Passive Prevention of Thermal Runaway in Li ion Batteries

Vijay V. Devarakonda

Analytical Scientific Products LLC, Dallas, TX

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Outline

- Introduction
- Technology description
- Technology development status
- Results from lab testing
- Summary of key findings
- Potential applications

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Introduction

- Li ion cells may fail due to manufacturing defects, abnormal use, and abuse
- Some failures develop slowly, while others occur very rapidly
- Irrespective of what causes failure, the cells undergo a series of chemical reactions that start at different temperatures
- Most reactions are exothermic, and the reaction rates increase with temperature (T). Positive feedback between reaction rate and heat release causes self-heating and potentially Thermal Runaway (TR)
- TR in one cell releases enough energy, flammable content and debris to propagate to the nearby cells eventually burning down even very large battery packs
- Key challenges in addressing battery fires: lack of knowledge of when and where the failure occurs and a lack of access to the failure location
- Currently, battery fires are fought using an outside-in approach: "when" a fire is detected, the entire battery pack is flooded with excess water to quench the fire, and to maintain cooling for a long time to prevent re-ignition

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ASP's Battery Safety Technology

Our technology improves battery safety through

1. Early Detection: passively detects cell overheat, a precursor to thermal runaway
2. Passive TR Prevention: converts some of the thermal energy from overheated cell into work to puncture nearby coolant channel, release coolant and prevent TR
3. Passive TR and Fire Propagation Prevention: prevents thermal propagation of TR and fire from the failed cell to the surrounding cells through preemptive cooling

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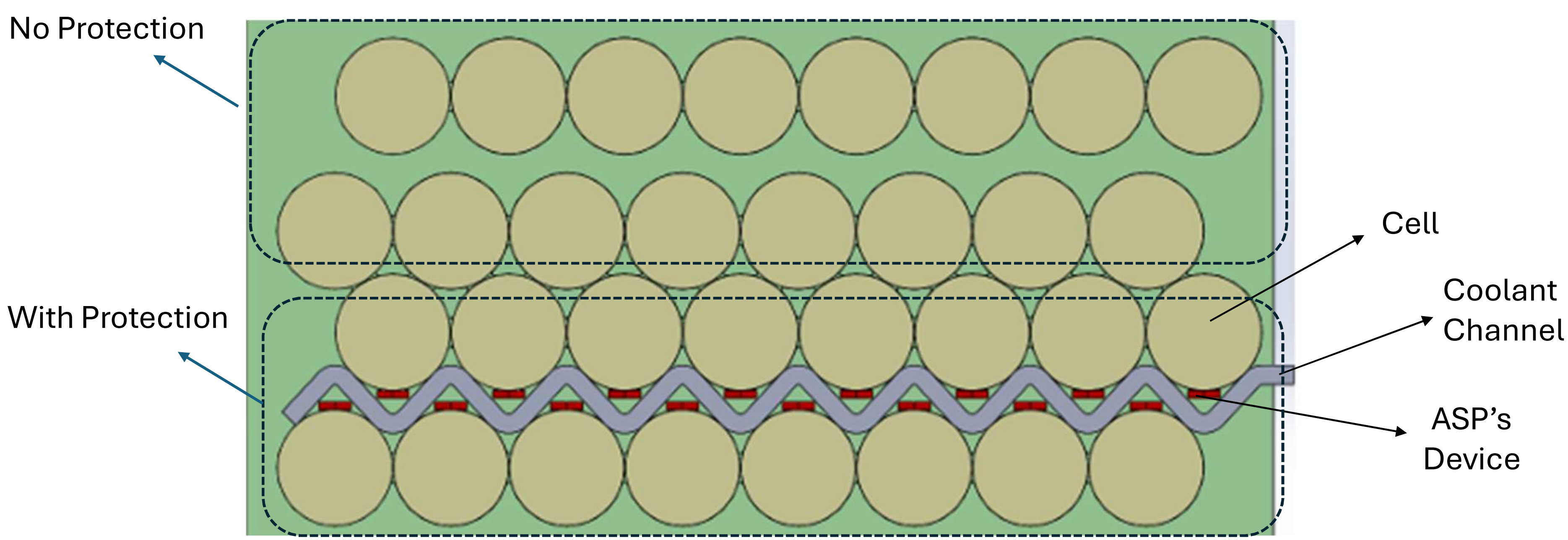
Illustration for a 32-cell Module



Technology Development Status

- Initial development funded internally
- IP status
  - Non-provisional utility patents filed in 2022 and 2025 (both in the US and internationally)
  - Our first US patent was awarded in August 2025
  - Other patents are under review
- Technology being developed under a Phase II SBIR project funded by the Department of Air Force
- We have completed component level testing
- Next step: design, construct and evaluate prototype battery modules equipped with our technology

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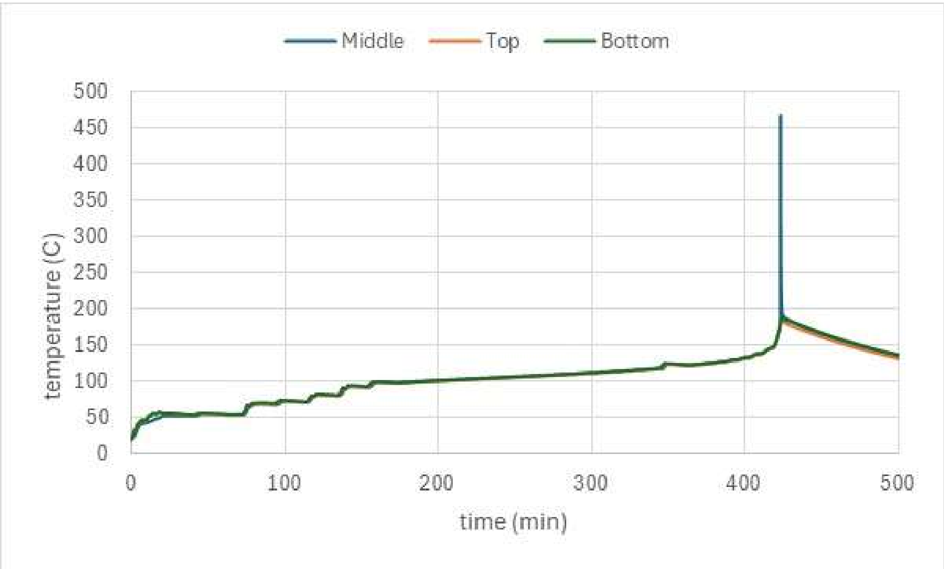
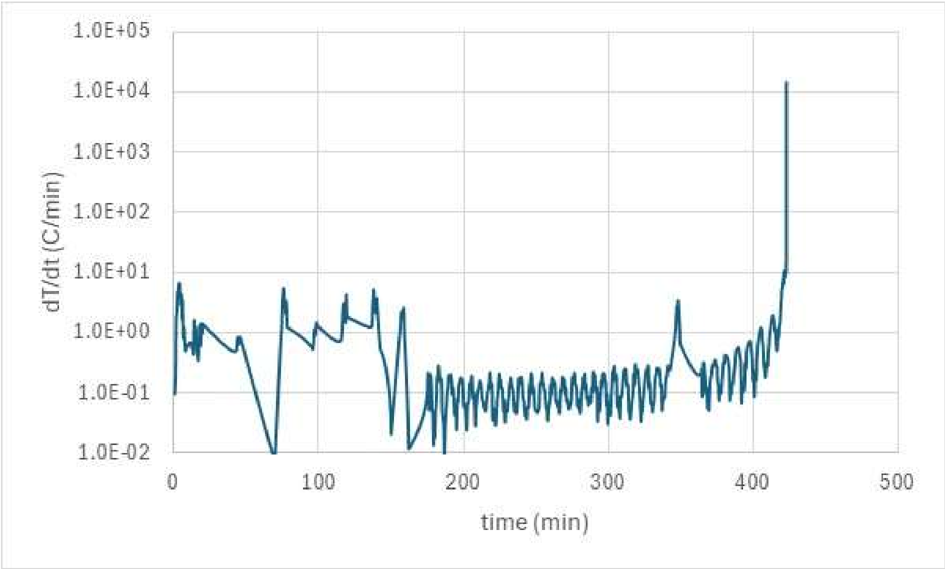
Accelerating Rate Calorimetry



Temperature-time histories from 3 thermocouples mounted on cell surface



Temperature rise rate from the middle thermocouple

Data generated by Prof. Partha Mukherjee & Anuththara S. Alujjage at Purdue University

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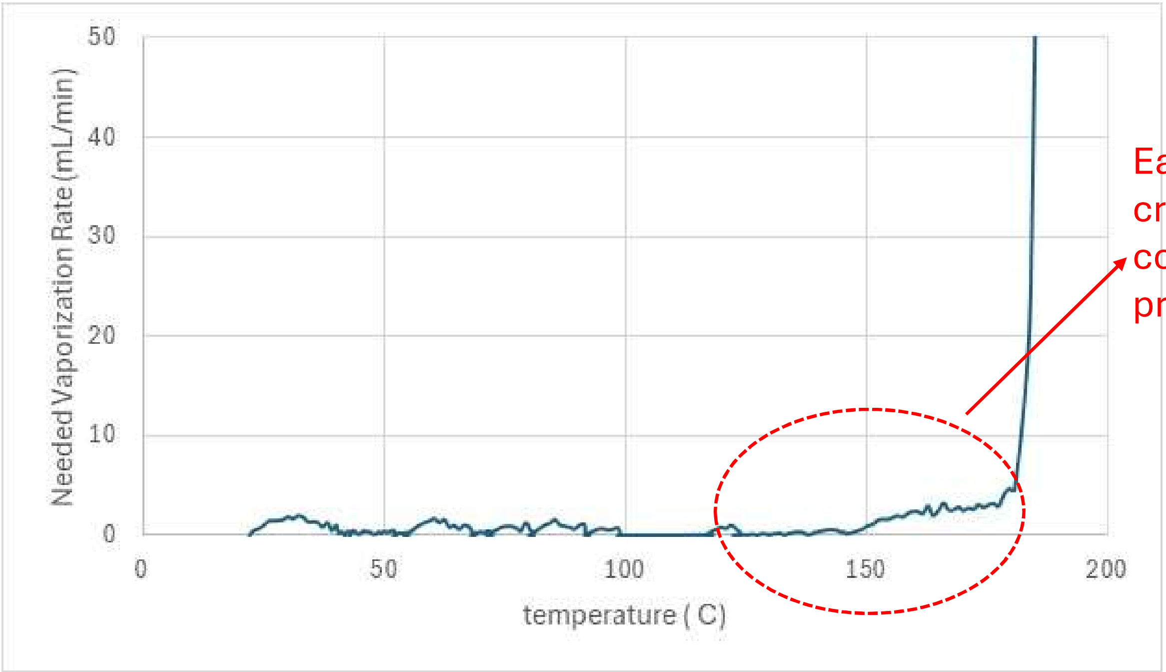
Liquid Injection Rate Needed to Prevent TR



Early Intervention is critical to minimize coolant needed to prevent TR

Assumption: Liquid vaporizes on cell surface by extracting latent heat of vaporization from the cell

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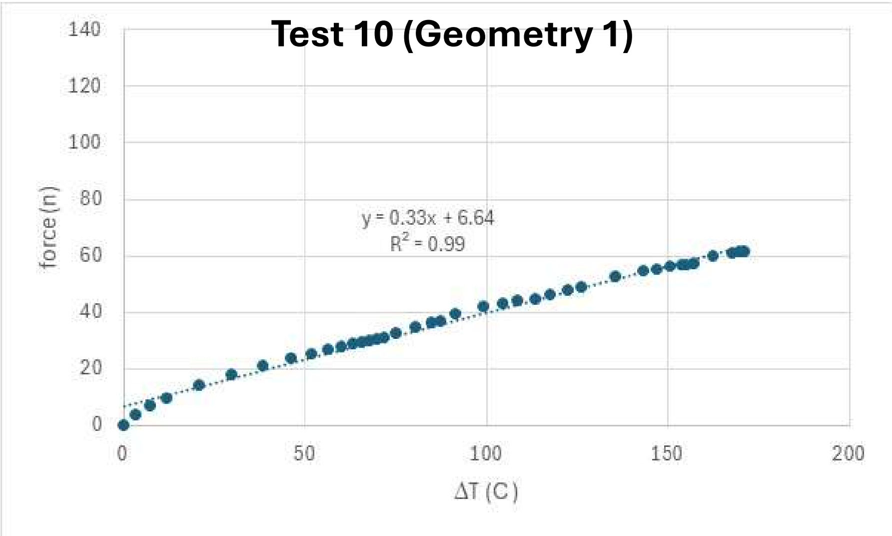
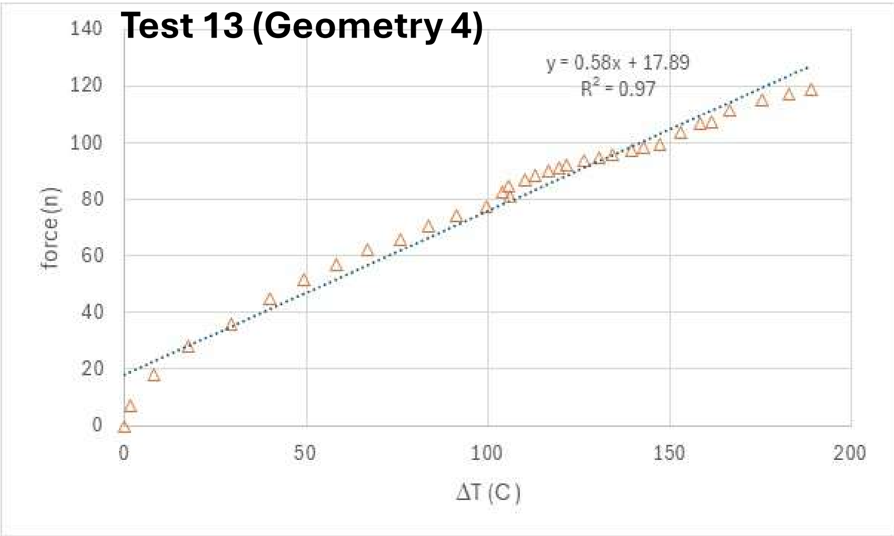
Key Questions

A. When heated, what force does the device impose on the coolant channel wall?
B. What force is needed to puncture the metal coolant channel walls used in liquid-based battery thermal management systems?
C. Is the force generated by our device sufficient to puncture the coolant channel wall?
D. Can coolant discharge on an overheated cell cool it adequately?
E. How well do the above components/processes work together?

A. Thermal Force vs. Temperature

We measured the thermal force generated when our device is heated. We considered four different geometries for our device





- Thermal force imposed by our device increases with rise in temperature (ΔT)
- Slope of force vs. ΔT curve increased by 76% from Geometry #1 to #4
- Sensitivity of our device (i.e., the slope of force vs. ΔT curve) can be increased further with other geometries

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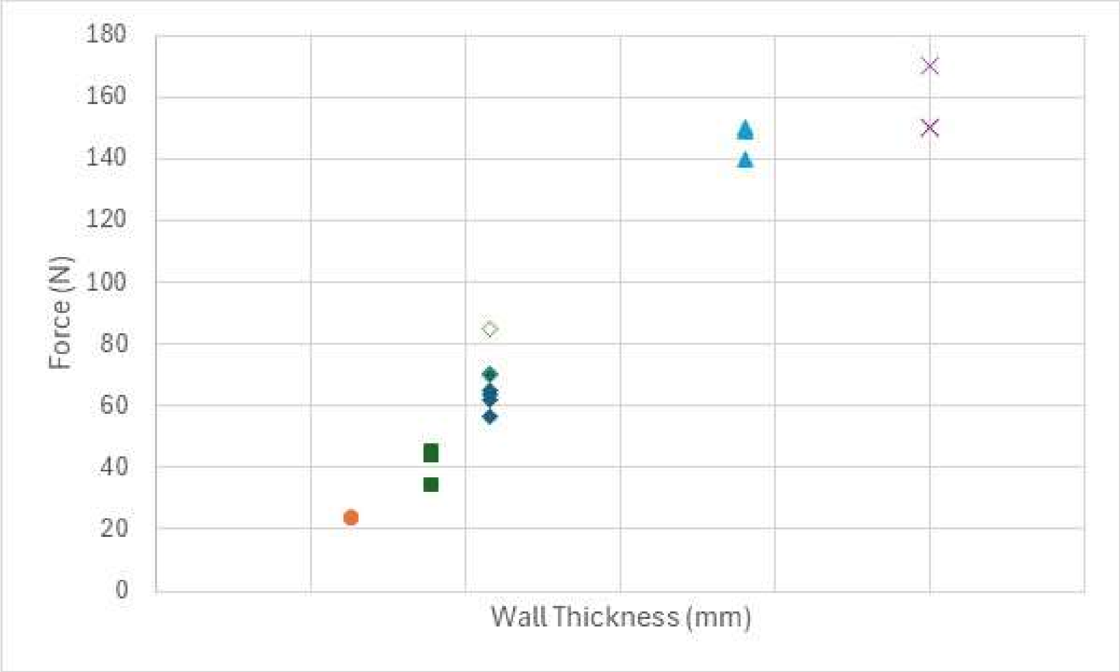
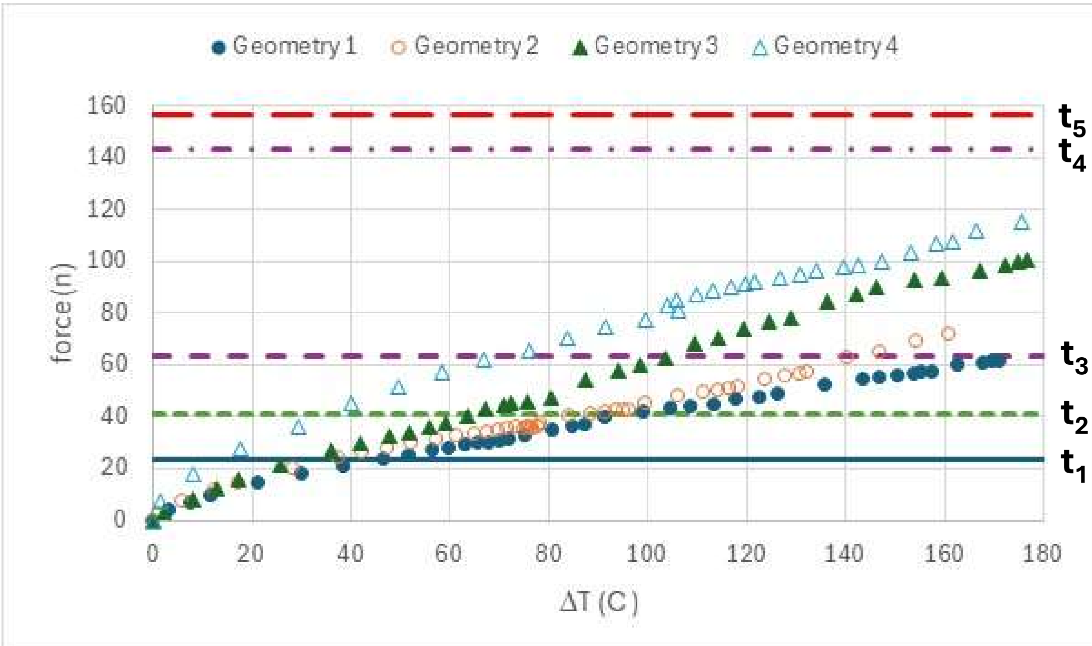
B. Force Needed to Puncture Metal Walls

We measured the force needed to puncture metal walls of different thickness



Force needed to puncture coolant channel wall increases with wall thickness

C. Thermal Force Generated by our Device Vs. Force Needed To Puncture Al Walls



$t_1 < t_2 < t_3 < t_4 < t_5$

- Geometry 4: *ΔT*s of ~18°, 40°, and 75°C are adequate for our device to puncture metal walls of thicknesses t_1, t_2 and t_3. Data extrapolation suggests that walls with thicknesses t_4 and t_5 can be punctured at 216° and 240°C.
- Thicker coolant channel walls can be punctured using other geometries.

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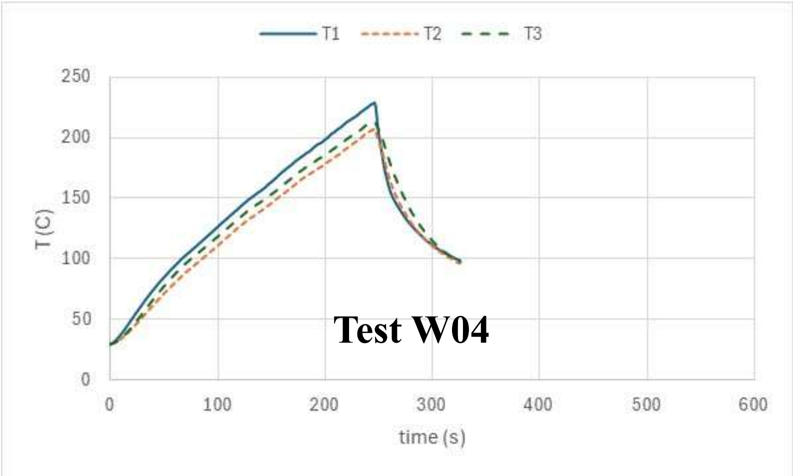
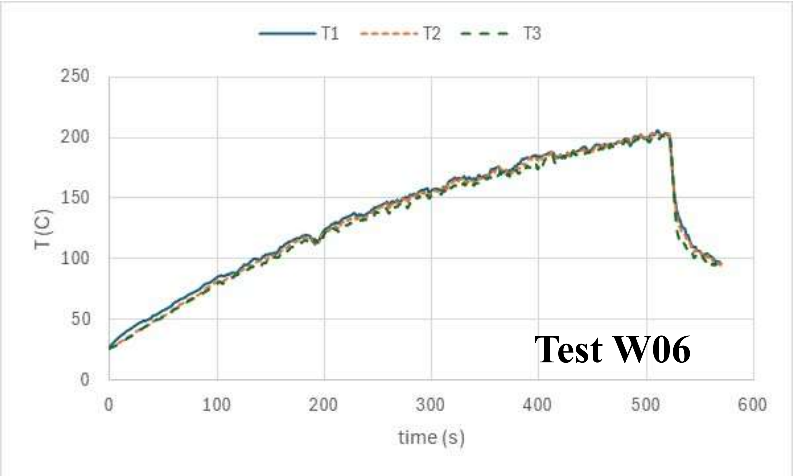
D. Effect of Coolant Deluge on Cell Temperature

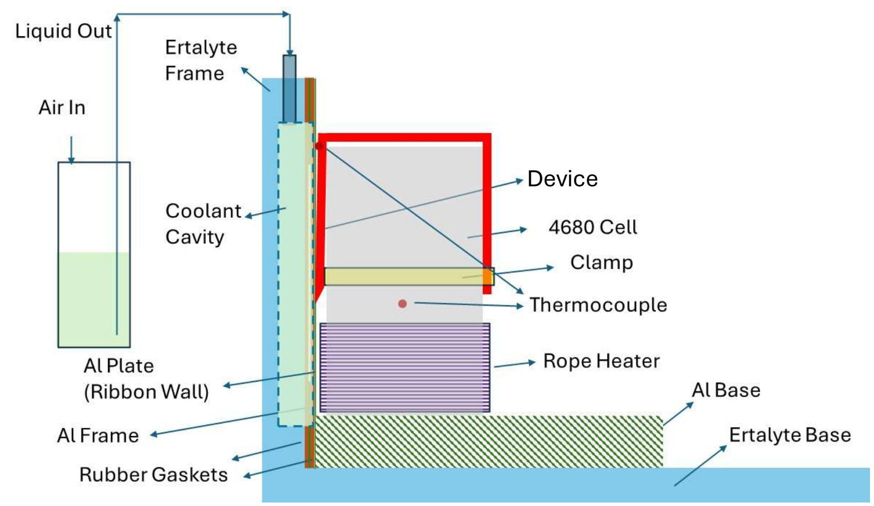
- We heated 18650 cell surrogates to different temperatures
- Once the cell reached the desired temperature, we injected 10 mL of liquid coolant directly on the cell surface
- Local boiling of coolant on the cell surface quenched the cell quickly





E. Tests with Integrated System

- Test setup
  - A liquid channel with an Al wall was used to simulate coolant ribbons used in batteries
  - Tests performed with 4680 cell surrogates equipped with a heating tape and insulation
  - Our device was anchored to the 4680 cell: a portion of the device (that was not touching the cell) was exposed to outside air
  - Coolant cavity was filled with liquid at ~5 psig
- Performed two tests with the integrated system
- Cell was heated at ~5°C/min to simulate thermal abuse



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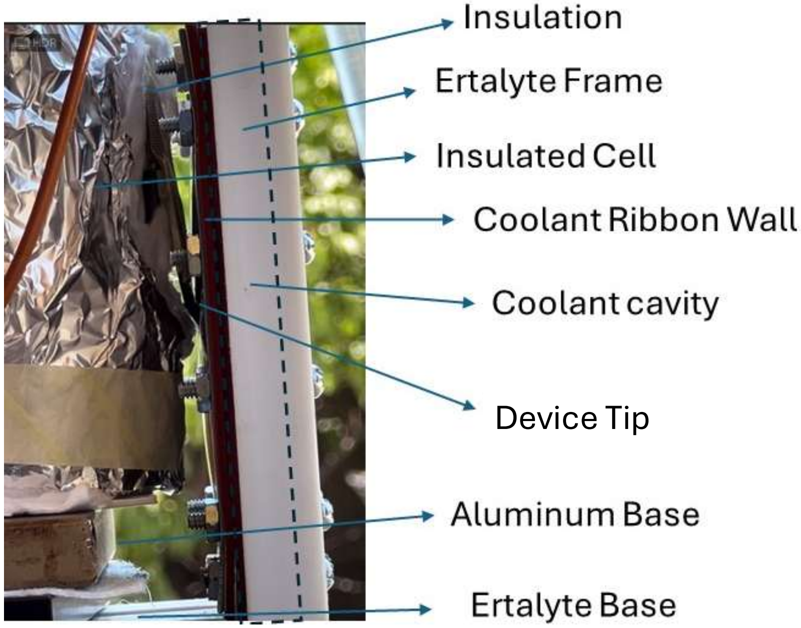
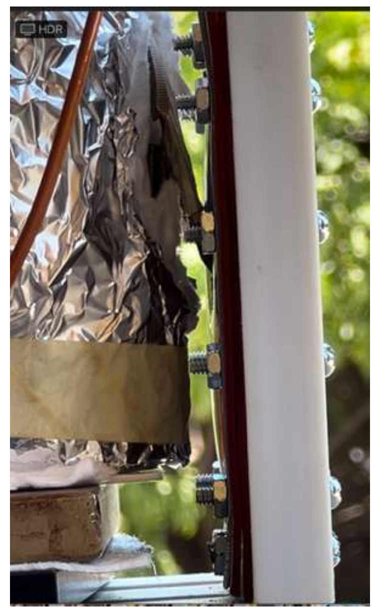
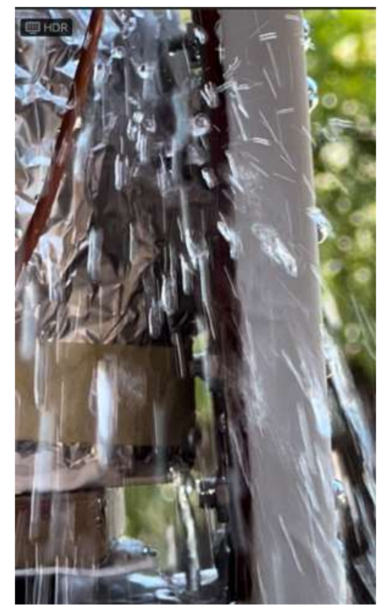
Test #BAT007



(a) t = 0 s (initial condition), *T* ~30°C

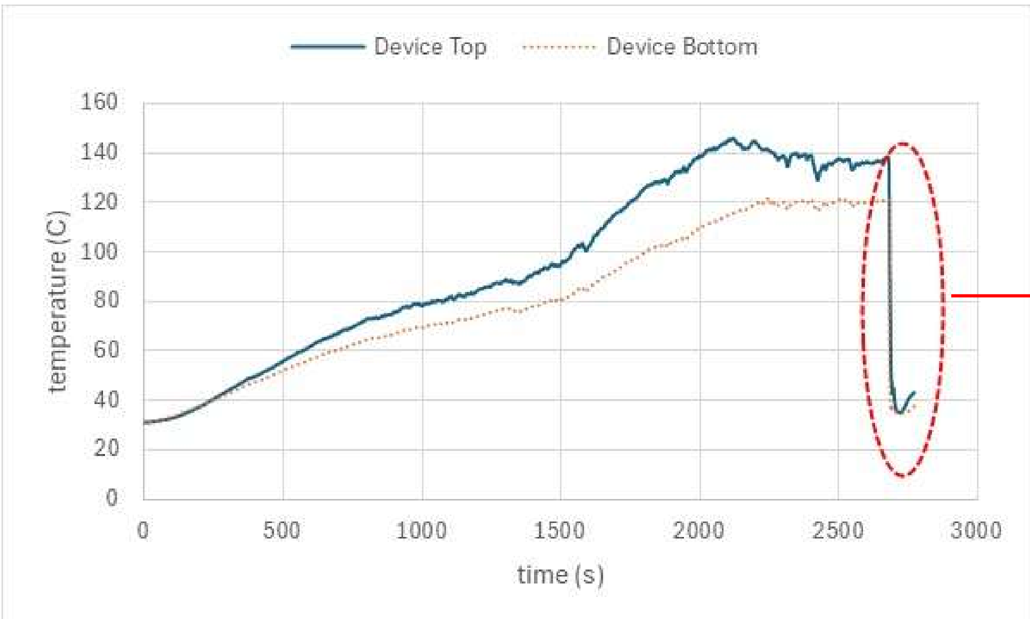


(b) t = 2678 s (just before coolant release), *T* ~122 – 138°C



(c) t = 2682 s (just after the start of coolant release), *T* ~49 – 99°C

Device Temperatures vs. Time



- Upon reaching 120° to 140°C, our device punctured the coolant channel wall to release the liquid coolant under pressure
- Contact between sub-cooled liquid coolant and overheated cell wall caused local boiling that cooled the cell quickly

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Test Fixture After Thermal Abuse Tests

Test BAT006

Test BAT007

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Conclusions

- Our device generates forces of 10s to 100s of N when heated that is adequate to puncture thin metal walls used to construct battery coolant ribbons
- Liquid coolant deluge quenches an overheated cell to sufficiently low temperatures to prevent thermal runaway
- Tests with integrated setup showed that all components work seamlessly and passively to quench an overheated cell
- The sensitivity and effectiveness of our device can be improved further through improvements in geometry and heat transfer
- Abuse tests with fully charged cells are planned over the next few months

Potential Applications

- Our technology can improve the thermal safety of Li ion batteries in most applications
- Example applications include
  - Air transport: eVTOL, aircraft, drones
  - Ground transport: Electric Vehicles, Electric Trucks and Electric Buses
  - eMobility systems: Ebikes and scooters
  - Battery Energy Storage Systems (BESS) for residential applications and power grids
  - Power tools
  - Medical devices

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Contact Information

Vijay Devarakonda, PhD
Analytical Scientific Products LLC
www.analyticalscientificproducts.com
vijay@analyticalscientificproducts.com