

Lithium Battery Update

Full Scale Tests Air Exchange Baseline

Presented to: Systems Working Group

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Date: November 15, 2012



Federal Aviation
Administration



Full Scale Fire Tests



Objective

- To document the characteristics of large battery fires in a realistic aircraft environment.
- With Suppression-Class C
- No Suppression-Class E



Full Scale Fire Test Plan

- **Baseline**
- **Class E Cargo**
 - Lithium-ion 5000 18650 cells
 - Lithium metal 4800 SF123A Cells
 - 5000 mixed alkaline, NiCad, NiMH



Full Scale Fire Test Plan

- **Class C Cargo w/
Halon 1301
Suppression**
 - Lithium-ion 5000
18650 cells
 - Lithium-metal 4800
SF123A cells
 - 5000 mixed alkaline,
NiCad, NiMH

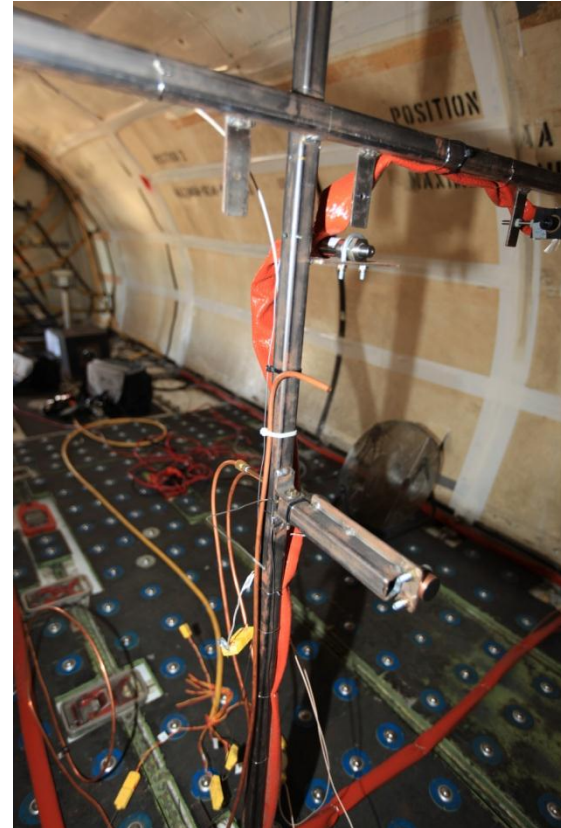


Instrumented 727 Test Article



Instrumentation: Class E

- Two trees
 - Thermocouples
 - Calorimeter
 - Smoke meter
 - Gas measurement – CO, CO₂, O₂
 - Compartment pressure
- Ceiling T/C's
 - 6" below cargo liner
 - Above cargo liner in vicinity of fire
- Video
 - cameras, infrared



Instrumentation: Flight Deck

- One instrumentation tree
 - Thermocouples
 - Smoke density meter
 - Gas measurement
 - Pressure
- Video
 - Overall
 - Smoke detector panel



Instrumentation: Class C

- Instrumentation tree
 - Thermocouples
 - Calorimeter
 - Smoke density
 - Gas measurement
 - Compartment pressure
- Ceiling T/C's above and below the cargo liner



Instrumentation: Battery Stack

- Distributed thermocouples
 - Track progress of thermal runaway
- Cartridge heater thermocouple
- Calorimeter
 - Above center of fire load



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 (Thanks Doug!), one for the main deck class E fire and one for the forward class C compartment**



Aircraft Ventilation Settings

Class E Depressurized

- **Aircraft Flight Manual**

- RH pack ON
- LH pack OFF
- The Cabin Air Distribution Lever is put in the AIR SHUTOFF position.
- The Gasper Fan is OFF
- The Cargo Heat Outflow is NORMAL
- The Cockpit air conditioning outlets and gasper outlets are OPEN
- The Passenger Cabin Temp Selector is MANUAL (as required)

- **Additional Settings**

- External air conditioner flow adjusted to simulate single pack airflow
- Avionics cooling fan ON
- Outflow valves closed

Class C Pressurized

- **Aircraft Flight Manual**

- The Cargo Heat Outflow is CLOSED
- Single Pack Operation – Do not depressurize
- The Cabin Air Distribution Lever is put in FULL OPEN

- **Additional Settings**

- Outflow valves chocked open ¼”
- Avionics cooling fan ON
- External air conditioner set to “wide body” to maintain 0.5 psi differential across the fuselage



Conducted Air Exchange Tests



Air Exchange Test Procedures

- **Air exchange tests were conducted in the main deck cabin (class E) and the flight deck. The class C tests will be conducted at a later date.**
- **Tests were conducted in each Airflow configuration, pressurized and unpressurized**
- **CO2 was discharged into each compartment and the concentration decay rate was measured. Fans insured uniform mixing.**



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



Baseline Test

- **Purpose:**
 - To insure operational status of all instrumentation
 - Validate airflow patterns
 - Provide a comparison class A fire for later battery tests
- **Fire load**
 - Four 18"x18"x18" cardboard boxes filled with shredded paper
- **Ignition:** NiChrome wire
- **Results:** Under Analysis



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