Preliminary **Detonation Calorimeter** Results **Richard N. Walters** FAA

Objective



Characterize fire & toxicity hazards of lithium ion & other battery chemistries on aircraft



Bulk Shipment (cargo)



Passenger Electronics

Forced Thermal Runaway

Thermal – Polymer Separator Melts

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

Mechanical – Crimp/Puncture

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

Electrical – Overcharge/Rapid Discharge

Short Circuit Repeatability? All lead to temperature increase and acceleration of chemical decomposition



Detonation Calorimeter

MOLINE, R. USA SODA T316-T 112322K-T S/N. ASOGA2308100001

Bomb

DC Test Evaluation & Calibrations

Test Setups

- Battery Cell, NiCr Wire & Insulation Purged with N2
- Heater Calibration
 Al Slug, NiCr Wire & Insulation
 Purged with N2
- Battery Simulator

 Ceramic tube, Insulation, Benzoic acid
 Pressurized with O2

Calculations / Corrections Energy Released = Corrected Temperature Rise * EE



DC Test Setup & Calibrations

Measurements

- Temperatures Bath & Bucket
- Pressure
 Differential
- Initial Masses





DC Calibrations – Thermal Initiation

- Corrections for thermal initiation heater
- Calculations / Corrections
 Heater Energy = Volts * Amps * Seconds
 = EE * Temp Rise = Joules
- Dependent on room conditions
 - 0.1C temperature rise
 - Adds or subtracts heat
 - Tests timed for building status





Calibration – 18650 Simulator

- Calculations / Corrections
 BA Energy = Temp Rise * EE / BA Mass = 26.454 kJ/g
 - 10x trials required
- 8 of 10 Calibration Runs so far
- Different masses to get average from multiple temperature rises









18650 Data – Battery Energies





0.07

3x 18650 – Battery Energies & Pressures



RAL AV/41 BUNNSTRATIO

Preliminary Gas Analysis – Ion Chromatography

IC was used to see what acids & other ions were generated during thermal runaway



Qualify ions in method Protect the GC/MS

- F- ion Evaluations
 - Indicative of HF
 - Can destroy equipment

Preventive Measures

- Plastic tubing
- Don't worry about it



Ion Chromatography Method - Calibration



Ion Chromatograms from 18650 Cells











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





Data – Gas Chromatography

- Preventive measures Glass wool filter placed in-line to scrub HF
- Several GC/MS trials were run for each bomb test-
 - Gas composition changed over time
- Tried to modify GC/MS method
 - Somewhat successful GC cal gas added
 - More training needed CDS OpenLab





Data – Gas Chromatography





Research Progress

- Detonation Calorimeter battery test method developed & standardized – Forced Thermal Runaway
- Characterized Detonation Calorimeter for thermal mass in 2 different configurations
 - Standard
 - 18650
- Thermal runaway product compositions screened using Ion Chromatography
- GC-MS MassHunter training & method development – June 2024



Future Work – DC/GC/MS

- Change GC capillary column
 - Better separation for the masses of interest
- Specialized training for GC/MS
 - Calibrations
 - Column swapping
 - Method development
- GC/MS Gas Calibrations
 - Certified mixture that represents battery gas composition



Planned Research – DC/GC/MS

- Characterize DC for thermal mass with different battery configurations
 - Alternate cells (phone, tablet, 26650, Li primary)
 - Alternate initiation methods (puncture, short, etc.)
- Characterize battery systems for energetics & pressures generated under different atmospheres
 - Chemical Energy vs. Combustion Energy
- Characterize gases from battery/cell degradation
- Use values generated for modeling safer systems for aircraft







Questions?



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