Risks related to Lithium Batteries

Presented by
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Content

• Lithium batteries technology

• In service incidents/accidents

• Manage the Risk

• Conclusion
Lithium batteries – A growing market since 1990’s

**Advantages**
- Large energy density for weight
- Low maintenance
- High durability

**Limitations**
- Fragile
- Protection circuit needed to maintain safe operation

Figure 6: Forecast lithium demand by application. (Source TRU Group, 2009).
Risk: thermal runaway

- Electrolyte reacts with the carbon anode → exothermic reaction at 80°C
- Pressure to build up inside the cell at 110°C
- Polymer separator melts → short circuits between the electrodes at 135°C
- Breakdown of the metal oxide cathode material at 200°C

Source: http://www.mpoweruk.com/
## Causes of Thermal runaway

### Main contributing factors
- Poor design
- Poor integration
- Poor manufacturing quality
- Poor safety monitoring/protection
- Poor handling/storage/packing conditions

### External Abuse Conditions
- External Heating
- Over-Charging
- Over-Discharging
- High Current Charging
- Structural damage
- Crush
- External Short

### Causing or Energizing Internal Events or Exothermic Reactions
- Electrode-Electrolyte Reactions
- Lithium Plating
- Decompositions
- Internal Short Circuit
- Electrochemical Reaction

### If Heating-Rate exceeds Dissipation-Rate
- Leak
- Smoke
- Gas Venting
- Flames
- Explosion

[Source: NREL]
Types of Lithium batteries – single / multi cells

**Single cell**
- Low quantity of Lithium per battery
- Single (time limited) thermal runaway.
- Can ignite surrounding flammable material

**Multi cells**, usually rechargeable (secondary) batteries
- Higher quantity of Lithium per battery
- Several subsequent thermal runaways (propagation) of adjacent cells
- Can ignite surrounding flammable material
It could be your laptop ...
Types of Lithium batteries

**Lithium-metal batteries**
- Usually, **non rechargeable** batteries used in watches, calculators, cameras ...
- Cells contain lithium metal (highly reactive)
- Capable of self-ignition (thermal runaway)
- May worsen an independent controllable fire event
- Violent release of a flammable electrolyte mixed with molten lithium metal (large pressure pulse)

**Technology**
- **Halon 1301 or water** are **not effective** at extinguishing a lithium metal cell fire

**Associated Risk**
- Capable of self-ignition (thermal runaway)
- May worsen an independent controllable fire event
- Generation of heat and pressure, resulting (for Li-ion only) in a spray of flammable electrolyte

**Fire fighting**
- **Halon 1301** is **effective** in controlling the open flame and the spread of the fire to adjacent materials
- **Halon 1301** is **not effective**, but **Water** is **effective** at stopping the propagation of thermal runaway within the shipment

**Lithium-ion / Lithium-polymer batteries**
- Usually **rechargeable** batteries used in mobile phones, laptops, cars, cordless devices, ...
- Cells contain ionic lithium
- Capable of self-ignition (thermal runaway)

**Technology**
- *Halon 1301* is **effective** in controlling the open flame and the spread of the fire to adjacent materials
- *Halon 1301* is **not effective**, but *Water* is **effective** at stopping the propagation of thermal runaway within the shipment
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In service incidents/accidents

Lithium batteries suspected to be the cause of fires

- **Local fires**: Several cases, Personal Electronic Devices in cabin
- **Fire on Cargo pallets**
  - Los Angeles, California, April 28, 1999
  - Memphis, Tennessee, August 7, 2004
- **Hull loss**: Philadelphia, February 7, 2006
- **Fatal Accident**: Dubai, September 3, 2010

lithium batteries = hazardous materials
Content

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• In service incidents/accidents

• Manage the Risk
  ➤ Minimize occurrences
  ➤ Mitigate potential consequences

• Conclusion
Permanently installed batteries

Specific design requirements apply

ELT

CVR / DFDR

AED

Flashlights

A/C systems batteries
Aircraft systems – permanently installed lithium batteries

Are developed with specific Airbus standards:

- ✔ Compliance with specific FAA/EASA policies (certified)
- ✔ Prevention and Containment of thermal effect
  - High standard electronic protections against overheat, over current/voltage, short circuits
  - Specific choice of battery structural material and design
  - Independence of cells / cooling areas between cells
- ✔ Mitigation of pressure release effect
  - Venting areas within the battery
  - Specific venting outside the battery/aircraft when relevant
- ✔ High robustness to shocks (handling) and ageing
- ✔ Adequate integration in the Aircraft
Buyer Furnished Equipment (AED, Flashlights, portable ELT, megaphone, etc.)

- TSO-C142 & TSO-C179 apply
  - Adequate identification and marking
  - Compliance to industry standard for Safety for Lithium batteries
  - Adequate Design Assurance Level
  - Compliance to RTCA/DO-160E Environmental Conditions and Test procedures for Airborne equipment
  - Applicable operating, installation and maintenance requirements
In service experience

Although lithium batteries have been in use in Aircraft systems (such as ULB, ELT, etc) for more than 10 years without specific reported issues, however the FAA recorded 2 recent events on flashlights with limited consequences

<table>
<thead>
<tr>
<th>DATE/SOURCE</th>
<th>TYPE OF BATTERY</th>
<th>DEVICE (If applicable)</th>
<th>AIRCRAFT TYPE (Passenger or Cargo)</th>
<th>INCIDENT SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-AUG-2010 DOT5800.1 Form</td>
<td>CR 123A primary lithium battery in a device</td>
<td>Flashlight</td>
<td>Cargo</td>
<td>Initial report from Fed Ex indicated that the flashlight in a backpack belonging to a jumpseating crewing member caught on fire while at the gate in Memphis, TN. The report indicated that one of the flashlight batteries exhibited signs of thermal runaway causing the fire.</td>
</tr>
<tr>
<td>18-MAR-2008 United Airlines (UALA) Pilots’ internet forum</td>
<td>“CR123A” Lithium metal</td>
<td>Flashlight</td>
<td>Passenger</td>
<td>In Denver, a UALA employee had two flashlights that contained CR123A Lithium batteries. Flashlight used for inspection of aircraft started to dim. Flashlight was turned off and placed in storage compartment in cockpit of 757. A banging noise described like gunshots originated from the flashlight. Cap on the on/off switch blown off and became projectile. Employees hand and fingers burned when he touched the flashlight to move it to the rear of the cockpit. Mechanic responded and safely removed the flashlight.</td>
</tr>
</tbody>
</table>
Lithium batteries carried in the cabin

- Cameras
- Spare batteries
- Laptops
- Tablets, MP3
- Cordless devices
- Cell Phones

Berlin, 19-22 March 2012
How many lithium batteries are we carrying today?
Fire Fighting principles for fires caused by Lithium-ion batteries

**Specific CCOM procedure** based on FAA Safety Alerts for Operators (SAFO 09013)

- Relocate passenger away from the device, use halon, halon replacement or water fire extinguisher to prevent the spread of the fire to adjacent battery cells and materials.
- Pour water, or other non-alcoholic liquid, from any available source over the cells immediately after extinguishing the fire.

*Note:* Only water or other non-alcoholic liquid can provide sufficient cooling to prevent re-ignition and/or spreading of the fire to adjacent batteries. Significant cooling is needed to prevent the spread of fire to additional cells in a battery pack.

**WARNING**

- Do not attempt to pick up and move a smoking or burning device.
- Do not cover the device or use ice to cool down the device. Ice or other materials insulate the device increasing the likelihood that additional battery cells will ignite.
- Do not use fire resistant burn bags to isolate burning lithium type batteries. Transferring a burning appliance into a burn bag may be extremely hazardous.

- Halon to extinguish the flame
- Water to cool down the battery and prevent adjacent cell thermal runaway
In service experience with batteries carried in the Cabin

• Two events (2007&2010) reported to Airbus
Guidance material for carry-on baggage

Operator approval required
Lithium batteries *carried* in the hold

- Cameras
- Spare batteries
- Laptops
- Tablets, MP3
- Cordless devices
- Cell Phones
- Cordless devices
- Tablets, MP3
- Laptops
- Cameras
- Spare batteries
- Cell Phones
Lithium batteries fire in cargo zone

- Cargo areas not accessible for direct fire fighting
- Halon efficient to suppress the flame (Lithium-ion rechargeable batteries) and prevent the spread of fire to other ordinary combustibles but
- Halon
  - Insufficient to stop the thermal runaway and prevent propagation to adjacent cells
  - Ineffective in controlling a lithium metal cell fire

“There are currently no approved and tested containers that can sufficiently contain the known effects of accidental lithium metal battery ignition. Common metal shipping containers, pails and drums, are not designed to withstand a lithium metal cell fire“

FAA SAFO 09/10
Minimize occurrences: Applicable instructions for transport/shipping

Primary lithium batteries forbidden for transport aboard passenger aircraft.

Caution!
Lithium battery
do not load or transport package if damaged.

Warning: Lithium batteries that have been recalled by the manufacturer for safety reasons must not be shipped by air.
FAA & PHMSA recommended actions

“It is recommended that all air carriers institute additional procedures for safely transporting lithium batteries by aircraft

1. Request customers to **identify** bulk shipments of currently excepted lithium batteries by information on airway bills and other documents provided by shippers offering shipments of lithium batteries.

2. Where feasible and appropriate, stow bulk shipments of lithium batteries in **Class C cargo** compartments or in locations where alternative fire suppression is available.

3. Evaluate the **training, stowage, and communication protocols** in your operation with respect to the transportation of lithium batteries in the event of an unrelated fire.

4. Pay special attention to ensuring **careful handling** and compliance with existing regulations covering the air transportation of Class 9 hazardous materials, including lithium batteries “
“Shipping lithium-ion cells in an approved over-pack minimizes the hazard significantly” (FAA)

<table>
<thead>
<tr>
<th>COMBINATION PACKAGINGS</th>
<th>Quantity per package – Passenger Aircrafts</th>
<th>Quantity per package – Cargo Aircraft Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully Regulated Class 9 Lithium Ion Cells and Batteries</td>
<td>5 kg</td>
<td>35 kg</td>
</tr>
<tr>
<td>Excepted Lithium Ion Cells and Batteries</td>
<td>10 kg</td>
<td>10 kg</td>
</tr>
<tr>
<td>Fully Regulated Class 9 Lithium Metal and Lithium Alloy Cells and Batteries</td>
<td>2.5 kg (UN 3090*) 5kg (UN 3091*)</td>
<td>35 kg</td>
</tr>
<tr>
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</tr>
</tbody>
</table>

**PHMSA- Pipeline and Hazardous Materials Safety Administration & FAA (US specific rule):**
Primary (non-rechargeable) lithium metal batteries and cells (UN 3090) are forbidden for transportation aboard passenger-carrying aircraft.

*UN 3090 : Batteries without equipment / UN 3091 : Batteries packed within or with equipment
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Conclusion

The risks associated to Lithium Batteries require the attention of the entire Industrie

**Lithium batteries manufacturers & integrators:**
- Manufacturing quality
- Batteries integration / installation
- Passive and active protection devices
- User manual (risk awareness)
- Storage
- Fire fighting recommendations
- Packaging / marking

**Aircraft manufacturers**
- Fire protection capabilities
- Fire fighting procedures

**Airlines and crews**
- Risk awareness
- Training – Fire fighting

**Passengers**
- Risk awareness
- Packaging

**Air carriers**
- Handling precautions
- Stowage and storage
- Risk awareness and training

**Certification & rulemaking bodies**

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Questions ?