Passive Fire Protection for Lithium Battery Shipments

Federal Aviation Administration

[1]

[2]

Presented to: Systems Meeting

By: Thomas Maloney, FAA Fire Safety

Date: 05-23-2013

Background

- **Dubai Accident (2010)**
  - The heat from an onboard fire created slack in the aircraft control cables. [3]
  - The fire created smoke which blocked the view of aircraft controls. [3]
- **UPS DC-8 (2006)**
  - Lithium batteries may not have been the initial source of fire but contributed upon ignition. [1]
- **Other incidents**
  - Approximately 63 other Lithium and Lithium-ion cell related aviation incidents from 1991 to 2012 [4]

Background (Cell Packaging)

Typical 18650 cell packages

Related Tests

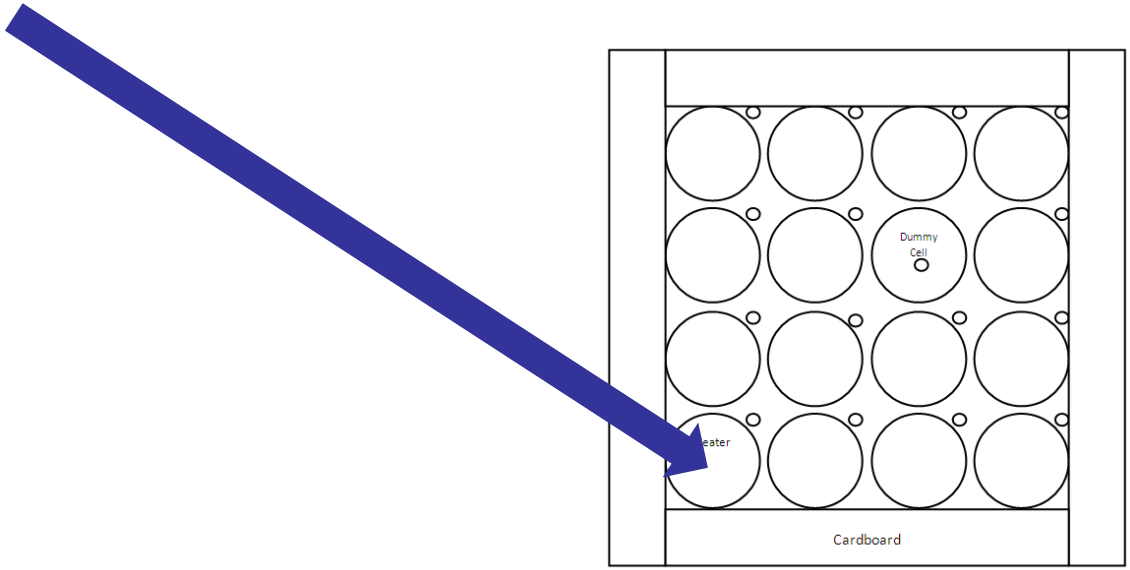
- **Fire Protection Research Foundation**
  - Provided a detailed report of battery chemistry and technology [5]
- **FAA**
  - Showed the usefulness of various materials to replace cardboard in cell packaging.
    - Cardboard with intumescent paint.
    - Aluminum foil instead of cardboard.
    - Composite sheets instead of cardboard.
  - Work was done that demonstrated the dependence of cell propagation on state of charge.
  - An Oxygen generator overpack box was tested with lithium primary cells
    - Standard taping: Box lid failed exposing flames.
    - Wire reinforced taping: The staples on the side of the box failed due to pressure.
    - Wire reinforced taping with pressure relief vent: Flame exited from vent.
- **Other related tests**
  - Calorimeter tests have been done to determine the heat release of cells in thermal runaway.

Objective

- **Perform experiments to better understand the effect of variation in cell packaging and cell state of charge.**
  - Variation of cell “state-of-charge”.
  - Variation in shipment packaging

Test Setup (18650 Lithium Ion Cells)

- 16 cell (4 cell x 4 cell) boxes were made from cardboard.
- One cell in the array was an aluminum cylinder to be used to approximate heat flow into a cell.
- The cells had a 2600mah capacity.
- Each cell location had a thermocouple for data collection.
- A 100 Watt heater was used to initiate the propagation.



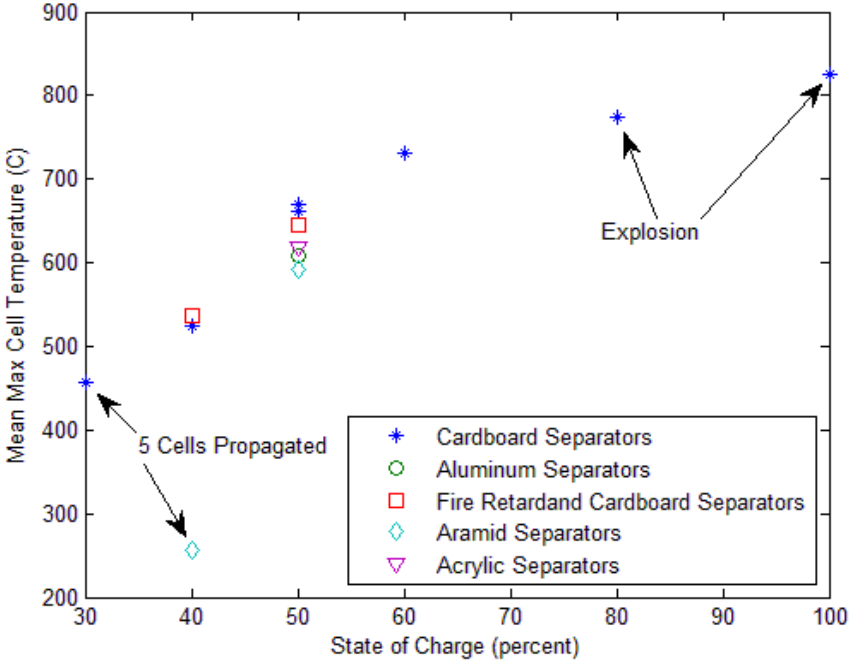
Tests (Lithium-ion)

- **Baseline repeatability tests were performed at 50% state-of-charge with typical cardboard cell separators.**
- **Substitute cell separators.**
  - Aluminum sheet metal
  - Fire retardant cardboard
  - Thermoplastics
- **Other test: 35 gram Plastic bag of water above the cells (5% of package weight)**

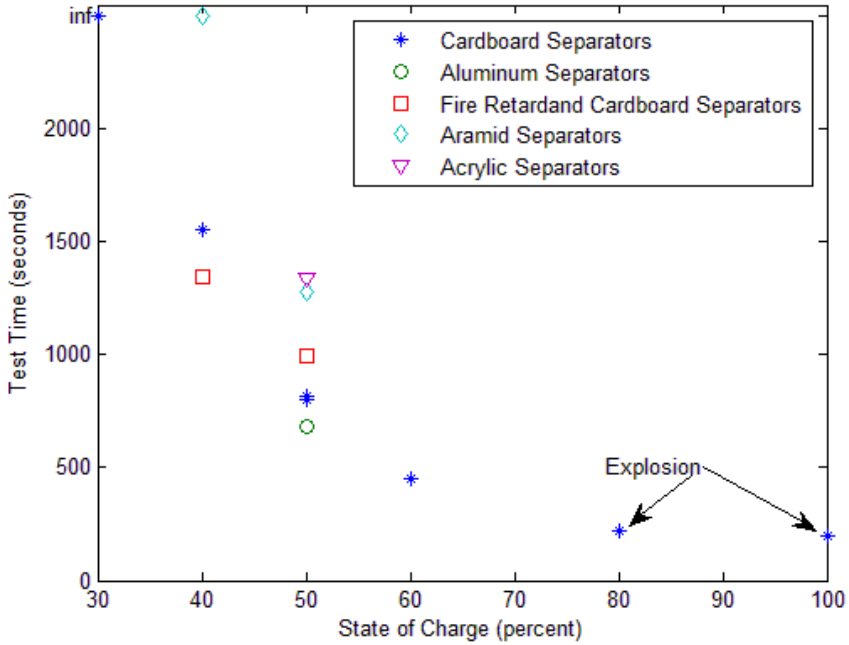
State of Charge	Cardboard Separators (as shipped)	Aluminum Separators	Fire Retardant Cardboard	Aramid Separators	Acrylic	Water Pack Above the Cells
30%						
40%						
50%	x2 (repeatability)					
60%						
80%						
100%						

Lithium-ion Results (State-of-Charge)

Temperature



Propagation time

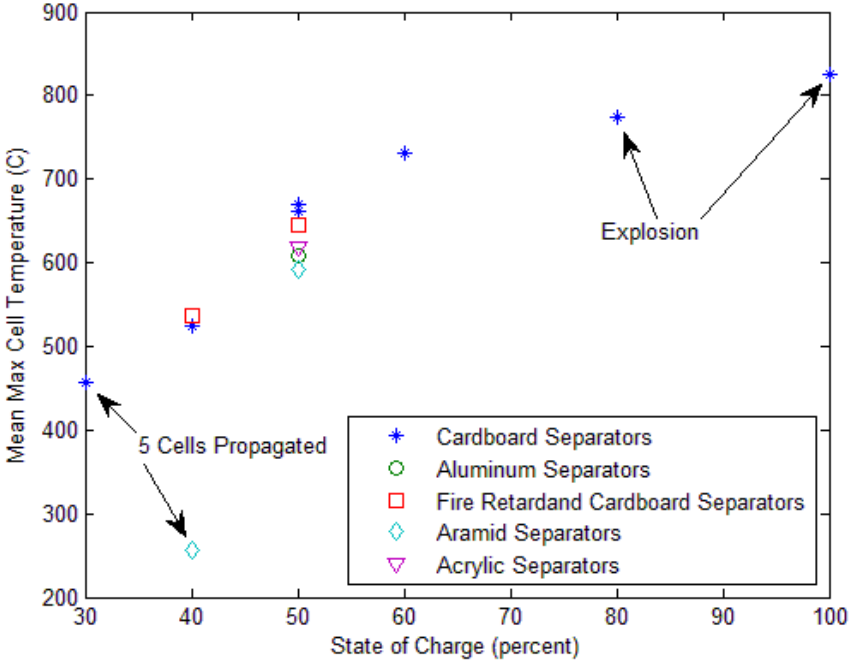


40% state-of-charge, fire retardant cardboard

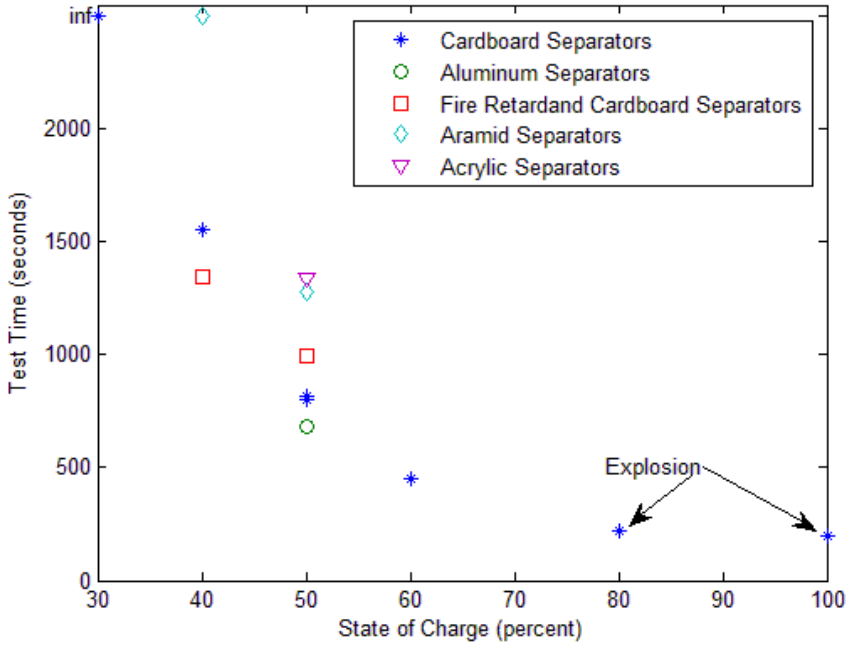
50% state-of-charge, fire retardant cardboard

Lithium-ion Results (Material Variation)

Temperature



Propagation time



- **Aluminum**: At 50% SOC, propagation took 180% longer to initiate but caused the cells to burn 15% faster once initiated.
- **Fire retardant cardboard:** Relatively small effect on propagation.
- **Aramid:** At 50% SOC, propagation took 120% longer and the time for all cells to propagate took 160% longer.
- **Acrylic:** At 50% SOC, propagation took 120% longer and the time for all cells to propagate took 165% longer.

Lithium-ion Results (water pouch)

Water Pouch Above Cells

•Water stopped propagation (no temperature data)

Additional Observation (Lithium-ion)

- **Explosions separated packaging and sometimes stopped propagation.**

Summary of Results (Lithium-ion)

- **The tendency for cells to propagation is highly dependent on the state-of-charge of the cell.**
- **Aluminum, acrylic, and aramid are effective at delaying the onset of propagation.**
- **Acrylic, and aramid are effective at lengthening the propagation time.**
- **Water is effective at absorbing energy and preventing propagation.**
- **When a cell explodes it may break apart the cell package and decrease the likelihood of propagation.**

Future Tests

- **Perform cardboard (as shipped) tests with another Lithium-ion chemistry**
- **Once conditions that prevent cell propagation are determined they are to be verified with a full box test.**
- **Perform tests with lithium primary cells.**

Questions or Suggestions?

- **Contact**
  - Thomas Maloney
  - Office: 609-485-7542
  - Thomas.ctr.Maloney@faa.gov

Citations

- [1] Thurber, Matt. "Cargo Carriage of Lithium Batteries Suspected in Some Accidents." *AINonline*. Aviation International News, Feb. 2012. Web. 01 Nov. 2012. <http://www.ainonline.com/aviation-news/aviation-international-news/2012-02-01/cargo-carriage-lithium-batteries-suspected-some-accidents>.
- [2] Lowy, Joan. "Report: Lithium Batteries on Crashed UPS Plane." *Salt Lake City and Utah Breaking News, Sports, Entertainment and News Headlines*. Associated Press, 3 Apr. 2011. Web. 01 Nov. 2012. <http://www.deseretnews.com/article/700124082/Report-Lithium-batteries-on-crashed-UPS-plane.html?pg=all>.
- [3] "Air Accident Investigation Interim Report." General Civil Aviation Authority, n.d. Web. 1 Nov. 2012. <http://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/16/2010-Interim%20Report%20B747-400F%20-%20N571UP%20-%20Report%2013%202010%20-%20Rev%201.pdf>.
- [4] "BATTERIES & BATTERY-POWERED DEVICES." FAA Office of Security and Hazardous Materials Safety, n.d. Web. 1 Nov. 2012. <http://www.faa.gov/about/office_org/headquarters_offices/ash/ash_programs/hazmat/aircarrier_info/media/Battery_incident_chart.pdf>.
- [5] Exponent Failure Analysis Associates. "Lithium-Ion Batteries Hazard and Use Assessment." N.p., July 2011. Web. 1 Nov. 2012. <http://www.nfpa.org/assets/files/pdf/research/rflithiumionbatterieshazard.pdf>.