Thermal propagation

China
2018.09

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Key questions and responses

① What are we trying to simulate?

As can be seen from the report of the electric vehicle accidents, some of the battery fires occurred when the vehicle was driving or parked without clear reasons such as overcharging, crashing, or external short circuit.

The internal short circuit may cause thermal runaway of a cell and thermal propagation of a battery pack, which may cause great harm to the occupants. And currently it is not effective to predict the occurrence of internal short circuit.

Therefore, we hope to obtain a method that can effectively trigger a internal short circuit and thermal runaway, to test the safety of the battery pack/system or vehicle in the event of a thermal runaway happen, so that the battery system or the vehicle can effectively resist this kind potential hazard.

Key questions and responses

② Initiation methods of thermal runaway

Questions	Responses
Feasibility, repeatability, reproducibility?	We need first to determine the definition of repeatability in order to evaluate it. Repeatability can be evaluated by introducing standard deviation coefficients for key parameters. Feasibility and reproducibility can be evaluated by comparison of test results from different agencies.
Specific test parameters of Initiation methods?	Define test conditions by orthogonal tests and expect to find the best test conditions by comparing of the standard deviation coefficients to ensure good repeatability.
Potential new methods for initiation?	Precise Controlled Internal Short Circuit & Self-Heating, proposed by CATL. We are interested in the method proposed by Canada. If more information on heating device can be provided, China is willing to carry out some related work.
Criteria for thermal runaway?	The parameters are affected by the battery type and the initiation method. So there will be a big difference in the parameters when thermal runaway occur. However, regardless of the cause of thermal runaway, the appearance and parameters after thermal runaway are very similar, and the process of thermal runaway of a cell is extremely short. The effect of continuous operation or introduced energy is very small in this short time. Therefore, the criteria for thermal runaway are the common parameters of the battery after thermal runaway occur. In the approval draft of GB, we recommend 1℃/s temperature rate last 3 seconds, and 25% voltage drop as the criteria for thermal runaway.

Key questions and responses

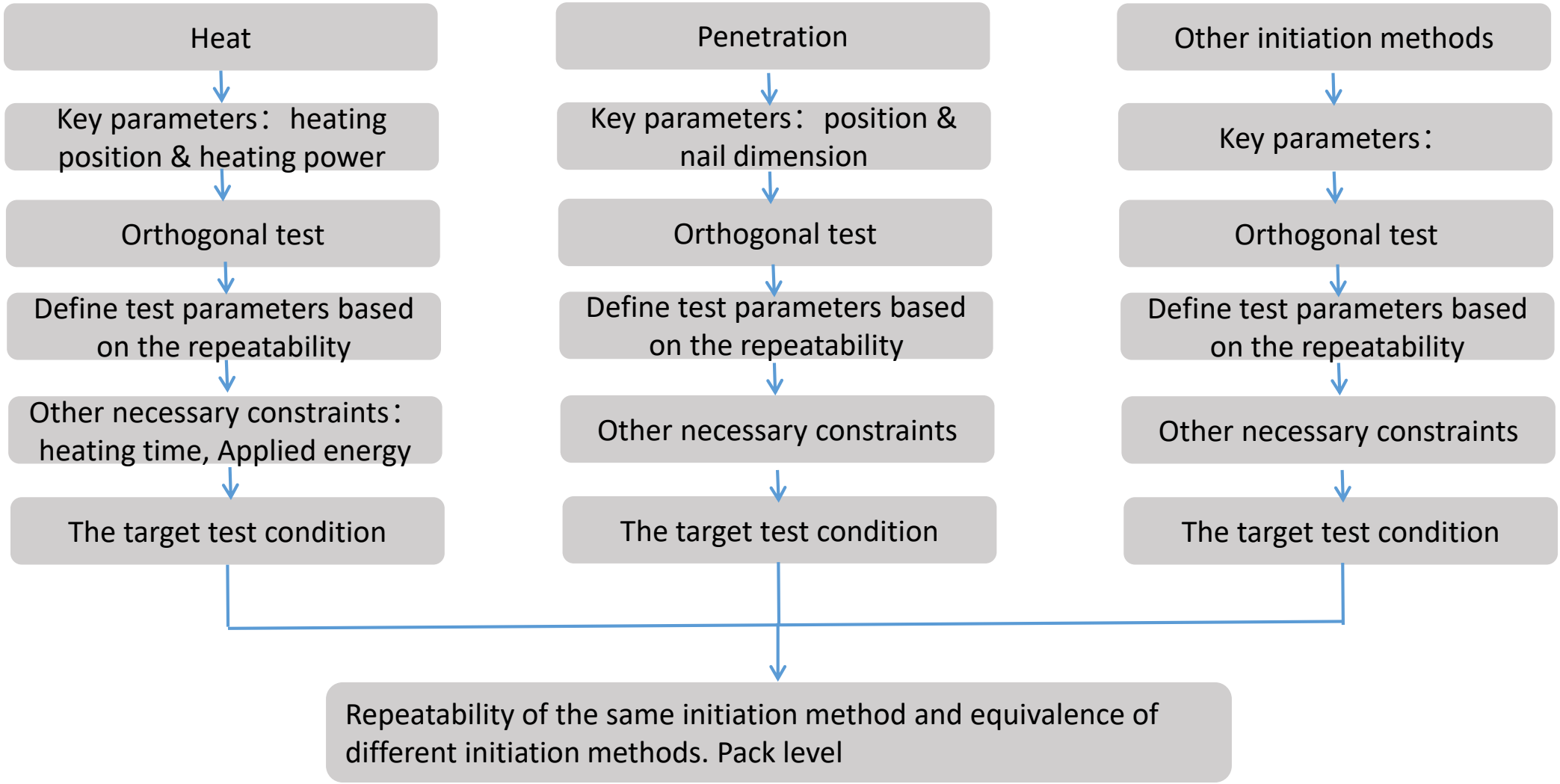
③ Thermal propagation test method

Questions	Responses
Feasibility, repeatability, reproducibility?	Repeatability can be evaluated by introducing standard deviation coefficients for key parameters(the time interval from initiation to external fire observed). Feasibility and reproducibility were evaluated by comparison of test results from different agencies.
Are different methods of initiating single cell thermal runaway equivalent?	Equivalence is judged by the consistency of the test results of different test methods, and different methods should be consistent in the thermal propagation test results.

Research plan

Item		2018		2019				2020			
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
The specific test parameters of initiation methods	heating										
	penetration										
	others										
Criteria for thermal runaway											
Repeatability of the same initiation method and equivalence of different initiation methods. Pack level											
Evaluation criteria of thermal propagation											

Research plan



Research of test parameters of heating

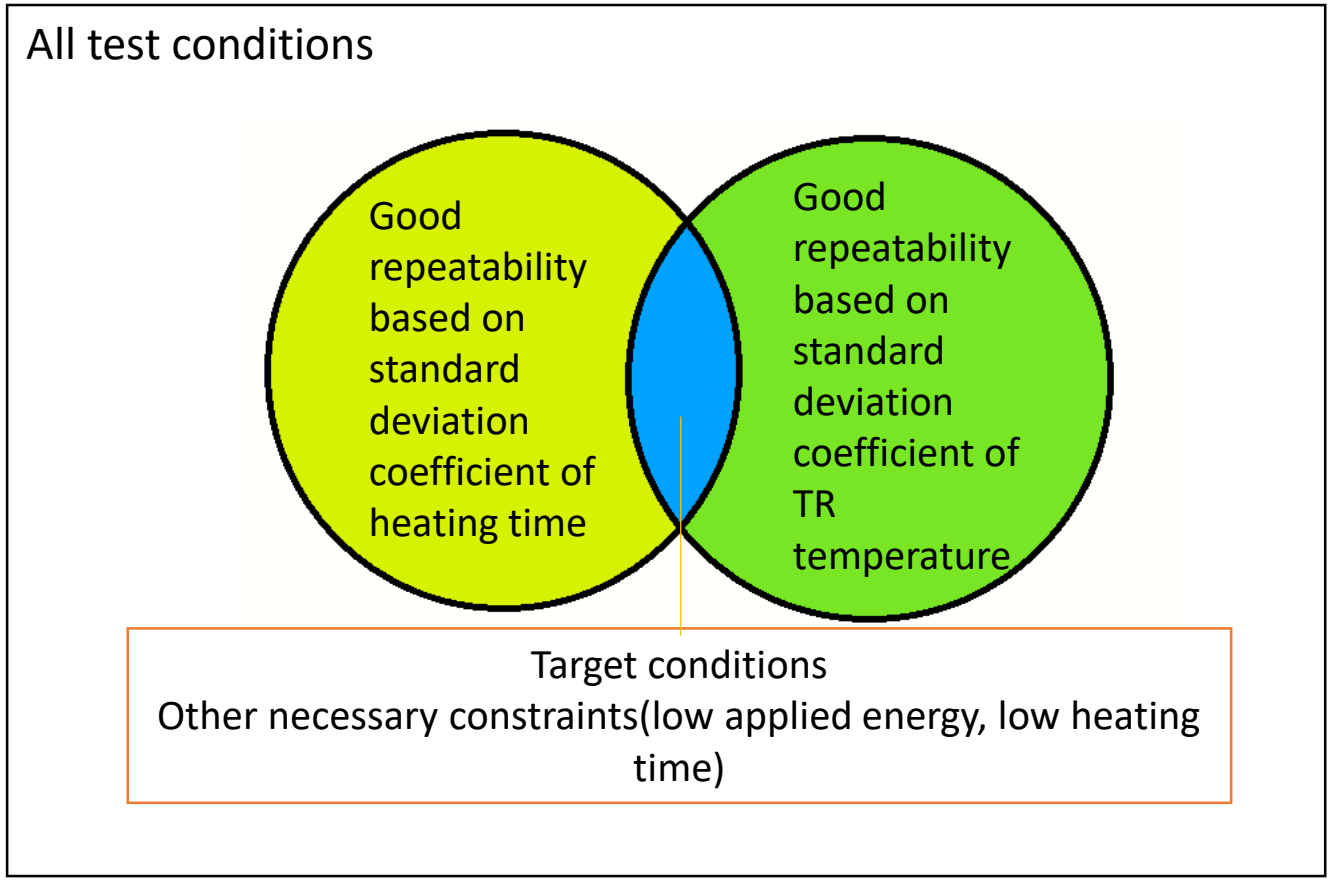
- For heating： mainly investigates two key parameters of heating position and heating power.

	Power1	Power2	Power3	Power4	Power5	……
position1	5	5	5	5	5	5
position2	5	5	5	5	5	5
position3	5	5	5	5	5	5
……	5	5	5	5	5	5

- Comparing the repeatability of different test conditions by the standard deviation coefficients of the two parameters of the heating time and the TR temperature.
- Heating energy is the energy introduced into the system.

Research of test parameters of heating

Screening method for test conditions



For different types of cells, it is desirable to get a function of the heating power related to the energy and weight of the cell to ensure the good repeatability of initiation and control the energy introduced into the system.

$$P_{heat} = f(E_{cell}, m_{cell})$$

Research of test parameters of heating

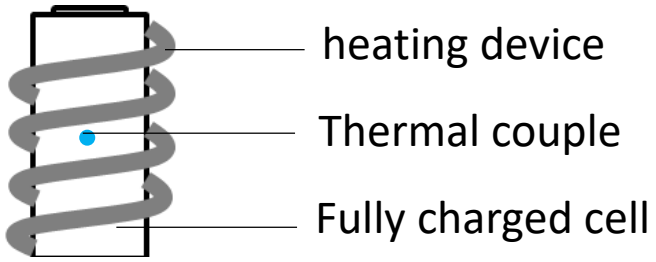
We plan to conduct testing and research on 15 products.

18650 Cylindrical		21700 Cylindrical		Pouch		Prismatic	
LFP	NCM	LFP	NCM	LFP	NCM	LFP	NCM
1#	2#	/	4#	6#	8#	11#	13#
/	3#	/	5#	7#	9#	12#	14#
/	/	/	/	/	10#	/	15#

Research of test parameters of heating

Research progress

- Heating conditions for cylindrical cells



18650-3.0Ah-10.95Wh			
Heating power	80W	100W	120W

Research of test parameters of heating

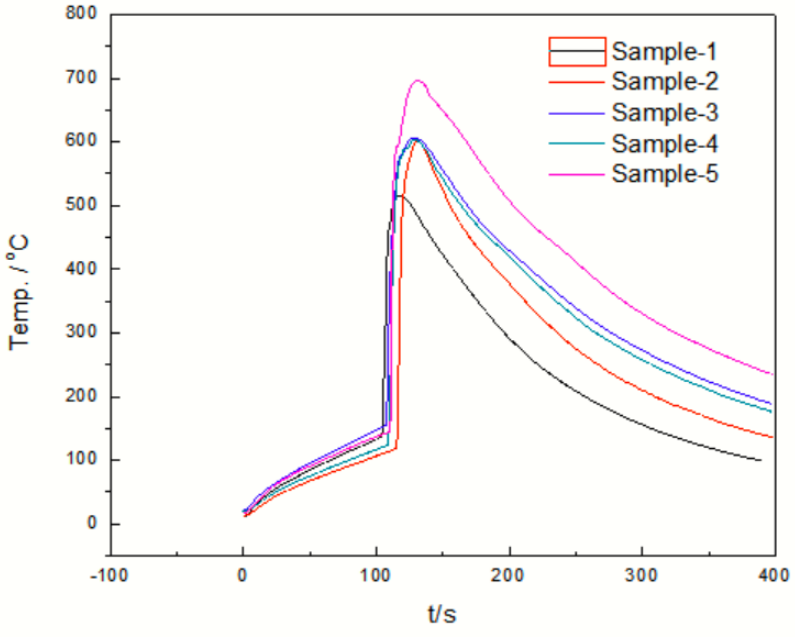
Research progress

Item	18650-3.0Ah-10.95Wh-80W			18650-3.0Ah-10.95Wh-100W			18650-3.0Ah-10.95Wh-120W			More heating power conditions
No.	Heating time/s	Trigger temp./℃	Introduced energy/Wh	Heating time/s	Trigger temp./℃	Introduced energy/Wh	Heating time/s	Trigger temp./℃	Introduced energy/Wh	
1	108.00	116.60	2.40	66.00	148.00	1.83	70.00	165.60	2.33	
2	107.00	160.70	2.38	62.00	140.50	1.72	77.00	199.20	2.57	
3	110.00	145.30	2.44	96.00	185.20	2.67	50.00	117.10	1.67	
4	104.00	133.30	2.31	96.00	197.20	2.67	87.00	227.30	2.90	
5	106.00	150.20	2.36	fail			80.00	189.80	2.67	
Standard deviation	2.24	16.92	0.04	18.55	27.72	0.45	14.13	41.43	0.42	
Average	107.00	141.22	2.38	80.00	167.73	2.22	72.80	179.80	2.43	
Standard deviation coefficient	0.02	0.12	0.02	0.23	0.17	0.20	0.19	0.23	0.17	

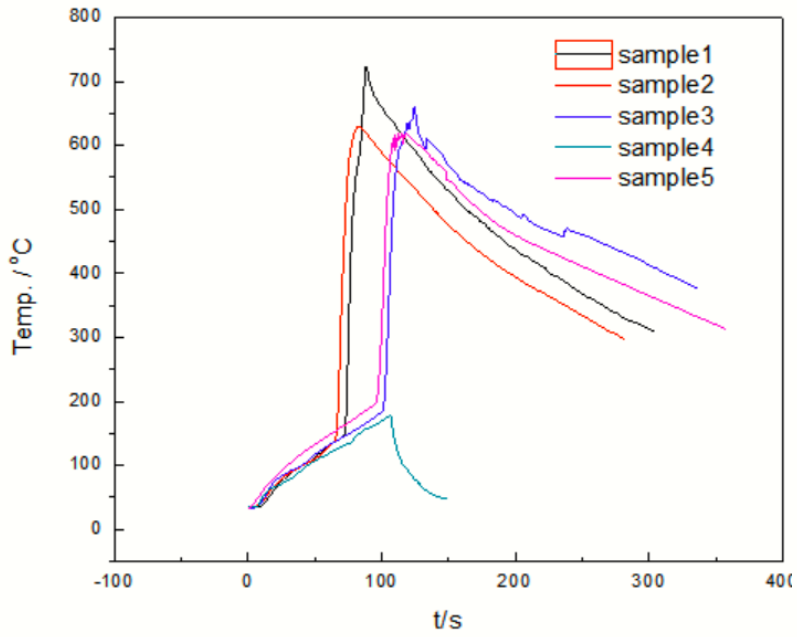
More tests to do to get the best conditions

Research of test parameters of heating

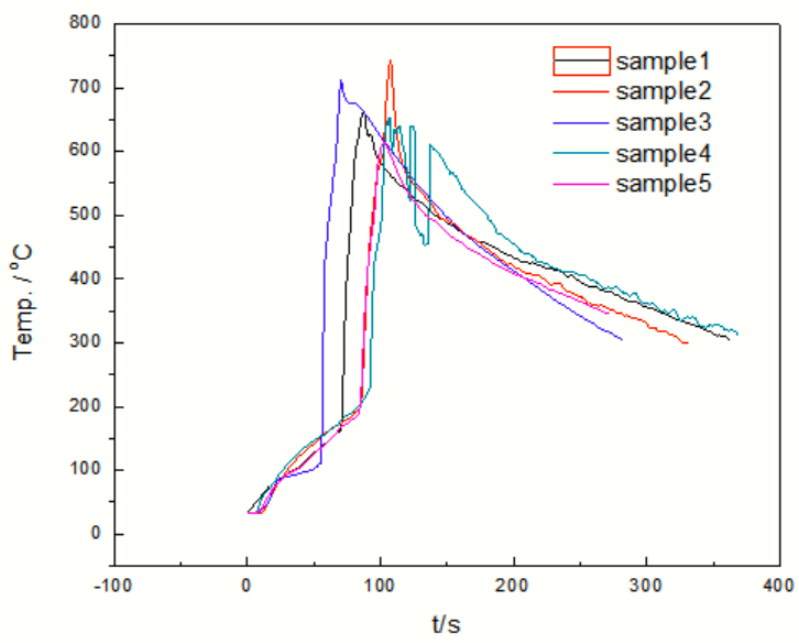
Research progress



80W



100W

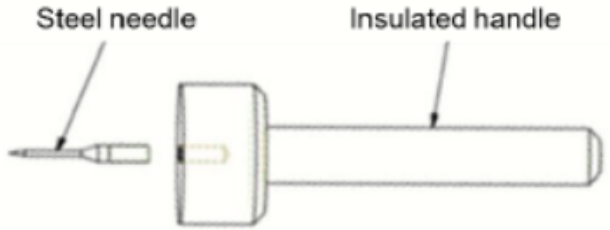


120W

Potential new methods for initiation

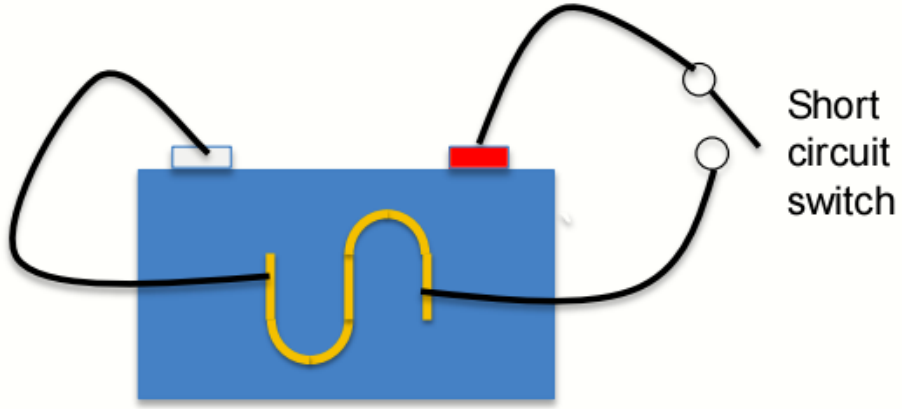
- Trigger method is another key issue to be solved and has been picked out through years of discussions for EVS-GTR.
- Much work continuing on test development in CATL, such as：

Method1：Precise Controlled Internal Short Circuit(PCISC)



- Perform this test with a needle(material: stainless steel, with a diameter of 1mm and a cone shaped tip, tip angle 20^0)，the rate of penetration shall be 0.1mm/s or less
- PCISC has been proposed to IEC-62660-4 as the test procedure to simulate internal short circuit
- We are also studying PCISC as a trigger method for thermal propagation test

Method2：Self-Heating

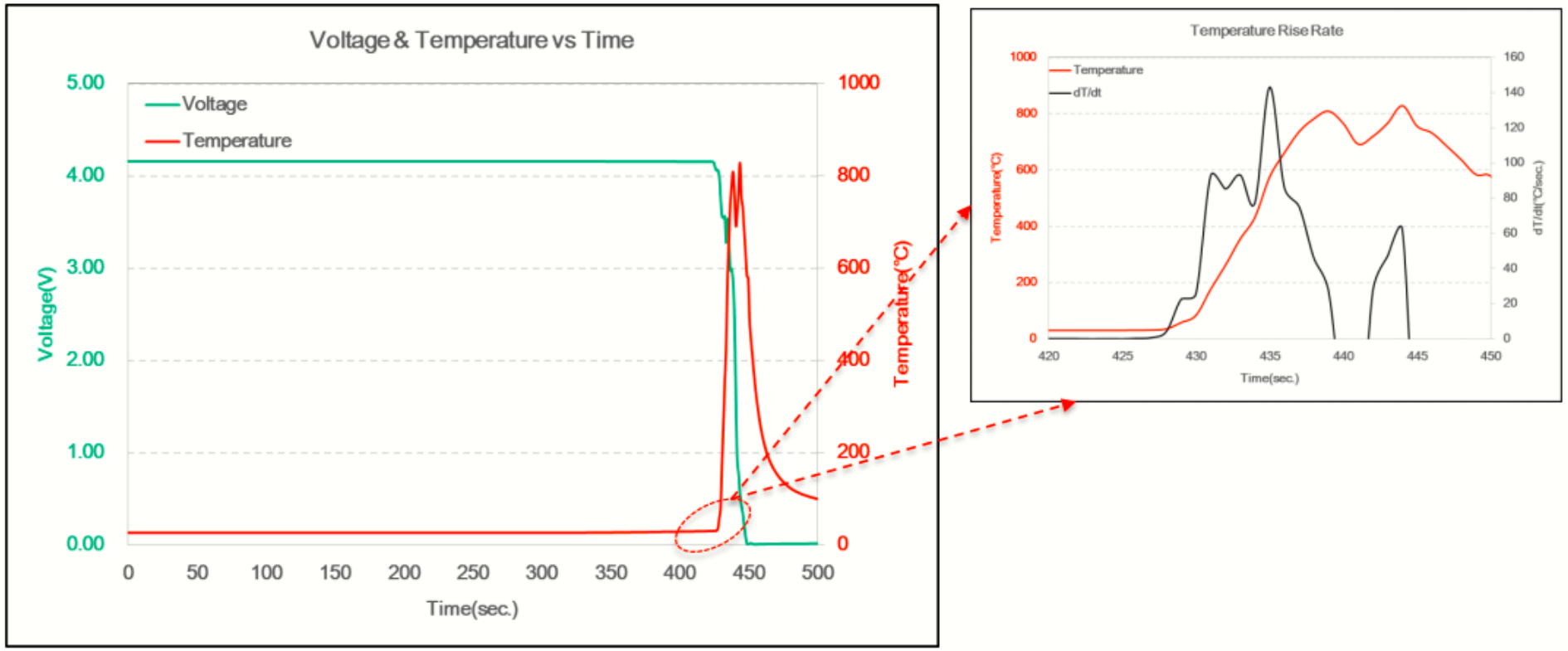


- Simulated a local short circuit
- The additional energy is controlled by the heat resistance

Potential new methods for initiation

Example：Propagation Test Triggered by PCISC

- Test Procedure: Φ1mm, 0.1mm/s, nail the cell until thermal runaway



- The temperature rise rate was >>1℃/s, so the cell had thermal runaway.

Recommendations on evaluation criteria of thermal propagation

Evaluation Criteria

1. No thermal runaway after initiation pass
2. No propagation at all pass
3. Total containment pass
4. Egress test

The objective is sufficient egress time. This can vary for different vehicles.

We can study the sufficient egress time for different types of vehicles according to the research method in Phase I.

“hazardous situation”should be quantitatived or proofed more clearly.

Thanks for your attention!