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Thermal Runaway Testing and Database Development of Large-format Li-ion Cells at ORNL and SNL

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Introduction

- Safety Roadmap from 2017 Safety Forum identified an important area for future expansion of stationary energy storage applications
- Industry lacks a database of 'battery thermal runaway risk' data for Li-ion cells
- Safety risks become important topics as system sizes increase
- Safety is not a priority in the battery development stage, but is one of the most important concerns for applications
- Common solutions:
  - Conservative in engineering the system with armor-like protection
  - Implementing isolation solutions to prevent fire propagation
- Assist first responders to make proper decisions in case of a battery fire
- Results will be collected in a usable database for the Li-ion battery development community

2013 Nissan Leaf

Image courtesy of: https://www.windpowerengineering.com/how-three-battery-types-work-in-grid-scale-energy-storage-systems/

Methodology

A)

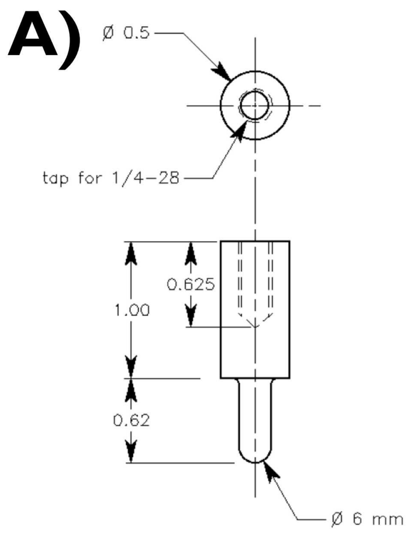
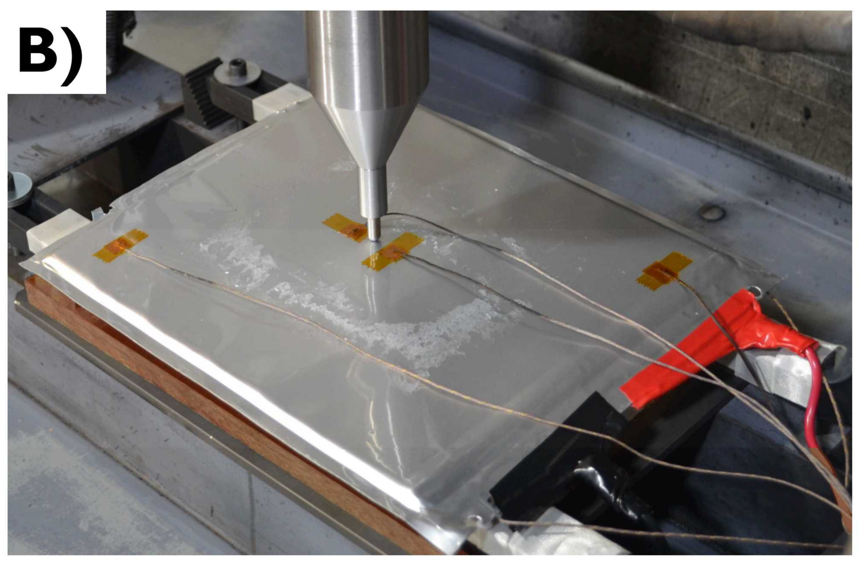


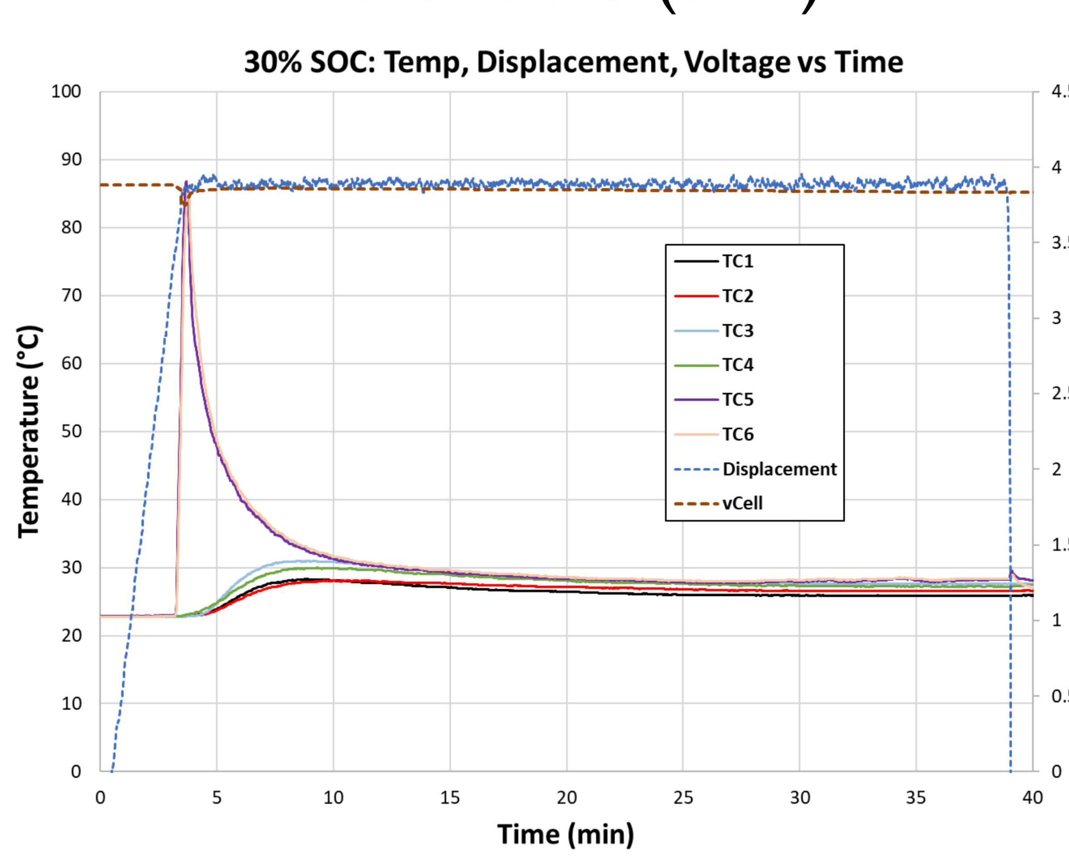
Image 1:
A) The 6 mm indenter – modified attachment to work with existing hydraulic equipment
B) Single cell prepped for testing with thermocouples and voltage sense leads

B)



- Protocol was developed with specific test parameters to initiate failure in large format Li-ion cells
  - 6 mm diameter blunt indenter
  - Indentation speed of 0.05" per minute
  - Indent until ≥ 100 mV voltage drop or full penetration
- Single cells were extracted from modules obtained from a 2013 Nissan Leaf and a 2017 Chevy Volt
- Tests will be repeated (in duplicate) for the following 4 states of charge (SOC): 30%, 50%, 75% and 100%, at both ORNL and SNL

30% SOC (SNL)



- Two cells tested at 30% SOC
- SOC based on the nominal capacity of the cell after cycling
- Displacement of ~4.0 mm
- Force reached was just under 2,200 N
- No significant voltage drop (3.88 V to 3.75 V)
- No thermal runaway event, max temp = 86.8°C

A)

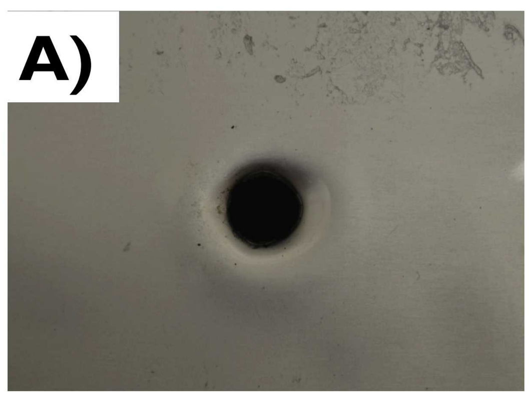
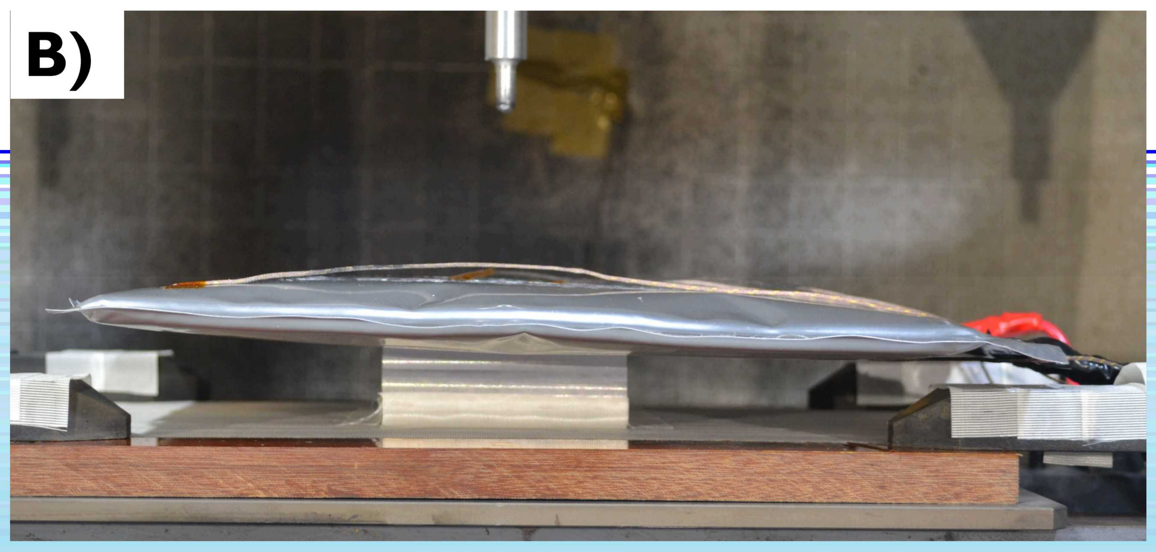
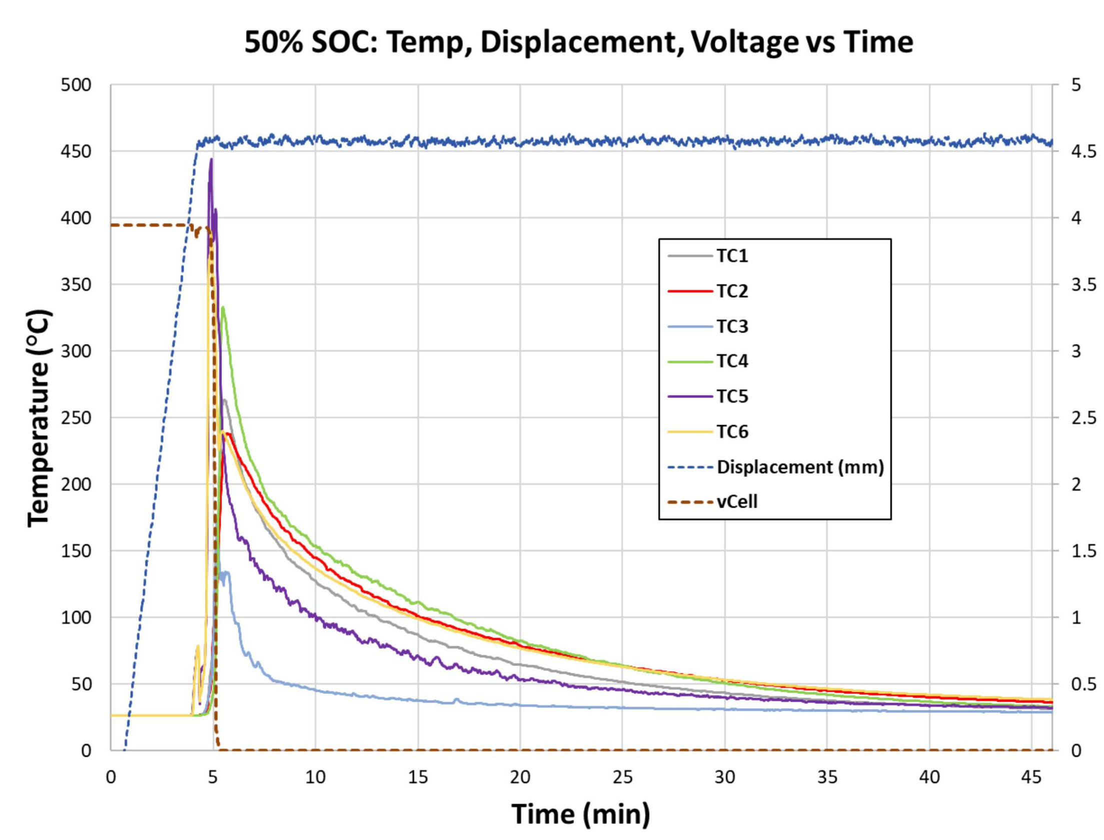


Image 2:
A) Post-test Indenter hole of the 30% SOC cell
B) Side view of cell swelling (indenter can be seen at the top of the image)

B)



50% SOC (SNL)

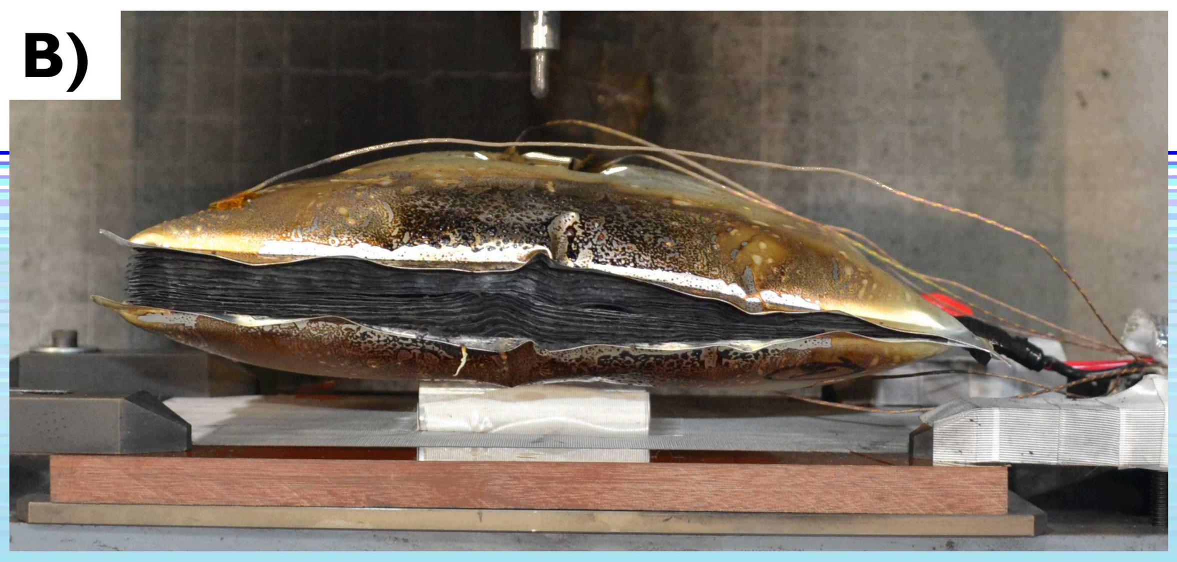


- Two cells tested at 50% SOC
- SOC based on the nominal capacity of the cell after cycling
- Displacement of ~4.7 mm
- Force reached was ~ 2,120 N
- Voltage drop to 0V (beginning voltage of 3.95%)
- Thermal runaway event, max temp = 444.6°C

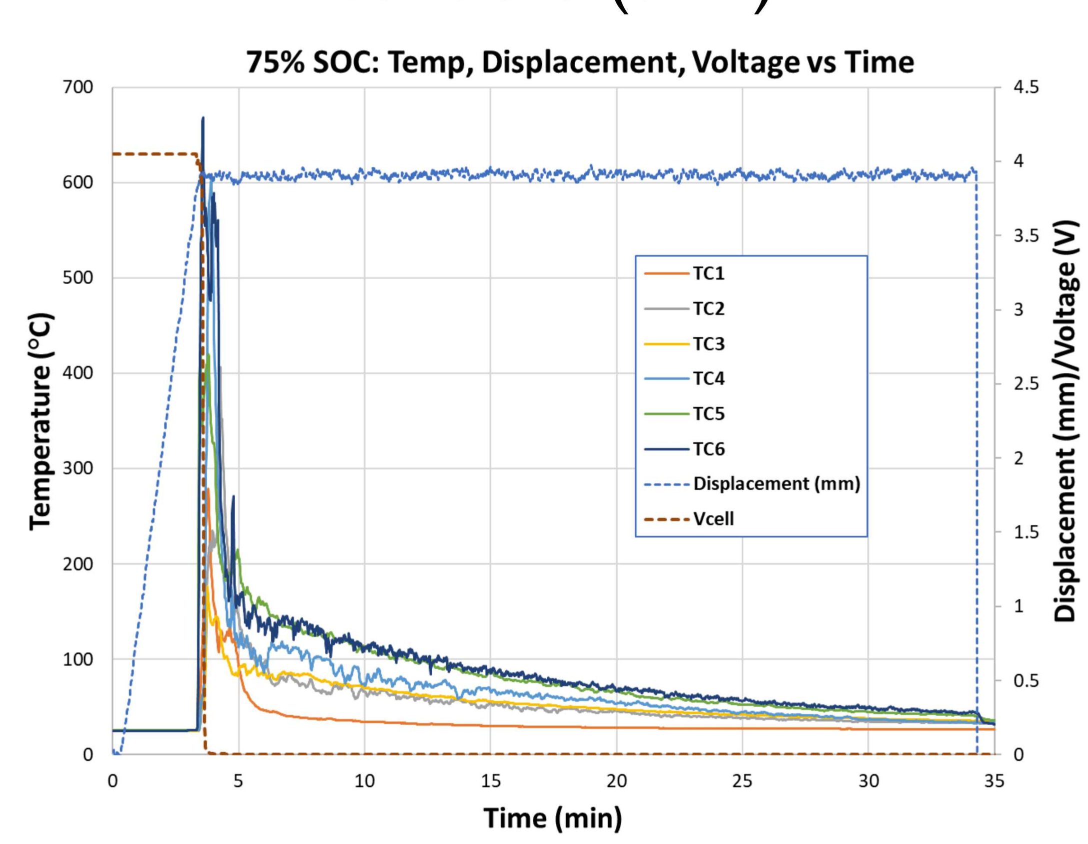
A)

Image 3:
A) Post-test Indenter hole of the 50% SOC cell
B) Side view of cell swelling and seam separation, showing interior contents

B)



75% SOC (SNL)



- One cell tested at 75% SOC (thus far)
- SOC based on the nominal capacity of the cell after cycling
- Displacement of ~4.1 mm
- Force reached was just ~ 2,050 N
- Complete loss of voltage (beginning voltage of 4.07 V)
- Significant thermal runaway event, max temp = 668.3°C

A)

Image 4:
A) Post-test Indenter hole of the 75% SOC cell
B) Side view of cell swelling, charring and seam separation showing interior contents

B)

Future Work

- Complete our abuse testing of the Nissan Leaf single cells at 75% SOC (1 cell) and 100% SOC (2 cells)
- Acquire individual cells from Chevy Volt battery modules from ORNL
- Perform indenter abuse tests on Chevy Volt cells at same SOCs
- Acquire large-format Li-ion batteries from stationary energy storage applications
- Perform indenter abuse tests on large-format cells at same SOCs
- Deliver data to ORNL for entry into database

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