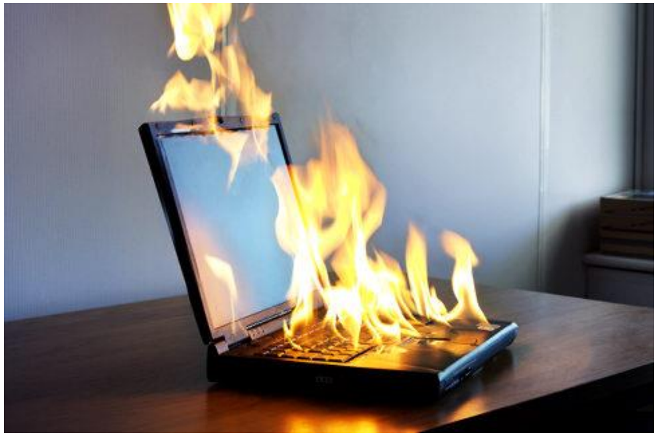
Extinguishment of Lithium Batteries

Federal Aviation Administration



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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

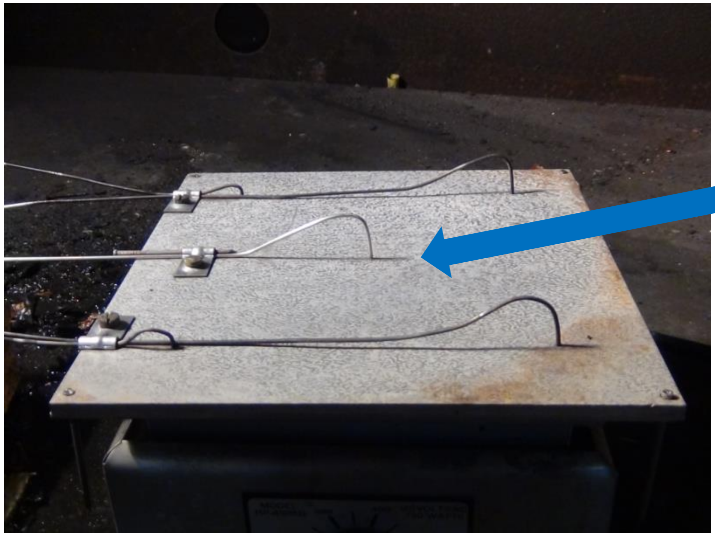
- **FAA**
  - Tests done at the FAA showed that water was effective at extinguishing burning electrolyte from lithium-ion cells as well as stopping the propagation of thermal runaway.
  - Halon 1211 was effective in extinguishing burning electrolyte from lithium-ion cells, but was ineffective in stopping 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 $^{1}/_{16}$” 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).



Agent Target

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**

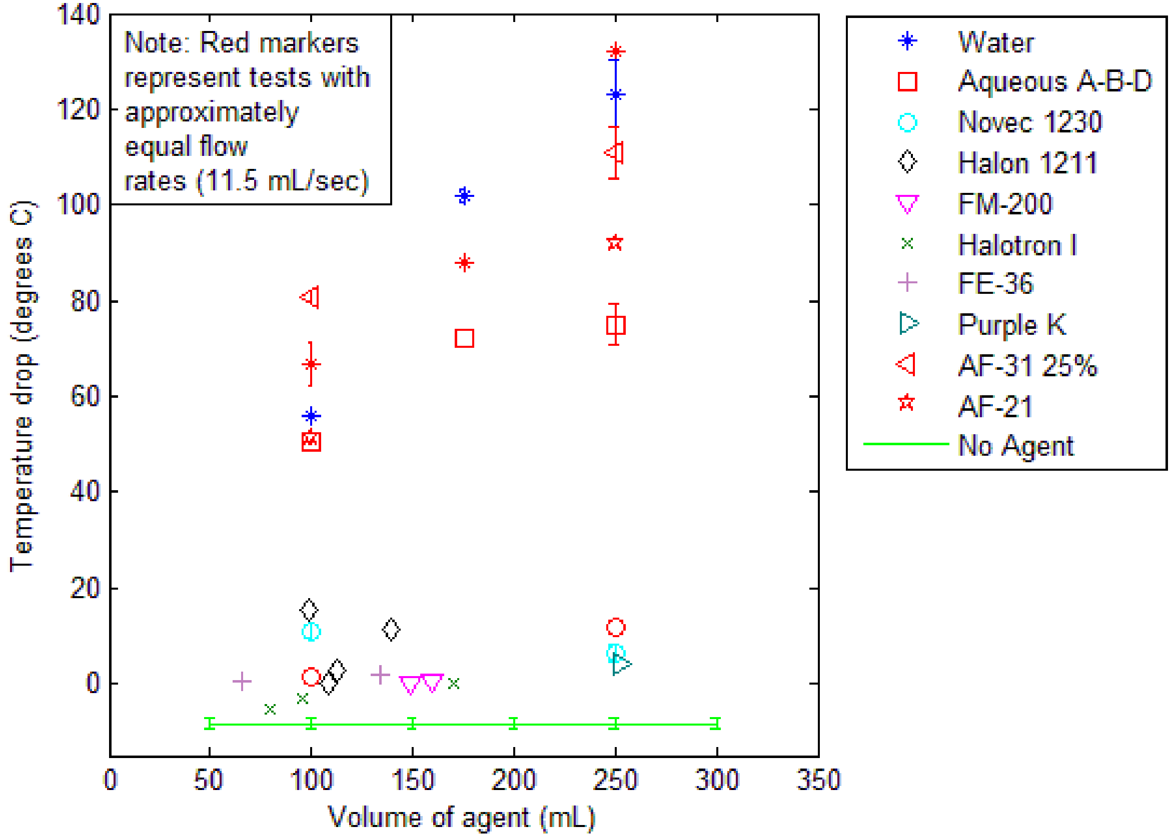
$$\boldsymbol{T_d = T_i - \overline{T}_{100}}$$

where: T_d **= average temperature drop**

T_i **= The temperature immediately before agent release**

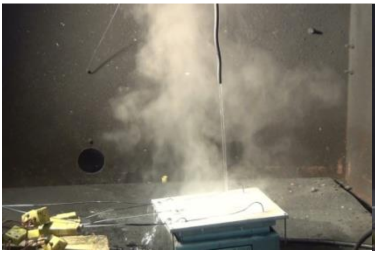
$\overline{T}_{100}$ **= The average temperature for the 100 seconds following agent release**

Results

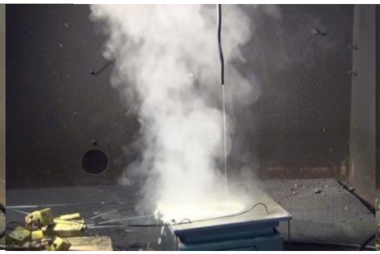


Note: Red markers represent tests with approximately equal flow rates (11.5 mL/sec)
Temperature drop (degrees C)
Volume of agent (mL)
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
Water
Aqueous A-B-D
Novec 1230
Halon 1211
FM-200
Halotron I
FE-36
Purple K
AF-31 25%
AF-21
No Agent

Results (continued)

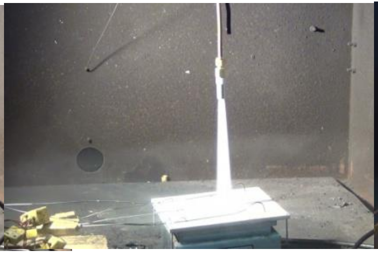


Water

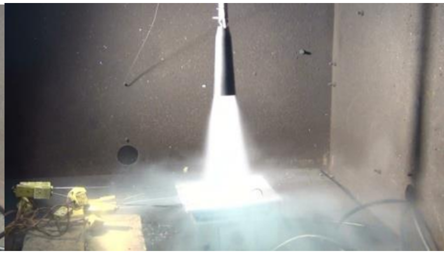


Aqueous A-B-D Agent

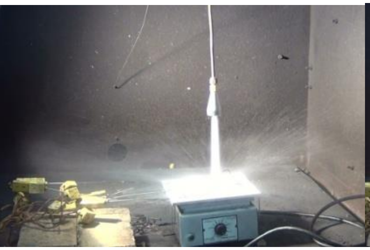
Novec 1230



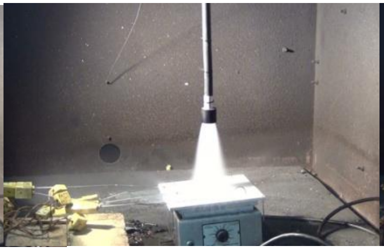
Halon 1211



FM-200

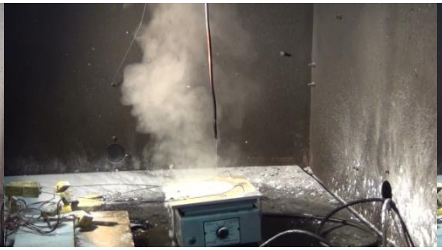


Halotron I



FE-36

Purple-K



AF-31 25% (aqueous)

AF-21 (aqueous)

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?

- **Contact**
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Citations

- [1] http://oxford.tab.co.uk/files/2013/03/laptop2.jpg
- [2] http://billpstudios.blogspot.com/2006/08/dell-batteries-and-fire-safety.html
- [3] http://www.reuters.com/article/2013/04/12/us-usa-batteries-technology-idUSBRE93A0SQ20130412