Full Scale Battery Tests

Aircraft response to fires involving large numbers of small lithium batteries

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By: Harry Webster, FAA Fire Safety Br.

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Summary of Findings From Previous Tests – Lithium-ion

- **Capable of thermal runaway, through cell defect, cell damage, heat, rapid discharge, overcharging**
- **Thermal runaway results in high case temperatures, exceeding 1100 DegF**
- **Releases flammable electrolyte**
- **Generates sufficient heat to cause adjacent cells to go into thermal runaway**
- **Will propagate thermal runaway throughout shipping box, and box to box**

Summary of Findings From Previous Tests – Lithium-ion

- Can experience catastrophic disassembly
- Generally do not self ignite, but high case temperatures easily ignite current packing materials, which ignite the electrolyte
- Halon 1301 can suppress the electrolyte fire
- In the presence of Halon, or no ignition source, unburned hydrocarbons from released electrolyte accumulate, increasing the risk of flash fire or explosion

Summary of Findings From Previous Tests – Lithium Metal

- **Capable of thermal runaway, through cell defect, cell damage, heat, rapid discharge**
- **Thermal runaway results in high case temperatures, exceeding 1400 DegF**
- **Releases flammable electrolyte and molten burning lithium**
- **Generates sufficient heat to cause adjacent cells to go into thermal runaway**
- **Will propagate thermal runaway throughout shipping box, and box to box, very rapid fire buildup**

Summary of Findings From Previous Tests – Lithium Metal

- **Can experience catastrophic disassembly**
- **Self igniting, will rapidly ignite packaging**
- **Generates pressure**
- **Halon 1301 can suppress the electrolyte fire, but not the lithium fire. Has no effect on propagation of thermal runaway.**
- **In the presence of Halon, unburned hydrocarbons from released electrolyte accumulate, increasing the risk of flash fire or explosion**

Full Scale Fire Tests

Objective

- **To document the characteristics of fires involving large numbers of small lithium batteries in a realistic aircraft environment.**

Class E (Main Deck)Cargo Compartment

- **Upper deck compartment on most freighters**
  - Has fire detection system
  - Means to shut off ventilation flow to the compartment
  - Means to exclude hazardous quantities of smoke, flames, or noxious gases, from the flight crew compartment

Full Scale Fire Test Plan

- **Baseline**
- **Class E and C Cargo**
  - Lithium-ion 5000 18650 cells
  - Lithium metal 4800 SF123A Cells
  - 5000 mixed alkaline, NiCad, NiMH
- **Simulated thermal runaway ignition source**
- **External fire exposure**

Instrumented 727 Test Article

Aircraft Ventilation

- **Airflow patterns within the aircraft can have significant impact on the behavior of the battery fire and smoke penetration.**
- **The aircraft air packs are configured differently depending on the location of the fire.**
- **Two configurations were developed with input from the Boeing Company, one for the main deck class E fire and one for the forward class C compartment.**

Conducted Air Exchange Tests

Air Exchange Rate Results

- **Pressurized configuration**
  - Main deck cabin: 5.75 minutes per air change
  - Flight deck: 1.68 minutes per air change
- **Unpressurized configuration**
  - Main deck cabin: 47.72 minutes per air change
  - Flight deck: 1.71 minutes per air change

Conducted Baseline Test

Preliminary Fire Assessment

Class E (Main Deck)Tests

- **Aircraft in emergency mode**
- **High ventilation to flight deck**
- **No ventilation to main deck**
- **Fire control is by oxygen starvation**

Results Mixed Cell Test

- **Test terminated at 102 minutes with water**
- **Approximately 700 cells were damaged**
- **Low ceiling temp: 119 DegF@ 40 min**
- **Moderate battery fire temp: 975 DegF@ 44 min**
- **Gradual smoke obscuration in the compartment**
- **No smoke on the flight deck**

Results Lithium-ion

- **Test terminated at 57 minutes with water**
- **More than half of the cells consumed**
- **High ceiling temp: 1490 DegF@ 49 min**
- **High battery fire temp: 1300 DegF@ 55 min.**
- **Oxygen depletion slowed fire progress**
- **Some light smoke on the flight deck**
- **Significant damage to cargo liner**

Results Lithium Metal

- Test terminated at 16 minutes with water.
- Approximately half of the cells were consumed.
- Very high ceiling temp: 1700 DegF@ 16 min
- Very high battery fire temp: 2250 DegF@ 12 min
- Oxygen starvation had little or no effect on fire intensity
- Smoke on flight deck in less than 4 minutes from first observable fire, obscured in less than 6 minutes
- Significant cargo liner damage

Class E Lithium Metal Video

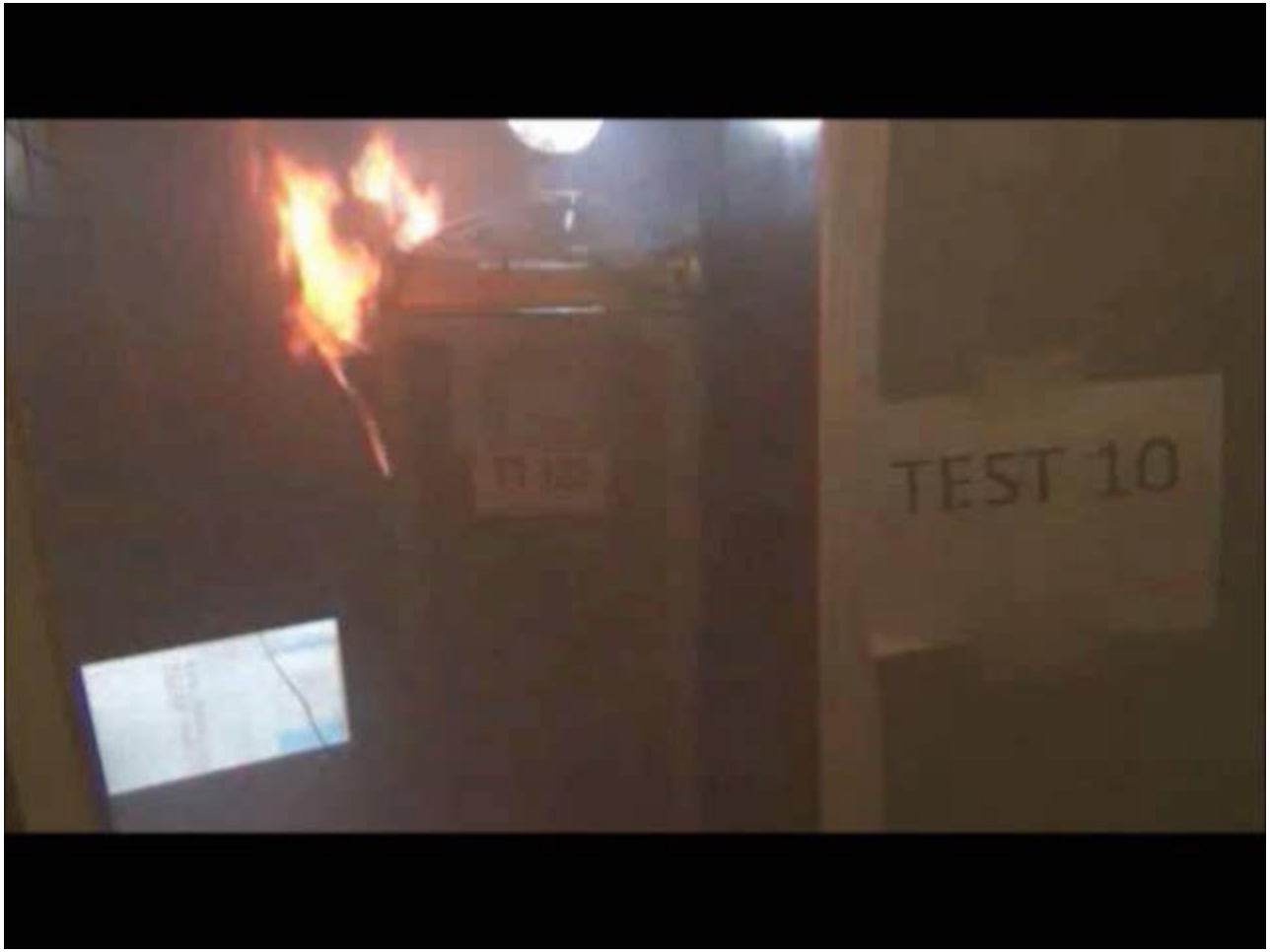
Ignition Source Results

- **Class E Compartment**
  - There was little difference between igniting the battery shipment by simulated thermal runaway vs. an external fire

Class E (Main Deck) Cargo Compartment Fire Containment Summary

Fire Load	Result
• Mixed Cells	Contained
• Lithium-ion	Marginal
• Lithium metal	Did not Contain

Explosion from Tablet Battery



For More Information

- **FAA Fire Safety Website**
  - www.fire.tc.faa.gov
  - Triennial Conference proceedings
  - Systems meeting proceedings
  - Lithium battery laptop fire fighting video
  - Lithium battery SAFO's

Questions?

Contact Information

Harry Webster
FAA William J Hughes Technical Center
Atlantic City, NJ
609-485-4183
Harry.Webster@faa.gov