

# Conditions

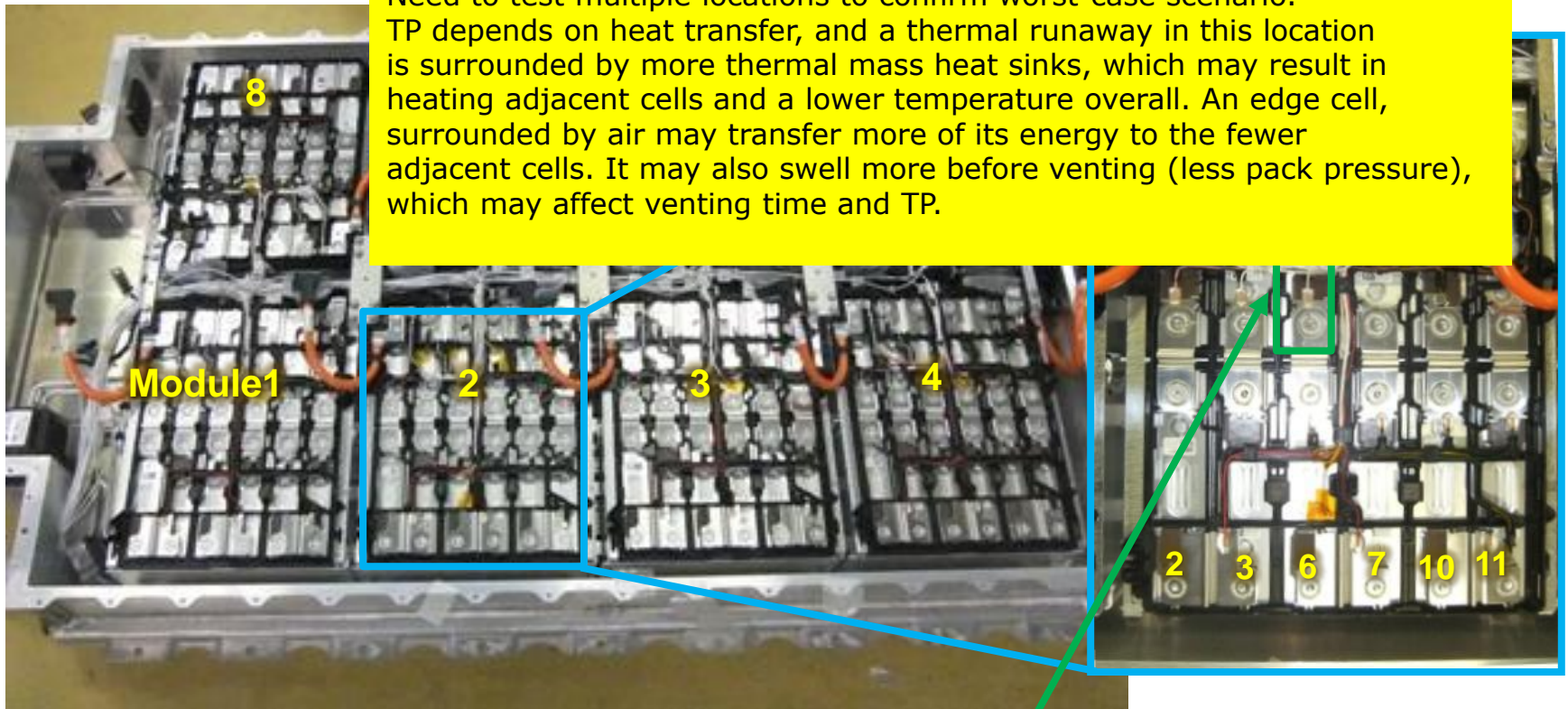
		Condition		Reason
			Reference (Phase1 Part1)	
Nail	Material	Alloy tool steel	Steel	Same as Phase1 Part1 condition.
	Diameter	3mm	More than 3mm	Within Phase1 Part1 condition.
	Angle	60°	20 - 60°	↑
	Speed	0.1mm/sec	0.1 - 10mm/sec	↑
	depth	½ of cell height	-	Because of test equipment spec
SOC		100%	90/95% or more	Within Phase1 Part1 condition.
Temperature		Depends on		Institute B doesn't have air
		Depth – this will be dependent on cell positioning within pack,		
		Does nail stay inserted in pack (less reactive) or insert and release (more reactive)?		
Position of target cell		See page 5		Concerned by sulfur-concentrational propagation is likely to happen.
Insertion point of cell		See page 6		To surely cause internal short circuit.
Modification of pack		See page 7		Made holes for nail.
Voltage and thermocouple points		Target cell, surrounding cells and various points inside pack		To detect thermal runaway of trigger cell and surrounding cells.
Pressure sensor point		Lower case near front		-

# Conditions

## Position of target cell

- Cell 5 is surrounded by other cells. Thermal propagation is likely to happen.

Need to test multiple locations to confirm worst-case scenario. TP depends on heat transfer, and a thermal runaway in this location is surrounded by more thermal mass heat sinks, which may result in heating adjacent cells and a lower temperature overall. An edge cell, surrounded by air may transfer more of its energy to the fewer adjacent cells. It may also swell more before venting (less pack pressure), which may affect venting time and TP.



Target cell  
(Cell5 in Module2)

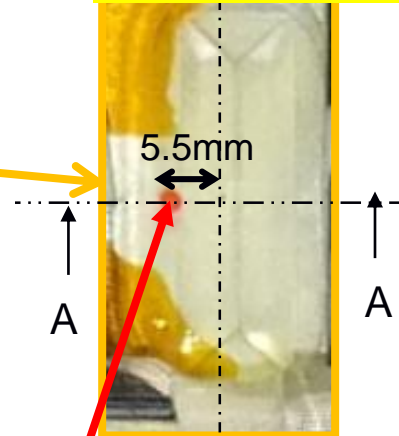
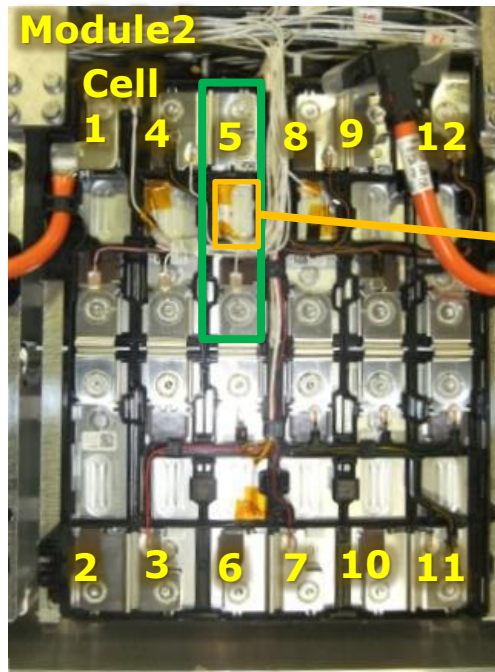
# Conditions

## Insertion point of cell

- Inserted nail from cell safety vent.
- There are 4 electrodes inside cell. To surely cause internal short circuit, we selected below point.

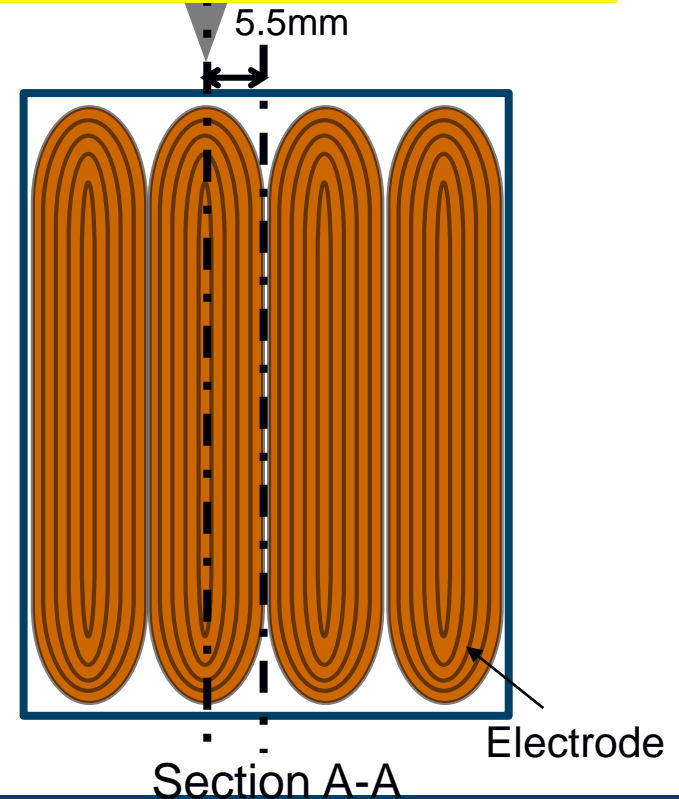
This will require knowledge of inner electrode construction, Where does this information come from?

How does location accuracy of test affect outcome?



Cell vent

Insertion point  
(5.5mm away from  
center of vent)



Section A-A

Electrode

# Results

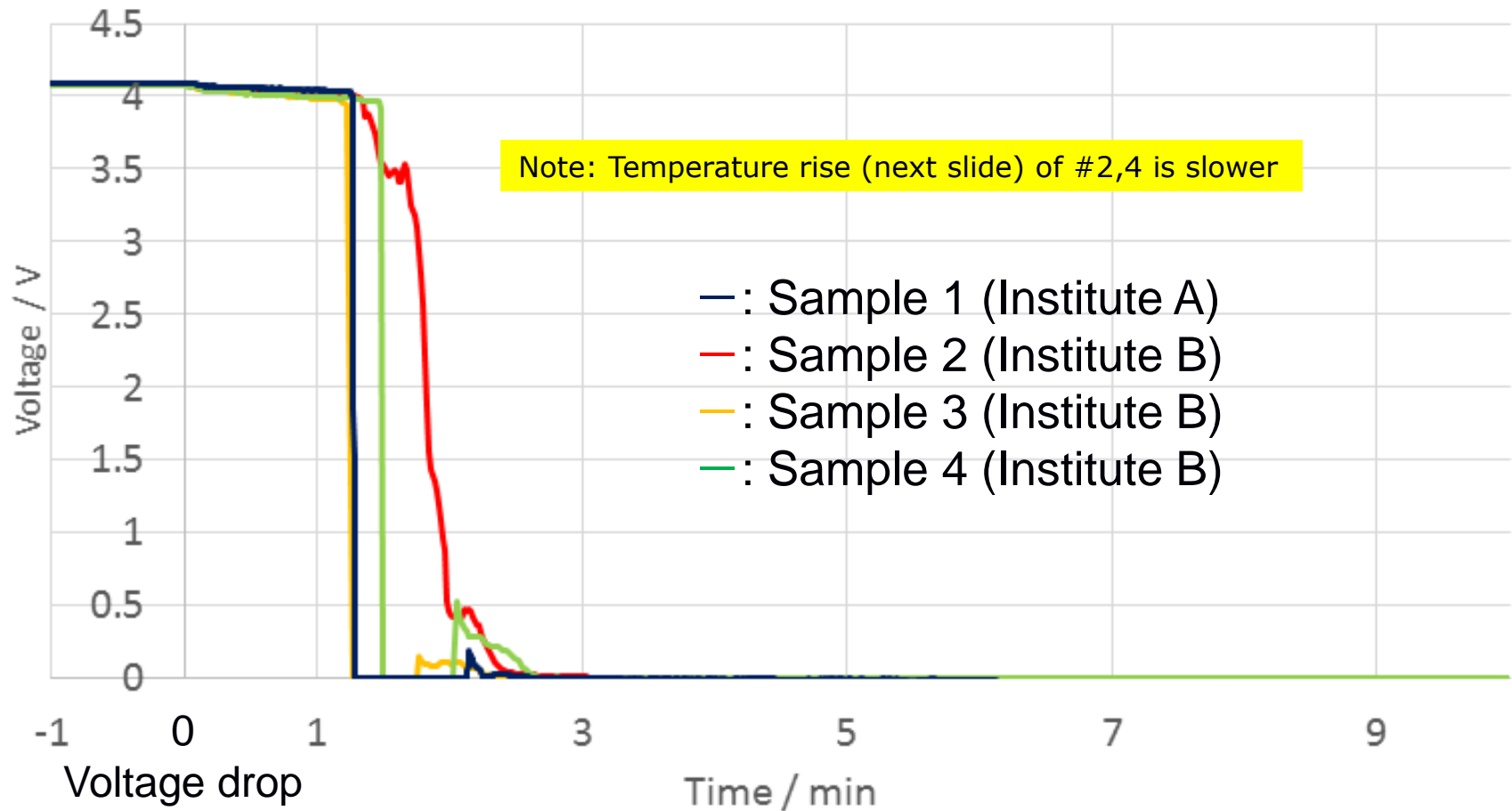
Sample	1	2	3	4	Repeatability/ Reproducibility
Institute	A	B			
Thermal runaway occurs/ not occurs	Occurred	←	←	←	High
Thermal propagation occurs/ not occurs	Not occurred	←	←	←	High
Fire and explosion occurs/ not occurs	Not occurred	←	←	←	High
Voltage drop of initiation cell	P8				Variations were observed.
Temperature of Initiation cell and adjacent cell	P9, P10, 11				
Pressure of pack	P12				

What does arrow mean?



# Results (Voltage drop of initiation cell)

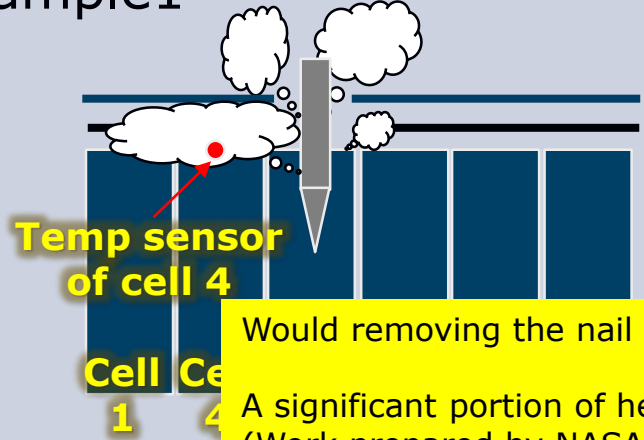
- The results of sample 1 and 3 were similar.
- There were variations in sample 2, 3 and 4 though these were conducted at the same institute. This might be the difference of time when CID worked.



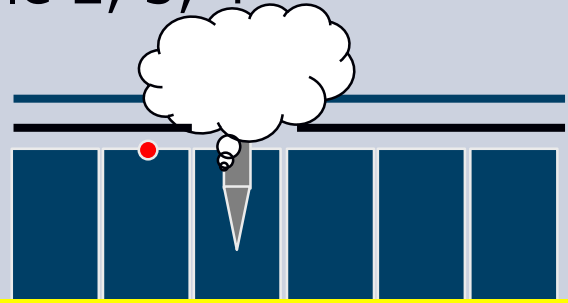
# Difference of short term temperature

- Direction of gas released immediately after thermal runaway may have been different due to the difference of how to open vent.  
⇒ Only in sample 1, the temperature of cell 4 was higher.

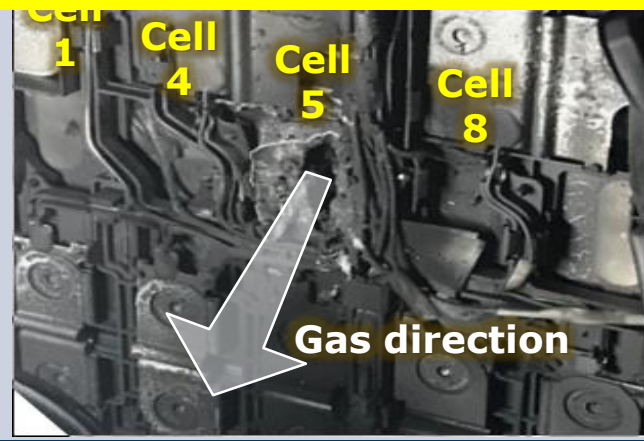
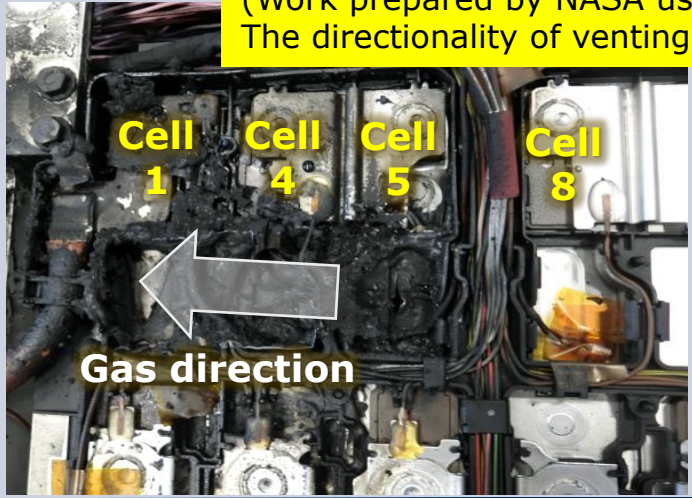
Sample 1



Sample 2, 3, 4



Would removing the nail after insertion help this?  
A significant portion of heat released is through the mass transfer of venting gases (Work prepared by NASA using a battery calorimeter estimates up to 40% of the total energy). The directionality of venting gases is an important consideration, but can be stochastic.



# Summary

- Conducted thermal propagation test at institute A and B to confirm repeatability and reproducibility of thermal propagation test.

Propagation could be dependent on cell choice, do you have plans for pouch cell testing?

- All samples showed similar results. Pouch testing will have more stochastic venting behaviours (no dedicated vent hole), that will certainly affect the repeatability of TP. n.  
But voltage drop, pressure and temperature rise in short term were different in each sample.

- The variation of temperature rise was due to the difference of how to vent. We will conduct additional test to clarify why venting of each cell was different.

- Based on these results, we would like to discuss and decide how much degree of variation is accepted.