UN IWG Thermal Propagation Test Report

2020. 11. 20

KOREA

BACKGROUND

Thermal propagation test procedure and details of the test parameters that need to be specified are under discussion in UN IWG meeting, and influences of parameters need to be clarified by testing and evaluation.

Korea participants have planned to evaluate that how several test parameters affect test results and should be determined for the clarification based on the intended purpose. Total 5 models(Pouch type: 2 models, Prismatic type: 2 models, Cylindrical type: 1 model) chosen according to cell type and chemistry are tested, and closed type case with venting hole, cartridge heater controlled by constant heating rate are specifically formulated to realize this test procedure.

Test parameters that need to be specified are

- SOC (20, 30, 50%)
- Case type (Closed type, Opened type)
- Heating rate (20, 100℃/min, rapid heating)

All test results are analyzed to figure out the influence of each parameters through measured voltages, temperatures and visual inspection.

Thermal Propagation Test Procedure

❑ Experimental Setup

- This test is conducted for evaluating thermal propagation between 6 cells inside thermal insulation box when one single cell goes into thermal runway by cartridge heater.
- Experimental setup is based on influence analysis of

1) Cell type (Pouch, Prismatic, Cylindrical), 2) SOC (20, 30, 50%) 3) Case type (Closed cover, Opened cover) 4)Heating rate (20, 100℃/min, rapid heating)

Pack 6 cells inside thermal insulation box, and attach cartridge heater on the initiation cell → Heat initiation cell at specified heating rate until thermal runaway is achieved. → The test sample shall be observed until it is stabilized up to an ambient temperature.

Figure 1. Closed type case

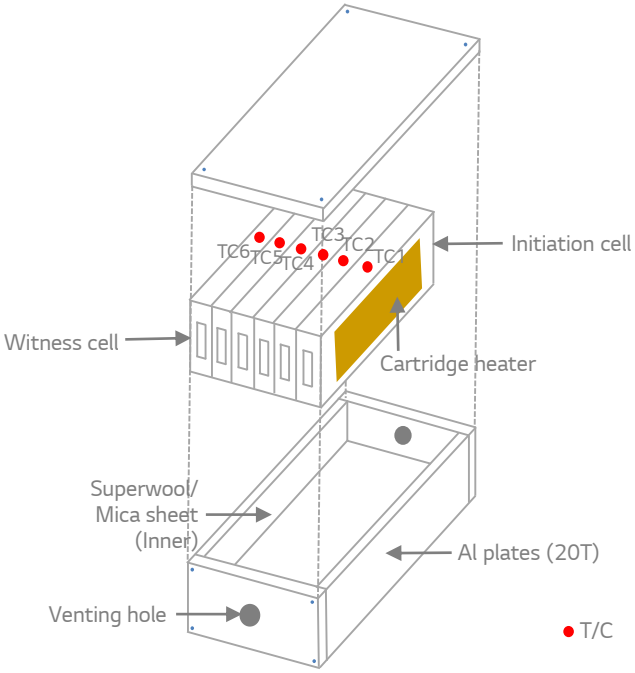


Figure 2. Opened type case

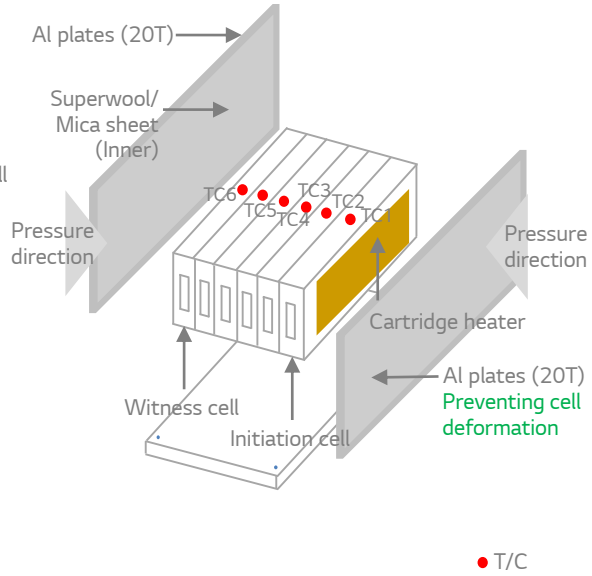


Figure 3. Experimental Setup

Cell type (Model)	SOC(%)	Case type	Heating rate (℃/min)
Pouch (A model) 60Ah	50%	Closed	20℃/min
	50%	Opened	20℃/min
	20%	Closed	20℃/min
	50%	Opened	100℃/min
	30%	Closed	20℃/min
		Opened	
Pouch (B model) 70Ah	50%	Closed	20℃/min
	50%	Opened	20℃/min
	20%	Closed	20℃/min
		Opened	
	50%	Opened	100℃/min
Prismatic (C model) 60Ah	50%	Opened	400℃/min
	20%	Closed	20℃/min
	20%	Opened	600℃/min
	30%	Closed	700℃/min
Prismatic (D model) 50Ah	50%	Opened	600℃/min
	20%	Opened	300℃/min
	30%	Opened	450℃/min
Cylindrical (E model) 5Ah	50%	Closed	290℃/min
	50%	Opened	320℃/min
	20%	Closed	348℃/min

Thermal Propagation Test Result – Influence analysis of SOC

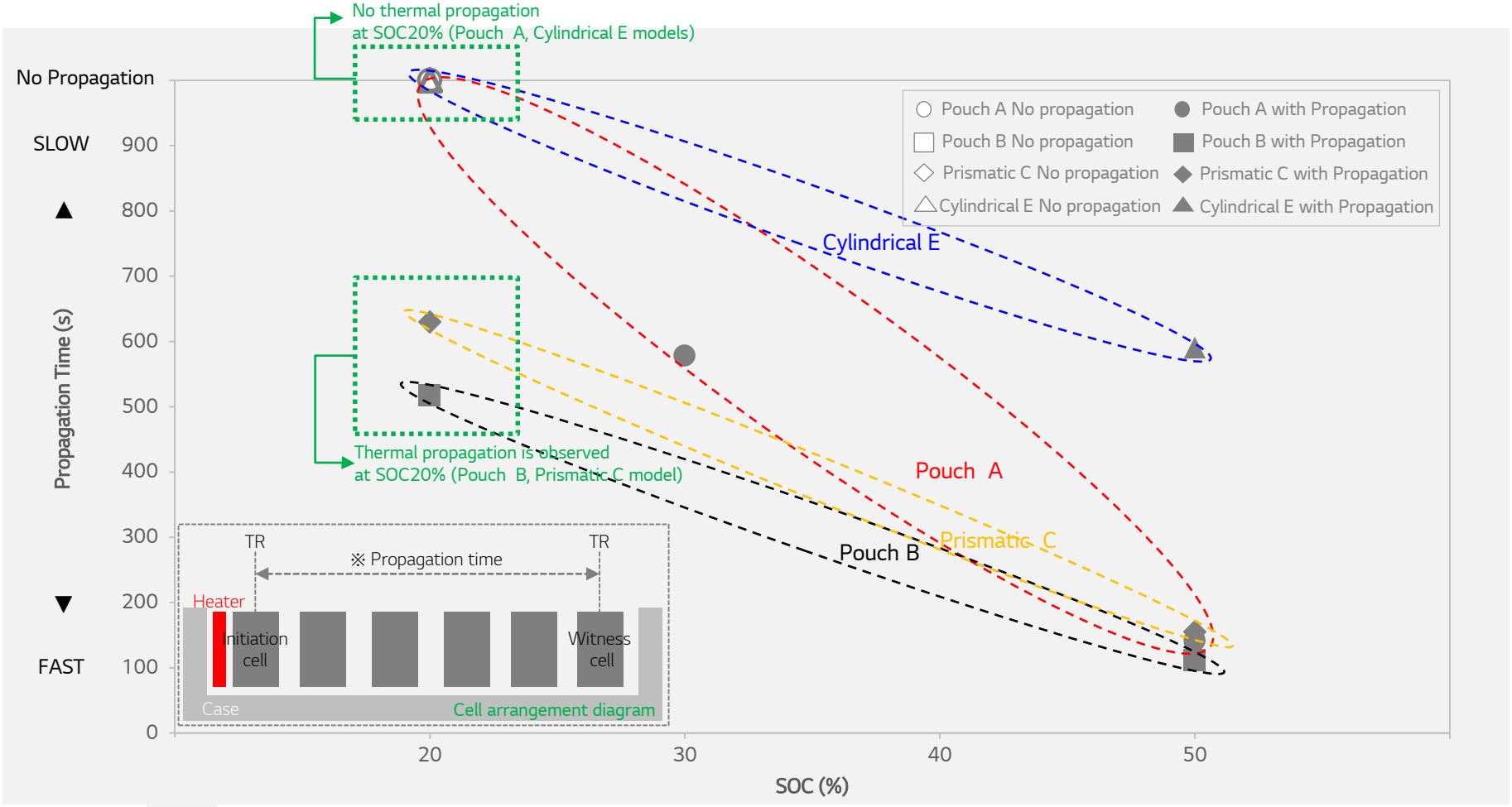
※ Please see appendix pages first if you don't understand the analysis result.

❑ Influence analysis of SOC (20/30/50%)

The lower SOC cells are conditioned, the more propagation time from initiation cell to witness cell is delayed. (SOC ↓ → Propagation time ↑)

Thermal propagation is commonly observed at SOC50% regardless of cell type and model, and test results at lower SOC tend to be varied.

→ Cells are not classified at over SOC 50% because they have the similar test result that thermal runaway is created on witness cell with gas emission or flame after propagation phenomenon.



※ Propagation time : Lead time from thermal runaway of initiation cell to thermal runaway of witness cell

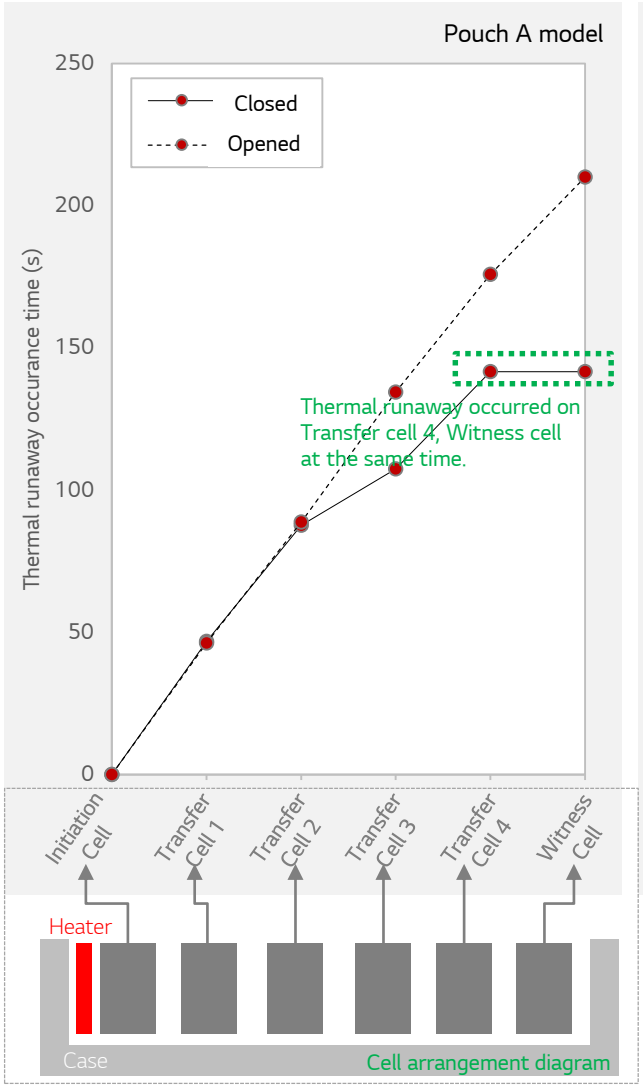
Thermal Propagation Test Result – Influence analysis of case type

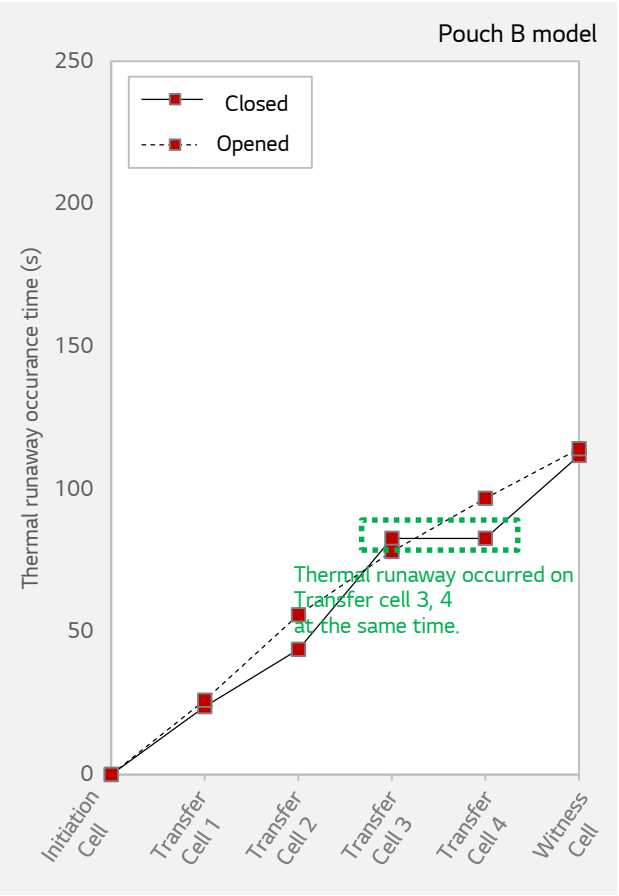
※ Please see appendix pages first if you don't understand the analysis result.

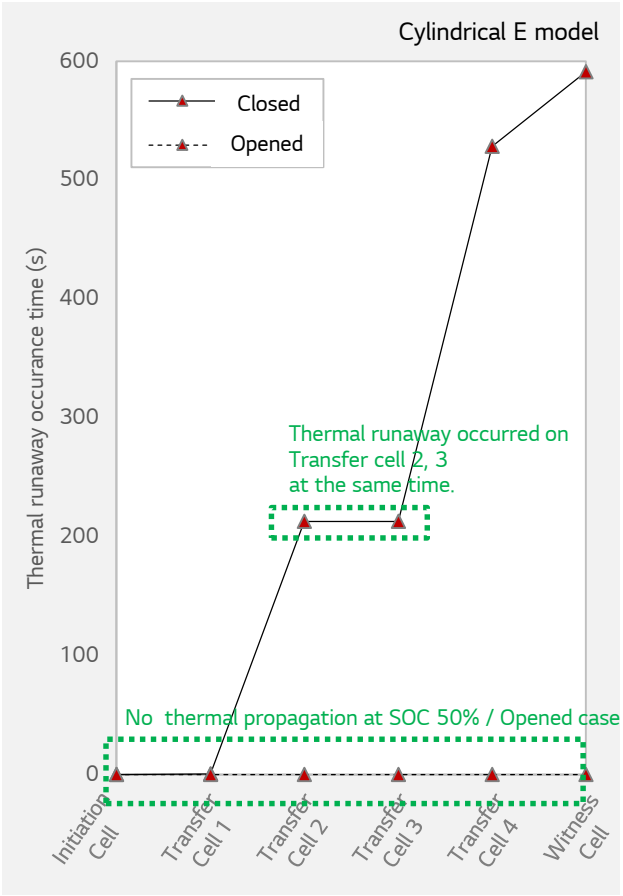
❑ Influence analysis of case type (Closed / Opened)

Thermal runaway is occurred at regular time intervals of each cells in opened type case of Pouch A, Pouch B model, whereas it is occurred at the same time in closed type case due to thermal insulation effect. Thermal energy released from multiple cells is accumulated in the closed box and affects one witness cell on thermal insulation environment of closed type case continuously, it is not realistic 'cell to cell thermal propagation'.

In Cylindrical E model, thermal propagation is affected by case type and there is no thermal propagation in opened type case. (SOC 50%)







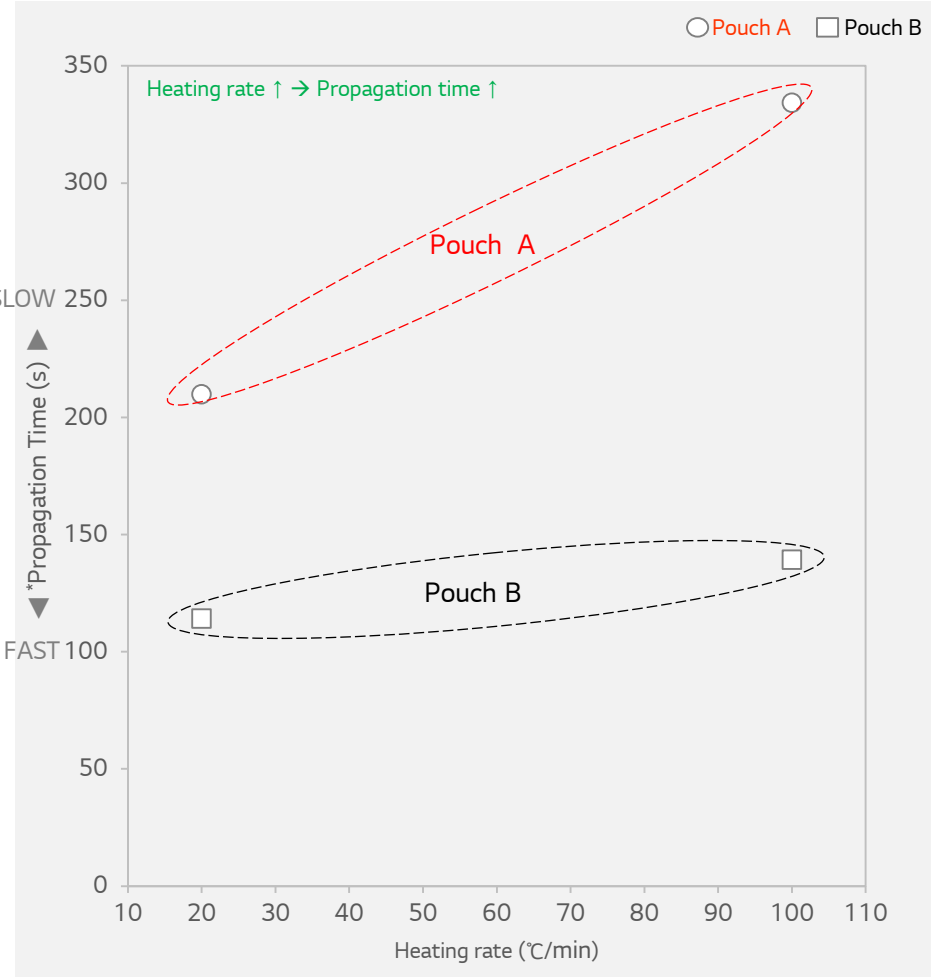
Thermal Propagation Test Result – Influence analysis of Heating rate

※ Please see appendix pages first if you don't understand the analysis result.

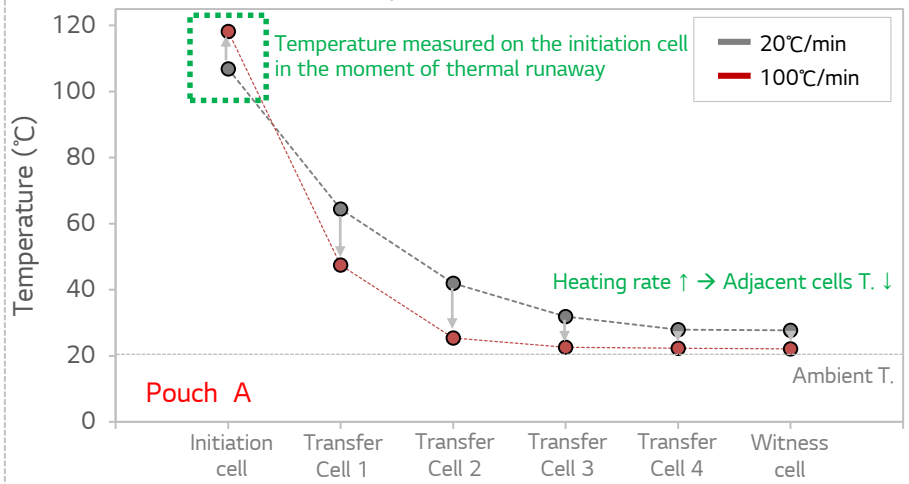
❑ Influence analysis of Heating rate (20, 100℃/min)

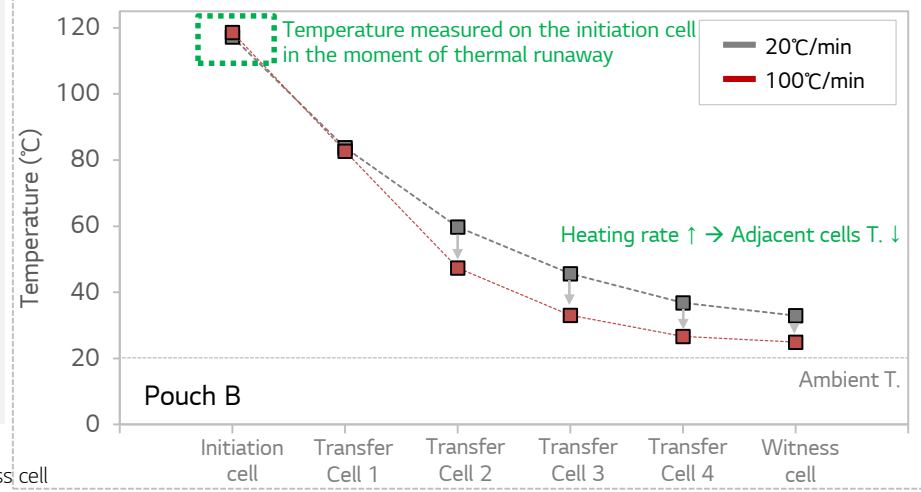
The higher the heating rate is specified, the more delayed propagation time is, because thermal energy released by cartridge heater has a continuous influence on adjacent cells until thermal runaway occurred on an initiation cell. Rapid heating rate has little influence on adjacent cells compared with slow heating rate, and temperatures measured on adjacent cells are relatively low at the moment when thermal runaway is achieved on the initiation cell.

※ All Temperatures recorded for influence analysis of heating rate are measured on the center of cell body.



■ Temperatures measured on adjacent cells in the moment of that thermal runaway of an initiation cell is created.





※ Propagation time : Lead time from thermal runaway of initiation cell to thermal runaway of witness cell

CONCLUSION

For verifying cell thermal propagation property and realizing battery safety level clarification based on the intended purpose, test parameters need to be specified like the below sheet.

Test parameter	Proposal direction	Rationale
SOC	SOC based on transportation condition (e.g. SOC 30%)	Cells are not classified at higher SOC in thermal propagation test because test results tend to be similar regardless of cell type, chemistry, thermal runaway is commonly created on witness cell with gas emission or flame if same experimental setup. Thermal propagation properties are varied according to SOC, and it should be conditioned by realistic simulation of transportation for practical risk levelling.
Case type (Closed / Opened)	Opened type case	Thermal runaway tends to be occurred on a couple of cells at the same time in closed type case due to thermal insulation effect, the reason is because thermal energy released from multiple cells affects one cell on thermal insulation environment of closed type case continuously. It is far from realistic simulation of thermal propagation.
Heating rate	Rapid heating (No limitation)	The test result shows that rapid heating by cartridge heater has less influence on adjacent cells compared with slow heating rate and it affects the test result(thermal propagation time). Heating rate influence needs to be considered for more reliable test performance.

Appendix 1. Thermal Propagation Test Result Summary

❑ Test Result Summary

Experimental Setup				Test result		
Cell type (Model)	SOC(%)	Case type	Heating rate (℃/min)	Thermal runaway (Witness Cell)	[1)]Propagation time / Sec	External flame (Witness cell)
Pouch (A model) 60Ah	50%	Closed	20℃/min	O	141.6	X
	50%	Opened	20℃/min	O	210.0	O
	20%	Closed	20℃/min	X	N/A	X
	50%	Opened	100℃/min	O	334.4	O
	30%	Closed	20℃/min	O	578.0	X
		Opened		O	850.8	X
Pouch (B model) 70Ah	50%	Closed	20℃/min	O	111.8	X
	50%	Opened	20℃/min	O	114.2	X
	20%	Closed	20℃/min	O	517.4	X
		Opened		O	460.2	X
	50%	Opened	100℃/min	O	139.4	X
Prismatic (C model) 60Ah	50%	Opened	400℃/min	O	155	O
	20%	Closed	20℃/min	O	510	X
	20%	Opened	≧600℃/min	O	630	X
	30%	Closed	≧700℃/min	O	395	X
Prismatic (D model) 50Ah	50%	Opened	600℃/min	X	N/A	X
	20%	Opened	300℃/min	X	N/A	X
	30%	Opened	450℃/min	X	N/A	X
Cylindrical (E model) 5Ah	50%	Closed	290℃/min	O	590.6	X
	50%	Opened	320℃/min	X	N/A	X
	20%	Closed	348℃/min	X	N/A	X

External flame is not observed due to Closed case.

Thermal runaway is occurred on Transfer cell 1.

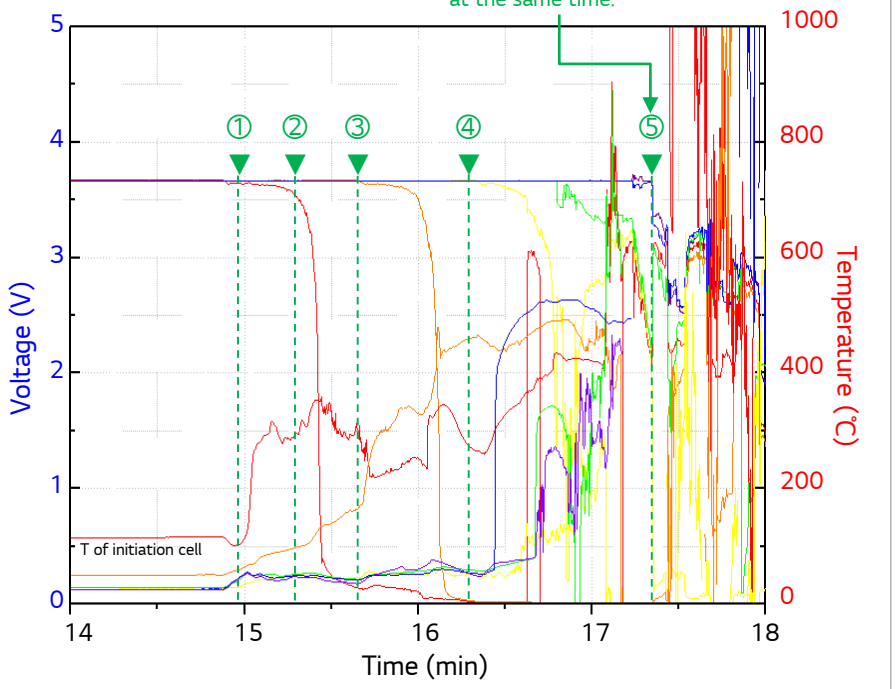
1) **Propagation time** : Lead time from thermal runaway of initiation cell to thermal runaway of witness cell

Appendix 2. Test result of pouch A model (SOC50%)

❑ Test result of pouch A model (SOC 50% / Closed type / Heating rate 20℃/min)

Multiple simultaneous thermal runaway of transfer cells and witness cell is created. (Any external flame is not observed during thermal propagation.)

▶ Voltage/Temperature graph



Red : Initiation Cell

Orange : Transfer Cell 1

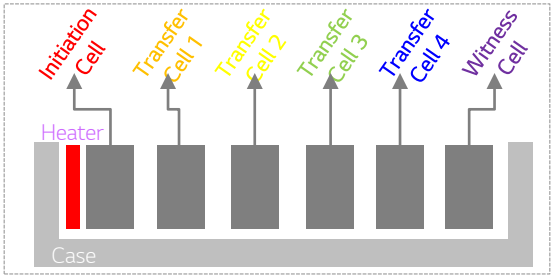
Yellow : Transfer Cell 2

Green : Transfer Cell 3

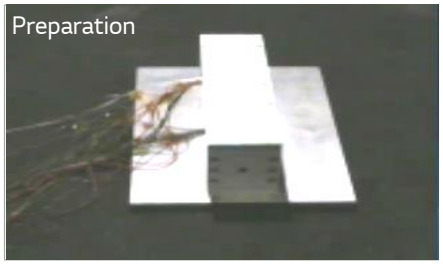
Blue : Transfer Cell 4

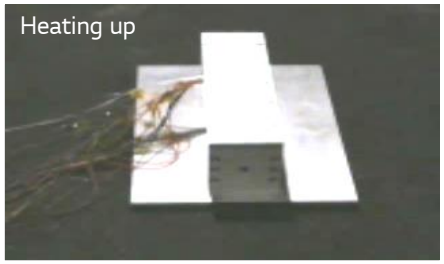
Purple : Witness Cell

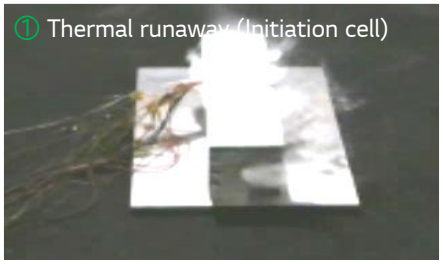
※ Cell arrangement diagram

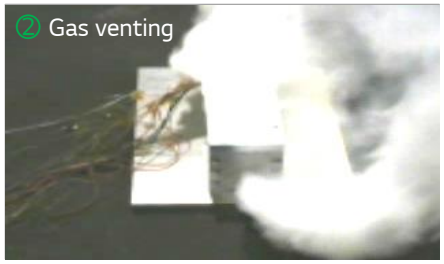


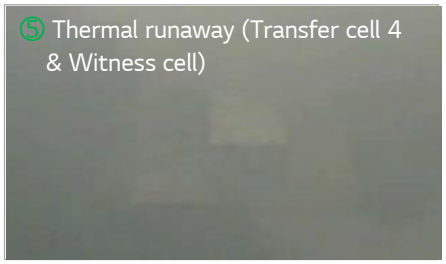
▶ Motion capture

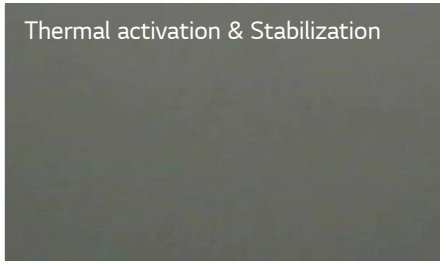










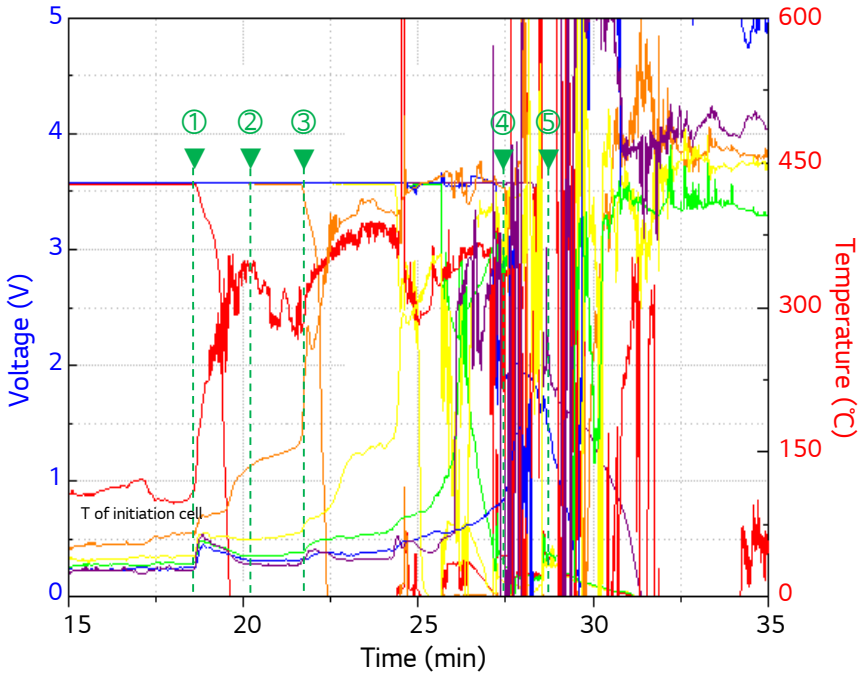


Appendix 3. Test result of pouch A model (SOC30%)

❑ Test result of pouch A model (SOC 30% / Closed type / Heating rate 20℃/min)

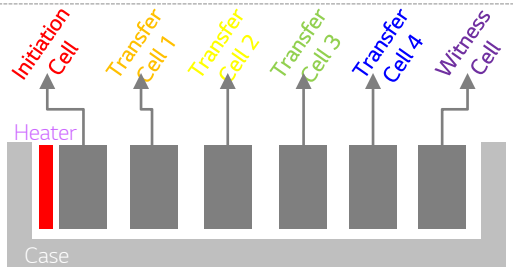
It takes longer to propagate from initiation cell to witness cell than SOC 50% condition.

▶ Voltage/Temperature graph



Red : Initiation Cell
Orange : Transfer Cell 1
Yellow : Transfer Cell 2
Green : Transfer Cell 3
Blue : Transfer Cell 4
Purple : Witness Cell

※ Cell arrangement diagram



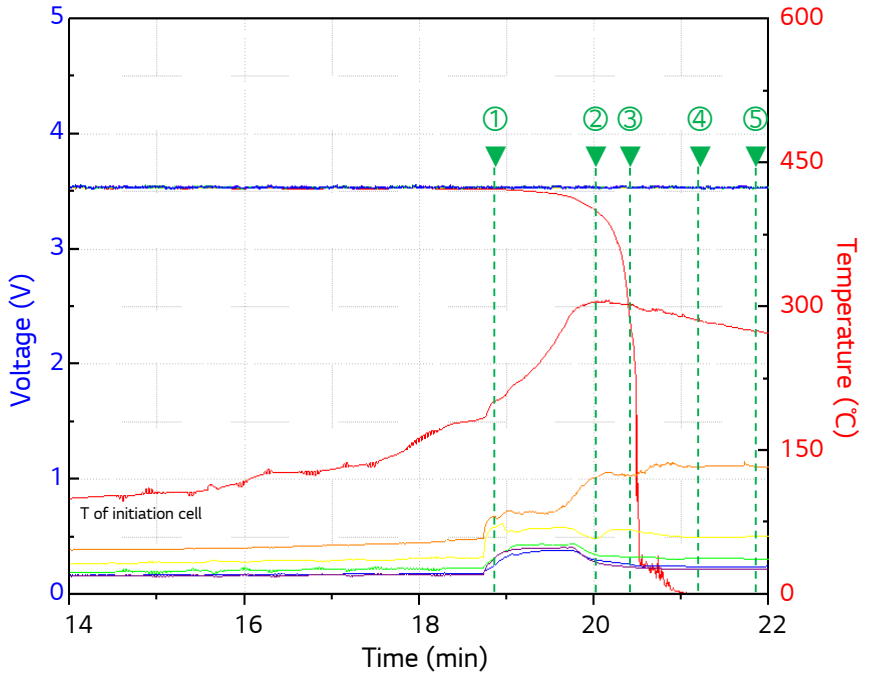
▶ Motion capture

Appendix 4. Test result of pouch A model (SOC20%)

❑ Test result of pouch A model (SOC 20% / Closed type / Heating rate 20℃/min)

No thermal propagation from initiation cell to witness cell in the condition of SOC 20%

▶ Voltage/Temperature graph



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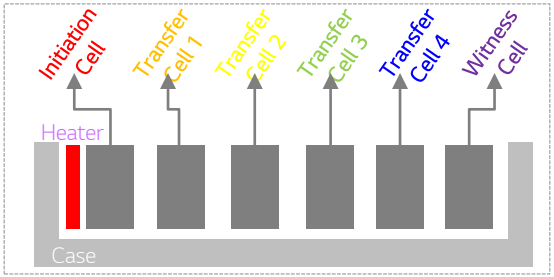
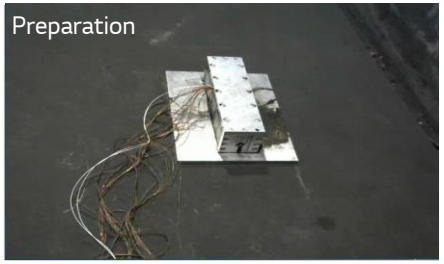
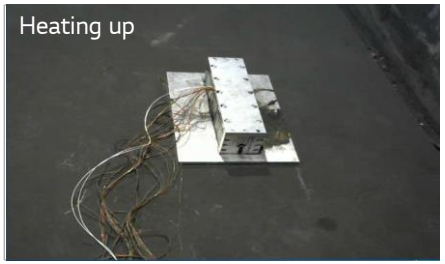
Yellow : Transfer Cell 2
Green : Transfer Cell 3
Blue : Transfer Cell 4
Purple : Witness Cell

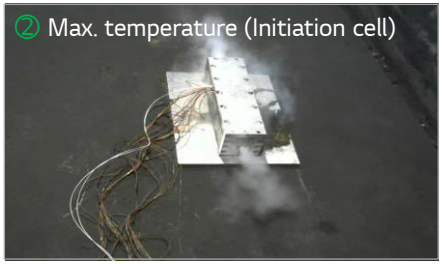
※ Cell arrangement diagram

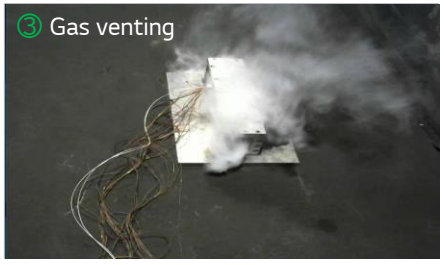


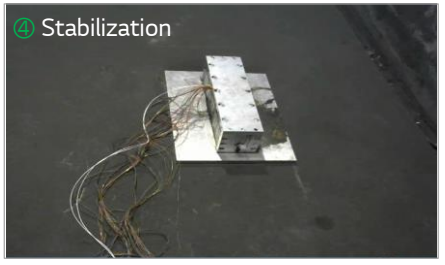
▶ Motion capture

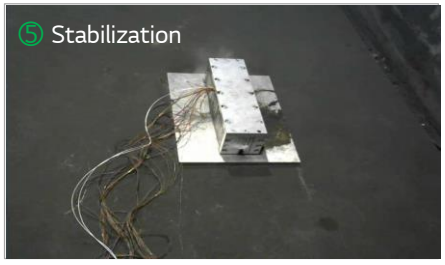


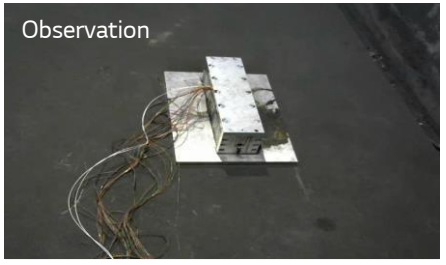










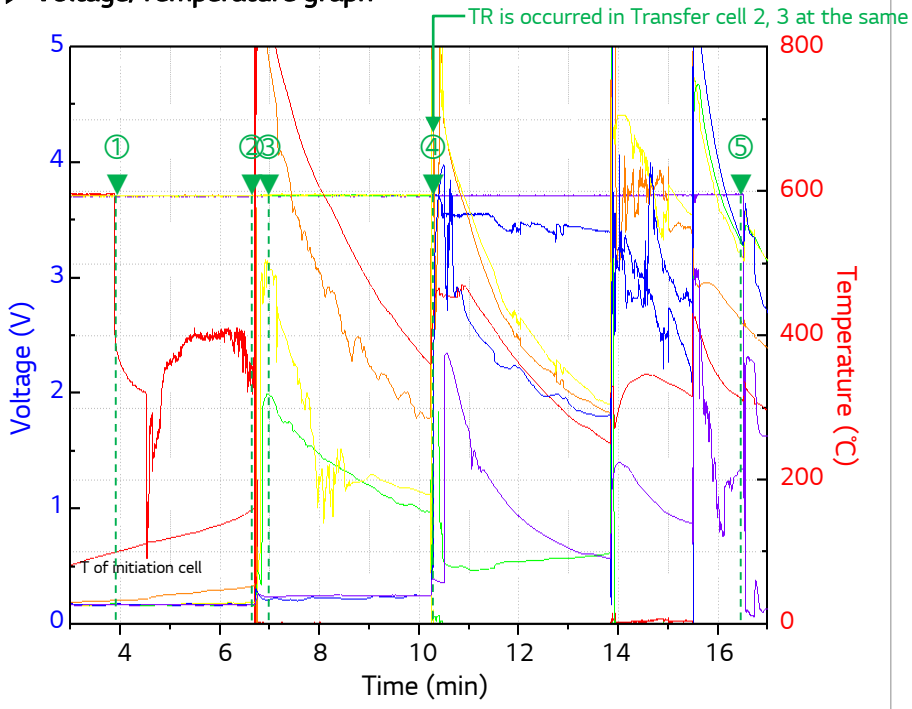


Appendix 5. Test result of cylindrical E model (SOC50%)

❑ Test result of cylindrical E model (SOC 50% / Closed type / Heating rate 290℃/min)

Multiple simultaneous thermal runaway of transfer cells and witness cell is created. (Flame is observed with sparks for a few seconds.)

▶ Voltage/Temperature graph



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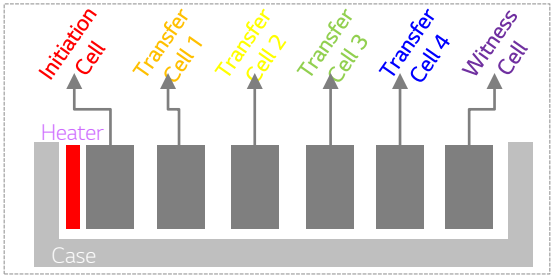
Blue : Transfer Cell 4
Purple : Witness Cell

※ Cell arrangement diagram



▶ Motion capture