# TF5-Thermal propagation

Tokyo, Japan

2016/03/01

- Technical rationale and justification
- Initiation of the thermal runaway
- Difference between the two proposals
- Other questions
- suggestions for next step

## Technical rationale and justification

Thermal propagation is generally known as one of the mechanisms that may lead the lithium ion battery system to safety critical situations, such as fire or explosion, which is dangerous for vehicle occupants.

We all agreed the importance and necessity of doing the test in the past meetings.

For this assessment, we all agreed that the DUT should be a vehicle or system level.

thermal propagation is only applicable for the cells that contain flammable electrolyte.

## Definition of the term of thermal runaway

◆ Japan:

"**Thermal runaway**" means the phenomena of uncontrollable heat generation with continuous temperature rise caused by exothermal chain reaction in the cell.
热失控：电芯内部放热链反应引起的持续温升的发热失控现象

◆ OICA:

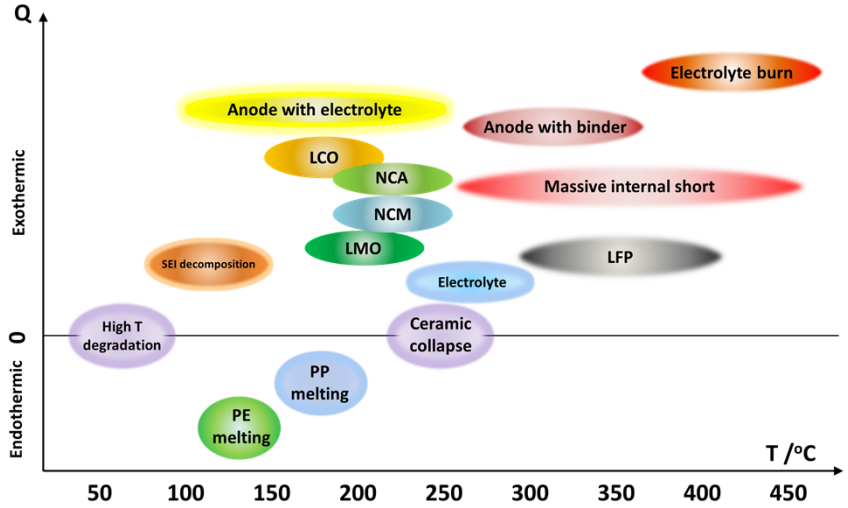
"**Thermal runaway**" means uncontrolled temperature rise of a cell caused by cylindrical exothermic chain reaction in the cell.
Thermal runaway is characterized by a distinct rapid change in rate of temperature rise over a short time period, rather than a single steady temperature rise."
热失控：电芯放热连锁反应导致电芯的失控温升**(温升速率)**

◆ China:

"**Thermal runaway**" means sudden increase of cell temperature rise rate caused by exothermic reactions inside the cell.热失控：电芯放热反应导致电芯的温升速率的急剧变化**(温升速率**dT/dt**的变化率达一个数量级)**

# Lithium ion cell thermal runaway mechanism

- Exothermic temperature range and heat release rate of materials inside the cell

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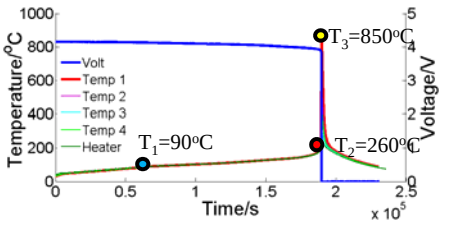
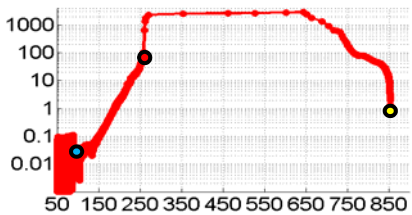
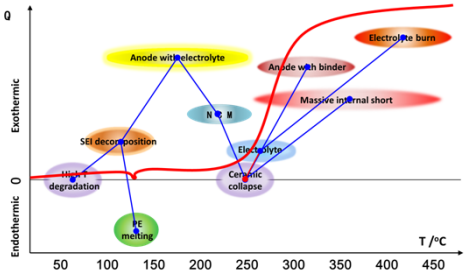
# Lithium ion cell thermal runaway mechanism

- NMC ternary cell

$$Q_{TR} = M \times C_p \times \Delta T_{3-2}$$
$$= 0.720 \times 1100 \times (850 - 260) = 467280J$$




Feng, X., Fang, M., He, X., Ouyang, M., Lu, L., Wang, H., Zhang, M., Thermal runaway features of large format prismatic lithium ion battery using extended volume accelerating rate calorimetry, Journal of Power Sources 255 (2014) 294-301

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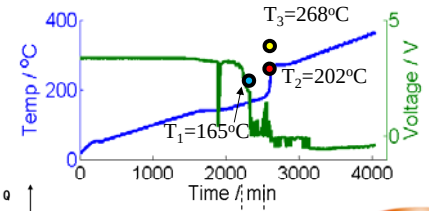
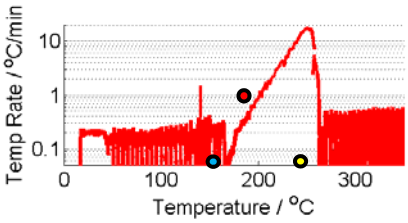
# Lithium ion cell thermal runaway mechanism

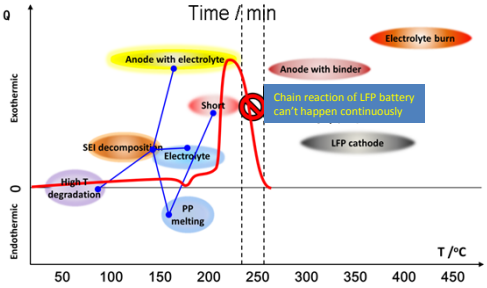
➢ LFP cell

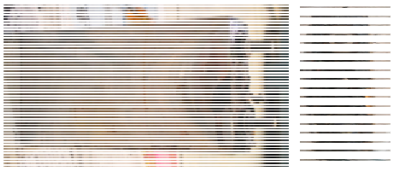
$T_1$: Self heating starting point temperature
$T_2$: Trigger temperature of thermal runaway （dT/dt>1°C/min）
$T_3$: Highest temperature of thermal runaway

$$Q_{TR} = M \times C_p \times \Delta T_{3-2}$$
$$= 0.393 \times 1100 \times (268 - 202) = 28532J$$



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# Definition of the term of thermal propagation

◆ Japan（OICA agrees）

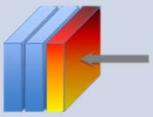
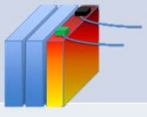
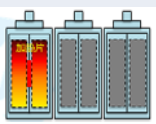
"**Thermal propagation**" means the sequential occurrence of thermal runaway within a battery system triggered by thermal runaway of a cell in that battery system.
热扩散：电池系统中一个电芯的热失控触发该电池系统中其他电芯的持续热失控的现象

◆ China also agrees on this definition

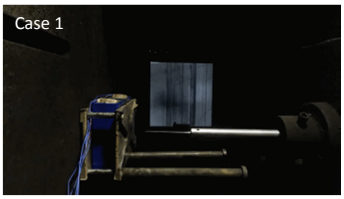
## Initiation method for thermal runaway

- choice of nail prick test and partial heating test, and also other methods
- rationale of the initiation device specifications,
- threshold parameters to confirm occurrence of internal short circuit
- priority in the selection of the cell to initiate internal short circuit,

## Method to initiate the thermal runaway

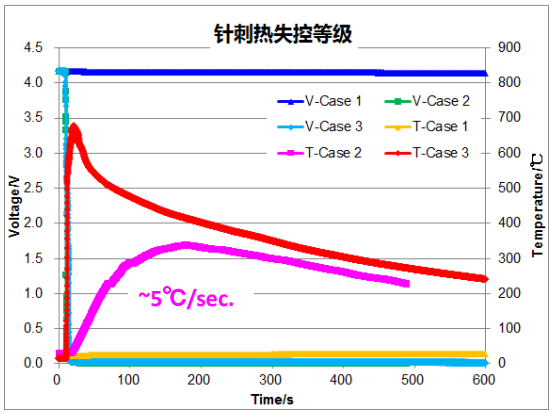
| Method | Test procedure | Sketch Map |
|---|---|---|
| Nail penetration | 用直径>8mm的钉子刺穿电芯(单电芯或并联电芯), 使其发生内部短路而引发热失控<br>Penetrate a test cell with D>8mm nail, make it internal short circuit happening to initiate the thermal runaway. |  |
| Heating | 一定功率的加热板紧贴测试电芯，通过功率发热将电芯加热到一定温度后导致其失控<br>Cling heater to a test cell closely, heat it to initiate the thermal runaway.<br>需要确认加热板的材质、加热功率、散热状况<br>Confirm the heater material, power, and thermal dissipation. |  |
| Overcharge | 对测试电芯施加1C倍率的电流，直至电芯发生热失控或其他阻碍发生<br>Overcharge a test cell with 1C current to initiate the thermal runaway or other safety issues happening. |  |
| Others | 例如：电芯内部内置发热装置，可以熔化隔膜使得电芯发生内短路<br>Examples: Embed the heater inside a cell, make it internal short circuit happening to initiate the thermal runaway by the melt membrane. |  |

## Method to initiate the thermal runaway - nail penetration

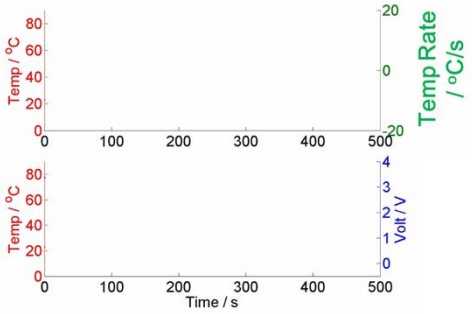


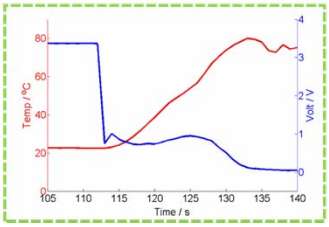



Different test result caused by thermal runaway




## Method to initiate thermal runaway - nail penetration

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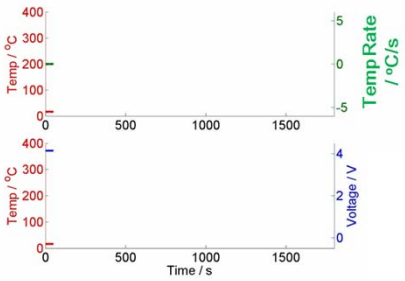
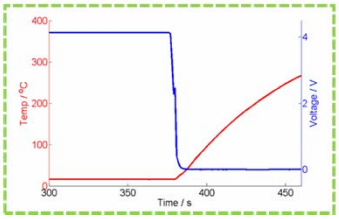
## Method to initiate thermal runaway - nail penetration

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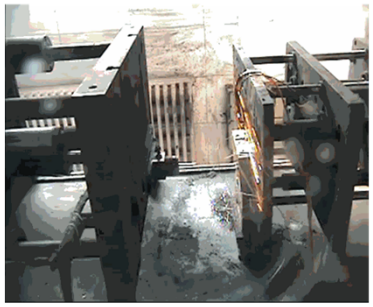
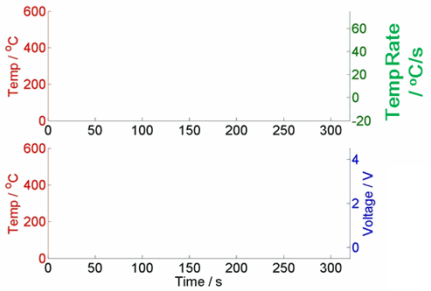
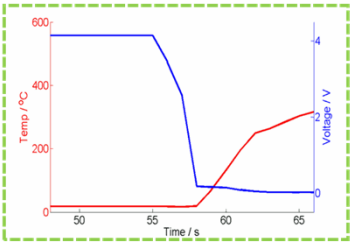
## Method to initiate thermal runaway - nail penetration



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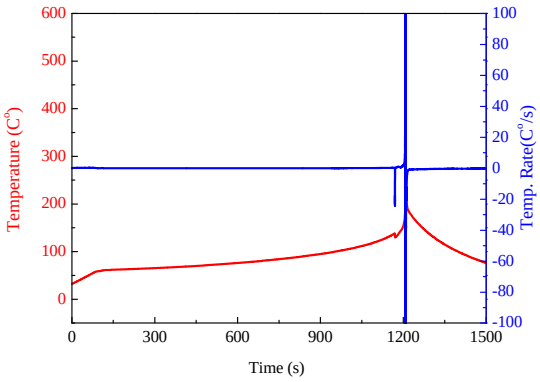
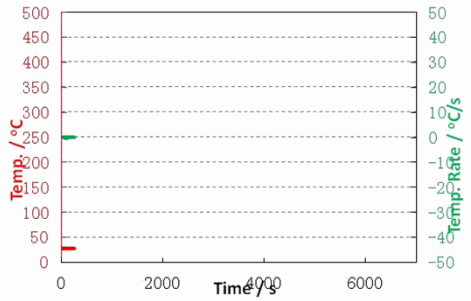
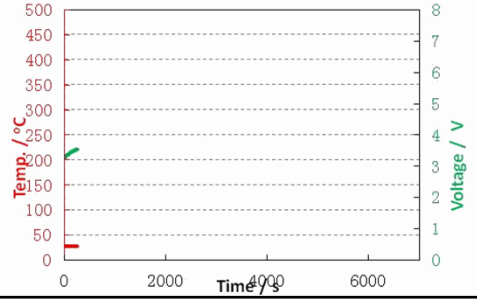
## Method to initiate the thermal runaway - heating




## Method to initiate the thermal runaway - overcharge

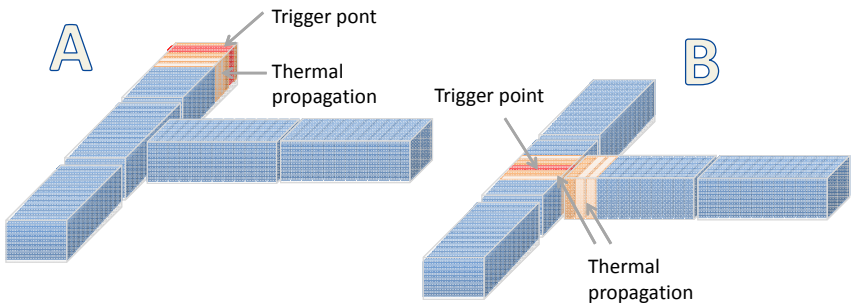



## Method to initiate the thermal runaway

- industry is familiar with their products, so the choice just can be done by them
- The value of DT/dt may different from different battery chemistry when the thermal runaway happens.
- The rapid increase of DT/dt is obvious when the thermal runaway happens.
- The value of DT/dt after the thermal runaway is 10 times more than that of the DT/dt before the thermal runaway.
- Define the start point of the thermal runaway: the change rate of (DT/dt )≥10

## Test procedure of the thermal propagation




- Different trigger point may cause different test result
- easy to conduct the initiation method,
- the cell is surrounded by other cells and its heat generated by thermal runaway most easily to propagate to adjacent cells.
- the cell that is the nearest center of battery casing or the cell that is surrounded by other cells and difficult to radiate heat.

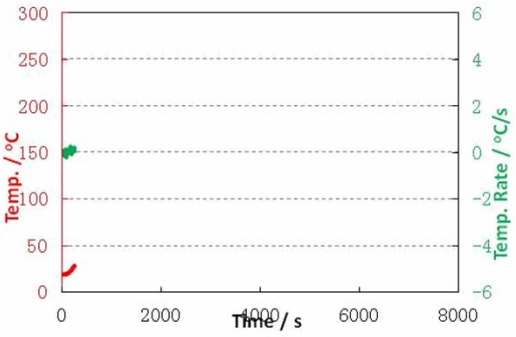
## Test procedure of the thermal propagation

- Fire, following the thermal runaway happening.

Play at 30× after nail penetration

## Test procedure of the thermal propagation

- Smoke, w/o the thermal propagation happening




## Suggestions on test method of the thermal propagation

- Method of the thermal runaway initiation

  Choose the test method according to the test samples (See the test procedure)
- Where is the exact start point of the thermal runaway?

  Rapid increase rate of dT/dt (≥10)
- What's the requirements of the thermal propagation?

  No fire, no explosion(except the trigger cell)

## Difference between the two proposals

Modification of proposal based on the Brussels meeting.

1. Definition
2. Add "NOTE Fire caused by the first cell is acceptable because its thermal runaway event is intentionally triggered for the test purpose."to 5.3.x
3. Add one choice of Initiation method: overcharge
4. Modification of "Stop of Initiation"
5. Initiation method is selected by the supplier according to types of cell.

## Other questions

influence of the modifications of the tested device by installing the initiation mechanism,
Every issue is unique. We just try our best to keep the consistency of the test device and decrease such influence.

fairness of single cell short circuit disregarding the divergence in the number of cells in a REESS (around 13 cells to 7000 cells.),
No matter how many cells used inside the system, the safety of pack need to be assured. So the requirement is the same. If you want to use more cells, you need to think more about the safety design.

## Suggestions for next step

- During Check the test procedure and rationale
- Do the test according to the test procedure before next meeting
- Improve the test procedure

Thank you!