Development of Packaging Standards for Lithium Ion and Lithium Metal by Air

October 31, 2013

Presented to ICAO DGP/24

Prepared by
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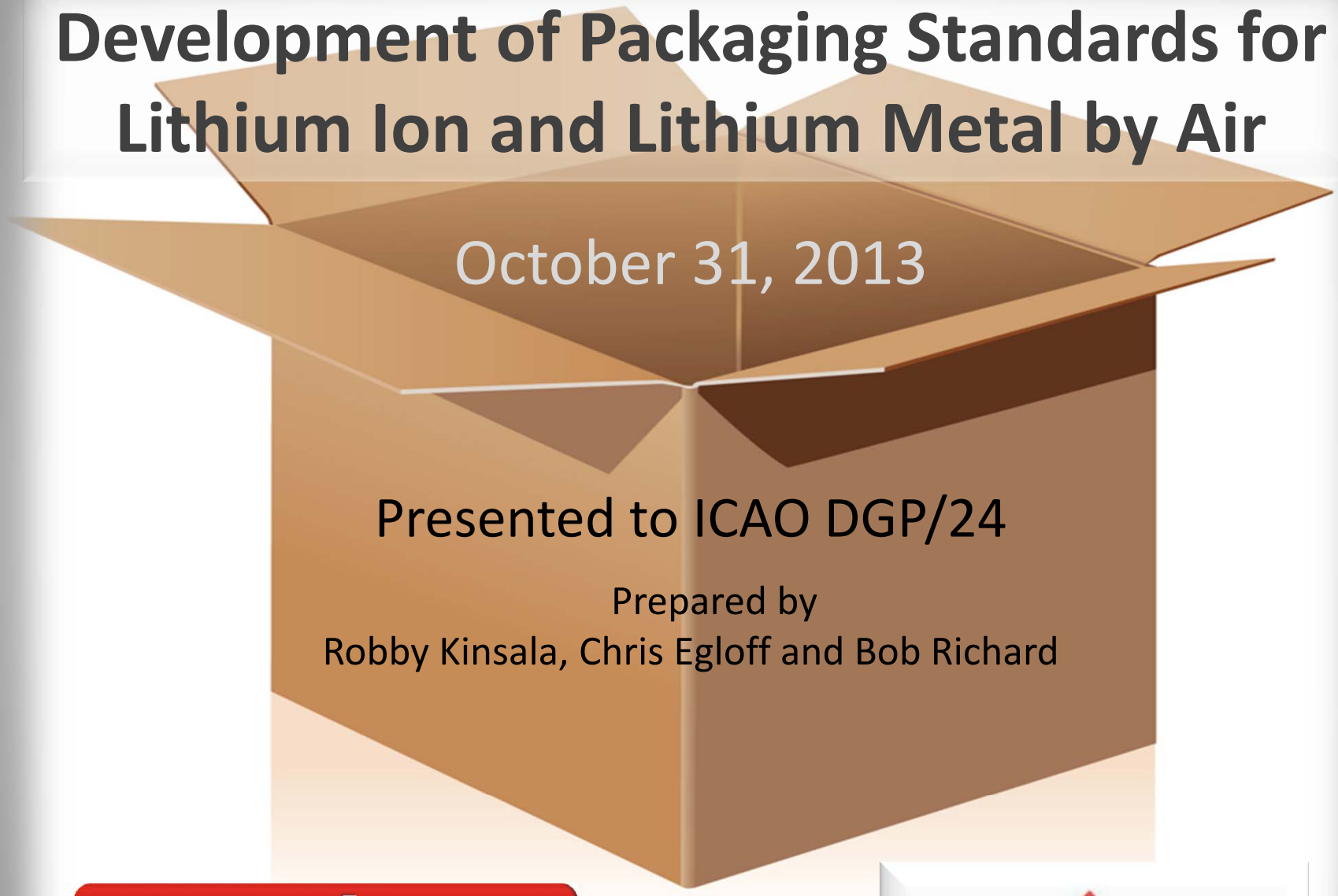

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Why is it necessary to transport damaged lithium batteries by air?

- Safety – In some cases rapid analysis may be necessary to prevent further incidents and facilitate corrective actions.
- This is important to both government and industry (e.g. 787 battery analysis).
- Completing a root cause analysis quickly can expedite addressing potential broad reaching safety issues and incidents.
- To preserve evidence and allow for appropriate diagnostic analysis.
- Other modes may not be practical or appropriate (e.g. sea transport may compromise evidence/forensics).

Research and Development

- Working closely with FAA, PHMSA, PRBA and others on packaging for Damaged and Defective Lithium Batteries as well as Prototype Lithium Batteries.
- Special Approvals granted pending for shipping damaged lithium batteries.
- Over a decade of Research and Development in flame and heat mitigating packaging.
- 3 years of intensive lithium battery research.
- Manufacturer of Oxygen Generator and Oxygen Cylinder packaging for air transport.

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Research and Development

- Internal Testing
  - 2 Laptop Videos

FAA Analysis (Lithium Ion)

November 2010

Final Report

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This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

U.S. Department of Transportation
Federal Aviation Administration

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DOT/FAA/AR-10/31

Air Traffic Organization
NextGen & Operations Planning
Office of Research and
Technology Development
Washington, DC 20591

Fire Protection for the Shipment of Lithium Batteries in Aircraft Cargo Compartments

FAA Analysis (Lithium Ion)

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A performance standard was developed for outer package (often called an overpack) designed for safely shipping compressed oxygen and chemical generators on passenger aircraft. This performance standard is defined in PHMSA Rule HM224B. The oxygen generator overpack is designed to protect against both exterior and interior threats, i.e., protection of oxygen containers from an external fire and prevention of hazards from an activated generator from spreading outside the overpack. The same exterior threats apply to a bulk shipment of lithium-ion cells exposed to a Halon 1301 suppressed cargo compartment fire. A test was designed to determine if the overpack performance standard would protect against an internal lithium-ion cell fire caused by thermal runaway.

5.2.3 Oxygen Generator Overpack Lithium-Ion Cell Test.

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soot on the top, and the top flaps were slightly brittle but intact. The cardboard box

the cells was charred but intact. All the cells were consumed. The overpack

contained the lithium-ion cell fire. The oxygen generator overpack performance st

be used as a basis for a performance standard for lithium-ion cells.

Figure 18. Oxygen Generator Overpack Lithium-Ion Posttest

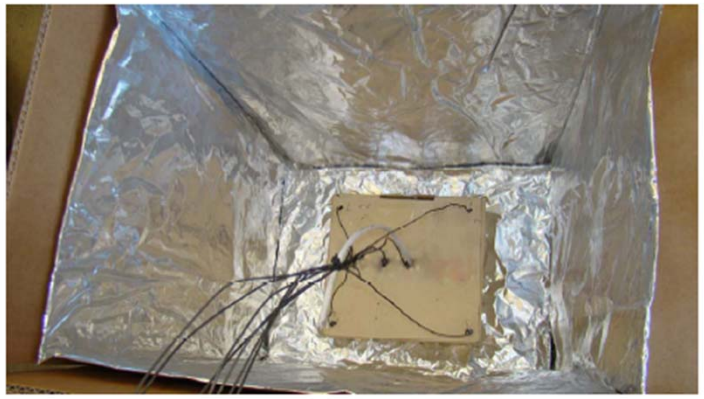

Figure 15. The Box of 99 Lithium-Ion Cells Installed in the Oxygen Generator Overpack

FAA Analysis (Lithium Ion)

LIST OF FIGURES

A cardboard container with a foil/ceramic insulator, which met the requirements of PHMSA Rule HM224B, was used for this test. A full box of 99 lithium-ion 18650 cells was prepared

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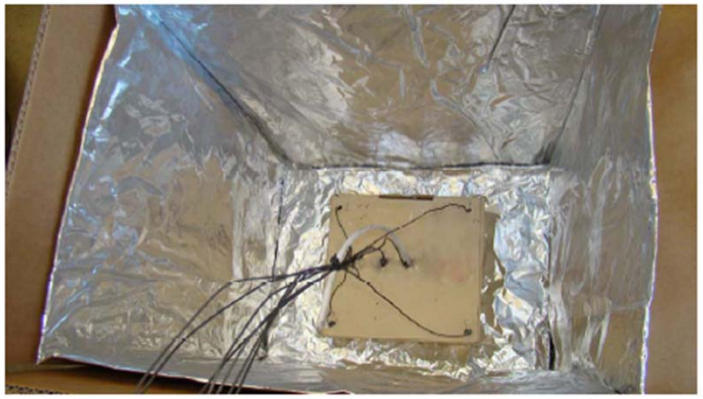
A cardboard container with a foil/ceramic insulator, which met the requirements of PHMSA Rule HM224B, was used for this test. A full box of 99 lithium-ion 18650 cells was prepared with a cartridge heater and thermocouples in the same locations as in the propagation tests



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FAA Analysis (Lithium Ion)

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The overpack was opened after 3 hours. The inside of the overpack was soot covered but undamaged (figure 18). The exterior of the overpack was not discolored except for a coating of soot on the top, and the top flaps were slightly brittle but intact. The cardboard box containing the cells was charred but intact. All the cells were consumed. The overpack successfully contained the lithium-ion cell fire. The oxygen generator overpack performance standards can be used as a basis for a performance standard for lithium-ion cells.

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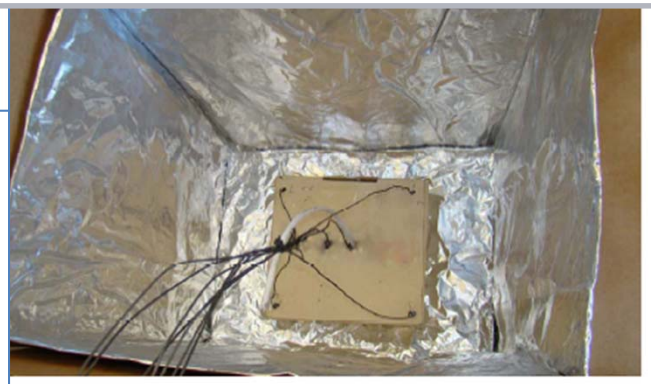


The Box of 99 Lithium-Ion Cells Installed in the Oxygen Generator Overpack

Development of Appropriate Performance Standards

Report # DOT/FAA/AR-10/31

Titled: FIRE PROTECTION FOR THE SHIPMENT OF LITHIUM BATTERIES IN AIRCRAFT CARGO COMPARTMENTS

Authored by: Harry Webster

Date: November 2010

DRAFT OVERPACK PERFORMANCE STANDARD FOR LITHIUM-ION CELLS

Tests have shown that cardboard containers designed to meet the requirements of PHMSA Rule HM224B have been successful in containing a lithium-ion cell fire. The requirements for a lithium-ion cell shipment overpack are somewhat different than for oxygen generators.

Development of Appropriate Performance Standards

The following performance standard states that an overpack constructed from any type of material (steel, cardboard, or other) must

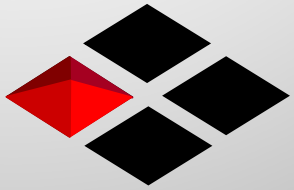
- *Meet the same flame penetration resistance standards as required for cargo compartment sidewalls and ceiling panels in transport category aircraft.*
- *Provide certain thermal protection capabilities to retain its contents during an otherwise controllable cargo compartment fire.*

The outer packaging standard that is being proposed addresses two safety concerns:

- *Protecting a shipment of cells from direct exposure to a fire*
- *Protecting a shipment of cells from indirect heating from a suppressed fire*

Where does our technology fit?

- Who are the End Users?
- Should we focus on
  - Ion?
  - Metal?
  - Small Qty?
  - Bulk Shipments?
- Can the technology be cost effective?



AkroFire

Realistic Direction

- Clients have contracted Americase to develop packaging for Damaged and Defective Batteries.
- Industry needs to ship prototype batteries that have not passed the appropriate testing.
- We have developed packaging solutions that afford a high level of safety and reduce the risk of shipping lithium batteries that normally wouldn't be allowed by air transport.
- New developments in disposable packaging and adoption of performance standards could provide cost effective solutions.

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Failures are part of the process

100 Lithium Ion 18650 Batteries

49 Lithium Metal CR2 Batteries

300 Lithium Metal CR123 Batteries

Development of Appropriate Performance Standards

An appropriate performance standard should incorporate key performance parameters such as:

Thermal Runaway Containment,

Flame Penetration,

and Thermal Resistance.

Proposed Test Method for Lithium Battery Packaging for Air Shipment

Thermal Runaway Containment

Package must maintain structural integrity. No projectiles may come from package. No Flames or Fire may escape from the packaging; smoke venting is okay. Exterior of box not to exceed 204 °C (399 °F).

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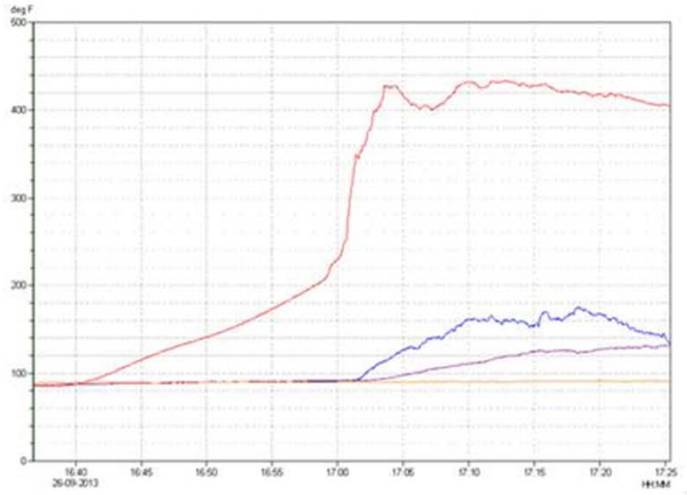
TEST REPORT

Project: Lithium Battery Shipping Container	
Test: Thermal Runaway Containment	Test Date: 09/26/2013
Document #: 2013-09-26_11-36-44	Rev A
Doc Date: 10/17/2013	Page 2 of 8

Test Quantity: 400 Cells
Cell type: Lithium Ion18650

Data Acquisition Results:

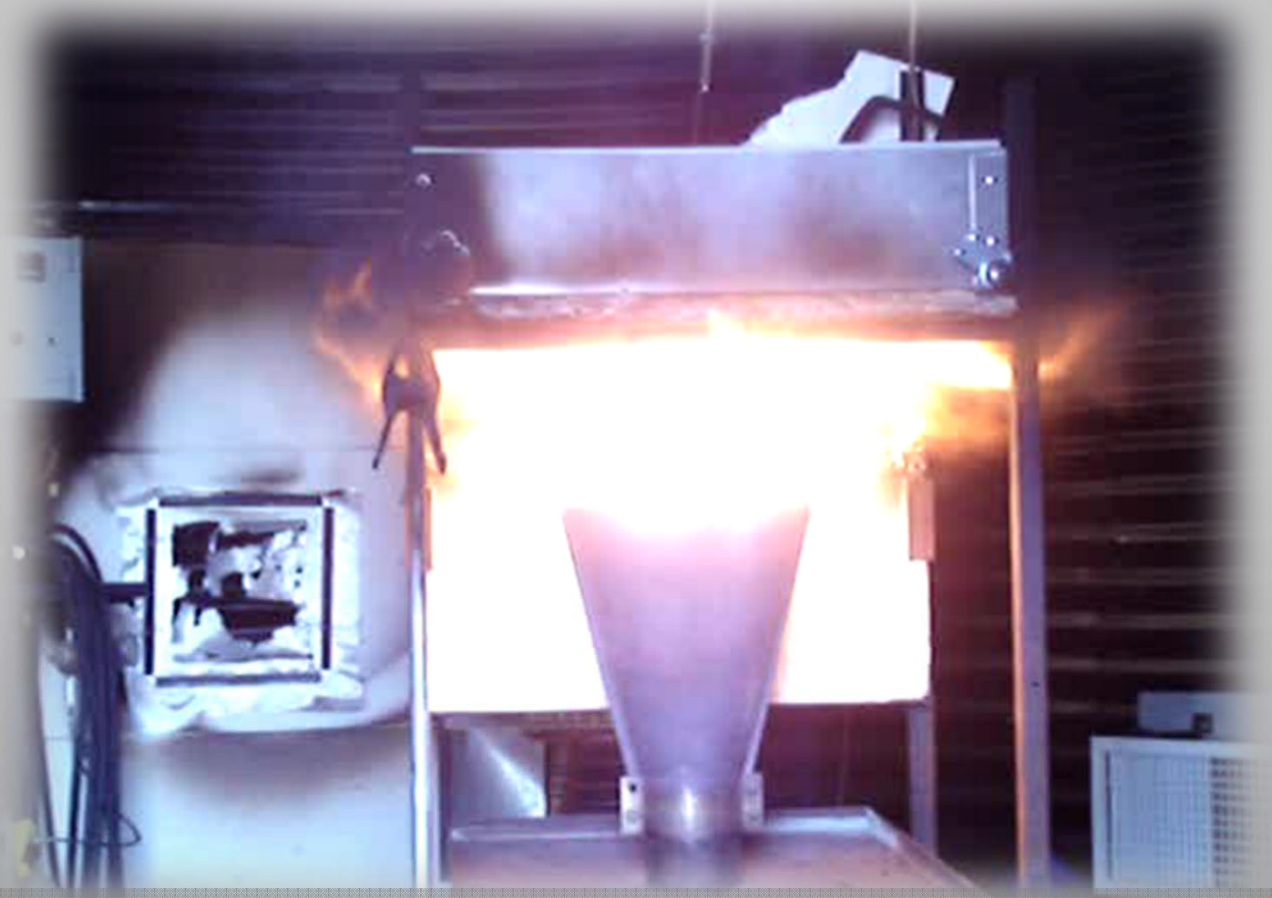
Database File: 2013-09-26_11-36-44.hds



- Probe 1 (-): Interior of Box; above 18650 cells.
- Probe 2 (-): Exterior; Mounted beside the seal to measure the temperature of exhausted gases.
- Probe 3 (-): Exterior; Top Surface of Box.
- Probe 4 (-): Ambient; Next to Data Logger.

Flame Penetration Test

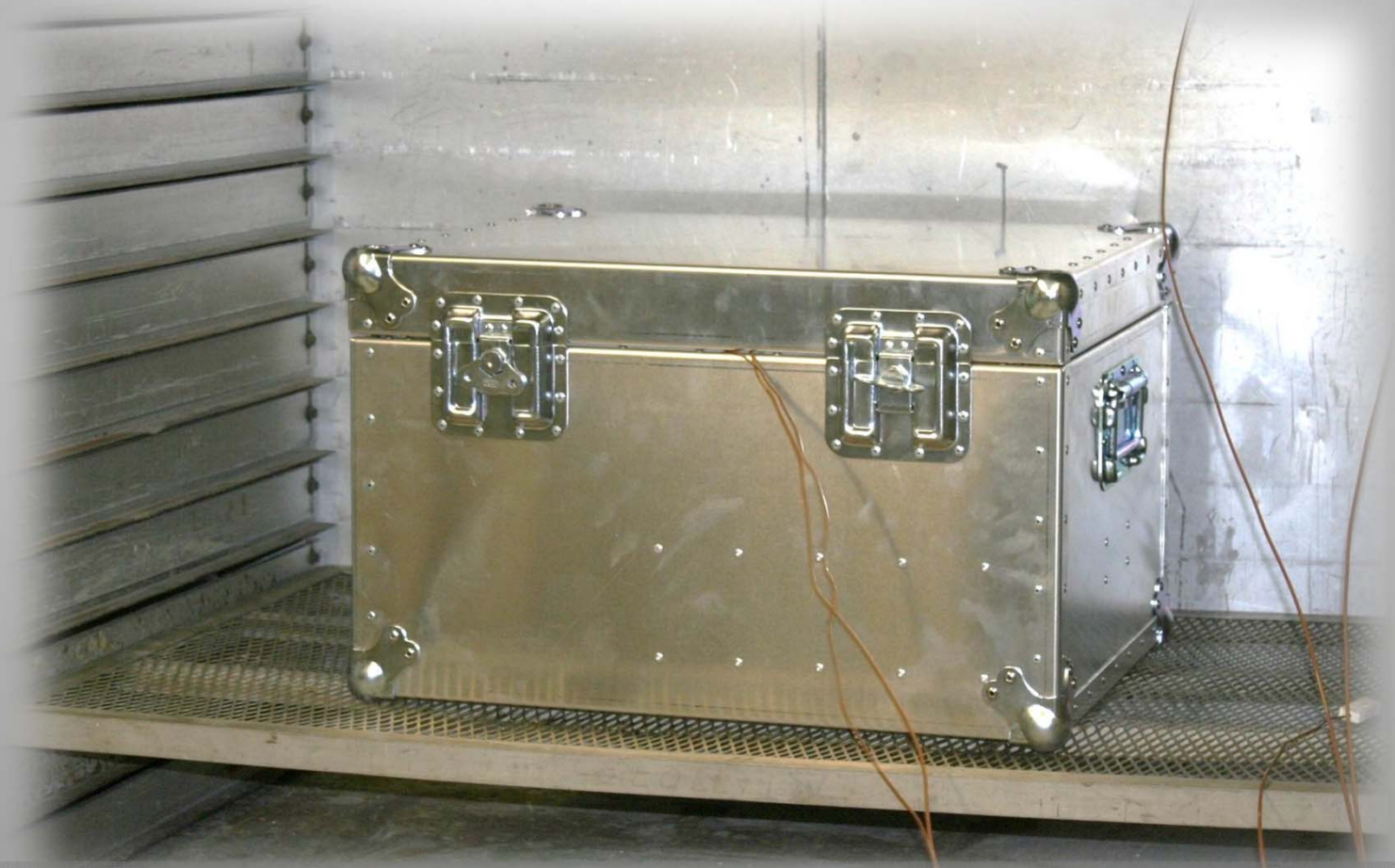
927 °C (1700 °F) Flame. No flame penetration after five minutes. Temp 4 inches above coupon must not exceed 205 °C (400 °F).



"Protecting a shipment of cells from direct exposure to a fire."

Thermal Resistance Test

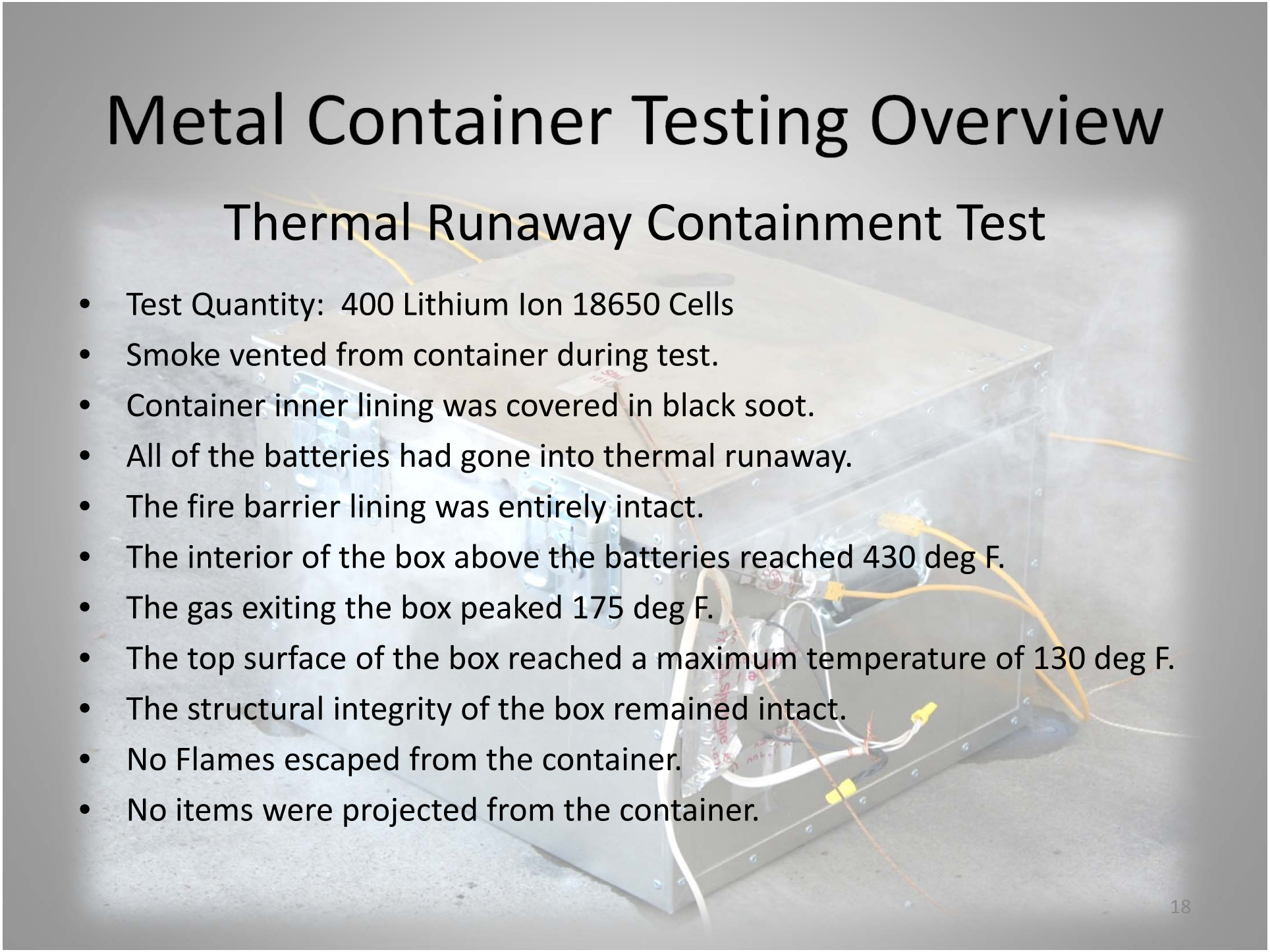
Package and contents subjected to 205 °C (400 °F) environment for duration of 3 hours. Contents inside not to exceed 148 °C (299 °F).



"Protecting a shipment of cells from indirect heating from a suppressed fire."

Metal Container Testing Overview

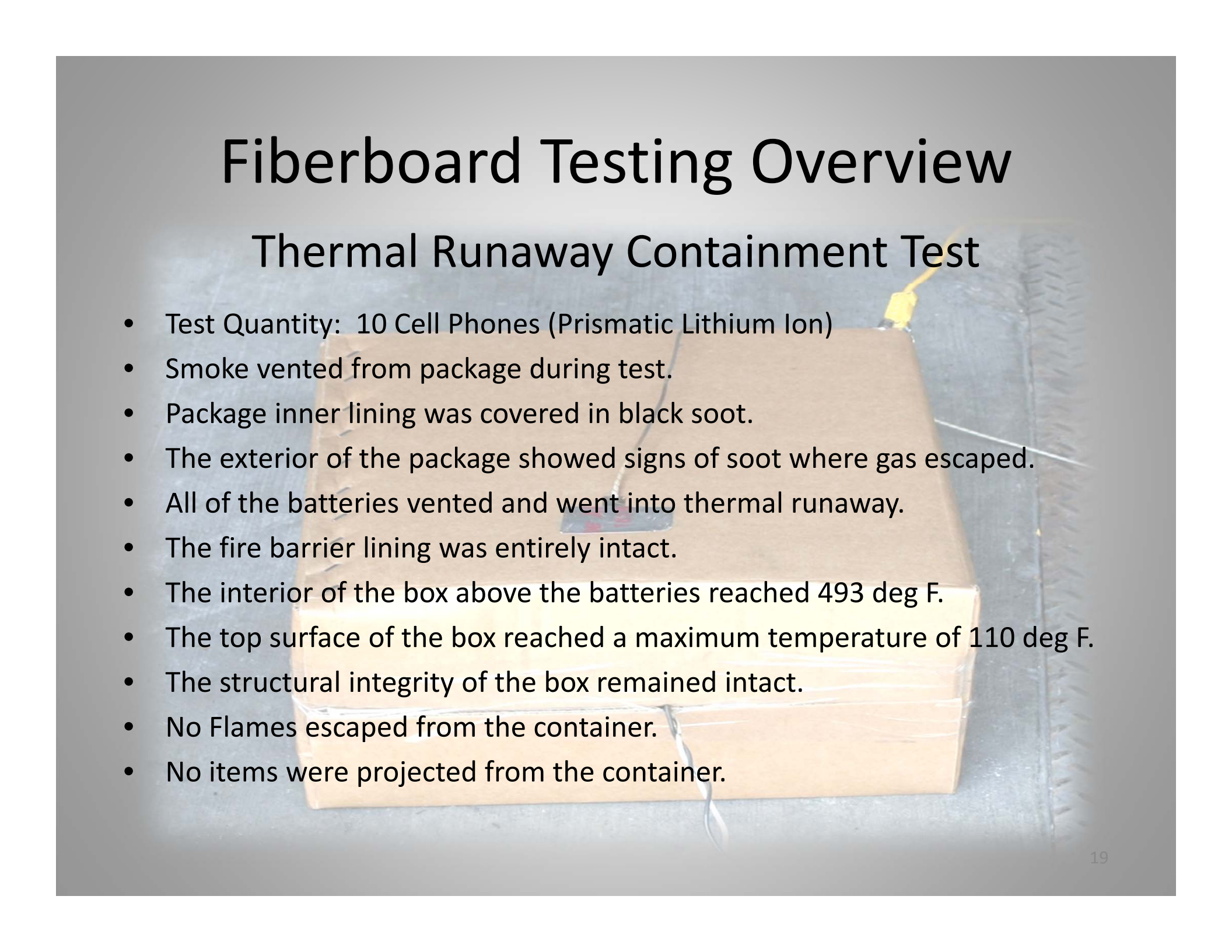
Thermal Runaway Containment Test



- Test Quantity: 400 Lithium Ion 18650 Cells
- Smoke vented from container during test.
- Container inner lining was covered in black soot.
- All of the batteries had gone into thermal runaway.
- The fire barrier lining was entirely intact.
- The interior of the box above the batteries reached 430 deg F.
- The gas exiting the box peaked 175 deg F.
- The top surface of the box reached a maximum temperature of 130 deg F.
- The structural integrity of the box remained intact.
- No Flames escaped from the container.
- No items were projected from the container.

Fiberboard Testing Overview

Thermal Runaway Containment Test



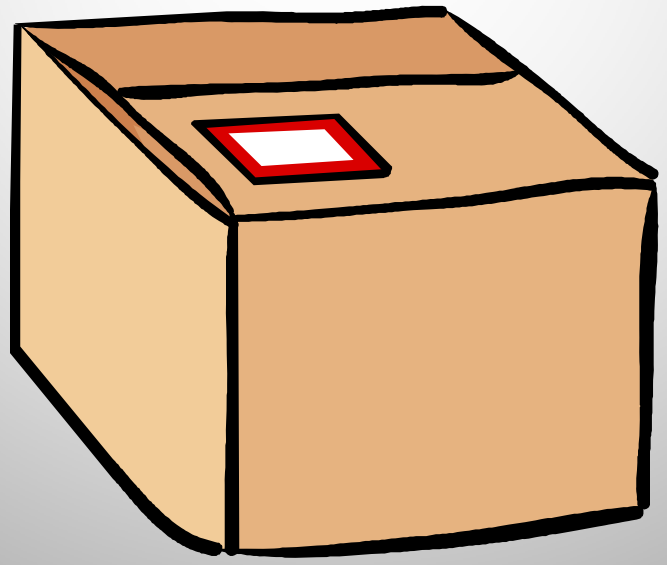
- Test Quantity: 10 Cell Phones (Prismatic Lithium Ion)
- Smoke vented from package during test.
- Package inner lining was covered in black soot.
- The exterior of the package showed signs of soot where gas escaped.
- All of the batteries vented and went into thermal runaway.
- The fire barrier lining was entirely intact.
- The interior of the box above the batteries reached 493 deg F.
- The top surface of the box reached a maximum temperature of 110 deg F.
- The structural integrity of the box remained intact.
- No Flames escaped from the container.
- No items were projected from the container.

Fiberboard Testing Overview

Example Closing Instructions

Damaged or Defective Lithium Ion Battery

Safety Battery Closure Instructions Rev 13 5 8.pdf



Why have a Performance Standard?

- Better question, why forbid lithium batteries in transport?

- Why forbid any lithium battery in transportation if an acceptable performance standard with a clearly defined test method will ensure an adequate level of safety and consistent oversight?

Why have a Performance Standard?

- Institution of an adequate performance standard ensures consistency in safety while reducing the approval burden on governing entities.

- If there are situations in which the performance standard is clearly unwarranted, relief from the standard may still be sought through the special approvals process.

Why have a Performance Standard?

- Even without a performance standard, the products will still be in transportation, but will be governed by Special Approvals with vast ranges of performance criteria (and arguably vacillating levels of safety).
- Additionally, a performance standard promotes competition and development of innovative and cost efficient solutions for the marketplace.

Q & A

Development of Packaging Standards for Lithium Ion and Lithium Metal by Air

October 31, 2013

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