New Battery Hazard Measurement Capabilities DC-GC-MS

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FAA

Objective

Measure fire & toxicity hazards of lithium ion & other battery/cell chemistries on aircraft

Passenger Electronics

Bulk Shipment (cargo)

Aircraft Incidents Involving Li Batteries

- **UPS Flight 1307** - Fire erupted in a cargo plane that landed in Philadelphia on Feb. 7, 2006. Aircraft Destroyed - 0/2 Fatalities

- **UPS Flight 6** - A cargo plane with 81,000 lithium batteries caught fire and crashed after it left Dubai on Sept. 3, 2010. Aircraft Destroyed - 2/2 Fatalities

- **Asiana Flight 991** - A cargo jet crashed into the East China Sea on July 28, 2011, after the crew reported a fire on board. Aircraft Destroyed - 2/2 Fatalities

Between March, 2006 and January, 2024, the FAA recorded 505 total aviation related incidents involving lithium batteries

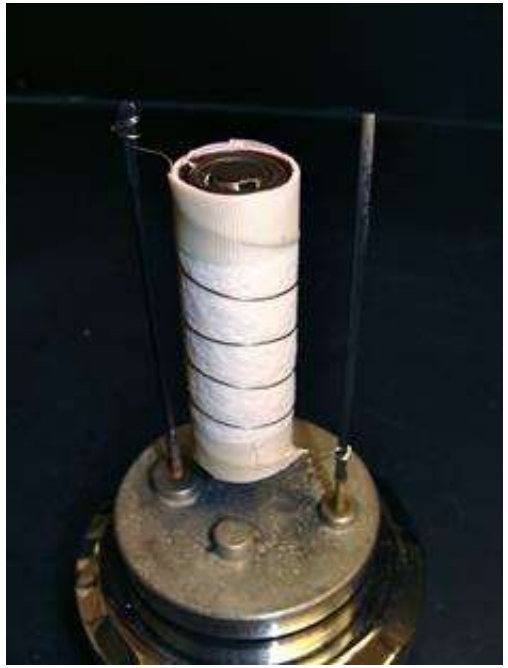
Causes of Thermal Runaway

- Thermal
  - Separator melts due to high temperature causing internal short circuit that liberates heat. Contents mix, react and thermally decompose.
- Mechanical
  - Physical damage (puncture)
  - Li dendrite grows to short circuit
- Electrical
  - Overcharge
  - Rapid discharge

All lead to temperature increase and acceleration of chemical decomposition

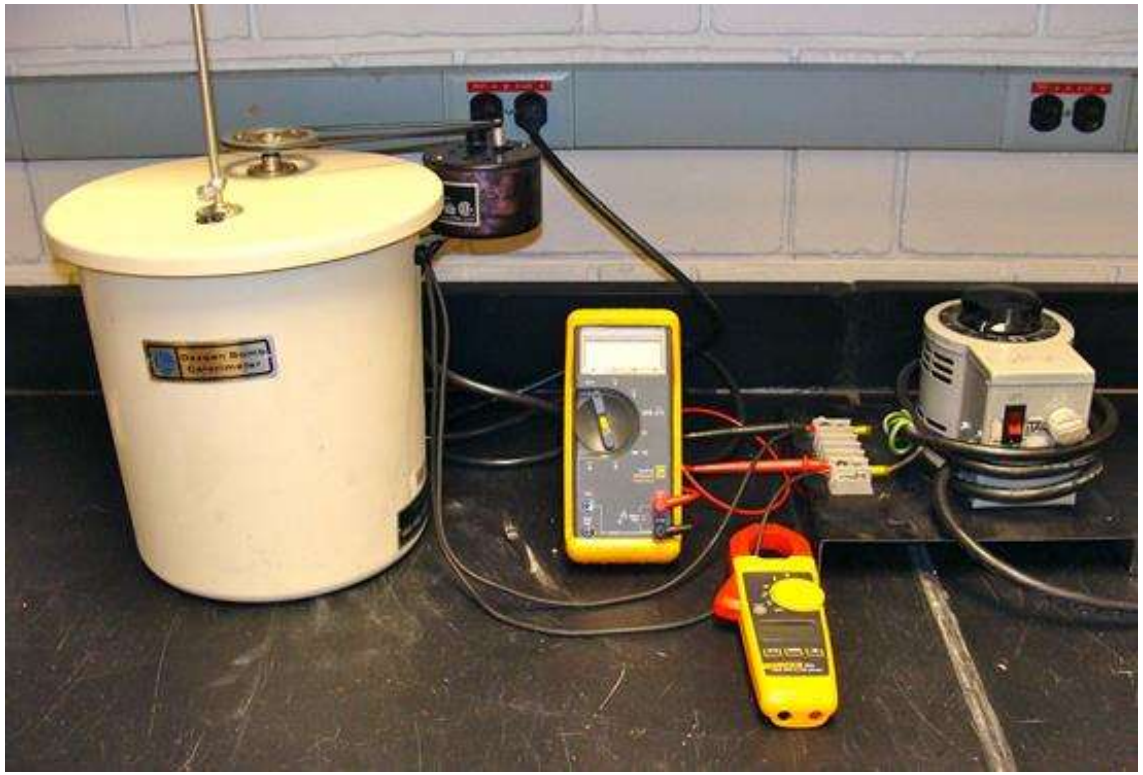
Bomb Calorimeter (ASTM D5865)

- Parr Instruments Model 1341 Plain Jacket Oxygen Bomb Calorimeter
- Resistance heating to force thermal runaway of LIBs
- Nitrogen purge (1 Atm) to prevent oxidation of contents after failure
- Temperature, voltage and current logged for all tests



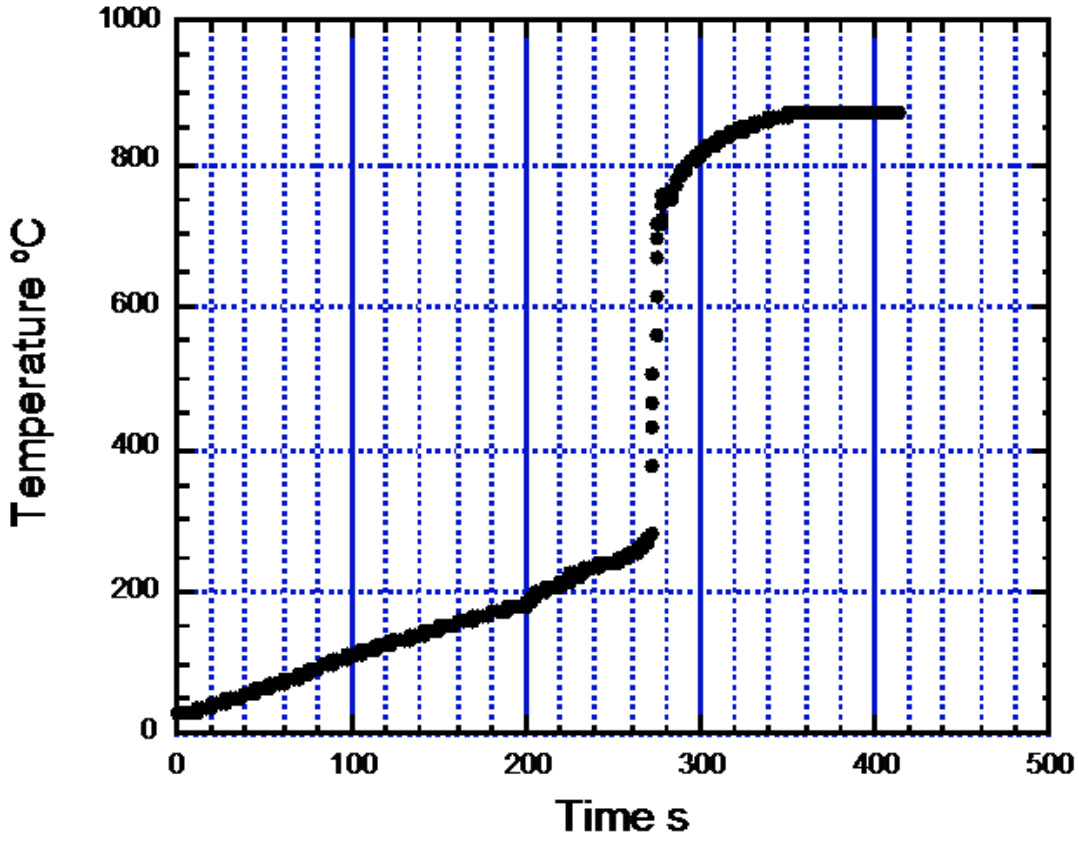
Bomb and other components for 18650 battery tests

Experimental Setup

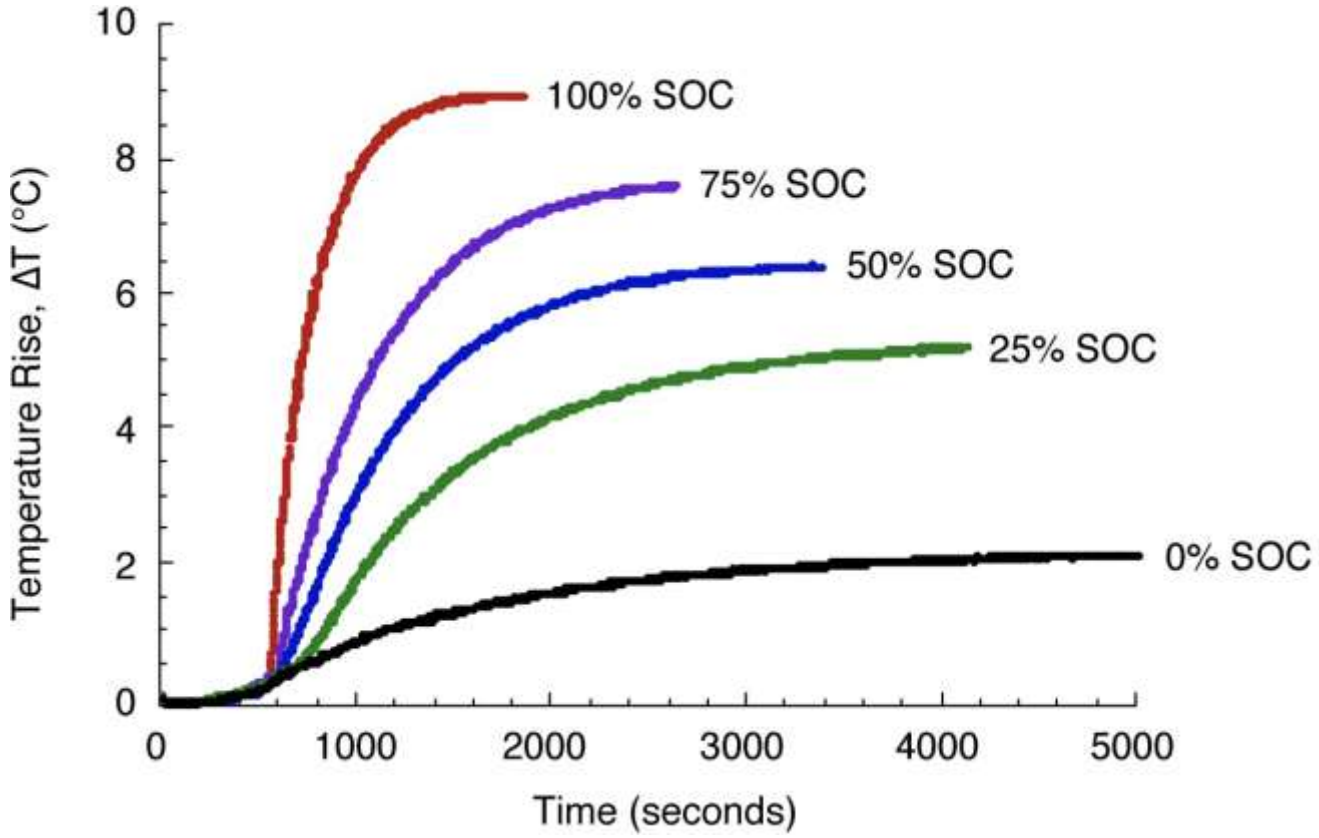


Temperature Measurements

Battery Temperature Rise

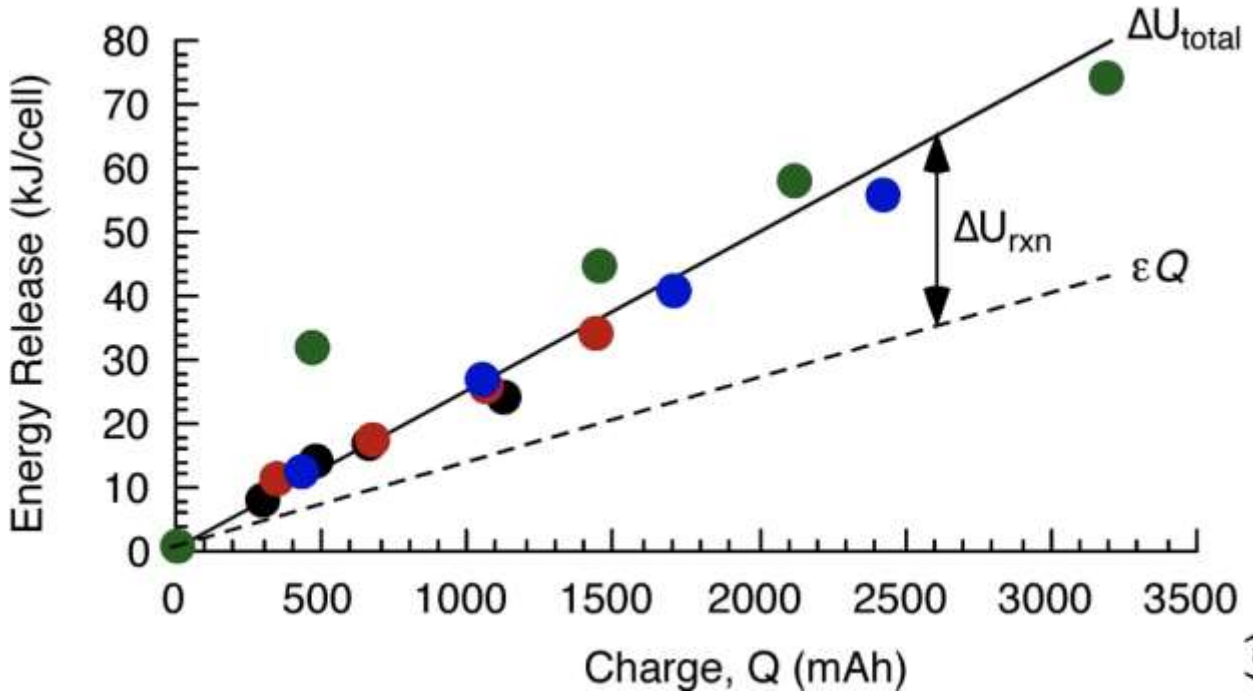


BOMB Temperature Rise

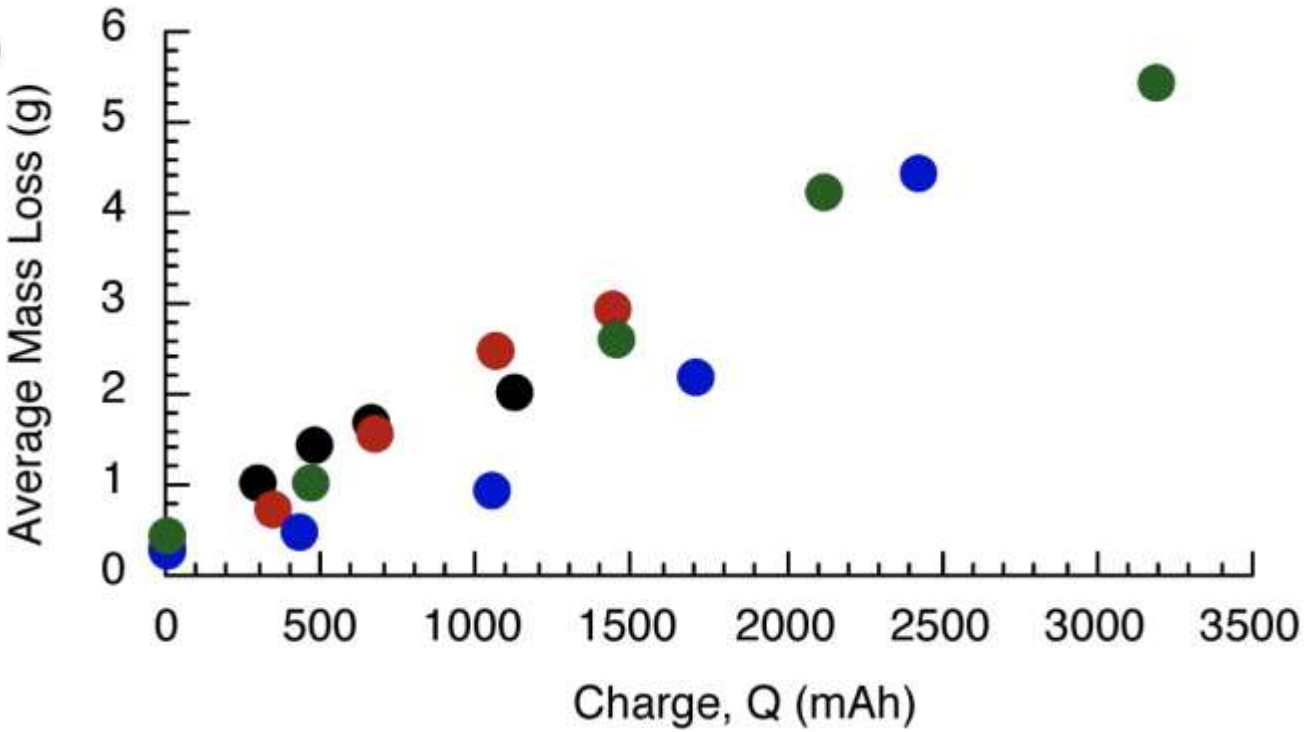


Previous Work

Energy vs. SOC



Gas Mass



Bomb Calorimeter

- Used for Calories in Food & Fuel
- Quantify Fuel Values for Polymers
- Modified for Batteries

Detonation Calorimeter

- Large Scale Bomb Calorimeter
- Used for High Explosives
- Modified for Batteries
- Coupled with GC/MS for Gas Analysis

Detonation Calorimeter

Bomb

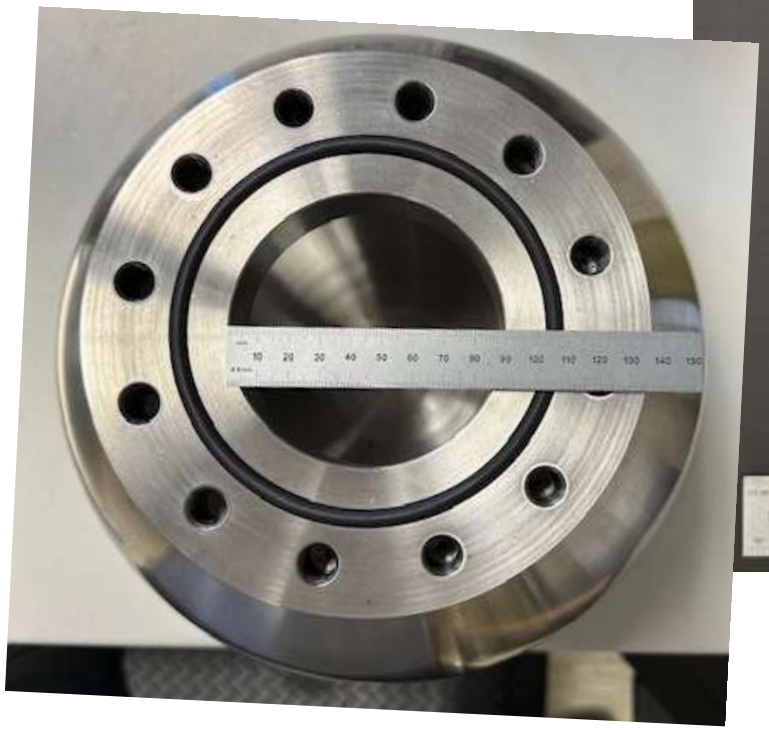
Bomb Geometry

Space Constraints

- 8” Spherical hollow inside 11” Sphere
- 3.5” opening

Measurements

- Temperature
- Pressure change
- Contents contained



Forced Thermal Runaway

Thermal

- Cell/Battery wrapped with Heating Wire
- Resistance, Voltage, Current & Time measured
- Input Energy subtracted from total energy measured
- Very Repeatable

Mechanical

- Nail pushed into cell to initiate thermal runaway
- No heat corrections needed
- Additional mass added to system (different calibration)
- Repeatability?

Electrical

- Short Circuit
- Repeatability?

Battery Gas Analysis

Gas Chromatograph

- Separates gas/liquid mixtures into individual components
- Quantitative determination of known species
  - H2, C2H6, etc.
  - Method specific
- Unknowns
  - Qualitative/Semi-Quantitative
  - Can be further analyzed (MS)

Mass Spectrometer

- Fragments molecules into smaller pieces (mass spectrum)
- Fragment patterns can be searched for identification of unknowns

Planned Research

- Characterize Detonation Calorimeter for thermal mass in different configurations
- GC-MS training & method development – June 2024
- Detonation Calorimeter battery test method development – Forced Thermal Runaway
- Characterize battery systems for energetics & pressures generated in different atmospheres – Chemical Energy vs. Combustion Energy
- Characterize gases generated from battery/cell degradation
- Use values generated for modeling safer systems for aircraft