Lithium Battery Update

Comparison of battery chemistries flammability

Medium Scale Propagation Tests

Presented to: Int'l Aircraft Systems Working Group

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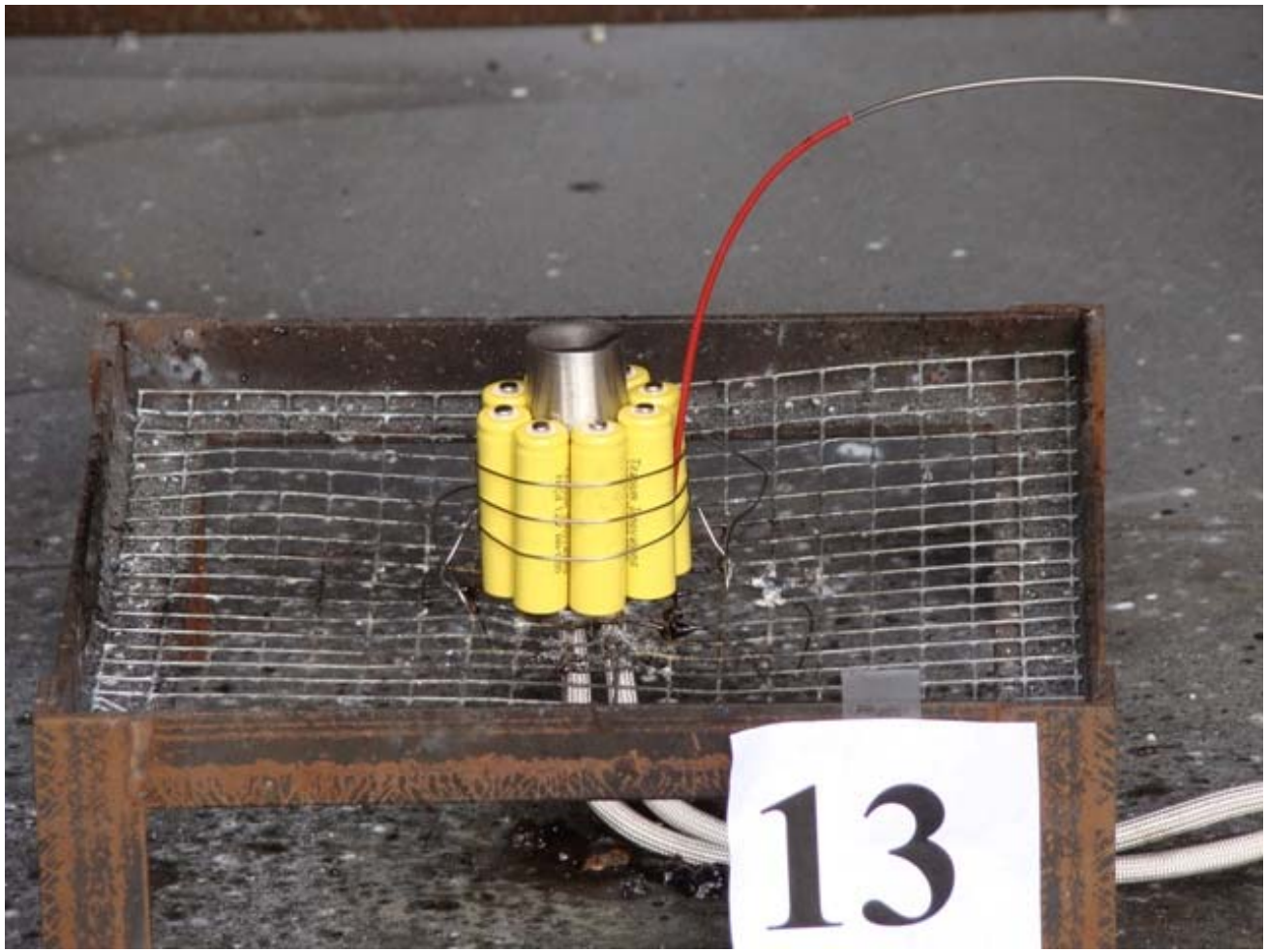
Federal Aviation Administration

Relative Flammability of Various Common Battery Chemistries

- **Tests were conducted using AA size cells**
  - Lithium metal, lithium-ion (3.8 volt), Nickel Cadmium (rechargeable), Nickel Metal Hydride (rechargeable) and common Alkaline.
- **Groups of cells were tested in two modes:**
  - heated using an external alcohol flame
  - heated with a 100 watt cartridge heater

Alcohol Fire Configuration

Cartridge Heater Test Configuration



Relative Flammability of Various Common Battery Chemistries

- **Results (in order of risk)**
  - Lithium metal: very strong initial pressure release, highly flammable, molten lithium, flammable electrolyte, pressure pulse
  - Lithium-ion, flammable electrolyte, pressure pulse
  - Nickel Metal Hydride: Pressure release (small), electrolyte somewhat flammable
  - Alkaline: Pressure release (small), non flammable in these tests
  - Nickel Cadmium: non flammable in these tests

- **Future tests: cone calorimeter, measure of heat release**

Relative Flammability of Various Common Battery Chemistries

Medium Scale Propagation Tests

- **Tests designed to measure the propagation between cells when a single cell fails (thermal runaway)**
  - Lithium-ion and metal
  - Tests with multiple boxes of cells in original shipping packaging
  - Unsuppressed compartments, main deck freighter (ongoing)
  - Suppressed compartments, class C cargo compartment (future)

Medium Scale Propagation Tests

- **Test conditions-Lithium-ion:**
  - Unsuppressed compartment, 300 cells, 18650 lithium-ion, three boxes, 100 cells per box
  - Single cell in lower box replaced with 100 watt cartridge heater, simulating thermal runaway
  - Two tests completed
    - Closed test chamber, minimal ventilation
    - Open test chamber, unlimited ventilation

Medium Scale Propagation Tests

- **Preliminary Results:**
  - Closed test chamber, limited ventilation
    - Thermal runaway propagated within the lower box
    - Thermal runaway propagated to the upper box
    - Thermal runaway propagated to the side box
    - Very little open flame
    - 280 cells went into thermal runaway
    - 158 vented as designed, releasing flammable electrolyte
    - 122 exploded, ejecting contents, large pressure release
    - Flash fire near end of test

Medium Scale Propagation Tests

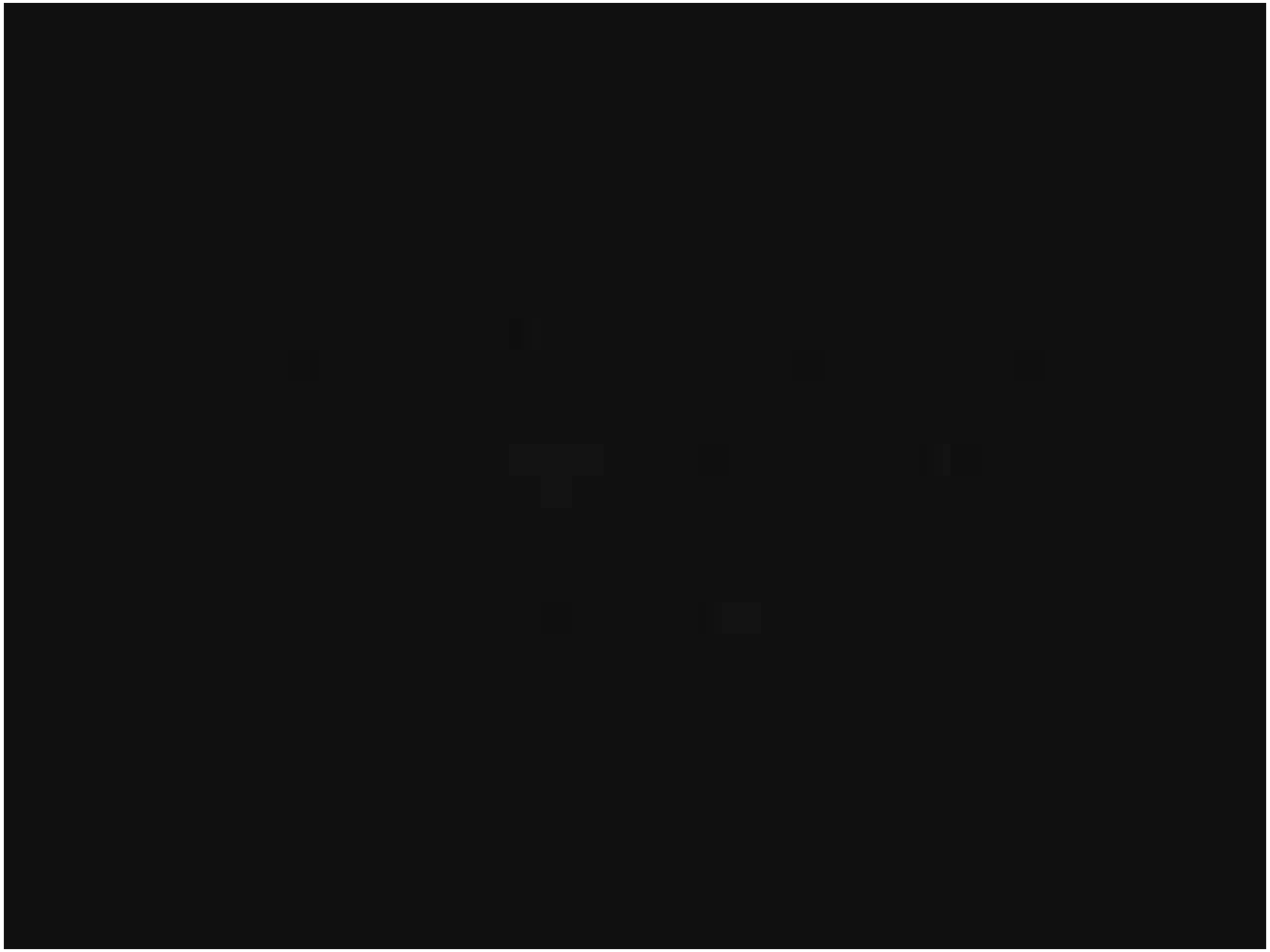
Medium Scale Propagation Tests

Medium Scale Propagation Tests

- **Preliminary Results**
  - Open test chamber, unlimited ventilation
    - Thermal runaway propagated within the lower box
    - Thermal runaway propagated to the upper box
    - Thermal runaway propagated to the side box
    - Cardboard packaging ignited
    - Vented electrolyte torched, open flame
    - All cells went into thermal runaway

Medium Scale Propagation Tests

Medium Scale Propagation Tests



Future Tests

- **Medium scale propagation tests with Lithium Primary cells**
- **Halon 1301 suppressed compartment propagation tests**
  - Lithium-ion cells
  - Lithium primary cells