CHINA ELECTRIC VEHICLE FIRE SAFETY INDEX

ASSESSMENT PRTOCOL

Version 2023 R1

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CHINA ELECTRIC VEHICLE FIRE SAFETY INDEX（C-EVFI）

ASSESSMENT PROTOCOL

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PREFACE

Adhering to the development of electric vehicles is the fundamental strategic thought of China's automobile industry. After years of development, China's electric vehicle industry has reached a global leading level in terms of scale, production and sales volume, and technology, establishing a complete R&D system for electric vehicles and their components. However, in recent years, the frequent occurrence of electric vehicle fires has drew high social attention. These accidents involve various types of electric vehicles (pure electric vehicles, plug-in hybrid electric vehicles, and range-extended electric vehicles), and the fires are characterized by their suddenness, harmfulness, and the difficulty of extinguishment. This has become the third major challenge hindering the sustainable and healthy development of the electric vehicle industry, following range anxiety and charging anxiety. Statistics on electric vehicle fire accidents over the years show that battery system faults, high voltage system faults, and electronic and electrical component faults are the three main vehicle-related factors in electric vehicle fires. Therefore, research on the fire safety of electric vehicles is urgently needed to ensure their higher quality, safer, and more stable development.

To address this, China Merchants Testing Vehicle Technology Research Institute Co., Ltd. (hereinafter referred to as CMVR) took the lead in developing the China Electric Vehicle Fire Safety Index (C-EVFI). This index starts from the perspective of the safety protection of drivers and passengers, providing an independent, objective, and fair assessment of the overall safety performance of vehicles in the event of a fire. It offers a standard for intuitive and quantitative assessment, serving as a reference for vehicle research and development, and consumer purchasing and usage. This initiative continuously promotes the technological advancement of electric vehicles in China and fosters the high-quality development of the electric vehicle industry

The C-EVFI 2023 R1 version evaluates the safety of electric vehicles following a battery thermal runaway incident from four dimensions: safety warnings, emergency rescue, fire protection, and data monitoring. It encompasses 11 secondary indicators and 25 assessment criteria, establishing the testing and assessment methods for the overall fire safety of electric vehicles.

1. APPLICATION SCOPE

This protocol specifies the test and assessment methods for the fire safety of electric vehicles triggered by battery thermal runaway.

This protocol applies to M_1 category electric vehicles, including pure electric vehicles and hybrid electric vehicles.

This protocol does not apply to fuel cell electric vehicles.

2. NORMATIVE REFERENCES

The content of the following documents is constituted by the normative references cited within the text. For the referenced documents with specified dates, only the version corresponding to those dates applies to this document. For the referenced documents without specified dates, the latest version (including all amendments) shall apply to this document.

GB/T 4780 Automobile Body Terms

GB/T 15089 Classification of Power-driven Vehicles and Trailers

GB/T 19596 Terminology for Electric Vehicles

GB 38031 Safety Requirements for Traction Battery of Electric Vehicle

3. TERMS AND DEFINITIONS

The terms and definitions defined in GB/T 4780, GB/T 15089, GB/T 19596, GB

38031, and the following terms and definitions shall apply to this document.

3.1 State of Charge

The percentage of capacity that can be released under the discharge conditions specified by the manufacturer in the current battery cell, module, pack, or system relative to the actual capacity.

3.2 Thermal Runaway

The phenomenon where a thermal runaway reaction in a single battery cell causes an uncontrollable rise in battery temperature.

3.3 Thermal Propagation

The phenomenon where thermal runaway in one battery cell within a battery pack or system causes the remaining cells to successively undergo thermal runaway.

3.4 Vehicle Door Emergency Switch

When a stationary vehicle experiences battery thermal runaway, if the door can be opened by pulling the door switch, then it is considered that the door switch has emergency switch function. The car door emergency switch can be independent or integrated.

3.5 Hazardous Condition

A state that threatens the safety of passengers and the vehicle itself can be determined as a hazardous condition when one or more of the following situations occur:

a)The battery pack explodes;

b) Flames appear outside the vehicle;

c) Flames appear inside the vehicle;

d) The smoke concentration within the passenger compartment is ≥1000 ppm;

e) The concentration of carbon monoxide within the passenger compartment is ≥600 ppm;

f) The oxygen content within the passenger compartment is ≤19.5%;

g) The temperature at any temperature monitoring point inside the vehicle exceeds 60 ℃.

3.6 High Temperature Warning

When the battery overheats, the alarm information issued inside the passenger compartment is usually presented in the form of audio signals, visual signals, or a combination of both.

3.7 Thermal Runaway Warning

When the battery experiences thermal runaway, the alarm information issued inside the passenger compartment is typically presented in the form of audible and visual signals along with textual messages.

3.8 Thermal Runaway External Warning

When the battery experiences thermal runaway, the warning information issued on the exterior of the vehicle is typically presented in the form of one or more combinations such as activating the hazard warning flashers, turning on the headlights, and sounding the horn.

3.9 Available Safety Egress Time

The time, from when the driver and passengers receive the thermal runaway alarm signal to when the vehicle enters a dangerous state, is represented by t_1.

3.10 Emergency Response Time

The time, from when the battery experiences thermal runaway to when the regulatory platform proactively contacts the vehicle or the owner via SMS, phone , or app, is represented by t_2.

4. TEST METHOD

4.1 Condition of Test

4.1.1 Site and Environment

a) The test should be conducted in a professional fire testing laboratory, with the internal dimensions of the laboratory being no less than 20 m×20 m× 20 m;

b) The test laboratory should be equipped with a fresh air system;

c) The test laboratory should be equipped with a smoke treatment system, with an exhaust volume of ≥230000 m^3/h;

d) The test laboratory should have the capability to collect wastewater;

e) The test laboratory should be equipped with comprehensive fire-fighting facilities;

f) During the test process, there should be established safety distances and isolation measures between personnel and the test vehicles;

g) The initial environmental temperature of the test should be >0 ℃, with a relative humidity of 10% to 90%, an atmospheric pressure of 86 kPa to 106 kPa, and a wind speed of ≤2.5 km/h.

4.1.2 Equipment and Facilities

4.1.2.1 Precision of Instruments and Gauges

The accuracy of the measuring instruments and gauges should not be less than the following requirements:

Voltage measuring devices: ±5% FS;

b) Temperature measuring devices: ±0.5°C;

c) Time measuring devices: ±0.1% FS;

d) Gas concentration measuring devices: ±5% FS.

4.1.2.2 Measurement Process Error

The required error between the control value (actual value) and the target value is as follows:

a) Voltage: ±1%;

b) Temperature: ±2°C;

c) Gas concentration: ±2% RH.

4.1.2.3 Data Logging and Recording Interval

Unless otherwise specified, the recording interval for test data during the test process shall be ≤1 s.

4.1.3 Test Vehicle

a) The state of charge (SOC) of the traction battery shall not be less than 95% of the normal SOC working range specified by the manufacturer.

b) For hybrid vehicles, the fuel tank should be emptied.

c) The auxiliary battery should be fully charged.

d) The vehicle should be in the start mode, with the gear selector in the 'P' position.

e) The vehicle communication should be normal, the system should function properly, and there should be no fault alarms.

f) During the test, all doors, windows, and sunroof should be closed and locked (child locks should be in the unlocked position).

g) The vehicle's lighting, signaling devices, and other auxiliary equipment should be turned off; the air conditioning system should be set to the internal circulation mode and turned off.

h) The vehicle seats should be positioned centrally - front and rear, the backrest centrally aligned, the headrest height adjusted to the middle, and the steering wheel centered.

i) Tire pressure should be adjusted to the values specified by the manufacturer.

j) Components not mentioned above should be maintained in factory condition.

k) Except for items needed for testing, no non-vehicle items should be placed inside the vehicle.

4.2 Fire Triggering Methods

For details on the triggering methods, refer to Appendix A.

4.3 Test Preparation

4.3.1 Vehicle Preparation

Adjust the vehicle status according to 4.1.3.

4.3.2 Test System Preparation

4.3.2.1 Battery Thermal Runaway Triggering Device

Set up the battery thermal runaway triggering device according to Appendix A.

4.3.2.2 Data Acquisition System

Arrange sensors according to Figure 1 and Table 1, with monitoring points defined as follows:

a) A_1, A_2, and A_3 represent the front of the headrest, the very front of the backrest, and the direct center of the seat surface, respectively;

b) Point B is located on the floor above the battery pack, in front of the seat;

c) Point C is at the very center of the steering wheel;

d) Point D is directly above the dashboard;

e) Point E is in the direct center of the vehicle's ceiling.

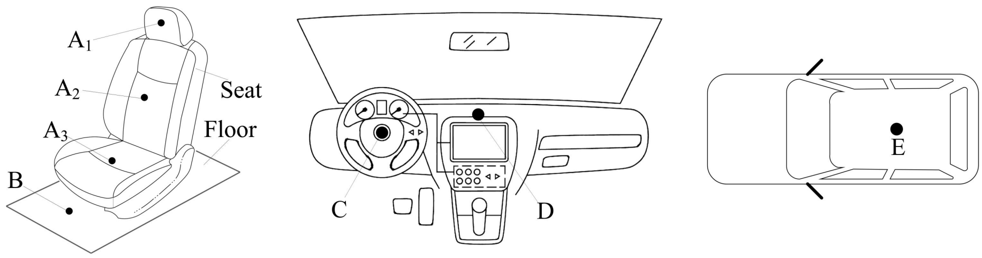

Figure 1. Monitoring Point Schematic

Table 1 Types of Sensors and Layout Requirements

Number	Monitoring Data Types	Layout Position	Quantity
1	Temperature	Monitoring points A_1, A_2, A_3, and B for all seats	Each 1
		Monitoring points C, D, E inside the passenger cabin	3
		Inside the battery pack, see Figure A.1	9
2	Carbon Monoxide Concentration	Monitoring point A_1 for all seats	Each 1
3	Oxygen Concentration Sensor	Monitoring point A_1 for all seats	Each 1
4	Smoke Concentration	Monitoring point A_1 for all seats	Each 1

	sensor		
5	Interior Video	Inside the vehicle, positions from where the dashboard, floor, seats, and doors can be observed, and outside the vehicle, positions from where the battery pack and overall condition of the vehicle's body can be observed	Determine as required
6	Exterior Video	Around the vehicle body, positions from where various angles of the body and the vehicle’s surrounding environment can be observed	4
7	Undercarriage Video	Underneath the vehicle, a perspective from below, positions from where the condition of the vehicle's underside can be observed	2
8	High Voltage Busbar Voltage	Refer to Appendix B	3

4.3.2.3 Vehicle Immersion

Immerse the vehicle for 12 hours in a 25 °C ± 5 °C environment before the test.

4.3.3 Emergency Door Switch Function Verification Test

4.3.3.1 Test personnel A sits inside the vehicle, closes the door, and locks it manually.

4.3.3.2 Turn off the vehicle power.

4.3.3.3 Test personnel B disconnects the positive and negative terminals of the auxiliary battery from the vehicle.

4.3.3.4 For vehicles equipped with independent mechanical emergency door switches, the inside test personnel sequentially pull all independent mechanical emergency door switches; for vehicles not equipped with independent mechanical emergency door switches, the inside test personnel sequentially pull all regular door switches at least twice.

4.3.3.5 Check whether the doors can be opened normally.

4.3.4 Whole Vehicle Thermal Propagation Test

4.3.4.1 Confirm the test site, environmental conditions, and the status of the test vehicle. Check the test vehicle parameters and configuration according to Appendix C, confirming the test conditions and vehicle status.

4.3.4.2 Start the test equipment according to the following requirements:

a) Turn on all lighting equipment and close the test chamber entrance and exit;

b) Start the test chamber smoke processing system and fresh air system;

c) Turn on the data acquisition system, ensuring all data collection and recording are normal and time-synchronized.

4.3.4.3 Trigger battery thermal runaway using the method outlined in Appendix A.

4.3.4.4 Observe the test data in real-time and determine the moment the vehicle enters a hazardous state.

4.3.4.5 If a hazardous state is emerged within 30 minutes after thermal runaway, verify the door switch function within 10 seconds of entering the hazardous state; if no hazardous state is entered within 30 minutes after thermal runaway, verify the door switch function 30 minutes after the occurrence of thermal runaway. Refer to Appendix D for the door switch function verification method.

4.3.4.6 If a flame appears after thermal runaway, undertake firefighting measures after continuous burning for 5 minutes until the flame is completely extinguished; if no flame appears after thermal runaway, take appropriate measures to prevent a hazardous situation.

4.3.4.7 Situate in the test environment and observe for at least 120 minutes, continuously observe and record the vehicle status and any re-ignition conditions.

4.3.4.8 After the vehicle temperature returns to room temperature, confirm the vehicle state, dismantle and analyze the vehicle and battery pack, and check the post-test vehicle state and inside of the test chamber according to Table E.1.

4.3.4.9 The test ends.

5. ASSESSMENT METHOD

5.1 Assessment Items and Indicators

Conduct experiments according to Chapter 4 of this document and score vehicle safety based on Table 2.

Table 2. Assessment Items and Indicators

<table>
<tr><th>Number</th><th>Primary Indicator</th><th>Secondary Indicator</th><th>assessment content</th><th>Score</th><th>Perfect Score</th><th>Weight</th></tr>
<tr><td rowspan="7">1</td><td rowspan="7">Safety warnings</td><td rowspan="2">Battery Pack High-temperature Warning</td><td>Optical warning available</td><td>5</td><td rowspan="2">10</td><td rowspan="7">20%</td></tr>
<tr><td>Auditory warning available</td><td>5</td></tr>
<tr><td rowspan="3">Thermal Runaway Alarm inside the Vehicle</td><td>Text alert available</td><td>20</td><td rowspan="3">55</td></tr>
<tr><td>Sound alarm available</td><td>20</td></tr>
<tr><td>Optical alarm available</td><td>15</td></tr>
<tr><td rowspan="2">Thermal Runaway Warning outside the Vehicle</td><td>Auditory warning signal available</td><td>20</td><td rowspan="2">35</td></tr>
<tr><td>Light warning signal available</td><td>15</td></tr>
<tr><td>2</td><td>Emergency rescue</td><td>Safe Evacuation</td><td>Can be normally opened from inside the vehicle after</td><td>30</td><td>70</td><td>30%</td></tr>
</table>

			thermal runaway			
			Can be normally opened from outside the vehicle after thermal runaway	20		
			The driver's door is equipped with an emergency switch feature	10		
			The passenger's door is equipped with an emergency switch feature	5		
			The rear passenger door is equipped with an emergency switch feature	5		
		Electric Shock Prevention Safety	≤30 V AC or 60 V DC	30	30	
3	**Fire protection**	Available Safety Egress Time t_1	$t_1 \geq 30$ min	20	20	40%
			20 min $\leqslant t_1 <$ 30 min	15		
			10 min $\leqslant t_1 <$ 20 min	10		
			5 min $\leqslant t_1 <$ 10 min	5		
			$0 \leq t_1 <$ 5 min	0		
		Thermal Propagation Protection	No thermal propagation	15	15	
			Number of thermal propagation cells n=1	10		
			Number of thermal propagation cells n =2	5		
			Number of thermal propagation cells n> 2	0		
		Fire Safety	No explosion in the battery pack	15	65	
			No flames outside of the vehicle	15		
			No flames inside of the vehicle	15		
			Interior monitoring point temperature < 60 °C	10		
			Within time t_1, smoke concentration < 1000 ppm and CO concentration < 600 ppm and oxygen concentration > 19.5%	10		
4	**Data linkage**	Security Monitoring	The regulatory platform can accurately monitor the status	50	50	10%

			of the vehicle.			
		Emergency Response Time t_2	$0<t_2\leq 3$ min	50	50	
			$3<t_2\leq 5$ min	20		
			$t_2>5$ min	0		

5.2 Method of Calculating Comprehensive Score

The comprehensive score, denoted as S, is the sum of the weighted scores from four assessment items: safety warnings, emergency rescue, fire protection, and data linkage.

$$S=\sum_{1}^{4}\left(s_i \times w_i\right)$$

Where, S is the comprehensive score, s_i is the score of the i-th primary index, w_i is the Weight of the i-th primary index.

5.3 Assessment Results

The assessment results are divided into five levels, as detailed in Table 3.

Table 3. Assessment Results and Score Distribution

Assessment Results	**Score**
⭐⭐⭐⭐⭐	S≥90
⭐⭐⭐⭐	85≤S<90
⭐⭐⭐	70≤S<85
⭐⭐	60≤S<70
⭐	S<60

Appendix A:Battery Thermal Runaway Trigger Method

A.1 Thermal Runaway Trigger Object

The battery cell within the battery pack that is close to the temperature acquisition point.

A.2 Thermal Runaway Trigger Method

A.2.1 Vehicle bottom needle puncture

After determining the trigger object, create an opening in the vehicle's bottom protective plate directly opposite the bottom of the trigger object, ensuring the hole is no smaller than the size of the steel needle. Place the test vehicle on the platform for vehicle bottom needle puncturing and take measures to secure it to prevent movement. Adjust the bottom needle puncturing module, use a (Φ6~Φ8) mm flat head high-temperature resistant steel needle, and puncture the trigger object from a direction perpendicular to the battery's bottom at a speed of (0.1~3) mm/s, until the trigger object undergoes thermal runaway. The steel needle remains inside the trigger object until the end of the test.

A.2.2 Heating

Use a planar or rod-shaped heating device, and its surface should be covered with ceramic, metal, or insulating layer. For thin-film heating devices, they should always be attached to the surface of the trigger object; the heating area of the heating device should not be greater than the surface area of the battery cell; the heating surface of the heating device should be in direct contact with the surface of the battery cell; heat the trigger object with the maximum power of the heating device; The power of the heating device should be no less than twice the energy of a single battery cell, e.g.: if the electrical energy of the battery cell is 100 Wh, then the maximum power of the heating device is 200 W; stop triggering when thermal runaway occurs or when the monitoring point temperature defined in A.4 reaches 300°C.

A.2.3 Other methods

Other methods, such as striking the bottom of the vehicle with a ball or overcharging the battery, can be used to trigger thermal runaway in the battery.

A.3 Data Monitoring Plan

The monitoring targets are the triggering object and its adjacent battery cells, with the monitored parameters being the temperature and voltage of the targets. The monitoring locations are the positive electrode, negative electrode, and large surface of the monitoring targets, as shown in Figure A.

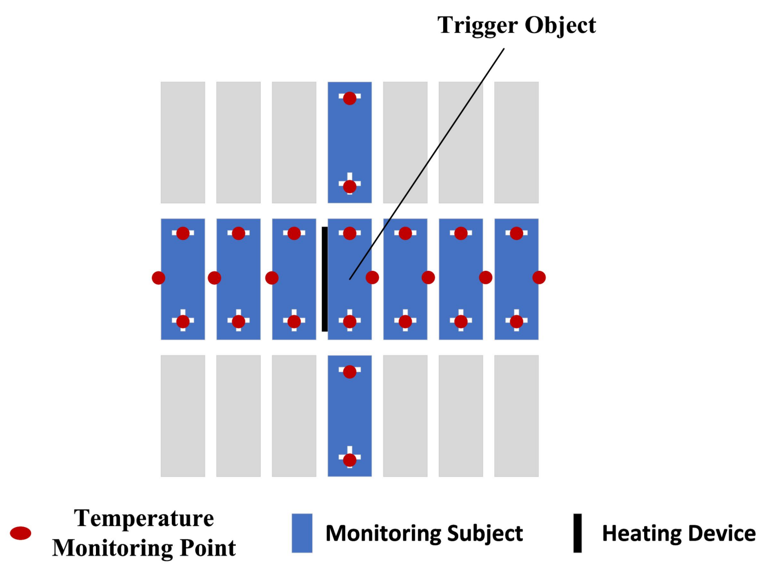

Figure A Temperature Monitoring Scheme

A.4 Thermal Runaway Trigger Judgement Criteria

a) The voltage drop of the monitored object occurs, and the decrease exceeds 25% of the initial voltage;

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

c) The rate of temperature rise at the monitoring point $dT/dt \geq 1°C/s$, and the condition persists for more than 3 seconds.

Thermal runaway is determined when either a) and c) or b) and c) occur.

Appendix B:Electrical Safety Monitoring Method

Place the voltage collection points according to the method shown in Figure B.Voltage measurement should be continuously conducted throughout the entire test process, taking the minimum voltage value within time t_1.

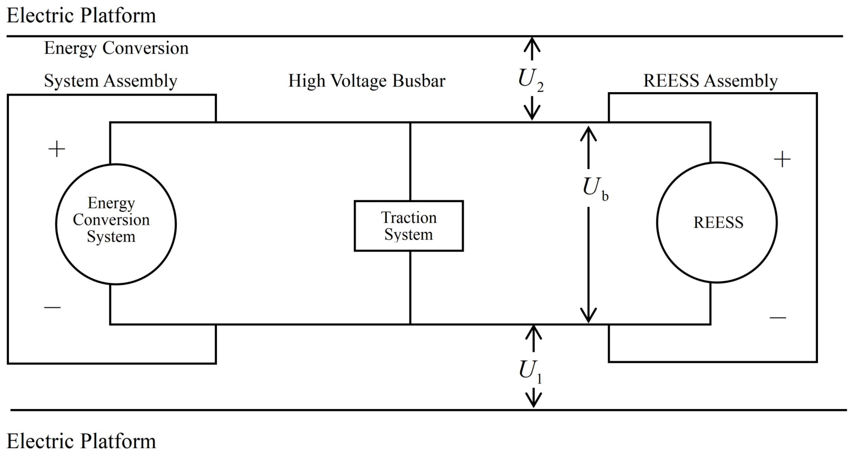

Figure B. Schematic Diagram of Voltage Measurement

Appendix C:Pre-Experiment Information Confirmation

Table C.1 Test Conditions and Status of Test Equipment

Environmental Condition	Temperature:_________; Relative Humidity:_________; Atmospheric Pressure:_______; Wind Speed______。
Experimental Equipment Status	Is the smoke treatment system normal: ☐ Yes ☐ No, abnormal condition:__________。
	Is the air supply system normal: ☐ Yes ☐ No, abnormal condition:__________。
	Is the fire extinguishing system normal: ☐ Yes ☐ No, abnormal condition:__________。
	Are the crane and hoisting equipment normal: ☐ Yes ☐ No, abnormal condition:__________。
	Is the laboratory lighting normal: ☐ Yes ☐ No, abnormal condition:__________。
	Is the test bench normal: ☐ Yes ☐ No, abnormal condition:__________。
	Is the data acquisition system normal: ☐ Yes, ☐ No, abnormal condition:__________。
	Are other experimental equipment normal: ☐ Yes ☐ No, abnormal condition:__________。

Table C.2 Vehicle Information

Vehicle Basic Information	Vehicle Brand:
	Vehicle Model:
	Production Date:
	Body Color:
	Vehicle Identification Number (VIN):
	Odometer Reading:
	Power Battery System Model:
	Power Battery Manufacturer:
	Drive Motor Model:
	Motor Controller Model:

	Vehicle Factory Certification Number:
Vehicle Condition	Vehicle Appearance:
	Battery System SOC (State of Charge) Value:
	Vehicle Start Status:
	Gear Position:
	Operation of Vehicle Emergency Lights and Alarm Devices:
	Vehicle Auxiliary Equipment Switch Status: ☐ Air Conditioning Off, ☐ Lights Off, ☐ Other Auxiliary Equipment Off.
	Other Functions to be Tested:___________________, Functioning Properly: ☐ Yes ☐ No.

Table C.3 Pre-Test Vehicle and On-Site Photography

No.	**Shooting Direction**	**Confirmation**	**No.**	**Shooting Direction**	**Confirmation**
1	Front view of the vehicle		2	45° view from the front left side of the vehicle	
3	Left side view of the vehicle		4	45° view from the rear left side of the vehicle	
5	Rear view of the vehicle		6	45° view from the rear right side of the vehicle	
7	Right side view of the vehicle		8	45° view from the front right side of the vehicle	
9	Undercarriage view of the vehicle		10	Top view of the vehicle	
11	Dashboard		12	Front seats	
13	Rear seats		14	Trunk	
15	Front engine compartment		16	Dashboard instruments	
17	Nameplate		18	VIN (Vehicle Identification Number)	
19	Vehicle manufacturer's certificate of conformity		20	Overall condition of the laboratory	
21	Laboratory temperature,		22	Wind speed in the laboratory	

	atmospheric pressure, and relative humidity				
23	Other information of interest				

Appendix D:Method for Verifying Door Lock Functionality

D.1 The door switch function verification device

D.1.1 The installation method of the external door switch functionality verification device is illustrated in Figure D.1. The tension device is fixed to the laboratory floor through a pillar and a fixed plate, with the tension device being at the same height above the ground as the door handle. The steel wire rope is perpendicular to the door handle. During the test, the tester controls the tension device to apply a force of ≥50 N to the door handle through the steel wire rope. The length of the pulling motion should not be less than the maximum travel of the door handle, and the force should be applied for ≥3 seconds.

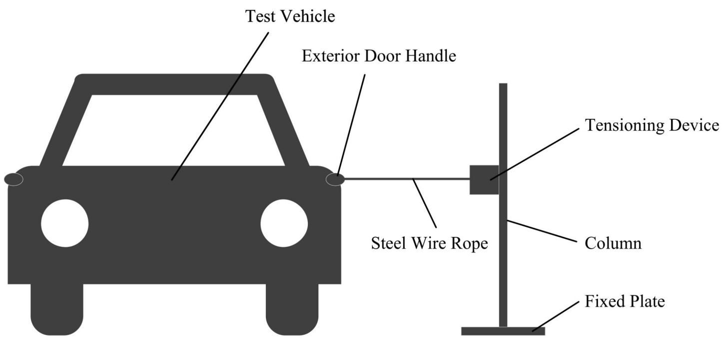

Figure D.1 External Door Lock Functionality Verification Device and Installation Method

D.1.2 The internal vehicle door switch functionality verification device consists of a door unlocking mechanism and a door pushing force applying mechanism, which are installed and adjusted according to the actual structure of the vehicle. The door unlocking mechanism applies a pulling or pressing force of ≥30 N to the door unlocking handle or button, with the force travel being not less than the maximum travel of the door lock handle or button, and the force applied for ≥3 seconds; the door pushing force applying mechanism exerts a pushing force of ≥50 N on the door. During the test, the test personnel control the door unlocking mechanism and the door pushing force applying mechanism to verify the door's opening and closing functionality.

D.2 Verification Sequence and Judgment Method of Vehicle Door Switch Functionality

Firstly, verify the functionality of the door opening and closing from outside the vehicle. If the door opens normally, it is judged that the door can be opened normally from both outside and inside the vehicle. If the door cannot be opened from outside, then verify the functionality of the door opening and closing from inside the vehicle. If the door opens normally from inside, it is judged that the door can be opened normally from inside the vehicle and cannot be opened normally from outside. If the door cannot be opened normally from inside, it is judged that the door cannot be opened normally from both outside and inside the vehicle.

Appendix E:Post-Test Information Confirmation

Table E.1 Post-Test Vehicle and Site Photography

No.	Shooting Direction	Confirmation	No.	Shooting Direction	Confirmation
1	Front View of the Vehicle		2	45° View from the Front Left Side of the Vehicle	
3	Left Side View of the Vehicle		4	45° View from the Rear Left Side of the Vehicle	
5	Rear View of the Vehicle		6	45° View from the Rear Right Side of the Vehicle	
7	Right Side View of the Vehicle		8	45° View from the Front Right Side of the Vehicle	
9	Undercarriage View of the Vehicle		10	Top View of the Vehicle	
11	Dashboard		12	Front Seats	
13	Rear Seats		14	Trunk	
15	Front Engine Compartment		16	Overall Appearance of the Battery Pack	
17	Battery Pack Interior		18	Other Vehicle Details that Require Attention	
19	Overall Condition of the Test Laboratory		20	Other Test Laboratory Information that Requires Attention	