Japan Position for Thermal Runaway Initiation Method

EVS-GTR IWG Apr. 2023

<Items>

1, Japan Position for Initiation Method

2, Draft Proposal for Optional Initiation Method

3, Comparison Study of Initiation Methods

JAPAN AUTOMOBILE STANDARDS INTERNATIONALIZATION CENTER

- Japan points out that the issue which is different from what it used to be discussed in the past discuss. What is point of equivalence?

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- The requirement specified in GTR20 is below.

  “The vehicle occupants shall not be exposed to any hazardous environment caused by thermal propagation which is triggered by an *internal short circuit leading to a single cell thermal runaway*.”

⇩

- The point of equivalence is that the initiation method should cause *“single cell thermal runaway*”.

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- According to a comparison study (see later pages), though severity of thermal runaway and behavior of thermal propagation are different between the nail and heater, both methods can create single cell thermal runaway.

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- Japan believes that other methods should be allowed as optional initiation methods, e.g. "nail method".

■ Japan propose to add the following sentence (red text) to the JRC draft

6. Test procedures

Procedures

Test procedure

Carry out the following steps to implement this method at the vehicle level.
— Instrument the REESS as outlined above and connect all cooling/communication and high voltage lines and reinstall REESS into vehicle.

Connect to CAN-bus or other vehicle monitoring system to collect data about battery management system.
— Install video camera inside vehicle cabin to record video (dashboard/information screen) and audio (warnings) from vehicle during test if applicable.

— Perform multi-gas measurement according to "Recorded data and measurements" paragraph if applicable.
— Turn vehicle "on" and set it in the "parked" mode.
— Begin recording temperature and battery management system data.
— Begin sending power to the heating element.
— Open relay to heater after:
  — a predetermined maximum heating period, or
  — a total energy input to the heater that is > 20 % of initiation cell energy, or
  — after 5 min of heating if any active system is inoperable (for example cooling), or
  — earlier, based on thermal runaway detection criteria in the initiation cell given in "Detection of thermal runaway" paragraph.
— If a thermal runaway reaction occurs:
  — monitor and observe until the maximum temperature of all temperature measurements, drops below 60 ° C, then continue recording for an additional 2 h.
  — external vehicle-temperatures may be viewed through IR cameras.
— If a thermal runaway reaction does not occur:
  — monitor and observe for a minimum of 2 h.
—Wait 24 h with remote monitoring of test vehicle to ensure no further thermal reactions.

Current description

Optional initiation methods.

At the discretion of the manufacturer, any other initiation methods that can cause thermal runaway of the target cell satisfying the conditions specified in paragraph "Detection of thermal runaway" could be selected.
The vehicle/Tested-Device shall be observed for 5 minutes after providing the warning specified in 5. Performance requirements.

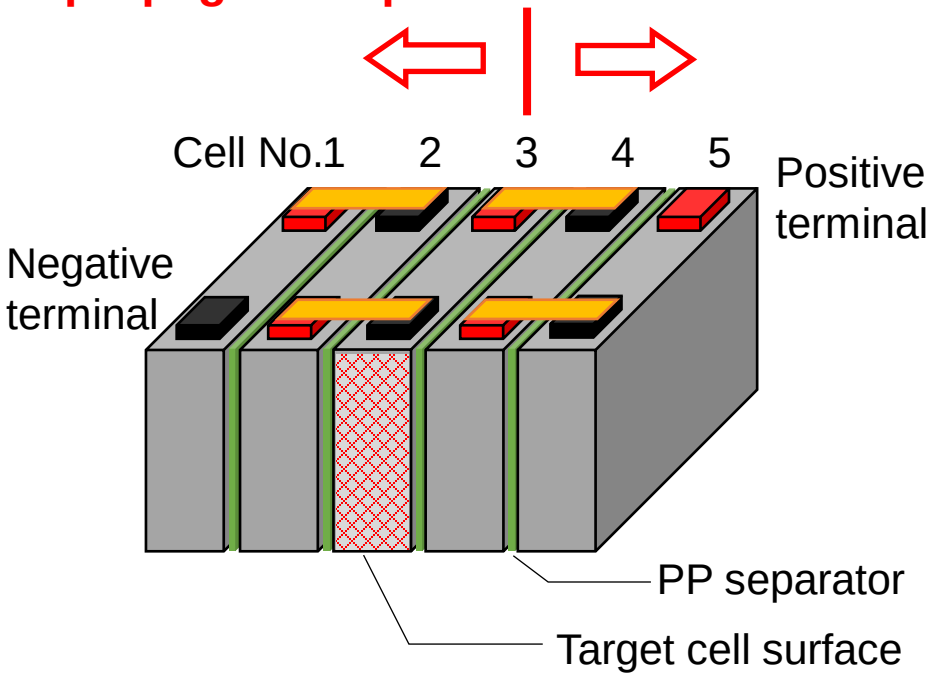
Additional proposal

■ Test module and Target cell selection

- ✓ 5-cell stacked module
- ✓ Target cell : center (No.3)
- ✓ Target face : Narrow side

Cell type	Prismatic
Cell voltage	4.1 V
Cell case material	Aluminum
Cathode material	NCM
Anode material	Graphite

Worst case cell selection
(Thermal propagation spreads into two directions.)



Pass/Fail Criteria:

A warning should be provided more than 5 min. prior to hazardous situations.

Worst case scenario:

Maximum spreading of thermal propagation in 5 min. is expected.

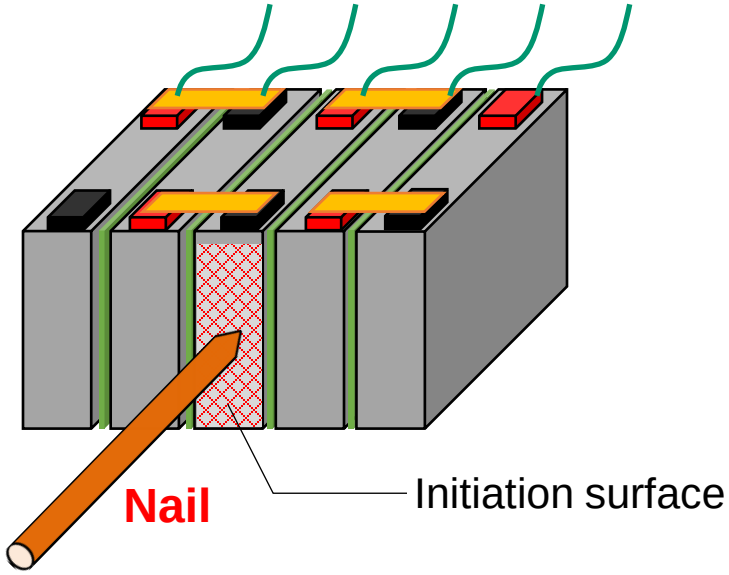
Cell selection: Center cell of the test module

■ Test conditions

Nail and heater initiation method are compared under same test conditions.
(Thermal runaway is initiated at the same location of same cell)

Nail method

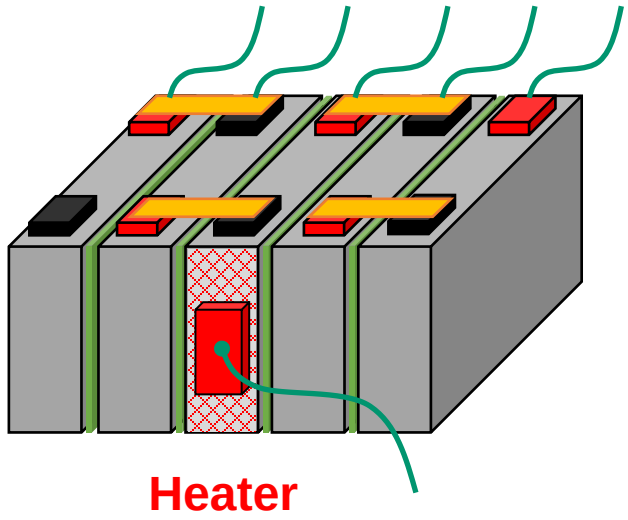
Cell temperature measurement
(backside of initiation surface)



Nail material	**steel**
Diameter	**3 mm**
Tip angle	**60°**
Speed	**1 mm/s**

Heater method

Cell temperature measurement
(backside of initiation surface)



Heater temperature control target 600°C
(Temperature measurement at the back of the heater)

Issue **: Weak thermal contact between the cell case and cell inside material → It takes more time and more energy input to cause thermal runaway.**

■ Test results _Nail method

Thermal runaway : Occurred

Thermal propagation : Not occurred

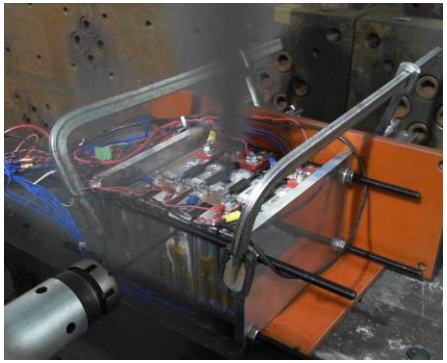
Events over time

21 s	The cell safety valve opened
24 s	dT/dt > 1C°/s ⇦ Thermal runaway
25 s	Nail stopped
26 s	Cell voltage < 2V

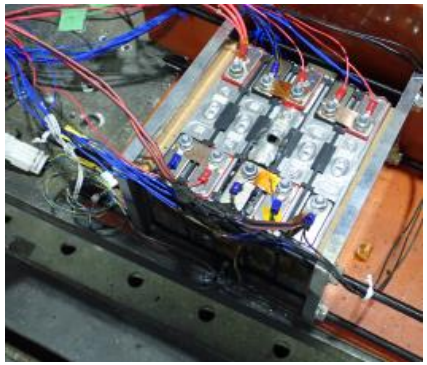
Energy input to the initiation cell : 39J

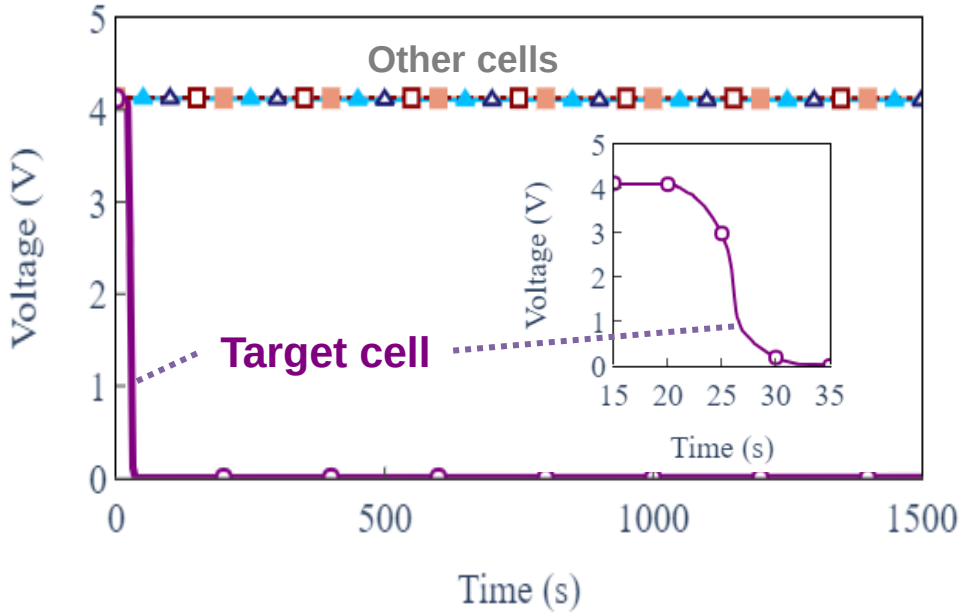
(Workload : Force[N] × displacement[m])

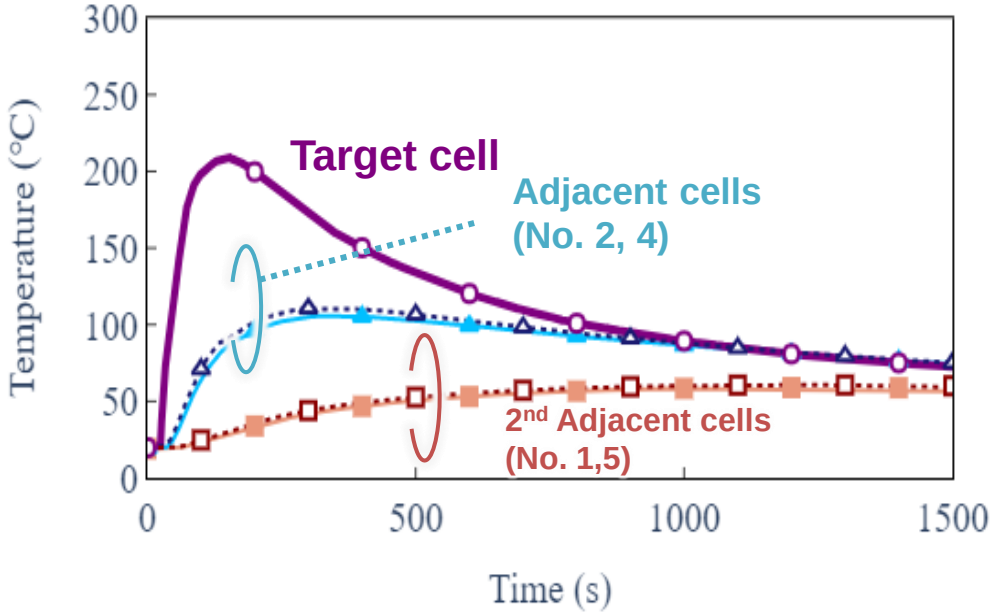
Thermal runaway



After test







■ Test results _Heater method

Thermal runaway : Occurred
Thermal propagation : Occurred

Events over time

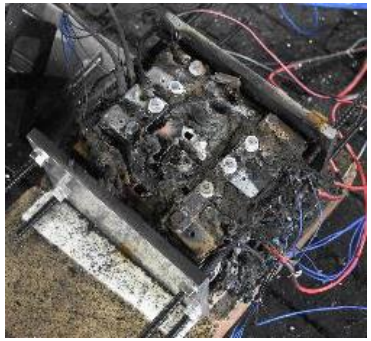
28 min **10** s	Cell safety valve opened
28 min **16** s	Cell voltage < 2V
28 min **17** s	dT/dt > 1C°/s ⇦ Thermal runaway
28 min **19** s	Heater power OFF
28 min **35** s	Thermal runaway of No.4 cell
29 min **13** s	Thermal runaway of No.2 cell
30 min **07** s	Thermal runaway of No.5 cell
30 min **45** s	Thermal runaway of No.1 cell

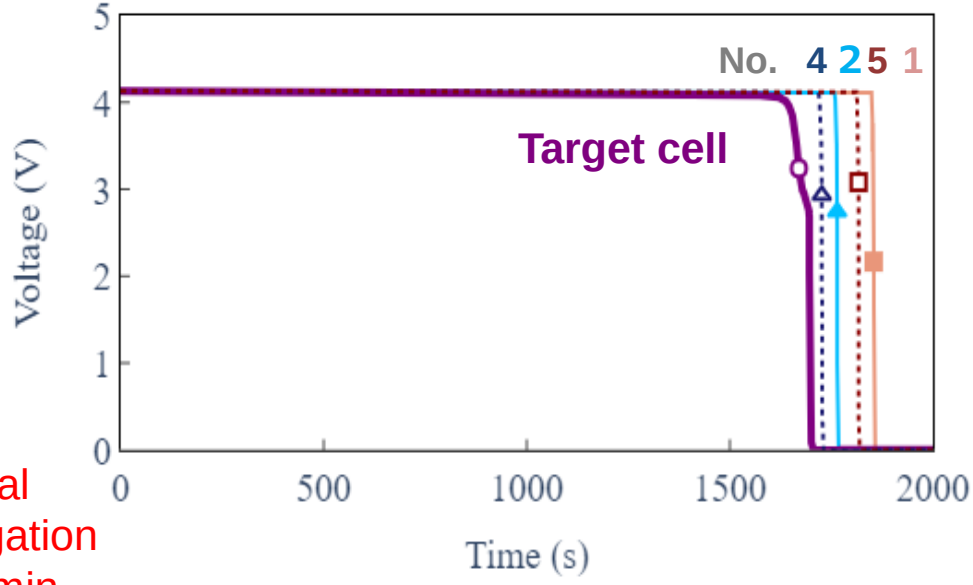
Thermal propagation in 2.5 min

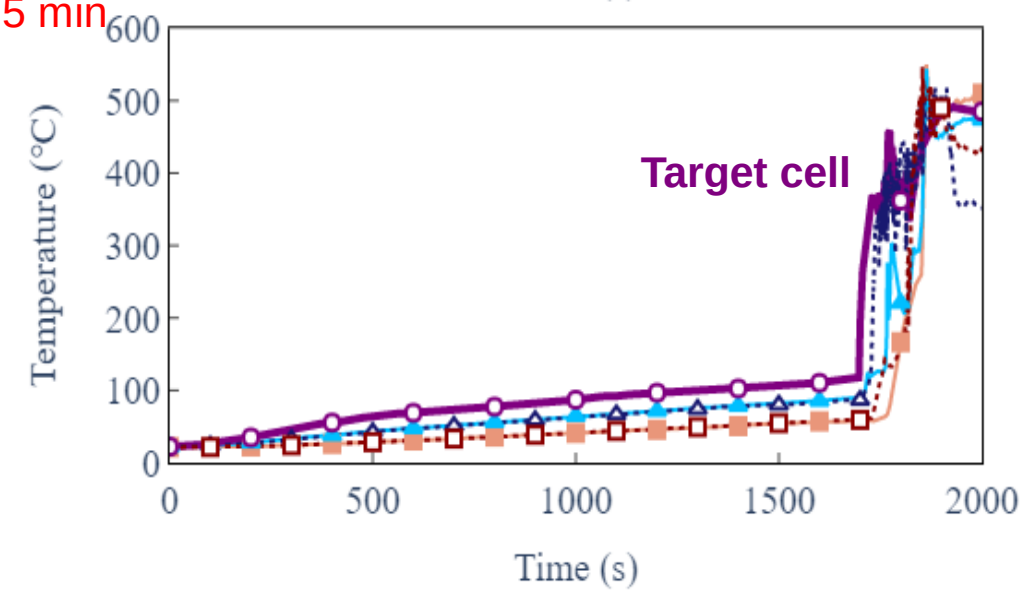
Energy input into the initiation cell : 410 kJ
≒ Energy of test cell (SOC100%)

Thermal propagation

After test





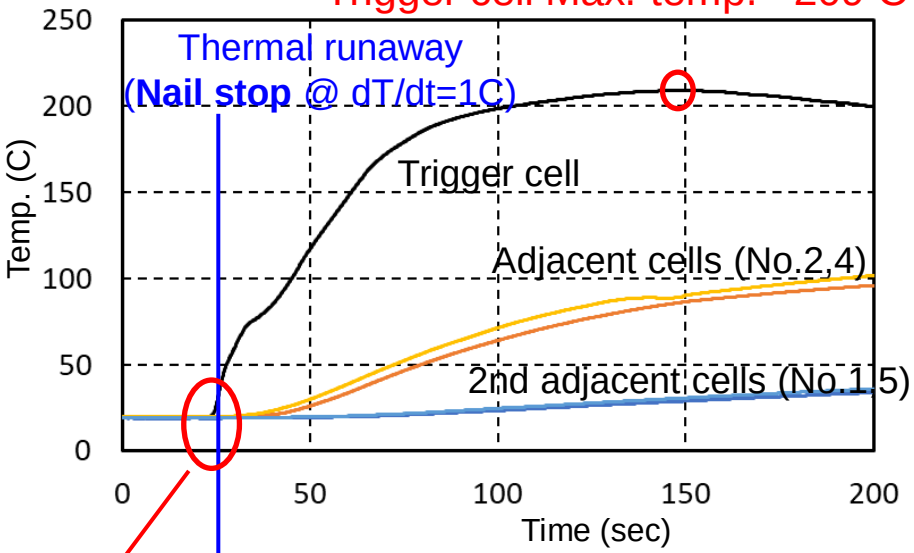


■ Comparison of test results _Cells' temp. and voltage

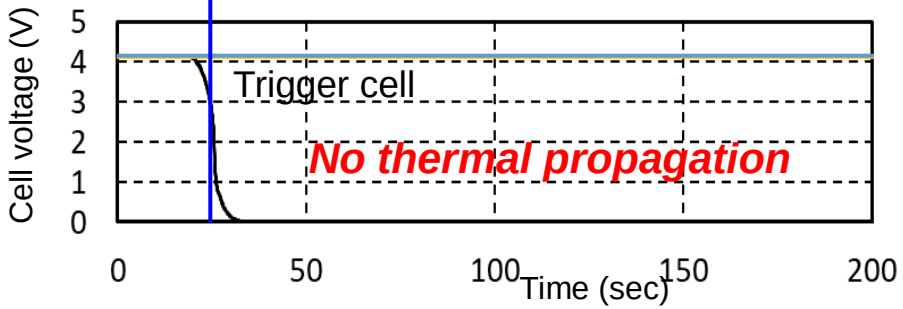
Nail method :	**Thermal runaway of target cell**	**→ No thermal propagation**
Heater method :	**Thermal runaway of target cell Prior temp. rise of adjacent cells**	**→ Thermal propagation**

Nail method

Trigger cell Max. temp.= 209 C

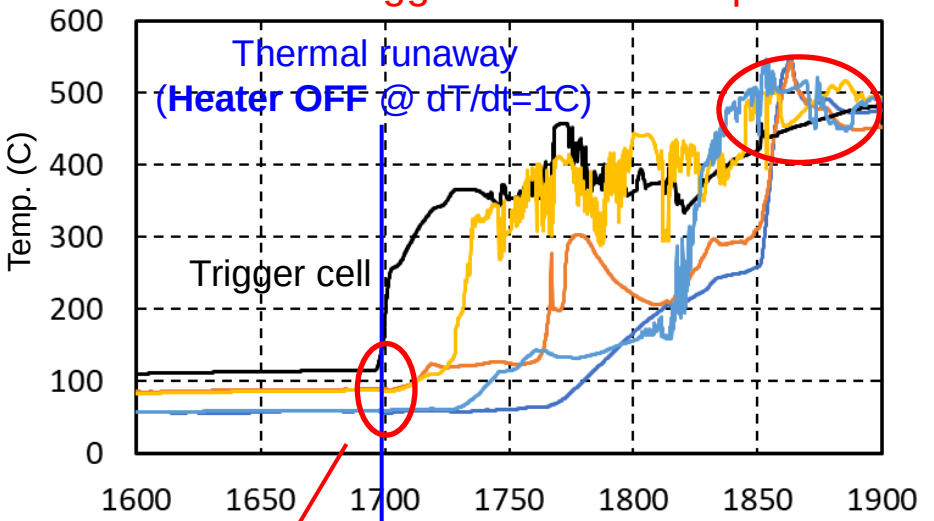


Trigger cell (No.3) : 23 C (start temp. 20C)
Adjacent cells (No.1,2,4,5) : 20 C

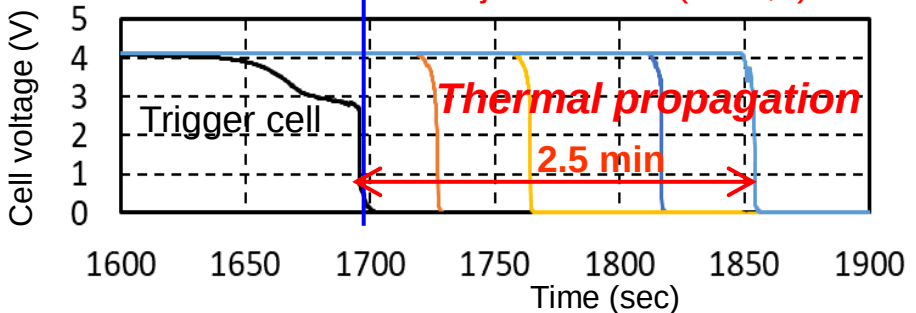


Heater method

Trigger cell Max. temp.≒ 500 C

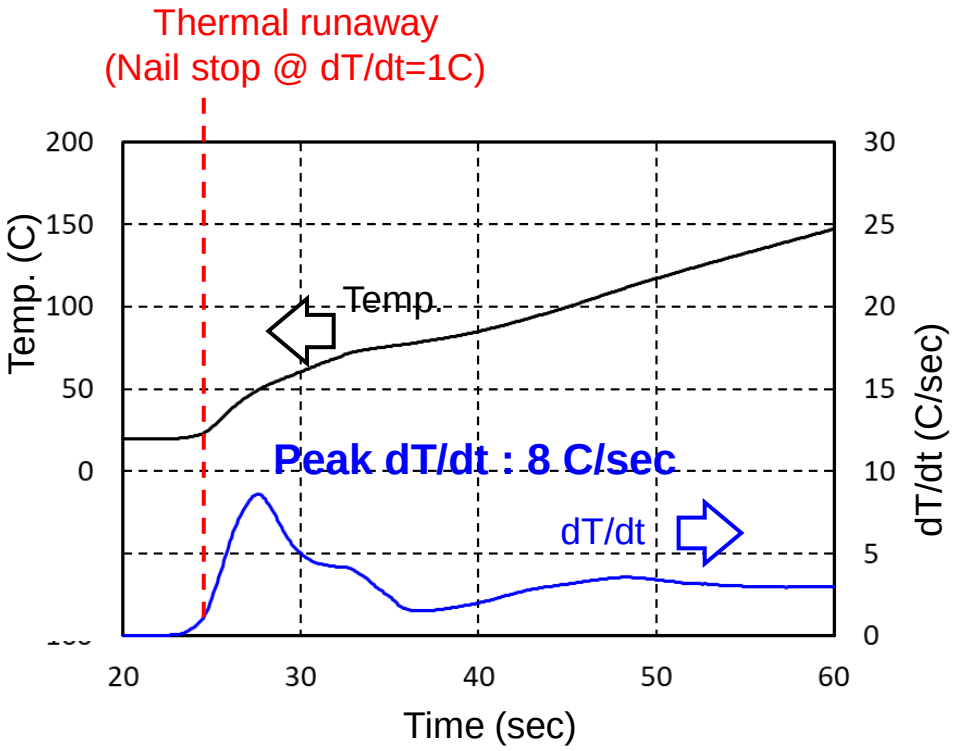


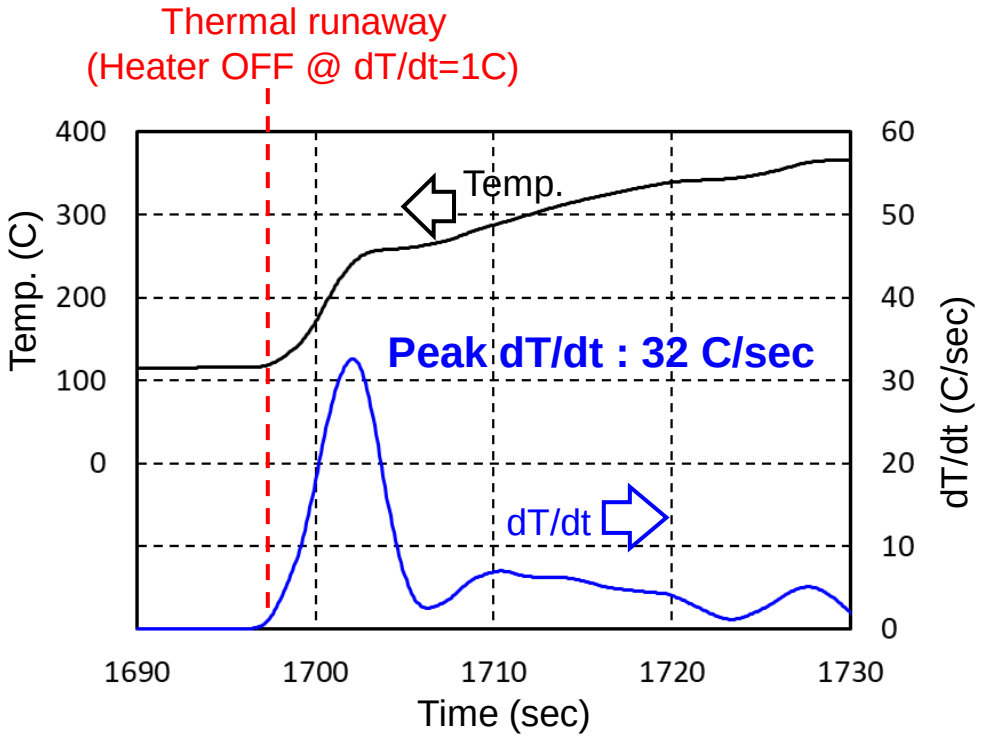
Trigger cell (No.3) : 112 C
Adjacent cells (No.2,4) : 90 C
2nd adjacent cells (No.1,5) : 60 C



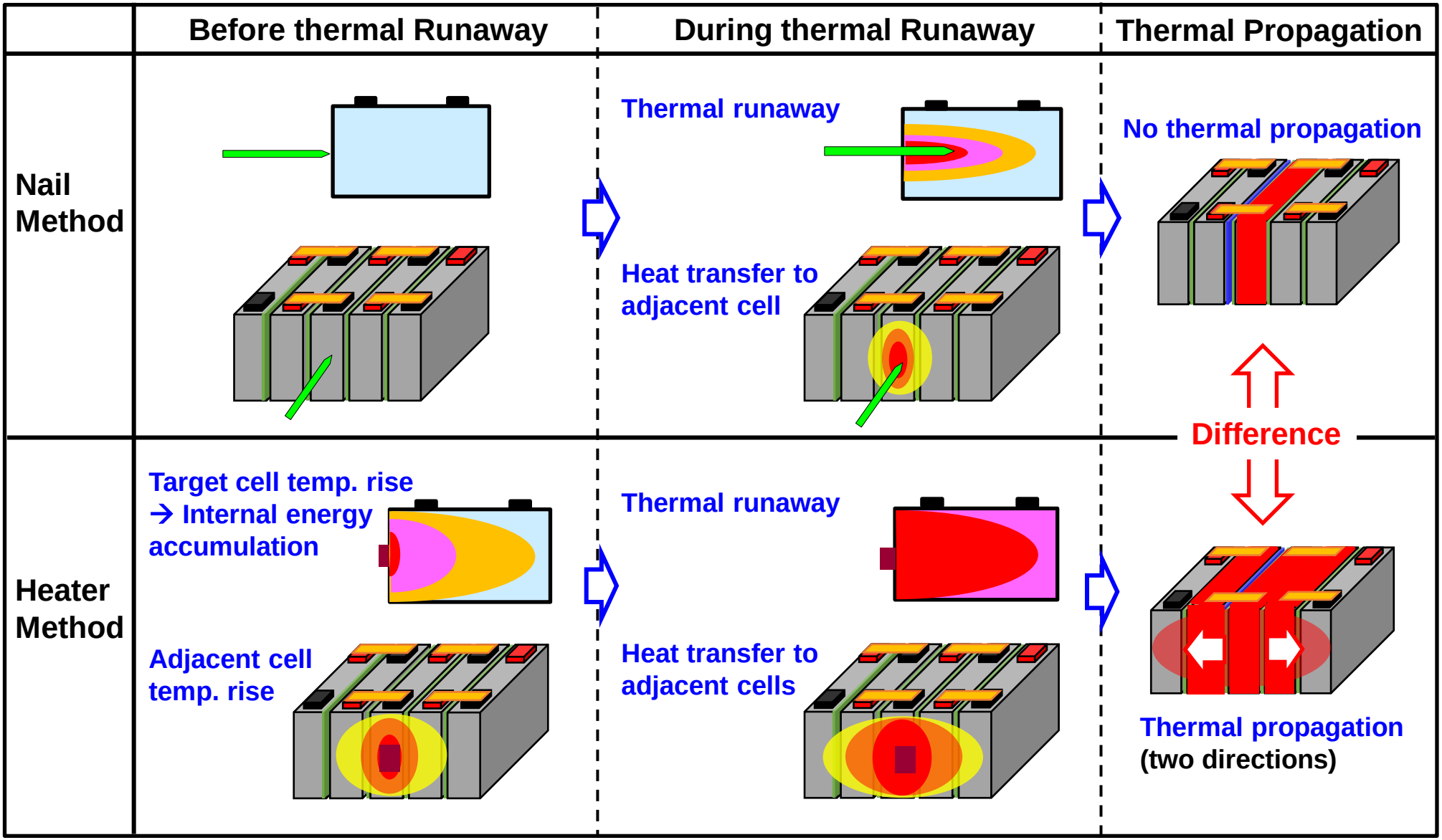
■ Comparison of test results _Trigger cell' dT/dt

Peak dT/dt	**Nail method : 8 C/sec** **Heater method : 32 C/sec**	**>**	**1 C/sec** **Criterion in JRC draft (=GTR20)**





■ Comparison of phenomenon (image)



■ Comparison summary

Though severity of thermal runaway and behavior of thermal propagation are different between the nail and heater, thermal runaway can be initiated with both methods.

Items		Nail	Heater
Thermal runaway (Target cell)		**Yes**	**Yes**
Criteria (JRC Draft)	Voltage drop > 25% of initial voltage	**Yes**	**Yes**
	Temperature > Maximum operating temperature	**Yes**	**Yes**
	dT/dt ≥ 1 °C/s at least 3s	**Yes**	**Yes**
Thermal propagation		No	Yes
Target cell	Max. temp. (℃)	209℃	≒ 500℃
	Temp. just before trigger cell thermal runaway (℃)	20℃	112℃
	Max. dT/dt (℃/sec)	8℃/sec	32℃/sec
	Input energy (J)	39J	410kJ
Adjacent cell	Temp. just before trigger cell thermal runaway (℃)	20℃	90℃
	Max. temp. (℃)	110℃	≒ 500℃