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

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

IEC 62619:2022-05(en-fr)

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7.2 Reasonably foreseeable misuse

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

a) Requirements

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

b) Test

Fully charged cells are stored in an ambient temperature of 25 °C ± 5 °C. Each cell is then short-circuited by connecting the positive and negative terminals with a total external resistance of 30 mΩ ± 10 mΩ.

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

c) Acceptance criteria

No fire, no explosion.

7.2.2 Impact test (cell or cell block)

a) Requirements

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

b) Test

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

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

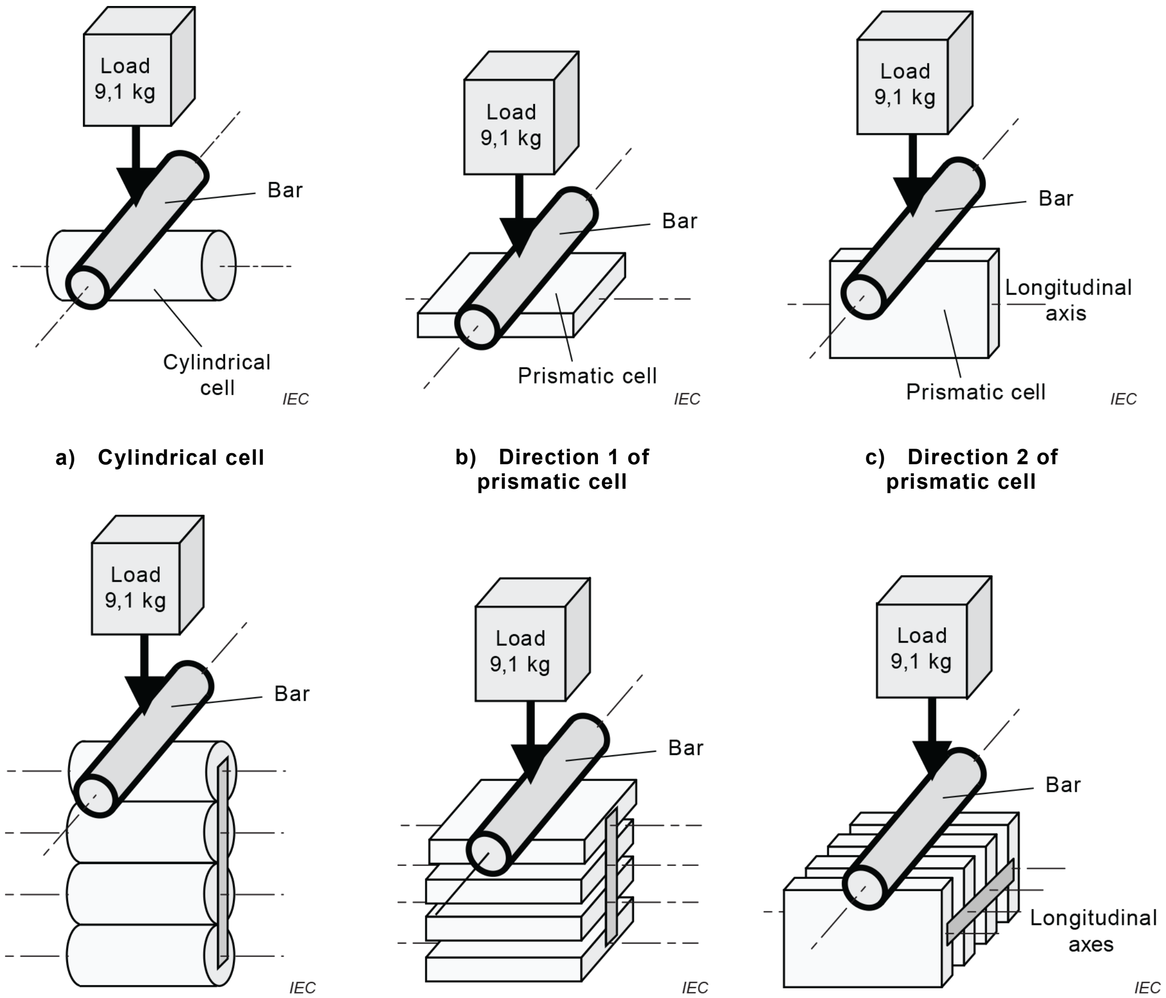
A cylindrical or prismatic cell is to be impacted with its longitudinal axis parallel to the flat concrete or metal floor and perpendicular to the longitudinal axis of the 15,8 mm diameter curved surface lying across the centre of the test sample. A prismatic cell is also to be rotated 90 degrees around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

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

Pouch cells are tested as prismatic cells.

c) Acceptance criteria

No fire, no explosion.



a) Cylindrical cell

b) Direction 1 of prismatic cell

c) Direction 2 of prismatic cell

d) Several cylindrical cells

e) Direction 1 of several prismatic cells

f) Direction 2 of several prismatic cells

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

Figure 1 – Configuration of the impact test

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

7.2.3.1 General

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

Table 2 – Drop test method and condition

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

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

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

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

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

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

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

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

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

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

c) Acceptance criteria

No fire, no explosion.

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

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

a) Requirements

Dropping the test unit shall not cause fire or explosion.

b) Test

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

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

c) Acceptance criteria

No fire, no explosion.

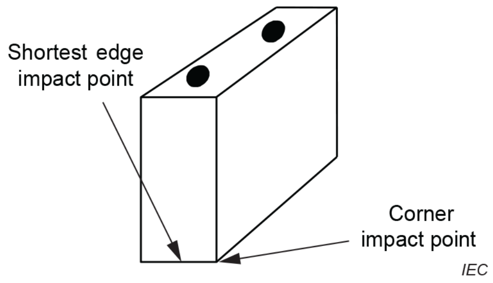


Figure 2 – Impact location

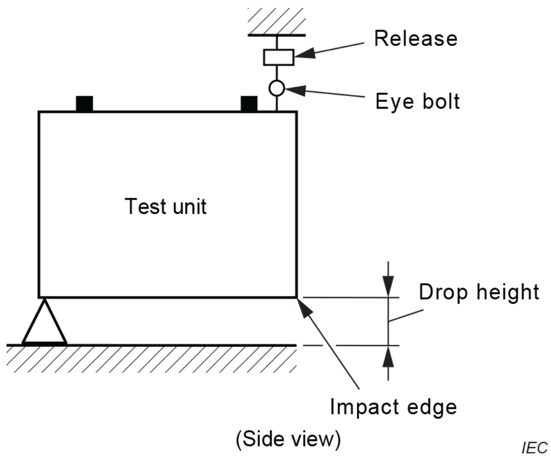
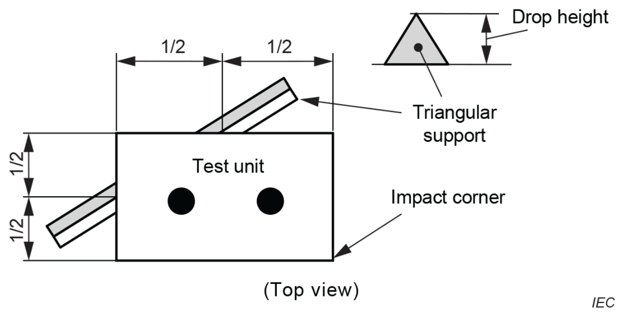


Figure 3 – Configuration for the shortest edge drop test



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

Figure 4 – Configuration for the corner drop test

7.2.4 Thermal abuse test (cell or cell block)

a) Requirements

An elevated temperature exposure shall not cause fire or explosion.

b) Test

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

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

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

c) Acceptance criteria

No fire, no explosion.

7.2.5 Overcharge test (cell or cell block)

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

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

- a measurement device to monitor each cell voltage in a battery system with a function to control the charging current to prevent the highest cell voltage from exceeding the upper limit charging voltage;

  and

- a diagnostic monitoring system that detects the failure of the cell voltage monitoring device and functions to terminate the charging. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

a) Requirements

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

b) Test

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

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

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

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

c) Acceptance criteria

No fire, no explosion.

7.2.6 Forced discharge test (cell or cell block)

a) Requirements

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

b) Test

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

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

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

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

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

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

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

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

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

where

t is the test period (min);

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

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

- a measurement device to monitor each cell voltage in a battery system, and a function to terminate the discharging process when at least one of the cell voltages reaches the cut off voltage or the lower limit discharging voltage;

  and

- a diagnostic monitoring system which detects the failure of the cell voltage monitoring device and functions to open the discharge circuit. For example, a diagnostic monitoring system can be realized by comparing the total battery system voltage measured directly and the voltage calculated by summing up each cell voltage.

c) Acceptance criteria

No fire, no explosion.

7.3 Considerations for internal short-circuit – Design evaluation

7.3.1 General

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

7.3.2 Internal short-circuit test (cell)

a) Requirement

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

b) Test

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

1) Charging procedure

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

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

2) Pressing the winding core with the nickel particle

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

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

i) Preparation for the test

– The temperature of the chamber is controlled at 25 °C ± 5 °C. Refer to the sample preparation guidance in Clause A.5 and Clause A.6 of IEC 62133-2:2017. Put the aluminium laminated bag with the winding core and nickel particle into the chamber for 45 min ± 15 min.

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

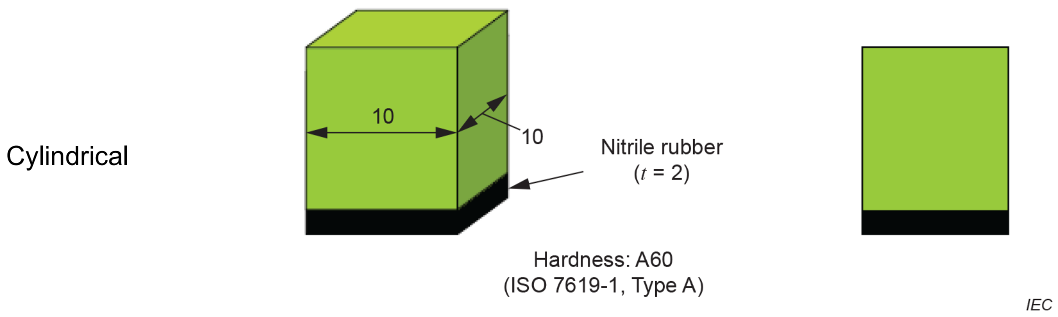
  To prevent evaporation of electrolyte, finish the work within 10 min from removing the winding core from the chamber for temperature conditioning to closing the chamber door where the equipment is located.

– Remove the insulating sheet and close the chamber door.

ii) Internal short-circuit

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

Dimensions in millimetres



Dimensions in millimetres

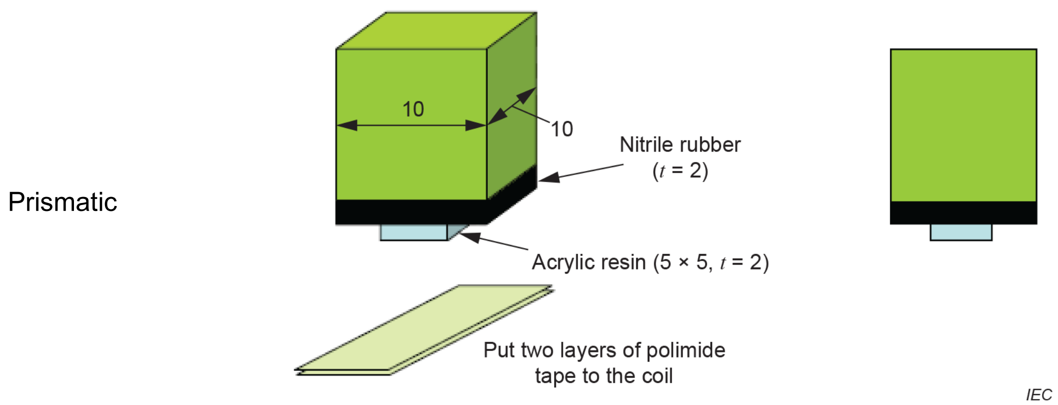


Figure 5 – Jig for pressing

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

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

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

– the nickel particle may be inserted into a discharged electrode element and then charged, or

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

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

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

c) Acceptance criteria

No fire.

7.3.3 Propagation test (battery system)

a) Requirement

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

b) Test

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

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

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

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

c) Acceptance criteria

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

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

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

8 Battery system safety (considering functional safety)

8.1 General requirements

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

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

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

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

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

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

The procedure is as follows:

a) hazard analysis;

b) risk assessment;

c) safety level target (e.g. safety integrity level (SIL) target.

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

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

8.2 Battery management system (or battery management unit)

8.2.1 Requirements for the BMS

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

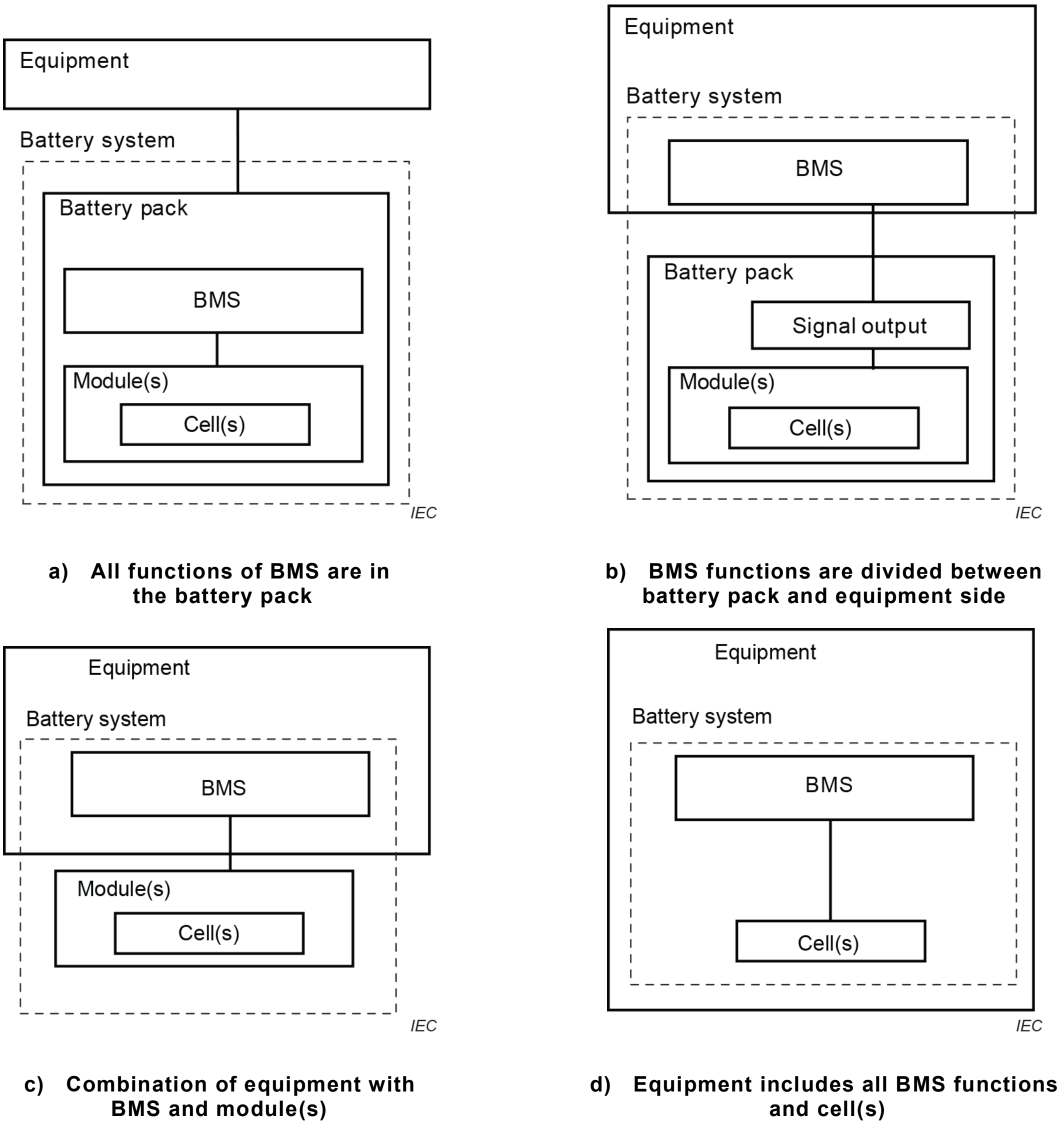
To evaluate the charge control that affects safety, the battery system manufacturers shall perform the tests mentioned in 8.2.2 to 8.2.4.

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

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

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

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



a) All functions of BMS are in the battery pack

b) BMS functions are divided between battery pack and equipment side

c) Combination of equipment with BMS and module(s)

d) Equipment includes all BMS functions and cell(s)

Figure 6 – Examples of BMS locations and battery system configurations

8.2.2 Overcharge control of voltage (battery system)

a) Requirement

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

b) Test

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

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

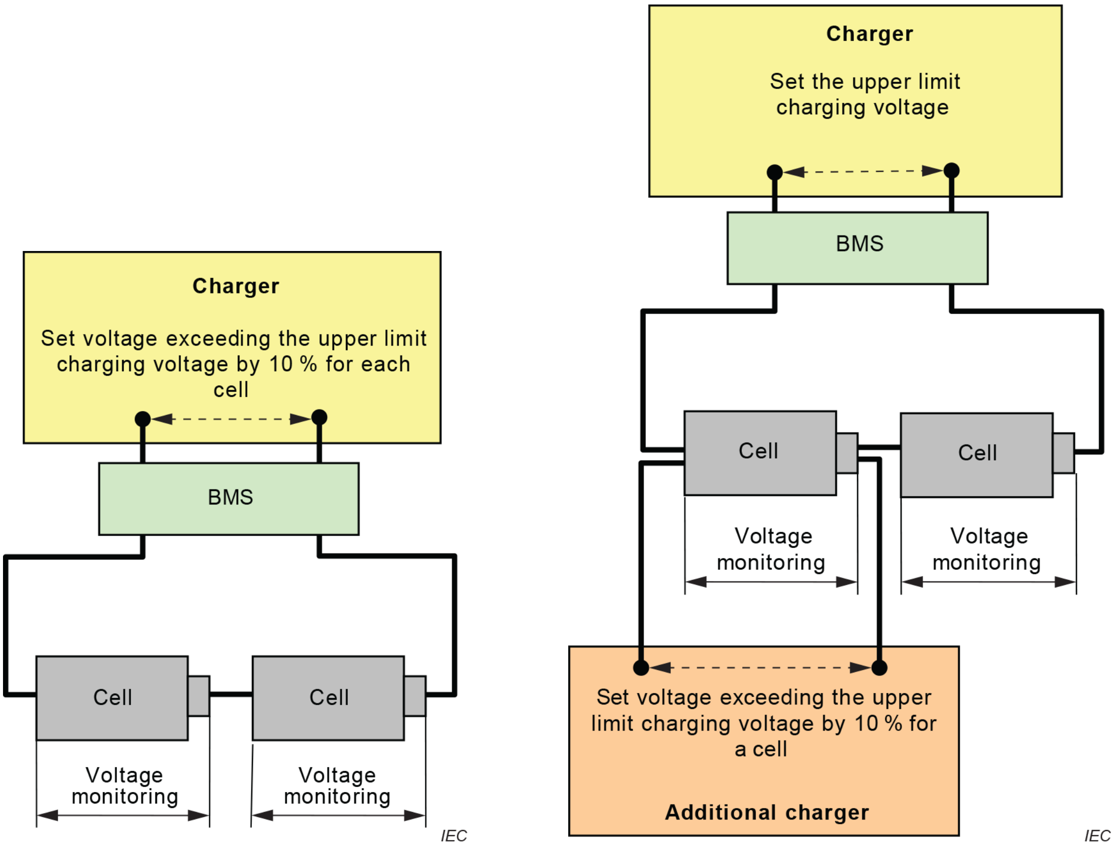
The test shall be carried out until the BMS terminates the charging. Data acquisition/monitoring shall be continued for 1 h after charging is stopped. During the test, all functions of the battery system shall be fully operational, as designed.

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

c) Acceptance criteria

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

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



a) The exceeded voltage is applied to a whole battery system

b) The exceeded voltage is applied only to a part such as a cell in the battery system

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

8.2.3 Overcharge control of current (battery system)

a) Requirement

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

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

b) Test

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

c) Acceptance criteria

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

No fire, no explosion.

8.2.4 Overheating control (battery system)

a) Requirement

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

b) Test

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

c) Acceptance criteria

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

No fire, no explosion.

9 EMC

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

10 Information for safety

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