

The aircraft hazards of flammable gasses produced by lithium batteries in thermal runaway



Federal Aviation
Administration

Presented to: ICAO

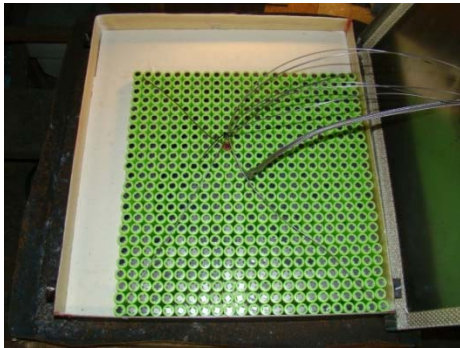
By: FAA Fire Safety

Date: 07/2015



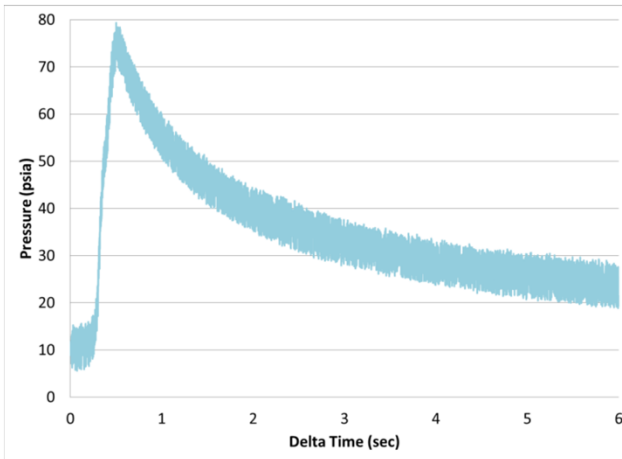
Halon Tests

- Tests were performed in a 10.8m³ chamber to evaluate the effectiveness of Halon 1301 with vent gasses.

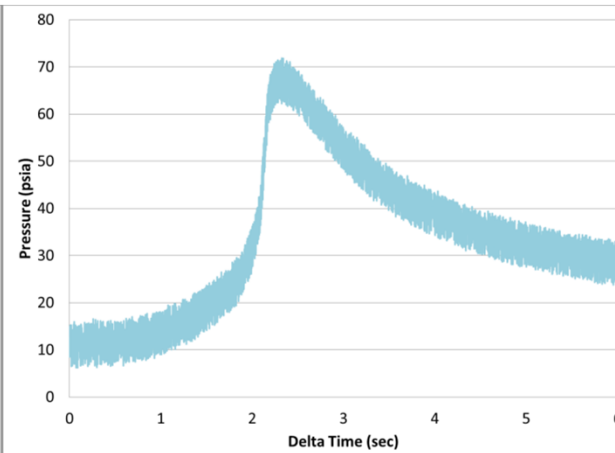


- Runaway was initiated => Halon was introduced => Spark was activated => Pressure was recorded

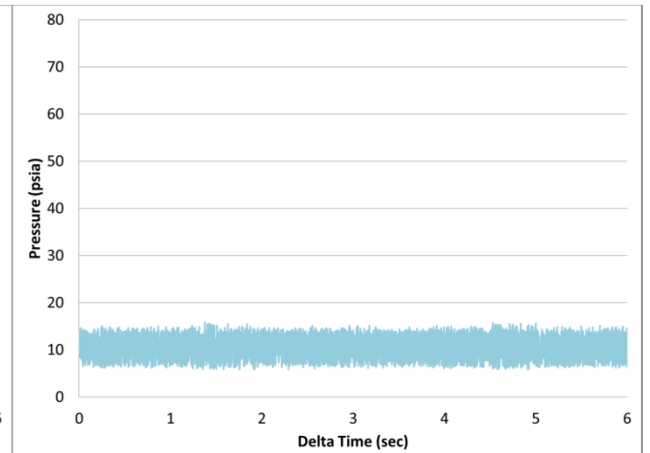
Halon Results



Test without
suppression



Test with
5.28% Halon



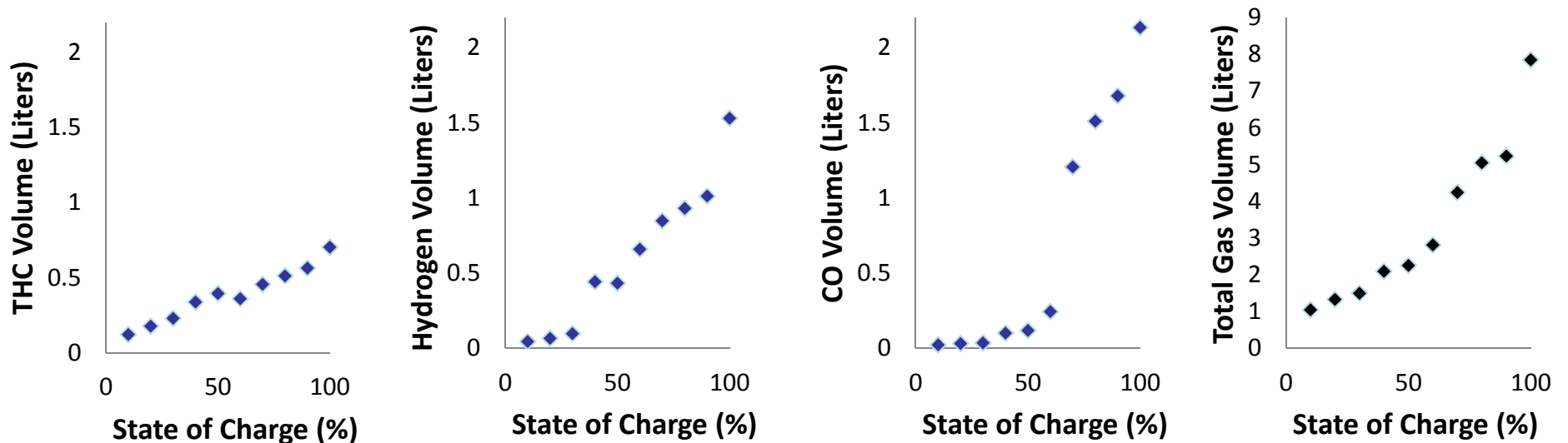
Test with
10.43% Halon

Gas Analysis from Cells

- **Tests were performed in a 21.7L combustion sphere to determine vent gas composition and quantity.**
 - Composition measured with GC, NDIR, Paramagnetic
 - Volume measured with pressure calculations



Gas Analysis Results



Tests conducted at cabin pressure at altitude
(10psia)

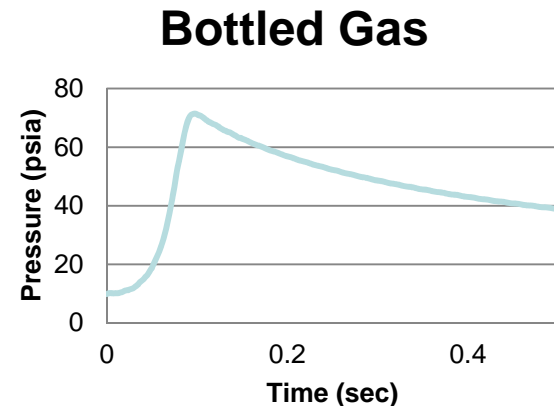
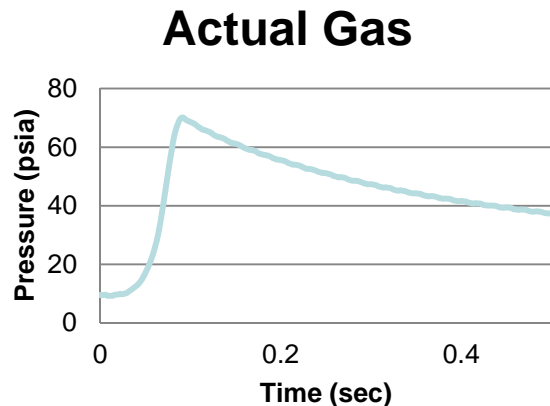
Bottled Gas

- Rather than collect Li-Ion vent gasses for subsequent tests, a bottle of mixed gas was purchased that matched the composition from previous analysis.
 - 30.1% CO₂
 - 27.6% H₂
 - 22.9% CO
 - 6.37% CH₄
 - 4.48% C₃H₆
 - 2.21% C₂H₄
 - 1.57% C₄H₁₀
 - 1.17% C₂H₆
 - .56% C₄H₈
 - .268% C₃H₈



Bottled Gas

- **We then verified that pressure rise from bottled gas was identical to pressure rise from actual gas.**
 - Max pressure from actual gas at altitude: 70.1 psia
 - Max pressure from bottled gas at altitude: 71.4 psia



Pressure Chamber Cargo Compartment Tests

- Tests were conducted with small pockets of gas (in a balloon) to determine how many 18650 sized cells would compromise fire suppression in cargo compartment.



Lithium Battery Thermal Runaway Vent Gas

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Pressure Chamber Cargo Compartment Tests

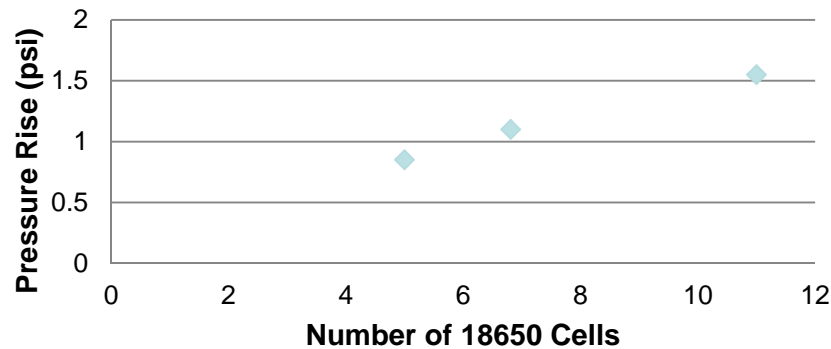
- **Balloon pressure rise was verified with gas accumulation in a box.**
 - Pressure from volume of gas corresponding to 5 cells at 50% SOC in balloon: .85 psi
 - Pressure from volume of gas corresponding to 5 cells at 50% SOC in box: .97 psi



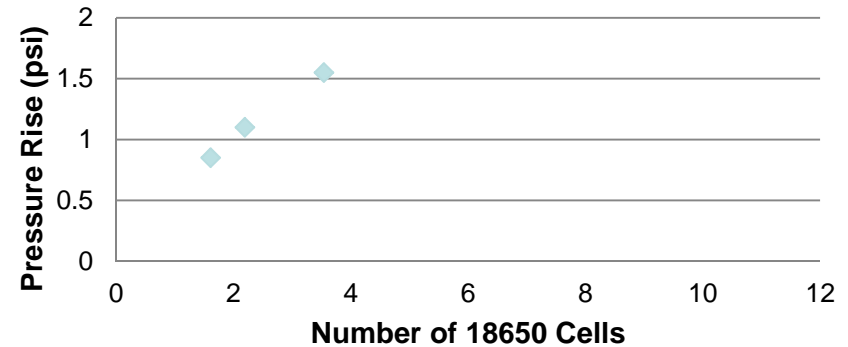
Results Pressure Chamber Cargo Compartment

- Tests at Sea Level:

Sea Level, 50% SOC

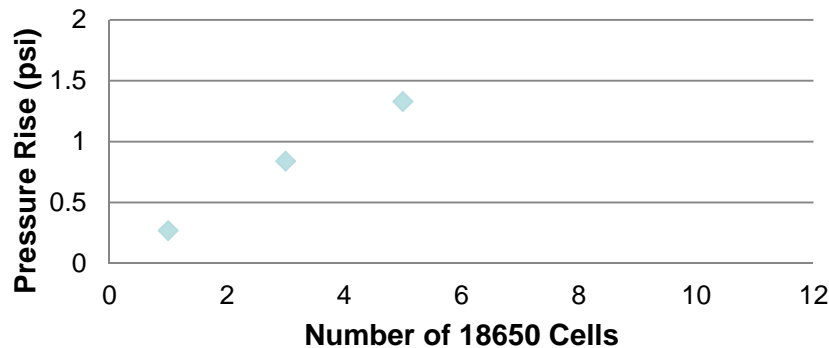


Sea Level, 100% SOC

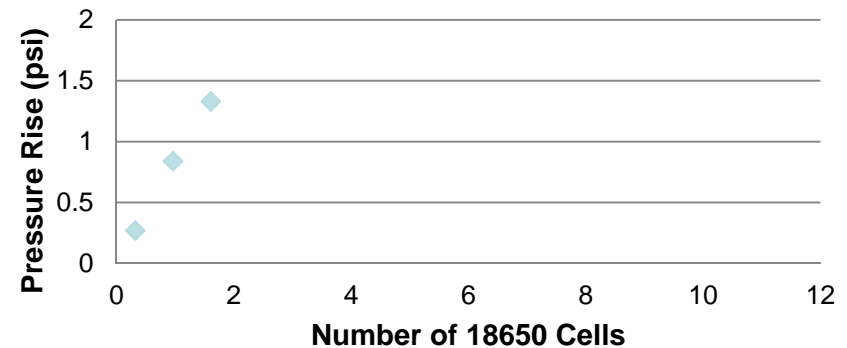


- Tests at Altitude:

Altitude, 50% SOC



Altitude, 100% SOC



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Verification in 737 Cargo Compartment

- **Pressure chamber tests were repeated in fwd. cargo compartment of 737 with 70% loading.**
 - Total volume of compartment (documented): 370ft³
 - Volume of boxes based on 70% loading: 259ft³



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737 Cargo Compartment Results



5 cells at 50% SOC

1.61 cells at 100% SOC

.252 psi peak pressure

737 Cargo Compartment Results



20 cells at 50% SOC

6.44 cells at 100% SOC

1.22 psi peak pressure

Additional panel behind door (not shown) and panel on sidewall (not shown) were also compromised.

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737 Cargo Compartment Results

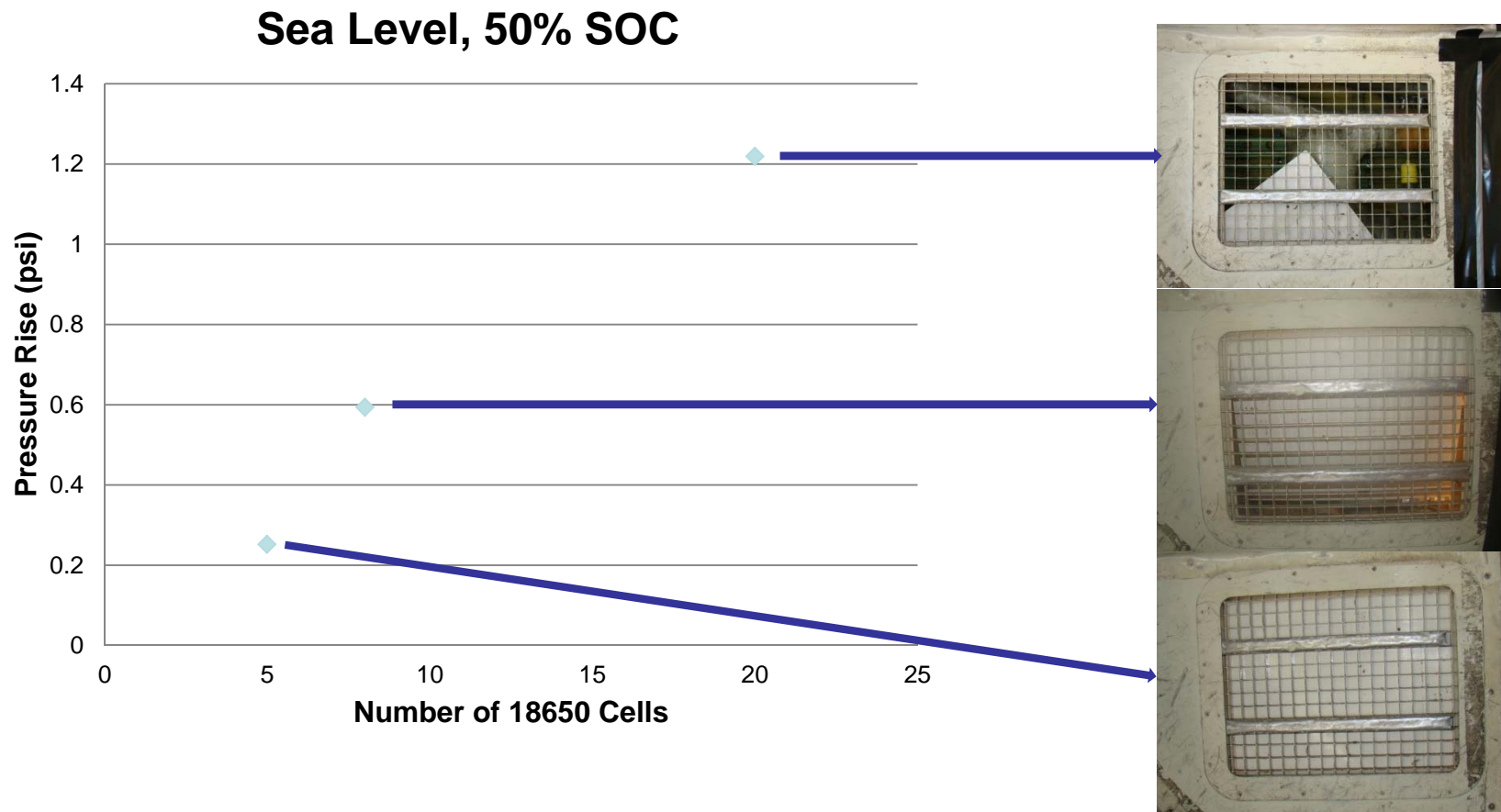


8 cells at 50% SOC

2.6 cells at 100% SOC

.594 psi peak pressure

737 Cargo Compartment Results



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Summary

- **If gasses from 8 18650 cells at 50% SOC**
- or**
- **If gasses from 3 18650 cells at 100% SOC**

accumulate in a loaded 737 fwd. cargo compartment and ignite, the halon suppression system would be compromised.