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

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

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Part 2: Lithium systems

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International Standard IEC 62133-2 has been prepared by subcommittee 21A: Secondary cells and batteries containing alkaline or other non-acid electrolytes, of IEC technical committee 21: Secondary cells and batteries.

This first edition cancels and replaces the second edition of IEC 62133 published in 2012. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC 62133:2012:

– separation of nickel systems into a separate Part 1;
– inclusion of coin cell requirements;

– update of assembly of cells into batteries (5.6);
– mechanical tests [vibration, shock] (7.3.8.1, 7.3.8.2);
– insertion of IEC TR 62914 within the Bibliography.

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

FDIS	Report on voting
21A/620/FDIS	21A/628/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.

The following different practices of a less permanent nature exist in the countries indicated below.

7.3.9: Design evaluation – Forced internal short-circuit test only applies to Korea, Japan, Switzerland and France.

A list of all parts of the IEC 62133 series, published under the general title *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*, 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.

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SECONDARY CELLS AND BATTERIES CONTAINING ALKALINE OR OTHER NON-ACID ELECTROLYTES – SAFETY REQUIREMENTS FOR PORTABLE SEALED SECONDARY CELLS, AND FOR BATTERIES MADE FROM THEM, FOR USE IN PORTABLE APPLICATIONS –

Part 2: Lithium systems

1 Scope

This part of IEC 62133 specifies requirements and tests for the safe operation of portable sealed secondary lithium cells and batteries containing non-acid electrolyte, under intended use and reasonably foreseeable misuse.

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 60050-482:2004, *International Electrotechnical Vocabulary – Part 482: Primary and secondary cells and batteries* (available at http://www.electropedia.org)

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-482, ISO/IEC Guide 51 and the following apply.

3.1
safety
freedom from unacceptable risk

3.2
risk
combination of the probability of occurrence of harm and the severity of that harm

3.3
harm
physical injury or damage to the health of people or damage to property or to the environment

3.4
hazard
potential source of harm

3.5
intended use
use of a product, process or service in accordance with specifications, instructions and information provided by the supplier

3.6
reasonably foreseeable misuse
use of a product, process or service in a way which is not intended by the supplier, but which may result from readily predictable human behaviour

3.7
secondary cell
basic manufactured unit providing a source of electrical energy by direct conversion of chemical energy, that consists of electrodes, separators, electrolyte, container and terminals, and that is designed to be charged electrically

3.8
secondary battery
assembly of secondary cell(s) which may include associated safety and control circuits and case, ready for use as a source of electrical energy characterized by its voltage, size, terminal arrangement, capacity and rate capability

Note 1 to entry: Includes single cell batteries.

3.9
leakage
unplanned, visible escape of liquid electrolyte

3.10
venting
release of excessive internal pressure from a cell or battery in a manner intended by design to preclude rupture or explosion

3.11
rupture
mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

3.12
explosion
failure that occurs when a cell container or battery case opens violently and major components are forcibly expelled

3.13
fire
emission of flames from a cell or battery

3.14
portable battery
battery for use in a device or appliance which is conveniently hand-carried

3.15
portable cell
cell intended for assembly in a portable battery

3.16
lithium ion polymer cell
cell using gel polymer electrolyte or solid polymer electrolyte, not liquid electrolyte

3.17
rated capacity
capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

Note 1 to entry: The rated capacity is the quantity of electricity C_5 Ah (ampere-hours) declared by the manufacturer which a single cell can deliver when discharged at the reference test current of 0,2 I_t A to a specified final voltage, after charging, storing and discharging under specified conditions.

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – Note 1 to entry has been added.]

3.18
reference test current
I_t
charge or discharge current expressed as a multiple of I_t A, where I_t A = C_5 Ah/1 h, as defined in IEC 61434, and based on the rated capacity (C_5 Ah) of the cell or battery

3.19
upper limit charging voltage
highest charging voltage in the cell operating region, which is specified by the cell manufacturer

3.20
maximum charging current
maximum charging current in the cell operating region, which is specified by the cell manufacturer

3.21
coin cell
button cell
coin battery
small round cell or battery in which the overall height is less than the diameter

Note 1 to entry: In English, the term “coin cell” or “coin battery” is used for lithium batteries only while the term “button cell” or “button battery” is only used for non-lithium batteries. In languages other than English, the terms “coin” and “button” are often used interchangeably, regardless of the electrochemical system.

[SOURCE: IEC 60050-482:2004 482-02-40, modified — The term “coin battery” has been added, and the NOTE “In practice terms, the term coin is used exclusively for non-aqueous lithium cells.” has been replaced with Note 1 to entry.)]

3.22
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]

3.23
prismatic cell
cell having the shape of a parallelepiped whose faces are rectangular

Note 1 to entry: Prismatic cells may be provided with either a rigid metal case or flexible laminate film case.

[SOURCE: IEC 60050-482:2004, 482-02-38, modified – The source term is "prismatic" (adj.). In the definition, "qualifies a cell or a battery" has been replaced with "cell". Note 1 to entry has been added.]

3.24
cell block
parallel connection
arrangement of cells or batteries wherein all the positive terminals and all the negative terminals, respectively, are connected together

[SOURCE: IEC 60050-482:2004, 482-03-39, modified — The term "cell block" has been added.]

3.25
functional safety
part of the overall safety that depends on functional and physical units operating correctly in response to their inputs

[SOURCE: IEC 60050-351:2013, 351-57-06]

3.26
end-of-discharge voltage
final voltage
specified voltage of a battery at which the battery discharge is terminated

[SOURCE: IEC 60050-482:2004, 482-03-30, modified — The terms "cut-off voltage" and "end-point voltage" have been deleted.]

4 Parameter measurement tolerances

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

a) ± 1 % for voltage;

b) ± 1 % for current;

c) ± 2 °C for temperature;

d) ± 0,1 % for time;

e) ± 1 % for dimension;

f) ± 1 % for capacity.

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

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

5 General safety considerations

5.1 General

The safety of secondary cells and batteries requires the consideration of two sets of applied conditions:

1) intended use;

2) reasonably foreseeable misuse.

Cells and batteries shall be so designed and constructed that they are safe under conditions of both intended use and reasonably foreseeable misuse. It is expected that cells or batteries subjected to misuse may fail to function following such experience. They shall not however present significant hazards. It may also be expected that cells and batteries subjected to intended use shall not only be safe but shall continue to be functional in all respects.

Potential hazards which are the subject of this document are:

- fire,
- burst/explosion,
- leakage of cell electrolyte,
- venting,
- burns from excessively high external temperatures,
- rupture of battery case with exposure of internal components.

Conformity with 5.2 to 5.7 for cells and batteries other than coin cells, with an internal resistance greater than 3 Ω, is checked by inspection, by the tests of Clauses 7, and in accordance with the appropriate standard (see Clause 2 and Table 1). The internal resistance is to be measured in accordance with Annex D.

5.2 Insulation and wiring

The insulation resistance between the positive terminal and externally exposed metal surfaces of the battery excluding electrical contact surfaces shall be not less than 5 MΩ at 500 V DC when measured 60 s after applying the voltage.

Internal wiring and insulation should be sufficient to withstand the maximum anticipated current, voltage and temperature requirements. The orientation of wiring should be such that adequate clearances and creepage distances are maintained between conductors. The mechanical integrity of internal connections should be sufficient to accommodate conditions of reasonably foreseeable misuse (i.e. solder alone is not considered a reliable means of connection.).

5.3 Venting

Battery cases and cells shall incorporate a pressure relief mechanism or shall be so constructed that they will relieve excessive internal pressure at a value and rate that will preclude rupture, explosion and self-ignition. If encapsulation is used to support cells within an outer case, the type of encapsulant and the method of encapsulation shall neither cause the battery to overheat during normal operation nor inhibit pressure relief.

5.4 Temperature, voltage and current management

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

5.5 Terminal contacts

The size and shape of the terminal contacts shall ensure that they can carry the maximum anticipated current. External terminal contact surfaces shall be formed from conductive materials with good mechanical strength and corrosion resistance. Terminal contacts shall be arranged so as to minimize the risk of short-circuit.

5.6 Assembly of cells into batteries

5.6.1 General

Each battery should have an independent control and protection for current, voltage, temperature and any other parameter required for safety and to maintain the cells within their operating region. However this protection may be provided external to the battery such as within the charger or the end devices. If protection is external to the battery, the manufacturer of the battery shall provide this safety relevant information to the external device manufacturer for implementation.

If there is more than one battery housed in a single battery case, each battery should have protective circuitry that can maintain the cells within their operating regions.

Manufacturers of cells shall specify current, voltage and temperature limits so that the battery manufacturer/designer may ensure proper design and assembly (see Annex A).

Batteries that are designed for the selective discharge of a portion of their series connected cells shall incorporate circuitry to prevent operation of cells outside the limits specified by the cell manufacturer.

Protective circuit components should be added as appropriate and consideration given to the end-device application. The manufacturer of the battery should provide a safety analysis of the battery safety circuitry with a test report including a fault analysis of the protection circuit under both charging and discharging conditions confirming the compliance.

5.6.2 Design recommendation

The voltage of each cell, or each cellblock consisting of parallel-connected plural cells, should not exceed the upper limit of the charging voltage specified in Table 2, excepting the case where the portable electronic devices or similar devices have the equivalent function.

The following should be considered at the battery level and by the device designer.

- For the battery consisting of a single cell or a single cellblock, it is recommended that the charging voltage of the cell does not exceed the upper limit of the charging voltage specified in Table 2;
- For the battery consisting of series-connected plural single cells or series-connected plural cellblocks, it is recommended that the voltages of any one of the single cells or single cellblocks does not exceed the upper limit of the charging voltage, specified in Table 2, by monitoring the voltage of every single cell or the single cellblocks.
- For the battery consisting of series-connected plural single cells or series-connected plural cellblocks, it is recommended that charging is stopped when the upper limit of the charging voltage is exceeded for any one of the single cells or single cellblocks by measuring the voltage of every single cell or the single cellblocks.
- For batteries consisting of series-connected cells or cell blocks, nominal charge voltage shall not be counted as an overcharge protection.
- For batteries consisting of series-connected cells or cell blocks, cells should have closely matched capacities, be of the same design, be of the same chemistry and be from the same manufacturer.
- It is recommended that the cells and cell blocks should not be discharged beyond the cell manufacturer’s specified final voltage.
- For batteries consisting of series-connected cells or cell blocks, cell balancing circuitry should be incorporated into the battery management system.

5.6.3 Mechanical protection for cells and components of batteries

Mechanical protection for cells, cell connections and control circuits within the battery should be provided to prevent damage as a result of intended use and reasonably foreseeable misuse. The mechanical protection can be provided by the battery case or it can be provided by the end product enclosure for those batteries intended for building into an end product.

The battery case and compartments housing cells should be designed to accommodate cell dimensional tolerances during charging and discharging as recommended by the cell manufacturer.

For batteries intended for building into a portable end product, testing with the battery installed within the end product should be considered when conducting mechanical tests.

5.7 Quality plan

The manufacturer shall prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells and batteries and which covers the whole process of producing each type of cell or battery. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product safety.

5.8 Battery safety components

See Annex F.

6 Type test and sample size

Tests are made with the number of cells or batteries specified in Table 1 using cells or batteries that are not more than six months old. The internal resistance of coin cells shall be measured in accordance with Annex D. Coin cells with internal resistance less than or equal to 3 Ω shall be tested in accordance with Table 1. Unless otherwise specified, tests are carried out in an ambient temperature of 20 °C ± 5 °C.

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

Table 1 – Sample size for type tests

Test		Cell [a, d]	Battery
7.2.1	Continuous charge	5	–
7.2.2	Case stress	–	3
7.3.1	External short-circuit	5 per temperature	–
7.3.2	External short-circuit	–	5
7.3.3	Free fall	3	3
7.3.4	Thermal abuse	5 per temperature	–
7.3.5	Crush	5 per temperature	–
7.3.6	Overcharge	–	5
7.3.7	Forced discharge	5	–
7.3.8	Mechanical – 7.3.8.1 Vibration – 7.3.8.2 Mechanical shock	–	 3 3
7.3.9	Forced internal short [b, c]	5 per temperature	–
D.2	Measurement of the internal AC resistance for coin cells	3	–

[a] Excludes coin cells with an internal resistance greater than 3 Ω.

[b] Country specific test: only required for listed countries.

[c] Not applicable to coin and lithium ion polymer cells.

[d] For tests requiring charge procedure of 7.1.2 (procedure 2): 5 cells per temperature are tested

The safety analysis of 5.6.1 should identify those components of the protection circuit that are critical for short-circuit, overcharge and overdischarge protection. When conducting the short-circuit test, consideration should be given to the simulation of any single fault condition that is likely to occur in the protecting circuit that would affect the short-circuit test.

7 Specific requirements and tests

7.1 Charging procedures for test purposes

7.1.1 First procedure

This charging procedure applies to subclauses other than those specified in 7.1.2.

Unless otherwise stated in this document, the charging procedure for test purposes is carried out in an ambient temperature of 20 °C ± 5 °C, using the method declared by the manufacturer.

Prior to charging, the battery shall have been discharged at 20 °C ± 5 °C at a constant current of 0,2 I_t A down to a specified final voltage.

7.1.2 Second procedure

This charging procedure applies only to 7.3.1, 7.3.4, 7.3.5, and 7.3.9.

After stabilization for 1 h and 4 h, respectively, at ambient temperature of highest test temperature and lowest test temperature, as specified in Table 2, cells are charged by using the upper limit charging voltage and maximum charging current, until the charging current is reduced to 0,05 I_t A, using a constant voltage charging method.

Table 2 – Condition of charging procedure

Upper limit charging voltage	Maximum charging current	Charging temperature upper limit	Charging temperature lower limit
Specified by the manufacturer of cells/cell	Specified by the manufacturer of cells	Specified by the manufacturer of cells	Specified by the manufacturer of cells

See Figures A.1 and A.2 for an example of an operating region for charge and discharge. See Table A.1 for a list of lithium ion chemistries and examples of operating region parameters.

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

7.2 Intended use

7.2.1 Continuous charging at constant voltage (cells)

a) Requirement

A continuous charge at constant voltage shall not cause leakage, fire or explosion.

b) Test

Fully charged cells are subjected for 7 days to a charge using the charging method for current and standard voltage specified by the cell manufacturer.

c) Acceptance criteria

No fire, no explosion, no leakage.

7.2.2 Case stress at high ambient temperature (battery)

a) Requirement

Internal components of batteries shall not be exposed during use at high temperature. This requirement only applies to batteries with a moulded case.

b) Test

Fully charged batteries, according to the first procedure in 7.1.1, are exposed to a moderately high temperature to evaluate case integrity. The battery is placed in an air circulating oven at a temperature of 70 °C ± 2 °C. The batteries remain in the oven for 7 h, after which they are removed and allowed to return to room temperature.

c) Acceptance criteria

No physical distortion of the battery case resulting in exposure of internal protective components and cells.

7.3 Reasonably foreseeable misuse

7.3.1 External short-circuit (cell)

a) Requirements

Short-circuiting of the positive and negative terminals of the cell at high temperature shall not cause fire or explosion.

b) Test

Fully charge each cell according to the second procedure in 7.1.2. Store in an ambient temperature of 55 °C ± 5 °C. After stabilization for 1 h to 4 h and while still in an ambient temperature of 55 °C ± 5 °C, the cell is short-circuited by connecting the positive and negative terminals with a total external resistance of 80 mΩ ± 20 mΩ. The cell remains on test for 24 h or until the surface temperature declines by 20 % of the maximum temperature rise, whichever is the sooner.

c) Acceptance criteria

No fire, no explosion.

7.3.2 External short-circuit (battery)

a) Requirements

Short-circuiting of the positive and negative terminals of the battery shall not cause fire or explosion.

b) Test

A fully charged battery according to the procedure in 7.1.1 is stored in an ambient temperature of 20 °C ± 5 °C. The battery is then short-circuited by connecting the positive and negative terminals with a total external resistance of 80 mΩ ± 20 mΩ. The battery remains on test for 24 h or until the case temperature of battery declines by 20 % of the maximum temperature rise, whichever is the sooner. However, in case of a rapid decline in the short-circuit current, the battery should remain on test for an additional one hour after the current reaches a low end steady state condition. This typically refers to a condition where the per cell voltage (series cells only) of the battery is below 0,8 V and is decreasing by less than 0,1 V in a 30-min period.

A single fault in the discharge protection circuit should be conducted on one to four (depending upon the protection circuit) of the five samples before conducting the short-circuit test. A single fault applies to protective component parts such as MOSFET (metal oxide semiconductor field-effect transistor), fuse, thermostat or positive temperature coefficient (PTC) thermistor.

NOTE Examples of single fault conditions in the discharge protection circuit can include shorting over a discharge MOSFET or over a fuse or other protection device. Protection devices found to meet the requirements of applicable component standards such as those outlined in Annex F or electronics circuits evaluated for functional safety are not subject to single fault conditions.

c) Acceptance criteria

No fire, no explosion.

7.3.3 Free fall

a) Requirements

Dropping a cell or battery (for example, from a bench top) shall not cause fire or explosion.

b) Test

Free fall test is conducted at an ambient temperature of 20 °C ± 5 °C, by using cells or batteries that are charged to a fully charged state, in accordance with the first procedure in 7.1.1. Each cell or battery is dropped three times from a height of 1,0 m onto a flat concrete floor or metal floor. The cells or batteries are dropped so as to obtain impacts in random orientations. After the test, the cell or battery shall be put on rest for a minimum of 1 h and then a visual inspection shall be performed.

c) Acceptance criteria

No fire, no explosion.

7.3.4 Thermal abuse (cells)

a) Requirements

An extremely high temperature shall not cause fire or explosion.

b) Test

Each fully charged cell, according to the second procedure in 7.1.2, is placed in a gravity or circulating air-convection oven, in an ambient temperature of 20 °C ± 5 °C, for 1 h. The oven temperature is raised at a rate of 5 °C/min ± 2 °C/min to a temperature of 130 °C ± 2 °C. The cell remains at this temperature for 30 min before the test is terminated.

c) Acceptance criteria

No fire, no explosion.

7.3.5 Crush (cells)

a) Requirements

Severe crushing of a cell shall not cause fire or explosion.

b) Test

Each fully charged cell, charged according to the second procedure at the upper limit charging temperature in 7.1.2, is immediately transferred and crushed between two flat surfaces in an ambient temperature. The force for the crushing is applied by a device exerting a force of 13 kN ± 0,78 kN. Once the maximum force has been applied, or an abrupt voltage drop of one-third of the original voltage has been obtained, the force is released.

A cylindrical or prismatic cell is crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. Test only the wide side of prismatic cells.

A coin cell shall be crushed by applying the force on its flat surface.

c) Acceptance criteria

No fire, no explosion.

7.3.6 Over-charging of battery

a) Requirements

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

b) Test

The test shall be carried out in an ambient temperature of 20 °C ± 5 °C. Each test battery shall be discharged at a constant current of 0,2 I_t A, to a final discharge voltage specified by the manufacturer. Sample batteries shall then be charged at a constant current of 2,0 I_t A, using a supply voltage which is:

- 1,4 times the upper limit charging voltage presented in Table A.1 (but not to exceed 6,0 V) for single cell/cell block batteries or
- 1,2 times the upper limit charging voltage presented in Table A.1 per cell for series connected multi-cell batteries, and
- sufficient to maintain a current of 2,0 I_t A throughout the duration of the test or until the supply voltage is reached.

A thermocouple shall be attached to each test battery.

For batteries with a case, the temperature shall be measured on the battery case. The test shall be continued until the temperature of the outer case reaches steady state conditions (less than 10 °C change in a 30-min period) or returns to ambient.

c) Acceptance criteria

No fire, no explosion.

7.3.7 Forced discharge (cells)

a) Requirements

A cell shall withstand polarity reversal without causing fire or explosion. A protective device in a battery or system can be adopted.

b) Test

Discharge a single cell to the lower limit discharge voltage specified by the cell manufacturer.

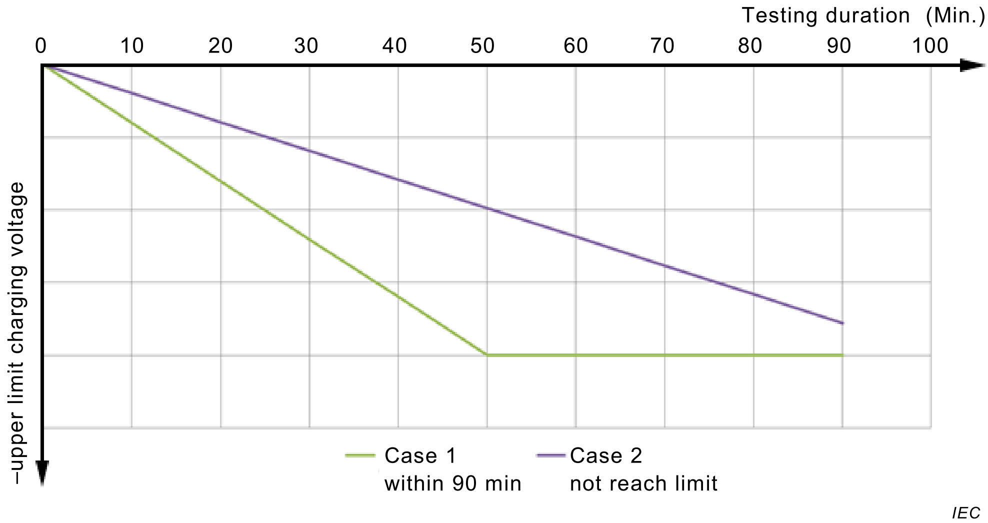
The discharged cell is then subjected to a forced discharge at 1 I_t A to the negative value of the upper limit charging voltage. The total duration for the forced discharge testing is 90 min.

If the discharge voltage reaches the negative value of upper limit charging voltage within the testing duration, the voltage shall be maintained at the negative value of the upper limit charging voltage by reducing the current for the remainder of the testing duration. (Case 1 of Figure 1)

If the discharge voltage does not reach the negative value of upper limit charging voltage within the testing duration, the test shall be terminated at the end of the testing duration. (Case 2 of Figure 1)

c) Acceptance criteria

No fire, no explosion.



NOTE The curves shown in Figure 1 are just examples as the curves (except the horizontal segment) may not be linear or straight.

Figure 1 – Forced discharge time chart

7.3.8 Mechanical tests (batteries)

7.3.8.1 Vibration

a) Requirements

Vibration encountered during transportation and use shall not cause leakage, fire or explosion.

b) Test

Test batteries, fully charged in accordance with the charging procedure of 7.1.1, shall be firmly secured to the platform of the vibration machine without distorting them in such a manner as to faithfully transmit the vibration. Test batteries shall be subjected to sinusoidal vibration according to Table 3. This cycle shall be repeated 12 times for a total of approximately 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

c) Acceptance criteria

No fire, no explosion, no rupture, no leakage or venting.

Table 3 – Conditions for vibration test

Frequency range (Hz)		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
from	**to**				
f_1 = 7 Hz	f_2	A1 = 1 g_n	Approximately 15 min	X	12
f_2	f_3	S = 0,8 mm		Y	12
f_3	f_4 = 200 Hz	A2		Z	12
and back to f_1 = 7Hz				Total	36

NOTE Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0,8 mm corresponds to a peak-to-peak displacement of 1,6 mm.

Key

f_1, f_4 lower and upper frequency

f_2, f_3 cross-over frequencies
- f_2 ≈ 17,62 Hz
- f_3 ≈ 49,84 Hz

A1, A2 acceleration amplitude
- A2 = 8 g_n

S displacement amplitude

7.3.8.2 Mechanical shock

a) Requirements

Shock encountered during transportation and use shall not cause leakage, fire or explosion. This test simulates rough handling during transport and use.

b) Test procedure

Test batteries, fully charged in accordance with the charging procedure of 7.1.1, shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test battery. Each test battery shall be subjected to three shocks in each direction of three mutually perpendicular mounting positions of the battery for a total of 18 shocks. For each shock, the parameters given in Table 4 shall be applied.

c) Acceptance criteria

There shall be no leakage, no venting, no rupture, no explosion and no fire during this test.

Table 4 – Shock parameters

	Waveform	Peak acceleration	Pulse duration	Number of shocks per half axis
Batteries	Half sine	150 g_n	6 ms	3

7.3.9 Design evaluation – Forced internal short-circuit (cells)

a) Requirements

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

NOTE This is a country specific test, which is only applicable to France, Japan, Korea and Switzerland and is not required on lithium ion polymer cells.

b) Test

The forced internal short-circuit test is performed in a chamber according to the following procedure.

1) Number of samples

This test shall be carried out on five lithium ion cells per test temperature.

2) Charging procedure

i) Conditioning charge and discharge

The sample shall be charged at 20 °C ± 5 °C according to the manufacturer's recommendation. The sample is then discharged at 20 °C ± 5 °C, at a constant current of 0,2 I_t A, down to the final voltage specified by the manufacturer.

ii) Storage procedure

The test cell shall be stored for 1 h to 4 h at an ambient temperature as specified in Table 5.

iii) Ambient temperature

Table 5 – Ambient temperature for cell test [a]

Test item	Test at lowest test temperature °C	Test at highest test temperature °C
b) 2) ii)	10 ± 2	45 ± 2
b) 2) iv)	10 ± 2	45 ± 2
b) 3) i) A	5 ± 2	50 ± 2
b) 3) ii) A	10 ± 5	45 ± 5

[a] The test is conducted using conditions in Table 2.

iv) Charging procedure for forced internal short test

The test cell shall be charged at an ambient temperature as specified in Table 5, at the upper limit charging voltage at the constant current specified by the manufacturer. When the upper limit charging voltage is reached, continue charging at constant voltage until the charge current drops to 0,05 I_t A.

3) Pressing the winding core with nickel particle

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

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

i) Preparation for the test

A The temperature of the chamber is controlled as specified in Table 5. Sample preparation guidance is provided in Clause A.5 and in Figure A.6 and Figure A.9. Put the aluminium laminated bag with the winding core and nickel particle into the chamber for 45 min ± 15 min.

B Remove the winding core from the sealed package and attach the terminals for voltage measurement and the thermocouple(s) for temperature measurement on the surface of the winding core. Set the winding core under the pressure equipment making sure to locate the point of placement of the nickel particle under the pressing jig.

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

C Remove the insulating sheet and close the chamber door.

ii) Internal short-circuit

A Confirm that the winding core surface temperature is as defined in Table 5, and then start the test.

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

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

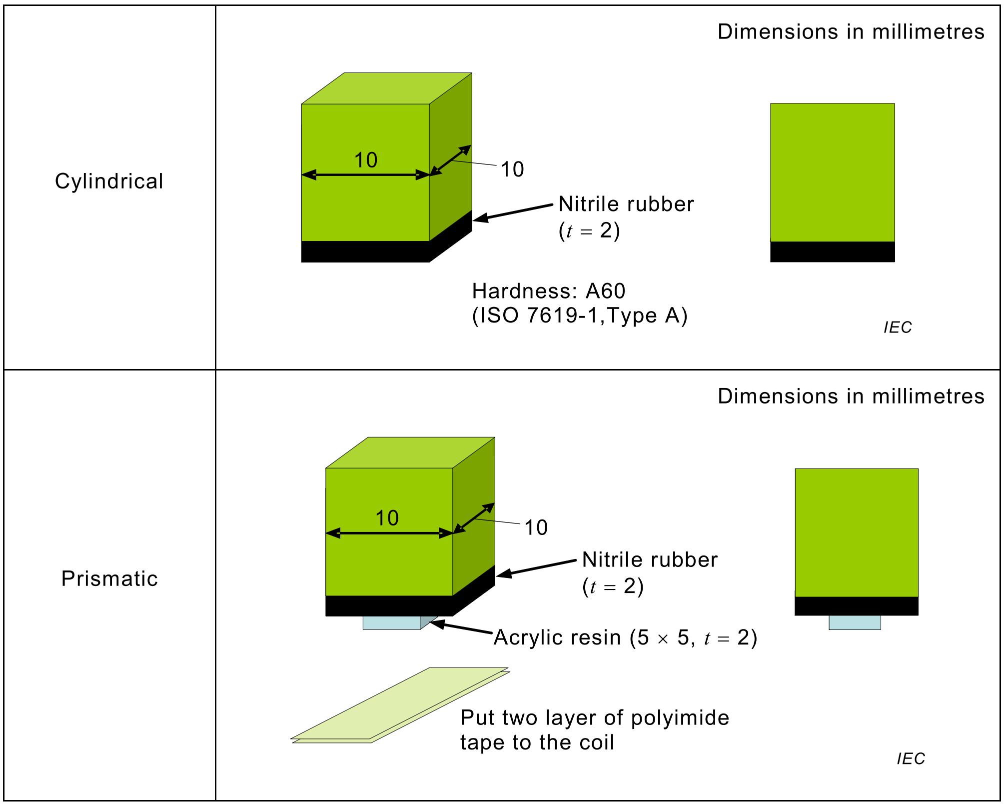


Figure 2 – Jig for pressing

c) Acceptance criteria

No fire. Record the force when an internal short-circuit occurs if there was no fire.

8 Information for safety

8.1 General

The use, and particularly abuse, of portable sealed secondary lithium cells and batteries may result in the creation of hazards and may cause harm. Manufacturers of secondary cells shall ensure that information is provided about current, voltage and temperature limits of their products. Manufacturers of batteries shall ensure that equipment manufacturers and, in the case of direct sales, end-users are provided with information to minimize and mitigate hazards.

It is the equipment manufacturer’s responsibility to inform end-users of the potential hazards arising from the use of equipment containing secondary cells and batteries. Systems analyses should be performed by device manufacturers to ensure that a particular battery design prevents hazards from occurring during use of a product. As appropriate, any information relating to hazard avoidance resulting from a system analysis should be provided to the end user.

Guidance is provided in IEC TR 62188 on the design and manufacture of portable batteries, and non-exhaustive lists of good advice are provided for information in Annexes B and C.

Conformity can be checked by examination of manufacturer's documentation.

Do not allow children to replace batteries without adult supervision.

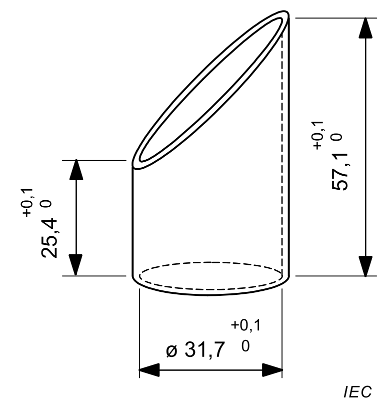
8.2 Small cell and battery safety information

Small cells and batteries and equipment using small cells and batteries are to be provided with information regarding ingestion hazards. Small cells and batteries that may pose an ingestion hazard are those that can fit within the limits of the ingestion gauge shown in Figure 3.

The following warning language is to be provided with the information packaged with the small cells and batteries or equipment using them:

- Keep small cells and batteries which are considered swallowable out of the reach of children.
- Swallowing may lead to burns, perforation of soft tissue, and death. Severe burns can occur within 2 h of ingestion.
- In case of ingestion of a cell or battery, seek medical assistance promptly.

Dimensions in millimetres



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

Figure 3 – Ingestion gauge

9 Marking

9.1 Cell marking

Cells shall be marked as specified in IEC 61960, except coin cells. Coin cells whose external surface area is too small to accommodate the markings on the cells shall show the designation and polarity.

By agreement between the cell manufacturer and the battery and/or end product manufacturer, component cells used in the manufacture of a battery need not be marked. However, the cell marking can be indicated with the battery, the instructions and/or the specifications.

Conformity is checked by inspection.

9.2 Battery marking

Batteries shall be marked as specified in IEC 61960, except for coin batteries. Coin batteries whose external surface area is too small to accommodate the markings on the batteries shall show the designation and polarity. Batteries shall also be marked with an appropriate caution statement.

Terminals shall have clear polarity marking on the external surface of the battery.

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

Conformity is checked by inspection.

9.3 Caution for ingestion of small cells and batteries

Coin cells and batteries identified as small batteries according to 8.2 shall include a caution statement regarding the hazards of ingestion in accordance with 8.2.

When small cells and batteries are intended for direct sale in consumer-replaceable applications, caution for ingestion shall be given on the immediate package.

Conformity is checked by inspection.

9.4 Other information

The following information shall be marked on or supplied with the battery:

- storage and disposal instructions;
- recommended charging instructions.

Conformity is checked by examination of markings and manufacturer's documentation.

10 Packaging and transport

Packaging for coin cells shall not be small enough to fit within the limits of the ingestion gauge of Figure 3.

Refer to Annex E for information regarding packaging and transport.

Annex A
(normative)

Charging and discharging range of secondary lithium ion cells for safe use

A.1 General

Annex A supplements the descriptions in both the main part and annexes. It constitutes a part of this document.

A.2 Safety of lithium ion secondary battery

In order to ensure the safe use of lithium ion secondary batteries, manufacturers who design and produce lithium ion secondary cells or batteries shall strictly observe the requirements which are specified in this document. In case of a different upper limit charging voltage (i.e. other than for systems as noted in Table A.1), it may be appropriate to adjust the upper limit charging voltage and upper limit charging temperatures accordingly to fulfil the criteria of the tests.

A.3 Consideration on charging voltage

A.3.1 General

The charging voltage shall be applied for secondary cells so as to promote the chemical reaction during charging. However, if the charging voltage is too high, excessive chemical reaction or side reactions occur, and the battery becomes thermally unstable. (It may overheat and thermal runaway may occur.) Consequently, it is most important that the charging voltage never exceeds the value which is specified by the battery manufacturer. On the other hand, battery manufacturers shall verify the safety of secondary cells, which are charged at the specified charging voltage.

A.3.2 Upper limit charging voltage

A.3.2.1 General

Lithium ion secondary batteries which employ lithium cobalt oxide as the positive active material and carbon as the negative material are commonly used. In this battery, the upper limit charging voltage, as defined in Table A.1 is specified based on the cell manufacturer’s specifications with an example value of 4,25 V for the lithium ion cell which is a permissible upper limit charging voltage from a safety viewpoint. Figure A.1 illustrates the basic operating region for charging.

A.3.2.2 Explanation of safety viewpoint

When a lithium ion battery is charged at a higher voltage than the upper limit charging voltage, excess amount of lithium ion is de-intercalated from the positive electrode active material and its crystalline structure tends to collapse. As a result, it becomes easy to generate oxygen and metallic lithium deposits on the carbon surface, which is employed as the negative material.

In these conditions, when an internal short-circuit occurs, thermal runaway can more easily occur than when said battery is charged under the specified condition.

Consequently, lithium ion secondary battery should never be charged at a higher voltage than this recommended upper limit charging voltage. A suitable protection device shall also be provided, by assuming the possible failure of charge control by the charger.

For alternating current of over 50 kHz, which assumes ripple, the above statements are not applicable, since lithium ion in the battery does not respond to it.

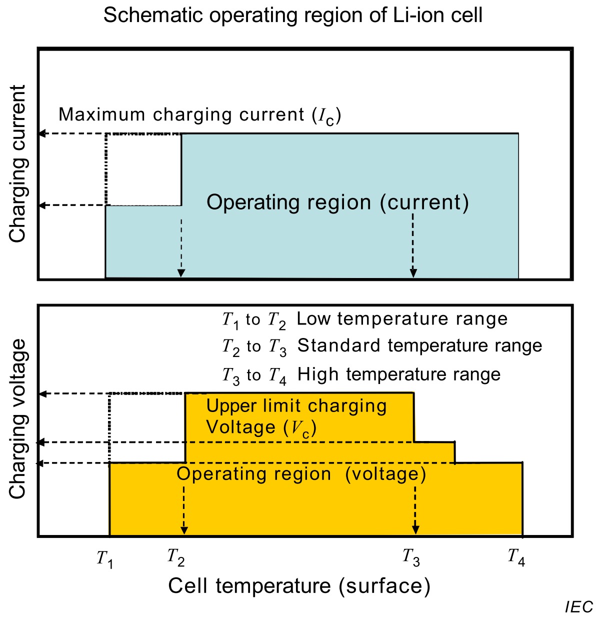


Figure A.1 – Representation of lithium ion cells operating region for charging

Table A.1 – Examples of operating region charging parameters

Cell type	Positive electrode	Electrolyte	Negative electrode	Upper limit charging voltage	Recommended temperature range (T_2 to T_3)
Lithium ion cell	Lithium transition metal (nickel, cobalt, manganese, etc.) oxide	Non-aqueous solution with lithium salt	Carbon	Specified by the cell manufacturer (Example: 4,25 V/cell)	Specified by the cell manufacturer (Example: 10 °C to 45 °C)
			Tin based Compound	Specified by the cell manufacturer (Example: 4,25 V/cell)	Specified by the cell manufacturer
			Titanium oxide	Specified by the cell manufacturer (Example: 2,85 V/cell)	Specified by the cell manufacturer
	Lithium iron phosphate		Carbon	Specified by the cell manufacturer (Example: 3,80 V/cell)	Specified by the cell manufacturer
Lithium ion polymer cell	Lithium transition metal (nickel, cobalt, manganese, etc.) oxide	Gel polymer with lithium salt	Carbon	Specified by the cell manufacturer (Example: 4,25 V/cell)	Specified by the cell manufacturer (Example: 10 °C to 45 °C)

A.3.2.3 Safety requirements, when different upper limit charging voltage is applied

It is sometimes necessary that upper limit charging voltages different from the values noted in Table A.1 be applied for a lithium ion cell. Examples are as follows:

- positive active material, other than lithium-cobalt-oxide is employed;
- ratio of the capacity of the positive electrode and the negative electrode is changed from the design viewpoint.

When an upper limit charging voltage different from the values noted in Table A.1 is to be applied for lithium ion secondary cells, tests that are specified in 7.2 to 7.3 shall be conducted by using cells which are charged under the different upper limit charging voltage. Also, relevant documents explaining reasons for the change of upper limit charging voltage shall be kept so that said different voltage can be used as the new upper limit charging voltage.

Examples of the documents explaining reasons of the change of upper limit charging voltage are as follows:

a) test results which verify that the stability of the crystalline structure of the positive active electrode material when the cell is charged at a voltage higher than the values specified in Table A.1 is equivalent to or higher than that when the cell is charged at the specified values;
b) test results which verify that the acceptance of lithium into the negative active electrode material when the cell is charged at a voltage higher than the values specified in Table A.1 is equivalent to or higher than that when the cell is charged at the specified values;
c) test results which verify that the cells charged at new upper limit charging voltage (higher than the values specified in Table A.1) are tested by the test methods at the upper limit of high temperature range and necessary requirements are met;
d) test results which verify that the cells charged at a voltage lower than the values specified in Table A.1 are tested by the test methods at the upper limit of high temperature range and necessary requirements are met;

A.4 Consideration of temperature and charging current

A.4.1 General

Charging produces a chemical reaction and is affected by temperature. The amount of side reaction or the condition of charge products is dependent on temperature even when the same upper limit charging voltage and charging current are employed.

Consequently, it is necessary that one or both of the upper limit charging voltage and maximum charging current shall be reduced at both the low temperature range and high temperature range. These conditions are considered to be more severe than the standard temperature range from a safety viewpoint.

Figure A.1 shows a basic operating region under which typical lithium ion batteries can be safely charged.

A.4.2 Recommended temperature range

A.4.2.1 General

Within the standard temperature range secondary cells can be charged at both the upper limit of charging voltage and the maximum charging current which is specified from a safety viewpoint.

The upper limit of the test temperature and the lower limit of the test temperature are specified as the highest limit and the lowest limit of standard temperature, respectively. For example, the recommended temperature range of some lithium ion batteries which employ lithium-cobalt-oxide as the positive active material and carbon as the negative material is specified as 10 °C to 45 °C.

A.4.2.2 Safety consideration when a different recommended temperature range is applied

In some secondary cells, a different recommended temperature range other than 10 °C to 45 °C is applied due to the difference of thermal stability of the electrolyte and other factors. When a new recommended temperature range is applied, tests that are specified in 7.2 to 7.3 shall be conducted by using cells which are charged at the different test temperature. Also, relevant documents explaining reasons of the change of test temperature shall be kept so that different temperature can be used.

Examples of the documents, explaining reasons of the change of test temperature are as follows:

a) test results which verify that the stability of the crystal structure of the positive active electrode material, when the cell is charged at the new upper limit of test temperature, higher than 45 °C (highest limit of the standard temperature range for typical lithium ion cells), is equivalent to or higher than that when the cell is charged at 45 °C;
b) test results which verify that the cells, charged at the new upper limit of test temperature (higher than 45 °C + 5 °C) and by using the upper limit charging voltage, are tested by the test methods specified in 7.2 to 7.3;
c) test results which verify that the acceptance of lithium into the negative active material, when the cell is charged at the new lower limit of test temperature, lower than 10 °C, is equivalent to or higher than that when the cell is charged at 10 °C;
d) test results which verify that the cells, charged at the new lower limit of test temperature (lower than 10 °C to 5 °C) and by using the upper limit of charging voltage, are tested by the test methods specified in 7.2 to 7.3.

A.4.3 High temperature range

A.4.3.1 General

In the high temperature range the temperature is higher than in the standard temperature range. Within the high temperature range, charging is permissible by charging at a lower voltage than the upper limit charging voltage which is specified for the standard temperature range.

A.4.3.2 Explanation of safety viewpoint

When lithium ion is charged at a higher temperature at the same condition as that for the standard temperature range, a larger amount of lithium is de-intercalated from the positive electrode active material. Since the increase in the amount of lithium de-intercalated leads to deterioration of the stability of the crystalline structure, the safety performance of the battery tends to decrease.

Also the temperature difference between the high temperature range and that at which thermal runaway occurs is relatively small. Consequently, in case there is an accident such as an internal short-circuit, it is easier for the battery to reach said temperature.

As a result, charging conditions are differently specified in the high temperature range, as follows.

- When the surface temperature of the lithium ion cell is higher than the upper limit of the test temperature, a different charging condition which is specially specified for the high temperature range is applied.
- When the surface temperature of the lithium ion cell is higher than the upper limit of the high temperature range, said battery shall never be charged under any charging current.

A.4.3.3 Safety considerations when specifying charging conditions in the high temperature range

Charging conditions in the high temperature range are sometimes specified based on the thermal stability of the electrolyte and other factors. When charging conditions in the high temperature range are to be specified, test cells shall be charged under these conditions and tested by the test methods specified in 7.2 to 7.3.

A.4.3.4 Safety considerations when specifying a new upper limit in the high temperature range

In some cases, a different upper limit in the high temperature range, other than that shown in Figure A.1 is applied due to the difference of thermal stability of positive electrode active material and other factors. When a new upper limit in the high temperature range is to be adopted, tests that are specified in 7.2 to 7.3 shall be conducted. Also, relevant documents explaining reasons of the change of high temperature range shall be kept so that the different high temperature range can be used.

Examples of the documents explaining reasons of the change of high temperature range are as follows:

a) test results which verify that the stability of the crystalline structure of the positive active electrode materials, when the cell is charged at the new upper limit of the high temperature range, is equivalent to or higher than that when the cell is charged at the highest limit of the present high temperature range;
b) test results which verify that the cells charged at the new upper limit of the high temperature range + 5 °C, when tested by the methods specified in 7.2 to 7.3, meet the requirements.

A.4.4 Low temperature range

A.4.4.1 General

In the low temperature range, the temperature is lower than that in the standard temperature range. In the low temperature range, charging of the battery is permissible by changing one or both of the upper limit of charging voltage and maximum charging current which are specified for the standard temperature range.

A.4.4.2 Explanation of safety viewpoint

When a lithium ion battery is charged in the low temperature range, the mass transfer rate decreases and the lithium ion insertion rate into the negative electrode active material becomes low. Consequently, metallic lithium is easy to deposit on the negative electrode surface. In this condition, the battery becomes thermally unstable and may overheat and lead to thermal runaway.

Also, in the low temperature range, the acceptance of lithium ion is highly depends on the temperature. Consequently, in a lithium ion battery which consists of multi-cells of a series connection, the acceptance of lithium ion by these cells can be different due to temperature differences. In this case, sufficient safety may not be ensured.

As a result, charging conditions are differently specified in the low temperature range, as follows.

- When the surface temperature of lithium ion cells is lower than the lower limit of test temperature, different charging conditions which are specially specified for the low temperature range are applied.
- When the surface temperature of lithium ion cells is lower than the lower limit of the low temperature range, the battery shall never be charged under any charging current.

A.4.4.3 Safety considerations, when specifying charging conditions in the low temperature range

Charging conditions in the low temperature range are sometimes specified based on design factors, such as the acceptance of lithium into the negative electrode active material. When charging conditions in the low temperature range are to be specified, test cells shall be charged under these conditions and tested by the test methods specified in 7.2 to 7.3 and meet the requirements.

A.4.4.4 Safety considerations when specifying a new lower limit in the low temperature range

In some cases, a different lower limit in the low temperature range other than that shown in Figure A.1 is applied. This may be due to the difference of acceptance of lithium into the negative electrode active material and other factors. When a new lower limit in the low temperature range is to be adopted, tests that are specified in 7.2 to 7.3 shall be conducted and the requirements met. Also, relevant documents explaining the reasons of the change of the low temperature range shall be kept.

Examples of the documents explaining reasons of the change of low temperature range are as follows:

a) test results which verify that the acceptance of lithium into the negative electrode active material when the cell is charged at the new lower limit of the low temperature range is equivalent to or higher than when the cell is charged at the lowest limit of the present low temperature range;
b) test results which verify that the cells charged at the new lower limit of the low temperature range − 5 °C when tested by the methods specified in 7.2 to 7.3 meet the requirements.

A.4.5 Scope of the application of charging current

The charging current, as specified in the above, is not applied to an alternating current of over 50 kHz, which assumes ripple and other effects, since lithium ion batteries do not respond to such effects. (Ripple currents over 50 kHz are acceptable.)

A.4.6 Consideration of discharge

A.4.6.1 General

Figure A.2 illustrates the general operating region for discharging for a lithium ion cell.

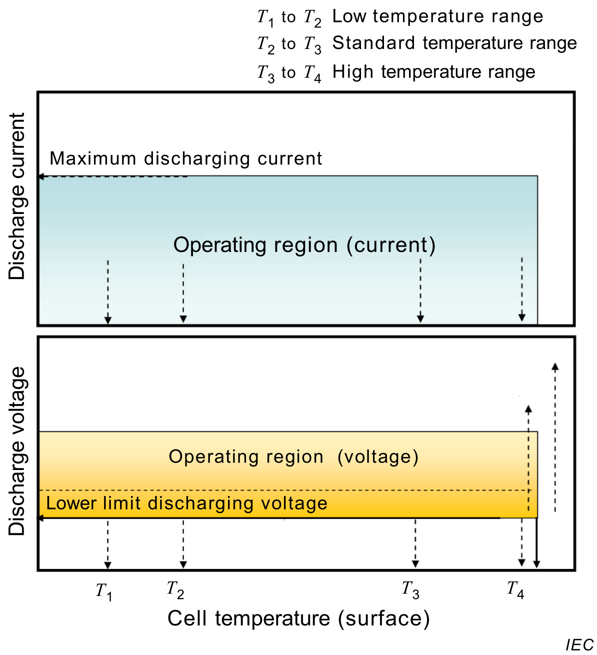


Figure A.2 – Representation of lithium ion cell operating region for discharging

A.4.6.2 Final discharge voltage and explanation of safety viewpoint

The cell should not be discharged beyond the manufacturer's specified final discharge voltage. If a cell is discharged beyond the final discharge voltage, the collector metal may leach from the negative electrode and deposit locally during charging. This deposition may grow toward the positive electrode and cause an internal short-circuit or liquid leakage.

If the battery voltage becomes lower than the specified final discharge voltage, continued charging of the cell should be avoided.

A.4.6.3 Discharge current and temperature range

During discharging, the highest discharging temperature should not be exceeded. If the temperature is over the highest discharge-start temperature before discharging, discharging should not be started. During discharging, the maximum discharging current should not be exceeded.

A.4.6.4 Scope of application of the discharging current

The discharging current as specified above does not apply to alternating current components (ripple, etc.) at 50 kHz or greater where lithium ions do not react inside of the cell.

A.5 Sample preparation

A.5.1 General

In order to provide more information regarding the sample preparation for test 7.3.9, the following additional details are provided.

A.5.2 Insertion procedure for nickel particle to generate internal short

The insertion procedure is carried out at 20 °C ± 5 °C and below −25 °C dew point.

A.5.3 Disassembly of charged cell

Remove winding core (assembled electrode/separator, roll, and coil) from the charged cell (see Figure A.6 and Figure A.9).

A.5.4 Shape of nickel particle

The shape of the nickel particle shall be as shown in Figure A.3.

Dimensions: Height: 0,2 mm; Thickness: 0,1 mm; L shape (Angle: 90° ± 10°): 1,0 mm for each side with 5 % tolerance. Material: more than 99 % (mass fraction) pure nickel.

Dimensions in millimetres

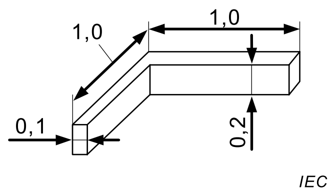


Figure A.3 – Shape of nickel particle

A.5.5 Insertion of nickel particle in cylindrical cell

A.5.5.1 Insertion of nickel particle in winding core

a) Insertion of nickel particle between positive (active material) coated area and negative (active material) coated area for cylindrical cell. (see Figure A.4).

   1) If outer turn of positive substrate is aluminium foil, cut off foil at the dividing line between aluminium foil and active material, in order to make the short-circuit test between the positive active material and the negative active material.

   2) Insert nickel particle between positive active material and separator. The alignment of the nickel particle shall be as shown in Figure A.4. Position of the insertion of the nickel particle shall be 20 mm from the edge of the cut aluminium foil. Direction of L-shaped corner is towards the direction of winding.

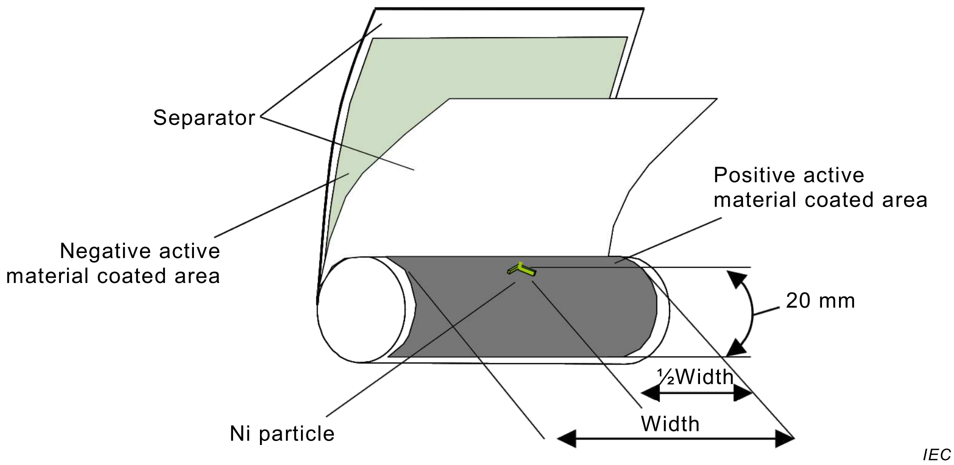


Figure A.4 – Nickel particle insertion position between positive and negative active material coated area of cylindrical cell

b) Insertion of nickel particle between positive aluminium foil (uncoated area) and negative (active material) coated area for cylindrical cell.

When aluminium foil of positive electrode is exposed at outer turn and the aluminium foil is facing the coated negative active material, the following procedure shall be used.

1) When aluminium foil of positive electrode is exposed at outer turn, cut off the aluminium foil 10 mm from the dividing line between aluminium foil and active material.
2) Insert Ni particle between aluminium foil and separator. The alignment of nickel particle shall be as shown in Figure A.5.

   Position of the insertion of nickel particle shall be at 1,0 mm from the edge of the coating of positive active material on aluminium foil.

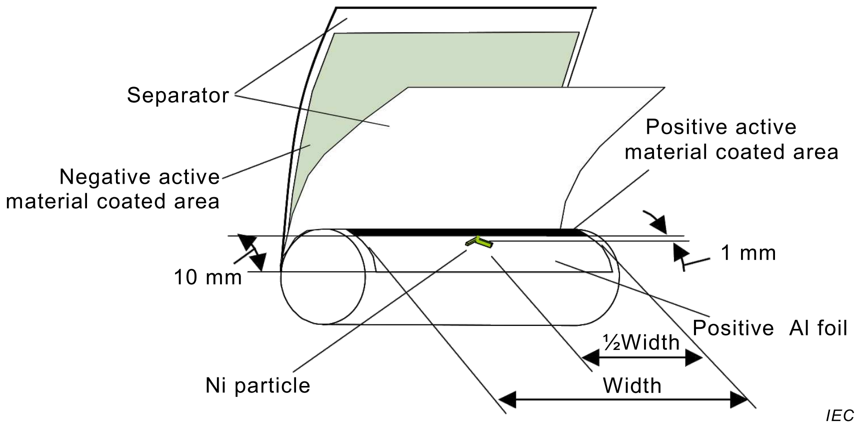


Figure A.5 – Nickel particle insertion position between positive aluminium foil and negative active material coated area of cylindrical cell

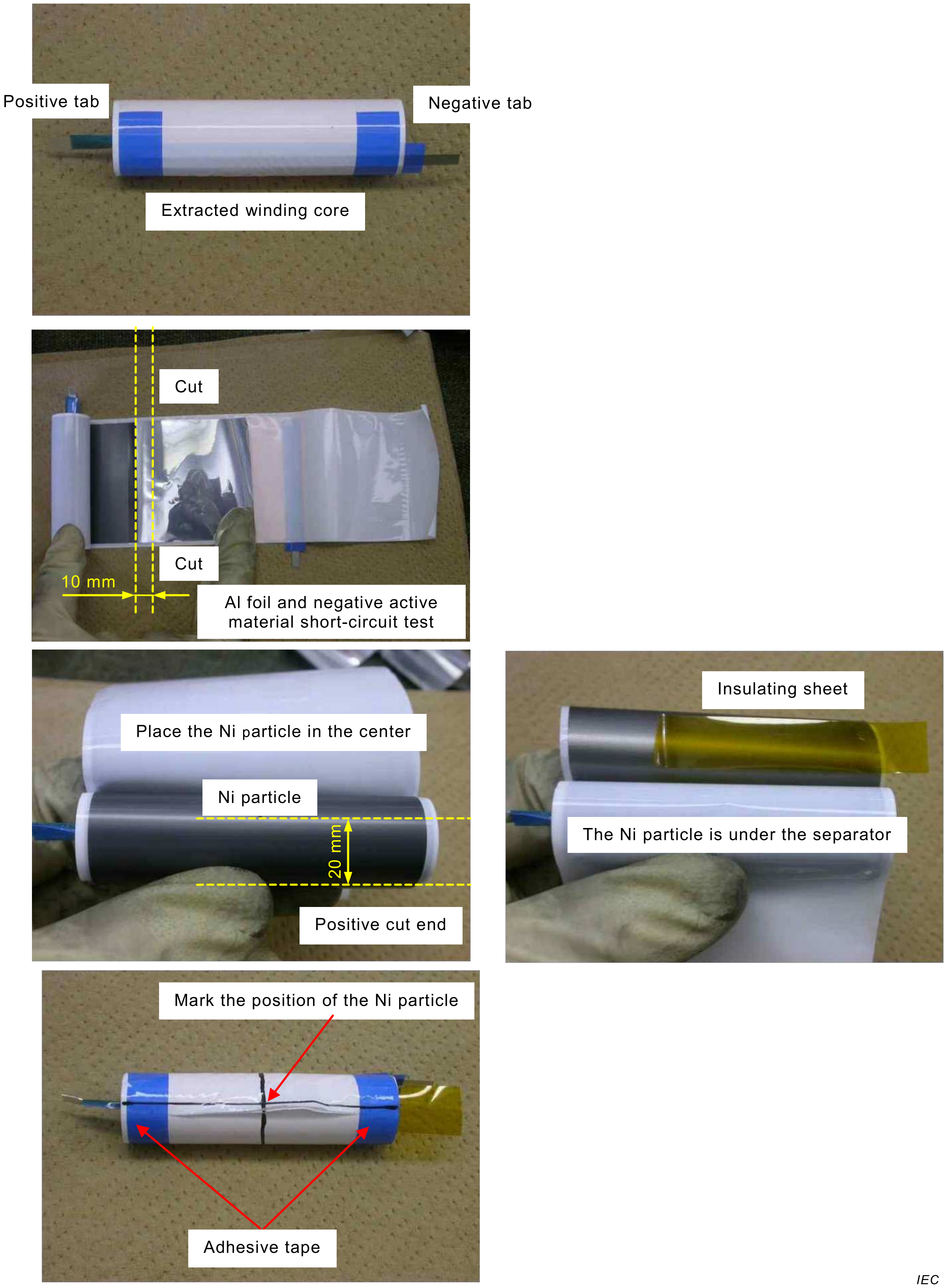


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Figure A.6 – Disassembly of cylindrical cell

A.5.5.2 Marking the position of the nickel particle on both ends of the winding core of the separator

The procedure is as follows.

a) Place insulating sheet between the separator that is facing the nickel particle and the negative electrode to protect against short-circuits.

b) Manually roll back the electrodes and separator keeping the nickel particle in place and apply adhesive tape to the winding core.

c) Mark position of the nickel particle across the winding core.

d) Put winding core in a polyethylene bag with sealing zipper and seal it. Put the polyethylene bag into aluminium laminated bag to prevent from drying out.

Remark: Procedure shall be completed within 30 min.

A.5.6 Insertion of nickel particle in prismatic cell

a) Prior to inserting the nickel particle, insert an insulating sheet between the negative electrode and the separator that is below the nickel particle and the negative electrode, as shown in Figure A.7, to protect against short-circuit.

b) Insertion of nickel particle in winding core.

   1) Insertion of nickel particle between positive (active material) coated area and negative (active material) coated area for prismatic cell (see Figure A.9).

      i) Insert nickel particle between positive (active material) coated area and separator or between separator and negative (active material) coated area. In case of aluminium cell case, insert nickel particle between positive (active material) coated area and separator.

      ii) Insert nickel particle between positive active material and separator. The alignment of the nickel particle shall be as shown in Figure A.7. Nickel particle is set at the centre (diagonally) of the winding core. Direction of nickel particle L-shape corner is towards the direction of winding.

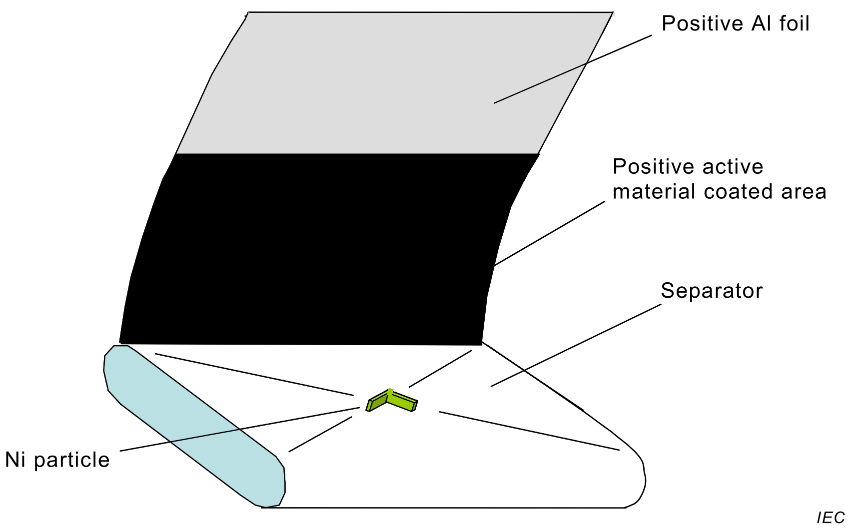


Figure A.7 – Nickel particle insertion position between positive and negative (active material) coated area of prismatic cell

   2) Insertion of nickel particle between positive aluminium foil (uncoated area) and negative (active material) coated area for prismatic cell. When aluminium foil of positive electrode is exposed at outer turn and the aluminium foil is facing the coated negative active material, the following test shall be performed.

i) When the aluminium foil of positive electrode is exposed at outer turn and the aluminium foil is facing the coated negative active material, insert nickel particle between aluminium foil and separator.

ii) The alignment of nickel particle shall be as shown in Figure A.8. Nickel particle is set at the centre of the flat winding core surface. Direction of nickel particle L-shape corner is towards the direction of winding.

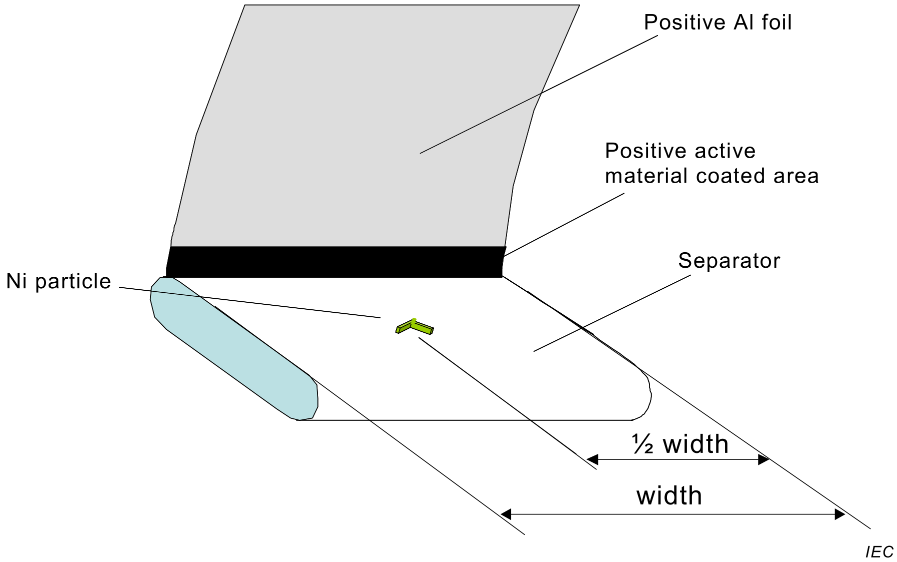


Figure A.8 – Nickel particle insertion position between positive aluminium foil and negative (active material) coated area of prismatic cell

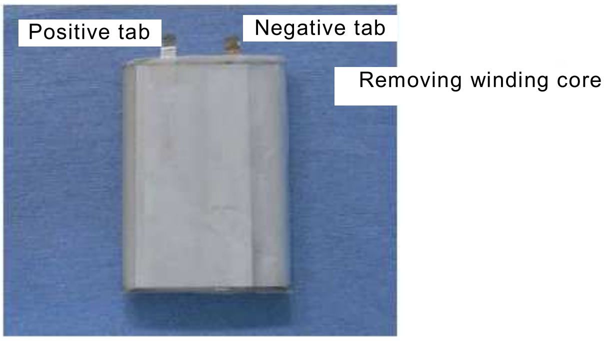
iii) Manually roll back the electrodes and separator keeping the nickel particle in place and apply adhesive tape to the winding core.

iv) Mark the position of nickel particle across the winding core.

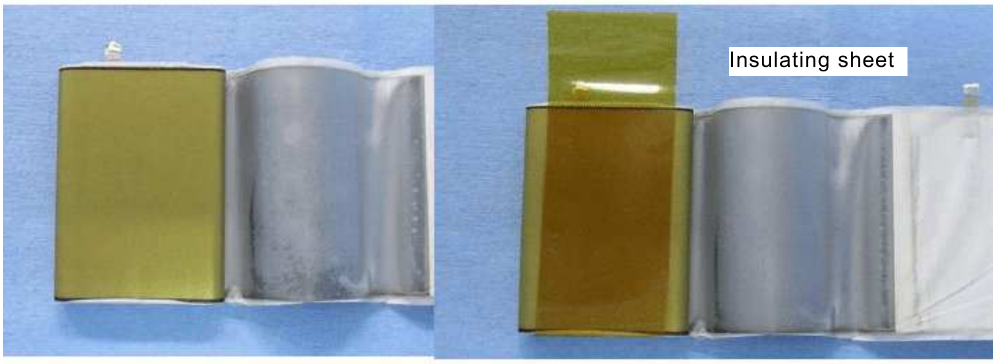
v) Put two layers of polyimide tape (10 mm width, 25 µm thickness) at the marking position.

vi) Put winding core into a polyethylene bag with sealing zipper and seal it. Put the polyethylene bag into aluminium-laminated bag to prevent from drying.

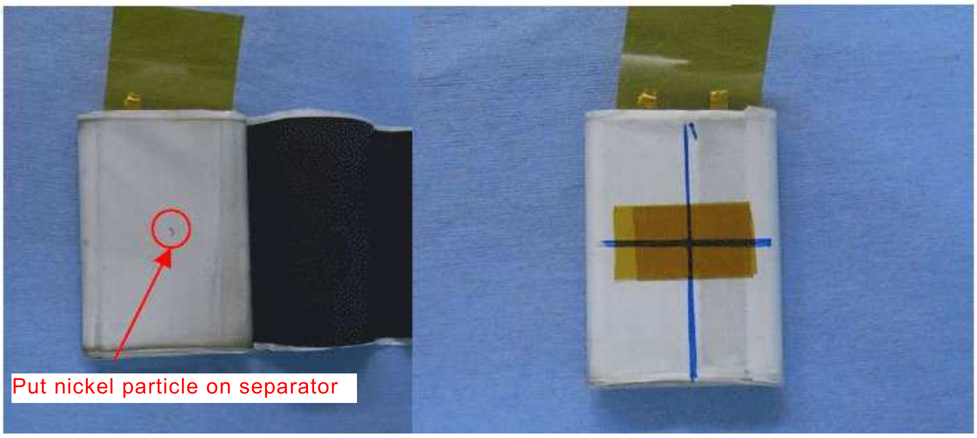
Remark: Procedure should be completed within 30 min.



Remove outer layers and put insulating sheet on negative surface



After roll back the separator, put nickel particle
at the centre of the winding core.



Roll back the electrode and separator and put two layers of polyimide tape
at the position of the nickel particle.

IEC

Figure A.9 – Disassembly of prismatic cells

A.6 Experimental procedure of the forced internal short-circuit test

A.6.1 Material and tools for preparation of nickel particle

The necessary material and tools required for this preparation are listed below.

a) a nickel piece: Prepare nickel plate (soft temper; ISO 6208, NW2200 (Ni 99,0) or NW2201 (Ni 99,0-LC) 0,10 mm ± 0,01 mm thick made into a piece $0,20^{+0,05}_{-0,03}$ mm wide and 2,00 mm ± 0,30 mm long by slit processing or using a punching press;

b) stereomicroscope;

c) cutter knife;

d) glass slides (2 slides: 1 mm or thicker with square corners);

e) graph paper (1 mm square);

f) storage container for nickel particles.

A.6.2 Example of a nickel particle preparation procedure

The following steps are to be undertaken.

a) Place graph paper on the stage of the stereomicroscope and focus the microscope on the lines of the graph paper.

b) While looking through the microscope, place the nickel piece parallel to a line of the graph paper. The nickel piece should be placed horizontally, with its 0,20 mm sides extending downward perpendicularly from and its 2,00 mm sides running parallel to the line on the graph paper.

c) Place a glass slide vertically over the left half (1,0 mm) of the nickel piece. Use a line of the graph paper as a guide to position the edge of the glass slide.

d) While holding the glass slide in place with your fingers, fold and raise the right half (1,0 mm) of the nickel piece using a cutter.

e) Place the other glass slide to the right of the nickel piece to sandwich the raised part. Slightly press the right slide against the raised part so that the nickel piece is bent to an angle of 90°.

f) Store the completed nickel particles in a storage container to prevent them from being deformed before the test.

NOTE The completed nickel particles can also be obtained by using a press machine.

Figure A.10 shows the nickel material after folding to a nickel particle.

Dimensions in millimetres

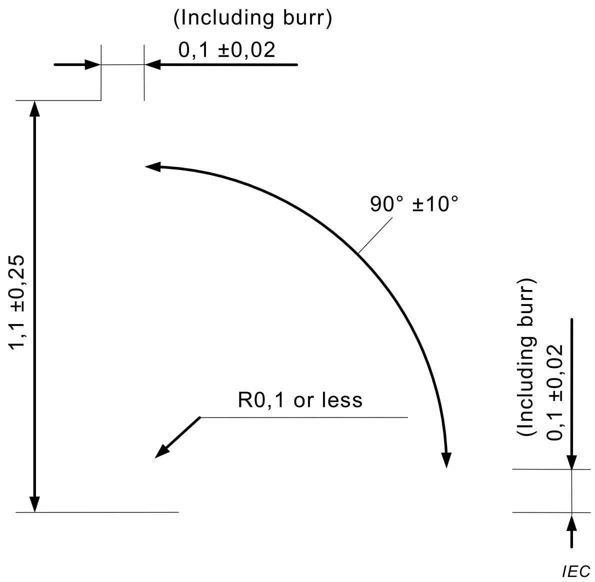


Figure A.10 – Dimensions of a completed nickel particle

A.6.3 Positioning (or placement) of a nickel particle

The following represents some recommendations on the way to place nickel particle.

a) In the case that nickel particle cannot be placed in the position as described in Clause A.5, the position can be changed.

b) For a prismatic cell, a nickel particle may be placed in a flat area. However, it shall be positioned in the centre of the pressurized surface. If it is difficult to place a nickel particle under the most outside layer, it may be placed under an inside layer as shown in Figure A.11.

c) A nickel particle shall not be placed in an area where the positive active material has become detached from the aluminium foil. If the material has become detached in the specified area, place the nickel particle in another area where the positive active material exists, where the position can be pressed with the centre of the pressuring jig.

d) The position of nickel particle may be determined by the cell manufacturer and the test agent.

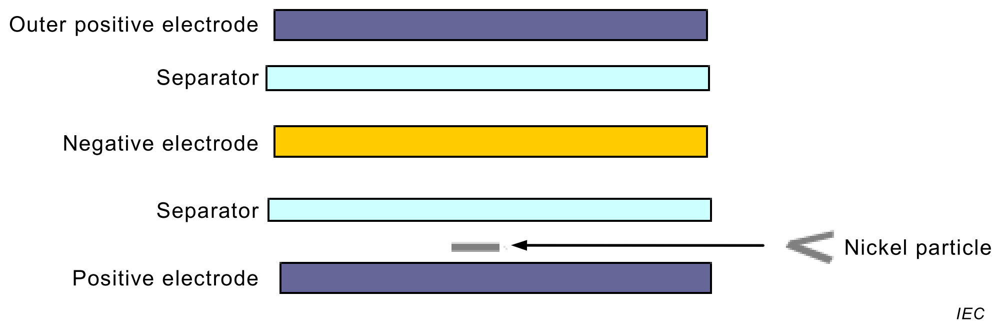


Figure A.11 – Positioning of the nickel particle when it cannot be placed in the specified area

A.6.4 Damaged separator precaution

The sample for evaluation shall not be used when a separator is damaged during preparation e.g. separator is torn.

When a separator is damaged, e.g. the membrane is ruptured; the cell shall not be used as a sample for evaluation.

A.6.5 Caution for rewinding separator and electrode

During rewinding of the core to original position by pulling the positive electrode, negative electrode and separator, pay attention to avoid loosening the wound core.

Figure A.12 below shows an example of cylindrical cell.

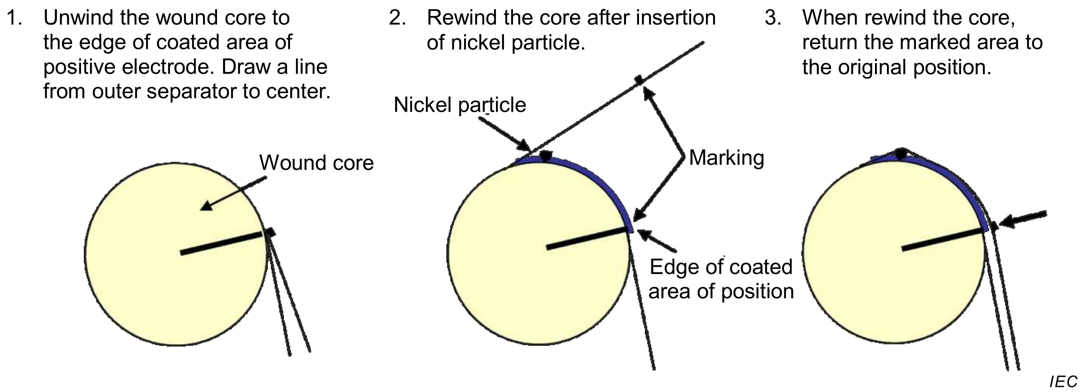


Figure A.12 – Cylindrical cell

A.6.6 Insulation film for preventing short-circuit

To prevent short-circuit before the test, it is recommended to insert an insulation film of a thickness of 25 µm or less.

A.6.7 Caution when disassembling a cell

The following represents some recommendations on the way to disassemble the cell.

a) Cells should be disassembled in an open-type dry chamber or a dry room, where the temperature is 20 °C ± 5 °C and the dew point temperature is below −25 °C.
b) Be careful not to short-circuit cells during disassembling. For example, use tools whose edges are made of ceramic or insulated. Take great care to disassemble sealing area of cells in particular.
c) There are many different cell structures, so it is recommended to check with the manufacturer for the most appropriate structure and part where a short-circuit may easily happen.
d) Cells short-circuited during disassembling should not be used for the following test.

A.6.8 Protective equipment for safety

Long sleeved protective clothing, protective glasses, a mask and gloves should be worn.

A.6.9 Caution in the case of fire during disassembling

The following represents some recommendations on the way to manage a fire.

a) To prevent fire spreading, unnecessary flammable materials should not be placed in the work area.
b) Take countermeasures to prevent the cell contents scattering when cells catch fire. For example, a fire protection cloth or sand should be available in the work area, and the gas should be exhausted effectively.

A.6.10 Caution for the disassembling process and pressing the electrode core

The following represents some recommendations on the way to handle the wound core.

a) Place one wound core in one zip-lock polyethylene bag, and then place them in one aluminium laminated bag. To minimize vaporization of the electrolyte, use bags as small as possible. For example, use a polyethylene bag of 100 mm (width) × 140 mm (height) × 0,04 mm (thickness) and an aluminium laminated bag of 120 mm (width) × 180 mm (height) × 0,11 mm (thickness).
b) Carry out the work from cell disassembling to placing in the aluminium laminated bag within 30 min.
c) The storage period in the aluminium laminated bag should not exceed 12 h.
    1) The wound core should be placed on the testing machine within 2 min after taking out the wound core from the bags.
    2) When the temperature of the wound core reaches the testing temperature, start pressurizing.
    3) When the test is conducted at a high temperature, to minimize vaporization of the electrolyte, it is desirable to start pressurizing within 3 min after placing the wound core on the testing machine. When the test is conducted at a low temperature, it is desirable to start the test within 10 min.

A.6.11 Recommended specifications for the pressing device

The locus of the servo-motor press moves linearly, however a hydraulic press mechanism does not. When the internal short-circuit occurs, the pressing device shall stop immediately by detecting the cell voltage drop. The servo-motor press can stop immediately; however, the hydraulic press cannot. Therefore, the servo-motor press is recommended for the pressing device.

The recommended specifications of the servo-motor press are shown in Table A.2.

Table A.2 – Recommended specifications of a pressing device

Item	Specifications in IEC 62133:2012	Recommendation
Pressurizing method	–	Servo-motor press
Press speed	0,1 mm/s	(0,1 ± 0,01) mm/s
Position stability after pressurizing	–	± 0,02 mm
Maximum pressurizing capability	Cylindrical: 800 N max.	1 000 N or more (recommended press capability to achieve the specification in left column)
	Prismatic: 400 N max.	
Pressure measuring method	–	Directly measured with a load cell
Pressure measuring period	–	5 ms or less
Time to stop pressure head after 50 mV delta is detected	–	100 ms or less

Figure A.13 shows the plots of the distance from the start point of the pressing devices.

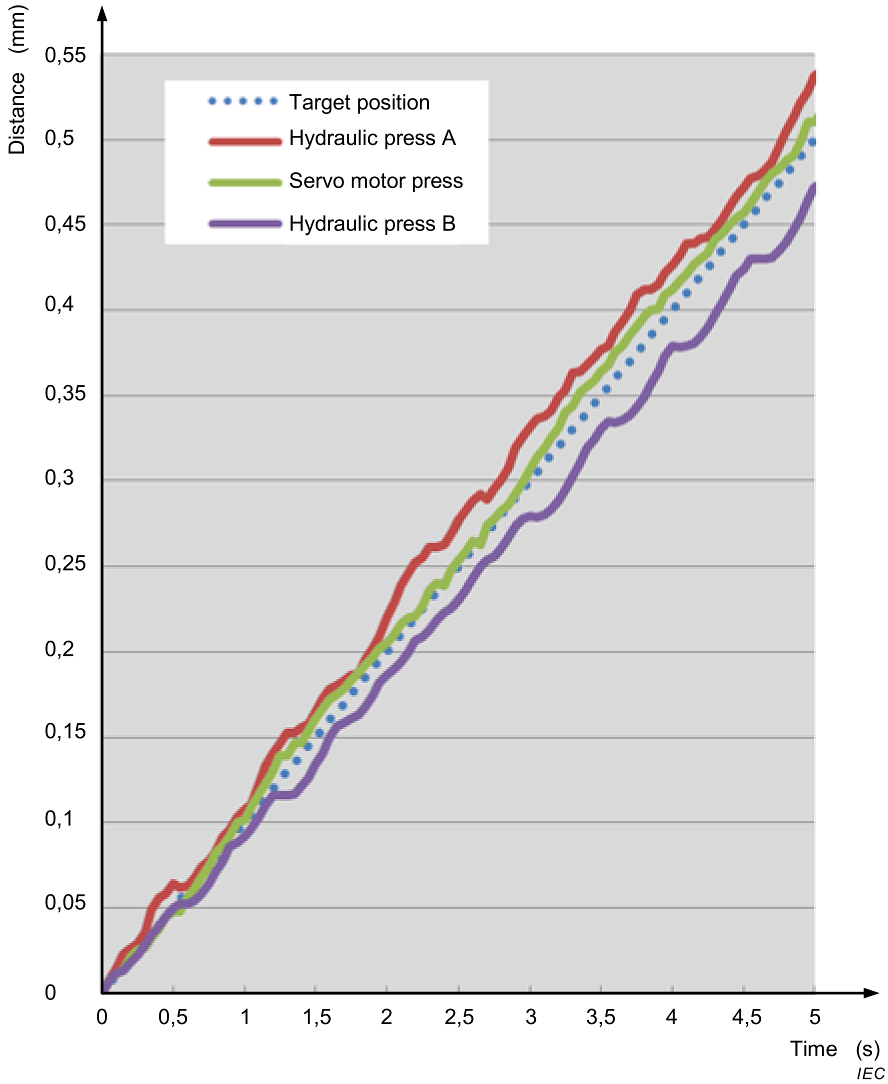


Figure A.13 – Distance / time ratio of several types of pressing devices

Annex B
(informative)

Recommendations to equipment manufacturers and battery assemblers

The following represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of secondary cells and batteries to equipment manufacturers and battery assemblers.

a) Do not dismantle, open or shred cells. Batteries should be dismantled only by trained personnel. Multi-cell battery cases should be designed so that they can be opened only with the aid of a tool.

b) Compartments should be designed to prevent easy access to the batteries by young children.

c) Do not short-circuit a cell or battery. Do not store cells or batteries haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by conductive materials.

d) Do not remove a cell or battery from its original packaging until required for use.

e) Do not expose cells or batteries to heat or fire. Avoid storage in direct sunlight.

f) Do not subject cells or batteries to mechanical shock.

g) In the event of a cell leaking, do not allow the liquid to come into contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water and seek medical advice.

h) Equipment should be designed to prohibit the incorrect insertion of cells or batteries and should have clear polarity marks. Always observe the polarity marks on the cell, battery and equipment and ensure correct use.

i) Do not mix cells of different manufacture, capacity, size or type within a battery.

j) Seek medical advice immediately if a cell or battery has been swallowed.

k) Consult the cell or battery manufacturer on the maximum number of cells which may be assembled in a battery and on the safest way in which cells may be connected.

l) A dedicated charger should be provided for each equipment. Complete charging instructions should be provided for all secondary cells and batteries offered for sale.

m) Keep cells and batteries clean and dry.

n) Wipe the cell or battery terminals with a clean dry cloth if they become dirty.

o) Secondary cells and batteries need to be charged before use. Always refer to the cell or battery manufacturer’s instructions and use the correct charging procedure.

p) Do not maintain secondary cells and batteries on charge when not in use.

q) After extended periods of storage, it may be necessary to charge and discharge the cells or batteries several times to obtain maximum performance.

r) Retain the original cell and battery literature for future reference.

s) When disposing of secondary cells or batteries, keep cells or batteries of different electrochemical systems separate from each other.

Annex C
(informative)

Recommendations to the end-users

The following represents a typical, but non-exhaustive, list of good advice to be provided by the equipment manufacturer to the end-user.

a) Do not dismantle, open or shred secondary cells or batteries.

b) Keep batteries out of the reach of children

   Battery usage by children should be supervised. Especially keep small batteries out of reach of small children.

c) Seek medical advice immediately if a cell or a battery has been swallowed.

d) Do not expose cells or batteries to heat or fire. Avoid storage in direct sunlight.

e) Do not short-circuit a cell or a battery. Do not store cells or batteries haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by other metal objects.

f) Do not remove a cell or battery from its original packaging until required for use.

g) Do not subject cells or batteries to mechanical shock.

h) In the event of a cell leaking, do not allow the liquid to come in contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water and seek medical advice.

i) Do not use any charger other than that specifically provided for use with the equipment.

j) Observe the plus (+) and minus (−) marks on the cell, battery and equipment and ensure correct use.

k) Do not use any cell or battery which is not designed for use with the equipment.

l) Do not mix cells of different manufacture, capacity, size or type within a device.

m) Always purchase the battery recommended by the device manufacturer for the equipment.

n) Keep cells and batteries clean and dry.

o) Wipe the cell or battery terminals with a clean dry cloth if they become dirty.

p) Secondary cells and batteries need to be charged before use. Always use the correct charger and refer to the manufacturer's instructions or equipment manual for proper charging instructions.

q) Do not leave a battery on prolonged charge when not in use.

r) After extended periods of storage, it may be necessary to charge and discharge the cells or batteries several times to obtain maximum performance.

s) Retain the original product literature for future reference.

t) Use the cell or battery only in the application for which it was intended.

u) When possible, remove the battery from the equipment when not in use.

v) Dispose of properly.

Annex D
(normative)

Measurement of the internal AC resistance for coin cells

D.1 General

Annex D provides a method for measuring the internal resistance of a coin cell to determine if testing according to Table 1 is required.

D.2 Method

a) Requirement

To measure the internal resistance of a coin cell to determine if the cell's internal resistance is less than or equal to 3 Ω and the testing per Table 1 is required.
See Clause 6.

b) Test

A sample size of three coin cells is required for this measurement.

Step 1 – The cells shall be charged, in an ambient temperature of 20 °C ± 5 °C, using the method declared by the manufacturer.

Step 2 − The cells shall be stored, in an ambient temperature of 20 °C ± 5 °C, for not less than 1 h and not more than 4 h.

Step 3 – The measurement of internal AC resistance shall be performed as noted below.

The alternating r.m.s. voltage, U_a, shall be measured when applying to the cell an alternating r.m.s. current, I_a, at the frequency of 1,0 kHz ± 0,1 kHz for a period of 1 s to 5 s.

The internal AC resistance, R_ac, is given by:

$$R_\mathrm{ac} = \frac{U_\mathrm{a}}{I_\mathrm{a}} \quad [\Omega]$$

where

U_a is the alternating r.m.s. voltage;

I_a is the alternating r.m.s. current.

NOTE 1 The alternating current is selected so that the peak voltage stays below 20 mV.

NOTE 2 This method will measure the impedance which, in the range of frequency specified, is approximately equal to the resistance.

NOTE 3 Connections to the battery terminals are made in such a way that voltage measurement contacts are separate from contacts used to carry current.

c) Acceptance criteria

Coin cells with an internal resistance of less than or equal to 3 Ω are subjected to the testing according to Clause 6 and Table 1. Coin cells with an internal resistance greater than 3 Ω require no further testing.

Annex E
(informative)

Packaging and transport

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

Lithium ion cells and batteries are regulated by the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), the International Maritime Organization (IMO) and other government agencies.

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

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

Annex F
(informative)

Component standards references

Components relied upon for safety of the battery should comply with their appropriate component standard if applicable. See Table F.1 for some component standards that may apply to battery components.

Table F.1 – Component standard references

Component	IEC standard reference
Fuse	IEC 60127 (all parts), *Miniature fuses*
PTC device	IEC 60738-1, *Thermistors – Directly heated positive temperature coefficient – Part 1: Generic specification*
Thermal link	IEC 60691, *Thermal-links – Requirements and application guide*
FET	IEC 60747-8, *Semiconductor devices – Discrete devices – Part 8:Field-effect transistors*