Evaluation of Watt Hour Size Limitations for Lithium Ion Batteries Inside of Carry-on Baggage

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Objective

- This research will evaluate the appropriateness of lithium battery size limitations and provide guidance as to whether new limitations should be recommended.

Background

Cell size limit Lithium Ion/lithium metal	Quantity limit
100 Wh/2 grams of lithium per battery	Unlimited, but must be for use by the passenger
160 W/8 grams of lithium per battery	2 spares

- **Size limits**: Lithium metal (non-rechargeable) batteries are limited to 2 grams of lithium per battery. Lithium ion (rechargeable) batteries are limited to a rating of 100 watt hours (Wh) per battery. These limits allow for nearly all types of lithium batteries used by the average person in their electronic devices. With airline approval, passengers may also carry up to two spare larger lithium ion batteries (101–160 Wh) or Lithium metal batteries (2-8 grams). This size covers the larger after-market extended-life laptop computer batteries and some larger batteries used in professional audio/visual equipment.
- **Quantity limits**: None for most batteries — but batteries must be for use by the passenger. Batteries carried for further sale or distribution (vendor samples, etc.) are prohibited. There is a limit of two spare batteries per person for the larger lithium ion batteries described above (101–160 watt hours).

Previous study setup

- 10 pouch cells were sandwiched together (about 100Wh at 100% SoC) in various configurations:
  - Uncovered
    - 50% SoC

  - Partially covered (holes in the plastic container)
    - Polycarbonate plastic at 100% SoC

  - Fully enclosed
    - ABS plastic at 100% SoC
    - Polycarbonate plastic at 100% SoC
    - Polycarbonate plastic at 50% SoC

Previous study results

- A spark igniter was used to ensure immediate ignition
- Thermocouples were used to monitor temperatures to ensure the events were finished.
- Test Procedure:
  - After the first sign of smoke wait approximately 2 minutes.
  - Knock the flames down with halon.
  - Pour water from 0.5L bottles onto the cells until runaway stops.

100% SOC in Polycarbonate box w/o holes

Previous study results

- Propagation was difficult to stop with cells that were fully enclosed.
- Uncovered cells required approximately two 0.5L water bottles.
- Covered cells usually fully propagated.
- Significant difference between 50%SoC (50Wh) and 100%SoC (100Wh)
- Smoke buildup may be a concern in an aircraft.
- In some cases, opening the overhead bin door may be hazardous due to the potential of a cell venting or exploding in someone's face.

Future study

- Preliminary tests, similar to the previous study (mockup overhead bin) with additional variables
- Validation test using the worse case scenario from the preliminary tests in an aircraft cabin
  - The test is designed to determine the thermal and toxicity hazard associated with the maximum sized batteries permitted for carry-on baggage.

Variables to study – battery type

160 Wh

One 160 Wh cell

100 Wh

One 100 Wh cell

One box of twenty 18650 cells (1920Wh)

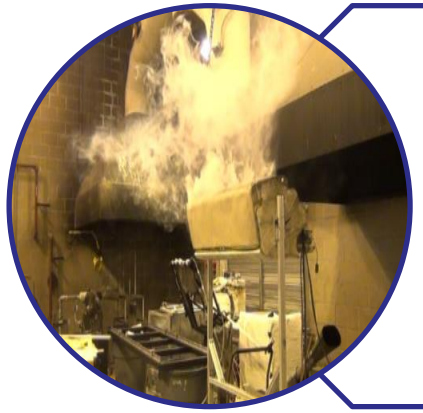
Variables to study – battery location

Inside of overhead bin without luggage

Inside of overhead bin in carry-on luggage

Variables to study – fire fighting

Using recommended fire protection strategies



Without fire protection

Validation testing

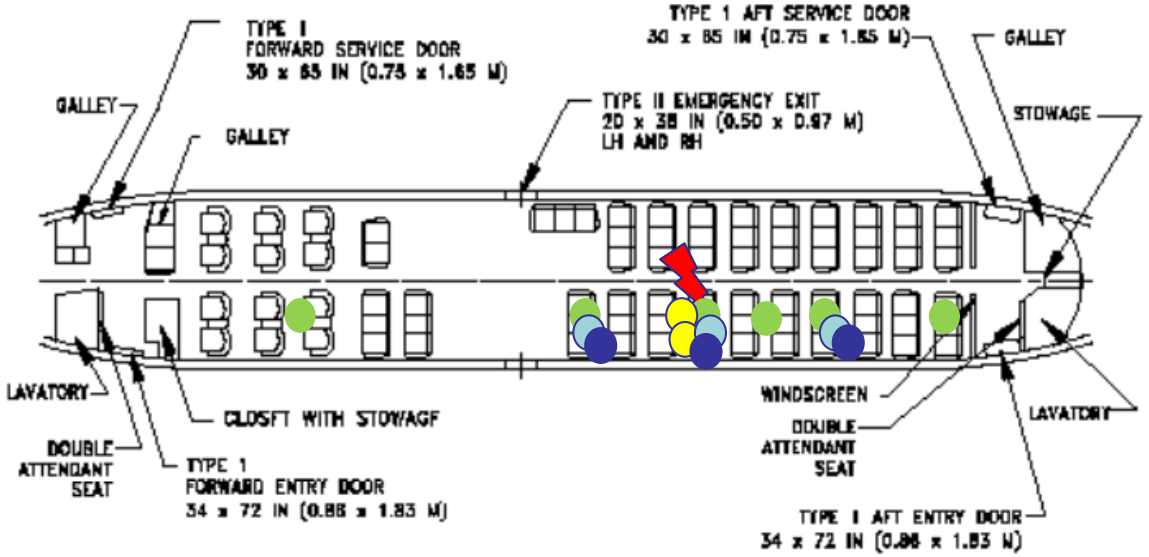
- One test using the worse case scenario from the preliminary tests in an aircraft cabin
  - The test is designed to determine the thermal and toxicity hazard associated with the maximum sized batteries permitted for carry-on baggage
  - It will address the concern of smoke buildup within an aircraft from the 2017 study.

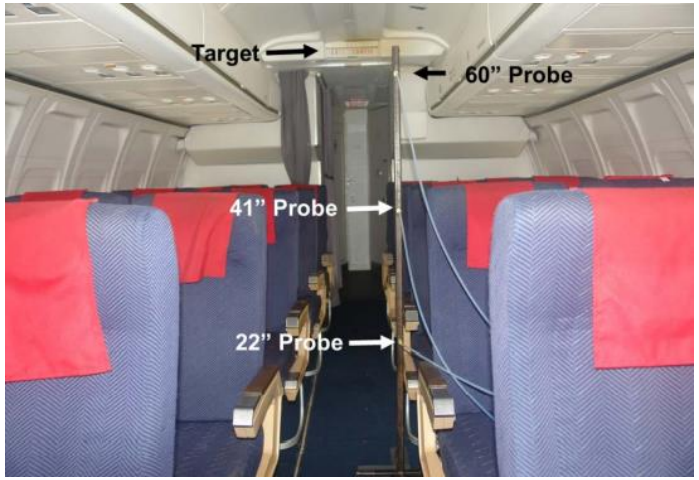
B-737-275 test aircraft

Constant variables

Factor Description	Value	Comments
Air change	~1.16 minutes	The exchange rate will be calculated according to the flight manual and calculated using CO2 decay
Length of test	~30 minutes	

Response variables





Visual	Video and photography lab
CO2/CO	Nondispersive infrared radiation sensor
Toxicity	Integrion Dionex Ion Chromatography
Temperature	Type-k thermocouples
Light obscuration	2.3mW 670nm laser and silicon diode light sensor

Summary

- The current watt hour size limitations for lithium ion batteries inside of carry-on baggage are 100 Wh, or 160 Wh with airline approval
- This research will evaluate the appropriateness of these size limitations and provide guidance as to whether new limitations should be recommended
- Previous studies were conducted in an overhead bin in a laboratory but was limited in the variety of cells tested and did not demonstrate how the smoke will travel throughout an aircraft cabin and the toxicity hazard
- This study will consider 160 Wh, 100 Wh, and one box of twenty 18650 cells at 100% SOC placed inside an overhead bin with and without carry on luggage and with and without fire protection
- The worse case scenario will be tested inside a ventilated aircraft cabin
- Response variables include gas measurements, temperature measurements, and light obscuration measurements

Questions and answers

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