Passive Fire Protection for Lithium Battery Shipments

Presented to: Systems Meeting
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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)

<table>
<thead>
<tr>
<th>State of Charge</th>
<th>Cardboard Separators (as shipped)</th>
<th>Aluminum Separators</th>
<th>Fire Retardant Cardboard</th>
<th>Aramid Separators</th>
<th>Acrylic</th>
<th>Water Pack Above the Cells</th>
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</thead>
<tbody>
<tr>
<td>30%</td>
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<td>40%</td>
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<td>50%</td>
<td>x2 (repeatability)</td>
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Lithium-ion Results (State-of-Charge)

Temperature

- Mean Max Cell Temperature (°C)
- State of Charge (percent)
- Explosion
- 5 Cells Propagated
- 40% state-of-charge, fire retardant cardboard
- 50% state-of-charge, fire retardant cardboard

Propagation time

- Test Time (seconds)
- State of Charge (percent)
- Aluminum Separators
- Fire Retardant Cardboard Separators
- Aramid Separators
- Acrylic Separators
Lithium-ion Results (Material Variation)

- **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?

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Citations


