

18th Flight safety conference

Berlin, 19-22 March 2012



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

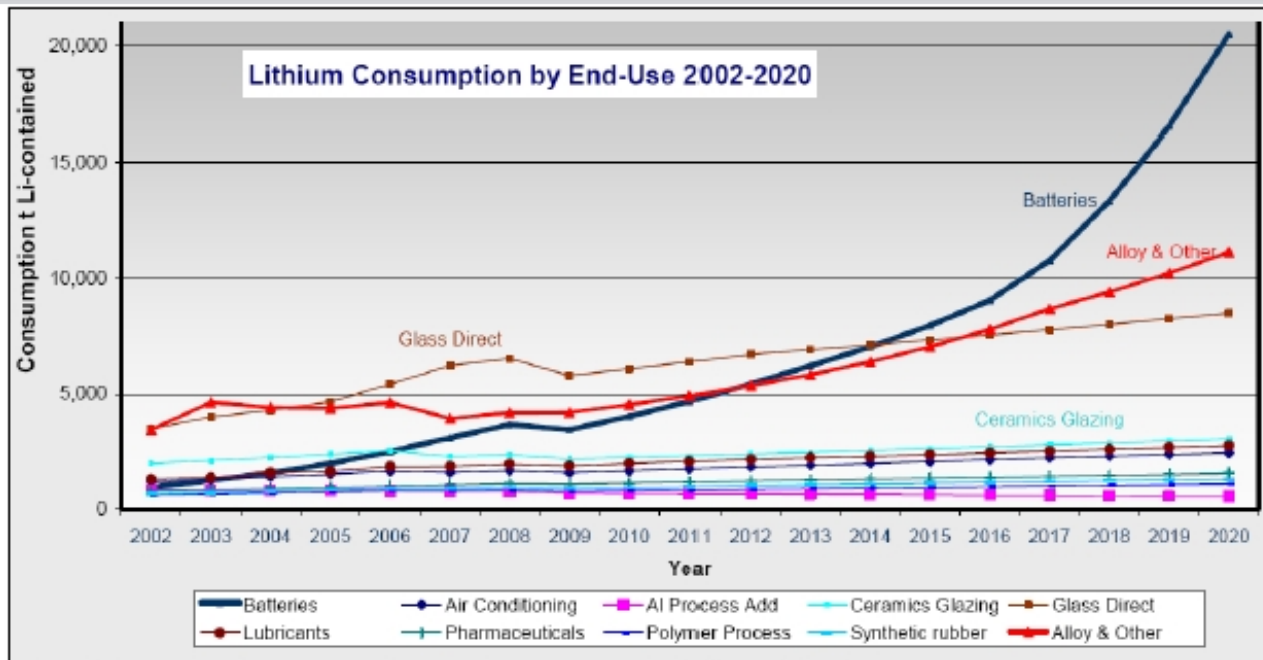


Figure 6: Forecast lithium demand by application. (Source TRU Group, 2009).

Advantages



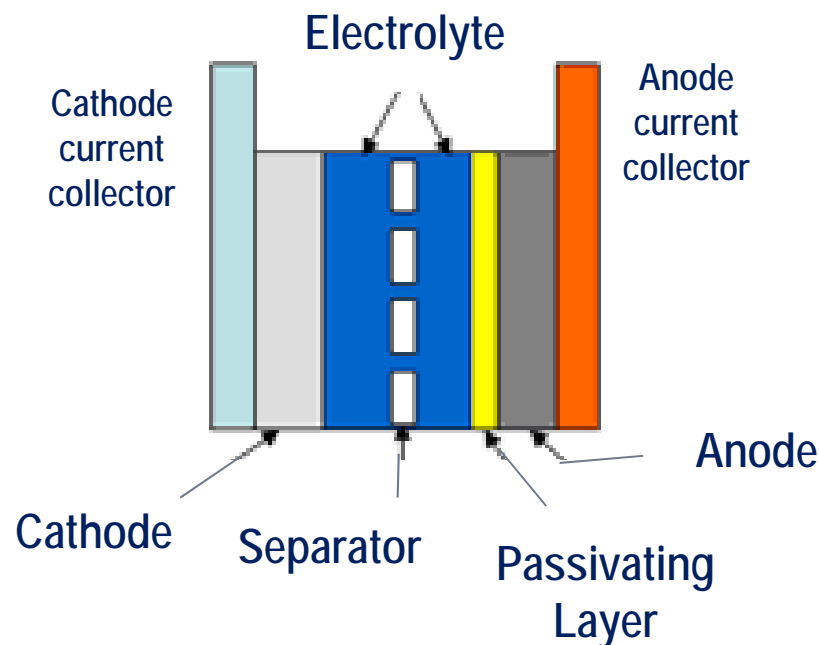
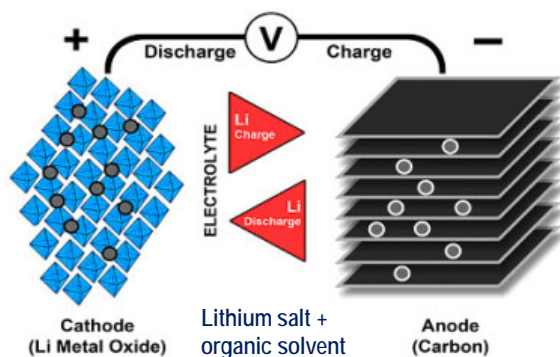
- Large energy density for weight
- Low maintenance
- High durability

Limitations



- Fragile
- Protection circuit needed to maintain safe operation

Risk : thermal runaway



80°C electrolyte reacts with the carbon anode → exothermal reaction 110°C pressure to build up inside the cell 135°C 200°C

breakdown of the thin passivating layer

breakdown in the electrolyte releasing flammable hydrocarbon gases

polymer separator melts → short circuits between the electrodes

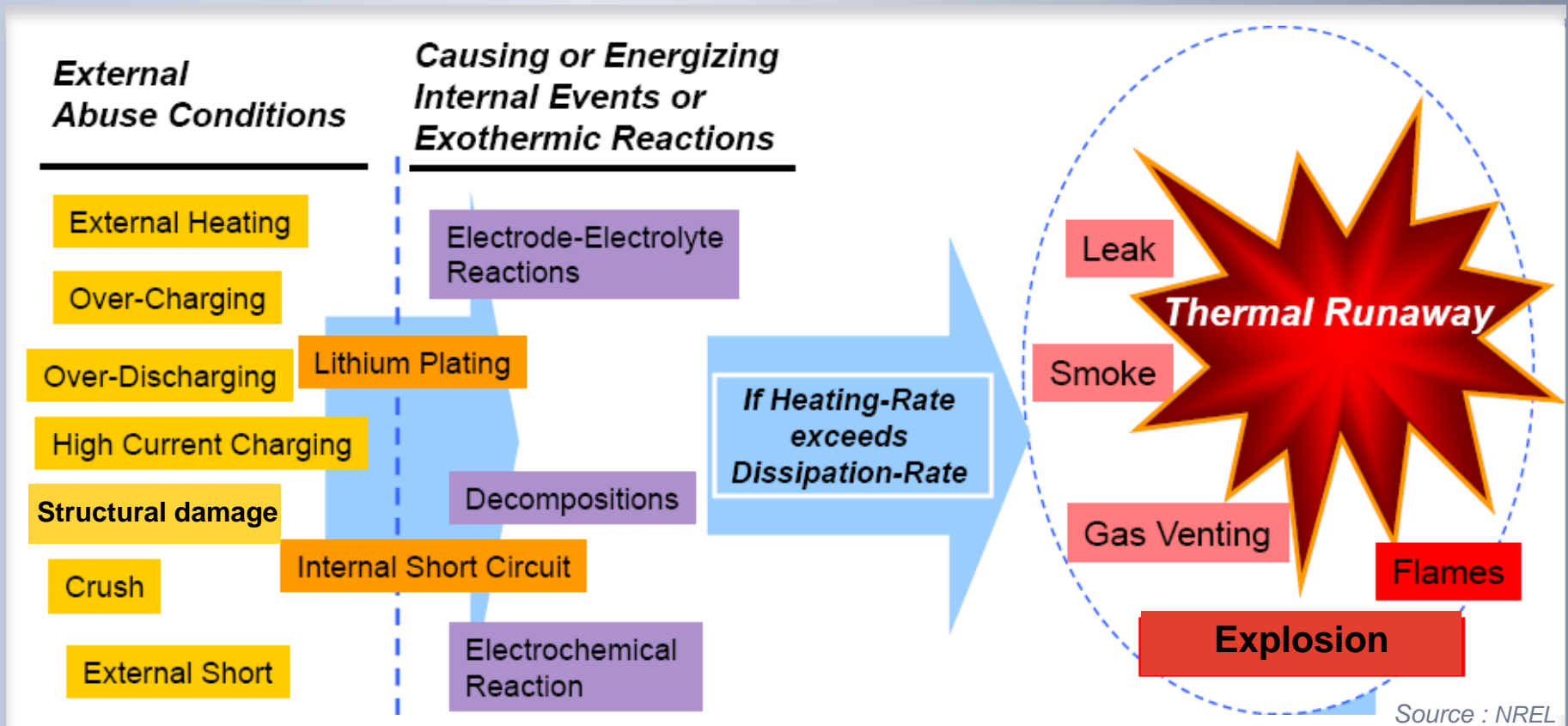
Breakdown of the metal oxide cathode material



Highly exothermic

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

Types of Lithium batteries – single / multi cells

Single cell



Multi cells, usually rechargeable (secondary) batteries



- Low quantity of Lithium per battery

- Higher quantity of Lithium per battery

Associated Risk

- Single (time limited) thermal runaway.
- Can ignite surrounding flammable material

- Several subsequent thermal runaways (propagation) of adjacent cells
- Can ignite surrounding flammable material

It could be your laptop ...



ACTUAL LAPTOP FIRE AT LAX

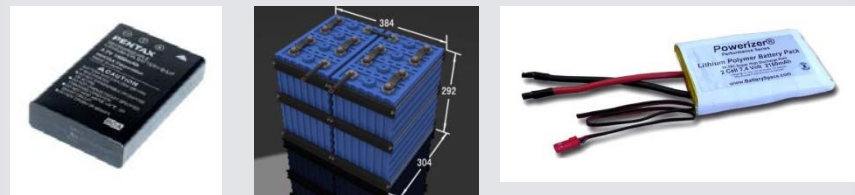
Source : FAA

Types of Lithium batteries

Lithium-metal batteries



Lithium-ion / Lithium-polymer batteries



Technology

- Usually, **non rechargeable** batteries used in watches, calculators, cameras ...
- Cells contains lithium metal (highly reactive)

- Usually **rechargeable** batteries used in mobile phones, laptops, cars, cordless devices, ...
- Cells contains ionic lithium

Associated Risk

- 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)

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

- **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

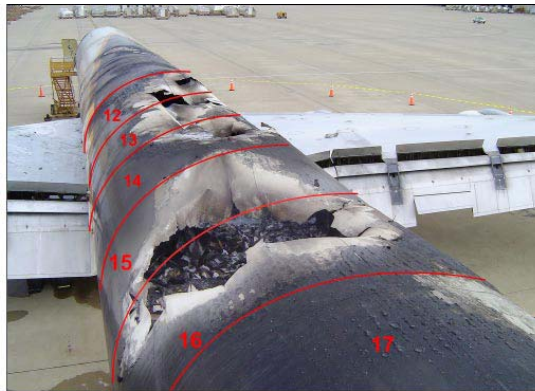
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In service incidents/accidents

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



Source : NTSB Official investigation report Philadelphia



lithium batteries = hazardous materials

Content

- Lithium batteries technology
- In service incidents/accidents
- Manage the Risk
 - Minimize occurrences
 - Mitigate potential consequences
- Conclusion

Permanently installed batteries

Specific design requirements apply

ELT



AED



Flashlights



CVR / DFDR

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

| DATE/ SOURCE | TYPE OF BATTERY | DEVICE (if applicable) | AIRCRAFT TYPE (Passenger or Cargo) | INCIDENT SUMMARY |
|--|--|-----------------------------------|---|---|
| 28-AUG- 2010 DOT5800.1 Form | CR 123A primary lithium battery in a device | Flashlight | Cargo | 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. |
| 18-MAR-2008 United Airlines (UALA) Pilots' internet forum | "CR123A" Lithium metal | Flashlight | Passenger | 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. |

Lithium batteries **carried** in the cabin



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.



Source : FAA

- 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

 **Australian Government**
Civil Aviation Safety Authority

IS YOURS SAFE TO CARRY?

If in doubt, **ASK!**

The abundant stored energy that makes lithium batteries practical also makes them dangerous when **not** carried properly. There are limits to the lithium batteries you can carry on board an aircraft.



Which lithium batteries can I carry and how many can I take?

| BATTERY TYPE | BATTERIES | CARRY-ON BAGGAGE | CHECKED BAGGAGE | NUMBER OF SPARES |
|---|--|------------------|---|--|
| Rechargeable—up to 100Wh • cameras • mobile phones/iPods • laptops/iPads | In equipment | ✓ | Yes, but recommended in your carry-on baggage | No limit • original packaging or • terminals taped |
| | Spares | ✓ | ✗ | |
| Rechargeable—101–160Wh • commercial cameras and video equipment Approval required—contact airline | In equipment | ✓ | Yes, but recommended in your carry-on baggage | Limit of TWO only • original packaging or • terminals taped |
| | Spares | ✓ | ✗ | |
| Non-rechargeable (less than 2 grams of lithium) • AA size or smaller | In equipment | ✓ | Yes, but recommended in your carry-on baggage | No limit • original packaging or • terminals taped |
| | Spares | ✓ | ✗ | |
| Non-rechargeable (more than 2 grams of lithium) • 'C' size battery and above | Must be carried only as cargo/freight in accordance with dangerous goods regulations. | | | |
| Rechargeable (above 160Wh) | | | | |

Watt hours (Wh) = Amps (Ah) x Voltage (v)

Operator approval required

Lithium batteries **carried** in the hold



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



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 “

IATA Technical Instruction for the Safe Transport of Dangerous Goods by Air – Freighter Aircraft

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



“Shipping lithium-ion cells in an approved over-pack minimizes the hazard significantly” (FAA)

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



Air carriers

- Handling precautions
- Stowage and storage
- Risk awareness and training

Airlines and crews

- Risk awareness
- Training – Fire fighting

Passengers

- Risk awareness
- Packaging

Certification & rulemaking bodies





Questions ?

