

Lithium-Ion and Lithium Metal Battery Update

Hazardous Material Shipping

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Federal Aviation
Administration



Lithium-Ion Batteries

- **Rechargeable, most common usage include laptop computers and cell phones**
- **Lithium-ion cells contain no metallic lithium**
- **Fire hazard: Thermal runaway**
 - externally heated
 - Internal short circuits, overcharging, physical damage, rapid discharge

Lithium-Ion Batteries

- **Thermal runaway**

- An electro-chemical reaction within the cell
- Rapid temperature rise :1100 degrees F
- Pressure buildup with the cell
- Venting of flammable liquid electrolyte
- Propagation from cell to cell due to proximity heat transfer
- Ignition of flammable packing materials and vented electrolyte
- Cells may explode if heated rapidly enough

Lithium-Ion Batteries



Lithium-Ion Cell in Thermal Runaway & Exploding

Lithium-Ion Batteries

- **Two fire scenarios**
 - External fire from other source
 - Thermal runaway
 - 1100 degree cell temperature and vented electrolyte add to fire loading
 - Cell failure, single cell in thermal runaway
 - Heat transfer to other cells, triggering cascading thermal runaway
 - Vented electrolyte and flammable packaging

Lithium-Ion Batteries

- **Controlling a Lithium-ion battery fire**
 - Class C cargo compartment
 - External fire source
 - Halon 1301 total flood very effective, eliminates open flame
 - Deep seated fire can result in local temperatures high enough to cause cells to go into thermal runaway
 - Eliminates ignition of vented electrolyte and packing materials
 - Does NOT STOP propagation of thermal runaway between adjacent cells
 - No cooling effect

Lithium-Ion Batteries

- **Controlling a Lithium-ion battery fire**
 - Class C cargo compartment
 - Cell failure, single cell in thermal runaway
 - Smoke from charring packing material and vented electrolyte will trigger alarm.
 - Halon 1301 discharge
 - Propagation between cells will continue
 - Open flames extinguished
 - Spread of fire to adjacent flammable materials prevented

Lithium-Ion Batteries



Bulk Load Configuration before Testing

Lithium-Ion Batteries



Uncontrolled Bulk Load Fire Test

Lithium-Ion Batteries



Bulk Load Configuration after Testing

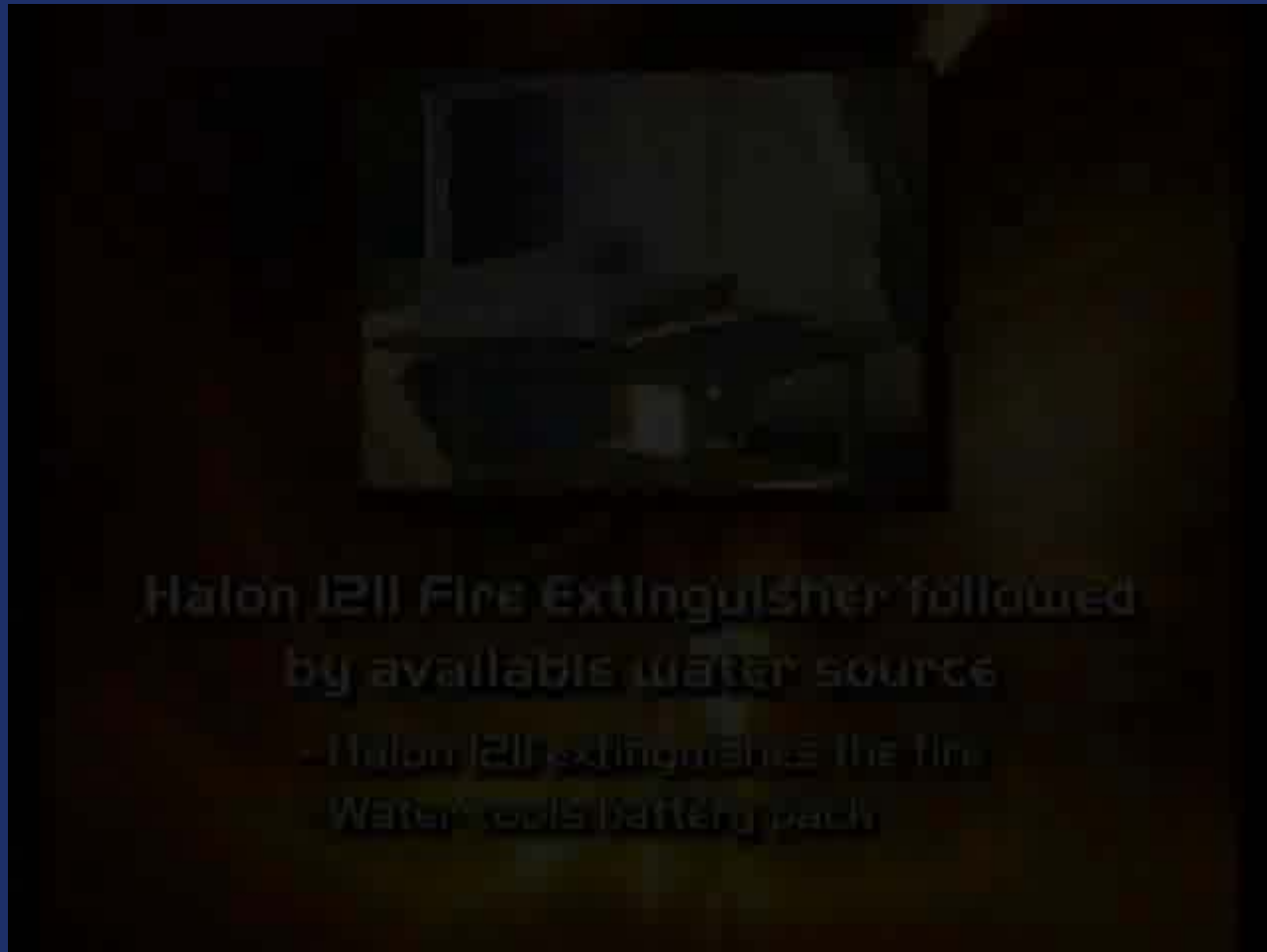
Lithium-Ion Batteries

- **Controlling a Lithium-ion battery fire**
 - Class E Cargo Compartments
 - No fire suppression system
 - Depressurization has no effect on propagation of thermal runaway from a single failed cell
 - Even depressurized, temperatures can be high enough to cause cells to go into thermal runaway
 - Accessible locations
 - Halon 1211 will knock fire down, but will not prevent reignition or propagation
 - Water effective, may take a lot of water to cool a large shipment

Lithium-Ion Batteries

- **Controlling a Lithium-ion battery fire**
 - Aircraft cabin, carry on items, laptops
 - Halon 1211 effective in knocking fire down and preventing spread to adjacent flammable materials
 - Will not prevent re-ignition or propagation between cells
 - Water very effective in both extinguishing open flames and stopping propagation between cells, eliminating re-ignition

Lithium-Ion Batteries



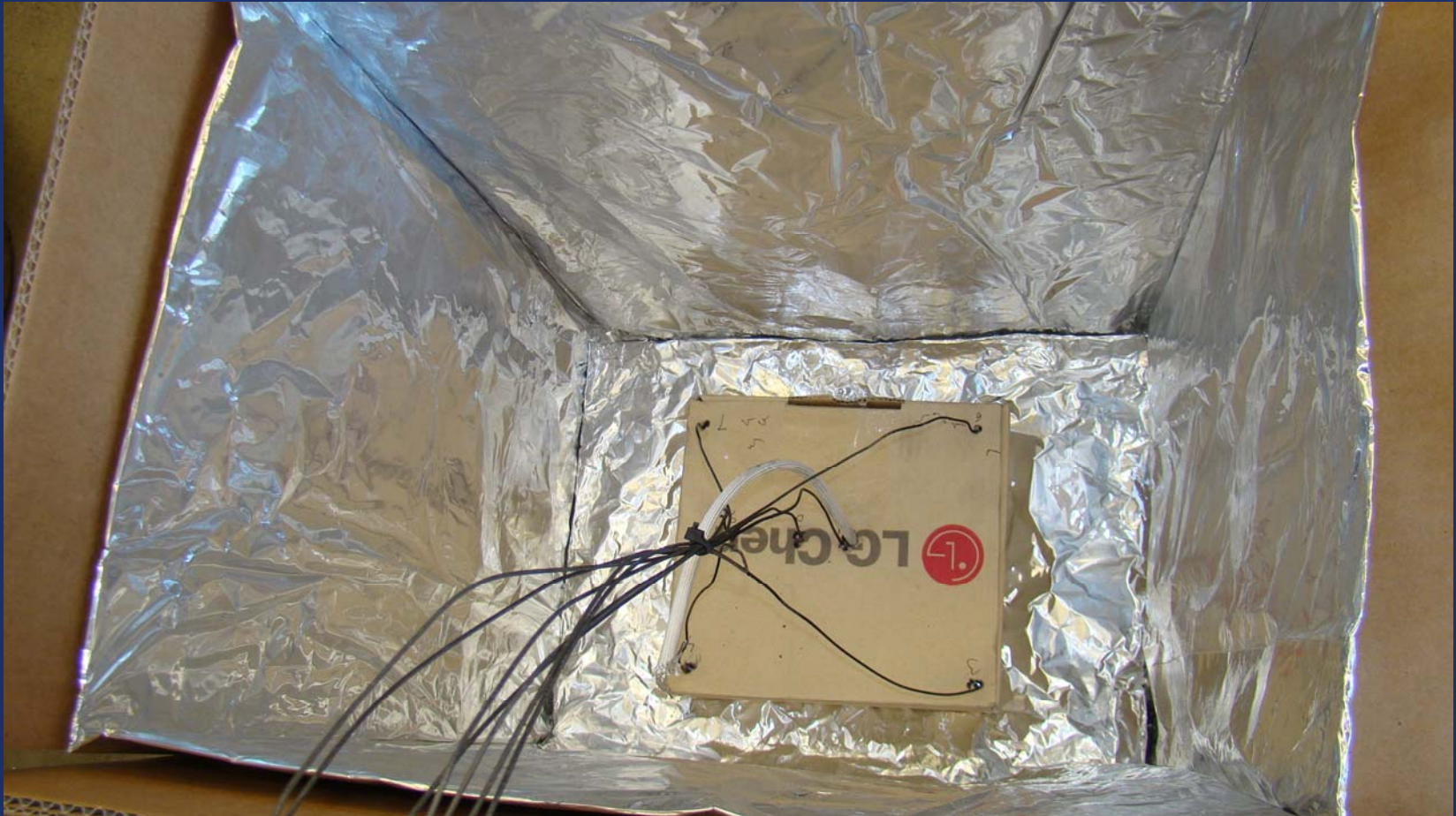
Halon 1211 & Water Extinguishing Method from Training Video

Lithium-Ion Batteries

- **Shipping containers**

- Metal drums effective, pressure relief necessary
- Plastic drums not effective, subject to damage from high temperatures generated by cells in thermal runaway
- Cardboard with fire resistant liners
 - Chemical Oxygen Generator over pack tested
 - Effective in controlling cell failure fire

Lithium-ion Batteries



Oxygen Canister Container with Lithium Ion Cells

Lithium-ion Batteries



Oxygen Canister Container with Lithium Ion Cells

Lithium-ion Batteries



Lithium-Ion Batteries

- **Improved packaging material**
 - Current bulk packaging consists of a corrugated cardboard outer box, and thin cardboard separators
 - Using a fire and thermal resistant separator material may stop the propagation between cells

Lithium Metal Batteries

- **Single use, non-rechargeable, available in wide variety of sizes, including common AA and AAA**
- **Contain metallic lithium**
- **Fire hazard- thermal runaway**
 - Externally heated
 - Internal short, physical damage
 - Flammable electrolyte, release of molten lithium metal
 - Large pressure pulse

Lithium Metal Batteries



Lithium Metal Cells

Lithium Metal Batteries

- **Thermal runaway**
 - An electro-chemical reaction within the cell
 - Rapid temperature rise
 - Pressure buildup with the cell
 - Venting of flammable liquid electrolyte
 - Discharge of molten lithium
 - Propagation from cell to cell due to proximity heat transfer
 - Ignition of flammable packing materials and vented electrolyte
 - Cells may explode if heated rapidly enough

Lithium Metal Batteries



Lithium Metal Cell in Thermal Runaway

Lithium Metal Batteries

- **Two fire scenarios**
 - External fire from other source
 - Thermal runaway
 - vented flammable electrolyte
 - Molten lithium
 - Pressure pulse
 - Cell failure, single cell in thermal runaway
 - Heat transfer to other cells, triggering thermal runaway
 - Vented electrolyte, molten lithium and pressure pulse

Lithium Metal Batteries

- **Controlling a Lithium Metal Fire**
 - Class C
 - Halon 1301 ineffective in extinguishing metal cells
 - Halon 1301 will prevent fire spread to other ordinary combustibles
 - Molten lithium can damage cargo liners
 - Pressure pulse can dislodge cargo liners or activate pressure relief systems, allowing 1301 to escape
 - Banned from shipment on passenger aircraft
 - Class E
 - Depressurization ineffective
 - Halon 1211 ineffective in accessible locations

Lithium Metal Batteries

- **Controlling a Lithium Metal Fire**
 - Aircraft cabin, carry on items
 - Prevent spread to adjacent flammable materials
 - Water is effective on small quantities of lithium metal cells, cooling adjacent cells stopping propagation

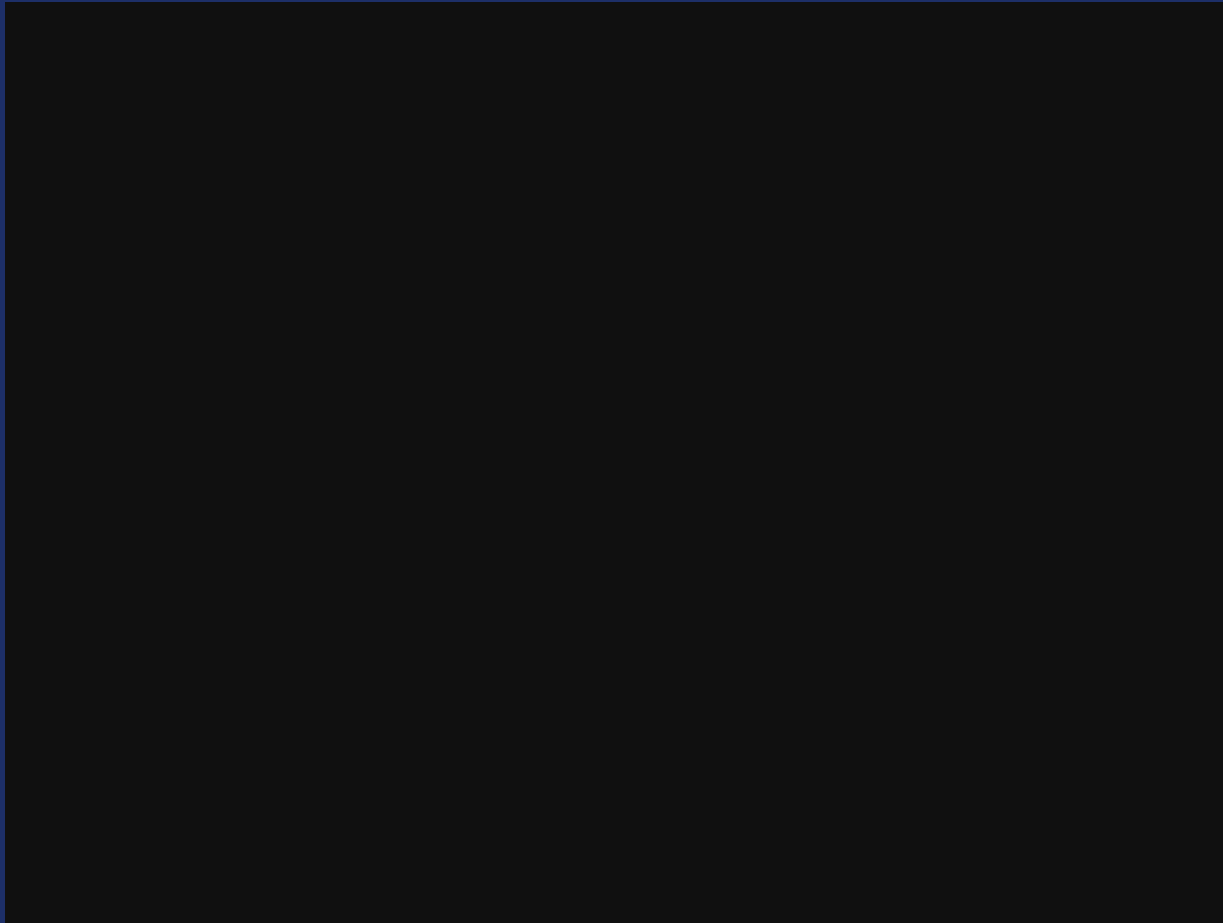
Controlling a Lithium Metal Fire

- **Shipping containers, over packs**
 - ICAO shipment of small numbers of lithium metal batteries in steel containers on passenger aircraft
 - FAA testing has shown that this is ineffective in controlling a metal cell in thermal runaway
 - Pressure buildup can rupture the container, releasing the pressure, causing damage to Class C cargo compartment, spilling the burning cells

30 Gal. Drum Test- 36 CR2 Cells



30 Gallon Drum Test- Six CR2 Cells



Lithium Polymer Batteries

- Plastic case, can be molded into shapes
- Flammable
- Halon 1301 and 1211 effective at extinguishing
- No pressure pulse

Lithium Polymer Laptop Battery



Lithium Polymer Battery-Post Test



Developing a Container or Over pack Specification

- **Internal cell fire threat**
- **External fire threat**
- **Pressure containment**
 - Controlled release
- **Metal Cells**
 - Resistance to molten lithium
- **Certification**
 - Chemical Oxygen Generator Overpack Spec.
 - Live fire tests with specific cells
 - Cost

Shipping Options

- **Containers**
 - Difficult for Metal Cells
 - Cost
- **Class C Compartment**
 - Significantly reduces hazard for Lithium-ion
 - Reduces fire spread for lithium-metal
 - Pressure pulse may damage compartment
- **Class E Compartment**
 - Depressurization not effective
 - Accessible location not effective
- **FEDEX Suppression System**
 - Not yet tested against battery threat

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Risks in Transporting Lithium Batteries in Cargo By Aircraft

Recommended Action:

1. Identify bulk shipment of currently excepted batteries
2. Stow in Class C when possible
3. Evaluate training
4. Comply with existing regulations for Class 9 Haz Materials

Report

- **Fire Protection for the Shipment of Lithium Batteries in Aircraft Cargo Compartments**
- **Publication on fast track**
- **Will be available on our web site**
- **<http://www.fire.tc.faa.gov/index.stm>**
 - Reports
 - Search by author
 - Harry Webster