BS EN 62660-3:2016

BSI Standards Publication

Secondary lithium-ion cells for the propulsion of electric road vehicles

Part 3: Safety requirements

bsi.

National foreword

This British Standard is the UK implementation of EN 62660-3:2016. It is identical to IEC 62660-3:2016.

The UK participation in its preparation was entrusted to Technical Committee PEL/21, Secondary cells and batteries.

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

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English Version

Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements (IEC 62660-3:2016)

Éléments d'accumulateurs lithium-ion pour la propulsion des véhicules routiers électriques - Partie 3: Exigences de sécurité
(IEC 62660-3:2016)

Lithium-Ionen-Sekundärzellen für den Antrieb von Elektrostraßenfahrzeugen -
Teil 3: Sicherheitsanforderungen
(IEC 62660-3:2016)

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European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 21/890/FDIS, future edition 1 of IEC 62660-3, prepared by IEC/TC 21 "Secondary cells and batteries" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62660-3:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-07-03
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-10-03

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Endorsement notice

The text of the International Standard IEC 62660-3:2016 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 62133	NOTE	Harmonized as EN 62133.
IEC 62660-1	NOTE	Harmonized as EN 62660-1.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60050-482	-	International Electrotechnical Vocabulary (IEV) - 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	EN 61434	-
IEC 62619	-	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	2010	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing	EN 62660-2	2011

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Safety requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62660-3 has been prepared by IEC technical committee 21: Secondary cells and batteries.

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

FDIS	Report on voting
21/890/FDIS	21/897/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 CO_2 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.

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 the acceptance criteria for safety performance of secondary lithium-ion cells and cell blocks used for the 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 International Standard intends to determine 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 standard 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 standard.

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

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

2 Normative references

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

IEC 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*

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

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

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in IEC 60050-482, as well as the following apply.

3.1
battery electric vehicle
BEV
electric vehicle with only a traction battery as power source for vehicle propulsion

3.2
cell block
a group of cells connected together in parallel configuration with or without protective devices, e.g. fuse or positive temperature coefficient resistor (PTC), not yet fitted with its final housing, terminal arrangement and electronic control device

3.3
explosion
failure that occurs when a cell container, if any, opens violently and major components are forcibly expelled

3.4
fire
emission of flames from a cell or cell block

3.5
hybrid electric vehicle
HEV
vehicle with both a rechargeable energy storage system and a fuelled power source for propulsion

3.6
internal short circuit
unintentional electrical connection between the negative and positive electrodes inside a cell

3.7
leakage
visible escape of liquid electrolyte from a part except vent, such as casing, sealing part and/or terminals

3.8
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.]

3.9
rated capacity
quantity of electricity C_3Ah (ampere-hours) for BEV and C_1Ah for HEV declared by the manufacturer

3.10
reference test current
$\boldsymbol{I_t}$
current in amperes 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).

3.11
room temperature
temperature of 25 °C ± 2 K

3.12
rupture
mechanical failure of a container case of cell induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

3.13
secondary lithium-ion cell
cell
secondary single cell whose electrical energy is derived from the insertion/extraction reactions of lithium-ions between the anode and the cathode

Note 1 to entry: The secondary cell is a basic manufactured unit providing a source of electrical energy by direct conversion of chemical energy. The cell consists of electrodes, separators, electrolyte, a container and terminals, and 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.

3.14
state of charge
SOC
available capacity in a battery expressed as a percentage of rated capacity

3.15
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

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.

4.2 Measuring instruments

4.2.1 Range of measuring devices

The instruments used shall enable the voltage and current values 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 the ammeter, the shunt and the 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 manufacturer shall be followed.

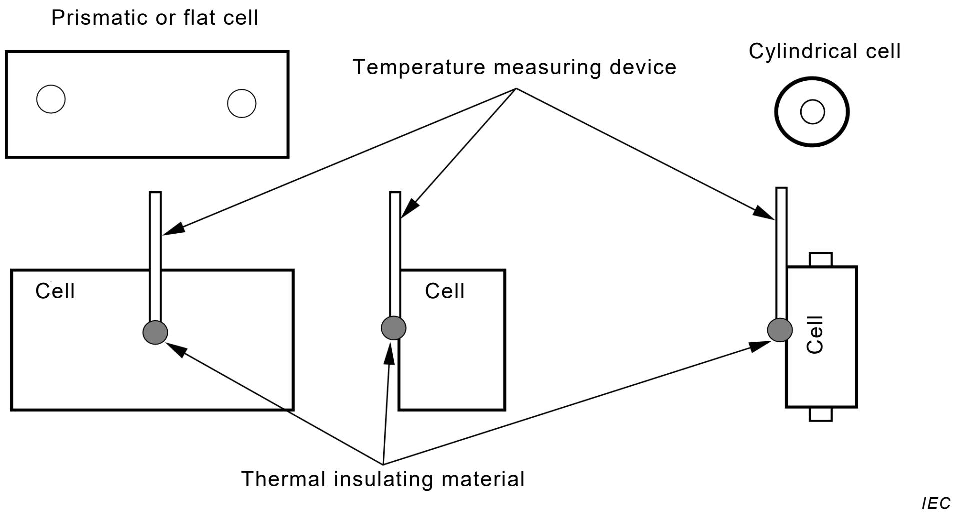


Figure 1 – Example of temperature measurement of cell

4.2.5 Other measurements

Other values including capacity and power may be measured by use of a measuring device, provided that 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 these tolerances:

a) ±0,1 % for voltage;

b) ±1 % for current;

c) ±2 K for temperature;

d) ±0,1 % for time;

e) ±0,1 % for mass;

f) ±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

If not otherwise defined, before each test the cell has to be stabilized at the test temperature for a minimum of 12 h. This period can be reduced if thermal equilibrium is reached. Thermal equilibrium 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 standard, 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 manufacturer. Then, the cell shall be charged according to the charging method declared by the manufacturer at room temperature.

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 steps.

Step 1 – The cell shall be charged in accordance with 5.1.

After recharge, the cell temperature shall be stabilized in accordance with 4.4.

Step 2 – The cell shall be discharged at the 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 by the manufacturer.

The method of designation of test current I_t is defined in IEC 61434. See also 3.9.

Step 3 – Measure the discharge endurance duration until the specified end-of-discharge voltage is reached, and calculate the capacity of cell expressed in Ah up to three significant figures.

5.3 SOC adjustment

The test cells shall be charged as specified below. The SOC adjustment is the procedure to be followed for preparing cells to the various SOCs for the tests in this standard.

Step 1 – The cell shall be charged in accordance with 5.1.

Step 2 – The cell shall be left at rest at room temperature in accordance with 4.4.

Step 3 – The cell shall be discharged at a constant current of 1/3 I_t (A) for BEV application and 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 the SOC (%) to be adjusted for each test.

6 Safety tests

6.1 General

For all the tests specified in this clause, the test installation shall be reported including the method used for fixing and wiring the cell.

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

The number and type of test sample (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 standard.

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 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 6.1.1.1 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.

6.2.2 Mechanical shock

6.2.2.1 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.

6.2.2.2 Test

The test shall be performed in accordance with 6.1.2.1 of IEC 62660-2:2010.

6.2.2.3 Acceptance criteria

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

6.2.3 Crush

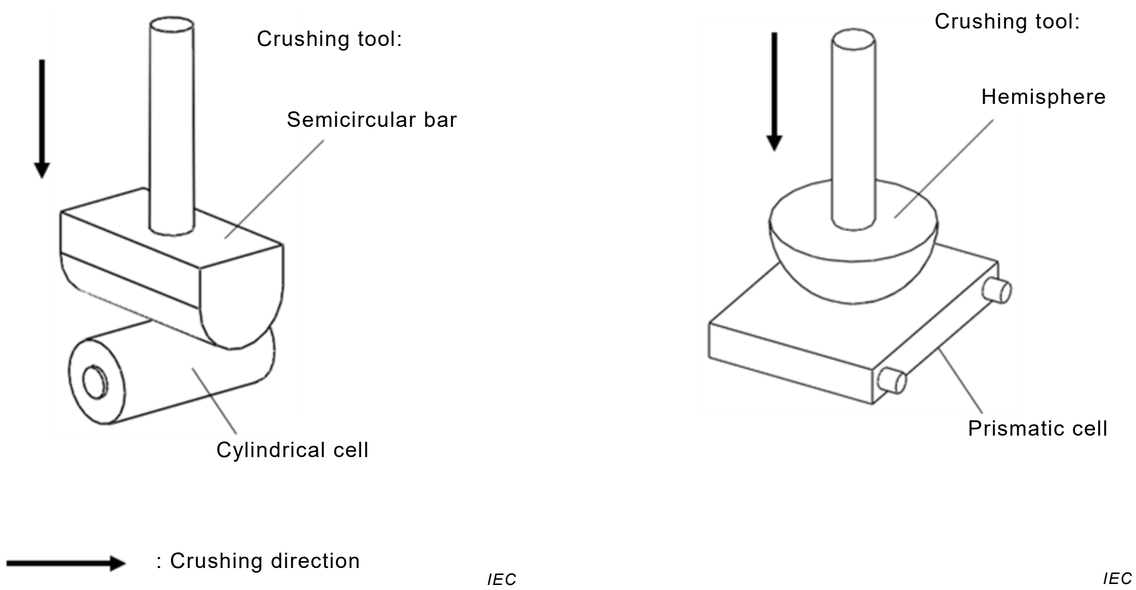
6.2.3.1 Purpose

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.

6.2.3.2 Test

The test shall be performed as follows.

a) Adjust the SOC of cell to 100 % for BEV application and 80 % for HEV application in accordance with 5.3.
b) The cell shall be placed on an insulated rigid flat supporting surface, and shall be applied a force 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 the layered face of the positive and negative electrodes inside 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.
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 is sooner.



a) Example for cylindrical cell **b) Example for prismatic cell**

Figure 2 – Example of crush test

6.2.3.3 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 6.2.2.1.1 of IEC 62660-2:2010.

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 6.3.1.1 of IEC 62660-2:2010.

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 for BEV application and 5 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 120 % of the maximum voltage specified by the manufacturer, or the quantity of electricity applied to the cell reaches the equivalent of 130 % SOC, whichever comes first.

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 over-discharge 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 manufacturer, or the cell is discharged for 30 min, whichever is 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 caused by the contamination of 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 the single layer shall be confirmed. The prescribed 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 the single layer. The case and electrodes of the cell shall not be crushed. The modification shall be recorded.

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 the cell, as long as the test result is not influenced.

NOTE 1 The internal short circuit of a single layer can be confirmed usually by the voltage drop of a few mV.

NOTE 2 In the event that the aluminium foil of the positive electrode is exposed at the outer turn, and 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 be checked by the design review, FMEA, etc. according to the agreement between the customer and the cell supplier.

6.4.4.2.2 Alternative tests

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.

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

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

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

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.

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 cells, for the safety precautions to the customers such as the manufacturers of battery packs and systems. A suitable protection device and function should also be provided in the battery control system to allow for a possible failure of the charge control.

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

A.2 Charging conditions for safe use

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 a voltage not exceeding the upper limit. The cell manufacturer may also set a temperature range higher or lower than the standard temperature range, provided that the safety measures, such as lowered charging voltage, are taken. The operating region means a range of voltages and temperatures 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 most important 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 more easily occur 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, by 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 by the safety test in Clause 6 at the upper limit of the standard temperature range, and the acceptance criteria of each test are met.

A.2.3 Consideration on temperature

A.2.3.1 General

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

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

A.2.3.3 Low temperature range

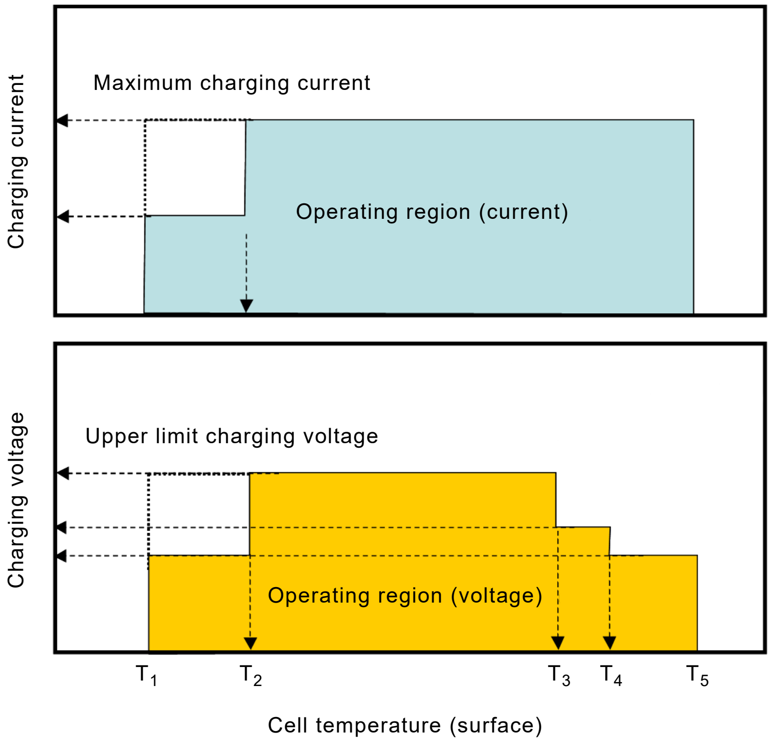
When a cell is charged in the low temperature range, the mass transfer rate decreases and the lithium-ion insertion rate into the negative material becomes low. Consequently, metallic lithium is easily deposited on the carbon surface. In this condition, the cell becomes thermally unstable and liable 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 cell is below the lower limit of the lower temperature range, the cell is never to be charged under any charging current.

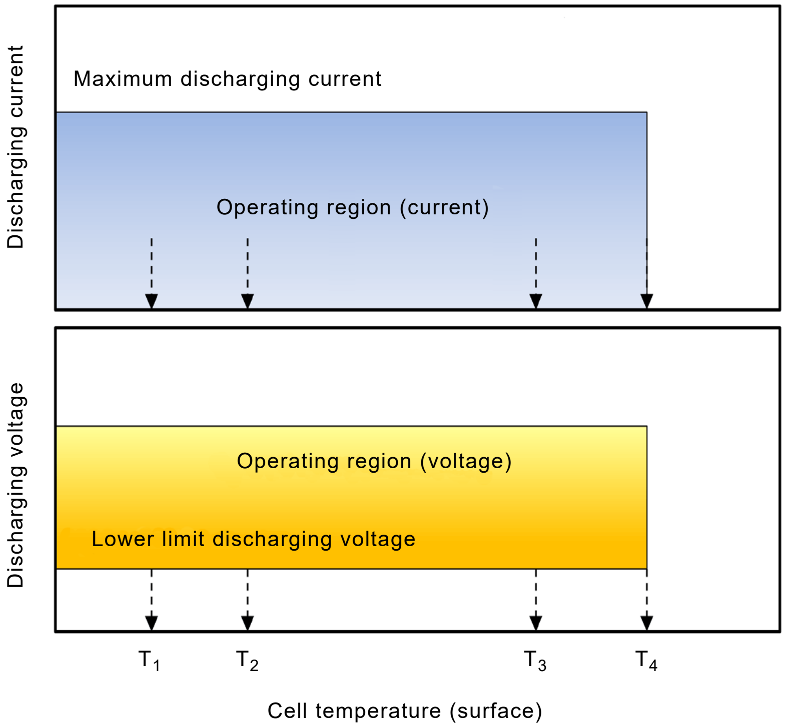
A.3 Example of operating region

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.



$T_1 - T_2$: Low temperature range
$T_2 - T_3$: Standard temperature range
$T_3 - T_5$: High temperature range

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



$T_1 - T_2$: Low temperature range
$T_2 - T_3$: Standard temperature range
$T_3 - T_4$: High temperature range

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 standard verify the cell's behaviour in some specific cases of internal short-circuiting. 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, demonstrate 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 of utmost importance to note that the comprehensive mitigation of the risk is necessarily 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 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 standard are intended to verify the basic safety of the cell against the various short-circuit phenomena (see Table B.1).

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

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)		6.2.2 Mechanical shock
	Crush of the cell		6.2.3 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 of 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 and IEC TR 62914. The FISC test is conducted with a test cell in which a nickel particle is inserted in order to simulate the worst-case condition of the internal short-circuit. The prescribed size of 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-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. It is verified that the thermal, chemical and electrical conditions of the processed test cell are equivalent to 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, the unprocessed cell, because of the low heat conductance of the polyethylene bag to be used for the test cell. The press jig made of acrylic resin or nitrile rubber has a low 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 test cell is almost entirely prevented according to the prescribed test procedure, so that there is no influence on the test result. The processed cell has almost the same performance as unprocessed states in both capacity and resistance.

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5 To be published.

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