Extinguishment of Lithium Batteries

Presented to: Systems Meeting
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Background

• Growth in Lithium Battery Use
  – The number of lithium-ion batteries made in the world grew from about 800 million in 2002 to about 4.4 billion in 2012. [3]

• Fire Risk
  – Many lithium ion cells have been known to overheat and create a potentially dangerous situation.

• Extinguishing Agents
  – Many extinguishing agents are suggested for use against lithium-ion battery fires but there is little data comparing the cooling effectiveness of various agents.
Introduction

• Thermal Runaway
  – A self reinforcing exothermic reaction resulting in very high temperature and pressure within the cell resulting in the release of flammable electrolyte or explosion.
  – A cell in thermal runaway generates enough heat to cause adjacent cells to go into thermal runaway, propagating throughout the battery pack or shipment.

• Extinguishing Agents
  – Extinguishing agents that cool the cells will decrease the likelihood of propagation of thermal runaway.
Related Tests

- **FAA**
  - Tests done at the FAA showed that water was effective at extinguishing burning electrolyte from lithium-ion cells as well as stopping the propagation of thermal runaway.
  - Halon 1211 was effective in extinguishing burning electrolyte from lithium-ion cells, but was ineffective in stopping the propagation of thermal runaway.
  - Halon 1301 was also effective in extinguishing burning electrolyte from lithium-ion cells, but was ineffective in stopping the propagation of thermal runaway.
  - Ice was not effective at preventing thermal runaway when placed directly on a laptop keyboard.
Objective

• Perform experiments to compare the cooling effectiveness of various extinguishing agents.
Setup and Procedure

- A ¼” aluminum plate had five $\frac{1}{16}$” inch ungrounded thermocouples embedded.
- The aluminum was set on a hot-plate.
- When the hot-plate reached 260C it was turned off and the extinguishing agents were dispersed about an inch from the center thermocouple (shown below).
Setup and Procedure (continued)

• Extinguishing agents were poured onto the plate and poured from an extinguisher.
  – Poured: Water, Aqueous A-B-D Agent, Novec 1230, AF-31, AF-21
  – Sprayed: FM-200, FE-36, Purple-K, Halon 1211, Halotron I

• The temperature drop was determined by

\[ T_d = T_i - \bar{T}_{100} \]

where:
- \( T_d \) = average temperature drop
- \( T_i \) = The temperature immediately before agent release
- \( \bar{T}_{100} \) = The average temperature for the 100 seconds following agent release
Results

![Graph showing temperature drop (degrees C) vs. volume of agent (mL) with different markers for extinguishing agents. Note: Red markers represent tests with approximately equal flow rates (11.5 mL/sec).](image-url)

- Water
- Aqueous A-B-D
- Novec 1230
- Halon 1211
- FM-200
- Halotron I
- FE-36
- Purple K
- AF-31 25%
- AF-21
- No Agent
### Results (continued)

<table>
<thead>
<tr>
<th>Extinguishing Agent</th>
<th>Image 1</th>
<th>Image 2</th>
<th>Image 3</th>
<th>Image 4</th>
<th>Image 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF-31 25% (aqueous)</td>
<td>![AF-31 25% Image]</td>
<td>![AF-31 25% Image]</td>
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<tr>
<td>AF-21 (aqueous)</td>
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Summary of Results

• Under these test conditions, the aqueous agents exhibited the highest cooling effectiveness.

• Increasing the volume of the aqueous agents resulted in higher temperature reductions.

• The non-aqueous agents exhibited little cooling capacity and showed minimal increase in effectiveness with greater volumes.
Future Work

• Demonstrate the effectiveness of each agent on a simulated laptop lithium-ion battery fire
  – Extinguish the electrolyte fire
  – Stop the propagation of thermal runaway

• Repeat with lithium metal cells
Questions?

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Citations

