ICS 43.120
CCS T 47

National Standard of the People's Republic of China

GB 38031—2025
Replace GB 38031—2020

Electric vehicles traction battery safety requirements

电动汽车用动力蓄电池安全要求

(English Translation)

Issue date: 2025-03-28 Implementation date: 2026-07-01

Issued by State Administration for Market Regulation
Standardization Administration of the People's Republic of China

Contents

Foreword

SAC/TC114 is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This document is drafted in accordance with the rules given in the GB/T 1.1—2020 *Directives for Standardization - Part 1: Rules for the Structure and Drafting of Standardizing Documents*.

This document replaces the GB 38031—2020 *Electric Vehicles Traction Battery Safety Requirements* in whole. In addition to a number of structural adjustment and editorial changes, the following technical deviations have been made with respect to GB 38031—2020 *Electric Vehicles Traction Battery Safety Requirements*.:

- The scope was changed (see Chapter 1 herein, and Chapter 1 in Version 2020);
- The definition of "battery subsystem" was added (see 3.5 herein);
- The definition of leakage was changed (see 3.14 herein, and 3.13 in Version 2020);
- The definition of thermal event was added (see 3.15 herein);
- The requirements and test methods for post-fast charging cycle safety of battery cell were added (see 5.1.7 and 8.1.8 herein)
- The safety requirements and test methods for vibration of battery pack or system were changed (see 5.2.1 and 8.2.1 herein, and 5.2.1 and 8.2.1 in Version 2020);
- The safety requirements for mechanical shock of battery pack or system were changed (see 5.2.2 herein and 5.2.2 in Version 2020);
- The safety requirements for simulated impact of battery pack or system were changed (see 5.2.3 herein and 5.2.3 in Version 2020);
- The safety requirements and test methods for crush of battery pack or system were changed (see 5.2.4 and 8.2.4 herein, 5.2.4 and 8.2.4 in Version 2020);
- The safety requirements for damp heat cycling of battery pack or system were changed (see 5.2.5 herein, and 5.2.5 in Version 2020);
- The safety requirements for water immersion of battery pack or system were changed (see 5.2.6 herein, and 5.2.6 in Version 2020);
- The safety requirements and test methods for thermal stability of battery pack or system were changed (see 5.2.7, 8.2.7 and Annex C herein, and 5.2.7, 8.2.7 and Annex C in Version 2020);
- The safety requirements and test methods for thermal shock of battery pack or system were changed (see 5.2.8 and 8.2.8 herein, and 5.2.8 and 8.2.8 in Version 2020);
- The safety requirements and test methods for salt spray of battery pack or system were changed (see 5.2.9 and 8.2.9 herein, and 5.2.9 and 8.2.9 in Version 2020);
- The safety requirements and test methods for battery pack or system at high altitude were changed (see 5.2.10 and 8.2.10 herein, and 5.2.10 and 8.2.10 in Version 2020);
- The safety requirements and test methods for over-temperature protection of battery pack or system were changed (see 5.2.11 and 8.2.11 herein, and 5.2.11 and

8.2.11 in Version 2020);

- The safety requirements and test methods for overcurrent protection of battery pack or system were changed (see 5.2.12 and 8.2.12 herein, and 5.2.12 and 8.2.12 in Version 2020);

- The safety requirements for external short-circuit protection of battery pack or system were changed (see 5.2.13 herein, and 5.2.13 in Version 2020);

- The safety requirements and test methods for overcharge protection of battery pack or system were changed (see 5.2.14 and 8.2.14 herein, and 5.2.14 and 8.2.14 in Version 2020);

- The safety requirements for over-discharge protection of battery pack or system were changed (see 5.2.15 herein, and 5.2.15 in Version 2020);

- The safety requirements and test methods for impact of battery pack or system or vehicle bottom were added (see 5.2.16 and 8.2.16 herein);

- The requirements for practical capacity were changed (see 6.1.9 herein, and 6.1.9 in Version 2020);

- Measuring instruments, instrument accuracy, testing process error, data recording and recording interval were changed (see 6.2, 6.3 and 6.4 herein, and 6.2, 6.3 and 6.4 in Version 2020);

- The requirements for preconditioning of battery cell, battery pack or system were changed (see 7.1.2 and 7.2.2 herein, and 7.1.2 and 7.2.2 in Version 2020);

- The test methods for over-discharge of battery cell were changed (see 8.1.2 herein, and 8.1.2 in Version 2020);

- The test methods for heating of battery cell were changed (see 8.1.5 herein, and 8.1.5 in Version 2020);

- The test methods for crsuh of battery cell were changed (see 8.1.7 herein, and 8.1.7 in Version 2020);

- The determination of the same type was added (see Chapter 9 herein);

- The test methods for insulation resistance of battery pack or system were changed (see Annex B, and Annex B in Version 2020).

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights.The issuing body of this document shall not be held responsible for identifying any or all such patent rights.

This standard was proposed by and prepared by the Ministry of Industry and Information Technology of the People's Republic of China.

The previous editions of this part are as follows:

- The first edition was issued in 2020 as GB 38031—2020 *Electric Vehicles Traction Battery Safety Requirements* in whole.

- This is the first revised edition.

Introduction

This document covers the most fundamental safety requirements for traction batteries used in electric vehicles, aiming to provide protection for personal safety and property. It does not address safety in production, transportation, maintenance, or recycling, nor does it cover performance or functional characteristics.

The safety of electric vehicle traction batteries depends on their design and operating conditions. These conditions include normal usage, foreseeable misuse or faults, as well as environmental factors such as temperature and altitude, which can impact safety.

With further advancement in technology and processes, revision of this document will be required.

Electric Vehicles Traction Battery Safety Requirements

1 Scope

This document specifies the safety requirements for cells, battery packs or systems of electric vehicles traction battery (hereinafter referred to as battery) and describes corresponding test methods.

This document is applicable to electric vehicles traction battery.

2 Normative References

The following normative documents contain provisions which, through reference in this text, constitute indispensable provisions 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.

GB/T 2423.4 *Environmental Testing for Electric and Electronic Products - Part 2: Test Method - Test Db: Damp Heat, Cyclic (12 h + 12 h Cycle*)

GB/T 2423.17—2024 *Environmental Testing - Part 2: Test Methods - Test Ka: Salt Mist*

GB/T 2423.43 *Environmental Testing for Electric and Electronic Products - Part 2: Test Methods - Mounting of Specimens for Vibration, Impact and Similar Dynamic Tests*

GB/T 2423.56 *Environmental Testing - Part 2: Test Methods - Test Fh: Vibration, Broad-band Random and Guidance*

GB/T 4208—2017 *Degrees of Protection Provided by Enclosure (IP Code)*

GB/T 19596 *Terminology of Electric Vehicles*

GB/T 28046.4—2011 *Road Vehicles - Environmental Conditions and Testing for Electrical and Electronic Equipment - Part 4: Climatic Loads*

3 Terms and Definitions

For the purposes of this document, the terms and definitions given in GB/T 19596 and the following apply.

3.1

battery cell

a basic unit device that converts chemical energy into electric energy and vice versa

Note: It typically consists of electrodes, separators, electrolyte, housing and terminals and is designed to be rechargeable.

3.2

battery module

a combination of more than one battery cell connected in series, parallel or series-parallel to serve as a power supply

3.3

battery pack

a unit capable of receiving electric energy from external sources and supplying electric energy to external loads

Note: It is usually composed of the battery cell, battery management module (excluding BCU), battery case and corresponding accessories (cooling components, connecting cables, etc.)

3.4

battery system

an energy storage device consisting of one or more battery packs and corresponding accessories (management system, high-voltage circuit, low-voltage circuit, mechanical assembly, etc.)

3.5

battery subsystem

any energy storage assembly composed of battery packs or system components

3.6

battery electronics

an electronic device collecting or monitoring electrical and thermal data of the battery pack simultaneously

Note: Battery electronics may include cell controllers and the electronics for equalizing battery cells. Such equalizing may be controlled by battery electronics or by battery control unit.

3.7

battery control unit

an electronic device that controls, manages, measures or calculates electrical and thermal parameters of the battery system and provides communication between the battery system and other vehicle controllers

3.8

rated capacity

the capacity of the battery cell, module, battery pack or system measured under the conditions specified and declared by the manufacturer

Note: The rated capacity is usually expressed in Ah or mAh.

3.9

practical capacity

the capacity measured from a fully charged battery cell, module, battery pack or system under the conditions specified by the manufacturer

3.10

state-of-charge

the percentage of the capacity of the current battery cell, module, battery pack or system that can be released under the discharge conditions specified by the manufacturer to the practical capacity

3.11

explosion

sudden release of energy sufficient to produce a pressure wave or ejecta

Note: Pressure waves or ejecta may cause structural or physical damage to the surrounding area.

3.12

fire

continuous combustion in any part of the battery cell, module, battery pack or system (with a flame duration greater than 1 s)

Note 1: "with a flame duration greater than 1 s" refers to the duration of a single flame, not cumulative time of multiple flames.

Note 2: Visual evaluation without disassembling the test object. Sparks and arcing are not considered combustion.

3.13

housing crack

mechanical damage to the housing of the battery cell, module, battery pack or system because of internal or external factors, resulting in internal material exposure or leakage

3.14

leakage

a phenomenon where visible substance leaks from the battery cell, module, battery pack or system to the outside of the test object

Note: Visible substances are assessed visually without disassembling the test object

3.15

thermal event

a phenomenon where the temperature in a battery pack or system significantly exceeds the maximum operating temperature (defined by the manufacturer)

3.16

thermal runaway

a phenomenon of uncontrollable rise in battery temperature caused by an exothermic chain reaction of battery cells

3.17

thermal propagation

a phenomenon where the sequential occurrence of thermal runaway of adjacent cells within a battery system is triggered by thermal runaway of a cell in that battery system

3.18

end-of-charge voltage

the maximum allowable voltage when a cell, module, battery pack, or system is charged under the conditions specified by the manufacturer

3.19

end-of-discharge voltage

the minimum allowable voltage when a cell, module, battery pack, or system is discharged under the conditions specified by the manufacturer

3.20

body frame

a spatial frame structure formed to ensure the strength and rigidity of the vehicle body

[Source: GB/T 4780-2020, 4.4.3]

4 Symbols and Abbreviations

4.1 Symbols

For the purposes of this document, the following symbols apply.

I_1: 1 h discharge current (A), which is equal to the rated capacity.

I_3: 3 h discharge current (A), which is equal to 1/3 of the rated capacity.

4.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

BCU: battery control unit

FS: full scale

PSD: power spectral density

RMS: root mean square

SOC: state-of-charge

5 Safety Requirements

5.1 Safety requirements for battery cell

5.1.1 The battery cell shall not exhibit any evidence of fire or explosion during the over-discharge tests conducted according to 8.1.2.

5.1.2 The battery cell shall not exhibit any evidence of fire or explosion during the over-charge tests conducted according to 8.1.3.

5.1.3 The battery cell shall not exhibit any evidence of fire or explosion during the external short-circuit tests conducted according to 8.1.4.

5.1.4 The battery cell shall not exhibit any evidence of fire or explosion during the heating tests conducted according to 8.1.5.

5.1.5 The battery cell shall not exhibit any evidence of fire or explosion during the temperature cycling tests conducted according to 8.1.6.

5.1.6 The battery cell shall not exhibit any evidence of fire or explosion during the crush tests conducted according to 8.1.7.

5.1.7 The battery cell shall not exhibit any evidence of fire and explosion during the post-fast charging cycle safety tests conducted according to 8.1.8.

5.2 Safety requirements for battery pack or system

5.2.1 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the vibration tests conducted according to 8.2.1. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.2 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the mechanical shock tests conducted according to 8.2.2. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.3 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the simulated impact tests conducted according to 8.2.3. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.4 The battery pack or system shall not exhibit any evidence of fire or explosion during the crush tests conducted according to 8.2.4. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.5 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the damp heat cycling tests conducted according to 8.2.5. The insulation resistance within 30 min after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.6 The battery pack or system shall meet one of the following requirements during the water immersion tests conducted according to 8.2.6:

a) There shall be no fire or explosion if the tests are performed according to the method 1;

b) The test shall be carried out according to the method 2, and the requirements of IPX7 in GB/T 4208-2017 shall be met after the test. There shall not exhibit any evidence ofleakage, housing crack, fire or explosion. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.7 Conduct the thermal stability tests in accordance with 8.2.7 (except for nickel-metal hydride battery packs or systems). The requirements are as follows:

a) The battery pack or system shall not exhibit any evidence of explosion during the external fire tests conducted according to 8.2.7.1;

b) The battery pack or system or the vehicle shall meet the following requirements when the thermal propagation analysis and verification are conducted according to 8.2.7.2:

1) No fire, no explosion;

2) The alarm signal for a thermal event shall be provided no later than 5 min after the thermal runaway of the battery cell is triggered;

3) For battery pack or system level tests, the technical specification document shall be provided, stating that smoke will not cause danger to the passenger compartment before and within 5 min after a thermal event alarm signal is sent out; for vehicle level test, no smoke enters the passenger compartment before and within 5 min after a thermal event alarm signal is sent out.

5.2.8 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the thermal shock tests conducted according to 8.2.8. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.9 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the salt spray tests conducted according to 8.2.9. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.10 The battery pack or system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the high altitude tests conducted according to 8.2.10. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.11 The battery system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the over-temperature protection tests conducted according to 8.2.11. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.12 The battery system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the overcurrent protection tests conducted according to 8.2.12. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.13 The battery system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the external short-circuit protection tests conducted according to 8.2.13. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.14 The battery system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the overcharge protection tests conducted according to 8.2.14. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.15 The battery system shall not exhibit any evidence of leakage, housing crack, fire or explosion during the over-discharge protection tests conducted according to 8.2.15. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

5.2.16 The battery pack, system or the vehicle shall not exhibit any evidence of leakage, housing crack, fire or explosion during the bottom impact tests conducted according to 8.2.16. The insulation resistance after the test shall not be less than 100 Ω/V. If there is an AC circuit, the insulation resistance shall not be less than 500 Ω/V.

6 Test Conditions

6.1 General conditions

6.1.1 Unless otherwise specified, the tests shall be carried out at an ambient temperature of 22℃ ± 5℃, a relative humidity of 10% ~ 90% and an atmospheric pressure of 86 kPa ~ 106 kPa.

6.1.2 If the test object is a battery cell, it can be tested with a fixture. If the battery cell cannot operate independently, a battery module shall be used for testing. The safety requirements of 5.1 shall be met.

6.1.3 For the battery pack or system covered by the body frame and constituting the battery pack box, the test can be conducted with the box or body frame.

6.1.4 The delivery of the battery pack or system test shall include necessary operation documents and interface components (such as connectors, plugs and cooling interfaces) required for connection to the test equipment. See Annex A for the typical structure of battery pack or system. In addition, additional sensors, wires and fixtures shall not affect the test results. The manufacturer shall provide the safe working limits of the battery pack or system.

6.1.5 The insulation resistance test shall be conducted before all tests and after partial tests of the battery pack or system. The test position is between the positive and negative output terminals and the electrical chassis. The test shall be carried out according to Annex B.

6.1.6 If the battery pack or system is not suitable for some tests due to certain reasons concerning size or mass, the manufacturer, after consultation and reaching an agreement with the technical service, may use a battery subsystem as the test object for all or part of the tests. However, the subsystem used as the test object shall include all parts (e.g., connecting parts or protective parts) related to vehicle requirements and may include the battery management system. If the battery subsystem is selected for tests, it shall be demonstrated that the test results can represent the safety performance of the battery pack or system under the same conditions.

6.1.7 Method of adjusting SOC to the test target value of n%: Fully charge the battery cell, battery pack or system according to the charging method provided by the manufacturer, keep it still for 1 h, and discharge it at a constant current of $1I_3$ for t (t is calculated according to Formula (1)); alternatively, adjust SOC with the method provided by the manufacturer. After each SOC adjustment, the test object shall be kept still for 30 min or according to the conditions specified by the manufacturer before the start of a new test.

$$t=\frac{100-n}{100}\times 3 \qquad (1)$$

Where,

t— discharge time, in h;

n— percentage of test target value.

6.1.8 The rates, methods and termination conditions of charge and discharge during the test shall be provided by the manufacturer.

6.1.9 The practical capacity of the battery cell shall not be lower than the rated capacity and shall not exceed 110% of the rated capacity. The absolute value of the difference between the practical capacity and the rated capacity of the battery pack or system shall not exceed 5% of the rated capacity.

6.1.10 Unless otherwise specified, the test object shall be tested at the maximum working SOC specified by the manufacturer.

6.1.11 The symbol of the battery cell, battery pack or system is positive for discharging current, and negative for charging current.

6.2 Accuracy of measuring instruments and meters

The accuracy of measuring instruments and meters shall at least meet the following requirements:

a) Voltage measuring device: ±0.5% FS;

b) Current measuring device: ±0.5% FS;

c) Temperature measuring device: ±1° C;

d) Humidity measuring device: ±2% (relative humidity);

e) Time measuring device: ±0.1 s;

f) Dimension measuring device: ±0.1% FS;

g) Mass measuring device: ±0.1% FS.

h) Pressure measuring device: ±1% FS;

6.3 Test process error

The requirements for the error between the control value (actual value) and the target value are as follows:

a) Voltage: ±1%;

b) Current: ±1%;

c) Temperature: ±2° C;

d) Time: ±0.1 s.

6.4 Data recording and recording interval

Unless otherwise specified, the recording interval of test data (such as voltage, current, temperature, time, etc.) shall not exceed 15 s.

7 Test Preparation

7.1 Preparation for battery cell test

7.1.1 Standard charging

Discharge at a current specified by the manufacturer of no less than 1 I_3 to the end-of-discharge voltage specified in the technical specifications of the manufacturer, and then let it stand for 1 h (or no more than 1 h as specified by the manufacturer), and then charge it according to the charging method provided by the manufacturer, and let it stand for 1 h (or no more than 1 h as specified by the manufacturer).

If the manufacturer does not provide a charging method, the technical service and the manufacturer shall negotiate to determine an appropriate method, or the following method shall be used:

Charge at a constant current of no less than 1 I_3 specified by the manufacturer until the end-of-charge voltage specified in the technical specifications of the manufacturer is reached, and then charge it at a constant voltage until the charging current drops to 0.05 I_1. After charging, let it stand for 1 h (or no more than 1 h as specified by the manufacturer).

7.1.2 Preconditioning

7.1.2.1 Before the formal test, the battery cell shall be subject to a preconditioning cycle. The steps are as follows:

a) Charge the battery cell as per 7.1.1;

b) Discharge at the current specified by the manufacturer, no less than 1 I_3, to the end-of-discharge condition specified by the manufacturer;

c) Let it stand for 1 h (or no more than 1 h as specified by the manufacturer);

d) Repeat steps a) ~ c) for no more than 5 times.

7.1.2.2 If the discharge capacity range of a battery cell does not exceed 3% of the rated capacity for three consecutive times, the preconditioning of battery cell is considered complete. The preconditioning cycle can then be terminated, and the average value of the last three test results is taken as the practical capacity.

7.2 Preparation for battery pack or system test

7.2.1 Confirmation of working status

Before official start of the test, battery electronics or BCU shall be in normal working condition.

7.2.2 Preconditioning

7.2.2.1 Before the formal test, the battery pack or system shall be subject to a preconditioning cycle. The steps are as follows:

a) Charge at a current of no less than 1 I_3 or according to the charging method recommended by the manufacturer to the end-of-charge conditions specified by the manufacturer;

b) Let it stand for 30 min or the time specified by the manufacturer;

c) Discharge at the current specified by the manufacturer, no less than 1 I_3, to the end-of-discharge condition specified by the manufacturer;

d) Let it stand for 30 min or the time specified by the manufacturer;

e) Repeat steps a) ~ d) for no more than 5 times.

7.2.2.2 If the change of two consecutive tests on discharge capacity of a battery pack or system does not exceed 3% of the rated capacity, the preconditioning of the battery pack or system is considered complete. The preconditioning cycle can then be terminated, and the average value of the last two test results is taken as the practical capacity.

7.2.2.3 Unless otherwise specified, if the time interval between the completion of the preconditioning cycles (with adjustment to the highest working SOC) and the start of a new test item exceeds 24 h, a recharge shall be performed. Charging shall be carried out using a current no less than 1I_3 until the end-of-charge condition specified by the manufacturer is reached, or according to the charging method recommended by the manufacturer. After charging, the battery shall rest for 30 min or for a duration specified by the manufacturer.

8 Test Methods

8.1 Safety test methods for battery cell

8.1.1 General requirements

All safety tests shall be conducted under conditions with adequate safety protection. If the test object includes additional active protection circuits or devices, they shall be removed.

8.1.2 Over-discharge

8.1.2.1 The test object is a battery cell.

8.1.2.2 Adjust the SOC of the test object to the end-of-discharge voltage state, and discharge it at a current of 1I_1 for 30 min.

8.1.2.3 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.1.3 Overcharge

8.1.3.1 The test object is a battery cell.

8.1.3.2 Charge the test object according to the standard charging method specified in 7.1.1.

8.1.3.3 Charge the test object at a constant current specified by the manufacturer, no less than $1I_3$, until it reaches 1.1 times the manufacturer's specified end-of-charge voltage or 115% SOC, then stop charging.

8.1.3.4 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.1.4 External short-circuit

8.1.4.1 The test object is a battery cell.

8.1.4.2 Charge the test object according to the standard charging method specified in 7.1.1.

8.1.4.3 Externally short-circuit the positive and negative terminals of the test object for 10 min. The external circuit resistance shall be less than 5 mΩ.

8.1.4.4 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.1.5 Heating

8.1.5.1 The test object is a battery cell.

8.1.5.2 Charge the test object according to the standard charging method specified in 7.1.1.

8.1.5.3 Place the test object in a temperature chamber. For test objects other than nickel-metal hydride cells, increase the chamber temperature from ambient to 130° C at a rate of 5° C/min and maintain this temperature for 30 min before heating stops. For nickel-metal hydride cells, increase the temperature to 85° C at the same rate and hold for 2 h.

8.1.5.4 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.1.6 Temperature cycling

8.1.6.1 The test object is a battery cell.

8.1.6.2 Charge the test object as per 7.1.1.

8.1.6.3 Place the test object in a temperature chamber and cycle the temperature according to Table 1 and Fig. 1 for 5 cycles.

8.1.6.4 After completing the above steps, observe the test object under ambient temperature for 1 h.

Table 1 Temperature and Duration for One Cycle of Temperature Cycling Test

Temperature (° C)	Time Increment (min)	Cumulative Time (min)	Temperature Change Rate (° C/min)
25	0	0	0
-40	60	60	13/12
-40	90	150	0
25	60	210	13/12
85	90	300	2/3
85	110	410	0
25	70	480	6/7

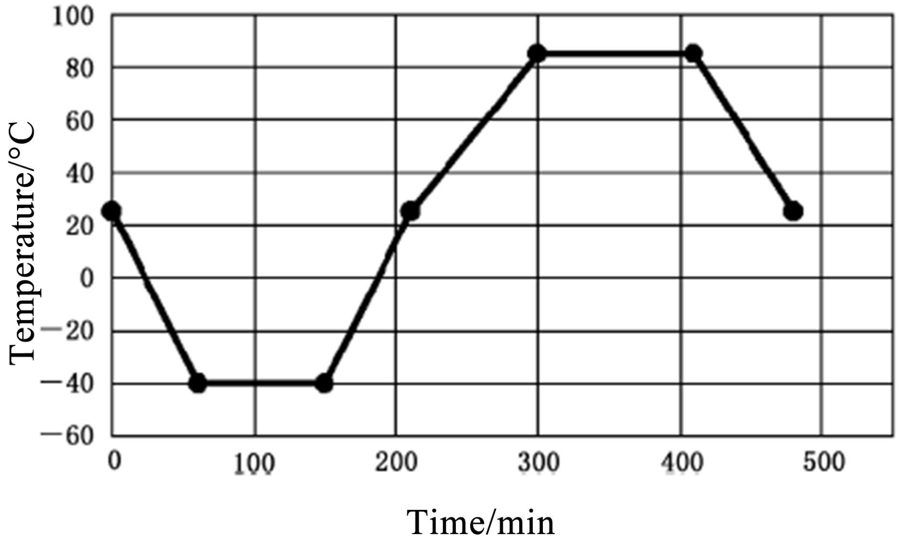


Fig. 1 Temperature Cycling Test

8.1.7 Crush

8.1.7.1 The test object is a battery cell.

8.1.7.2 Charge the test object as per 7.1.1.

8.1.7.3 Perform the test as follows:

a) Crushingdirection: Perpendicular to the cell plate direction or aligned with the direction most susceptible to crushing based on vehicle layout;

b) Crushingplate: Semi-cylinder with a radius of 75 mm and a length (L) greater than the cell size (see Fig. 6);

c) Crushingspeed: Not exceeding 2 mm/s;

d) Crushinglimit: Stop crushingwhen any of the following occurs - voltage reaches 0 V, deformation reaches 15%, applied force reaches 100 kN, or 1000 times the mass of the test object;

e) Holding time: Maintain the crushed statefor 10 min.

8.1.7.4 After completing the test, observe the test object under ambient temperature for 1 h.

8.1.8 Post-fast charging cycle safety

8.1.8.1 The test object is a battery cell capable of fast charging from 20% SOC to 80% SOC within 15 minutes (excluding cells charged only via vehicle energy systems).

8.1.8.2 Perform the test as follows:

a) Adjust SOC to 20% according to the method provided by the manufacturer;

b) Let it stand for 30 min or the period of time specified by the manufacturer;

c) Charge to 80% SOC using the manufacturer-specified fast charging method, not exceeding 15 min;

d) Let it stand for 30 min or the period of time specified by the manufacturer;

e) Repeat steps a)～d) 300 times.

f) Conduct the external short-circuit test according to 8.1.4.

8.2 Safety test methods of battery pack or system

8.2.1 Vibration

8.2.1.1 The test object is a battery pack or system.

8.2.1.2 Install the test object on the vibration bench as per its installation position and fixation method on the vehicle and the requirements in GB/T 2423.43. Apply random and constant-frequency vibration loads in each direction, respectively. The application sequence should be random load in z-axis direction, constant-frequency load in z-axis direction, random load in y-axis direction, constant-frequency load in y-axis direction, random load in x-axis direction and constant-frequency load in x-axis direction (the driving direction of the vehicle is along the x-axis direction, and the other horizontal direction perpendicular to the driving direction is the y-axis direction). The technical serviceis allowed to choose its own sequence to shorten the conversion time. The testing process shall comply with GB/T 2423.56;

8.2.1.3 For the battery pack or system mounted on vehicles of types other than M_1 and N_1, the vibration test parameters are set according to Table 2 and Fig. 2, in which the RMS of x-axis, y-axis and z-axis is 0.52 g, 0.57 g and 0.73 g respectively. If the test object has multiple mounting directions (x/y/z), the test shall be conducted in the mounting direction with large RMS. For the battery pack or system installed on the roof of the vehicle, the vibration test shall be conducted according to the vibration test parameters provided by the manufacturer that are not lower than those in Table 2 and Fig. 2.

8.2.1.4 For the battery pack or system mounted on vehicles of types M_1 and N_1, the vibration test parameters are set according to Table 3 and Fig. 3, in which the RMS of x-axis, y-axis and z-axis is 0.50 g, 0.45 g and 0.64 g respectively.

Table 2 Vibration Test Conditions of Battery Pack or System Installed on Vehicles of Types Other than M_1 and N_1

Random Vibration (12 h in Each Direction)			
Frequency (Hz)	z-axis PSD (g^2/Hz)	y-axis PSD (g^2/Hz)	x-axis PSD (g^2/Hz)
5	0.008	0.005	0.002
10	0.042	0.025	0.018
15	0.042	0.025	0.018
40	0.000 5	—	—
60	—	0.000 1	—
100	0.000 5	0.000 1	—
200	0.000 01	0.000 01	0.000 01
Sinusoidal Constant-frequency Vibration (2 h in Each Direction)			
Frequency (Hz)	z-axis constant-frequency amplitude (g)	y-axis constant-frequency amplitude (g)	x-axis constant-frequency amplitude (g)
20	±1.5	±1.5	±2.0

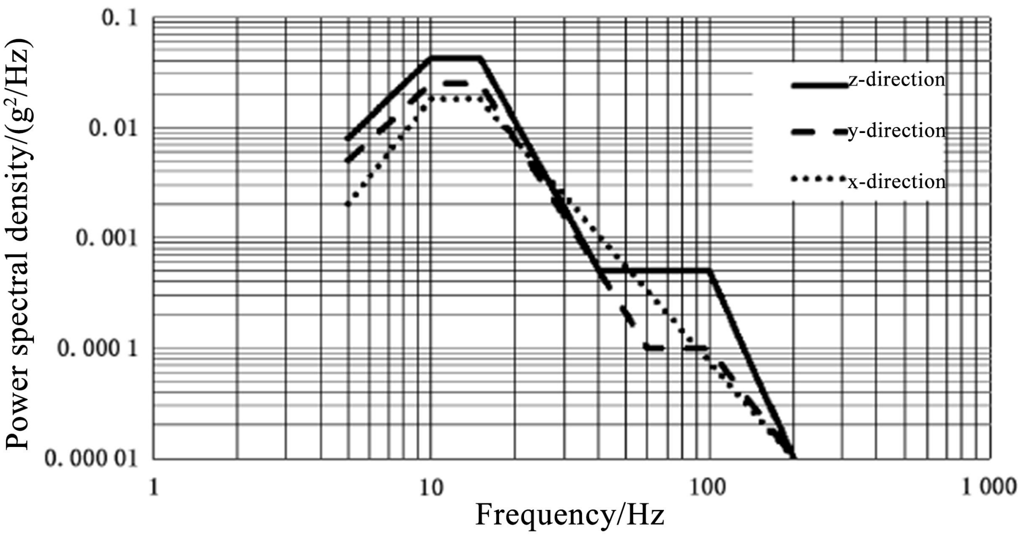


Fig. 2 Random Vibration Test Curve of Battery Pack or System Installed on Vehicles of Types Other than M_1 and N_1

Table 3 Vibration Test Conditions of Battery Pack or System Installed on vehicles of types M_1 and N_1

Random Vibration (12 h in Each Direction)			
Frequency (Hz)	z-axis PSD (g^2/Hz)	y-axis PSD (g^2/Hz)	x-axis PSD (g^2/Hz)
5	0.015	0.002	0.006
10	—	0.005	—
15	0.015	—	—
20	—	0.005	—
30	—	—	0.006
65	0.001	—	—
100	0.001	—	—
200	0.000 1	0.000 15	0.000 03
Sinusoidal Constant-frequency Vibration (1 h in Each Direction)			
Frequency (Hz)	z-axis constant-frequency amplitude (g)	y-axis constant-frequency amplitude (g)	x-axis constant-frequency amplitude (g)
24	±1.5	±1.0	±1.0

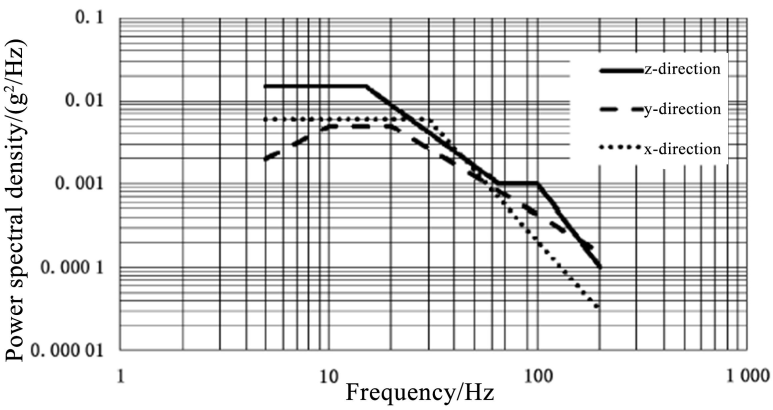


Fig. 3 Random Vibration Test Curve of Battery Pack or System Installed on Vehicles of Types M_1 and N_1

8.2.1.5 During the test, monitor the status of the minimum monitor unit inside the test object, such as voltage and temperature.

8.2.1.6 After completing the above steps, observe the test object under ambient temperature for 2 h.

8.2.2 Mechanical shock

8.2.2.1 The test object is a battery pack or system.

8.2.2.2 Apply the half-sine shock wave specified in Table 4 to the test object, 6 times in the ±z direction respectively, 12 times in total.

8.2.2.3 The maximum and minimum tolerance ranges of half-sine shock wave are shown in Table 5 and Fig. 4.

8.2.2.4 The time interval between two adjacent shocks shall meet the conditions that the responses of two shocks on the test sample do not affect each other, and it shall generally not be less than 5 times the duration of shock pulse.

8.2.2.5 After completing the above steps, observe the test object under ambient temperature for 2 h.

Table 4 Parameters of Mechanical Shock Test

Test Procedure	Parameter Requirements
Shock waveform	Half-sine wave
Test direction	±z
Acceleration	7g
Pulse time/ms	6
Number of shock	6 times for positive and negative directions respectively

Table 5 Tolerance Range of Mechanical Shock Pulse

Point	Pulse Width (ms)	Acceleration Value in ±z Direction (g)
A	1.00	0.00
B	2.94	5.95
C	3.06	5.95
D	5.00	0.00
E	0.00	2.68
F	2.00	8.05
G	4.00	8.05
H	7.00	0.00

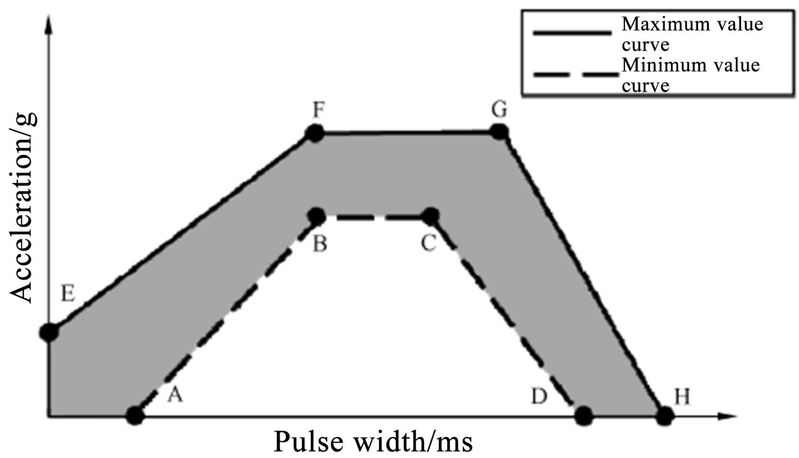


Fig. 4 Mechanical Shock Pulse Tolerance Range

8.2.3 Simulated impact

8.2.3.1 The test object is a battery pack or system.

8.2.3.2 Install the test object horizontally on a trolley with a bracket as per its installation position and fixation method on the vehicle and the requirements in GB/T 2423.43. Apply the specified pulse to the trolley according to the service environment of the test object to ensure the allowable maximum and minimum tolerance ranges in Table 6 and Fig. 5 (the driving direction of the vehicle is taken as the x-axis direction, and the other horizontal direction perpendicular to the driving direction is taken as the y-axis direction). If the test object has multiple mounting directions (x/y/z), the test shall be conducted in the mounting direction with large acceleration.

8.2.3.3 After completing the above steps, observe the test object under ambient temperature for 2 h.

Table 6 Tolerance Range of Simulated Impact Pulse

Point	Pulse Width (ms)	≤3.5 t (vehicle curb mass)		>3.5 t and <7.5 t (vehicle curb mass)		≥7.5 t (vehicle curb mass)	
		Acceleration in x-axis direction (g)	Acceleration in y-axis direction (g)	Acceleration in x-axis direction (g)	Acceleration in y-axis direction (g)	Acceleration in x-axis direction g	Acceleration in y-axis direction (g)
A	20	0	0	0	0	0	0
B	50	20	8	10	5	6.6	5
C	65	20	8	10	5	6.6	5
D	100	0	0	0	0	0	0
E	0	10	4.5	5	2.5	4	2.5
F	50	28	15	17	10	12	10
G	80	28	15	17	10	12	10
H	120	0	0	0	0	0	0

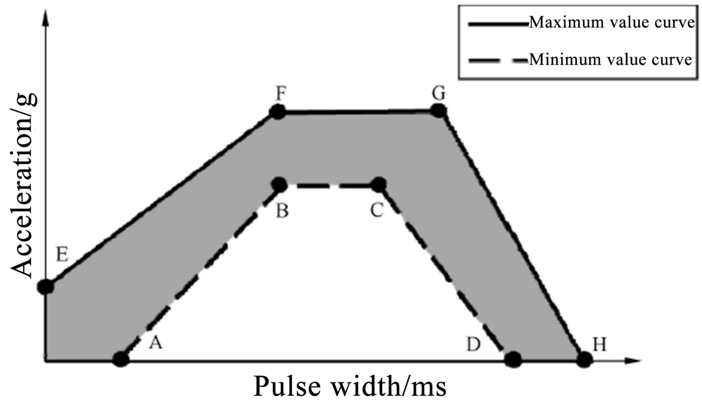


Fig. 5 Simulated Impact Pulse Tolerance Range

8.2.4 Crush

8.2.4.1 The test object is a battery pack or system. For the battery pack or system installed inside the body frame, the test can be conducted with the structural parts of the vehicle body.

8.2.4.2 Perform the test as follows:

a) Crush plate form (select one of the following two types):

1) The crush plate is shown in Fig. 6. The semi-cylinder has a radius of 75 mm and a length (L) greater than the height of the test object but not more than 1 m;

2) The crush plate is shown in Fig. 7. The dimensions are 600 mm × 600 mm (length × width) or smaller. The radius of the three semi-cylinders is 75 mm and the spacing between them is 30 mm.

b) Crushing direction: x and y directions (the driving direction of the vehicle is the x-axis direction, and the other horizontal direction perpendicular to the driving direction is the y-axis direction). In order to ensure the safety of test operations, tests can be performed on two test objects separately;

c) Crushing points: Weak points provided by the manufacturer;

d) Crushing speed:no more than 2 mm/s;

e) Crushing degree: Stop crushing when the crushing force reaches 100 kN or the crushing deformation reaches 30% of the overall size in the crushing direction. For crushing with vehicle body structural parts, the crushing force reaching 100 kN shall be taken as the termination conditions;

f) Holding time: Maintain the current position for 10 min.

8.2.4.3 After completing the test, observe the test object under ambient temperature for 2 h.

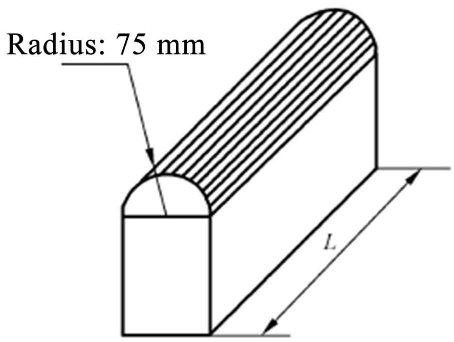


Fig. 6 Crush Plate Form I

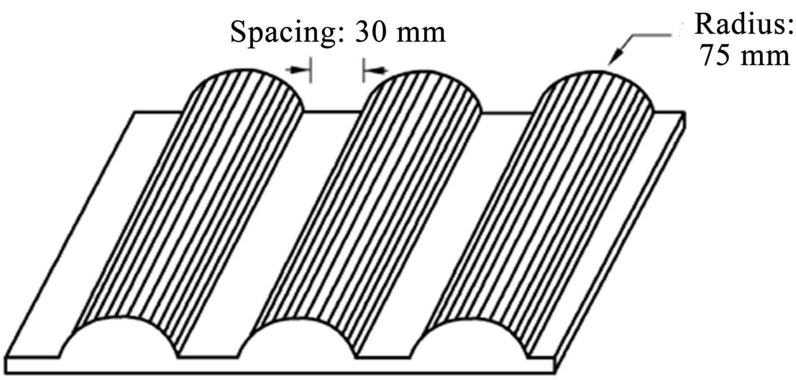


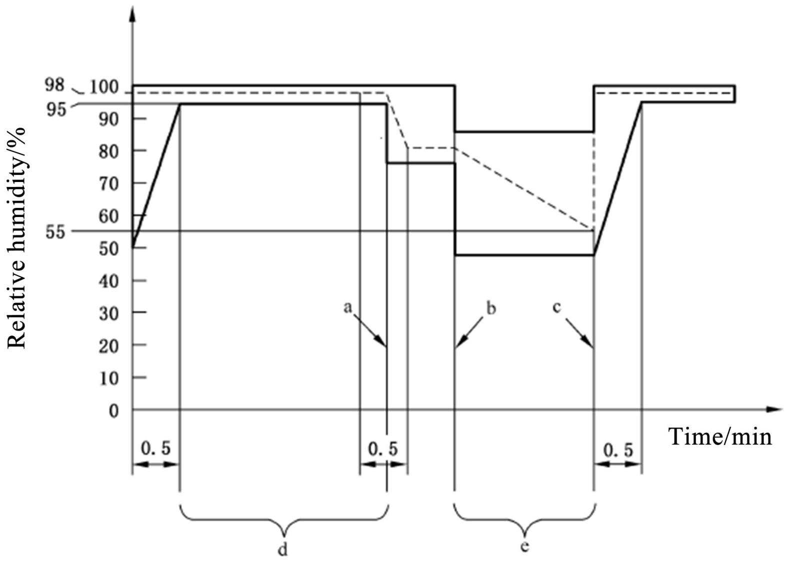
Fig. 7 Crush Plate Form II

8.2.5 Damp heat cycling

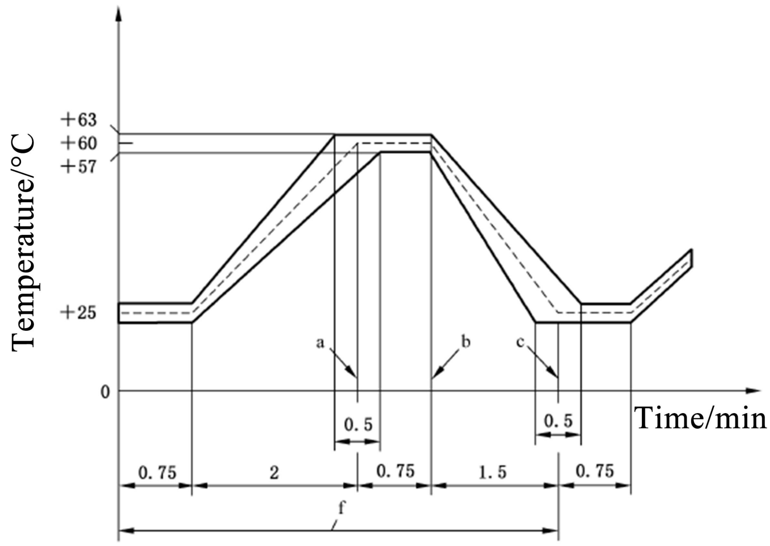
8.2.5.1 The test object is a battery pack or system.

8.2.5.2 Perform test Db according to GB/T 2423.4. Set the test parameters according to Fig. 8. The highest temperature is 60° C or above (if required by the manufacturer), with 5 cycles.

8.2.5.3 After completing the above steps, observe the test object under ambient temperature for 2 h.



a) Relative humidity curve



b) Temperature curve

Key:

a- End of heating;

b- Start of cooling;

c- Recommended temperature and humidity values;

d- Condensation;

e- Drying;

f- One cycle.

Fig. 8 Damp Heat Cycling Test

8.2.6 Water immersion

8.2.6.1 The test object is the battery pack or system that has passed the vibration test specified in 8.2.1.

8.2.6.2 Connect the test object with wiring harnesses, connectors and other parts according to the vehicle connection mode, and conduct the tests using one of the following two methods.

a) Method 1: Place the test object in 3.5% (mass fraction) sodium chloride solution for 2 h in the direction of real vehicle assembly. The water depth shall submerge the test object.

b) Method 2: The test object shall be tested according to the method and procedures described in 14.2.7 of GB/T 4208-2017. Immerse the test object completely in water according to the mounting state specified by the manufacturer. For test object with a height less than 850 mm, the lowest point shall be 1000 mm below the water surface. For the test object with a height no less than 850 mm, the highest point shall be 150 mm below the water surface. The test duration shall be 30 min. The temperature difference between water and the test object shall not exceed 5 ° C.

8.2.6.3 Take the test object out of water and let it stand for observation at the test ambient temperature for 2 h.

8.2.7 Thermal stability

8.2.7.1 External fire

8.2.7.1.1 The test object is a battery pack or system. The body structure that protects the battery pack or system can be involved in the fire test.

8.2.7.1.2 The ambient temperature of the test is above 0 ° C, and the wind speed is no more than 2.5 km/h.

8.2.7.1.3 The size of the flat pan containing gasoline shall exceed the horizontal projection size of the test object by 20 cm (but not exceed 50 cm) during the test. The height of the flat pan shall not be more than 8 cm above the gasoline surface. The test object shall be centered. The distance between the gasoline surfaceand the bottom of the test object is set to 50 cm or to the ground clearance of the bottom of the test object under unladen conditions of the vehicle. The bottom of the flat pan shall be filled with water. The combustion time shall begin or end when the test object, refractory partition and the oil pan are stationary. The external fire is shown in Fig. 9.

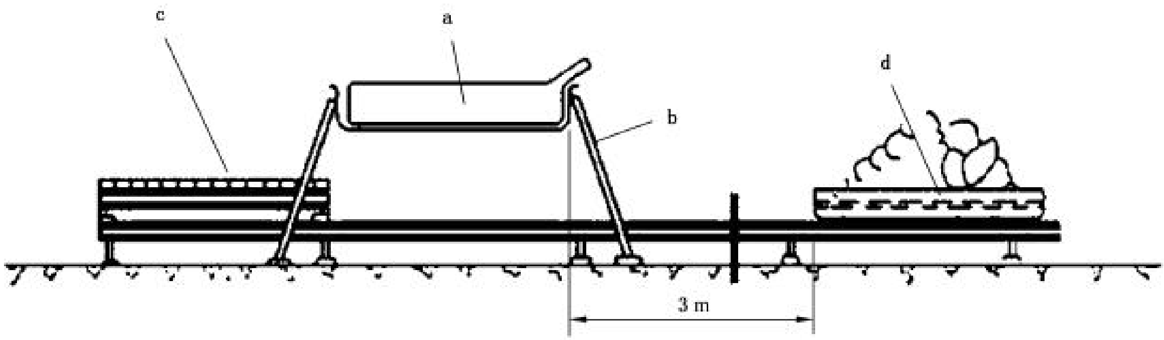
8.2.7.1.4 The external fire test includes the following 4 stages:

a) Warm-up. Ignite the gasoline at least 3 m away from the test object, and place the oil pan under the test object after 60 s of preheating. If the oil pan is too large to move, the test object and bracket can be moved.

b) Direct combustion. Expose the test object directly to flame for 70 s.

c) Indirect combustion. Cover the oil pan with a refractory partition. Test the test object in this state for 60 s. Alternatively, continue direct exposure to flame for 60 s as agreed by both parties through negotiation. The fire-resistant partition is made from standard fire bricks, with the sieve hole sizes specified in Fig. 10. Refractory materials can also be used to make the partition using these dimensions as a reference.

d) Move away from the fire. Remove the oil pan or test object, and observe it at the test ambient temperature for 2 h or until the surface temperature of the test object drops below 45° C.



Key:

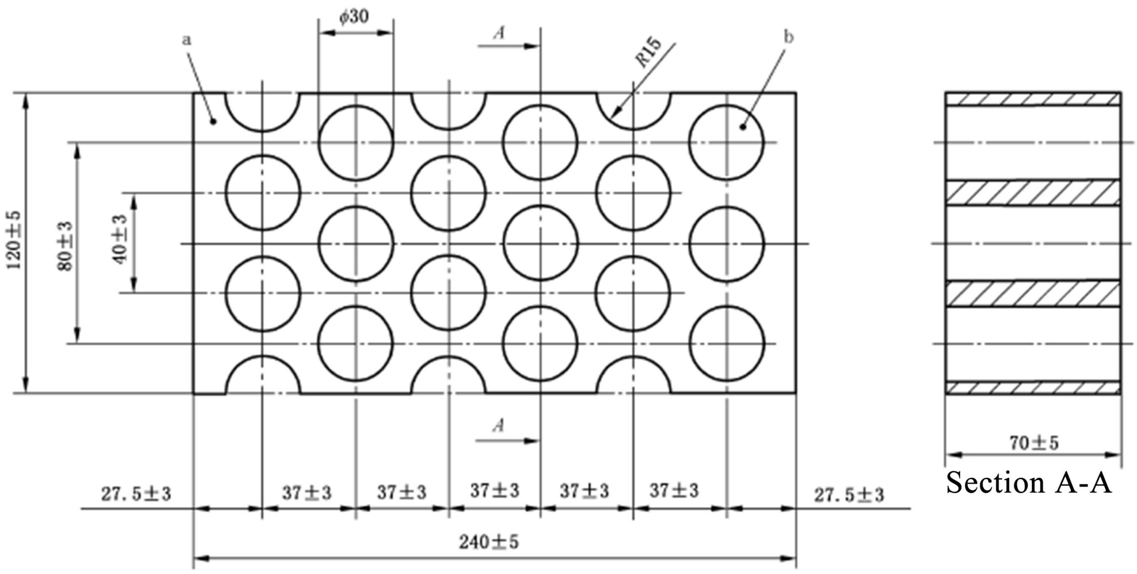
a- Test objects;

b- Test bench;

c- Refractory partition (paved with refractory bricks);

d- Flat pan for gasoline.

Fig. 9 Schematic Diagram of External Fire



Key:

a- Refractory partition (fire resistance: SK30; composition: 30%~33%Al_2O_3; density: 1900 kg/m^3~2000 kg/m^3);

b- Sieve (effective hole area: 44.18%; opening ratio: 20%~22% (by volume)).

Fig. 10 Dimensions and Technical Data of Refractory Partition

8.2.7.2 Thermal propagation

The thermal propagation analysis and verification shall be performed for the battery pack, system or vehicle according to Annex C.

8.2.8 Thermal shock

8.2.8.1 The test object is a battery pack or system.

8.2.8.2 Place the test object in an alternating temperature environment of (-40° C ~ 60° C) (more severe test temperatures can be used if required by the manufacturer), and carry out the cycle as shown in Fig. 11, with the conversion time between the two extremes of temperature within 30 min. Keep the test object in each extreme temperature environment for 8 h, with 5 cycles.

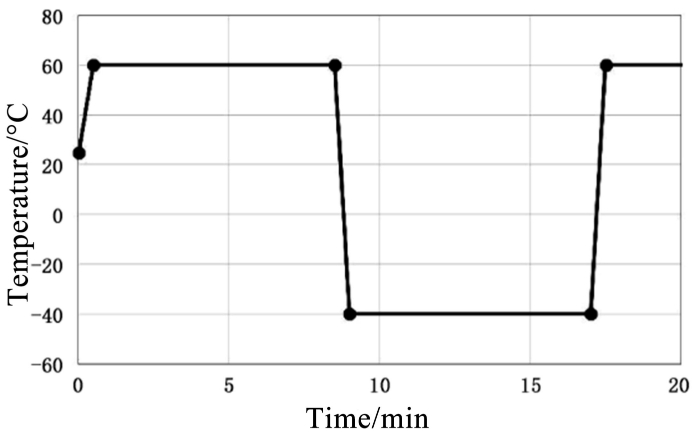


Fig. 11 Thermal Shock Test

8.2.8.3 After completing the above steps, observe the test object under ambient temperature for 2 h.

8.2.9 Salt spray

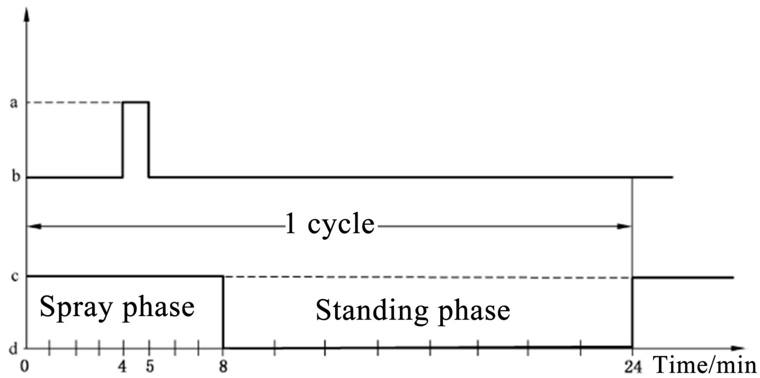
8.2.9.1 The test object is a battery pack or system. The salt spray test may not be conducted for test objects completely placed in the passenger compartment, luggage compartment or cargo compartment.

8.2.9.2 The test shall be carried out according to the test method in 5.5.2 of GB/T 28046.4-2011 and the test conditions of GB/T 2423.17—2024.

8.2.9.3 The salt solution shall be prepared with sodium chloride (chemically pure or analytically pure) and distilled water or deionized water, with a mass concentration of (50±5) g/L. The pH value measured at 35° C ranges from 6.5 to 7.2.

8.2.9.4 Place the test object in the salt spray chamber according to the installation conditions specified by the manufacturer. Conduct the test in cycles as shown in Fig. 12, with each cycle lasting 24 hours. Spray the test object at 35 ° C for 8 h, and then let it stand for 16 h. Perform low-voltage power-on monitoring between the 4th and the 5th hour of a cycle.

8.2.9.5 A total of 6 cycles shall be performed.



Key:

a- Low-voltage power-on monitoring;

b- The wiring harness is connected and not powered on;

c- ON (start salt spray);

d- OFF (stop salt spray).

Fig. 12 Salt Spray Test Cycle

8.2.10 High altitude

8.2.10.1 The test object is a battery pack or system.

8.2.10.2 Test environment: atmospheric pressure of 61.2 kPa (the atmospheric pressure at a simulated altitude of 4000 m), and the temperature equivalent to the test ambient temperature.

8.2.10.3 Maintain the test environment specified in 8.2.10.2 and let it stand for 5 h.

8.2.10.4 After standing, maintain the test environment in 8.2.10.2, and discharge the test object at a current specified by the manufacturer of no less than 1 I_3 to the end-of-discharge conditions specified by the manufacturer.

8.2.10.5 After completing the above steps, observe the test object under ambient temperature for 2 h.

8.2.11 Overtemperature protection

8.2.11.1 The test object is a battery system.

8.2.11.2 At the beginning of the test, except for the cooling system, all protective devices that affect the function of the test object and are relevant to the test results shall be in normal operating conditions.

8.2.11.3 The test object shall be continuously charged and discharged by external charging and discharging equipment at a current that will increase the cell temperature as quickly as possible within the normal working range specified by the battery system manufacturer until the end of the test.

8.2.11.4 The temperature in the indoor environment or temperature chamber shall be gradually increased from 20 °C ± 10 °C or a higher temperature as specified by the manufacturer, until the temperature determined according to a) or b) (as applicable) is reached. This temperature shall then be maintained at or above this value until the end of the test.

a) If the battery system is equipped with internal overheating protection measures, the temperature shall be raised to the operational temperature threshold corresponding to these protection measures, to ensure that the temperature of the test object increases according to the specifications outlined in 8.2.11.3.

b) If the battery system is not equipped with any specific internal overheating protection measures, the temperature shall be increased to the maximum operating temperature specified by the battery system manufacturer.

8.2.11.5 The test shall be ended when any of the following conditions is met:

a) The test object automatically terminates or limits the charging or discharging;

b) The test object sends a signal to terminate or limit the charging or discharging;

c) The temperature of the test object is stable, and the temperature change is less than 4°C within 2 h.

8.2.11.6 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.2.12 Overcurrent protection

8.2.12.1 The test object is a battery system that can be powered by an external DC power supply.

8.2.12.2 The test conditions are as follows:

a) The test shall be carried out at an ambient temperature of 20° C ± 10° C;

b) The SOC of the test object shall be adjusted to the middle partof the normal working range according to the normal operation recommended by the battery system manufacturer (e.g., using external charging and discharging equipment). As long as the battery system can operate normally, no accurate adjustment is required;

c) Consult with the battery system manufacturer to determine the overcurrent (assuming failure of external DC power supply equipment) and maximum voltage (within normal range) that can be applied.

8.2.12.3 Conduct the overcurrent test as per the following steps according to the instruction document provided by the battery system manufacturer:

a) Connect external DC supply equipment, and change or disable charging control communication to allow overcurrent level that has been determined through negotiation with the battery system manufacturer;

b) Start the external DC supply equipment to charge the battery system, so as to reach the maximum normal charging current specified by the battery system manufacturer. Then, increase the current from the highest normal charging current to the overcurrent level described in 8.2.12.2 c) within 5 s and continue charging.

8.2.12.4 The test shall be ended when any of the following conditions is met:

a) The test object automatically terminates the charging current;

b) The test object sends a signal to terminate the charging current;

c) The temperature of the test object is stable, and the temperature change is less than 4 ° C within 2 h.

8.2.12.5 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.2.13 External short-circuit protection

8.2.13.1 The test object is a battery system.

8.2.13.2 The test conditions are as follows:

a) The test shall be carried out at an ambient temperature of 20° C ± 10° C or a higher temperature required by the manufacturer;

b) At the beginning of the test, all protective devices that affect the function of the test object and are relevant to the test results shall be in normal operating conditions.

8.2.13.3 The external short-circuit process is as follows:

a) At the beginning of the test, all main contactors for charging and discharging shall be closed (e.g., relevant relays in the battery system circuit) to indicate the driving mode and the mode allowing external charging. If this cannot be done in a single test, two or more tests shall be performed.

b) Connect the positive terminal and the negative terminal of the test object to each other. The short-circuit resistance shall not exceed 5 mΩ.

8.2.13.4 Maintain the short-circuit state, and end the test until one of the following conditions is met:

a) The protection function of the test object works and the short-circuit current is terminated;

b) After the temperature of the test object housing is stable (with a temperature change of less than 4° C within 2 h), the short-circuit state continues for at least 1 h.

8.2.13.5 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.2.14 Overcharge protection

8.2.14.1 The test object is a battery pack or system.

8.2.14.2 The test conditions are as follows:

a) The test shall be carried out at an ambient temperature of 20° C ± 10° C or a higher temperature required by the manufacturer;

b) The SOC of the test object shall be adjusted to the middle part of the normal working range according to the normal operation recommended by the battery system manufacturer (e.g., using external charging and discharging equipment). As long as the test object can operate normally, no accurate adjustment is required;

c) At the beginning of the test, all protective devices that affect the function of the test object and are relevant to the test results shall be in normal operating conditions. All relevant main contactors for charging shall be closed (e.g., relevant relays in the battery system circuit).

8.2.14.3 The charging process is as follows:

a) The external charging equipment shall be connected to the main terminal of the test object. The charging control limit of the external charging equipment shall be disabled;

b) The test object shall be charged by external charging equipment under the charging strategy with the shortest time permitted by the battery system manufacturer.

8.2.14.4 The charging shall be continued and the test shall end when any of the following conditions is met:

a) The test object automatically terminates the charging current;

b) The test object sends a signal to terminate the charging current;

c) If the overcharge protection control of the test object fails to activate, or if the function described in 8.2.14.4 a) is absent, the charging shall continue until the temperature of the test object reaches 10° C above themaximum operating temperature specified by the manufacturer;

d) If the charging current has not been terminated and the temperature of the test object does not reach the highest operating temperature plus 10° C , the charging shall continue for 12 h.

8.2.14.5 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.2.15 Over-discharge protection

8.2.15.1 The test object is a battery system.

8.2.15.2 The test conditions are as follows:

a) The test shall be carried out at an ambient temperature of 20° C ± 10° C or a higher temperature required by the manufacturer;

b) The SOC of the test object shall be adjusted to the lower part of the normal working range according to the normal operation method recommended by the battery system manufacturer (e.g., using external charging and discharging equipment). As long as the test object can operate normally, no accurate adjustment is required;

c) At the beginning of the test, all protective devices that affect the function of the test object and are relevant to the test results shall be in normal operating conditions. All relevant main contactors for discharging shall be closed (e.g., relevant relays in the battery system circuit).

8.2.15.3 The discharging process is as follows:

a) The external discharging equipment shall be connected to the main terminal of the test object;

b) Consensusshall be made with the battery system manufacturer for discharging at a stable current within the specified normal working range.

8.2.15.4 The discharging shall be continued and the test shall end when any one of the following conditions is met:

a) The test object automatically terminates the discharging current;

b) The test object sends a signal to terminate the discharging current;

c) When the automatic interruption function of the test object does not work, or if the function described in 8.2.15.4 a) is absent, continue discharging until the test object discharges to 25% of its rated voltage;

d) The temperature of the test object is stable, and the temperature change is less than 4° C within 2 h.

8.2.15.5 After completing the above steps, observe the test object under ambient temperature for 1 h.

8.2.16 Bottom impact

8.2.16.1 The test object is the battery pack or system installed at the bottom of the vehicle, or the corresponding vehicle. When the test object is a battery pack or system, the vehicle body structure that protects the battery pack or system is allowed to be involved in the test. For the battery pack or system installed in vehicles of type N with a minimum ground clearance ⩾ 200 mm under laden conditions, or the corresponding vehicle, no bottom impact test will be carried out.

8.2.16.2 Secure the test object to the test bench and conduct the test under the following conditions (as shown in Fig. 13):

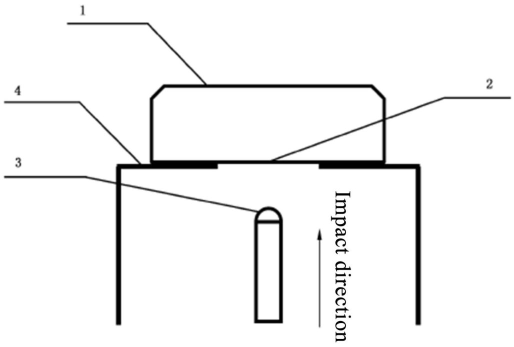
a) Impact head: hemisphere with a diameter of 30 mm, weighing 10 kg and made of 45# steel;

b) Impact direction: +z-axis direction (the driving direction of the vehicle is the x-axis direction, and the other horizontal direction perpendicular to the driving direction is the y-axis direction, while the direction perpendicular to both the x-axis and the y-axis is the z-axis direction);

c) Impact position: 3 bottom protection risk points provided by the manufacturer are impact positions (representing the front, middle and rear of the battery), and relevant technical specifications shall be provided;

d) Impact energy: 150 J ± 3 J.

8.2.16.3 After completing the test, observe the test object under ambient temperature for 2 h.



Key:

1- Test object;

2- The bottom of the test object;

3- Impact head;

4- Test bench.

Fig. 13 Bottom Impact Test

9 Determination of the Same Type

9.1 The battery pack or system is considered to be of the same type if it meets all of the following requirements:

a) Same specifications, model, and manufacturer for battery cells and modules;

b) Same enclosure material (metal/non-metal), outer shape, and mechanical structure;

c) Same installation method, the same (or increased) number of mounting points, the same position of mounting points, and the same structural design of mounting points;

d) Same battery energy inside the pack, or a reduction not exceeding 20%;

e) Same fixation and installation methods for battery cells and modules;

f) Same layout, operation mode, and refrigerant for the thermal management system inside the battery pack;

g) Same arrangement of thermal management system flow channels of the battery pack and same specifications and models for the refrigerant interfaces outside the battery pack;

h) Same insulation material;

i) Same number of series-connected battery cells and modules, or reduced number with unchanged internal structure;

j) Same hardware specifications, model, manufacturer, and software version number for BMS (unless it does not affect the safety of the power battery), identical protection parameters and thresholds in control software (e.g., thermal protection strategy, thermal alarm strategy, and thermal event alarm signals), and the same manufacturer for the battery management system;

k) No reduction in rated voltage and current load capacity for electrical components;

l) Same or reduced number of high-voltage circuits inside the battery pack;

m) Same number, specifications and models and layout position of maintenance switches and high/low-voltage connectors;

n) Same number, specification and layout position of pressure relief devices;

o) Same length/width of the battery pack, with deviations from the nominal value within ±1% o f the nominal value; Same height of the battery pack, with deviations from the nominal value within ±5% of the nominal value;

p) The weight of the battery pack shall be between 90% and 103% of the nominal value;

q) Symmetrically installed battery packs on the vehicle, with outer envelope structure and module layout in mirror symmetry.

9.2 If there are partial modifications to the battery pack or system, it is allowed to conduct supplementary tests according to the technical requirements related to the modified parameters in Table 7. Upon approval, they are considered to be of the same type without the need for complete retesting:

Table 7 Supplementary Test Items for Partial Changes

No.	Conditions of Equivalence for Changes	Test Items to Be Supplemented If Conditions of Equivalence Are Not Met
1	Same specifications, model, and manufacturer for battery cells and modules	All test items
2	Same enclosure material (metal/non-metal), outer shape, and mechanical structure	Vibration, mechanical shock, simulated impact, crush, thermal shock, damp heat cycling, water immersion, external fire exposure, salt spray, thermal propagation, and bottom impact.
3	Same installation method, the same (or increased) number of mounting points, the same position of mounting points, and the same structural design of mounting points.	Vibration, mechanical shock, simulated impact, water immersion, bottom collision, and crush
4	Same battery energy inside the pack, or a reduction not exceeding 20%	Vibration, water immersion, mechanical shock, simulated impact, crush, thermal propagation, overcharge protection, over-temperature protection, over-discharge protection, overcurrent protection, short-circuit protection, and bottom impact.
5	Same fixation and installation methods for battery cells and modules	Vibration, mechanical shock, simulated impact, crush, water immersion, and bottom impactn
6	Same layout, operation mode, and refrigerant for the thermal management system inside the battery pack	Vibration, water immersion, mechanical shock, simulated impact, crush, thermal propagation, and bottom impact
7	Same arrangement of thermal management system flow channels of the battery pack and same specifications and models for the refrigerant interfaces outside the battery pack.	Vibration, water immersion, mechanical shock, simulated impact, and bottom impact
8	Same insulation material	Thermal propagation, external fire exposure
9	Same number of series-connected battery cells and modules, or reduced number with unchanged internal structure	Vibration, water immersion, mechanical shock, simulated impact, crush, thermal propagation, overcharge protection, over-temperature protection, over-discharge protection, overcurrent protection, short-circuit protection, and bottom impact.
10	Same hardware specifications, model, manufacturer, and software version number for BMS (unless it does not affect the safety of the power battery), identical protection parameters and thresholds in control software (e.g., thermal protection strategy, thermal alarm strategy, and thermal event alarm signals), and the same manufacturer for the battery management system;	Over-temperature protection, short circuit protection, overcharge protection, over-discharge protection, overcurrent protection, and thermal propagation

No.	Conditions of Equivalence for Changes	Test Items to Be Supplemented If Conditions of Equivalence Are Not Met
11	No reduction in rated voltage and current load capacity for electrical components.	Over-temperature protection, short circuit protection, overcharge protection, over-discharge protection, and overcurrent protection
12	Same or reduced number of high-voltage circuits inside the battery pack	Over-temperature protection, short circuit protection, overcharge protection, over-discharge protection, overcurrent protection, and thermal propagation
13	Same number, specifications and models and layout position of maintenance switches and high/low-voltage connectors.	Vibration, external fire exposure, water immersion, short circuit protection, and overcurrent protection
14	Same number, specification and layout position of pressure relief devices.	Vibration, external fire exposure, thermal shock, damp heat cycling, water immersion, salt spray, and thermal propagation
15	Same length/width of the battery pack, with deviations from the nominal value within ±1% of the nominal value; Same height of the battery pack, with deviations from the nominal value within ±5% of the nominal value.	Vibration, water immersion, simulated impact, mechanical shock, crush, thermal propagation, and bottom impact.
16	Same weight of the battery pack, within 90% to 103% of the nominal value;	Vibration and water immersion
17	Symmetrically installed battery packs on the vehicle, with outer envelope structure and module layout in mirror symmetry.	Vibration, simulated impact, mechanical shock, external fire exposure, crush, thermal shock, damp heat cycling, high altitude, water immersion, thermal propagation, and bottom impact.

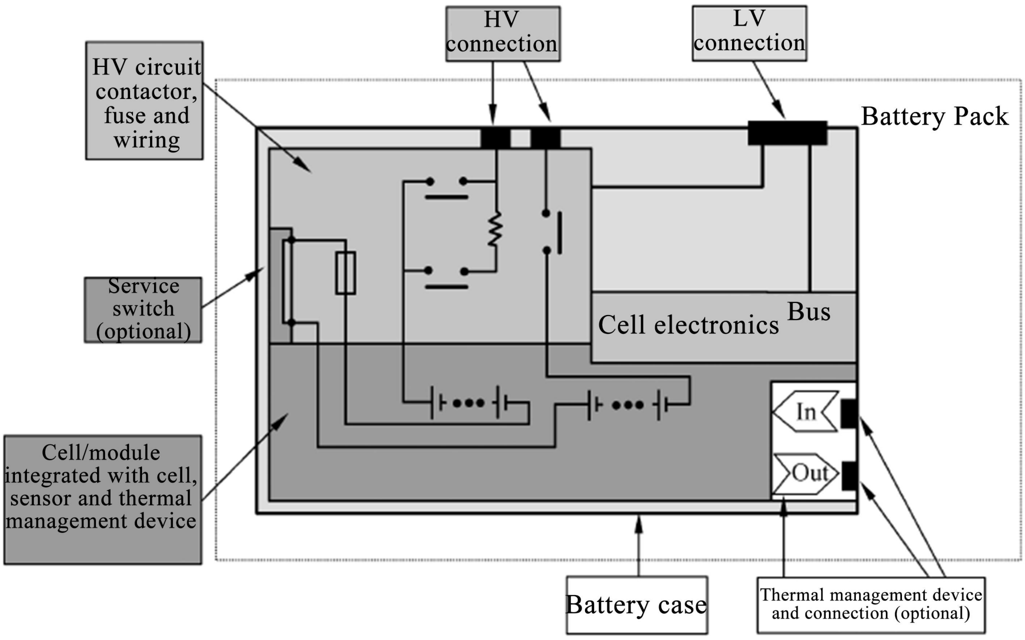
10 Implementation of Standard

For new vehicle types awaiting type approval, the implementation will start from the date of implementation of this document; for vehicle types with type approval, the implementation will begin in the 13th month from the date of implementation of this document.

Annex A
(Informative)
Typical Structure of Battery Pack or System

A.1 Battery Pack

A typical structure of a battery pack includes battery cell, components, high-voltage circuits, overcurrent protection devices and interfaces with other external systems (such as cooling, high-voltage, auxiliary low-voltage and communication systems). Fig. A.1 shows a typical structure of a battery pack.



Key:

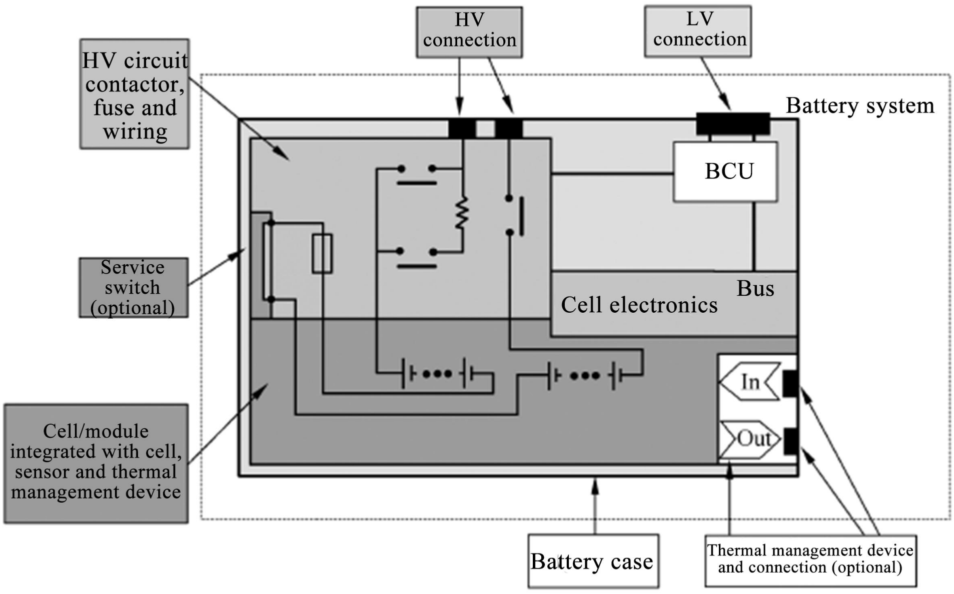
In- Coolant inlet;

Out- Coolant outlet.

Fig. A.1 Typical Structure of Battery Pack

A.2 Battery system

There are two typical structures of the battery system, namely the battery system with integrated battery control unit and the battery system with external battery control unit, as shown in Fig. A.2 and Fig. A.3 respectively.

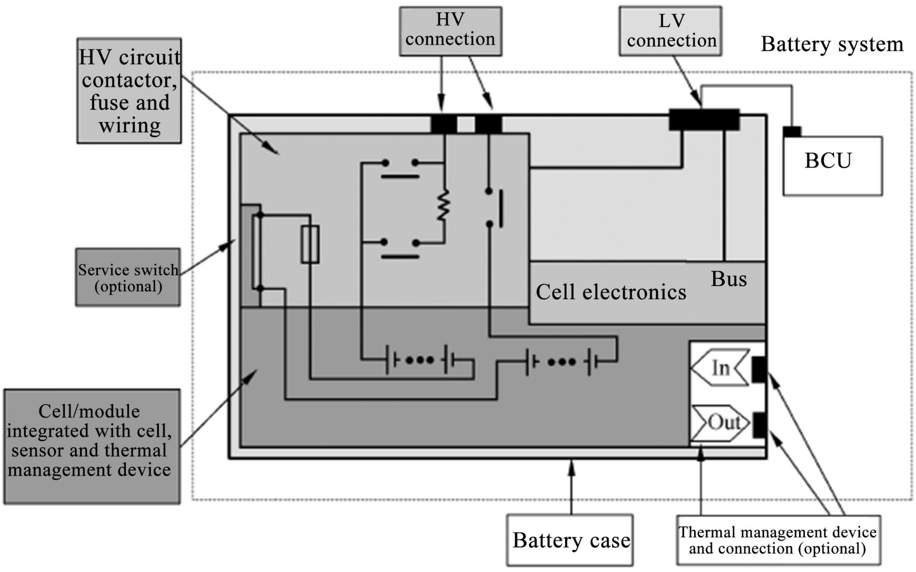


Key:

In- Coolant inlet;

Out- Coolant outlet.

Fig. A.2 Typical Structure of Battery System with Integrated BCU



Key:

In- Coolant inlet;

Out- Coolant outlet.

Fig. A.3 Typical Structure of Battery System with External Integrated BCU

Annex B
(Normative)
Test Method for Insulation Resistance of Battery Pack or System

B.1 Test conditions

The battery pack or system is fully charged as specified by the manufacturer, with an ambient temperature of 22° C±5° C and a relative humidity of 10%~90%.

The internal resistance of the voltage detection tool shall not be less than 10 MΩ. If the insulation monitoring function will affect the test of insulation resistance of the battery pack or system during measurement, the insulation monitoring function shall be disabled or the insulation resistance monitoring unit shall be disconnected from the class B voltage circuit to avoid affecting the measured value. Otherwise, the manufacturer may choose whether to disable the insulation monitoring function or disconnect the insulation monitoring unit from the Class B voltage circuit.

B.2 Insulation resistance test method

B.2.1 Method 1

B.2.1.1 Activate the electric and electronic switches in the battery pack or system to ensure that the battery system is turned on.

B.2.1.2 Simultaneously measure the voltage between the electrical chassis and positive as well as negative output terminals of the battery pack or system using two identical voltage detection tools, as shown in Fig. B.1. Once the tool reading is stable, the higher one is taken as U_1, while the lower one as U_1'. The electrical chassis of the battery pack or system may be a conductive enclosure linked to the electrical chassis of the vehicle.

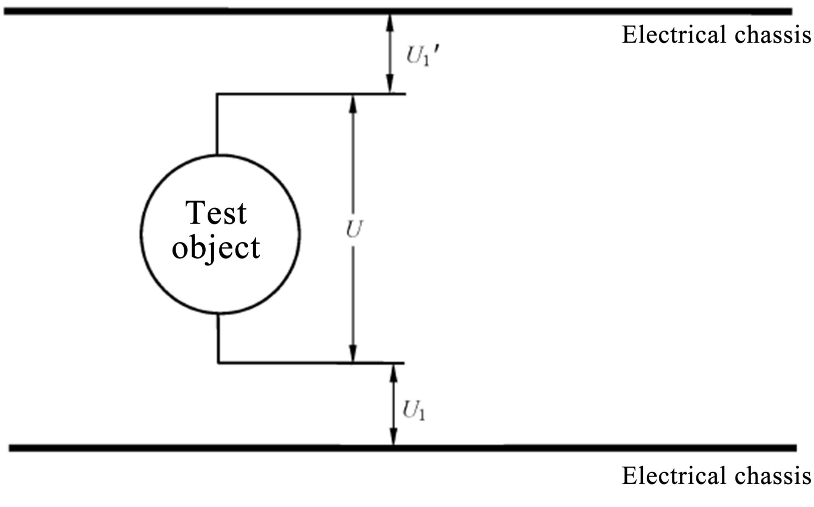


Fig. B.1 Insulation Resistance Measurement Step 1

B.2.1.3 Add a known resistor R_0, with the recommended resistance of 1 MΩ. As shown in Fig. B.2, connect it in parallel between the U_1 side terminal of the battery pack or system and the electrical chassis. Use the two voltage detection tools in B.2.1.2 to measure the voltage between the positive and negative output terminals of the battery pack or system and the electrical chassis simultaneously. When the tool reading is stable, the measured values are U_2 and U_2'.

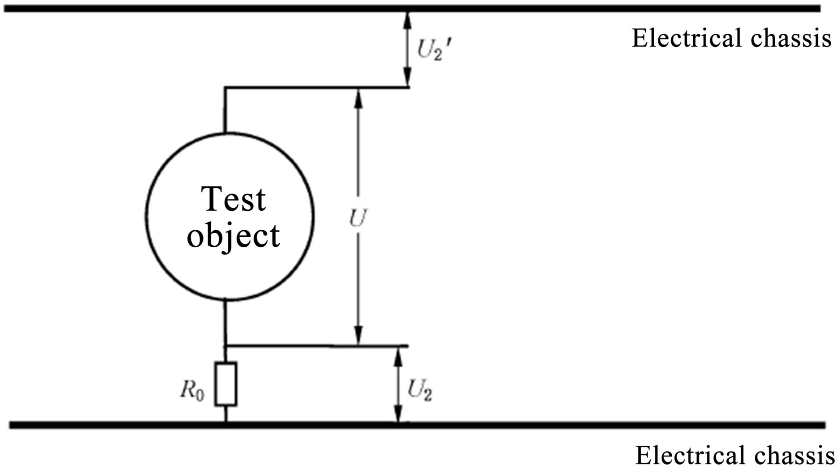


Fig. B.2 Insulation Resistance Measurement Step 2

B.2.1.3 Calculate the insulation resistance R_i as follows:

R_i can be calculated using R_0 and four voltage values U_1, U_1', U_2 and U_2', along with the internal resistance r of the voltage detection device, substituted into Formula (B.1) or (B.2).

$$\frac{R_i \times r}{R_i + r} = R_0\left(\frac{U_2'}{U_2} - \frac{U_1'}{U_1}\right) \quad \text{(B.1)}$$

$$R_i = \frac{1}{\dfrac{1}{R_0\left(\dfrac{U_2'}{U_2} - \dfrac{U_1'}{U_1}\right)} - \dfrac{1}{r}} \quad \text{(B.2)}$$

B.2.2 Method 2

B.2.2.1 Maintain the turned-on status of the battery pack or system.

B.2.2.2 Measure the insulation resistance between the positive and negative output terminals and the electrical chassis of the battery pack or system respectively via an insulation resistance tester. The electrical chassis of the battery pack or system can be used as a conductive enclosure linked to the electrical chassis of the vehicle.

B.2.2.3 Measuring voltage: The measuring voltage used shall be 1.5 times of nominal voltage of the battery pack or system or 500 V (DC) (whichever is higher).

B.2.2.4 Measuring time: The voltage shall be applied for no less than 30 s in order to obtain a stable reading.

Annex C
(Normative)
Thermal Propagation Analysis and Verification Report

C.1 General requirements

The battery pack or system shall not exhibit any evidence of fire or explosion after thermal runaway caused by internal short-circuit of a single battery. A thermal event alarm signal shall be provided no later than 5 min after the occurrence of thermal runaway, and there shall be no danger caused by the smoke in the passenger compartment before and within 5 min after the thermal event alarm signal is sent out.

C.2 Description of thermal event alarm signal defined by the manufacturer

C.2.1 The parameters of the thermal event that trigger a warning (e.g. temperature, rate of temperature rise, SOC, voltage drop, current, etc.) and associated threshold levels (usually clearly different from the working state specified by the manufacturer).

C.2.2 Warning signal description: Describe the sensor and battery pack or system control in case of a thermal event.

C.3 Safety description documents of battery packs or systems

C.3.1 In case of thermal runaway of a single battery, the battery cell, battery pack or system or vehicle shall be capable of achieving the functions or characteristics described in C.1. The manufacturer shall provide the safety description documents in C.3.2 ~ C.3.5.

C.3.2 Risk mitigation analysis: Use appropriate standard methods to record the risk to vehicle occupants caused by thermal runaway of a single battery and the mitigation functions or features used to reduce the risk (e.g. fault analysis in GB/T 34590, ISO 26262, GB/T 20438 and IEC 61508 or similar methods).

C.3.3 System diagrams of relevant physical systems and components. Relevant systems and components are those that contribute to achieving the functions or characteristics described in C.1.

C.3.4 Diagrams representing the functional operation of relevant systems and components, identifying all risk mitigation functions or features.

C.3.5 The manufacturer shall provide verification procedures and result documents for risk mitigation functions or features of battery pack or system safety, including the following parts:

a) A description of the operational strategy.

b) Identification of the physical system or component that implements the function.

c) Technical description of the risk mitigation function: procedures and result data for analysis or simulation verification.

d) Technical description of the risk mitigation function: verification test procedures and result data, including the following parts:

   1) Test time, place and technical parameters of the product;

   2) Test procedures: including test methods, test objects, trigger objects, monitoring point layout, thermal runaway trigger judgment conditions and lists of changes to the test object. The manufacturer can independently provide the test procedure or reference can be made to the procedure

described in C.5;

3) Test results: including photos, data and time of critical events in the test (thermal runaway triggering on/off, thermal event alarm signals, external smoke, fire, explosion, etc.).

e) If the manufacturer uses a battery pack or system as the test object in the test described in C.5, the technical description of the risk mitigation function shall include a technical specification that the smoke does not cause danger to the passenger compartment before and within 5 min after the thermal event alarm signal is sent out.

C.4 Description of verification and data provision

C.4.1 The technical service shall verify the results according to the technical description documents and test procedures provided by the manufacturer, and provide the test report.

C.4.2 The analysis and verification report of thermal propagation shall include 3 reports listed in Table C.1, of which items 1 and 2 are provided by the manufacturer and item 3 is issued by the technical service. The verification tests described in C.3.5 d) and C.4 can be the same test carried out at the same technical service.

Table C.1 Details of Thermal Propagation Analysis and Verification Report

No.	Report Name	Corresponding Sections
1	Description of thermal event alarm signal defined by the manufacturer	C.2.1, C.2.2
2	Technical documents describing the safety of battery packs or systems	C.3.2, C.3.3, C.3.4, C.3.5
3	The test report of the result verification carried out by the technical service according to the technical documents and test procedures provided by the manufacturer	C.4.1

C.5 Thermal propagation verification test procedure

C.5.1 Test object

The test object is a battery pack or system or vehicle.

C.5.2 Test conditions

The test shall be carried out under the following conditions:

a) This test is conducted in an indoor environment with a temperature above 0° C, relative humidity of 10% ~ 90%, and atmospheric pressure of 86 kPa ~ 106 kPa, or in an environment where the wind speed does not exceed 2.5 km/h. Before the test, adjust the temperature of battery pack or system to 22° C ± 5° C.

b) Before the test, adjust the SOC of the test object. For battery packs or systems designed for external charging, adjust the SOC to no less than 95% of the maximum operating state-of-charge specified by the manufacturer. For battery packs or systems designed for charging only with vehicle energy, adjust the SOC to no less than 90% of the maximum operating state-of-charge specified by the manufacturer.

c) Avoid unnecessary modifications to the test samples during testing. The manufacturer shall submit a list of changes made. Modifications to the test sample to a certain extent may result in the inability to charge, so it is necessary to confirm that the SOC of the test object meets the requirements before the start of the test.

d) Before the start of the test, confirm that the test object and the test devices are in normal conditions. For the battery pack or system level test, the control strategy for the operating state of the battery pack or system (e.g. whether the battery management system and thermal management system are operating) is consistent with that for the state within 1 h after the traction battery is powered off. For the vehicle level test, the instrument panel and central control screen of the vehicle shall display normally without alarm information before the test. A video recording device shall be arranged in the passenger compartment to ensure real-time monitoring of the internal space of the passenger compartment. The vehicle adopts the control strategy when the traction battery is powered off for less than 1 h: the parking mode is on, the doors, windows and sunroof are closed, and the air conditioner is turned off.

C.5.3 Test methods

C.5.3.1 It is recommended that methods in C.5.3.3, C.5.3.4 and C.5.3.5 to be used as optional trigger methods for thermal propagation test. The manufacturer may choose one of them or other methods to trigger thermal runaway.

C.5.3.2 Trigger object of thermal runaway: battery cell in the test object. Select a battery cell close to the center of the battery pack or surrounded by other battery cells.

C.5.3.3 The method for triggering thermal runaway by nail penetration is as follows:

a) Nail material: steel;

b) Nail diameter: 3 mm ~8 mm;

c) Nail tip shape: conical, with an angle of 20° ~ 60° ;

d) Rate of penetration: 0.1 mm/s ~ 10 mm/s;

e) Penetration position and direction: the position and direction (such as the direction perpendicular to the pole piece) which can trigger thermal runaway of the battery cell;

f) Stop conditions of penetration: the time when thermal runaway occurs, or the penetration depth reaches 90% of the size of the battery cell in the penetration direction;

g) The penetration hole position of the battery pack shall be blocked with sealing materials to inhibit exhaust gas from the penetration hole.

C.5.3.4 Method for triggering thermal runaway by external heating: Use a flat or rod-shaped heating device that shall be covered by a porcelain, metal or insulating layer on the surface. For a block heating device of the same size as a battery cell, this heating device may be used instead of one of the battery cells to come in direct contact with the surface of the trigger object. In the case of a film heating device, it shall always be attached to the surface of the trigger object. The heating area of the heating device shall not be greater than the surface area of the battery cell being heated. The heating surface of the heating device shall be in direct contact with the surface of the battery cell, and the position of the heating device shall correspond to that of the temperature sensor specified in C.5.3.6. The trigger object shall be heated, and the recommended heating power requirements are shown in Table C.2. When thermal runaway occurs or the temperature of the monitoring point defined in C.5.3.6 reaches 300° C, the triggering shall be stopped.

Table C.2 Selection of Heating Power

Electric Energy of Trigger Object, E Wh	Heating Power W
E<100	30~300

100≤E<400	300~1000
400≤E<800	300~2000
E≥800	>600

C.5.3.5 Method for triggering thermal runaway by internal heating: prepare battery cells and battery packs with internal heaters using the recommended heater devices from Table C.3, and proceed with heating.

Table C.3 Specification and Usage of Heating Device

Internal Heating Method		Parameter/Description
Specification of heating device	Material	Cu+ insulation, or other suitable resistance heating element
	Area	15mm×15mm~60mm×60mm
	Thickness	≤0.5mm
	Power	The electric energy E of the trigger object is < 500 Wh, and the power of the heating plate is 150 W~700 W; The electric energy E of the trigger object is ≥ 500 Wh, and the power of the heating plate is 200 W~700 W.
Usage	Layout	Center of jelly roll or surface of stacking
	Outlet hole/wire end seal	Resin adhesive (e.g., epoxy resin) or suitable means of structural sealing

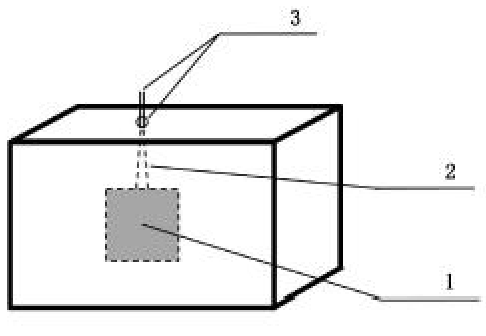
C.5.3.5.1 The preparation process of battery cell with internal heatersand its battery pack is as follows:

a) Before preparing the battery cell with internal heaters, make a hole of suitable size on the outer packaging of the battery cell so that the connecting wire of the heater can be led out from the inside of the battery cell.

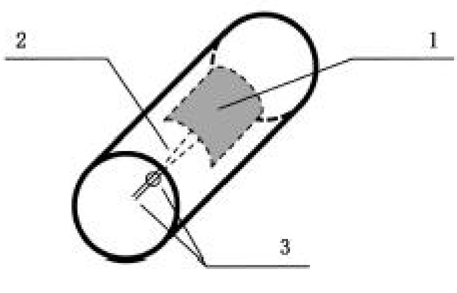
b) Place the heater in the center of jelly roll or stacking surface before the encapsulation of the battery cell.

c) After the cell is encapsulated, the outlet hole on the outer packaging of the cell and the connecting wire end of the heater shall be sealed (see Fig. C.1). After sealing, produce the battery cell according to the conventional manufacturing process.

d) Assemble the battery cell in the battery pack according to the conventional manufacturing process. Lead out the connecting wire of the heater from the battery pack, and seal the lead-out position.



a) Prismatic and pouch cells



b) Cylindrical battery

Key:

1- Heater;

2- Connecting wire;

3- Sealing position.

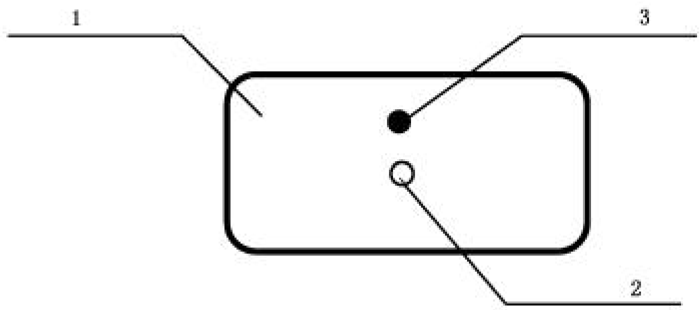
Fig. C.1 Layout of Heating Device and Lead-out of Its Connecting Wire

C.5.3.5.2 Test process: Heat the trigger object and stop triggering when thermal runaway occurs or the temperature at the monitoring point defined in C.5.3.6 reaches 300° C.

C.5.3.6 The layout of the monitoring point is as follows:

a) The original circuit or an additional test circuit shall be used to monitor voltage or temperature. The sampling interval for temperature data shall be less than 1 s.

b) During the triggering by penetration, the temperature sensor shall be located close to the short-circuit point, and the temperature of the nail may also be used (see Fig. C.2).



Key:

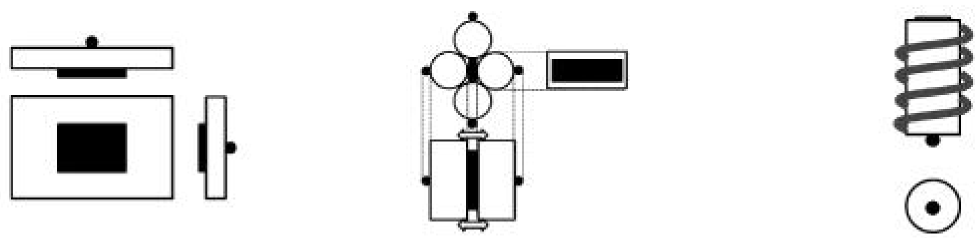
1- Trigger object;

2- Penetration position;

3- Temperature sensor.

Fig. C.2 Layout of Temperature Sensors in Case of Triggering by Penetration

c) The temperature sensor shall be located on the side far from heat conduction during the triggering by heating, i.e., the opposite side of the heating device (as shown in Fig. C.3 and Fig. C.4).



a) Prismatic battery and pouch battery   b) Cylindrical battery - I   c) Cylindrical battery - II

Symbol description:

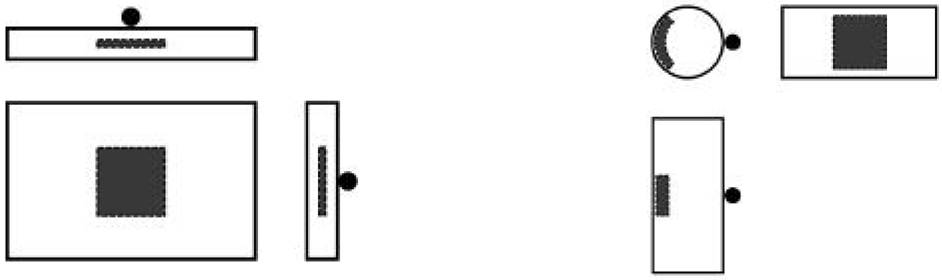
 Battery cell

 Heating device

 Heating device

Temperature sensor

Fig. C.3 Layout of Temperature Sensors in Case of Triggering by External Heating



a) Prismatic and pouch cells b) Cylindrical battery

Symbol description:

Battery cell

Heating device

Temperature sensor

Fig. C.4 Layout of Temperature Sensors in Case of Triggering by Internal Heating

C.5.3.7 Determination criteria for triggering thermal runaway:

a) The trigger object is subjected to voltage drop by more than 25% from the initial voltage;

b) The temperature at the monitoring point reaches the maximum operating temperature specified by the manufacturer;

c) The temperature rise rate dT/dt at the monitoring point is ≥ 1℃/s for more than 3 s.

When conditions a) and c) or b) and c) occur simultaneously, it is determined that thermal runaway has taken place. If the thermal runaway triggering method adopted does not trigger the thermal runaway of the battery cell, in order to ensure the safety of occupants and property, it is necessary to prove that thermal runaway will not occur by adopting any of the recommended methods above.

C.5.3.8 After the thermal runaway of battery cell is triggered, observe at the test ambient temperature until the temperatures of all monitoring points are not higher than 60° C and the observation duration shall be at least 2 h. Then, end the test.

Bibliography

[1] GB/T 4780—2020 *Terms for Motor Vehicle Body*

[2] GB/T 20438 (all parts) *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems*

[3] GB/T 34590 (all parts) *Road Vehicles—Functional Safety*

[4] ISO 26262 (all parts) *Road vehicles—Functional safety*

[5] IEC 61508 (all parts) *Functional safety of electrical/electronic/programmable electronic safety-related systems*