Lithium Battery Update

The Effect of State of Charge On Flammability and Propagation of Thermal Runaway

Presented to: Systems Working Group

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Federal Aviation Administration

The Effect of State of Charge On Flammability

- **Groups of rechargeable lithium-ion 18650 cells were tested in two modes.**

  - Heated using an external alcohol flame
    - 7 cells wired together
  - Cone calorimeter
    - 5 separate tests with 1 cell at each charge, 20%, 30%, 50%, 70%, 100%
      - *heat flux of 50 kw/m²*

The Effect of State of Charge On Flammability

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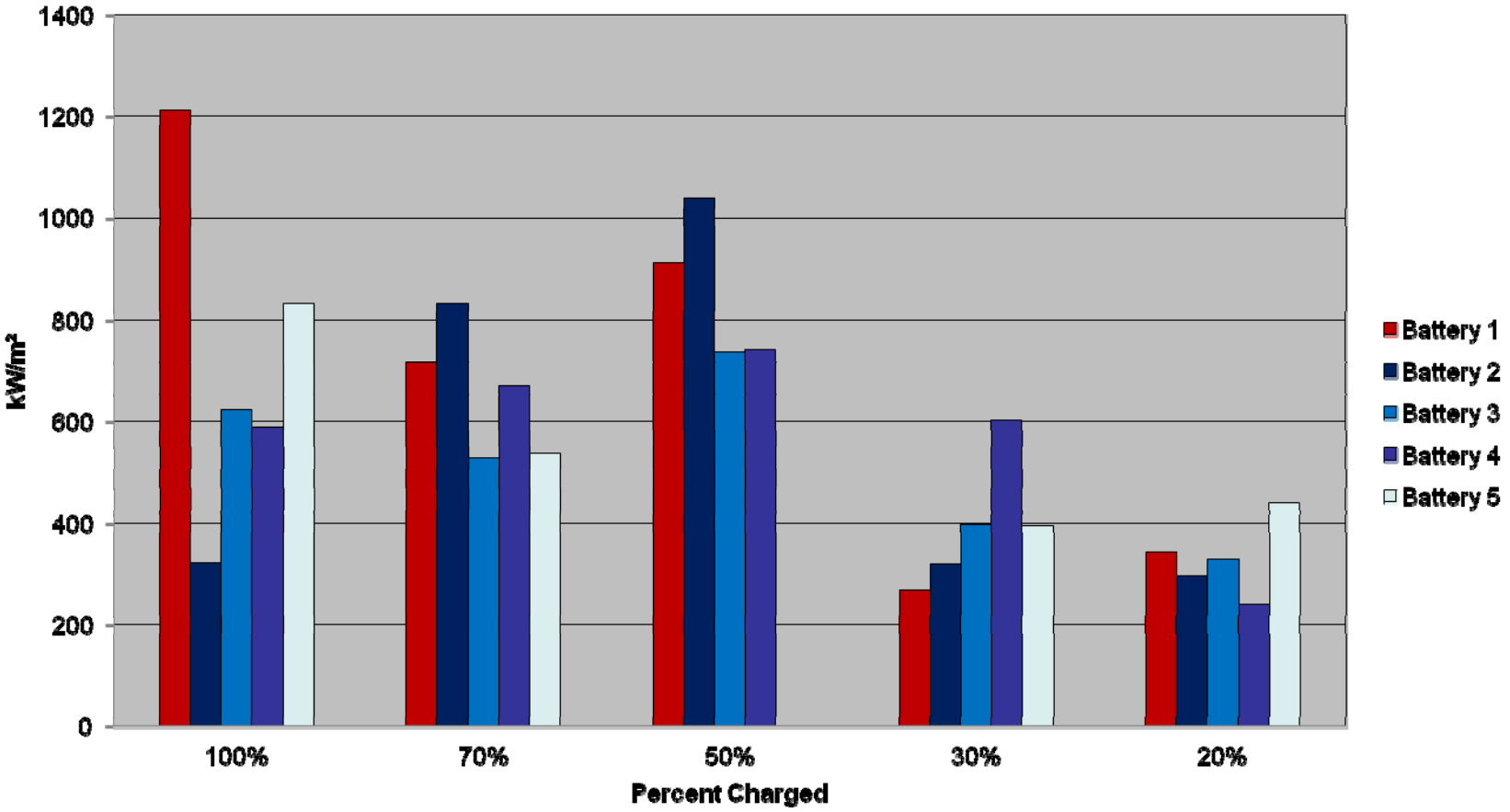
- **Results: Heated Using External Flame**
  - 100% Charge: produced flammable electrolyte, large pressure pulse, strong torching fire, sparks, vent 4:00 minutes, ignition of electrolyte 4:28
  - 50% Charge: produced flammable electrolyte, large pressure pulse, vent 3:46 minutes, ignition of electrolyte 4:56 minutes
  - 30% Charged: produced flammable electrolyte, small pressure pulse, vent 3:39 minutes, ignition of electrolyte 5:07 minutes

Peak Heat Release Rates For Different Charges



Cone-Calorimeter 100% charged Test

Cone-Calorimeter 30% Charged Test

Effect of State of Charge On Flammability – 100%

The Effect of State of Charge On The Propagation of Thermal Runaway

- **Tests were designed to measure the effect of state of charge on the propagation of thermal runaway**

  - 4 cells were wired together in line

  - A 100 Watt Cartridge Heater was secured to the first battery as the heat source

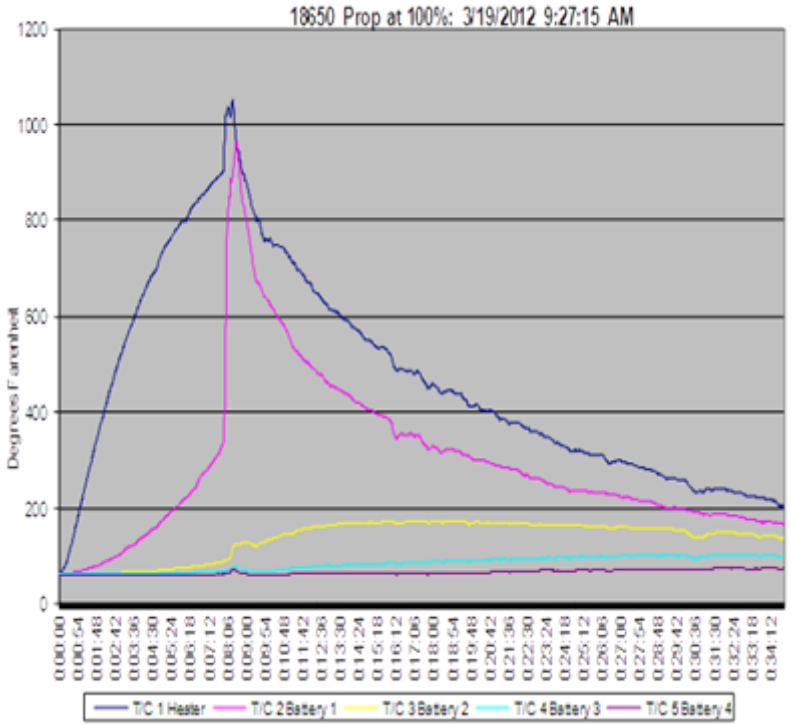
The Effect of State of Charge On The Propagation of Thermal Runaway

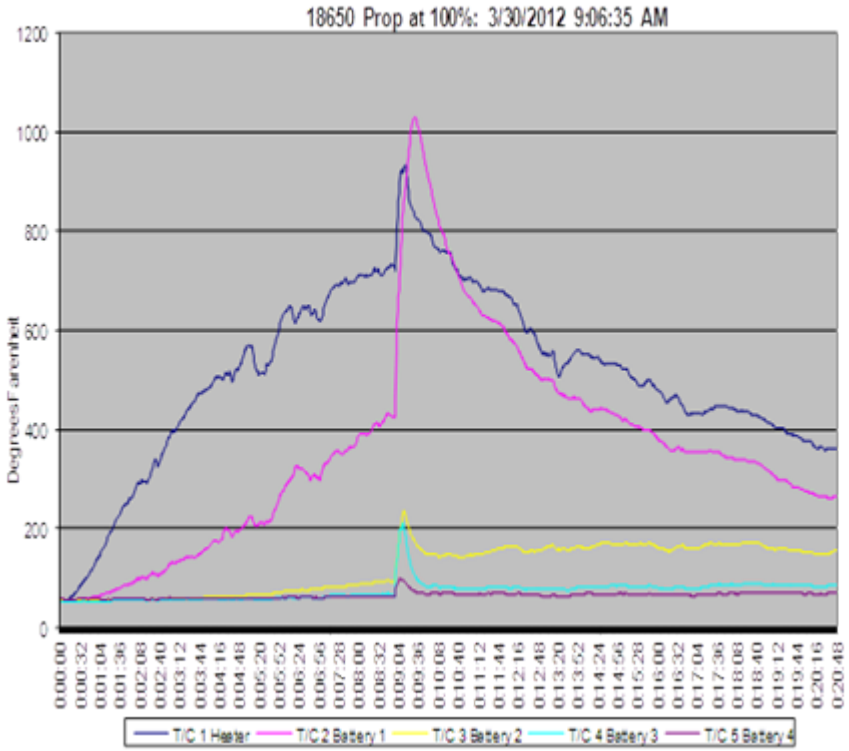
- **A series of 5 tests were conducted; 100%, 50%, 40%, 30%, 20% charge**

- **5 thermocouples (one for the heater and one for each corresponding battery) recorded the temperatures**

Propagation Test Configuration

Propagation Test Data





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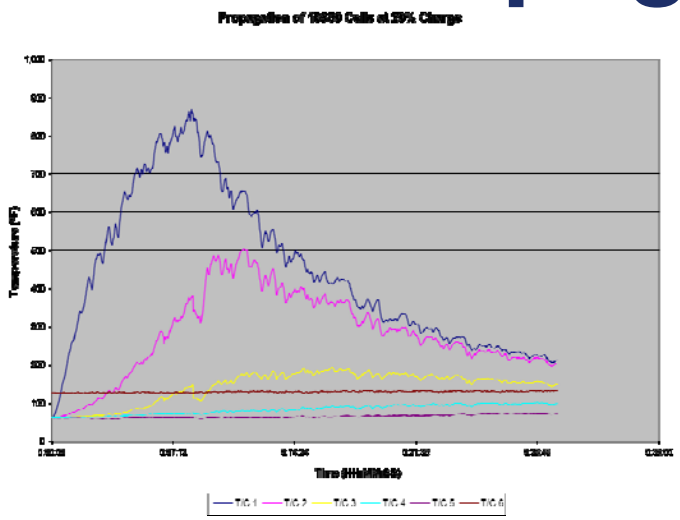

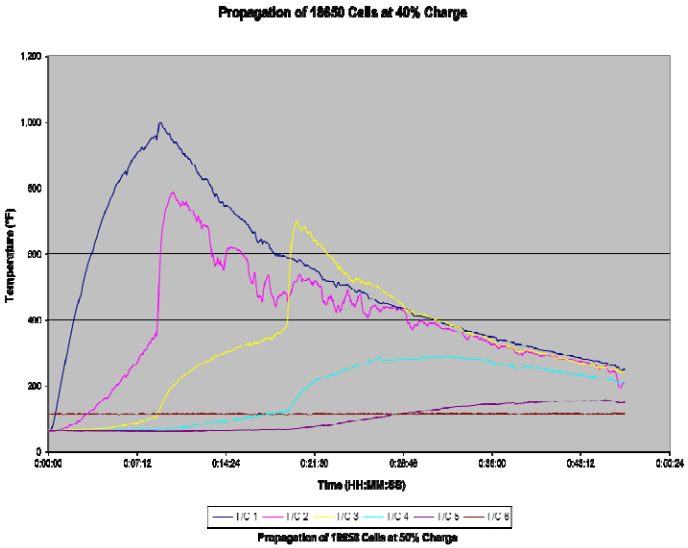

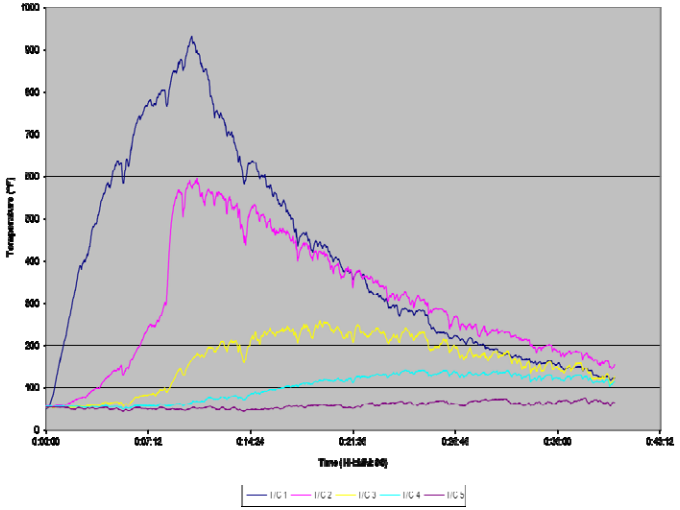

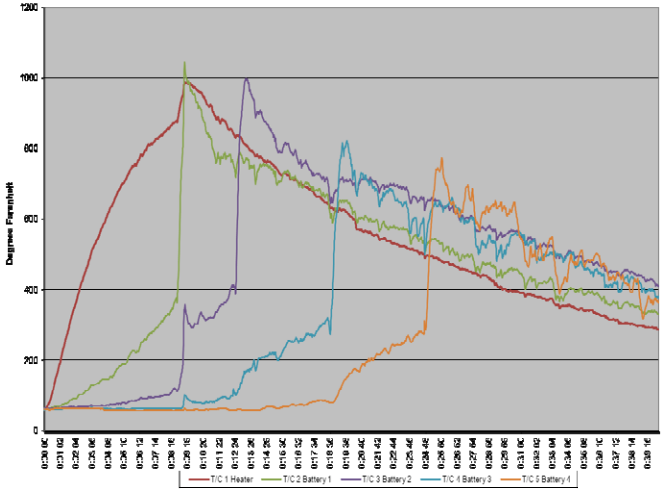

The Effect of State of Charge On The Propagation of Thermal Runaway

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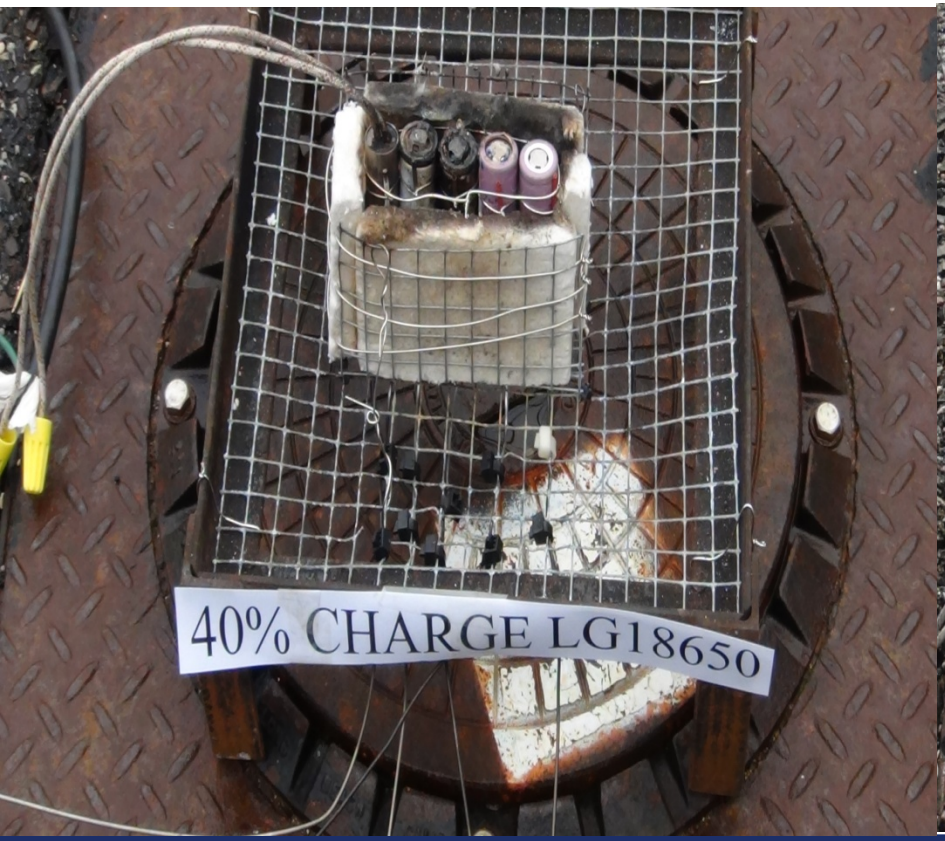

The Effect of State of Charge On The Propagation of Thermal Runaway

- **Results**
  - 100% Battery exploded in both tests, rapid cooling was observed. Peak temperature: 1030°F
  - 50% test consumed all cells. Peak temperature: 1044°F
  - 40% 2 cells were consumed, peak temperature 760°F decreased after thermal runaway in cell 2.
  - 30% venting occurred in battery 1 with no thermal runaway. Peak temperature: 560°F
  - 20% venting occurred with a peak temperature 502°F

The Effect of State of Charge On The Propagation of Thermal Runaway

- **Conclusions**
  - 50% charge produces the greatest possibility of thermal runaway propagation
  - 30% or less charge halts the propagation of thermal runaway
  - Heat release values decrease with reduced states of charge
  - Shipping cells at less than 50% state of charge may reduce the severity of a fire event

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