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Electric Vehicles Traction Battery Safety requirements

电动汽车用动力蓄电池安全要求

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Electric Vehicles Traction Battery Safety Requirements

1 Scope

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

This Standard is applicable to rechargeable energy storage devices for electric vehicles, such as: li-ion battery and nickel-metal hydride battery.

2 Normative References

The following documents are indispensable to the application of this document. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

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 *Environmental Testing for Electric and Electronic Products - Part 2: Test Method - 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, Broadband 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

What is defined in GB/T 19596, and the following terms and definitions are applicable to this document.

NOTE: rated capacity is generally expressed in (Ah) or (mAh).

3.8 Practical Capacity

Practical capacity refers to the capacity value released from fully charged secondary cell, module, battery pack or system under the conditions specified by the manufacturer.

3.9 State-of-charge

State-of-charge refers to the percentage of capacity in the current secondary cell, module, battery pack or system that can be released in accordance with the discharge conditions specified by the manufacturer to the practical capacity.

3.10 Explosion

Explosion refers to a sudden release of sufficient energy, which generates pressure waves or sprays, and might cause structural or physical damage to the surrounding area.

3.11 Fire

Fire refers to continuous combustion of secondary cell, module, battery pack or any part of the system (the duration of single flame is greater than 1 s). Sparks and electric arcs do not belong to combustion.

3.12 Housing Crack

Housing crack refers to mechanical damage to secondary cell, module, battery pack or system housing due to internal and external factors, which can result in exposure or spillage of internal substances.

3.13 Leakage

Leakage refers to the phenomenon that visible substances leak from secondary cell, module, battery pack or system to the outside of the test object.

3.14 Thermal Runaway

Thermal runaway refers to the phenomenon of uncontrollable rise in battery temperature caused by exothermic chain reaction of secondary cell.

3.15 Thermal Propagation

Thermal propagation refers to the phenomenon of successive thermal runaway of the remaining secondary cells caused by thermal runaway of one secondary cell in the battery pack or system.

3.16 End-of-charge Voltage

5.1.5 In accordance with 8.1.6, conduct temperature cycle test on secondary cell: there shall be no fire or explosion.

5.1.6 In accordance with 8.1.7, conduct extrusion test on secondary cell: there shall be no fire or explosion.

5.2 Safety Requirements of Battery Pack or System

5.2.1 In accordance with 8.2.1, conduct vibration test on battery pack or system: there shall be no phenomenon of leakage, housing crack, fire or explosion. In addition, abnormal termination conditions shall not be triggered. After the test, the insulation resistance shall be not less than 100 Ω/V.

5.2.2 In accordance with 8.2.2, conduct mechanical impact test on battery pack or system: there shall be no phenomenon of leakage, housing crack, fire or explosion. After the test, the insulation resistance shall be not less than 100 Ω/V.

5.2.3 In accordance with 8.2.3, conduct simulated collision test on battery pack or system: there shall be no phenomenon of leakage, housing crack, fire or explosion. After the test, the insulation resistance shall be not less than 100 Ω/V.

5.2.4 In accordance with 8.2.4, conduct extrusion test on battery pack or system: there shall be no fire or explosion.

5.2.5 In accordance with 8.2.5, conduct damp heat cycle test on battery pack or system: there shall be no phenomenon of leakage, housing crack, fire or explosion. Within 30 min after the test, the insulation resistance shall be not less than 100 Ω/V.

5.2.6 In accordance with 8.2.6, conduct water immersion test on battery pack or system: one of the following requirements shall be satisfies:

a) Comply with Mode 1: there shall be no fire or explosion;

b) Comply with Mode 2: after the test, IPX7 requirements must be satisfied: there shall be no phenomenon of leakage, housing crack, fire or explosion. After the test, the insulation resistance shall be not less than 100 Ω/V.

5.2.7 In accordance with 8.2.7, conduct thermal stability test on battery pack or system, excluding nickel-metal hydride battery or the system. It includes:

a) In accordance with 8.2.7.1, conduct external combustion test: there shall be no explosion;

b) In accordance with 8.2.7.2, conduct thermal propagation occupant protection analysis and verification. 5 min before a danger is caused in the passenger compartment due to thermal propagation, as a result of thermal runaway of a single battery, the battery pack or system shall provide a thermal event independently, battery module may be adopted for testing, and the safety requirements shall still comply with 5.1.

6.1.3 In terms of battery pack or system covered by car body and forms a battery pack box, it may be tested along with the box or the car body.

6.1.4 Battery pack or system test delivery needs to include necessary operating documents, as well as interface components required to connect with the test equipment, such as: connectors and plugs, including cooling system interfaces. The typical structure of battery pack or system is shown in Appendix A. The manufacturer needs to provide safe operating limits for the battery pack or system.

6.1.5 Before all the tests, and after some tests, battery pack or system need to be tested for insulation resistance. The test position is: between the two terminals and the electric platform. It is required that the measured insulation resistance value divided by the maximum working voltage of the battery pack or system is not less than 100 Ω/V. The specific test methods are shown in Appendix B.

6.1.6 If due to some reasons (for example: size or mass), battery pack or system is not suitable for some tests, then, after reaching a consensus through negotiation, the manufacturer and testing institution may use the subsystem of the battery pack or system as the test object for all or some of the tests. However, the subsystem, which serves as the test object, shall contain all the parts (for example: connecting parts or protective parts, etc.) related to the requirements of the vehicle.

6.1.7 The method of adjusting SOC to *n*% of test target value: in accordance with the charging mode provided by the manufacturer, fully charge the battery pack or system; place it still for 1 h. Then, with 1 I_3, at a constant current, discharge it for a duration of *T*. *T* is obtained through the calculation in accordance with Formula (1). Or, adopt the method provided by the manufacturer to adjust SOC. After each SOC adjustment, before a new test starts, the test object shall be placed still for 30 min.

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

Where,

T---discharging time, expressed in (h);

n---percentage value of test target value.

6.1.8 The charging and discharging rate, method and cut-off conditions during the test are provided by the manufacturer.

6.1.9 The rated capacity of secondary cell, battery pack or system shall comply with the product technical conditions provided by the manufacturer.

Firstly, at the current specified by the manufacturer and not less than 1 I_3, discharge secondary cell to the discharge cut-off voltage specified by the manufacturer in the technical conditions. Place it still for 1 h (or, the shelving time provided by the manufacturer and not more than 1 h). Then, in accordance with the charging method provided by the manufacturer, charge the secondary cell. After charging, place it still for 1 h (or, the shelving time provided by the manufacturer and not more than 1 h).

If the manufacturer does not provide charging method, then, the testing institution and the manufacturer shall negotiate and determine an appropriate charging method, or charge in accordance with the following methods:

At a constant current specified by the manufacturer and not less than 1 I_3, charge the secondary cell, till it reaches the charge cut-off voltage specified by the manufacturer in the technical conditions, then, transfer to constant-voltage charging, till the charging current drops to 0.05 I_1, then, stop charging. After charging, place it still for 1 h (or, the shelving time provided by the manufacturer and not more than 1 h).

7.1.2 Pre-treatment

7.1.2.1 Before the official test starts, secondary cell needs to undergo a pre-treatment cycle first, so as to ensure that the performance of the test object is activated and stable. Proceed as follows:

a) In accordance with 7.1.1, conduct standard charging on the secondary cell;

b) At a current specified by the manufacturer and not less than 1 I_3, discharge to the discharge cut-off conditions specified by the manufacturer;

c) Place it still for 30 min, or the time specified by the manufacturer;

d) Repeat a) ~ c) for not more than 5 times.

7.1.2.2 If discharging capacity change of the secondary cell in consecutive two times is not higher than 3% of the rated capacity, then, it is believed that the secondary cell has completed the pre-treatment, and the pre-treatment cycle can be terminated.

7.2 Test Preparation of Battery Pack or System

7.2.1 Confirmation of working status

Before the official test starts, the electronic components or BCU of the battery pack or system shall be in normal working status.

7.2.2 Pre-treatment

7.2.2.1 Before the official test starts, battery pack or system needs to undergo a pre-treatment cycle first, so as to ensure that the performance of the test object is activated and stable. Proceed as follows:

8.1.3 Over-charge

8.1.3.1 Test object is secondary cell.

8.1.3.2 In accordance with 7.1.1, charge the test object.

8.1.3.3 With a constant current specified by the manufacturer and not less than 1 I_3, charge to 1.1 times of the charge cut-off voltage specified by the manufacturer or 115% SOC, then, stop charging.

8.1.3.4 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.1.4 External short-circuit

8.1.4.1 Test object is secondary cell.

8.1.4.2 In accordance with 7.1.1, charge the test object.

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

8.1.4.4 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.1.5 Heating

8.1.5.1 Test object is secondary cell.

8.1.5.2 In accordance with 7.1.1, charge the test object.

8.1.5.3 Place the test object into a temperature box; use the following conditions for heating:

a) Li-ion secondary cell: at the rate of 5 °C/min, raise the temperature box from the ambient temperature of test to 130 °C ± 2 °C; maintain this temperature for 30 min, then, stop heating;

b) Nickel-metal hydride battery: at the rate of 5 °C/min, raise the temperature box from the ambient temperature of test to 85 °C ± 2 °C; maintain this temperature for 2 h, then, stop heating.

8.1.5.4 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.1.6 Temperature cycle

8.1.6.1 Test object is secondary cell.

8.1.7.3 In accordance with the following conditions, conduct the test:

a) Extrusion direction: apply pressure perpendicular to the direction of the secondary cell plate, or, in the same direction where the secondary cell is most easily extruded in the vehicle layout;

b) Form of extrusion plate: a half-cylinder with a radius of 75 mm; the length (*L*) of the half-cylinder is larger than the size of the extruded secondary cell (as it is shown in Figure 6);

c) Extrusion rate: not more than 2 mm/s;

d) Extrusion degree: when the voltage reaches 0 V, or the deformation reaches 15%, or the extrusion force reaches 100 kN or 1,000 times of the weight of the test object, stop the extrusion;

e) Maintain for 10 min.

8.1.7.4 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.2 Safety Test Method for Battery Pack or System

8.2.1 Vibration

8.2.1.1 Test object is battery pack or system.

8.2.1.2 In order to protect the safety of test operators and laboratories, the manufacturer shall provide voltage sharpness limits as abnormal termination conditions.

8.2.1.3 Before the test starts, adjust the SOC of the test object to not lower than 50% of the normal SOC working range specified by the manufacturer.

8.2.1.4 In accordance with the installation location of the test object and the requirements of GB/T 2423.43, install the test object on the vibration table. Respectively apply random and constant-frequency vibration loads in each direction. The sequence of loading should be: *z*-axis random, *z*-axis constant-frequency, *y*-axis random, *y*-axis constant-frequency, *x*-axis random, *x*-axis constant-frequency (the driving direction is *x*-axis direction, and the other horizontal direction perpendicular to the driving direction is *y*-axis direction). The testing institution may also, on its own, choose the sequence, so as to shorten the conversion time. The test process shall comply with GB/T 2423.56.

8.2.1.5 In terms of battery packs or systems mounted on vehicles other than Type-M_1 and Type-N_1, vibration test parameters shall comply with Table 2 and Figure 2. When the test object has multiple installation directions (*x*/*y*/*z*), conduct the test in accordance

X---time, h; c---recommended temperature and humidity value;

f---one cycle.

Figure 8 (continued from previous page)

8.2.6 Water immersion

8.2.6.1 Test object is battery pack or system that passes the vibration test in 8.2.1.

8.2.6.2 In accordance with the finished vehicle connection mode, properly connect components (such as: wiring harness and connectors, etc.) of the test object. Select one of the following modes for testing:

a) Mode 1: in the actual vehicle assembly direction, place the test object in 3.5% (mass fraction) sodium chloride solution for 2 h; the water depth shall be sufficient to submerge the test object;

b) Mode 2: in accordance with the method and the flow described in 14.2.7 in GB/T 4208-2017 to test the test object. In accordance with the installation state specified by the manufacturer, completely immerse the test object in water. In terms of test object whose height is less than 850 mm, the lowest power shall be 1,000 mm below the water surface. In terms of test object whose height equals to, or is more than 850 mm, the highest point shall be 150 mm below the water surface. The test duration is 30 min. The temperature difference between the water temperature and the test object is not more than 5 °C.

8.2.6.3 Take the battery pack out of the water. At the ambient temperature of test, place it still and observe for 2 h.

8.2.7 Thermal stability

8.2.7.1 External combustion

8.2.7.1.1 Test object is battery pack or system. The body structure that protects the battery pack or system can participate in the combustion test.

8.2.7.1.2 The ambient temperature of test is above 0 °C. The wind speed is not more than 2.5 km/h.

8.2.7.1.3 During the test, the size of the flat plate containing gasoline exceeds the horizontal protection size of the test object by 20 cm, and does not exceed 50 cm. The height of the flat plate is not higher than 8 cm above the gasoline surface. The test object shall be placed in the center. The distance between the gasoline liquid level and the bottom of the test object is set to 50 cm, or, the ground clearance of the bottom surface of the test object when the vehicle is under the no-load state. Fill the bottom of the flat plate with water. The schematic diagram of the external combustion is shown

8.2.10.3 Test environment: the air pressure condition is 61.2 kPa (air pressure condition when the simulated altitude is 4,000 m); the temperature is the ambient temperature of test.

8.2.10.4 Maintain the test environment in 8.2.10.3. Place it still for 5 h.

8.2.10.5 After the resting time is completed, maintain the test environment in 8.2.10.3. With a current specified by the manufacturer and not less than 1 I_3, discharge the test object to the discharge cut-off conditions specified by the manufacturer.

8.2.10.6 After completing the above test procedures, at the ambient temperature of test, observe for 2 h.

8.2.11 Over-temperature protection

8.2.11.1 Test object is battery system.

8.2.11.2 In order to protect the safety of test operators and laboratories, the manufacturer shall provide upper limit parameters as abnormal termination conditions.

8.2.11.3 When the test starts, all protection equipment that affects the functions of the test object and is related to the test result shall be in normal operation, except for the cooling system.

8.2.11.4 The test object shall be continuously charged and discharged by external charging and discharging equipment, so that the current can rise as quickly as possible within the normal operating range specified by the battery system manufacturer, till the end of the test.

8.2.11.5 The temperature of the room or the temperature box shall gradually rise from 20 °C ± 10 °C, or a higher temperature (if it is requested by the battery system manufacturer), till it reaches a temperature determined in accordance with a) or b) (if applicable). Then, maintain at this temperature, or higher than this temperature, till the end of the test:

a) When the battery system has internal over-temperature protection measures, it shall be raised to the temperature defined by the battery system manufacturer as the operating temperature threshold for such protection measures, so as to ensure that the temperature of the test object will rise in accordance with the stipulations of 8.2.11.4.

b) If the battery system is not equipped with any specific internal over-temperature protection measures, then, raise the temperature to the maximum operating temperature specified by the battery system manufacturer.

8.2.11.6 When any of the following conditions are met, end the test:

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

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

8.2.12.6 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.2.13 External short-circuit protection

8.2.13.1 Test object is battery system.

8.2.13.2 Test conditions are as follows:

a) The test shall be conducted under the ambient temperature of 20 °C ± 10 °C, or a higher temperature (if it is requested by the battery system manufacturer);

b) When the test starts, all protection equipment that affects the functions of the test object and is related to the test result shall be in normal operation.

8.2.13.3 The external short-circuit process is as follows:

a) When the test starts, relevant main contactors used for charging and discharging shall be closed (if relevant relays are included in the battery system loop), so as to indicate the feasible driving mode and the mode that allows external charging. If this cannot be completed in a single test, then, conduct two or more tests.

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

8.2.13.4 Maintain the short-circuit state, till any of the following conditions are met, then, end the test:

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

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

8.2.13.5 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

8.2.14 Over-charging protection

8.2.14.1 Test object is battery system.

8.2.14.2 In order to protect the safety of test operators and laboratories, the

8.2.15.1 Test object is battery system.

8.2.15.2 Test conditions are as follows:

a) The test shall be conducted under the ambient temperature of 20 °C ± 10 °C, or a higher temperature (if it is requested by the battery system manufacturer).

b) In accordance with the normal operation (if external charging and discharging equipment is used) recommended by the battery system manufacturer, adjust the SOC of the test object to a lower level, but still within the normal operating range. As long as the test object can normally operate, no precise adjustment is required.

c) When the test starts, all protection equipment that affects the functions of the test object and is related to the test result shall be in normal operation. All relevant main contactors used for discharging shall be closed (if relevant relays are included in the battery system loop).

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) Negotiate with the battery system manufacturer to discharge at a stable current within the specified normal operating range.

8.2.15.4 Discharging shall continuously proceed, till any of the following conditions are met, then, end the test:

a) The test object automatically terminates the discharging current;

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

c) When the test object's automatic cut-off function does not work, or, if there is no function described in 8.2.15.4 a), then, continue the discharging, till the test object is discharged to 25% of its rated voltage;

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

8.2.15.5 After completing the above test procedures, at the ambient temperature of test, observe for 1 h.

9 Implementation Date

Models with newly applied type approval shall implement this Standard since the implementation date of this Standard. Models which have obtained type approval shall

Appendix B

(Normative)

Insulation Resistance Test Method of Battery Pack or System

B.1 Objective

To clarify the test method for insulation resistance of battery pack or system.

B.2 Test Conditions

Battery pack or system shall all be tested in a fully charged state specified by the manufacturer. The ambient temperature of the test is 22 °C ± 5 °C; the humidity is 15% ~ 90%.

The internal resistance of the voltage detection instrument is not less than 10 MΩ. During the measurement, if the insulation monitoring function will affect the insulation resistance test of the battery pack or system, then, the insulation monitoring function shall be turned off, or, the insulation resistance monitoring unit shall be disconnected from Level-B voltage circuit, so as to avoid affecting the measured value. Otherwise, the manufacturer may choose whether to turn off the insulation monitoring function or disconnect the insulation monitoring unit from Level-B voltage circuit.

B.3 Insulation Resistance Test Method

B.3.1 Method 1

B.3.1.1 Activate the power and electronic switches in the battery pack or system, so as to ensure that the battery system is in on-state.

B.3.1.2 Use the same two voltage detection instruments to simultaneously measure the voltage between the two terminals and the electric platform of the battery pack or system, as it is shown in Figure B.1. Wait till the reading is stable; the higher one is U_1, the lower one is U_1'.

> **NOTE:** the electric platform of the battery pack or system may be a conductive housing connected to the electric platform of a finished vehicle.

Appendix C

(Normative)

Thermal Propagation Occupant Protection Analysis and Verification Report

C.1 Objective

5 min before a danger is caused in the passenger compartment due to thermal propagation, as a result of thermal runaway of a single battery, the battery pack or system shall provide a thermal event warning signal (serving the whole vehicle's thermal event alarm, which reminds the occupant to evacuate). If thermal propagation will not lead to situations that endanger the occupant, then, it is considered that this requirement has been met.

C.2 Description of Thermal Event Warning Signal Defined by the Manufacturer

C.2.1 Thermal event parameters (such as: temperature, temperature rise rate, SOC, voltage drop and current, etc.) that trigger warning and related threshold levels (generally, significantly different from the operating state specified by the manufacturer).

C.2.2 Description of warning signal: instructions that describe the sensor, and battery or system control when a thermal event occurs.

C.3 Technical Documents Describing Battery Pack or System Safety

C.3.1 In the case of thermal propagation caused by thermal runaway of a single battery, the secondary cell, battery pack or system, or the vehicle shall have the function or characteristic of protecting the occupant. The manufacturer shall provide documents on the safety of battery pack or system described in C.3.2 ~ C.3.5.

C.3.2 Risk reduction analysis: use appropriate industry standard methods to record the risks to the vehicle occupant caused by thermal propagation, as a result of thermal runaway of a single battery, as well as the mitigation functions or features adopted to reduce the risks (for example: fault analysis methods in GB/T 34590, ISO 26262, GB/T 20438, IEC 61508, or similar methods).

C.3.3 System diagram of related physical systems and components. Related systems and components refer to systems and components that are conductive to the protection of occupants from the harmful effects caused by thermal propagation, as a result of thermal runaway of a single battery.