 20° and 45°.

C.2.3 Preliminary test

The condition of the indenter stop, i.e. the value of the voltage drop, which corresponds to a one- or two-layer short-circuit of the cell under test, shall be determined before the test as follows:

- Prepare the cell in accordance with C.2.1, if applicable.
- Adjust the voltage of the cell to the upper limit charging voltage.
- Fix the cell to the test setup in accordance with C.2.2. The indenter shall be placed perpendicular to the electrode layers of the cell. The cell or the indenter shall move along this perpendicular axis. The indentation location shall be the same as that described in 6.4.4.2.1.
- The preliminary test shall be conducted at the test temperature of $25\text{ °C} \pm 5\text{ K}$. During the test, the voltage shall be recorded with sampling rate of 1 000 Hz or more.
- Press the indenter to the cell, or press the cell up to the indenter, with a constant velocity of 0,01 mm/s. The press speed may be faster than 0,01 mm/s if a one- to two-layer internal short-circuit can be achieved. The press should be stopped when a visible abrupt voltage drop is detected after the voltage between the indenter and the terminal reaches the voltage between negative and positive terminals. After the stop of the press, release the indenter from the cell within 10 s. Figure C.7 shows an example of the voltage drop.



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Figure C.7 – Example of abrupt voltage drop

- Discharge the cell to a safety voltage, and then disassemble the cell to check the number of shorted layer. Repeat steps a) to e) until a one- to two-layer internal short-circuit is achieved, and the voltage drop parameter for the indenter stop is determined. The number of short-circuit layers is equal to the number of shorted points between the positive and negative electrode. The shorted point where the indenter did not touch is not counted as shorted layer.

C.3 Test procedure

The test shall be conducted as follows:

- a) Prepare the cell in accordance with C.2.1, if applicable.
- b) Adjust the voltage of the cell to the upper limit charging voltage.
- c) Fix the cell to the test setup in accordance with C.2.2. The indenter shall be placed perpendicular to the electrode layers of the cell. The cell or the indenter shall move along this perpendicular axis. The indentation location shall be the same as described in 6.4.4.2.1.
- d) The test shall be conducted at the test temperature of $25\text{ °C} \pm 5\text{ K}$. During the test, the voltage shall be recorded with a sampling rate of 1 000 Hz or more. The temperature of the cell may be recorded with a sampling rate of 1 Hz or more. The temperature measuring device should be set on the surface of the cell, at a distance of less than 25 mm from the centre of the indentation.

NOTE After the press is stopped, the measuring frequency can be more than 1 Hz.

- e) Press the indenter to the cell, or press the cell up to the indenter, with a constant velocity of 0,01 mm/s. The press speed may be faster than 0,01 mm/s if a one- to two-layer internal short-circuit can be achieved. The press shall be stopped immediately when the voltage drop as determined in C.2.3 is detected.
- f) After stopping the press, the cell shall be observed for 1 h. The indenter shall remain in place at the stop, and be kept stable within $\pm 0,02\text{ mm}$ in the X, Y and Z directions until the end of the test including the observation period.

NOTE After the end of the observation period, the cell can be disassembled to check the number of shorted layers.

C.4 Acceptance criteria

See 6.4.4.3.

Bibliography

IEC 60050-482, *International Electrotechnical Vocabulary – Part 482: Primary and secondary cells and batteries*

IEC 61434, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Guide to designation of current in alkaline secondary cell and battery standards*

IEC 62133-2, *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 62660-1, *Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing*

IEC TR 62914, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Experimental procedure for the forced internal short-circuit test of IEC 62133:2012*

ISO 6469-1, *Electrically propelled road vehicles – Safety specifications – Part 1: Rechargeable energy storage system (RESS)*

ISO 12405-4, *Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 4: Performance testing*

ISO 18243, *Electrically propelled mopeds and motorcycles – Test specifications and safety requirements for lithium-ion battery systems*

UN ECE Regulation No.100 (UN ECE R100), *Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train (02 series of amendment or later)*

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ÉLÉMENTS D'ACCUMULATEURS LITHIUM-ION POUR LA PROPULSION DES VÉHICULES ROUTIERS ÉLECTRIQUES –

Partie 3: Exigences de sécurité

AVANT-PROPOS

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L'IEC 62660-3 a été établie par le 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 2016. Cette édition constitue une révision technique.

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

- a) La nouvelle méthode pour l'essai de court-circuit interne a été ajoutée au 6.4.4.2.2 et à l'Annexe C, comme option alternative à l'essai au 6.4.4.2.1.
- b) L'essai de vibration a été supprimé.
- c) Les conditions d'essai de la surcharge (6.4.2.2) ont été partiellement révisées.

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

Projet	Rapport de vote
21/1133/FDIS	21/1137/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.

Une liste de toutes les parties de la série IEC 62660, publiées sous le titre général *Éléments d'accumulateurs lithium-ion pour la propulsion des véhicules routiers électriques*, peut être consultée sur le site web de l'IEC.

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ÉLÉMENTS D'ACCUMULATEURS LITHIUM-ION POUR LA PROPULSION DES VÉHICULES ROUTIERS ÉLECTRIQUES –

Partie 3: Exigences de sécurité

1 Domaine d'application

La présente partie de l'IEC 62660 spécifie les procédures d'essai et les critères d'acceptation en matière de performance de sécurité des éléments d'accumulateurs lithium-ion et des blocs d'éléments utilisés pour la propulsion des véhicules électriques (VE), y compris les véhicules électriques à batterie (VEB) et les véhicules électriques hybrides (VEH).

Le présent document a pour objet de déterminer les performances de sécurité de base des éléments utilisés dans un groupe et système de batteries dans les conditions d'utilisation prévue et les mauvaises utilisations ou incidents raisonnablement prévisibles, pendant le fonctionnement normal du VE. Dans le présent document, les exigences de sécurité de l'élément s'appuient sur l'hypothèse selon laquelle les éléments sont correctement utilisés dans un groupe et système de batteries dans les limites de tension, de courant et de température spécifiées par le fabricant de l'élément (plage de fonctionnement de l'élément).

L'évaluation de la sécurité des éléments pendant le transport et le stockage n'est pas couverte par le présent document.

NOTE 1 Les exigences de performance de sécurité des groupes et systèmes de batteries lithium-ion sont définies dans l'ISO 6469-1. Les spécifications et exigences de sécurité des groupes et systèmes de batteries lithium-ion des cyclomoteurs et motocycles à propulsion électrique sont définies dans l'ISO 18243. L'IEC 62619 traite des exigences de sécurité des accumulateurs lithium-ion pour les applications industrielles, comprenant par exemple le chariot élévateur à fourche, la voiturette de golf et le véhicule à guidage automatique.

NOTE 2 Les éléments, les modules, les groupes et systèmes de batteries au lithium sont réglementés par l'Association du Transport Aérien International (IATA) et l'Organisation maritime internationale (OMI) pour le transport aérien et maritime, et, au niveau régional, par d'autres autorités, principalement pour le transport terrestre. Se reporter à l'IEC 62281 pour des informations supplémentaires.

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 62619:—¹, *Accumulateurs alcalins et autres accumulateurs à électrolyte non acide – Exigences de sécurité pour les accumulateurs au lithium pour utilisation dans des applications industrielles*

IEC 62660-2:2018, *Éléments d'accumulateurs lithium-ion pour la propulsion des véhicules routiers électriques – Partie 2: Essais de fiabilité et de traitement abusif*

ISO/TR 8713, *Véhicules routiers électriques – Vocabulaire*

¹ Deuxième édition en cours d'élaboration. Stade au moment de la publication: IEC FDIS 62619:2021.

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'ISO/TR 8713 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

VEB

véhicule électrique à batterie

véhicule électrique comportant seulement une batterie de traction comme source d'énergie pour sa propulsion

3.2

bloc d'éléments

groupe d'éléments connectés ensemble en parallèle avec ou sans dispositif de protection (fusible ou résistance à coefficient de température positif (CTP), par exemple) et pas encore équipé de son boîtier final, de ses bornes et d'un dispositif de commande électronique

3.3

élément cylindrique

élément de forme cylindrique dans laquelle la hauteur totale est supérieure ou égale au diamètre

[SOURCE: IEC 60050-482:2004, 482-02-39]

3.4

explosion

défaillance qui se produit lorsqu'un bac d'élément s'ouvre violemment et lorsque son contenu solide est éjecté de manière violente

3.5

feu

émission de flammes d'un élément ou d'un bloc d'éléments pendant plus de 1 s

Note 1 à l'article: Les étincelles et les arcs ne sont pas considérés comme des flammes.

3.6

VEH

véhicule électrique hybride

véhicule comportant à la fois un système de stockage d'énergie électrique rechargeable et une source d'énergie à carburant pour sa propulsion

3.7

court-circuit interne

connexion électrique accidentelle entre les électrodes négatives et positives à l'intérieur d'un élément

3.8

fuite

échappement d'électrolyte liquide par une partie de l'élément, sauf par un événement, telle que le boîtier, un joint et/ou les bornes de l'élément

3.9

tension nominale

valeur approchée appropriée d'une tension, utilisée pour désigner ou identifier un élément

[SOURCE: IEC 60050-482:2004, 482-03-31, modifié – Suppression de "une batterie, ou un système électrochimique" à la fin de la définition.]

3.10

élément poche

élément ayant la forme d'un parallélépipède dont les faces sont rectangulaires et dont le boîtier est constitué d'un film stratifié souple prismatique

3.11

élément parallélépipédique

élément ayant la forme d'un parallélépipède dont les faces sont rectangulaires et dont le boîtier est prismatique et rigide

[SOURCE: IEC 60050-482:2004, 482-02-38, modifié – Le mot "élément" a été ajouté au terme, "qualifie un élément ou une batterie" a été remplacé par "élément" dans la définition, et "et dont le boîtier est prismatique et rigide" a été ajouté.]

3.12

capacité assignée

C_n

valeur de la capacité d'un élément en ampères-heures (Ah), déterminée dans des conditions spécifiées et déclarée par le fabricant de l'élément

Note 1 à l'article: L'indice n de C_n est le temps de base en heures (h). Dans le présent document, $n = 3$ pour l'application VEB et $n = 1$ pour l'application VEH sauf spécification contraire.

Note 2 à l'article: Terme et définition issus de l'IEC 60050-482:2004, 482-03-15.

3.13

courant d'essai de référence

I_t

courant d'essai de référence en ampères (A) exprimé comme

$$I_t = C_n / 1$$

Note 1 à l'article: 1 a une dimension de temps en heures (h).

Note 2 à l'article: Voir l'IEC 61434:1996, Article 2.

3.14

rupture

défaillance mécanique du boîtier conteneur de l'élément, 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

3.15**élément d'accumulateur lithium-ion**

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

Note 1 à l'article: Un accumulateur est un dispositif unitaire manufacturé fournissant une source d'énergie électrique par conversion directe de l'énergie chimique. L'élément est constitué d'électrodes, d'électrolyte, de conteneur, des bornes, et le cas échéant, de séparateurs. L'électrode peut être monopolaire ou bipolaire. Le collecteur de courant dans le premier cas a une matière active de polarité unique et dans le second cas, a une matière active d'électrode positive et négative. L'électrolyte est composé d'un liquide ou d'un solide conducteur ionique, ou d'un mélange de ceux-ci. L'élément est conçu pour être chargé électriquement.

Note 2 à l'article: Lorsque le terme "élément" est utilisé seul dans ce document, il fait référence à un élément d'accumulateur lithium-ion.

3.16**SOC****état de charge**

quantité d'électricité stockée dans un élément, exprimée en pourcentage de la capacité assignée

Note 1 à l'article: L'abréviation "SOC" est dérivée du terme anglais développé correspondant "state of charge".

3.17**limite supérieure de la tension de charge**

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

Note 1 à l'article: Des informations relatives à la plage de fonctionnement des éléments sont données à l'Annexe A.

[SOURCE: IEC 62133-2:2017, 3.19, modifié - Ajout de la Note à l'article.]

3.18**échappement de gaz**

libération de pression interne excessive d'un élément d'accumulateur obtenue par conception, de manière à prévenir la rupture ou l'explosion

4 Conditions d'essai**4.1 Généralités**

Sauf indication contraire dans le présent document, les éléments doivent être soumis à l'essai à la température ambiante. Dans le présent document, la température ambiante est de $25\text{ °C} \pm 2\text{ K}$.

Les caractéristiques des instruments de mesure utilisés doivent être données dans tous les rapports de résultats.

Les blocs d'éléments peuvent être soumis à des essais à la place des éléments, en fonction de l'accord entre le fabricant de l'élément et le client.

Pour ce qui concerne l'élément d'un véhicule électrique hybride rechargeable (PHEV - plug-in hybrid electric vehicle), le fabricant de l'élément peut choisir la condition d'essai de l'application VEB ou de l'application VEH.

NOTE Les essais et le mesurage peuvent être réalisés dans un dispositif de fixation comme cela est recommandé par le fabricant de l'élément.

4.2 Instruments de mesure

4.2.1 Plage de mesure des dispositifs de mesure

Les instruments utilisés doivent permettre de mesurer les valeurs de tension et de courant. La plage de mesure de ces instruments et les méthodes de mesure doivent être choisies de façon à veiller à l'exactitude spécifiée pour chaque essai.

Pour des instruments analogiques, cela implique que les valeurs lues doivent être relevées sur le dernier tiers de l'échelle graduée.

Tout autre instrument de mesure peut être utilisé dans la mesure où il donne une exactitude équivalente.

4.2.2 Mesurage de la tension

La résistance des voltmètres utilisés doit être d'au moins $1 \text{ M}\Omega/\text{V}$.

4.2.3 Mesurage du courant

L'ensemble complet ampèremètre, shunt et fils doit être d'une classe d'exactitude de 0,5 ou meilleure.

4.2.4 Mesurages de la température

La température de l'élément doit être mesurée à l'aide d'un dispositif de mesure de la température de surface permettant une définition d'échelle et une exactitude d'étalonnage équivalentes à celles indiquées en 4.2.1. Il convient de mesurer la température à l'emplacement qui reflète le mieux la température de l'élément ou du bloc d'éléments. La température peut être mesurée, si nécessaire, à d'autres emplacements appropriés.

La Figure 1 donne des exemples de mesurage de la température. Les instructions de mesurage de la température spécifiées par le fabricant de l'élément doivent être respectées.

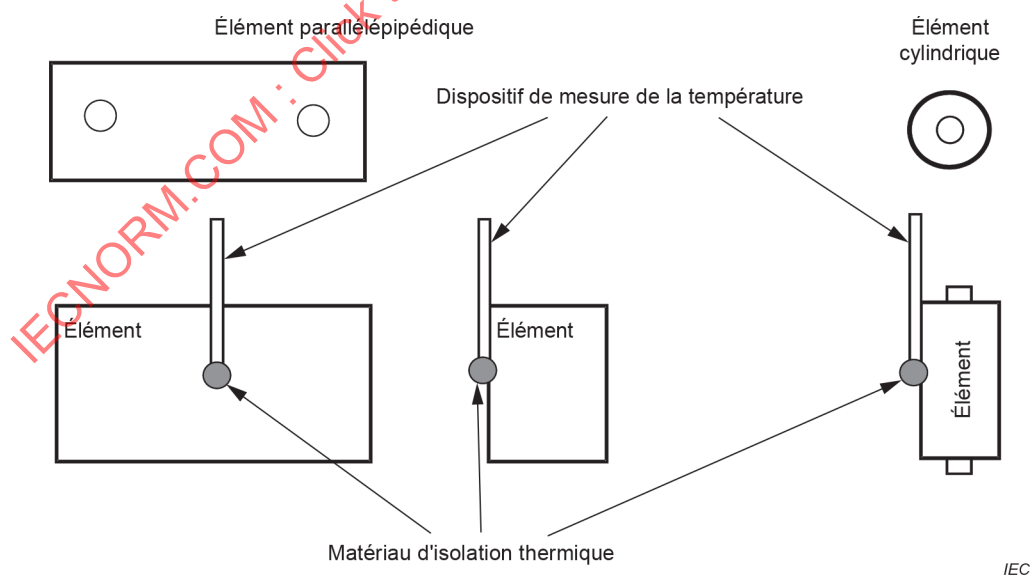


Figure 1 – Exemple de mesurage de température d'un élément

4.2.5 Autres mesurages

D'autres valeurs peuvent être mesurées au moyen d'un dispositif de mesure, à condition qu'il satisfasse à 4.3.

4.3 Tolérance

L'exactitude globale des valeurs contrôlées ou mesurées, relatives aux valeurs spécifiées ou réelles, doit être comprise dans les tolérances suivantes:

- a) $\pm 0,1$ % pour la tension;
- b) ± 1 % pour le courant;
- c) ± 2 K pour la température;
- d) $\pm 0,1$ % pour la durée;
- e) $\pm 0,1$ % pour la masse;
- f) $\pm 0,1$ % 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.

4.4 Stabilisation thermique

Pour la stabilisation de la température de l'élément, l'élément doit être trempé à une température ambiante spécifiée pendant au moins 12 h. Ce délai peut être réduit si la stabilisation thermique est atteinte. La stabilisation thermique est considérée comme étant atteinte si, après un intervalle de temps de 1 h, la variation de température de l'élément est inférieure à 1 K.

5 Mesurage électrique

5.1 Conditions générales de charge

Sauf indication contraire dans le présent document, avant le mesurage électrique, l'élément doit être chargé comme cela est indiqué ci-après.

Avant la charge, l'élément doit être déchargé à la température ambiante à un courant constant de $1/3 I_t$ (A) pour une application VEB et de $1 I_t$ (A) pour une application VEH jusqu'à une tension de fin de décharge spécifiée par le fabricant de l'élément. L'élément doit ensuite être chargé à la température ambiante conformément à la méthode de charge déclarée par le fabricant de l'élément.

5.2 Capacité

Avant d'ajuster le SOC (5.3), la capacité de l'élément d'essai doit être confirmée comme étant à la valeur assignée conformément aux phases suivantes.

- 1) Phase 1 – L'élément doit être chargé conformément à 5.1. Après la charge, la température de l'élément doit être stabilisée conformément à 4.4.
- 2) Phase 2 – L'élément doit être déchargé à la température ambiante à un courant constant de $1/3 I_t$ (A) pour une application VEB et de $1 I_t$ (A) pour une application VEH jusqu'à la tension de fin de décharge spécifiée par le fabricant de l'élément.
- 3) Phase 3 – Mesurer la durée de décharge tant que la tension de fin de décharge spécifiée n'est pas atteinte, puis calculer la capacité de l'élément en Ah jusqu'à trois chiffres significatifs.

5.3 Ajustement de l'état de charge

Les éléments d'essai doivent être chargés comme cela est indiqué ci-dessous. L'ajustement de l'état de charge (SOC) est la procédure à suivre pour préparer les éléments aux différents états de charge (SOC) destinés aux essais du présent document.

- 1) Phase 1 – L'élément doit être chargé conformément à 5.1.
- 2) Phase 2 – L'élément doit être laissé au repos, à la température ambiante, conformément à 4.4.
- 3) Phase 3 – L'élément doit être déchargé à un courant constant de $\frac{1}{3} I_t$ (A) pour une application VEB et de $1 I_t$ (A) pour une application VEH pendant $(100 - n)/100 \times 3$ h pour une application VEB et $(100 - n)/100 \times 1$ h pour une application VEH, où n est le SOC (%) à ajuster pour chaque essai.

6 Essais de sécurité

6.1 Généralités

Pour tous les essais spécifiés dans le présent Article 6, l'installation d'essai doit être consignée dans le rapport, y compris la méthode de fixation et de câblage de l'élément. Si nécessaire, pour éviter une déformation, l'élément peut être maintenu pendant l'essai d'une manière qui soit conforme à l'objectif de l'essai.

Les essais doivent être réalisés sur des éléments fabriqués depuis moins de six mois. Le nombre d'éléments soumis à chaque essai peut être déterminé dans le cadre d'un accord entre le fabricant de l'élément et le client. Un bloc d'éléments peut être utilisé pour l'essai à la place d'un seul élément conformément à l'accord entre le fabricant de l'élément et le client.

Le nombre et le type d'échantillons d'essai (élément ou bloc d'éléments) doivent être indiqués dans un rapport d'essai.

Chaque essai doit se terminer par une période d'observation d'une heure, sauf spécification contraire dans le présent document.

Avertissement: LES PROCÉDURES D'ESSAI UTILISÉES PEUVENT CONDUIRE À DES DOMMAGES SI DES MESURES 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 DES BRÛLURES, IL CONVIENT DE FAIRE PREUVE DE PRUDENCE ENVERS LES ÉLÉMENTS DONT LES BOÎTIERS PEUVENT DÉPASSER 75 °C PAR SUITE DES ESSAIS.

6.2 Essais mécaniques

6.2.1 Choc mécanique

6.2.1.1 Objectif

Cet essai est réalisé pour simuler les chocs mécaniques subis par un élément qui peuvent se produire pendant le fonctionnement normal du véhicule et pour vérifier les performances de sécurité de l'élément dans ces conditions.

6.2.1.2 Essai

L'essai doit être réalisé selon 6.2.2.2 de l'IEC 62660-2:2018.

6.2.1.3 Critères d'acceptation

Pendant l'essai, l'élément ne doit présenter aucune trace de fuite, d'échappement de gaz, de rupture, de feu ou d'explosion.

6.2.2 Compression

6.2.2.1 Objectif

Cet essai est réalisé pour simuler les contraintes extérieures qui peuvent déformer un élément et pour vérifier les performances de sécurité de l'élément dans ces conditions.

6.2.2.2 Essai

L'essai doit être réalisé comme suit:

- ajuster le SOC de l'élément à 100 % pour une application VEB et à 80 % pour une application VEH, conformément à 5.3;
- l'élément doit être placé sur un support isolé plat et rigide et une force doit lui être appliquée avec un outil de compression composé d'une barre en matériau solide de forme ronde ou semi-circulaire ou d'une sphère ou demi-sphère de 150 mm de diamètre. La force de compression doit être appliquée dans une direction sensiblement perpendiculaire à un grand côté de la face active des électrodes positives et négatives à l'intérieur de l'élément. La force doit être appliquée à proximité du centre de l'élément (voir la Figure 2). La vitesse de compression doit être inférieure ou égale à 6 mm/min;

NOTE La barre ronde peut être utilisée pour comprimer un élément cylindrique, et la sphère peut être utilisée pour comprimer un élément parallélépipédique ou un élément poche.

- la force doit être relâchée lorsqu'une chute de tension brusque d'un tiers de la tension d'origine de l'élément se produit, qu'une déformation d'au moins 15 % par rapport à la dimension initiale de l'élément est obtenue ou qu'une force de 1 000 fois le poids de l'élément est appliquée, selon l'événement survenant en premier. Les éléments doivent être en observation pendant 24 h ou jusqu'à ce que la température de l'élément diminue de 80 % de l'échauffement maximal, selon l'événement survenant le plus tôt.

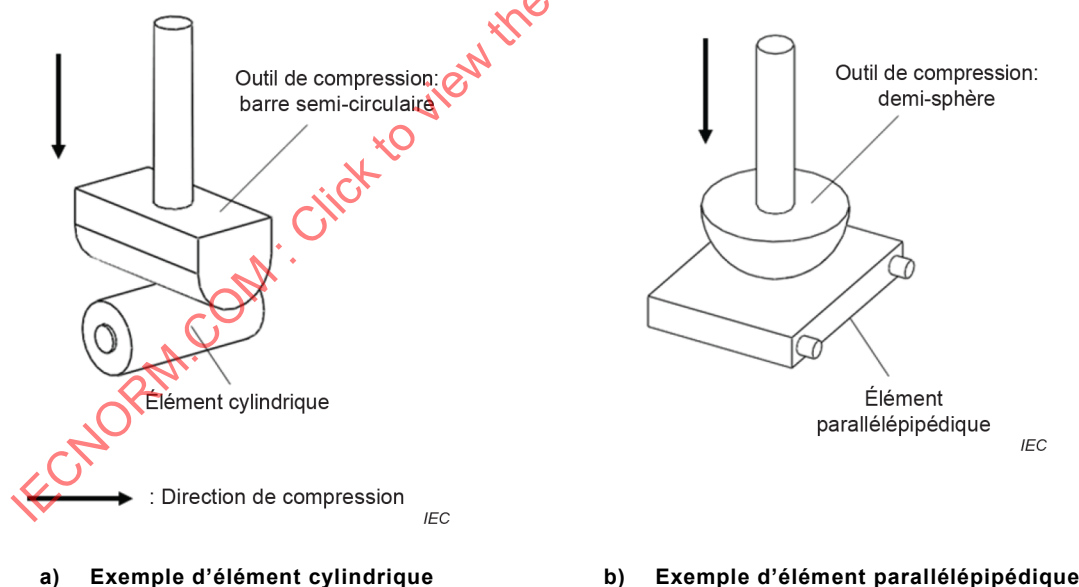


Figure 2 – Exemple d'essai de compression

6.2.2.3 Critères d'acceptation

Pendant l'essai, l'élément ne doit présenter aucune trace de feu ou d'explosion.

6.3 Essais thermiques

6.3.1 Endurance à haute température

6.3.1.1 Objectif

Cet essai est réalisé pour simuler un environnement à température élevée auquel l'élément peut être confronté en cas de mauvaises utilisations ou d'incidents raisonnablement prévisibles du véhicule et pour vérifier les performances de sécurité de l'élément dans ces conditions.

6.3.1.2 Essai

L'essai doit être réalisé comme suit:

- a) ajuster le SOC de l'élément à 100 % pour les applications VEB et à 80 % pour les applications VEH, conformément à 5.3;
- b) l'élément, stabilisé à la température ambiante, doit être placé dans une étuve à gravité ou à circulation d'air par convection. La température de l'étuve doit être augmentée à un taux de 5 K/min jusqu'à une température de $130\text{ °C} \pm 2\text{ K}$. L'élément doit rester à cette température pendant 30 min. Puis, une fois le chauffage coupé, l'élément doit être observé pendant 1 h dans l'étuve.

6.3.1.3 Critères d'acceptation

Pendant l'essai, l'élément ne doit présenter aucune trace de feu ou d'explosion.

6.3.2 Cycles de température

6.3.2.1 Objectif

Cet essai est réalisé pour simuler l'exposition anticipée à des variations de températures ambiantes faibles et élevées, qui peuvent se traduire par une dilatation et une contraction des composants de l'élément, et pour vérifier les performances de sécurité de l'élément dans ces conditions.

6.3.2.2 Essai

L'essai doit être réalisé selon 6.3.2.2 de l'IEC 62660-2:2018.

6.3.2.3 Critères d'acceptation

Pendant l'essai, l'élément ne doit présenter aucune trace de fuite, d'échappement de gaz, de rupture, de feu ou d'explosion.

6.4 Essais électriques

6.4.1 Court-circuit externe

6.4.1.1 Objectif

Cet essai est réalisé pour simuler un court-circuit externe d'un élément et pour vérifier les performances de sécurité de l'élément dans ces conditions.

6.4.1.2 Essai

L'essai doit être réalisé selon 6.4.1.2 de l'IEC 62660-2:2018.

6.4.1.3 Critères d'acceptation

Pendant l'essai, l'élément ne doit présenter aucune trace de feu ou d'explosion.