Safe Transport of PEDs in Transport Passenger Aircraft

Presented to: Aviation Industry
By: Fire Safety Branch
Federal Aviation Administration
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First and Foremost: Fire Prevention!

Aircraft are Designed, Certified, and Operated with the Philosophy of Preventing Accidents, which includes Preventing Any and All Fires from Occurring.
Cargo Fire Incidents (2002-2012)

Passenger Aircraft – Class “C” Compartments

• N Registered Aircraft
• 3 Incidents (2 Fires)
  – Hair spray released in compartment
  – Overheating electronic unit that was on.
  – Flashlight that was on and overheated
Why are PEDs with Lithium Batteries an Added Risk?

• Lithium batteries are both an ignition source and a fuel.
• Lithium batteries have been a fire source in the cabin.
• Lithium battery fires may reduce the effectiveness of the fire suppression system.
  – They produce hydrogen gas when in thermal runaway.
  – Thermal runaway can propagate from cell to cell unless cooled.
Tablets in a Galley Cart

https://www.fire.tc.faa.gov/temp/LT_FH/S5_Galley_Cart.wmv
Lithium Ion Batteries in a Cargo Container

https://www.fire.tc.faa.gov/temp/LT_FH/S6_LIB_CargoContainer.wmv
Why do cells go into thermal runaway and start fires?

- Over charged
- Discharge too fast
- Overheating
- Internal short (defective cell)
- Damage (punctured, dropped, etc.)
Fire Suppression System

• Halon system is the second line of defense.
  – Designed for fires likely to occur

• Lithium batteries were not considered in design of system.

• Halon system may or may not be effective in controlling PED fires, i.e., the reliability of the system is negatively influenced by PED fires.
Why Might Halon Not be Effective?

- Thermal runaway can propagate from cell to cell, and Halon is not a good cooling agent.
- Cells in thermal runaway produce hydrogen, and the design concentrations of halon will not provide protection from a hydrogen explosion.
Lithium Ion Battery Vent Gas Mixture

• Lithium batteries in thermal runaway produce flammable gasses and create significant hazards for aircraft.

• The three most prevalent gases are carbon dioxide (30.1 %), hydrogen (27.6 %), and carbon monoxide (22.9 %).

• Lithium ion battery vent gas mixture by percent concentration:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>30.10%</td>
</tr>
<tr>
<td>H₂</td>
<td>27.60%</td>
</tr>
<tr>
<td>CO</td>
<td>22.90%</td>
</tr>
<tr>
<td>CH₄</td>
<td>6.37%</td>
</tr>
<tr>
<td>C₃H₆</td>
<td>4.48%</td>
</tr>
<tr>
<td>CH₄</td>
<td>30.10%</td>
</tr>
<tr>
<td>C₂H₄</td>
<td>2.21%</td>
</tr>
<tr>
<td>C₄H₁₀</td>
<td>1.57%</td>
</tr>
<tr>
<td>C₂H₆</td>
<td>1.17%</td>
</tr>
<tr>
<td>C₄H₈</td>
<td>0.56%</td>
</tr>
<tr>
<td>C₃H₈</td>
<td>0.27%</td>
</tr>
</tbody>
</table>
Results (Large Scale Tests)

6 second time window

Test without suppression

Test with 5.28% Halon

Test with 10.43% Halon
Effectiveness May Be Scenario Dependent

- Fire buildup before detection
- Fire buildup before design concentration of agent penetrates container
- Fire involves other cargo
Aerosol Can Explosion in a Class D Cargo Compartment

https://www.fire.tc.faa.gov/temp/LT_FH/S13-S120_Aerosol_Can_Class_D.wmv
Why are Passenger PEDs a Greater Risk Than When Shipped by The Manufacturer?

• From Manufacturer:
  – Batteries not installed (unit always off).
  – Batteries at reduced state of charge (most at 30%).
  – Items are Marked and protected from damage.

• From Passenger:
  – Batteries installed (unit might be in sleep mode).
  – In most cases batteries are highly charged.
  – Minimal protection from damage.
  – Used (and potentially abused).
Gas Volume vs State of Charge
How to Mitigate or Reduce the Risk?

• **Prevention**
  – Prevent the fire
  – Contain the event within one laptop package

• **Control**
  – Control a PED fire such that the halon system can effectively suppress and contain the fire within the compartment.
Prevention

• **Operational Procedures:**
  – Laptops must be off. Much greater risk if on or in standby/sleep mode (can overheat the battery).
  – Packaged to prevent damage. (Any damage increases the risk of a fire).
  – Others as determined under **Control**.
Contain the Event within One Laptop Package

• Package a laptop or group of laptops into a “fire hardened package” such that, if a cell in one of the laptops goes into thermal runaway, the resultant fire will be contained within the package.
  – Logistics at the airport
  – Cost
  – Weight
Control:

• Use of Fire Containment Covers
  – Testing shows effectiveness
  – Logistics
  – Cost
  – Weight

• Use of Fire Hardened Containers
  – Testing shows effectiveness
  – Cost
  – Availability
Control:

• Improve effectiveness of Halon system
  – Optimal Placement of Laptops?
  – Best way to maximize halon at the laptop fire?
  – Quickest way to detect fire in container?
Summary:

• Understand Risks

• Minimize Risks

• Determine if Minimized Risks are Acceptable
THE ASSUMPTIONS BELOW ARE BASED ONLY ON CYLINDRICAL ION CELLS
(POUCH AND METAL CELLS HAVE NOT BEEN EVALUATED YET)

PED Removed from PAX Cabin

Airline Collects and Packages PED

- PED can be verified as “Off”
- Box can easily Ignite & Spread to Others
- Boxes can be grouped together (Segregated from other Cargo and Hazardous Materials)
- **Good** chance of Halon System control (if system is working 100% as certified)
- **Fair** chance Class D Compartment (no Halon) could control
- Mitigations exist to control or contain fire from one box (Fire Resistant Box, Covers, and Fire Hardened ULDs)
- Mitigation would improve Class C chance of control to **Very Good** and Class D to **Good**

Passenger puts PED in Checked Baggage

- Little Control for being “Off” or Damage Protection
- Bag may or may not contain fire (% unknown, many variables)

Bags may contain other Hazardous Materials; e.g. Aerosol Cans

Bags **without** Hazardous Materials:
- **Good** chance Halon system can control (if system working 100% as certified).
- **Fair-Poor** chance Class D compartment (no Halon) could control

Bags **with** Hazardous Materials:
- **Poor** chance Class D compartment (no Halon) could control.
- **Fair to Poor** chance Halon system can control (if system working 100% as certified)

*Note: The air carrier collecting the PED provides a higher likelihood that the PED will be completely powered down. Passenger control may not be as effective.*
What Has Been Learned from Testing
Based on Laptops Powered by 18650 Cylindrical Cells

- When packaged in a cardboard box with bubble wrap:
  - If a cell goes into thermal runaway the fire can easily penetrate the box and potentially spread.
  - There are commercially available packages (e.g. boxes) that will easily contain the fire.
  - The Halon system in a Class C Compartment, if working as certified, can control the fire of boxes packed in a ULD.
    - Explosive gases might still be present
- Class D Compartments might (not) control that same fire.
  - Explosive gas might still be present
What Has Been Learned from Testing
Based on Laptops Powered by 18650 Cylindrical Cells

• **When packed in passenger bags:**
  – If a cell goes into thermal runaway the fire may penetrate the bag.
    • Depends on many factors, including, packing density, materials in bag, type of bag and available air in bag.
  – If other Haz. Mat. (such as aerosol cans) is in the bag an explosion can occur, not related to the gases from the battery.
    • An explosion can occur before Halon, in a Class C compartment, would be discharged and reach a 3% suppression concentration in a ULD.
    • A Class D compartment would provide no protection from an explosion
What Has Been Learned from Testing
Based on Laptops Powered by 18650 Cylindrical Cells

• **Large scale test demonstrated:**
  – About 2 minutes from agent discharge until 3% suppression concentration was reached within a ULD.
    • That time will depend on many factors, including agent discharge time, load factor of the compartment, leakage rate of the compartment and tightness of the ULD.
  – A Halon system in a class c compartment, if working as certified, can control the fire of boxes packed in a ULD.
  – A Halon system in a class c compartment, if working as certified, might not provide enough agent inside a ULD in time to suppress an explosion of an aerosol can caused by a laptop battery fire.