Mitigating Battery Runaway & Propagation

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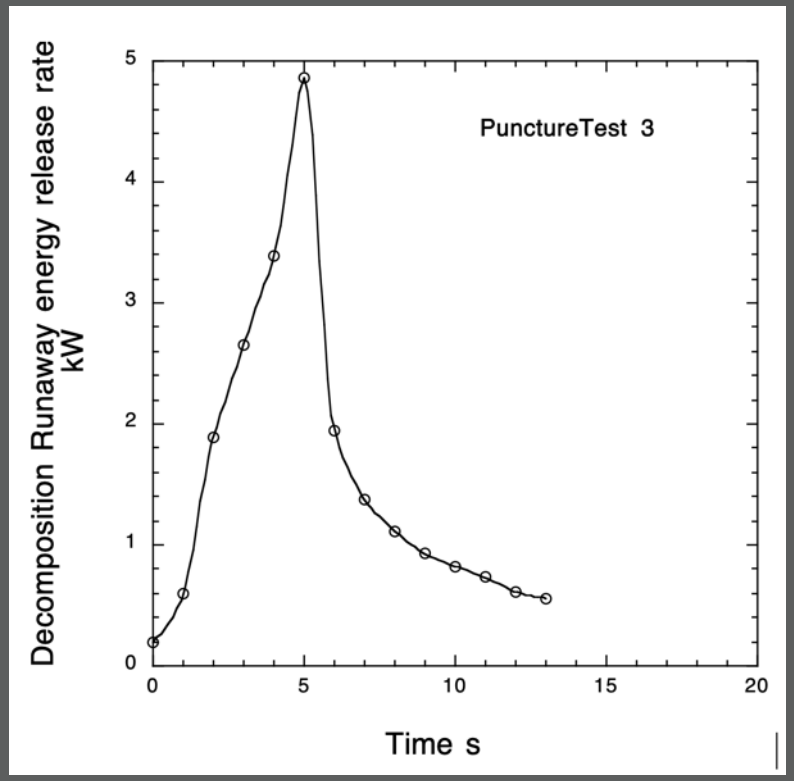
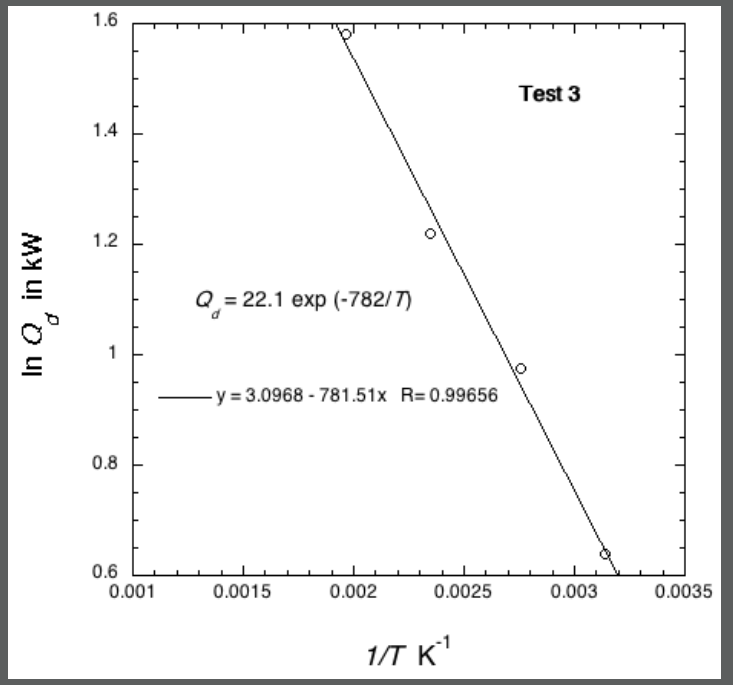
Background

- Purpose
  - Establish the research basis for designing a packaging technique to prevent the runaway of lithium-ion batteries.
- Project funded by
  - U. S. DoT, Pipeline and Hazardous Materials Safety Administration
  - Final Report Jan 2022
- Battery experiments
  - Conducted at Vitec Lab Inc (N. Shultz and B. Hon)

Runaway
energy rate (kW) vs total energy (kJ)

Rate: difficult: ARC onset kinetics, low temperatures



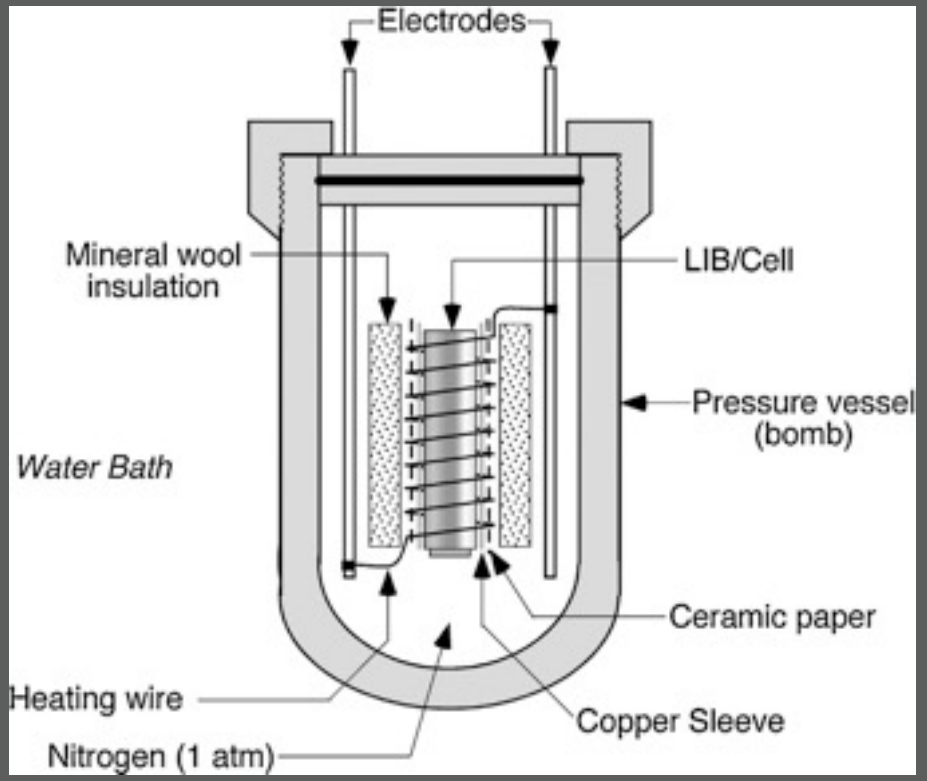


Total energy more practical measure

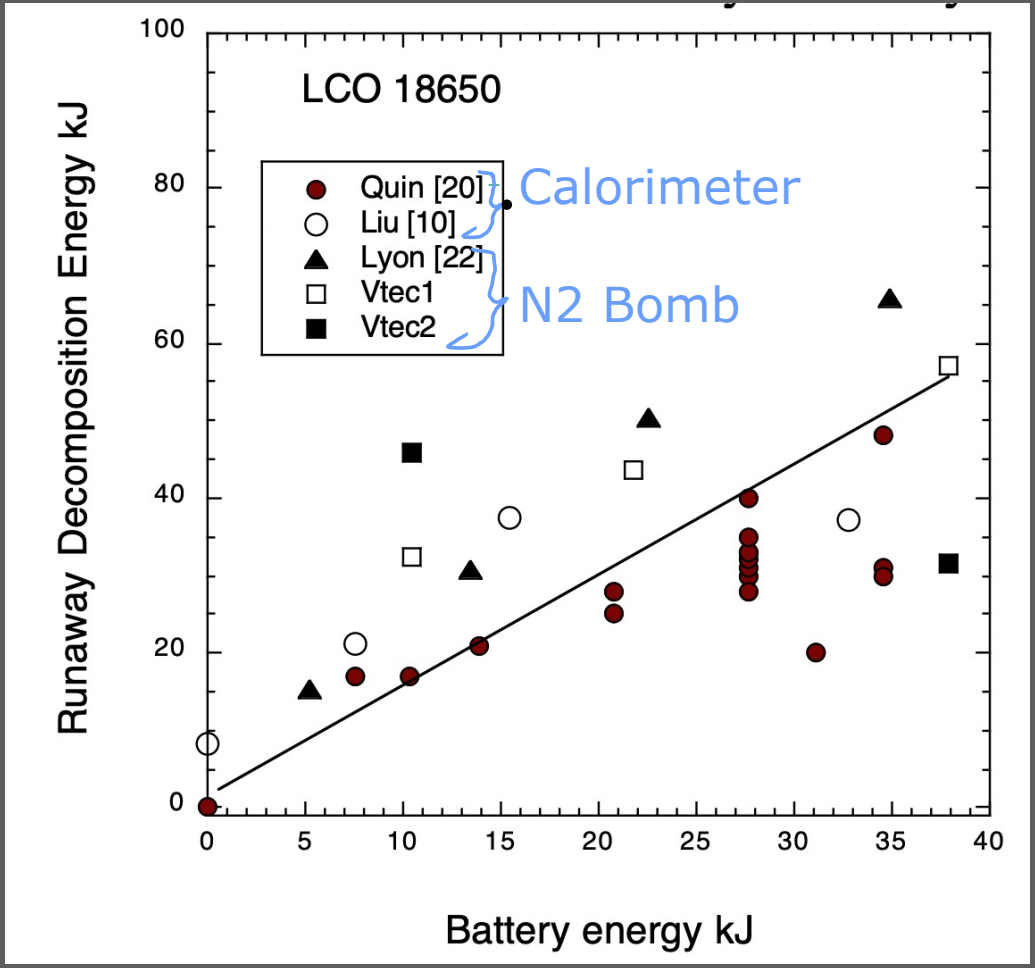
Measure Decomposition Energy

Battery as a calorimeter

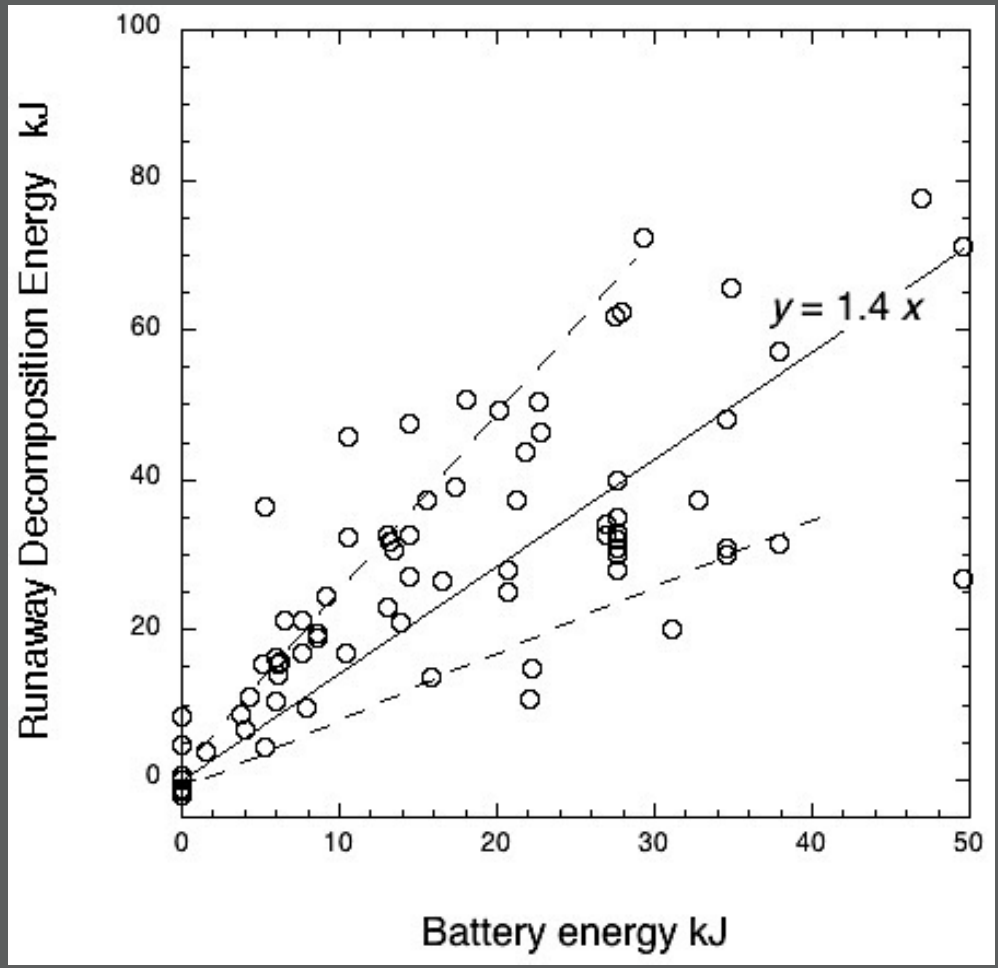
Nitrogen filled *Oxygen Bomb* *(Walters and Lyon)*



Comparing decomposition methods



25 Li cobalt oxide

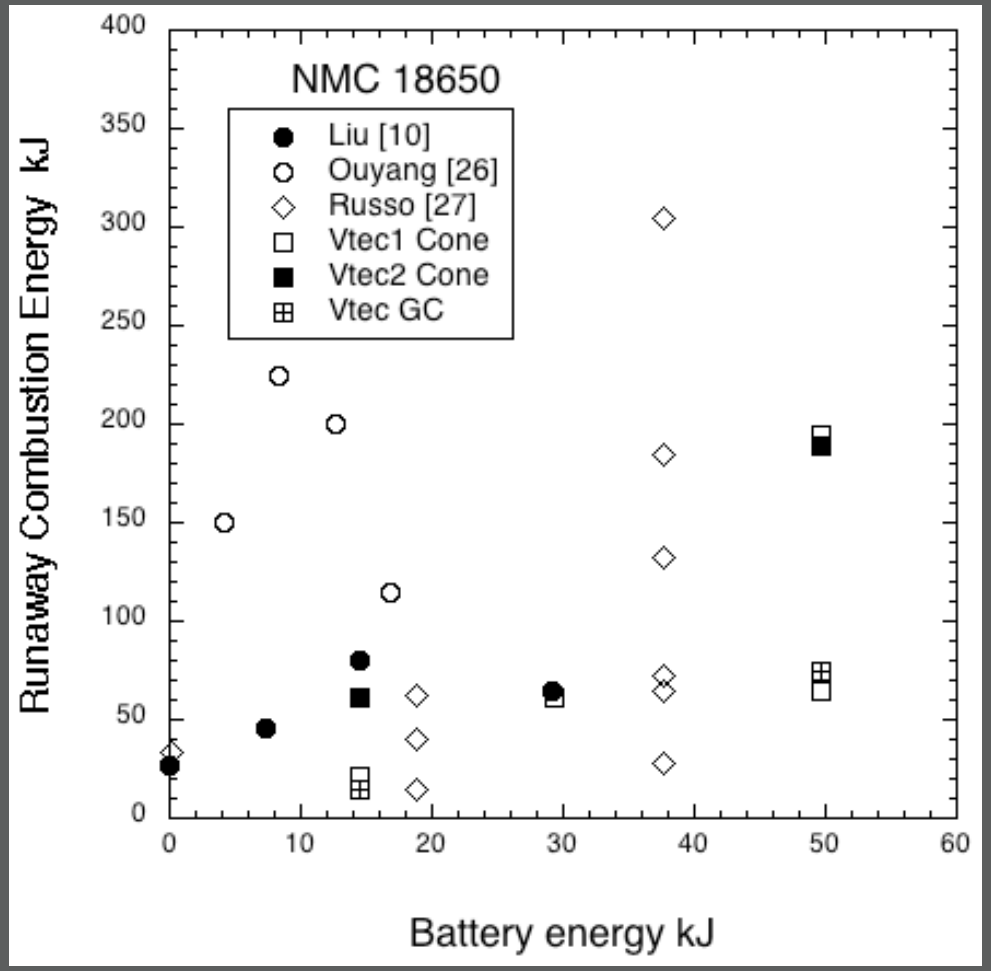


> 60 from literature ~ 2 X

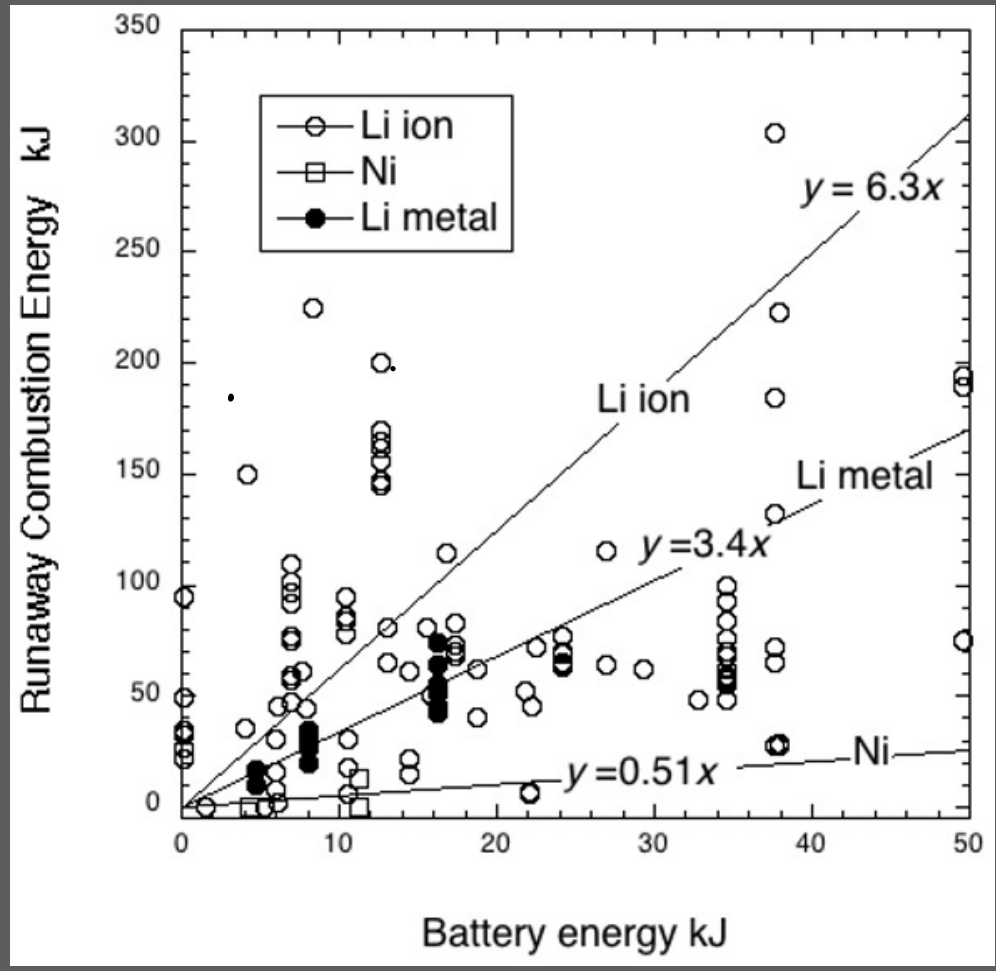
Measure combustion energy methods

- 1. Heating in Cone calorimeter
- 2. Direct oxygen bomb
- 3. Products from N_2 bomb into GC
- 4. Burn products directly in Cone

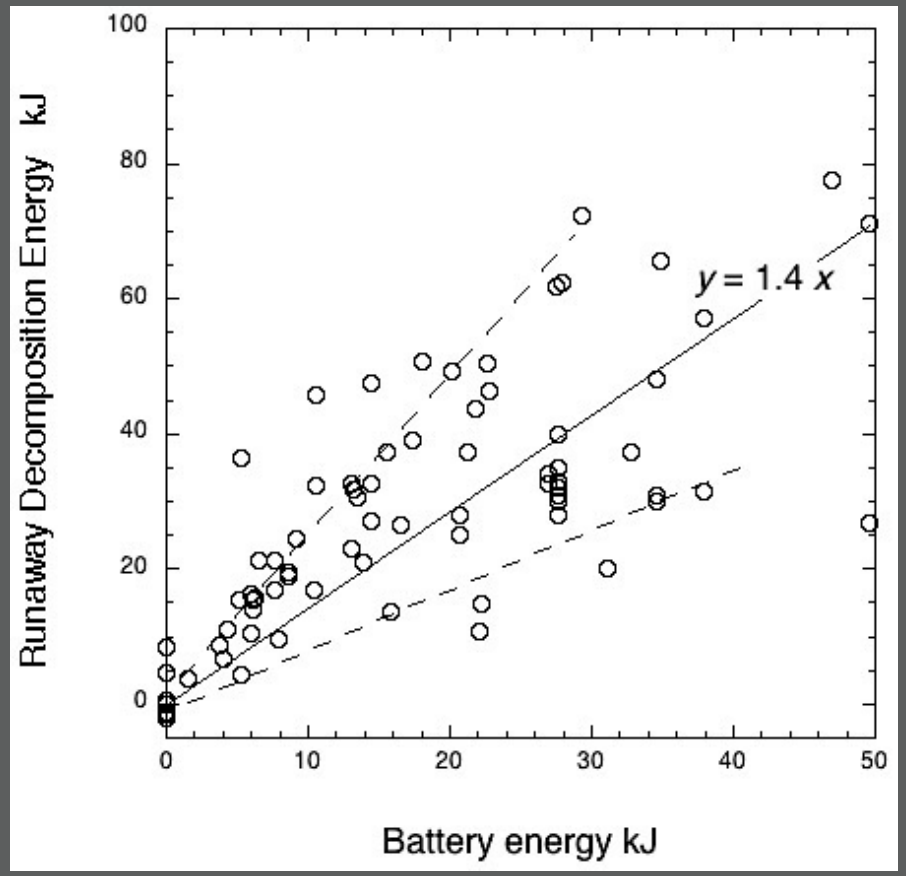
Comparing Combustion Methods
note scatter



Li - NMC



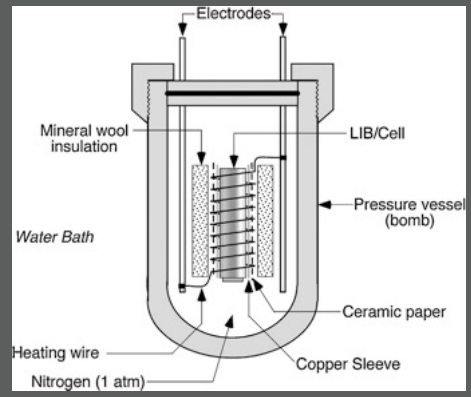
All from literature ~ 6 X



Decomposition Energy

~ 2 X Electric

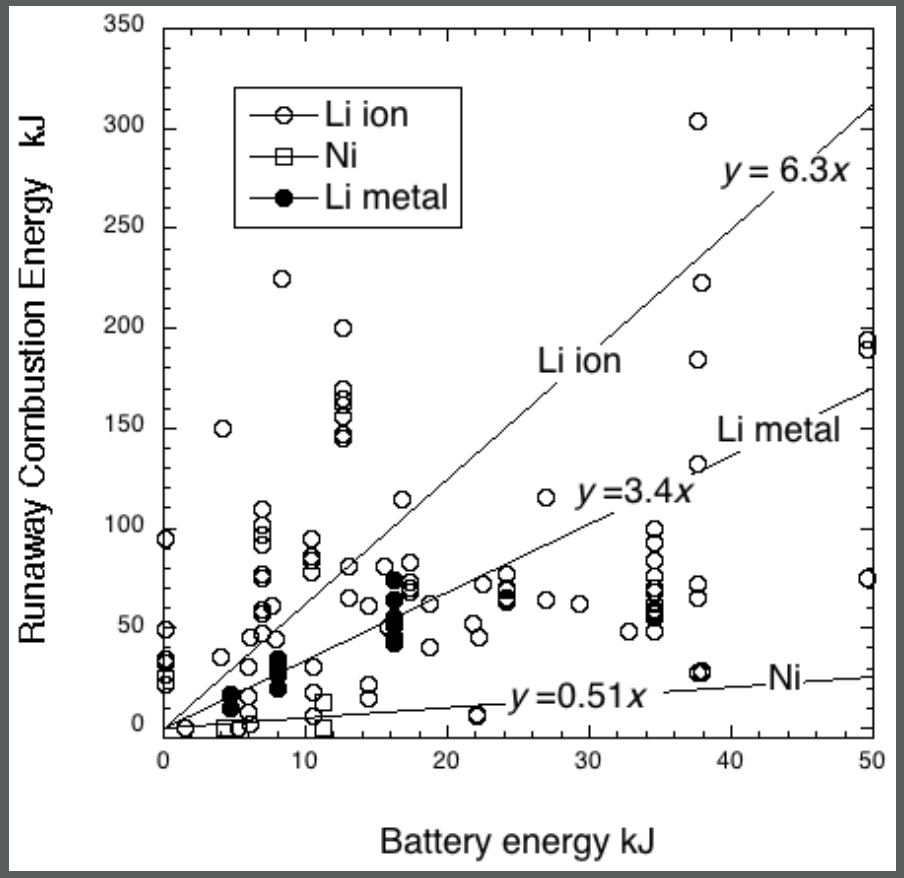
Oxygen Bomb with N_2



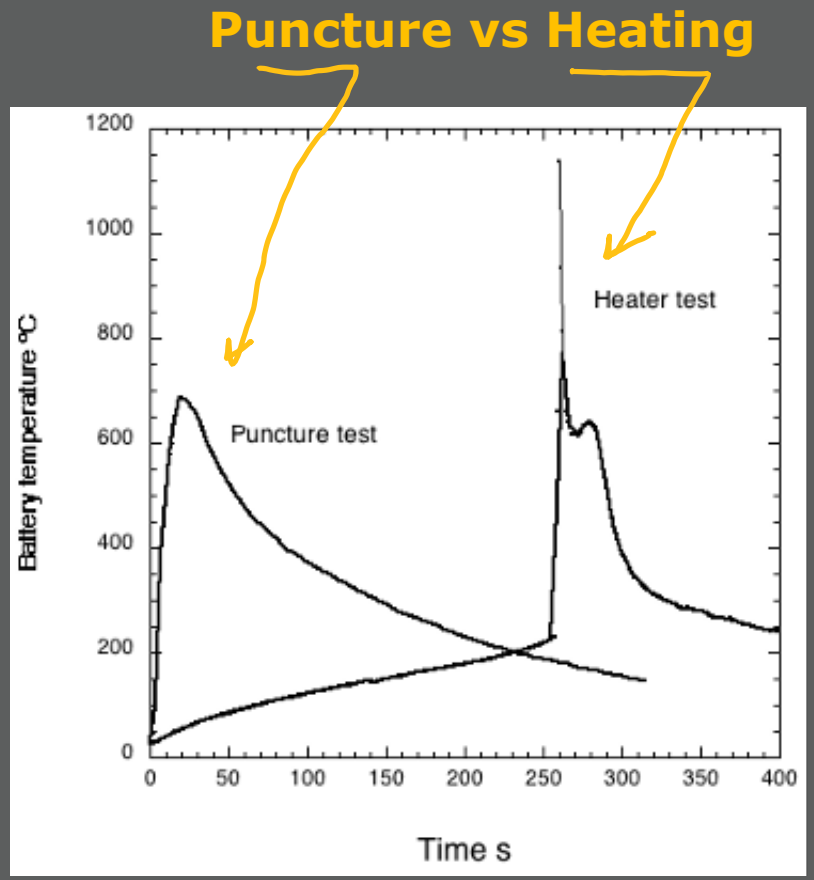
Combustion Energy

~ 6 X Electric

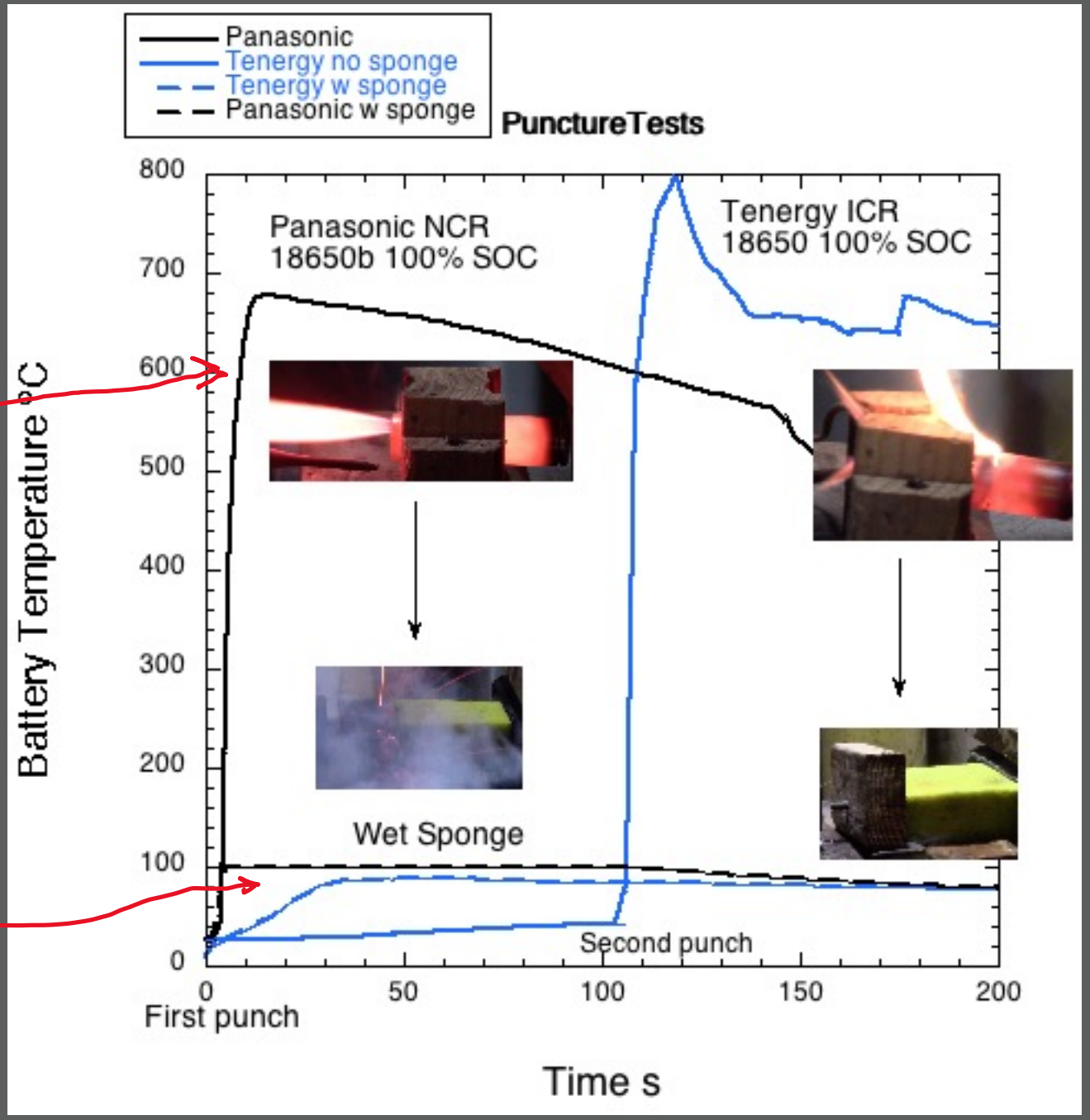
Burn Products



Proof of Concept
Trigger: Puncture vs Heating



PROOF OF CONCEPT

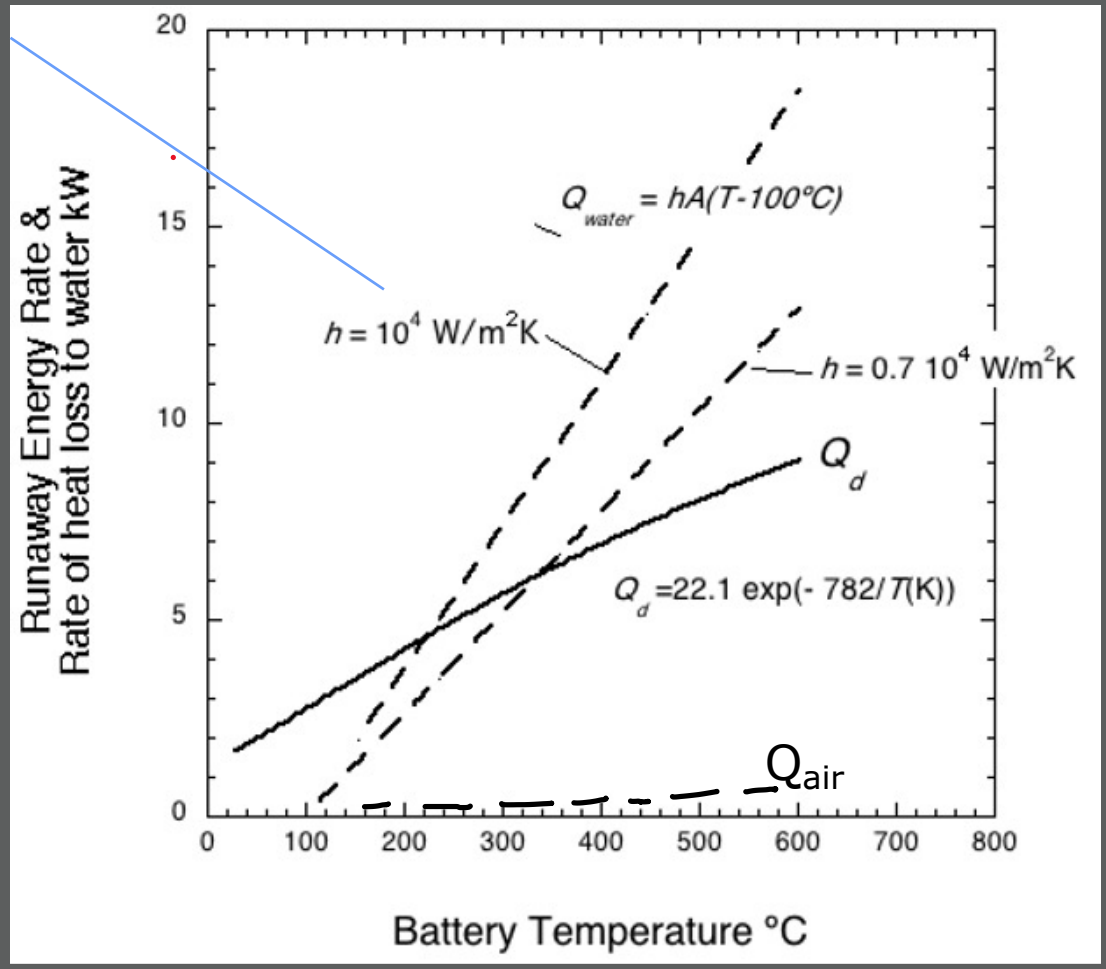


Mechanism of water mitigation: Boiling: high heat transfer

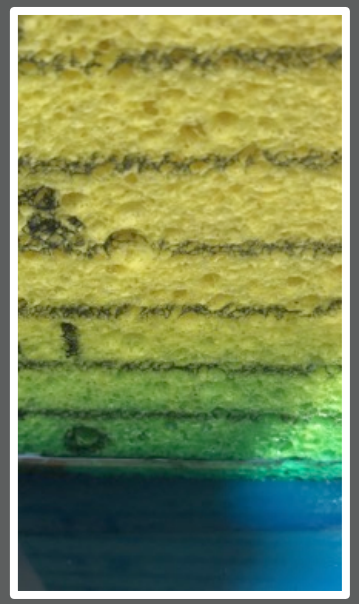
$$mc\frac{dT}{dt} = \dot{Q}_d - \dot{Q}_{loss}$$

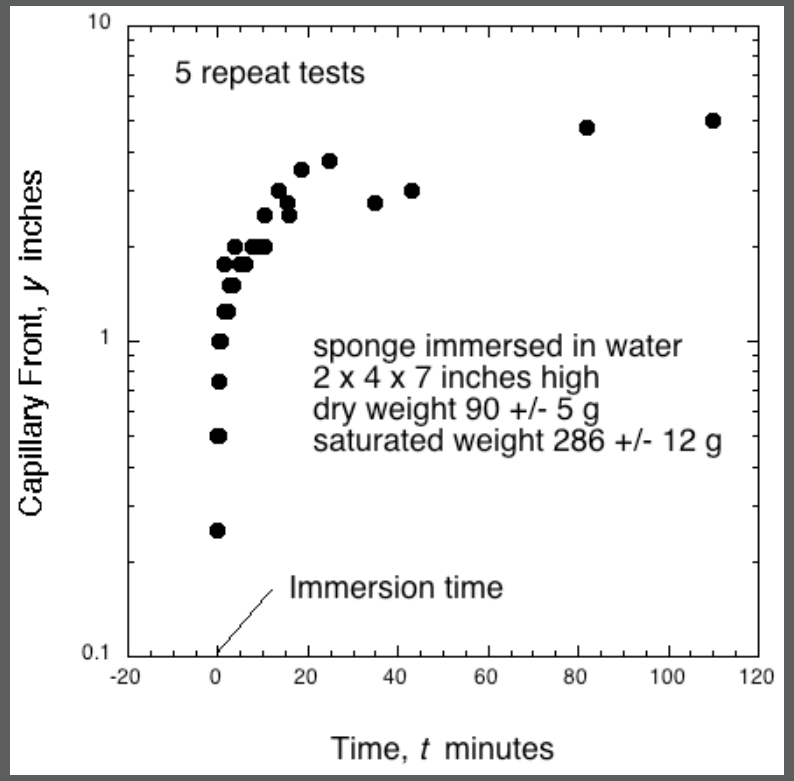
$\dot{Q}_d = \dot{Q}_{boiling\ water}$, equillibrium

$\dot{Q}_d > \dot{Q}_{loss,air}$, runaway



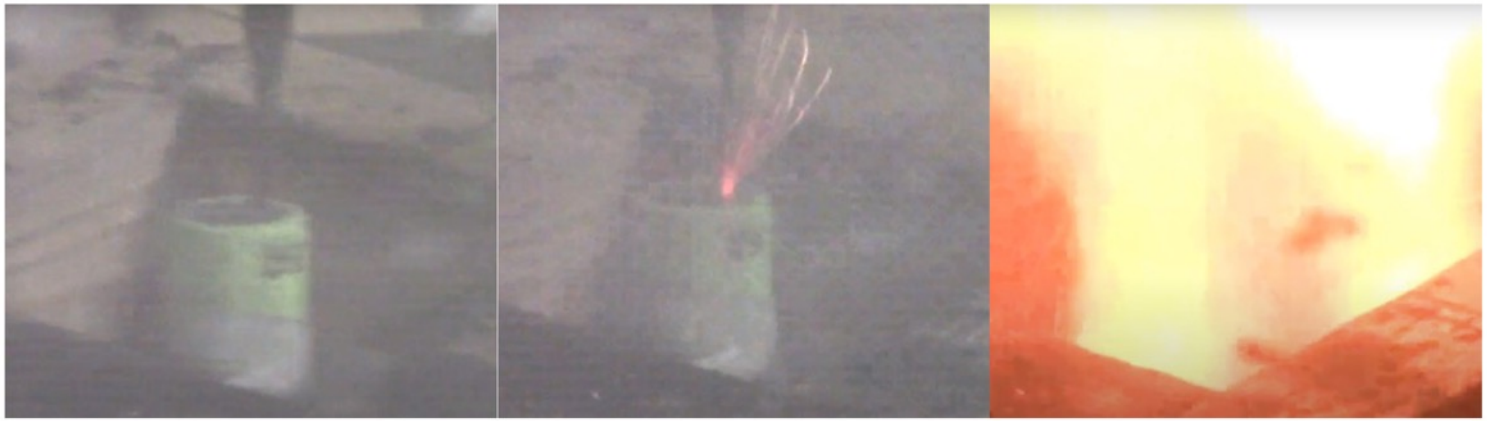
Mechanism of water mitigation: Rapid capillary action in sponge

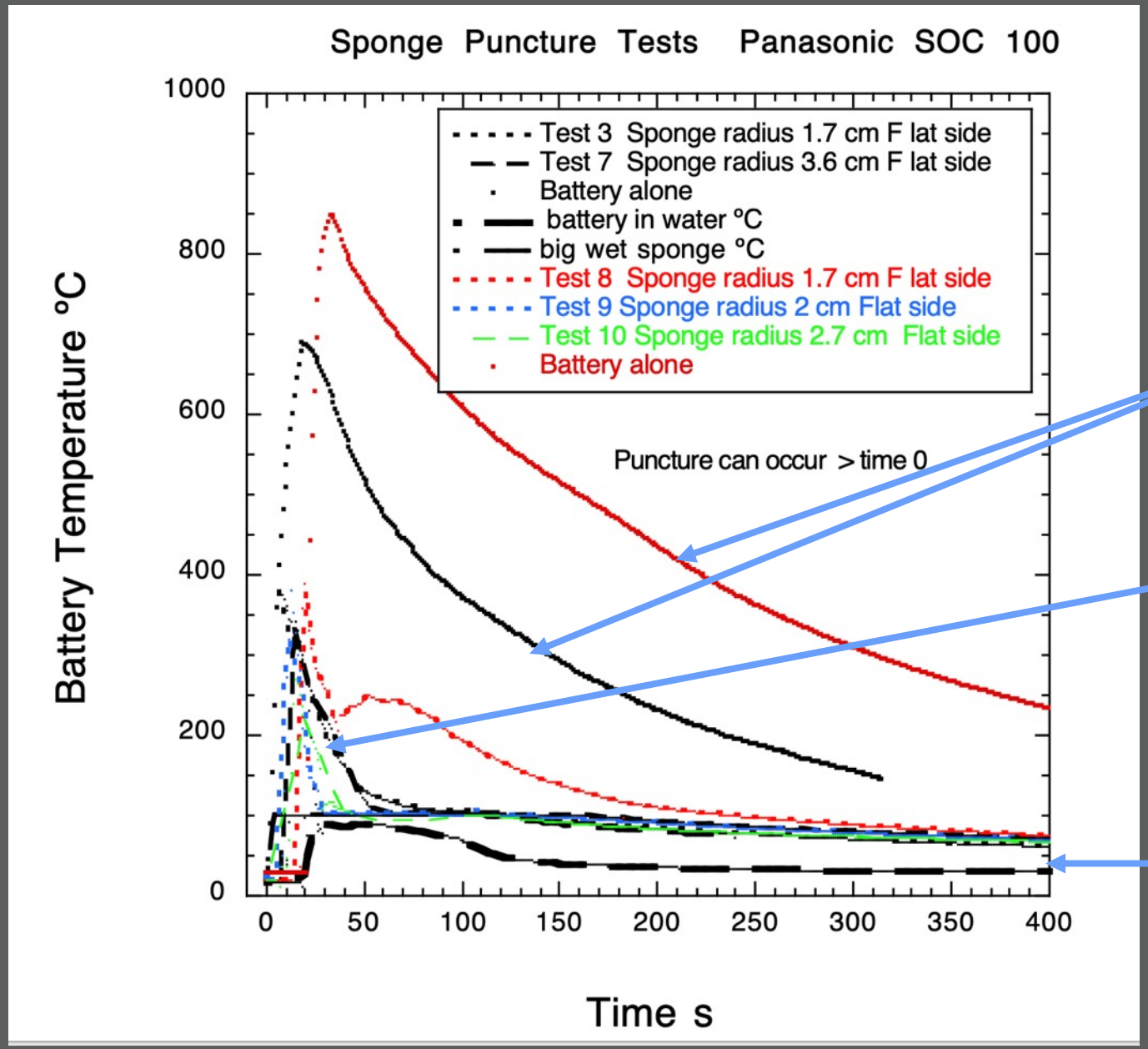




- **Initial velocity very fast**
- **Water continuous**
- **Boiling sustained**

Single battery water mitigation: 100 % SOC 18650 NMC puncture





PUNCTURE RESULTS

IN AIR

IN WET SPONGE
1.7 to 3.6 cm

IN WATER

PACKAGING RESEARCH

CARDBOARD
SEPARATORS

OUTER BOX

PUNCTURE @
CORNER AND CENTER

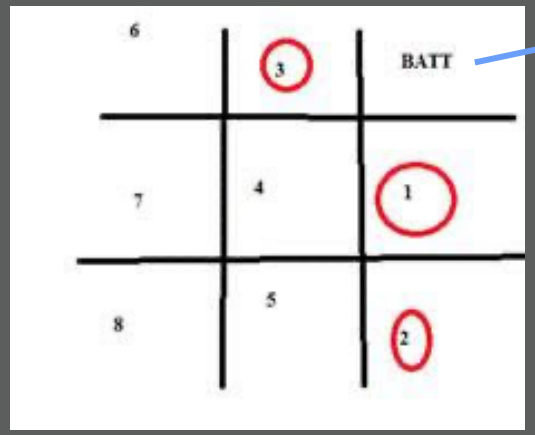
SATURATED WET
SPONGE SEPARATOR

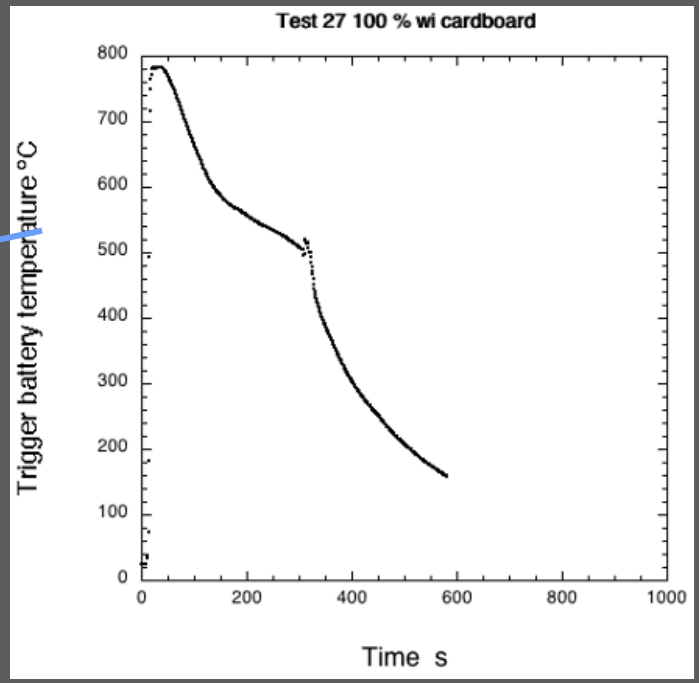
ARRAY IN CARDBOARD

318 s: Batteries #2&3

147 s: Battery #1

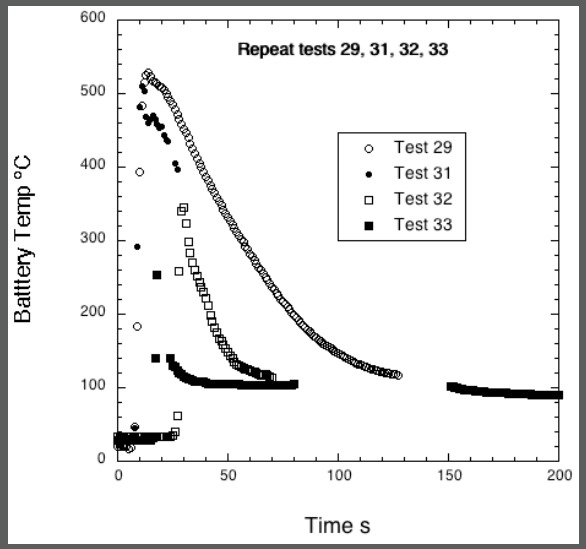
Glowing batteries ejected





0 s: corner puncture

Sponge array



Summary of Packaging Tests

- Array tests with a typical cardboard separator and a water-saturated sponge separator.
- The trigger battery was a 100 % SOC 18650 NMC punctured into runaway; center or at a corner.
- Cardboard array: corner trigger led to a rupture of the cardboard container with three surrounding batteries going into runaway.
- Sponge array, none of the surrounding batteries were damaged or vented.

Conclusions

- Best way to measure runaway energies
  - Decomposition: N2 bomb calorimeter
  - Combustion: ignited gas into Cone
- Decomposition energy 2X battery electrical energy
- Combustion energy 6X battery electric energy
- Water in sponge mitigates by boiling and rapid capillary flow

Work funded by PHMSA US DoT