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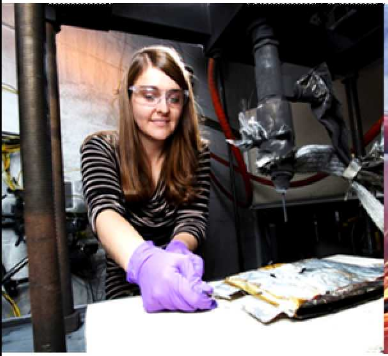
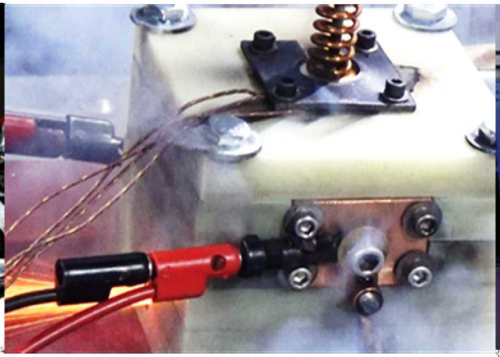


Characterization of Abuse Response during Fast Charge of Lithium Ion Batteries

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 # A01-0122, May 15, 2018

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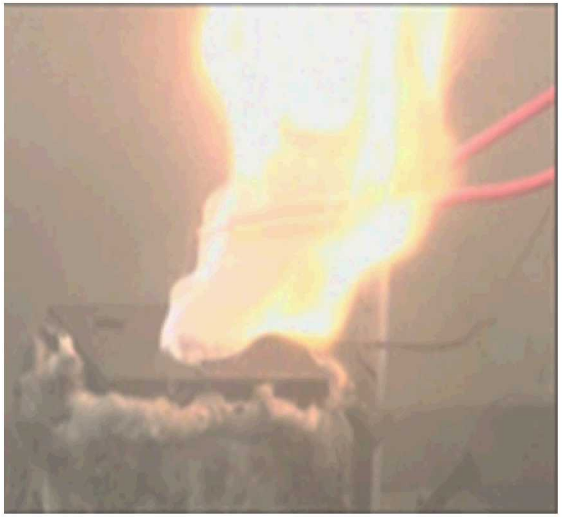
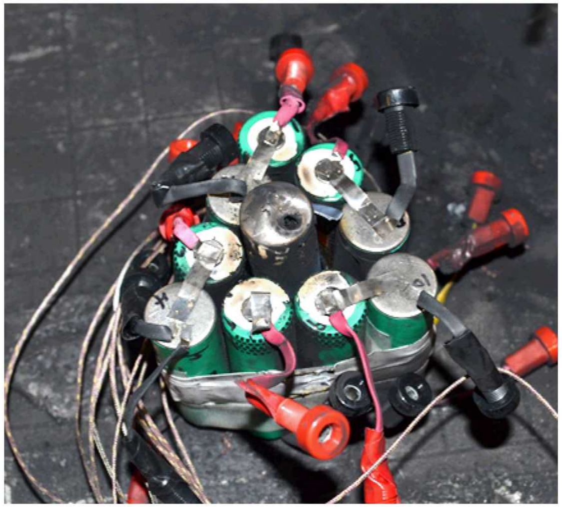
Outline

- Fast Charge and Abuse Response – Complimentary Processes
- COTS Fast Charge study design
- Abuse response
- Search for Fast Charge degradation markers
- Summary





Averse Cell Effects – Fast Charge vs Abuse

Fast Charging

- Cathode
  - Heating – Breakdown of active materials, binder and electrolyte
  - Localized Abuse – Overdelithiation
- Anode
  - Lithium Plating
  - Electrolyte and Double Layer issues

Fast Charge adverse effects resemble some abuse failure root causes

Overcharge

- High voltage breakdown of separator, binder, electrolyte, cathode
  - Cathode overdelithiation
- Lithium plating on anode

Thermal Ramp

- Cathode instability → heating → O_2 release
- Separator breakdown
- SEI dissolution
- Electrolyte breakdown

Initial Study: COTS Fast Charge

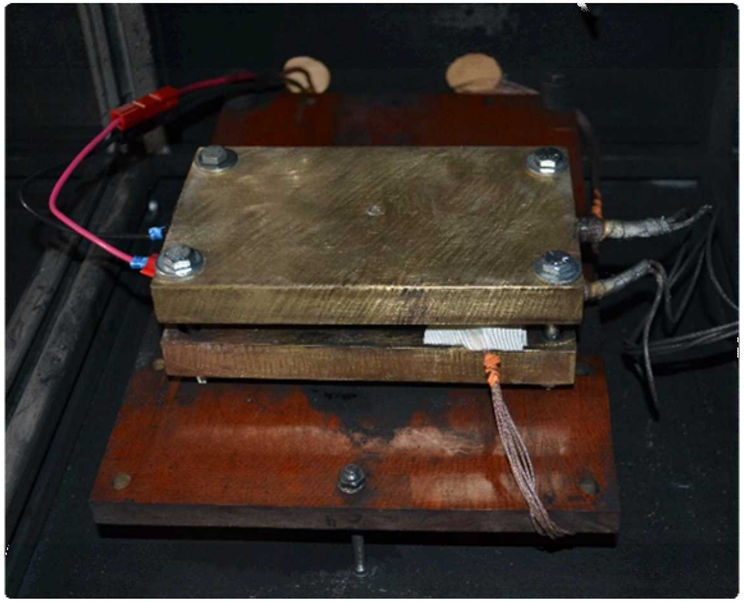
10Ah NMC // Graphite pouch
Supplier: Battery Space
Spec: 1C Charge/Discharge

Factors	Levels		
Charge Rate	1C	1.5C	
Cycles	20	100	300
Test	Over Charge	Thermal Ramp	

- **Establish baseline for further study on automotive cells** (see slide 4)
- Phase 1: Vary charge rate and cycles, and characterize changes in abuse response for thermal ramp and overcharge. *(in progress)*
- Phase 2: Use high precision cycling to track efficiency and EIS over 300 cycles; identify possible Li plating markers. *(lab upgrades complete)*
- Standard Charge = 1C, "Fast charge" = 1.5C (All discharge = 1C)
  - Higher charge rates produced prohibitively high polarization.

  ➔ **Highlights drawback of COTS cells**

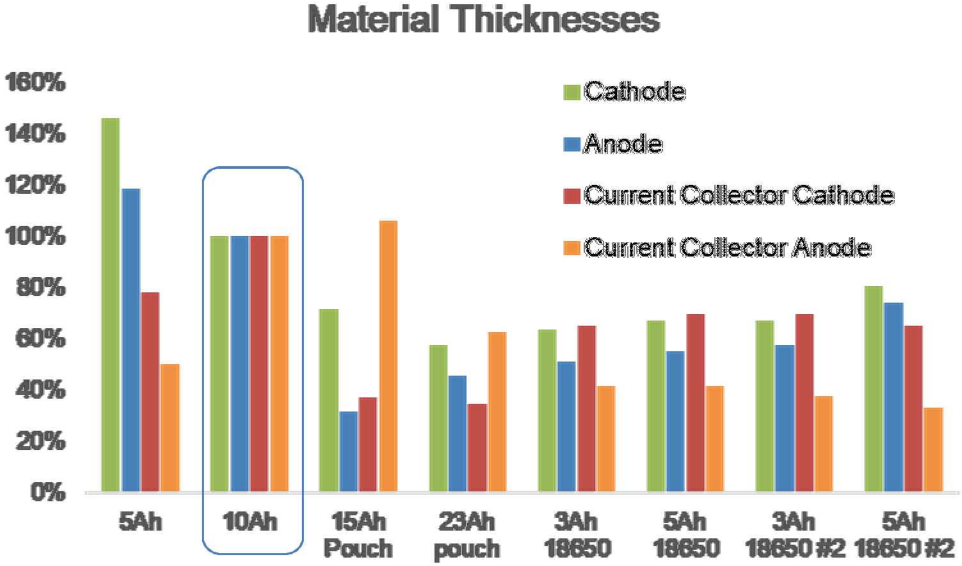
Design of Experiments for COTS Fast Charge



Thermal Ramp setup

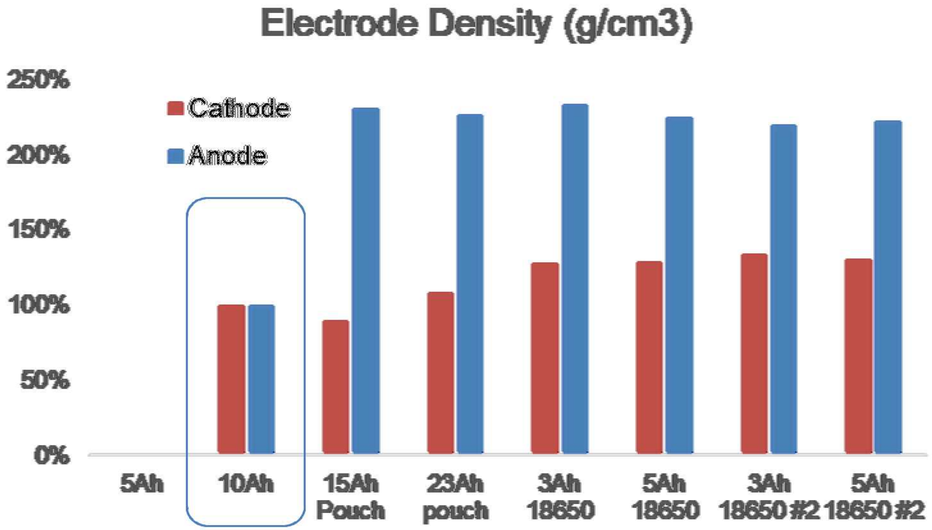
#	Charge C-Rate	Condition Cycles	Abuse
1	n/a	0	OverCh
2	n/a	0	TRamp
3	1	20	OverCh
4	1	20	TRamp
5	1	100	OverCh
6	1	100	TRamp
7	1	300	OverCh
8	1	300	TRamp
9	1.5	20	OverCh
10	1.5	20	TRamp
11	1.5	100	OverCh
12	1.5	100	TRamp
13	1.5	300	OverCh
14	1.5	300	TRamp
15	1	300	n/a
16	1.5	300	n/a

Importance and Validity of COTS Observations



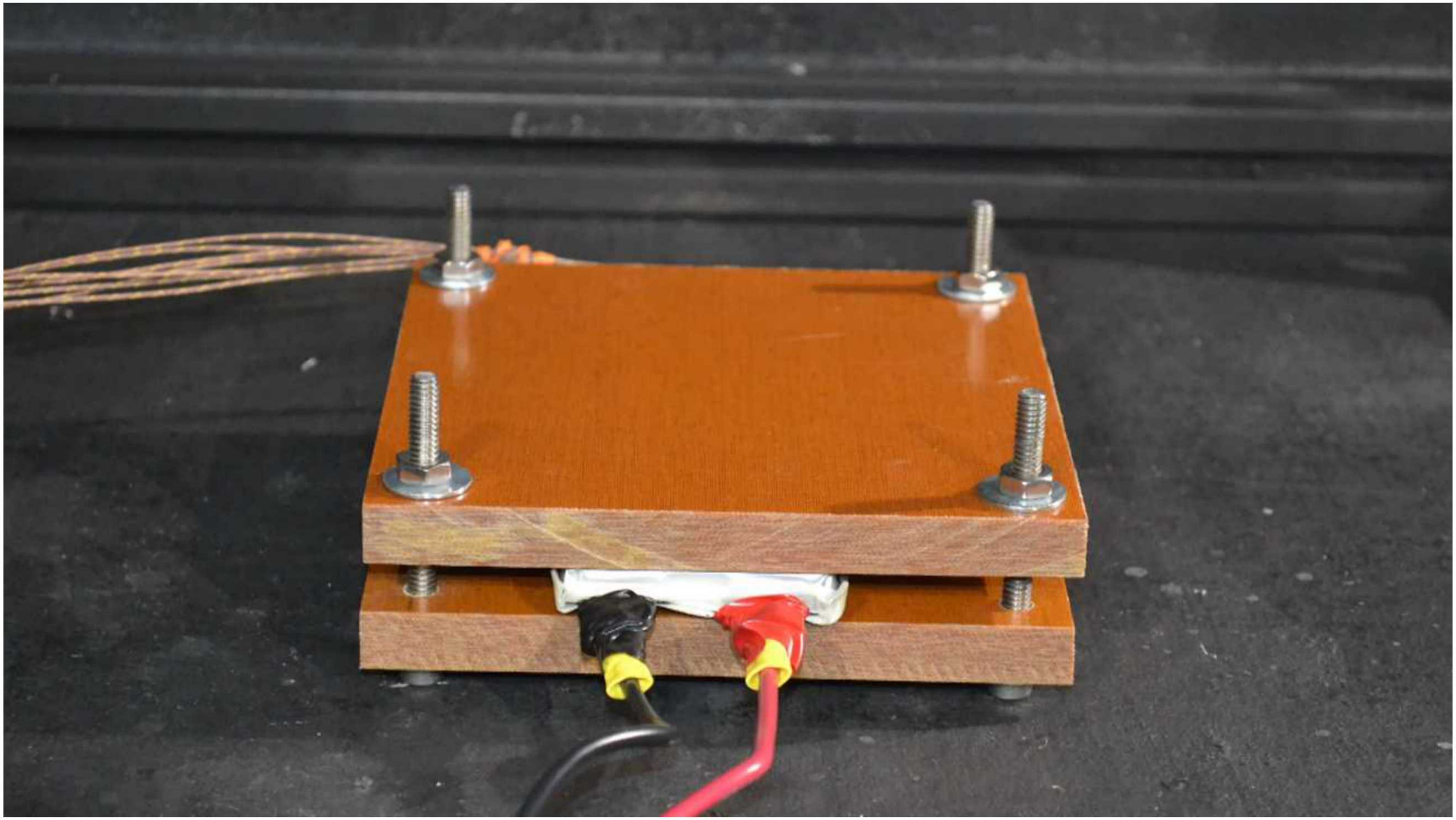
- Materials are thinner almost across the board for automotive vs COTS.
- Thinner: more heat, more delicate
- Automotive cells sport metrics that suggest fast charge outcomes could be more pronounced than COTS.

- Automotive cells have higher electrode density, from higher loading and higher calendaring.
- High compression improves electrical conductivity but leaves less from electrolyte – lower ion conductivity.
  - Resistance – heat, gradients, plating



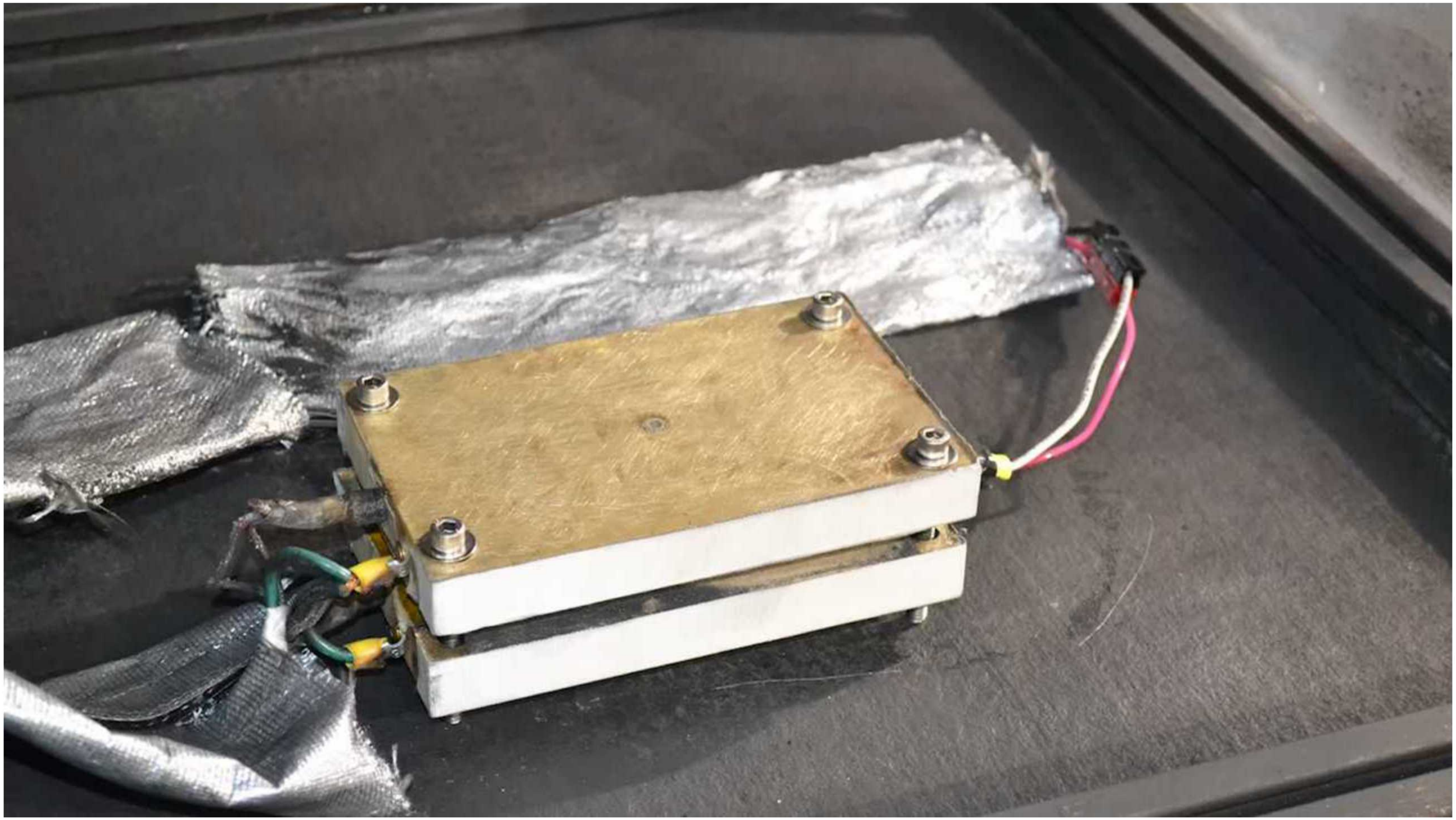
Video Results

Overcharge



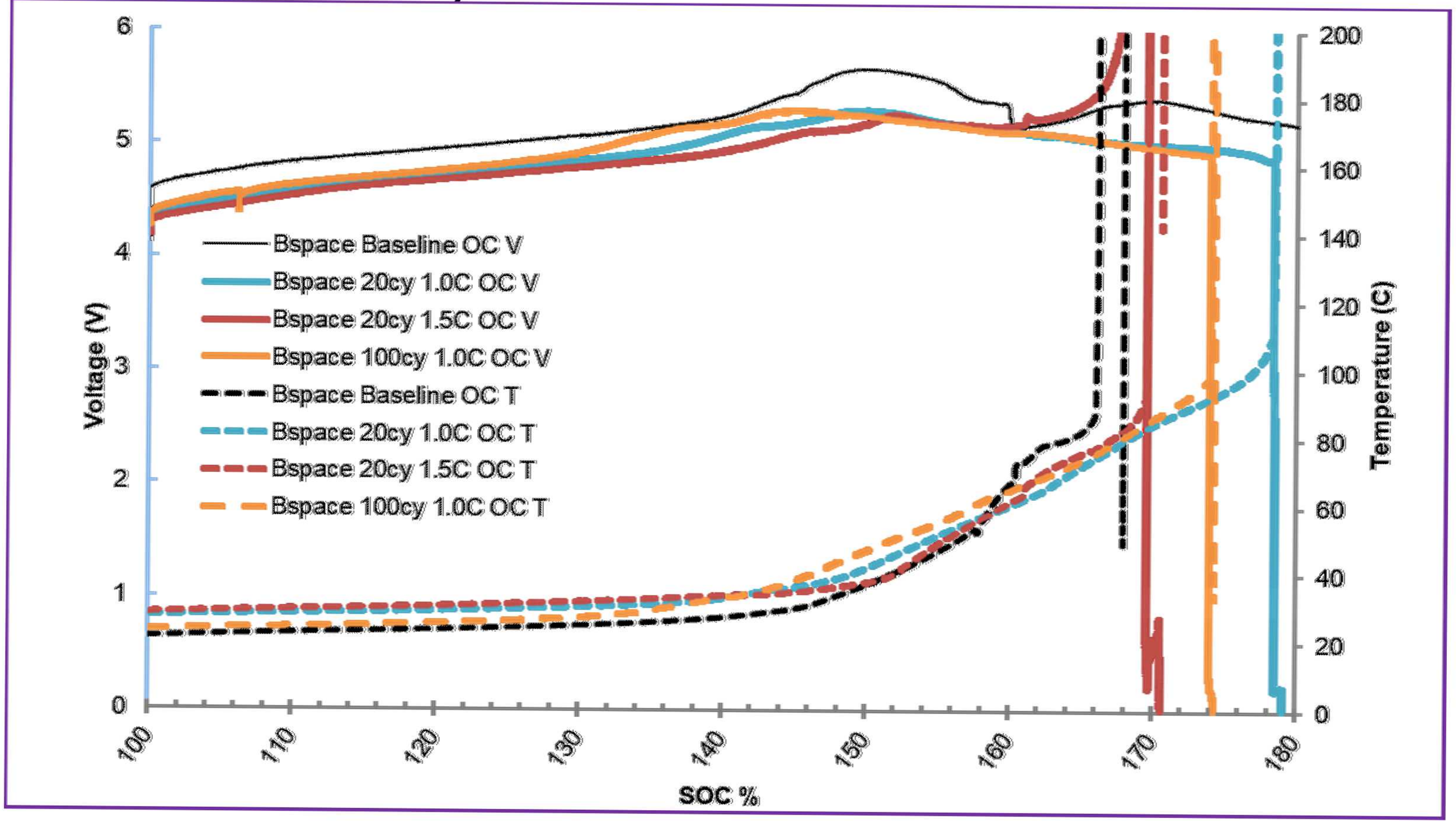
Video Results

Thermal Ramp

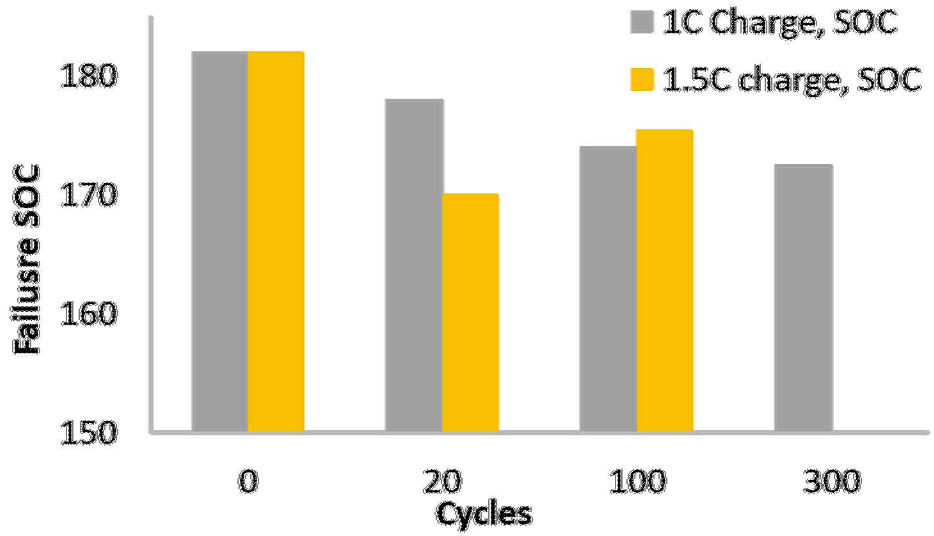


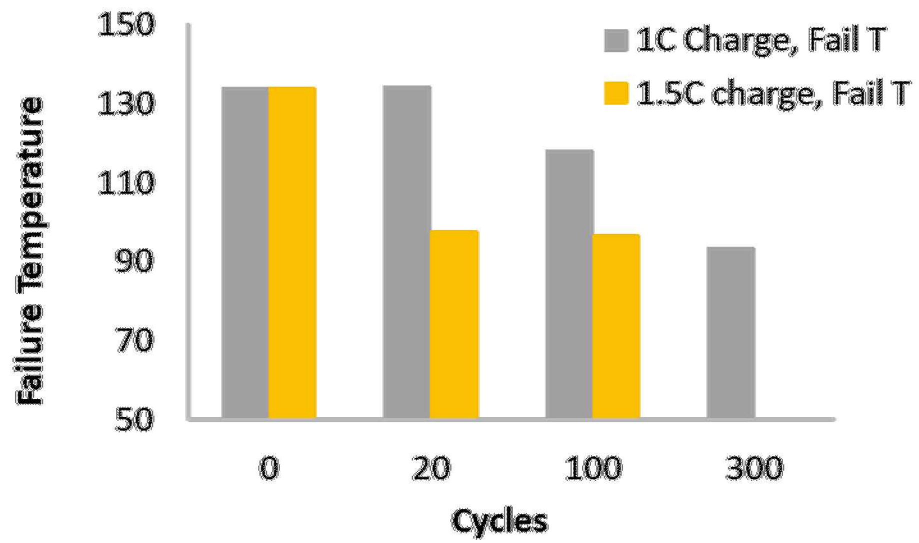
Typical in-test Data

Show a Thermal Ramp and OC test
Point out metrics that are on bar charts, like initiation SOC, etc.

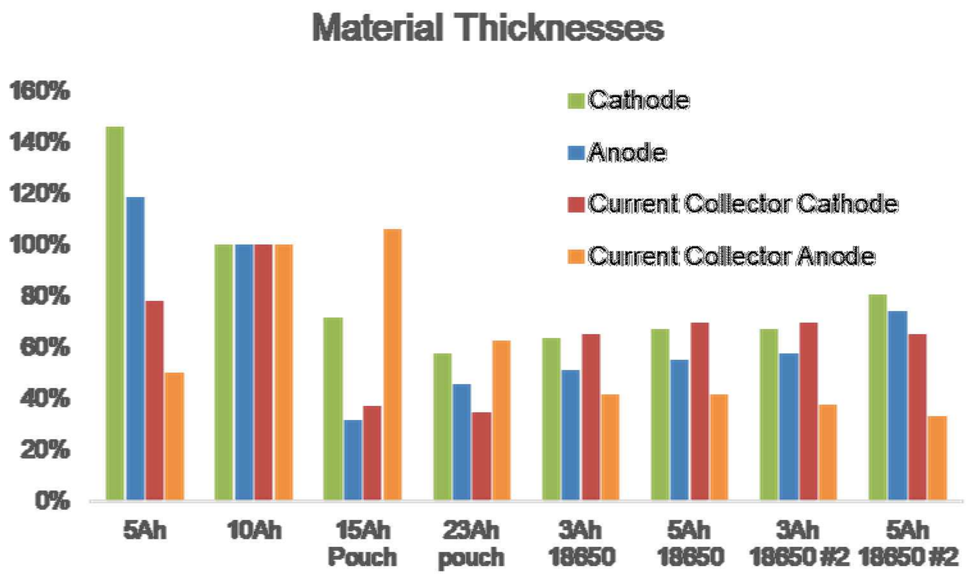


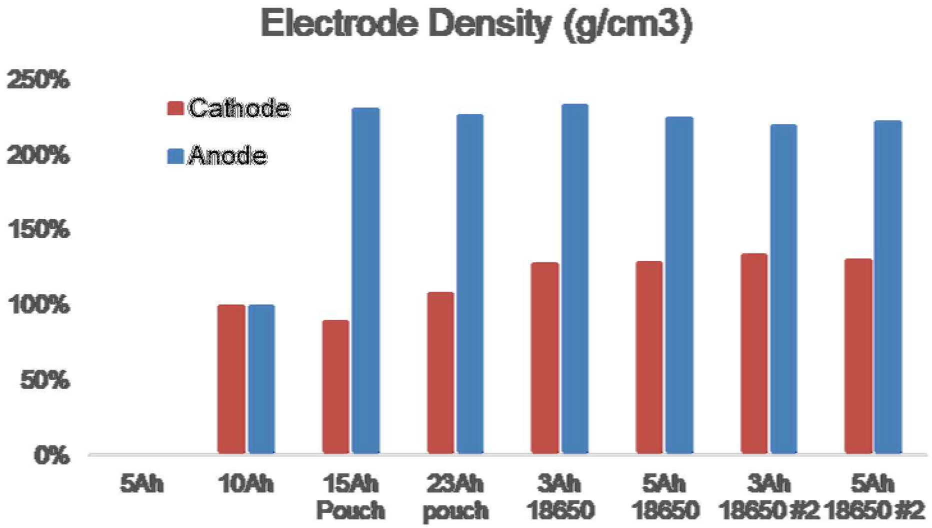
Overall COTS behavior





Revisit Why COTS cells are appropriate

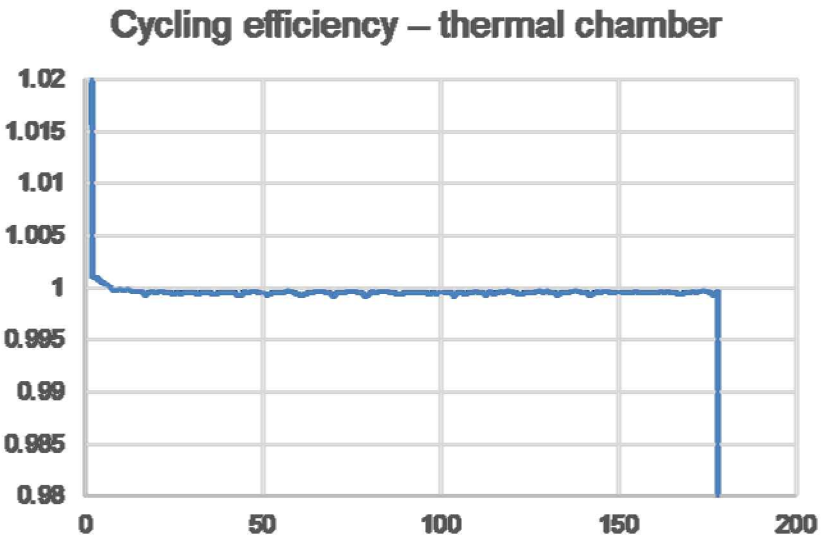


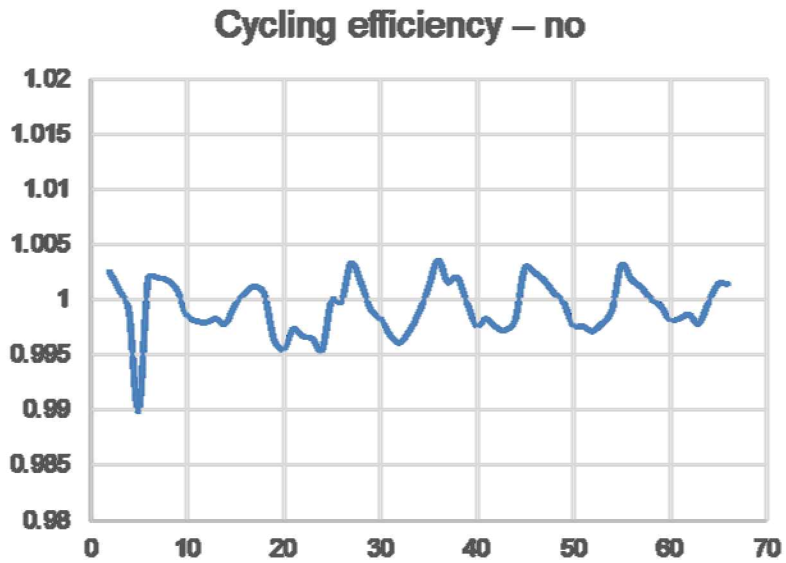


Conversation on failure markers

Issues with depending on cycle-to-cycle changes to predict failure on a vehicle. Uncontrolled environment, can have big effect on cells.

Better off looking at in-cycle data, or using controlled diagnostic testing ahead of time to *mitigate* rather than *anticipate.*





Summary

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