The Insurance Institute of London
Chartered Insurance Institute

The Insurance Institute of London

CII CPD accredited - demonstrates the quality of an event and that it meets CII/PFS member CPD scheme requirements.

This lecture and podcast count as 45 minutes of CPD and can be included as part of your CPD requirement should you consider it relevant to your professional development needs. It is recommended that you keep any evidence of the CPD activity you have completed and upload copies to the recording tool as the CII may ask to see this if your record is selected for review.

Battery Hazards: Which Technology Provides the Safest Solution?

Dr Geoffrey May

FOCUS Consulting

The Insurance Institute of London

Chartered Insurance Institute

2 May 2018

FOCUS

Lithium battery fires

- B787 battery fires
- Electric vehicle fires
- Laptop fires and product recalls
- Mobile phone fires and recalls

FOCUS

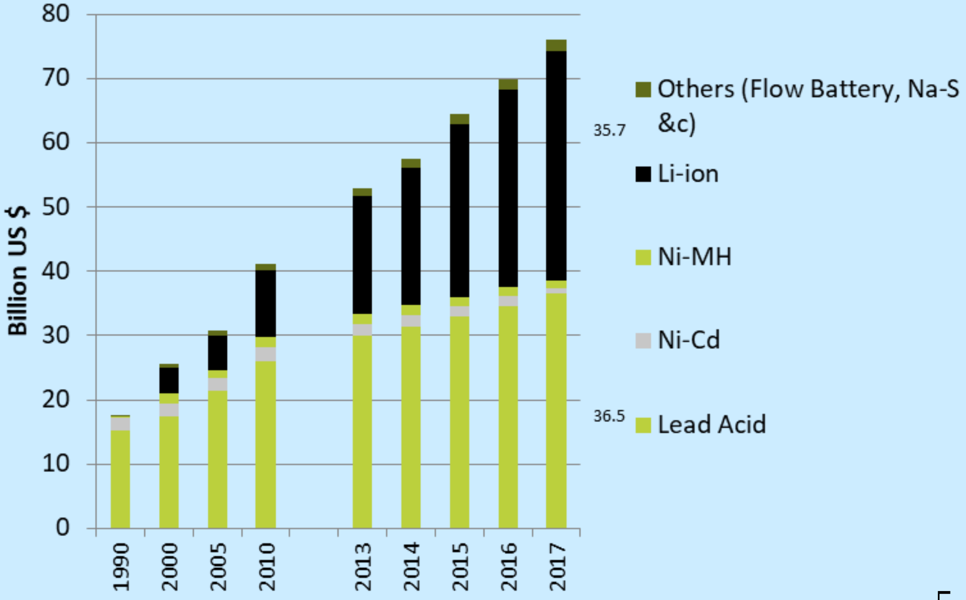
Battery hazards

- Batteries are self-contained energy sources – if they are short circuited, punctured, crushed, physically damaged or electrically abused, they may go into thermal runaway, catch fire and explode
- Batteries may go into thermal runaway as a result of internal defects or ageing in service
- Batteries exposed to heat or a fire may go into thermal runaway, initiating or fuelling a fire
- The level of hazard increases with the energy density – more energy stored in a smaller package, more energy released
- Batteries may also contain hazardous or toxic materials that may be released in an accident or a fire

FOCUS

Battery types and markets

- Primary batteries (non-rechargeable) - $17BN in 2017
- Secondary batteries (rechargeable) - $69BN in 2017
- Annual growth forecast at 7% for the next 5 years
- Drivers are consumer portable, electric vehicles, energy storage
- Highest growth will be for Li-ion batteries
- Lead-acid, $37BN
- Li-ion, $36BN



FOCUS

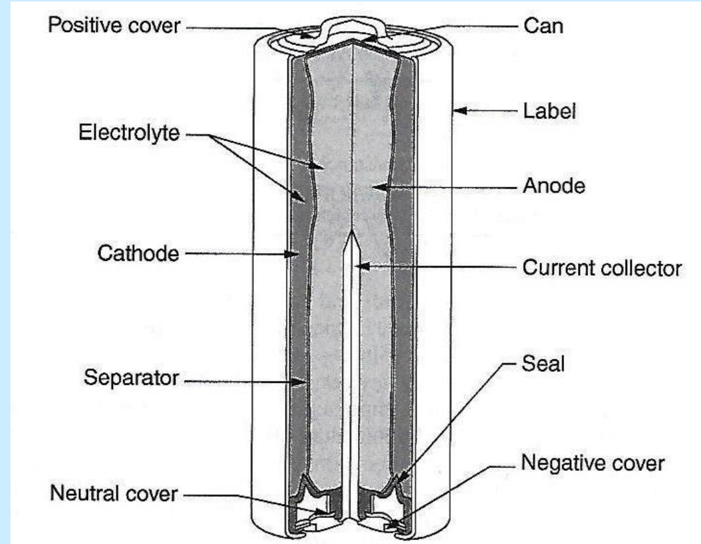
Battery types

Primary

- Alkaline-manganese, zinc-carbon
- Silver oxide-zinc
- Zinc-air
- Lithium

Secondary

- Lead-acid
- Nickel-cadmium
- Nickel-metal hydride
- Li-ion



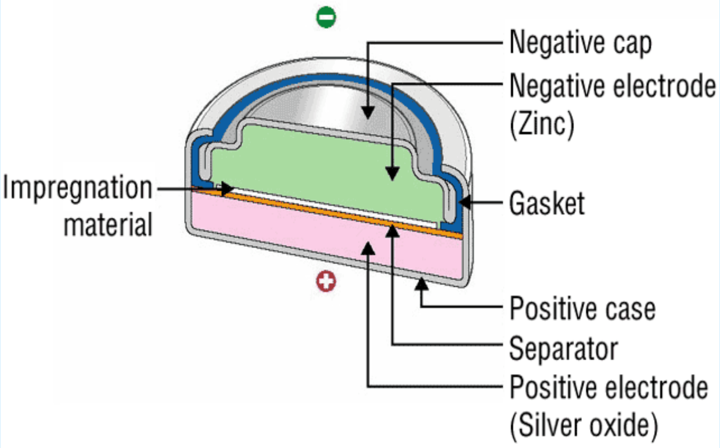
Alkaline-manganese

- Consumer primary cells, AAA, AA, C, D
- Zinc anode, aqueous alkaline electrolyte, manganese dioxide cathode
- Safe, cheap, reliable, good shelf life
- Capable of discharge at higher rates
- Also zinc-carbon and zinc chloride types

FOCUS

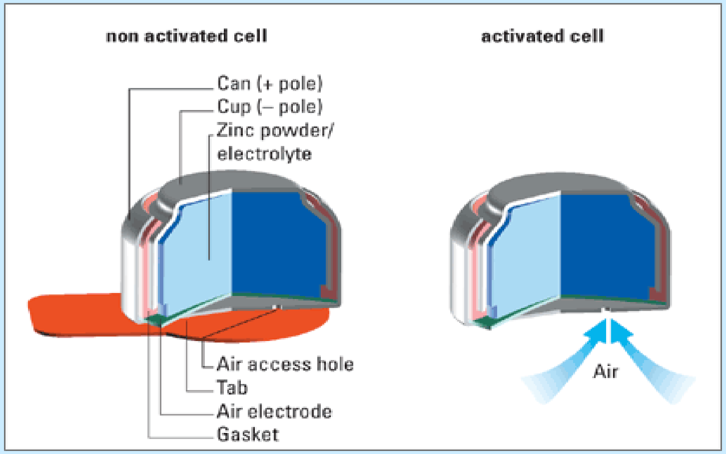
Silver oxide-zinc

- Watch batteries
- Zinc anode
- Aqueous alkaline electrolyte
- Silver oxide cathode
- Safe, reliable



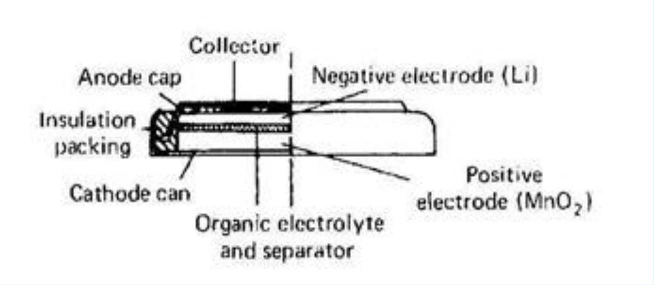
Zinc-air

- Hearing aid batteries
- Zinc anode
- Aqueous alkaline electrolyte
- Air cathode
- Activated by pulling tab off
- Safe, reliable



FOCUS

Lithium



Lithium-Manganese Dioxide – Car keys, remote controls, memory back-up

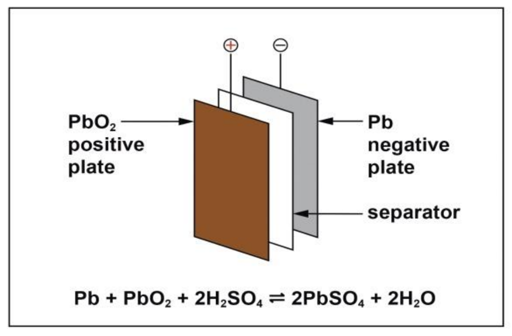
Lithium-Sulphur Dioxide – defibrillators, professional uses

Lithium-Thionyl Chloride – gas and water meters, toll tags

- Lithium metal anode, manganese dioxide cathode
- Liquid organic electrolyte, propylene carbonate and dimethoxyethane with lithium salts in solution for manganese dioxide cells
- High energy density, reactive active materials, flammable electrolyte
- Used as button cells and in larger cylindrical formats
- Sulphur dioxide and thionyl chloride less flammable but toxic

FOCUS

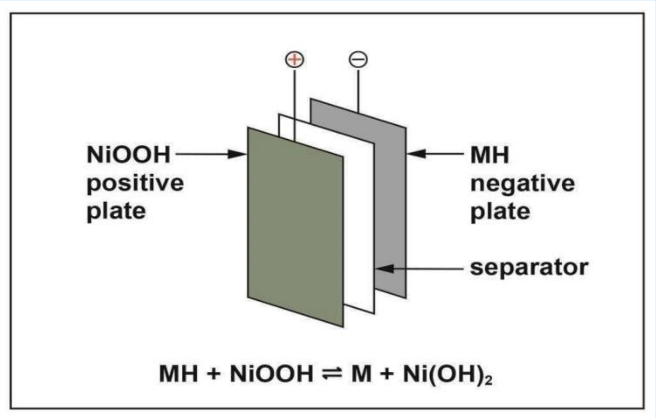
Lead-acid



- Most widely used battery – automotive, motive power, standby power and energy storage
- Simple chemistry – lead oxide cathode, lead anode, aqueous sulphuric acid electrolyte
- Reliable and safe in most applications
- Risks of fire from short circuits and thermal runaway
- Risks of hydrogen explosions in uncontrolled charging
- Risks of acid spillage from mechanical damage or fire

FOCUS

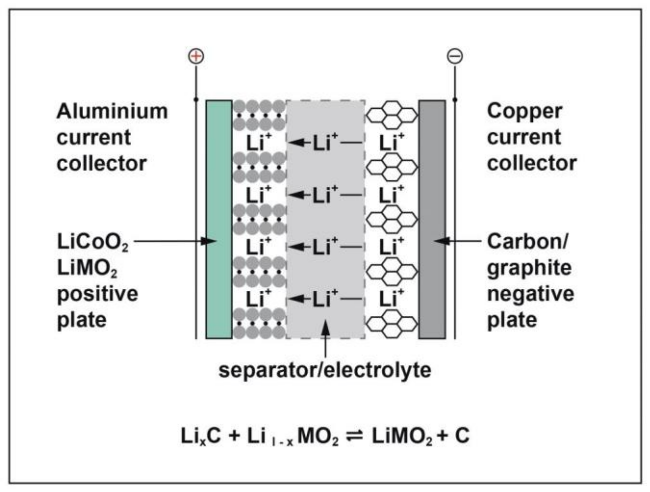
Nickel-Cadmium (Ni-Cd), Nickel-Metal Hydride (Ni-MH)

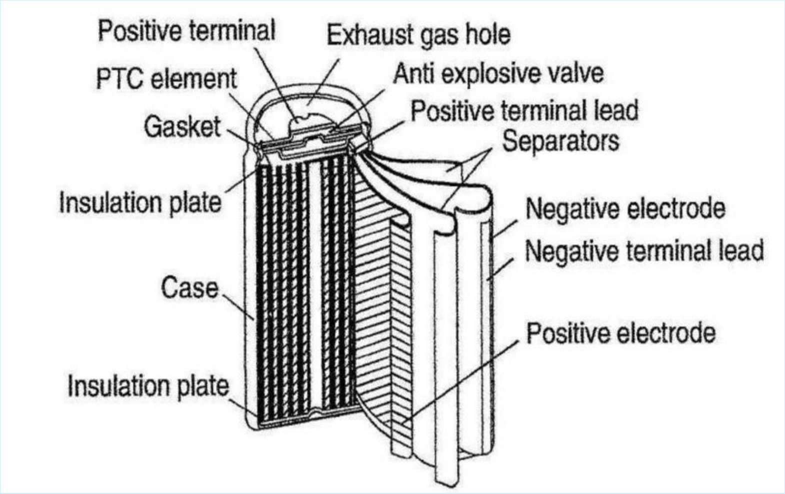


- Ni-Cd, cadmium anode, nickel hydroxide cathode, aqueous alkaline electrolyte
- Ni-MH, metal hydride store for hydrogen instead of cadmium as anode
- Ni-Cd and Ni-MH used for consumer portable applications
- Ni-Cd use is restricted by environmental regulations for consumer equipment but is used for industrial applications
- Ni-MH used for HEVs by Toyota and Honda
- Generally safe and reliable

FOCUS

Lithium-ion (Li-ion)





- Lithium cobaltite cathode ($LiCoO_2$), carbon/graphite anode
- Liquid organic electrolyte, ethylene carbonate and diethyl carbonate with lithium salts in solution
- When charged Li from the cathode is intercalated into layers in the graphite anode, on discharge it moves back to the cathode
- Anode is coated onto copper foil, cathode onto aluminium foil and the electrodes are wound together with a porous polymer separator

FOCUS

Li-ion battery applications

- Consumer portable, mobile phones, laptops, tablets, cameras



- Electric vehicles, HEVs, PHEVs, EVs


- Industrial applications, standby power, motive power, energy storage

FOCUS

Li-ion battery safety

- Cells may go into thermal runaway, catch fire or explode under conditions of abuse
- Active materials are very reactive, electrolyte is flammable
- Safety tests to IEC/UL standards for short circuit, overcharge, forced discharge, crushing, impact, shock, heating and altitude
- Cells must not ignite or explode – for some tests no venting or leakage
- Cells must not eject parts under certain conditions when incinerated
- Cells may occasionally go into thermal runaway because of internal defects
- Cells are designed to reduce risks with safety vents, shut-down separators and external protection against overcharge and over-discharge
- Batteries have additional protection and may have thermal barriers to reduce propagation from cell to cell

FOCUS

Technical standards and codes

- International Electrotechnical Commission (IEC)
- Underwriters Laboratories (UL)
- Building Codes/Guidance Notes
- NFPA/PIRG/BRE
- Material Safety Data Sheets (MSDS)
- Transportation Safety
- UN Classification
- ADR
- IMDG Codes
- IATA Regulations

FOCUS

Key issues for battery safety

- Lithium batteries with organic electrolytes and high energy density pose a much higher risk than chemistries with aqueous acidic or alkaline electrolytes
- Aqueous electrolytes are not flammable and will limit temperature rise
- Batteries should always be installed and used to suppliers guidelines
- Standards need to be respected
- Electrical (fuses, breakers) and electronic protection must be used
- Connector integrity is essential
- Maintenance inspections must be carried out regularly
- Large batteries should be installed in dedicated battery rooms with fire detection and barriers to prevent fire propagation
- Spill kits should be available for wet batteries

Case Study 1: Lead-acid battery fire at a telecoms switching centre

FOCUS

Case study 1

- Telecoms switching centre in mobile back-haul network
- 6 UPS batteries, 33 12 V, 150 Ah monoblocs, 396 V nominal
- VRLA AGM front access batteries supplied from China
- Mounted on open steel shelves in dedicated battery room with fire detection and suppression systems and CCTV
- Feeds two UPS systems each rated at 200 kVA
- Batteries operate at 2020 W per bloc, peak current 210 A
- New battery installed, checked visually by installation contractor with local management
- Fire occurred when public supply lost, fire alarm sounded, diesel genset started, fire suppression system operated
- Batteries damaged but smoke penetrated the building with the switching equipment rendering the whole centre inoperative
- Claim was for loss of service revenue as well as repairs

FOCUS

Case study 1

Cause

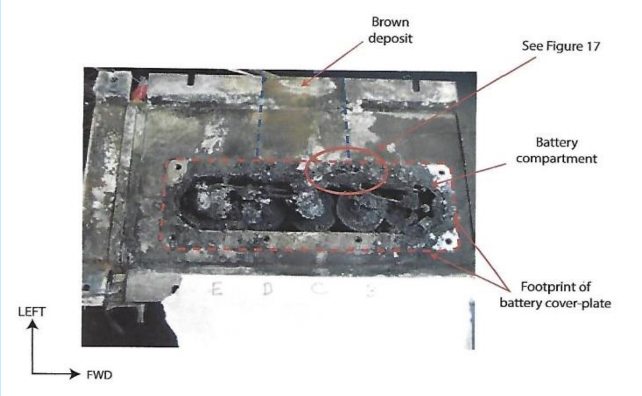
- Battery defects – none found on units recovered from site
- UPS operated correctly, battery fuses operated correctly
- Likely cause is high resistance inter-cell connection

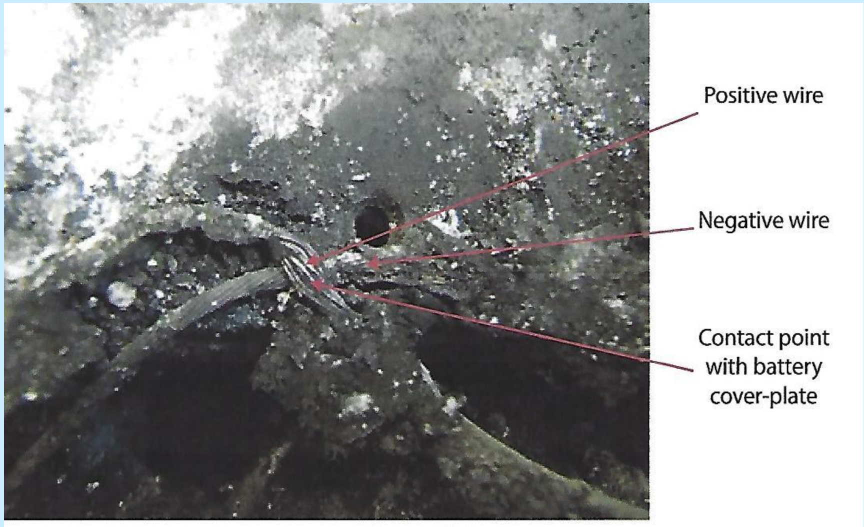
Lessons learned

- In a lead-acid battery fire, only the plastic cases (ABS) burn with large quantities of black sooty smoke – the battery room should not have ducting or routes for smoke to enter other buildings
- Connectors should be checked for the torque setting routinely and with an infra-red camera when on load for hot spots
- All monobloc voltages should be recorded on installation, on a load test and at annual inspections.

FOCUS

Case study 2: Fire on B787 Dreamliner at Heathrow





FOCUS

Case study 2

- Emergency locator transmitter (ELT) installed on B787
- Internal decelerometer activates ELT to transmit location of aircraft
- Powered independently by a primary lithium battery, 15 V, 5 cell lithium-manganese dioxide 11 Ah battery – single use apart from test
- Fire occurred when the aircraft was parked on a remote stand
- Control tower staff noticed smoke coming from the aircraft
- Fire extinguished by fire service
- Damage to composite fuselage and to aircraft interior
- Fully investigated and reported by AAIB

FOCUS

Case study 2

Cause

- Primary cause was battery wires trapped under cover plate – chafed through and short circuited after months in operation
- But the battery cells should discharge harmlessly if short circuited and the battery was protected with a thermal fuse (PTC)
- Compromised battery cover plate allowed moisture to enter ELT and may have caused one cell in the string to discharge faster than the others.
- Discharge of the battery caused one cell to be reverse charge, go into thermal runaway, vent and ignite. Flames and combustion products escaped through the compromised cover plate to ignite fuselage and other components

Case study 2

Lessons learned

- Inadequate attention to battery design and installation
- Battery cables shortened and relocated to prevent re-occurrence
- PTC was not correctly specified
- Recommendations on evaluation of the behaviour of composite aircraft structures in a fire, release of toxic materials, information provided to fire fighters on the location of lithium batteries in aircraft, FMEA methodology and certification procedures – also inspection of all in-service ELTs of the same type

FOCUS

Case study 3: Laptop fire in a house in the UK

FOCUS

Case study 3

- Laptop fire lead to serious house fire
- Computer on charge on the bed appears to be source of fire
- Examination of the computer shows cells have gone into thermal runaway, vented violently, exploded and ignited leading to fire
- Cells have ejected the caps and the electrolyte
- Burn pattern consistent with burning electrolyte
- Copper melted locally – temperatures over 1000 C
- Clear evidence of thermal runaway and that the laptop was located at the origin of the fire

FOCUS

Case study 3

Possible causes

- Intrinsic defect leading to short circuit in one cell
- Overheating because the air vents were blocked
- Laptop batteries are well protected electronically – high voltage, low voltage, high temperature, high current, reverse charging

Lessons learned

- Never block air vents
- Always use original equipment for replacement batteries and chargers

FOCUS

Conclusions

- Batteries are self-contained power sources and if abused will cause fires and explosions as a result of thermal runaway
- Occasionally latent defects can also cause thermal runaway
- Lithium batteries have a higher energy density and contain flammable electrolytes which increases the level of risk
- Lead-acid, Ni-Cd and Ni-MH batteries have lower energy densities and aqueous electrolytes which make them much safer
- Li-ion batteries are being deployed in much greater numbers for consumer applications, electric vehicles and for energy storage with the market forecast to double to $72BN by 2025
- Care is needed to ensure safe operation by respecting standards, codes of practice and by regular maintenance and inspection
- New standards and codes need to keep pace with technical changes in battery technology

Questions………..

Dr Geoffrey May

FOCUS Consulting

E-mail: g.j.may@btinternet.com

Tel: +44 1509 890547

Web: www.focusbatteryconsulting.com

The Insurance Institute of London
Chartered Insurance Institute

Feedback

Please take a moment to complete this Feedback Form. Your comments will enable us to ensure that future CPD activities satisfy the needs our members.

To access the survey, scan this Quick Response code with your QR reader app on your mobile phone