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Lithium - Ion Battery Safety

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Lithium-Ion Battery Safety Guidance (Code of Practice)

Document Information

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Lithium Batteries – Guidance on safe storage, use and disposal including e-bikes, e-scooters and e-cigarettes (vapes)

Introduction

The use of lithium batteries is becoming more common not just in research but in everyday life with the introduction of electric vehicles etc. However, if lithium batteries are not stored, used, charged, or disposed of correctly there can be serious consequences.

Fires involving lithium batteries are one of the fastest growing fire risks in general. In 2023, London Fire and Rescue Service reported a 78% rise in numbers of e-bike fires compared to 2022 (183 fires in total). Overall, statistics suggest there were 338 lithium-ion e-bike and e-scooter battery fires in the UK in 2023. Almost 40% of e-bike fires in 2023 were found to have been caused by conversion kits. In addition, lithium batteries put in household rubbish bins cause about 700 fires every year in bin lorries and waste-processing centres. From 1st June 2023, e-scooters, e-unicycles, and e-skateboards are not allowed to be taken onto UK trains.

One of the main issues with lithium battery fires is that they are very difficult to extinguish and are known to reignite even when thought to have been put out, presenting difficulties to firefighters. This document provides guidance on the safe storage, use and disposal of lithium batteries at the University of Bath. It also includes some information from external sources regarding e-bikes, e-scooters and e-cigarettes that could be applied to use outside of the University.

Lithium Batteries

There are many types of lithium batteries in different sizes, shapes, designs, materials and chemical composition. We are all very familiar with the small button cells found in watches etc., AA/AAA batteries in small appliances and the rechargeable type in a mobile phone or laptop.

There are two basic categories of lithium battery:

- Lithium metal: non-rechargeable battery which contains lithium metal (as the anode). These are known as a primary (or disposable) battery, or cell, as they are designed to be used once and discarded. They include the zinc-carbon, zinc chloride, and alkaline battery. These batteries are most commonly used in portable devices with low current drains, such as remote controls, cameras, toys and torches.
- Lithium-ion (Li-ion): rechargeable batteries containing salts of lithium. These are secondary batteries or cells as they can be charged, discharged into a load, and recharged many times. Rechargeable Li-ion batteries are used in mobile phones and laptops, and larger versions power electric vehicles (EV) including e-scooters and cars.

Types of Lithium-Ion Batteries

There are several types in popular use, with differing technologies. Each type or chemical composition has different properties and therefore may present different levels of risk.

Lithium-ion polymer (LiPO)

This type of battery uses a polymer electrolyte instead of a liquid one as in a conventional lithium-ion battery. The polymer is in the form of a high conductivity semisolid or gel. Therefore, batteries can be produced of any shape, presenting advantages for certain applications where shape and

weight matter such as in drones, radio-controlled hobby aircraft, as well as mobile devices and thin laptops.

Lithium Iron Phosphate (LFP)

LFP batteries have a long-life cycle with good thermal stability and electrochemical performance. LFP batteries are one of the safest lithium-ion battery options, even when fully charged. Low temperatures can affect performance. It is often used to replace the lead acid starter battery.

Lithium Cobalt Oxide (LCO)

LCO batteries are the most common and are used in small portable electronics such as mobile phones, tablets, laptops, and cameras. However, they are losing popularity to other types of lithium batteries due to the high cost of cobalt, relatively short lifespan and concerns around low thermal stability.

Lithium Manganese Oxide (LMO)

LMO batteries are commonly found in portable power tools, medical instruments, and some hybrid and electric vehicles. LMO batteries charge quickly and offer high specific power and flexibility. They also offer better thermal stability than LCO batteries, meaning they can operate safely at higher temperatures. The main downside to LMO batteries is their short lifespan.

Lithium nickel manganese cobalt oxide (NMC)

Similar to LMO batteries, NMC batteries are popular in power tools as well as electronic powertrains for e-bike, scooters, and some electric vehicles. The benefits of NMC batteries include high energy density and a longer lifecycle at a lower cost than cobalt-based batteries. They also have higher thermal stability than LCO batteries, making them safer overall although they have a slightly lower voltage than cobalt-based batteries.

Lithium nickel cobalt aluminium oxide (NCA)

These types of batteries have high energy and a relatively long life and so are mainly used in electric vehicles (such as TESLA). However, they aren't as safe as most other lithium batteries due to lower thermal stability and are expensive in comparison due to rare materials used.

Lithium titanate (LTO)

This type of battery is different to those described above in that they are an LMO or NMC battery with the graphite in the anode replaced with lithium titanate. This is an extremely safe battery with a long lifespan that charges faster than any other lithium battery type. These batteries though are very expensive and have a low energy density, which means they store a lower amount of energy relative to weight. Many applications use LTO batteries including electric vehicles and charging stations, uninterrupted power supplies, wind and solar energy storage, solar street lights, telecommunications systems, and aerospace and military equipment.

With a number of different types, it is important to choose the right type of battery for intended use, taking into account their differing properties.

Hazards

Batteries that are purchased from reputable sources and used in accordance with manufacturer's instructions, e.g. under normal working conditions, are inherently stable by design. Many have in-built battery management systems which prevent overcharging and actively manage fire risk. However, if batteries are subjected to some form of abnormal abuse or damage, such as an impact, fall from a height, extreme environment changes (such as high temperature or overcharging), then

these devices may be rendered unstable resulting in serious consequences such as fire and explosion.

The table below summarises the hazards posed by Lithium-ion batteries and the potential consequences if these are realised:

Hazard	**Consequences**
Overcharging	Venting, fire, explosion
Forced discharge	Venting, overheating
Short Circuit	Overheating, venting, fire, thermal runaway
Incineration/overheating	Venting, explosion (if heating/environmental temperature is excessive).
Physical damage	Release of potentially hazardous materials & spontaneous ignition. Short circuits (see above)
Leaving for a long term uncharged or unmanaged	Venting
Charging non rechargeable batteries	Venting, fire, explosion

Many of the hazards noted in the table above can be attributed to poor manufacturing standards where batteries have material defects or are poorly constructed or the cells are contaminated during the manufacturing process.

Venting in this context means the release of hazardous gases from the battery. Gases can include hydrogen fluoride (HF), phosphorus pentafluoride (PF5) and phosphoryl fluoride (POF3), each of which are very hazardous if breathed in. Some batteries have pressure release devices to allow 'safe' venting in case of over-heating or decomposition. Those that do not have pressure release devices may explode if they become over-pressurised. This venting effect in a sealed cell may be seen as bulging or swelling of the battery casing. In these circumstances the battery **MUST NOT** be reused or recharged. The battery has passed the end of its useful life and should be safely disposed of.

Thermal runaway is an uncontrollable exothermic chain reaction where there is a sharp increase in the internal battery temperature causing the inner structures of the battery to destabilize and degrade, which can lead to the total failure of the battery resulting in fire, explosion and venting of hazardous gas. The heat then spreads to nearby cells, causing them also to enter an uncontrollable and irreversible state of thermal runaway. This produces a fire that repeatedly flares up as each cell in turn ruptures and releases its contents.

See below for some further information and video:

Thermal runaway | Electrical Safety First

Precautions / Control Measures

The following summarises the precautions to be taken for safe storage, use including charging and disposal of lithium batteries.

Safe Storage

Non rechargeable batteries used in portable appliances that are stable by design should be stored at room temperature and protected from damage including high temperatures and liquid spills.

Rechargeable types:

- Should be separated from other materials particularly hazardous materials.
- Should be stored external to buildings, where practicable, in a secure, cool, well ventilated, dry storage area and away from sources of heat including direct sunlight. This area should be dedicated to battery storage where practicable.
- Whilst the University's insurers, UMAL, prefer storage and charging to be done away from buildings in dedicated facilities, they do not **currently** prohibit such activities, but do expect this practice to be risk assessed and suitable control measures to be implemented. The risk assessment should provide a justification for storage indoors. Stores should be located within dedicated fire compartments (30–60-minute fire resistance). Fire detection should be provided. A purpose designed battery storage box should be used with fire prevention measures (suppression systems) where possible. Use of a fireproof bag **as well as** the storage box or instead of should be determined by risk assessment.
- Suitable extinguishers – Aqueous Vermiculite Dispersion (AVD) or Class D L2 extinguishers should be provided adjacent to any storage or charging areas.
- Should be protected against physical impact damage such as being crushed or punctured.
- Must not be stacked or packed tightly together.
- In storage areas/containers that are clearly labelled and signed.
- Should not be stored fully charged for extended periods of more than 24 hours. Discharge to about 50-60% capacity for storage for long periods.
- Tape terminals or provide plastic covers for lithium batteries to prevent short circuiting.
- **Must not** be stored in fire escape routes.
- Ensure batteries are regularly inspected for damage, swelling etc. and damaged/waste batteries are regularly removed from premises to avoid significant accumulations.

Any deviation from the above precautions should be justified by risk assessment.

Staff and students must not bring their own e-bikes, e-scooters or other electronic travel devices 9or their batteries0 into the University's premises for storage or charging.

Safe Use

Lithium batteries should only be purchased from reputable companies and used in accordance with manufacturer's instructions.

Always inspect batteries for any signs of damage before use and never use damaged or defective batteries.

Emergency procedures and staff training should be in place to include specific instructions for dealing with damaged or faulty batteries and what to do in the event of a fire/explosion.

An Inventory and/or log of use/disposal should be kept and maintained.

The University operate a no smoking policy within University Buildings which includes e-cigarette's (also known as vapes). Charging of batteries for e-cigarettes is prohibited in all University buildings, including residential accommodation.

Rechargeable batteries for electric vehicles including e-scooters and e-bikes MUST NOT be brought into any University of Bath buildings including residences for storage or charging. This includes while on the vehicle or if removed. Bikes etc. should not be brought into the University's buildings for storage, or charging; secure storage areas are provided on campus.

Charging

Lithium Batteries | London Fire Brigade (london-fire.gov.uk) (includes video of an e-scooter fire where the e-scooter is being charged up in the owner's home).

- Follow manufacturer's instructions
- Only use a suitable charger purchased from a reputable company to UK safety standards, e.g. with a CE mark. Preferably the charger that was supplied with the battery/device/vehicle etc. should be used. It is designed to steadily charge the battery at a predetermined rate, it will monitor the charge and avoid overcharging.
- Do not leave unattended while charging, particularly higher power types such as those for e-bikes, e-scooters etc. Do not charge overnight.
- Let the battery cool before charging it.
- Where batteries are designed to be removed for charging, always remove the batteries from the device before charging.
- Unplug the charger once the battery is charged.
- Don't charge a battery when the ambient temperature is above 35°.
- Don't charge batteries close to combustible materials or hazardous substances. Consider creation of dedicated and segregated charging stations / areas.
- Do not cover lithium batteries when charging.

Safe Disposal

Damaged or expired batteries must not be disposed of in general waste as when punctured or crushed they can cause fires in bin lorries, recycling and waste centres.

This link shows a video of a fire at a waste site which was caused by a lithium-ion battery disposed of at a recycling centre in the UK.

Around the University there are battery bins that should be used for expired batteries in good condition. Lithium -ion batteries and disposable vapes should not be disposed of in these bins. Vapes (disposable and rechargeable) can be disposed of in a dedicated bin near the Lime Tree. There are also vape disposal facilities in the Fresh shop. Personal lithium-ion batteries should be disposed off at a registered recycling centre.

Batteries should be removed from the device before disposal where possible.

If the battery is damaged including bulging, severe corrosion etc. then this should be quarantined in a safe area. The waste team should be contacted at waste@bath.ac.uk for appropriate disposal.

Additional Resources

FPA RE2: LITHIUM-ION BATTERY USE AND STORAGE

Appendix 1 - Electric bikes and Scooters

The following is general advice regarding personal purchase, use, and charging of electric bikes and scooters (*source Avon Fire and Rescue service)*:

- Always buy electric bikes/scooters from reputable retailers and ensure they meet British and European Standards (i.e., have a suitable UKCA or CE mark). Note, A UKCA or CE mark is a declaration from the manufacturer that the product is safe, but like all markings, it can be forged.
- Never tamper with the electrics.
- If buying an electric bike conversion kit, purchase from a reputable seller and check that it complies with British and European Standards. Take particular care if buying from online auction or fulfilment platforms. Also be aware that if buying separate components, you should check that they are compatible.
- Charge batteries whilst you are awake and alert so if a fire should occur you can respond quickly. Don't leave batteries to charge while you are asleep or away from the home.
- Register your product with the manufacturer to validate any warranties – batteries are usually included in warranties. Registering makes it easier for manufacturers to contact you in the event of safety or recall information.
- Do not charge electric bikes/scooters on your escape routes, e.g. in corridors or blocking doorways, if there's a fire, it can affect people's ability to escape.
- Do not charge batteries or store your electric bike/scooter near combustible or flammable materials.
- Don't leave electric bikes/scooters continuously on charge after the cycle is complete.
- Ensure you have working smoke alarms and test them regularly. If you charge or store your electric bike/scooter in a garage or kitchen ensure you install detection, we recommend heat alarms rather smoke detectors for these areas.
- In the event of an electric bike, electric scooter or lithium-ion battery fire – do not attempt to extinguish the fire. Get out, stay out, call 999.
- Batteries can be damaged by dropping them or crashing electric bikes/scooters. Where the battery is damaged, it can overheat and catch fire without warning. Check your battery regularly for any signs of damage and if you suspect it is damaged it should be replaced and should not be used or charged.
- If you need to dispose of a damaged or end of life battery, don't dispose of it in your household waste or normal recycling. These batteries, when punctured or crushed can cause fires in bin lorries, recycling and waste centres. Your electric bike/scooter manufacturer may offer a recycling service. Alternatively check with your local authority for suitable battery recycling arrangements in your area.

Please note, whilst it is legal to purchase e-scooters, it is not legal to ride personal e-scooters on public highways or on land without the landowners / landlord's permission. The University only allows the use of Dott e-scooters (i.e., those operating under the BANES trial) on campus.

The following also provides useful information: Safer use | Electrical Safety First

Appendix 2 – E-Cigarettes

The following is general advice regarding e-cigarettes (*source Avon and Somerset Fire and Rescue)*:

When buying e-cigarettes or vapes, make sure that you:

- check that the output voltage and ratings marked on the charger and the electrical device (battery) are the same.
- look for a manufacturer's brand name or logo, model and batch number.
- check that the name and address of the producer that comes with the product is an address within the European Union
- check for a CE mark, but don't rely on this alone to guarantee a product's safety. A CE mark is a declaration from the manufacturer that the product is safe, but like all markings, it can be forged.
- make sure that instructions on how to use the product safely, conditions and limitations of use and how to safely dispose of the product are included.
- do not dispose of vapes or batteries in your household waste.