

Full Scale Battery Fire Test Plan Update

Presented to: Systems Working Group

By: Harry Webster, FAA

Date: May 23, 2012



Federal Aviation
Administration



Full Scale Battery Tests

- **Purpose:** To document the characteristics of large battery fires in a realistic aircraft environment.
- **Test article: FAA Fire Safety 727 freighter**
 - Class C compartment with Halon 1301 suppression
 - Class E main deck compartment, no suppression
 - Fire hardened with cargo liner material
 - Fully operational air-packs
 - Extinguishment system: CO2 and water spray

FAA Fire Safety 727



Full Scale Battery Tests

- **Fire load:**
 - 5000 cells in original fiberboard packing
 - Adjacent flammable materials: 18"x18"x18" cardboard boxes with shredded paper
- **Cell types:**
 - Lithium-ion, type 18650
 - Lithium metal, type 123
 - Mixed (AA size)
 - Nickel Cadmium
 - Nickel metal hydride
 - Alkaline

Full Scale Battery Tests

- **Test locations**

- Forward Class C compartment
- Main deck Class E compartment

- **Ignition sources**

- Nichrome wire in adjacent box with shredded paper.
 - Simulate fire from external source
- Cartridge heater replacing a single cell
 - Simulate a cell in thermal runaway

Full Scale Battery Tests



Full Scale Battery Tests

- **Measure:**
 - Propagation of thermal runaway within the battery shipment
 - Spread of fire to adjacent combustibles
 - Smoke density
 - Smoke penetration into the cabin and cockpit
 - Temperatures
 - Pressure
- **Compare: Baseline (no cells), cell chemistries, ignition sources**

Full Scale Battery Tests

- **Considerations**

- Compartment loading
 - Full compartment will increase smoke density
- Containerized or palletized cargo
- Aircraft emergency procedures
 - Air-pack setting
- Test article limitations
 - Temperature limits
 - Pressure limits

Full Scale Battery Test Matrix

- **Cargo compartment location**
 - Test 1. Baseline (no cells)
 - Test 2. 5000 mixed NiCad, NiMH, Alkaline, cartridge heater
 - Test 3. 5000 mixed, adjacent fire
 - Test 4. 5000 lithium-ion, cartridge heater
 - Test 5. 5000 lithium-ion, adjacent fire
 - Test 6. 5000 lithium metal, cartridge heater
 - Test 7. 5000 lithium metal, adjacent fire

Full Scale Battery Test Matrix

- **Main deck location**

- Test 8. Baseline (no cells)
- Test 9. 5000 mixed, cartridge heater
- Test 10. 5000 mixed, adjacent fire
- Test 11. 5000 lithium-ion, cartridge heater
- Test 12. 5000 lithium-ion, adjacent fire
- Test 13. 5000 lithium metal, cartridge heater
- Test 14. 5000 lithium metal, adjacent fire.

5000 Cell Battery Fire Characterization

Purpose

- To determine the severity of a large lithium-ion and lithium metal battery fire
- Outdoor Location
- Determine
 - Peak temperatures
 - Duration
 - Controllability
 - Water

5000 Cell Lithium-ion Fire

- 18650 lithium-ion cells
- 50 100 cell boxes
- 100 watt cartridge heater replaced one cell in box #3
- Thermocouples used to monitor propagation of thermal runaway
- Exterior thermocouples to measure fire severity

5000 Cell Lithium-ion Fire



5000 Cell Lithium-ion Fire



5000 Cell Lithium-ion Fire



5000 Cell Lithium-ion Fire



5000 Cell Lithium-ion Fire

Results:

•Propagation

- Much like the smaller scale tests the propagation of thermal runaway progressed from cell to adjacent cell
- Cell explosions, rocketing- flaming cells up to 133'

•Peak temperature

- 1400 DegF, 4" above the top box
- 1668 DegF, inside battery stack

•Test duration: 1:05

4800 Lithium Metal Cells

- **123A lithium metal cells**
- **12- 400 cell boxes**
- **100 watt cartridge heater replaced one cell in box #2**
- **Thermocouples used to monitor propagation of thermal runaway**
- **Exterior thermocouples to measure fire severity**

4800 Lithium Metal Cells



4800 Lithium Metal Cells



4800 Lithium Metal Cells



4800 Lithium Metal Cells

Results

•Propagation

- Similar to small scale, rapid escalation, fully involved
- Minimal rocketing, some explosions, cells fused together

•Peak temperatures

- 1933 DegF, 4" above battery stack
- 2009 DegF, in the battery stack

•Test duration: 17 minutes

Test 1&2 Video



Water Extinguisher Test

- A deluge water extinguisher was designed to protect the aircraft
- Four nozzles rated at 15 gpm @ 60 psi
- Concern about the effectiveness against a lithium metal battery fire.
- Test was conducted with 400 123A lithium metal cells
- Test was initiated with a cartridge heater and allowed to buildup to full intensity

Water Extinguisher Test

- **Results**

- The water was effective in knocking down the large fire
- Cells continued to go into thermal runaway and vent flames and molten lithium for approximately 20 seconds
- Temperature were reduced to 65 DegF after several minutes of water application
- After water shut off, several thermocouples showed a temperature rise, necessitating a second water application.

Contact Information

Harry Webster

609-485-4183

Harry.Webster@faa.gov

www.fire.tc.faa.gov

