

Venting of Gases Test for Electric Vehicles

China
2022.11

Quick Review

1. Standardization requirements of GTR

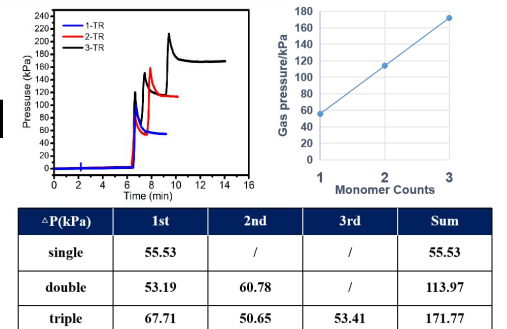
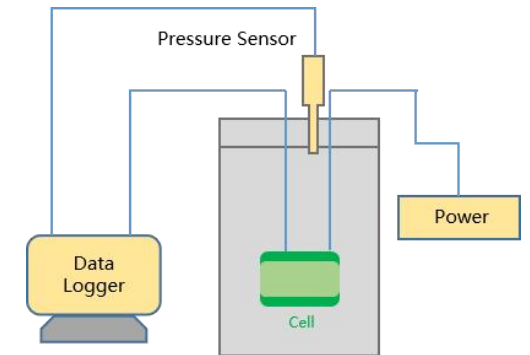
- **Phase 1** Several ideas from Japan, JRC and OICA were discussed but no suitable method
It was not possible to research and analyse this in Phase 1. Therefore, it will be considered in Phase 2
- **Phase 2** A unified, repeatable, easy to implement method that can evaluate the impact of battery gas production on occupants.

2. Establish a multi-level gas production test method

- **Cell→Module→Pack→Vehicle**
- **Test device & Trigger Method & Collection Method & Analysis**

3. Research progress of China

- **Cell Level:** The test method on cell level gas production was established
more data required
- **Module Level:** cell result multiplication (CRM) method is preliminarily explored



Research Progress

- Carried out a series of cell level toxicity analysis of venting gases
 - Toxic level definition of the venting gases
 - Thermal runaway venting gases analysis
- Gas and smoke analysis on pack and vehicle
 - Established the test building of the Venting of Gases Test for pack and vehicle level
 - Gas and smoke analysis of a vehicle and its corresponding battery pack TR

Toxic level Definition

Five classification levels including:

- I (very toxic)
- II (highly toxic)
- III (toxic)
- IV (low toxic)
- V (Non Toxic)

Levels are defined according to China National Standards including:

- [GB5044-1985](#) Classification of health hazard levels from occupational exposure to toxic substances
- [GBZ230-2010](#) Classification for hazards of occupational exposure to toxicant
- [T/CIAPS0018-2022](#) Composition Detection Method and Toxicity Classification of Traction Battery Thermal Runaway Leakage.

Thermal runaway venting gases analysis

1 Selection of Lithium-ion Batteries types

■ The experimental batteries (18650 LIB) were divided into three types according to the cathode material:

■ Ternary Polymer Lithium Ion Battery (NMC).

■ lithium cobalt oxide battery (LCO).

■ lithium iron phosphate battery (LFP).

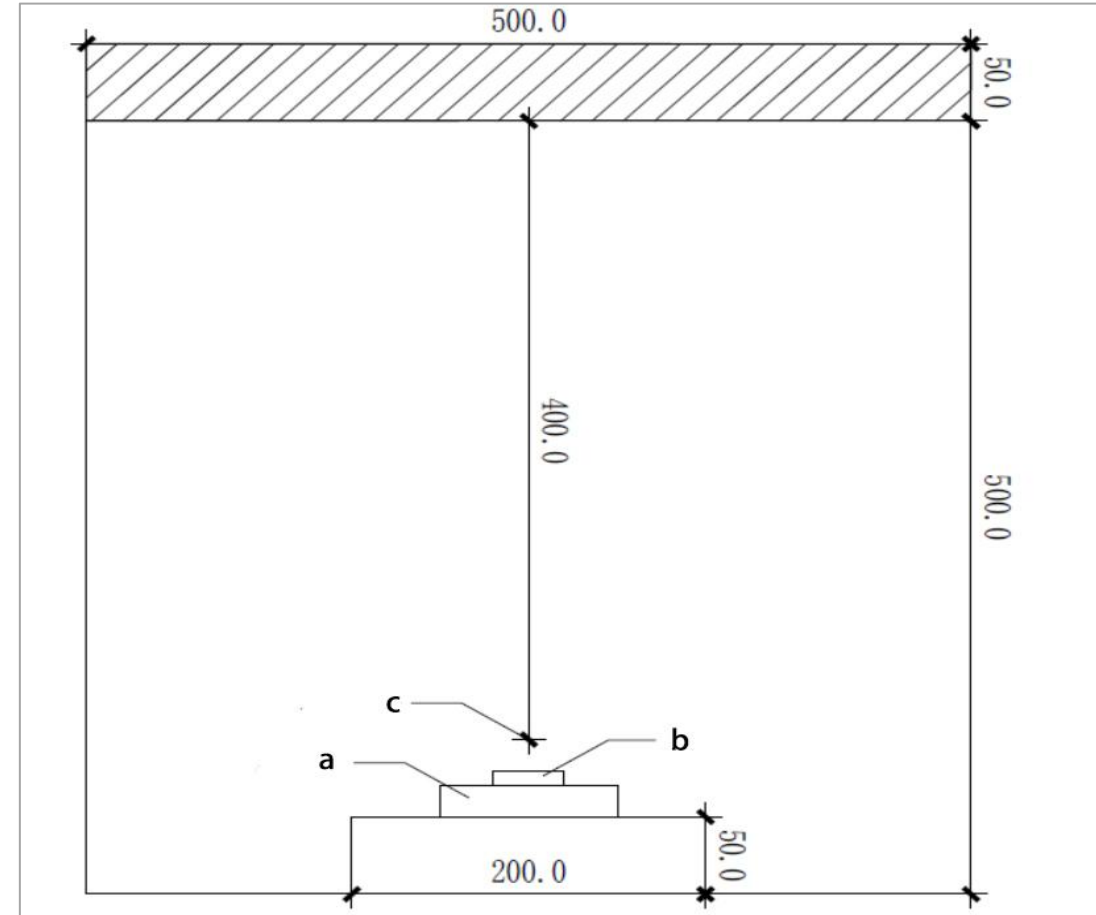
■ Four sets of samples were prepared for each kinds of battery, and the battery state was adjusted to 0%SOC, 30% SOC, 50% SOC, 100% SOC

LIB types	Nominal Capacity/mA·h	Nominal Voltage/V	Over Charge Protection Voltage/V	Over Discharge Release Voltage/V
NMC	2200	3.70	4.20	2.75
LCO	2600	3.70	4.20	2.75
LFP	1300	3.20	3.75	2.50

Thermal runaway venting gases analysis

2 Electro-Thermal triggering experiment

- The test box was a 500*500*500 mm³ stainless steel apparatus.
- The heating plate heats the 18650 LIBs to cause thermal runaway.
- The temperature of electric heating trigger is 170 °C. LIB is fixed by wire and placed on the surface of the heating plate.
- Thermocouple detects the temperature of the electric heating plate, the surface of lithium ion batteries, and the gas environment.
- The temperature measurement points were shown as [the right](#).
- High frame camera was used to record experimental phenomenon.



Thermal runaway electrical heating trigger for Li-ion batteries
a. The heating plate b. The surface of lithium ion batteries
c. The gas environment

Thermal runaway venting gases analysis

3 Detection of thermal runaway leaked gases

- GC-Mass (GC–MS) was used as a analysis device for lithium ion batteries thermal runaway reaction gases , including toxic industrial raw materials (Rapid monitoring and analysis of substances such as TIM) and toxic industrial chemicals (TIC).
- After the gas leakage process , the GC-Mass was used to collect and analyze the thermal runaway reaction gas.



a



b

The Thermal runaway phenomenon of NMC Li-ion batteries
a. 30% SOC b. 50% SOC



The Thermal runaway phenomenon of
NMC Li-ion battery with 100 % SOC



The Thermal runaway phenomenon of
LCO Li-ion battery with 100 % SOC

Thermal runaway venting gases analysis

4 Toxicity Analysis

NO.	Compound	CAS	Toxicity classification	NMC	LCO	LFP
1	2-Propenal (C ₃ H ₄ O)	107-02-8	I	30%	100%	
2	Dimethyl hydrazine(C ₂ H ₈ N ₂)	540-73-8	I			100%、 50%
3	Methyl vinyl ketone(C ₄ H ₆ O)	78-94-4	I	100%	100%	
4	Propanedinitrile(C ₃ H ₂ N)	09-77-3	I		100%	
5	Propanenitrile(C ₃ H ₅ N)	107-12-0	I		100%	
6	Ethyl thiocyanate(C ₃ H ₅ NS)	542-90-5	I			30%
7	1,3-cyclopentadiene(C ₅ H ₆)	542-92-7	II	100%	50%、 100%	
8	n-Butylamine(C ₄ H ₁₁ N)	109-73-9	II			30%
9	Crotonaldehyde(C ₄ H ₆ O)	4170-30-3	II		50%	
10	Allyl alcohol(C ₃ H ₆ O)	107-18-6	II		50%	
11	Acrylic acid(C ₃ H ₄ O ₂)	79-10-7	II			30%
12	2-Furaldehyde(C ₅ H ₄ O ₂)	98-01-1	II		50%	
13	1,1-Dimethylhydrazine (C ₂ H ₈ N ₂)	57-14-7	II			30%
14	Naphthalene(C ₁₀ H ₈)	91-20-3	II		50%、 100%	
15	1,2-epoxybutane(C ₄ H ₈ O)	106-88-7	II		50%	
16	Propylene oxide(C ₃ H ₆ O)	75-56-9	II			30%

Venting of Gases Test Building



Preparation before test

Battery pack is composed of 150 cells in series with LFP/C chemistry

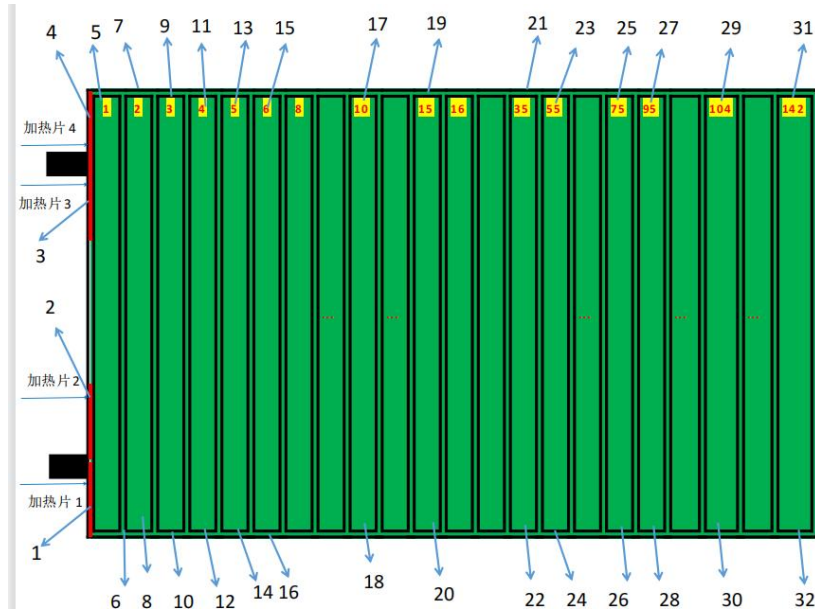
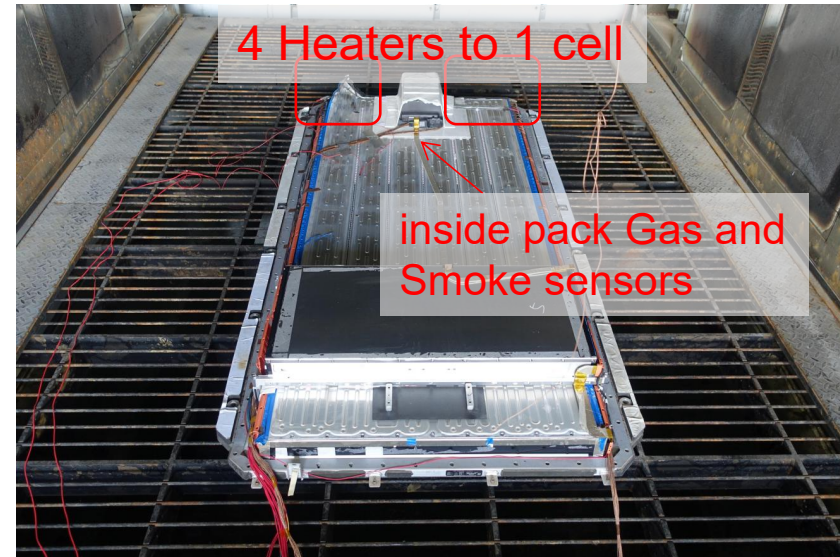
Cell voltage is about 3.3V. Due to the lack of information about the battery pack, we cannot accurately estimate the SOC of the pack

Four heating strips are arranged at the surface (in the direction of the vehicle head) of the 1st cell

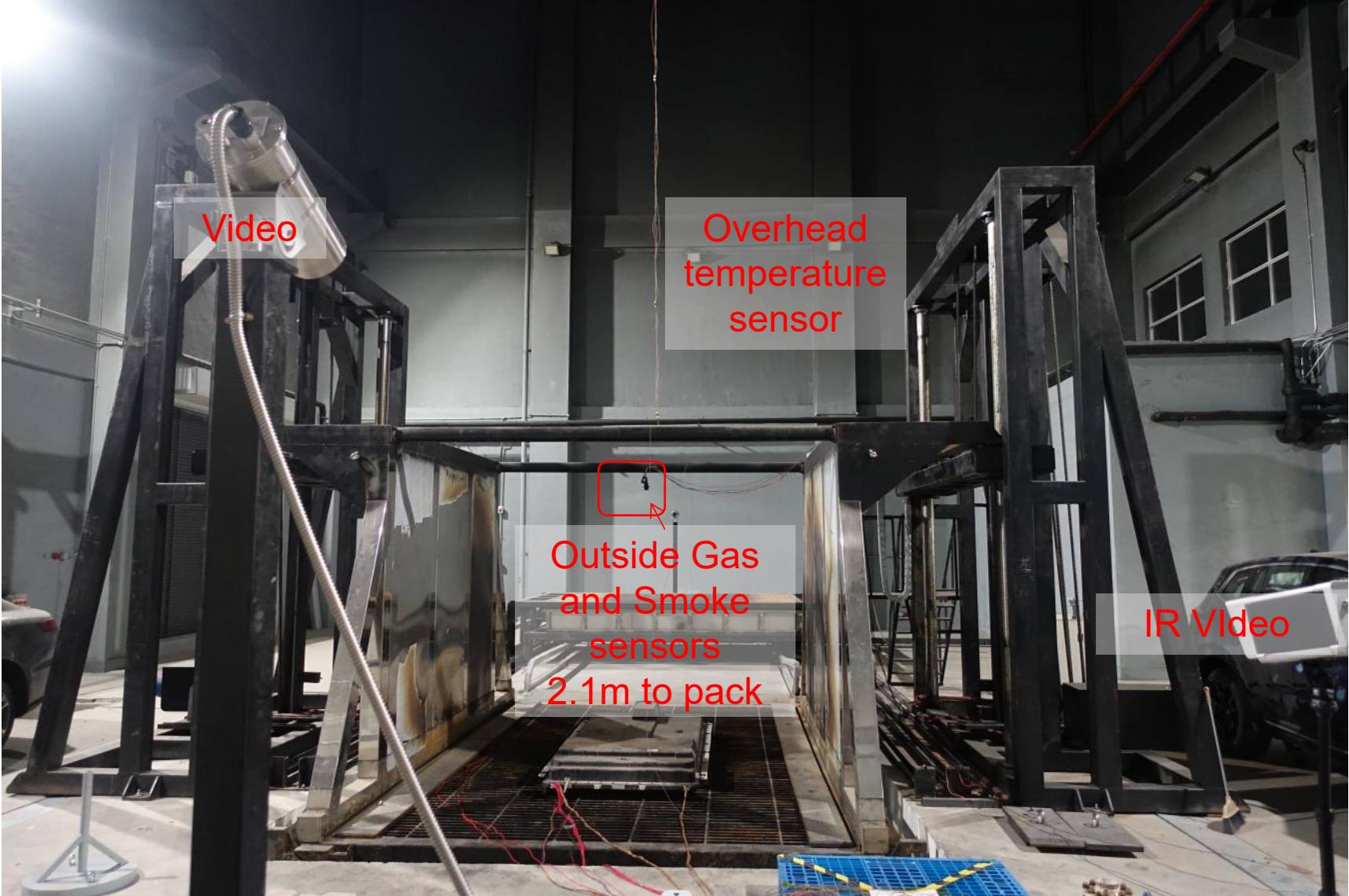
32 temperature sensors are arranged inside the battery pack

Voltage of the 1st, 2nd, 4th, 6th, 8th, 10th and 16th cells are Collected

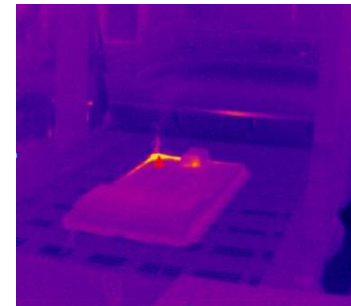
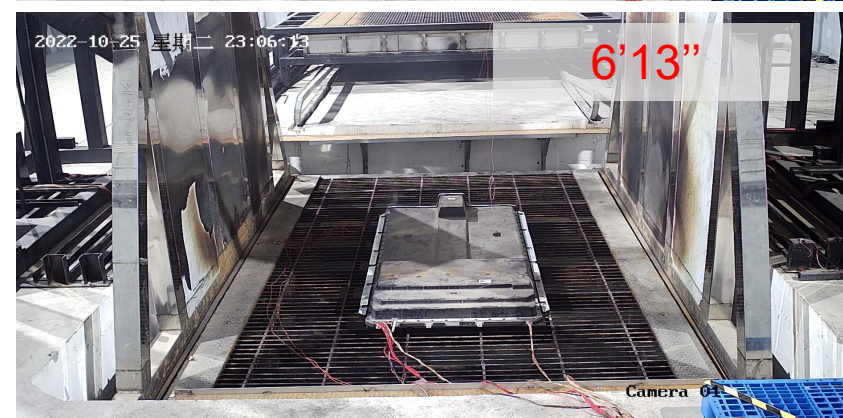
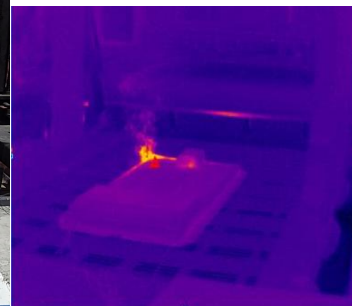
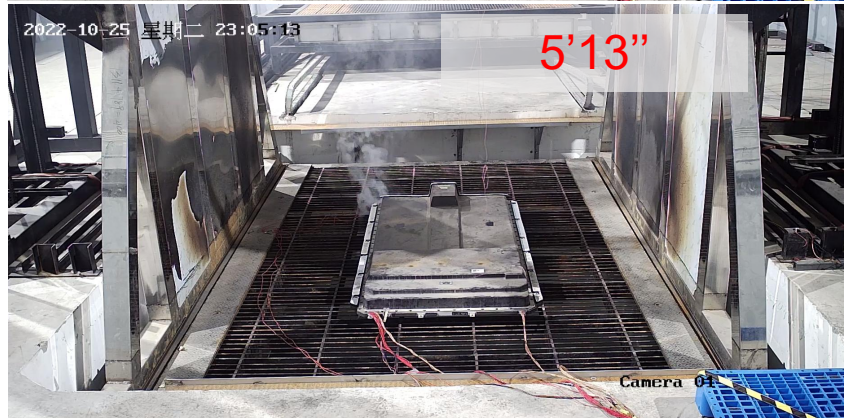
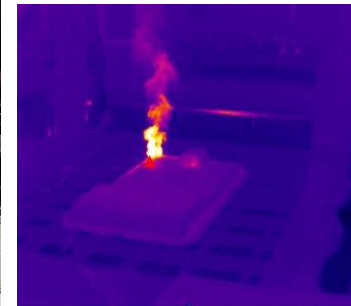
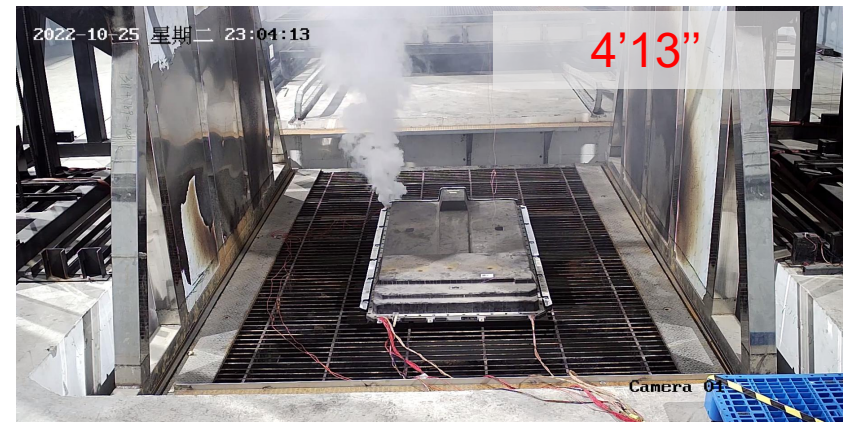
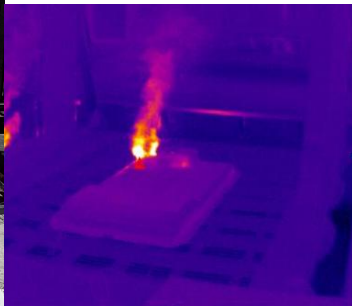
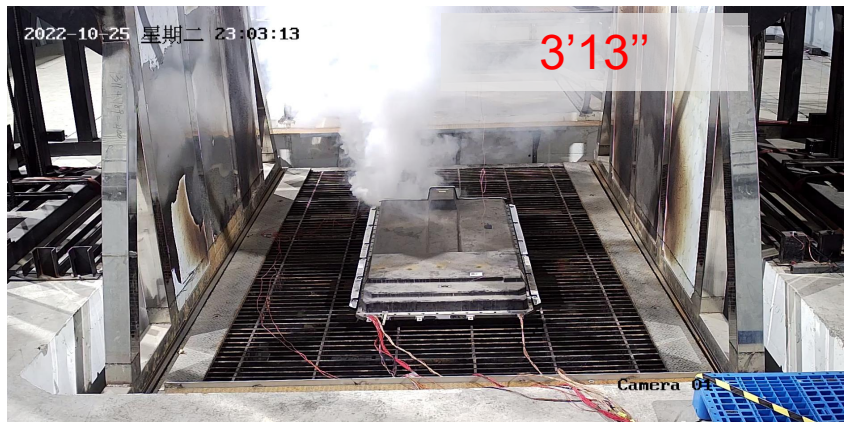
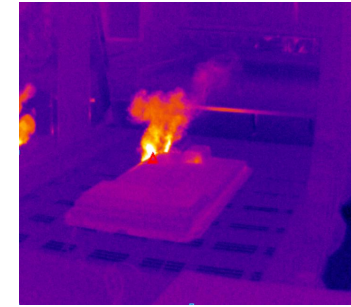
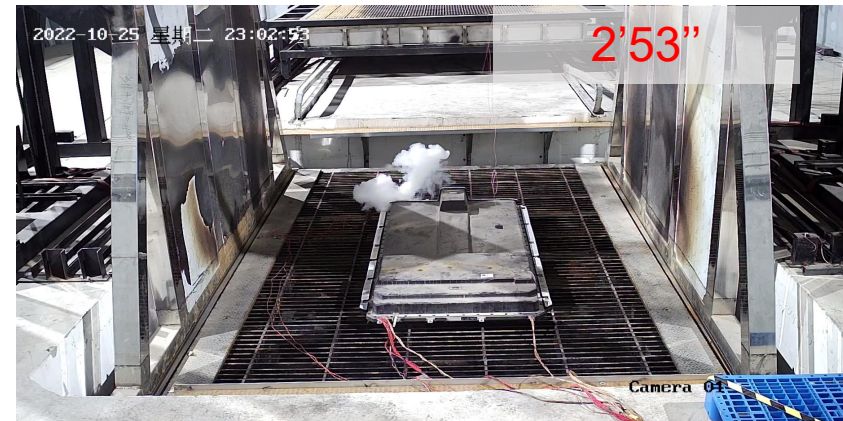
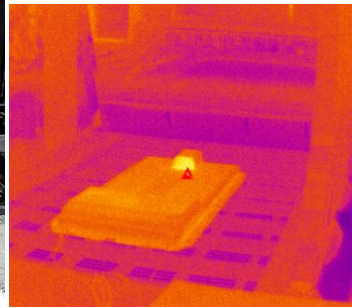
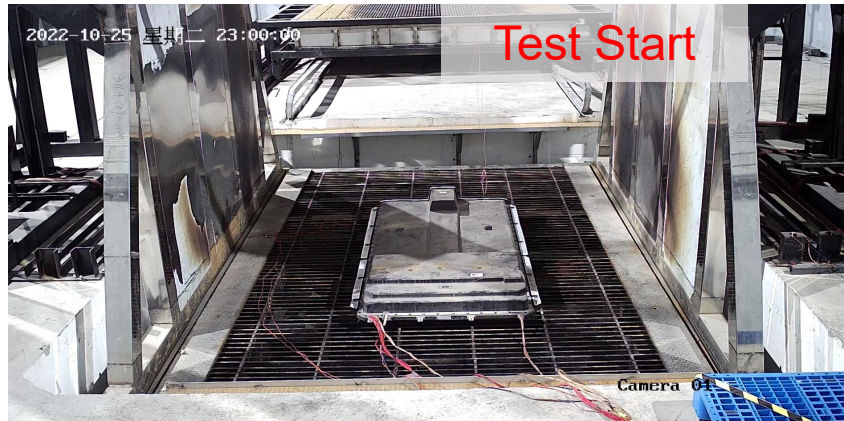
Restore the battery pack structure after modification



Preparation before test

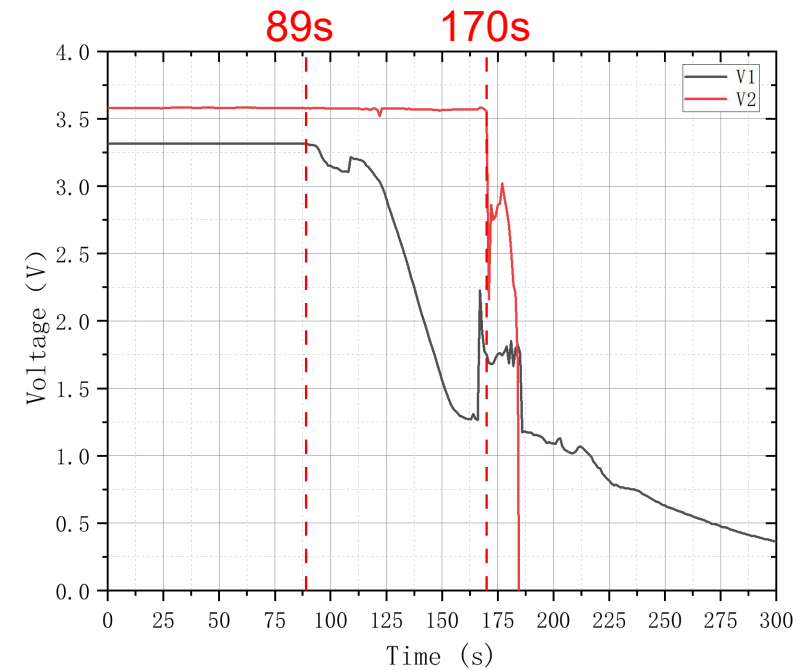
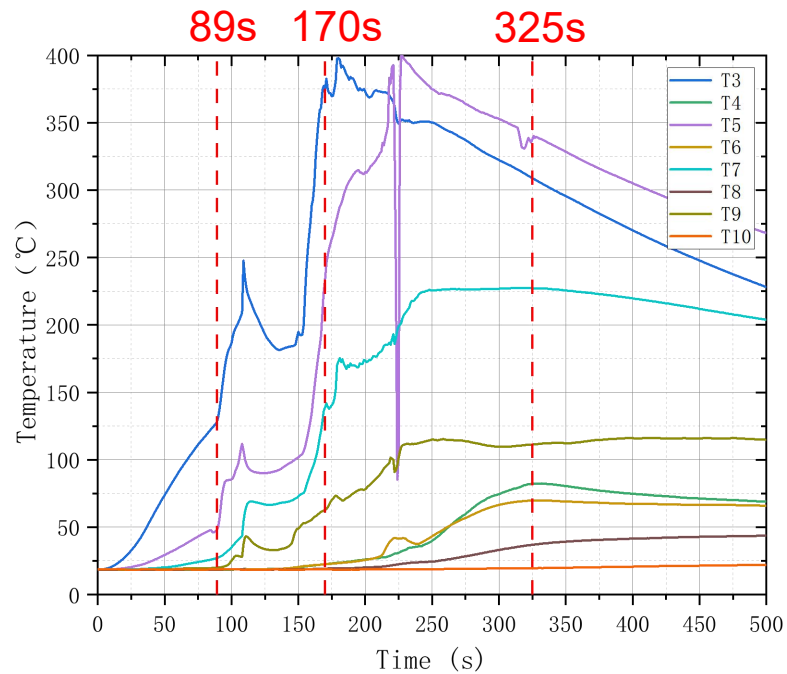
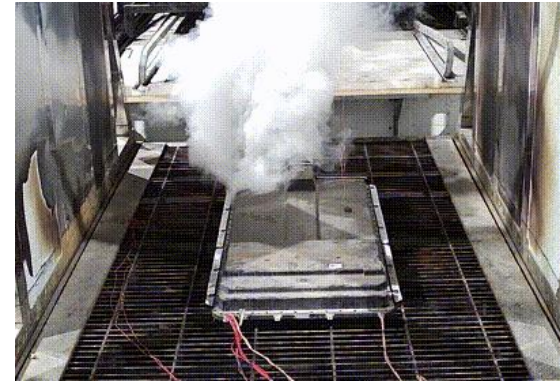


Test results

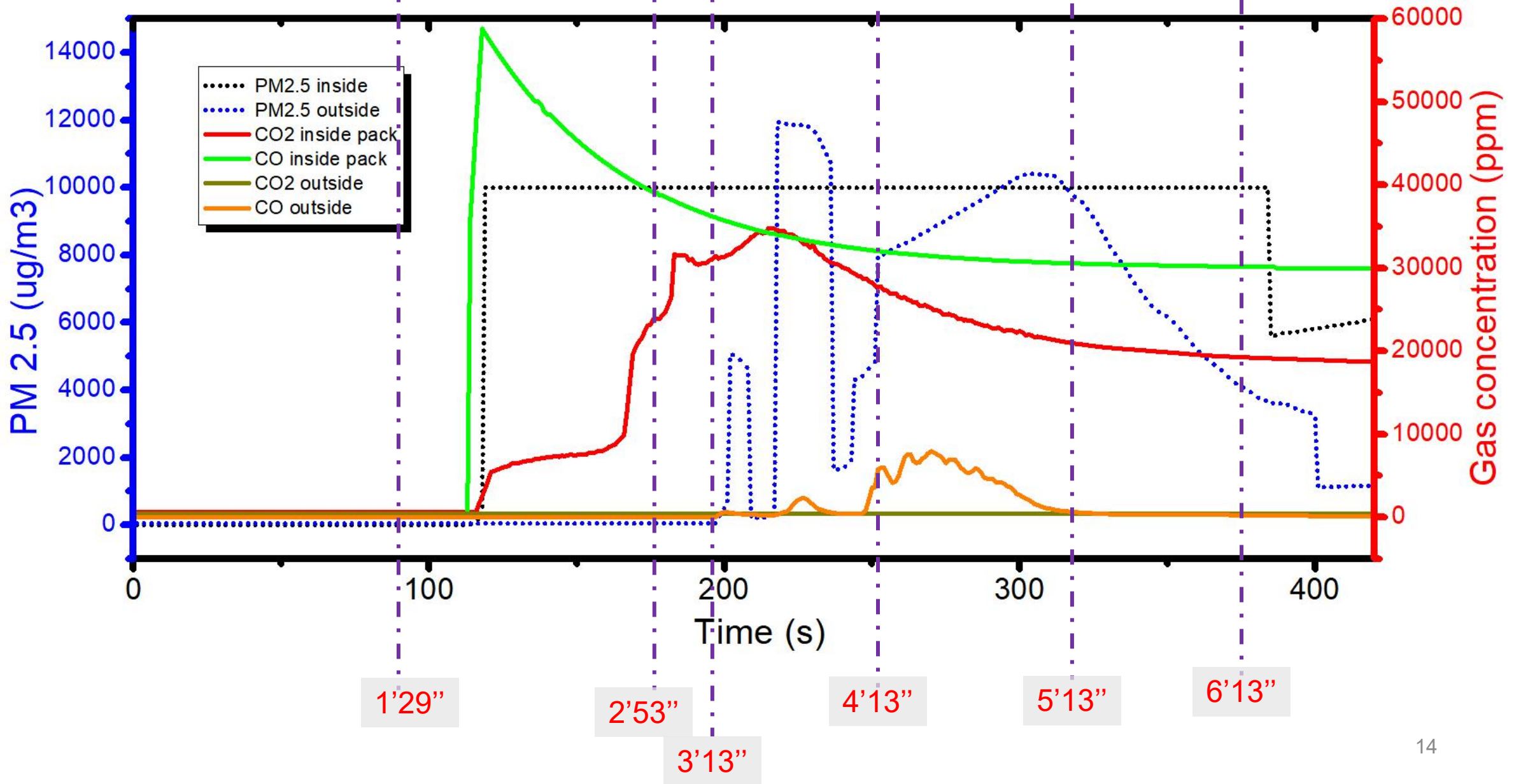


Test results

23:00:00 Start heating
23:01:29 (89s) TR of the first cell
23:02:50 (170s) TP to the 2nd
23:05:25 (325s), TP stopped and the temperature decreased



Gas and Smoke Analysis

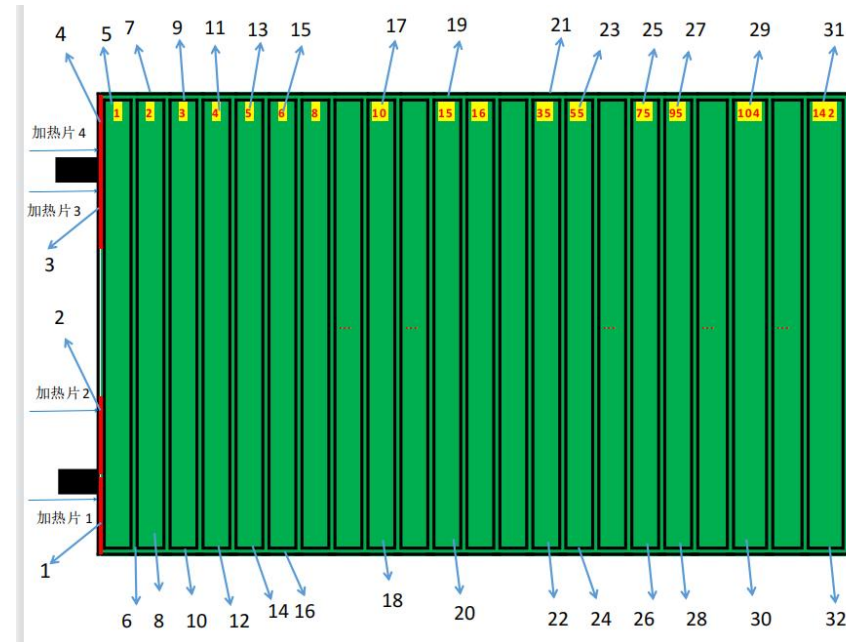


Vehicle level test

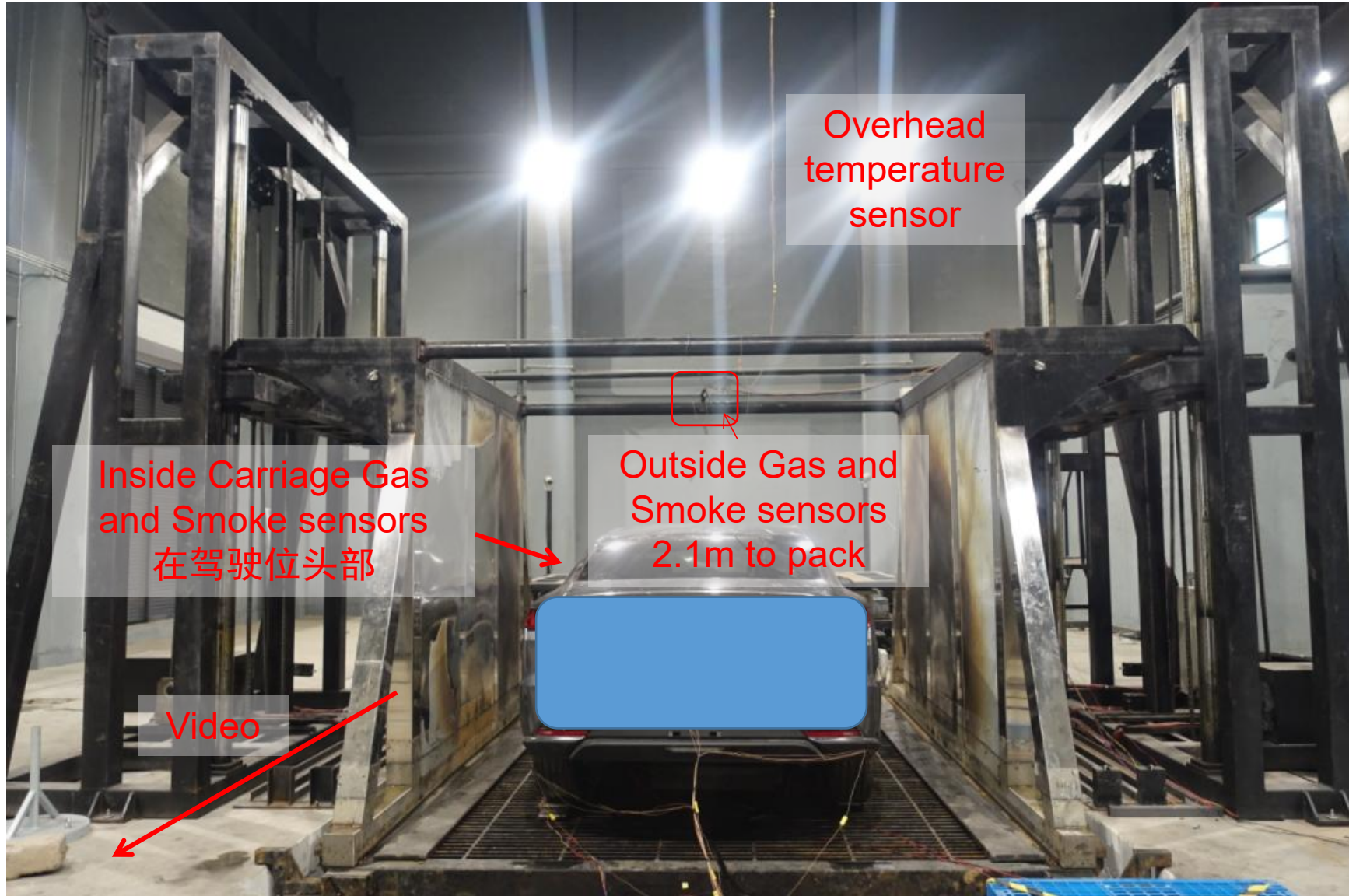
The battery pack voltage is 3.32V, but due to the electrochemical characteristics of the LFP chemistry, we cannot confirm whether the SOC of the two tests is consistent

The battery pack modification is completely consistent with the pack level test

Four heating plates with the same power are arranged for heating at the same time to trigger TR

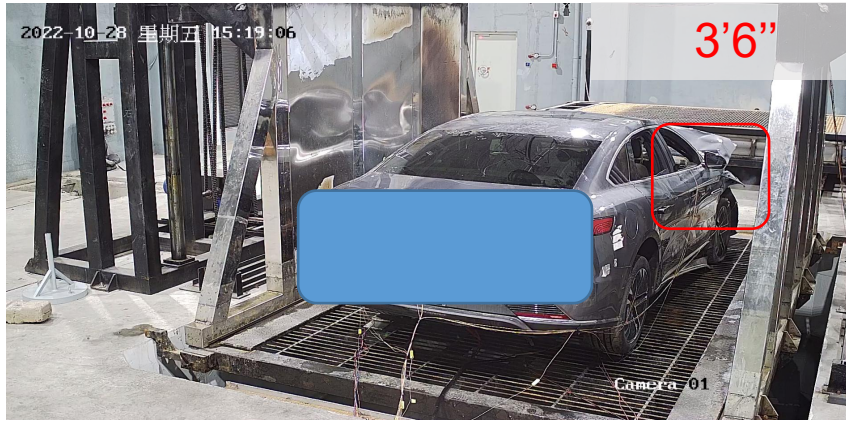


Preparation before test



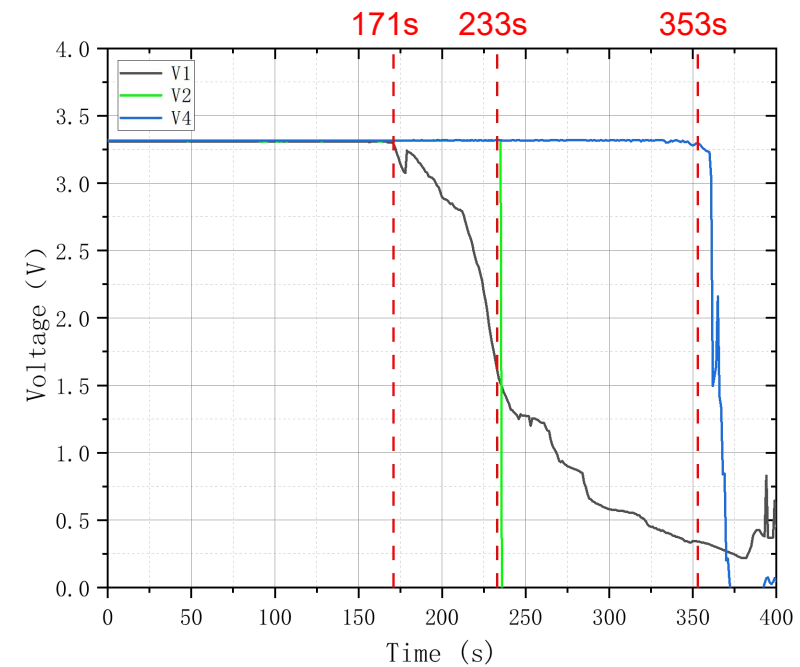
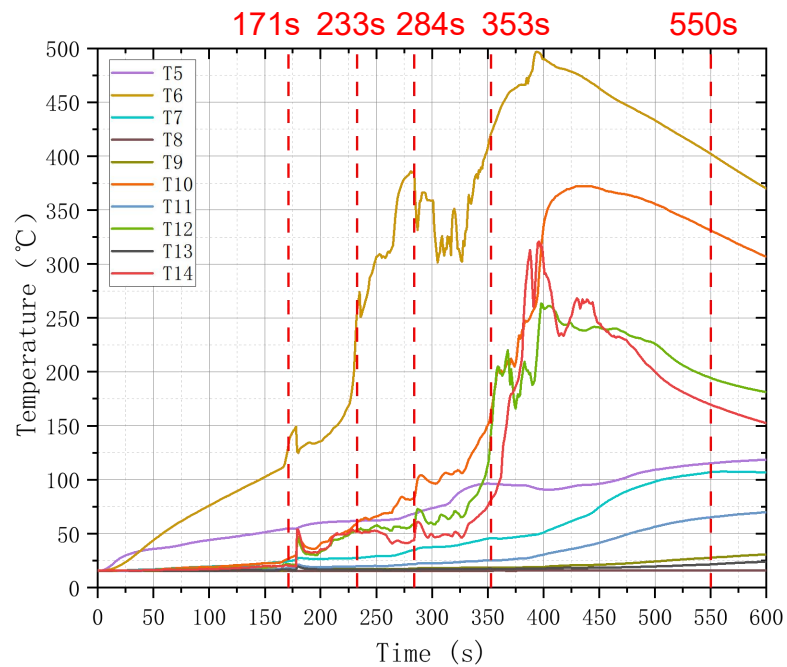
Test results

Test start at 15:16:00

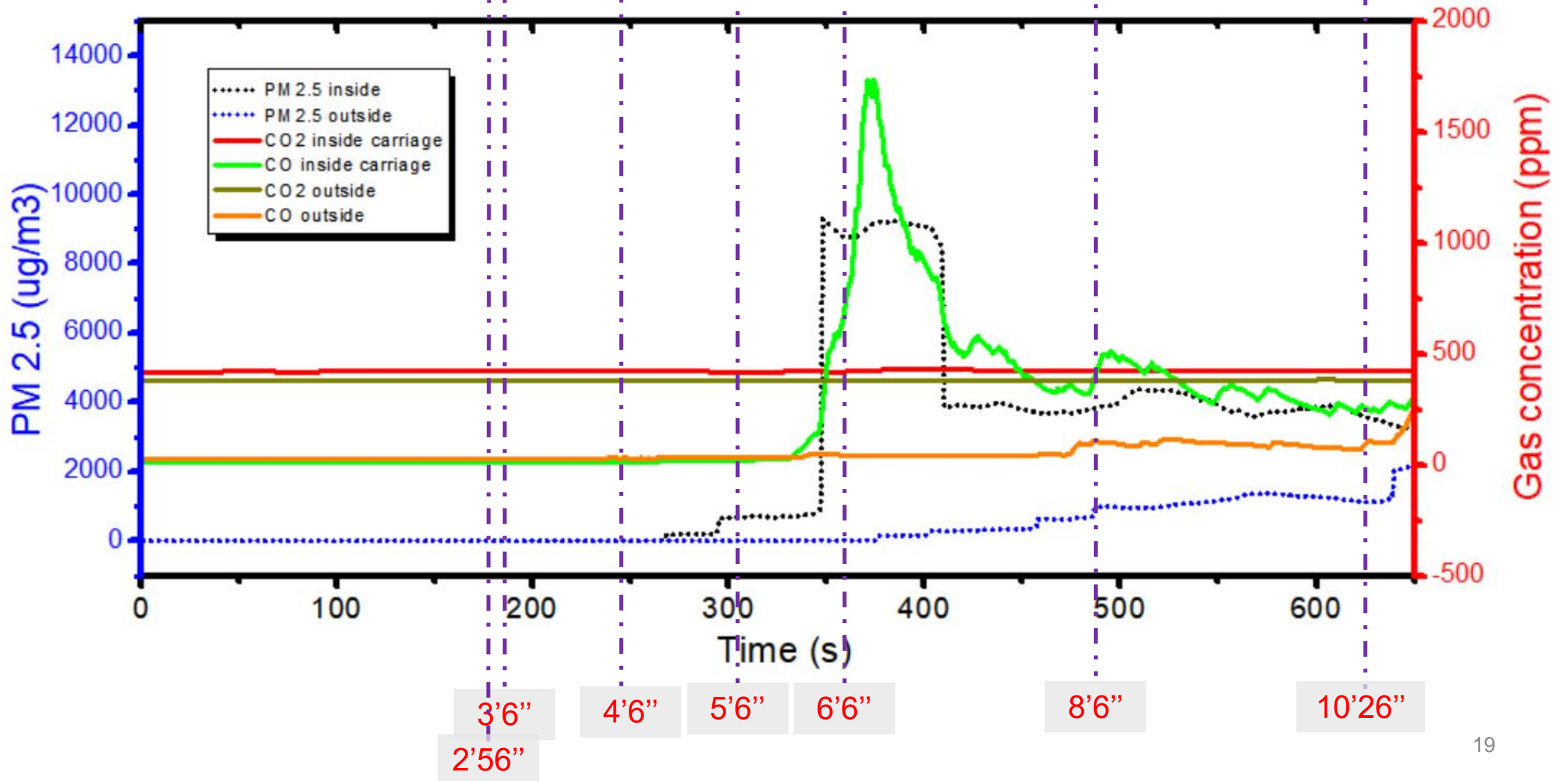


Test results

15:16:00 Test start
15:18:51 (171s) 1st cell TR
15:19:53 (233s) 2nd cell TP
15:20:44 (284s) 3rd cell TP
15:21:53 (353s) 4th cell TP
until 15:25:10 (550s) no more TP



Gas and Smoke Analysis



Next Plan

- Mechanism analysis of the toxic compounds production
- Carry out more venting gas tests on the battery pack and vehicle level
- Optimization of gas and smoke test conditions, such as arrange more sensors at different positions to research the propagation path of gas and smoke