cpi confederation of paper industries

Guidance on the safe use, charging and management of lithium and lead-acid batteries in material handling equipment

June 2026

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INTRODUCTION

This guidance has been produced following several serious incidents involving LPG powered vehicles, particularly forklift trucks (FLTs). As a result, many workplaces have increased their use of alternative powered vehicles, including those vehicles powered by lithium and lead-acid batteries.

The guidance sets out the legal duties, hazards, and control measures associated with the use, storage, charging, and maintenance of lithium and lead-acid batteries used in forklift trucks and other material handling equipment.

It is intended to support compliance with UK health, safety, and fire safety legislation and to inform risk assessments, safe systems of work, and emergency planning.

The Confederation of Paper Industries (CPI) has developed this guidance to support Members in:

- identifying hazards associated with lithium and lead-acid battery-powered vehicles;
- reviewing existing control measures; and
- implementing practical measures to reduce risk.

1. SCOPE

This guidance applies to workplace vehicles powered by lithium or lead-acid batteries.It does not apply to hydrogen-powered vehicles or to e-scooters and e-bikes.

The information in this guidance is based on a review of publicly available sources relating to the use and hazards associated with lithium and lead-acid battery-powered vehicles. It is generic in nature and does not refer to specific battery manufacturers or makes and models of material handling equipment.

The guidance may be used to review existing operating systems, but it does **not** replace the legal requirement under the '*Management of Health and Safety at Work Regulations 1999* to carry out a suitable and sufficient risk assessment. Employers remain responsible for ensuring that risks are adequately assessed and controlled.

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2. EXECUTIVE SUMMARY

This summary provides an overview of the guidance for the safe use, charging, and management of lithium and lead-acid batteries in material handling equipment, including forklift trucks.

PURPOSE

The purpose of this guidance is to set out clear legal duties, identify hazards, and recommend control measures for the safe operation, storage, charging, and maintenance of lithium and lead-acid batteries in workplace vehicles such as forklift trucks and other material handling equipment.

WHO SHOULD READ THIS

The guidance is intended for employers, health and safety practitioners, managers, supervisors and operators. It outlines the differences between lithium and lead-acid batteries used in material handling equipment and highlights the key health and safety issues that should be considered to help prevent injury and fires.

Key Risks

- Fire and explosion hazards, especially with lithium-ion batteries due to thermal runaway, off-gassing, and potential release of toxic substances.
- Acid spills and hydrogen gas release during charging of lead-acid batteries.
- Mechanical damage, incorrect handling or charging, and inappropriate storage conditions increasing risk of battery failure or incident.

Key Employer Duties

- Conduct suitable and sufficient risk assessments in accordance with relevant health and safety legislation.
- Plan, organise, monitor and review preventive and protective measures.
- Provide clear information, relevant training, and emergency procedures to all staff.
- Ensure work equipment is suitable, properly maintained, regularly inspected, and remains safe throughout its operational life.
- Include battery hazards in fire and hazardous substance risk assessments and comply with COSHH and DSEAR regulations.

High-Level Recommendations

- Identify hazards linked to lithium and lead-acid battery powered vehicles and review existing control measures.
- Implement practical risk reduction measures, such as safe storage, correct charging arrangements, and regular inspection.
- Ensure charging areas are well ventilated and segregated from combustibles, with appropriate fire detection and emergency equipment.
- Train operators and staff in safe handling, emergency procedures, and regular maintenance requirements.
- Engage with reputable suppliers and use Original Equipment Manufacturer (OEM) approved equipment and chargers at all times.

3. LEGAL REQUIREMENTS

The Health and Safety at Work etc Act 1974 (HASAWA 1974) is the primary piece of legislation covering workplace health and safety in Great Britain. Whereas delegated regulations, such as Statutory Instruments or Regulations provide specific detail and legal requirements. Regulations of relevance for employers in this guidance include:

3.1 The Management of Health and Safety at Work Regulations 1999 (MHSWR)

The key requirements for employers include:

- Identifying hazards, evaluating risks, and implementing suitable and sufficient control measures.
- Having arrangements in place to plan, organize, monitor and review preventative and protective measures.
- Providing clear, relevant info and training on risks, prevention, and emergency procedures.

3.2 Provision and Use of Work Equipment Regulations 1998 (PUWER)

The use of battery powered forklift trucks and other material handling equipment falls under PUWER. These regulations apply to anyone who owns, hires, operates, or controls work equipment, including electric vehicles and trucks.

Under PUWER, employers must ensure that work equipment:

- Is suitable for its intended use.
- Is properly maintained.
- Is inspected regularly by a competent person.
- Remains safe throughout its operational life.

3.3 Fire Safety and Dangerous Substances Legislation

Employers are legally required to consider lithium and lead-acid batteries as part of fire risk assessments under:

- The Regulatory Reform (Fire Safety) Order 2005
- The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002

This includes assessment of fire, explosion, and toxic gas risks associated with battery charging, storage, and failure.

3.4 Control of Substances Hazardous to Health (COSHH) Regulations 2002

While batteries are considered "articles" rather than substances in normal use. As they contain hazardous materials like acid, lithium, nickel, or lead, batteries are classified as hazardous waste, and the chemical contents inside can be highly hazardous if released. There is a duty to undertake a risk assessment to prevent risks to health and the environment. When undertaking a COSHH assessment, consideration should be given to:

- Hazard identification and batteries that contain toxic or corrosive materials (Lithium, lead-acid, nickel-cadmium).
- When lithium batteries are damaged, punctured, or subject to ‘thermal runaway’ (overheating), they can release toxic gases and corrosive liquids. Exposure to these fumes or liquids in a workplace constitutes a risk, requiring employers to perform a COSHH assessment and implement control measures.
- Any hazards and exposure to employees during handling, storing, or disposing of batteries, if they are damaged, leaking, or being stored in large quantities.

- Preventing or controlling exposure, which includes depending upon the batteries being used and the hazard identification, implementing safe storage (i.e. bunded or specially designed, protected areas, preventing terminal short-circuiting.

3.5 Electricity at Work Regulations 1989 (EAW Regulations)

Lithium batteries (and all electrical storage batteries) come under the **EAWR** when used in a workplace environment. They are considered as "electrical equipment" due to the direct electrical risks they pose i.e. charging, handling, and storage of batteries in the workplace.

3.6 Environmental Protection Act 1990

Battery disposal falls under the EPA 1990 and failing to comply with these regulations can result in substantial fines.

Specific Waste Types

- **Lead-acid batteries:** Specifically listed as hazardous.
- **Lithium batteries:** While sometimes classified as non-hazardous when intact, they are considered a significant fire risk and should be managed with strict safety measures.

4. TERMS AND DEFINITIONS

4.1 lithium-ion battery
a system incorporating one or more lithium-ion cells or battery packs, including a battery management system, disconnecting devices (e.g. contactors, fuses), and mechanical protection. (Source: BS EN 62620:2015+A1:2023)

4.2 lithium iron phosphate battery
a lithium iron phosphate (LiFePO4 or LFP) rechargeable battery refers to the use of a specific type of rechargeable lithium-ion technology designed for enhanced safety, long life cycles, and thermal stability.

4.3 lead-acid battery
a lead-acid rechargeable battery that uses lead and sulphuric acid to function. The lead is submerged into the sulphuric acid to allow a controlled chemical reaction, which causes the battery to produce electricity.

4.4 battery management system (BMS)
an electronic system that monitors and controls battery safety, performance, and service life, including protection against over-charging, over-current, and overheating.
(Source: BS EN 62620:2015+A1:2023)

4.5 charging efficiency
relates to how much input charging current is converted into energy stored in the battery.

4.6 charge time
charge time refers to how long it takes a battery to recharge 100% when discharged.

4.7 cycle life and lifespan
is the number of charges a battery can go through without a reduction in performance. One single cycle occurs once a battery discharges and is then recharged.

4.8 critical undervoltage limit
the lowest voltage below which a battery cell can be discharged before suffering irreversible capacity loss, permanent internal damage, or entering an unstable state where it becomes hazardous to recharge.

4.9 depth of discharge (DoD)
this is the percentage of the fully charged state to which a battery can be safely discharged, without harming it. A higher depth of discharge means you can use more energy stored in the battery.

4.10 energy density
the amount of energy the battery stores in ratio to its size and weight. A battery with a higher energy density is better since it supplies more energy per unit mass.

4.11 opportunity charging
short charging intervals during breaks or idle time to extend operational availability.

4.12 power density
the maximum rate at which a battery can accept energy relative to its weight (W/kg) or volume (W/L), dictating how fast it can recharge without overheating.

4.13 self-discharge rate (SDR)
this is the rate at which a battery discharges when not connected to any electrical load. This phenomenon occurs due to internal battery chemistries. A low SDR indicates a better performing battery.

5. PRE-PURCHASE / LEASE PROCUREMENT

Before committing to purchasing or leasing a lithium battery or lead-acid powered truck. There are some general points to consider.

5.1 When purchasing or leasing either battery type truck, only use well known and reliable suppliers.

5.2 If using lithium battery trucks, make sure they have a smart Battery Management System (BMS). This system helps avoid the dangers of overcharging or draining the battery too much. It works by communicating with the charger, as each type of lithium-ion battery needs to be charged to the correct (max) level and at the correct speed to prevent overheating. It is therefore crucial to use the supplied charger that comes from the truck’s OEM, or use the manufacturers recommended charger to ensure that everything charges correctly and safely.

5.3 Use parts only in accordance with the OEM instructions.

5.4 Consider using trucks that have safety features such as anti-collision and condition monitoring technology.

5.5 Ensure all personnel have received all the necessary training to safely operate and maintain the trucks.

5.6 Consult with your insurer who will be able to advise you on specific battery type trucks and general safety requirements and fire reduction measures. Ensure full disclosure is made to your insurers to reduce the risk of indemnity refusal if you must claim on insurance.

5.7 Involve your local fire service for support and advice. Work together on developing a pre-fire plan. The fire service should be regularly invited to the site with the purpose of ensuring that in the event of an emergency firefighters know what and where lithium powered equipment is used.

6. KEY BATTERY TYPES

Forklift trucks are primarily powered by three types of batteries:

- lead-acid**,**
- lithium-ion (including NMC nickel manganese cobalt), and
- lithium phosphate.

Lead-acid is the traditional type used, and sealed variants to this type of battery include Gel batteries and Absorbent Glass Mat (AGM) and nickel-cadmium.

Lithium-ion batteries and lithium-iron-phosphate batteries are two types of rechargeable power sources with different chemical compositions. While each has its unique strengths, their differences lie in energy density, lifespan, safety features, and efficiency.

7. BATTERY COMPARISON

Before deciding which battery type truck to use, there are several operational factors for consideration, for example:

Lithium batteries are better suited for 24/7 operations, where quick 15-30 min opportunity charging is an important factor. They also deliver full power throughout the entire discharge cycle, meaning the truck doesn’t slow down as the battery drops.

Lead-acid batteries require longer pre-planned charging, or the use / access to multiple spare batteries. In this type of battery, the voltage drops as the battery discharges, causing the truck to become slower. This could be an important factor during loading and unloading operations, where time is critical.

NB: Not all lead-acid batteries are the same. Failing to distinguish between them can severely damage equipment, cause batteries to leak, or completely dry out the cells.

Flooded (Wet-Cell) Batteries: These feature removable caps over the individual cells to allow access. You should periodically check the fluid levels and "top them up" using only distilled or de-ionised water (never tap water or acid) to cover the plates.

For these types of batteries, it is best practice to only top off the fluid after the battery is **fully charged**. If you fill them when they are discharged, the fluid can expand during the charging process and cause acid to overflow.

Sealed Lead-Acid (SLA, AGM, or Gel) Batteries: These are maintenance-free and permanently sealed. Attempting to pry open these cells to add water will destroy the battery, void the warranty, and potentially cause injury.

Other factors for consideration include:

7.1 Charging Efficiency

- **Lead-acid Batteries** have an efficiency of about 70% - 85%. That means that 30% - 15% of the current supplied to the battery is lost.
- **Lithium-ion Batteries** have an efficiency of > 95% - 99%. All the energy supplied to the battery is stored and ready for use.
- **Lithium Phosphate Batteries** typically achieve a charging efficiency of between 95% and 99%. This means that almost all energy from the charger is converted into stored energy,

7.2 Charging Times

- **Lead-acid Batteries** typically require 8 hours or more for a full charge and may not be suitable for opportunity charging.
- **Lithium-ion Batteries** can be charged much faster, often in 1-3 hours, and support opportunity charging, allowing for quick top-ups during breaks.
- **Lithium Phosphate Batteries** depending upon the charger capacity, these batteries typically charge from 0% - 100% in 1-2 hours.

7.3 Cycle Life and Life Span

- **Lead-acid Batteries** offer 500-1,000 charge cycles, with capacity and efficiency declining as they age.
- **Lithium-ion Batteries** typically last for 2,000-3,000+ charge cycles and depending upon operational use have a life span of circa 8-10 years.
- **Lithium Phosphate Batteries** typically last 8–12 years or 3,000–5,000+ full charge cycles at 80% depth of discharge (DoD).

7.4 Depth of Discharge

- **Lead-acid Batteries** the depth of discharge is only about 50%. Once you have used half the battery capacity, you will need to recharge it, as it could significantly limit the battery performance and range.
- **Lithium-ion Batteries** the depth of discharge is 95% or more. If you invest in a high-quality lithium battery, the depth of discharge increases to 98%.
- **Lithium Phosphate Batteries** have a high usable depth of discharge (DoD), typically between 80% and 100%, allowing nearly their full capacity to be used without damage.

7.5 Self-Discharge Rate

- **Lead-acid Batteries** typically have an SDR of about 4% per week. You must regularly check to ensure the battery has not discharged during storage.
- **Lithium-ion Batteries** SDR is very low, about 1-2% per month. It means that it retains almost all the charge regardless of how long you store it.
- **Lithium Phosphate Batteries** lose very little of its stored energy when it is sitting idle, unused, or stored for long periods. Typically, these batteries have a SDR of around 1% to 3% per month.

7.6 Size and Weight

- **Lead-acid Batteries** contain significant amounts of lead, a high-density heavyweight material. Additionally, the liquid electrolytes further add to the weight of the battery. On average, a 3KWh lead-acid battery weighs around 30kg which is 5 times more than lithium batteries.
- **Lithium-ion Batteries** lithium is 55% lighter than lead. You can expect a 3KWh lithium battery to weigh about 6kg. Lithium-ion batteries also have a greater energy density, and don’t need the same physical space as conventional lead-acid batteries.
- **Lithium Phosphate Batteries** are similar in weight to lithium-ion batteries.

7.7 Energy Density

- **Lead-acid Batteries** have one of the lowest energy density ratings since they are huge but provide the least power. Additionally, with a 50% depth of discharge, they only supply half of their rated battery capacity.
- **Lithium-ion Batteries** can supply significantly more energy than a lead-acid battery. Additionally, with a higher depth of discharge, almost the entire battery capacity is available for use.
- **Lithium Phosphate Batteries** have 3 to 5 times the energy density of lead-acid batteries and are generally 1.5 to 3 times less energy dense than high-performance lithium-ion batteries.

7.8 Maintenance

- **Lead-acid Batteries** depending on the type of lead-acid battery used ‘flooded’ or ‘sealed’, will determine the level of maintenance.

    - Flooded batteries are not sealed and require regular maintenance. Watering with distilled water (post-charge), keeping terminals and tops clean to prevent discharge, and ensuring proper, uninterrupted charging cycles to avoid sulphation.
    - Sealed units, the electrolyte is immobilized, maintenance free and contains valves that allow pressure to vent safely, controlling gas release. In the case of a sealed lead-acid battery, you need to monitor the charging cycle to ensure the battery does not become overcharged, or it will be permanently damaged. Additionally, regular ventilation checks are required.

- **Lithium-ion Batteries** are largely maintenance-free requiring no watering or cleaning of acid residue. Key maintenance involves keeping them cool (5^0C - 20^0C) Some new models are so advanced that they have an inbuilt battery management system (BMS). A BMS protects the battery against being overcharged. Once the battery becomes fully charged, the BMS automatically stops the charging cycle. The BMS also monitors the operating temperature of the battery to ensure safety.

- **Lithium Phosphate Batteries** require minimal maintenance, focusing on proper storage, regular charging (ideally keeping them 40-80% charged), and terminal inspection to ensure long-term, high-cycle performance (2500–5000+ cycles). Key actions include using a dedicated LiFePO4 charger, keeping them cool (5^0C - 20^0C), and if storing, checking voltage every 3-6 months.

7.8.1 General Maintenance Procedures

- FLT's and battery chargers should be part of the routine plant maintenance program.
- Make battery inspection part of pre-use work equipment inspections. Keep records of these inspections.
- Check regularly for damage or defects. If a battery is damaged, do not use it, do not charge it and isolate it from the general workspace.
- Lithium batteries are generally maintenance free. However, visual inspection of battery casing, cables, connectors, and charge equipment should be inspected and maintained as part of a regular maintenance regime according to OEM instructions.
- Any faults, damage, leakage, or exposed live parts should be reported immediately and referred to an appropriately trained and experienced technician for more detailed assessment. Batteries that show mechanical damage or signs of gaseous or liquid discharge must immediately be removed from service and referred to a specialist for assessment.
- Charge units and some batteries may contain cooling fans and other equipment that requires servicing and/or cleaning. Refer to manufacturer's instructions for further details.
- Any external damage such as penetration by an object or crash collision damage near the battery system should be reported. The battery should be examined to ensure it is safe for use before being returned to service.
- Using non-combustible cleaning solutions, keep trucks clean by regularly removing any build-up of grease, oil, or other flammable materials like dust.
- Protect the cables and connectors from damage by using load balancers (spring reels) to keep them from touching the floor.
- The hydraulic oil used in lithium trucks can become a fire hazard if it leaks or sprays into the air and meets an ignition source. Ensure regular maintenance checks for leaks and choose fire resistant hydraulic fluids.

7.9 Environmental Impact

At some point the battery will need to be replaced, and the environmental impact of the battery needs to be considered.

- **Lead-acid Batteries** the two main components of a lead-acid battery, the lead plates and the acid, are both highly toxic. They can degrade the environment, and many additional costs are incurred to ensure they are disposed of safely. Also, a lead-acid battery releases very toxic gases into the atmosphere during its lifetime.
- **Lithium-ion Batteries** offer significant environmental improvements over traditional lead-acid batteries during operation, but present different ecological challenges regarding production and end-of-life disposal. On a positive this battery type produces no exhaust, improving warehouse air quality. They are more energy efficient, and with no 'gassing' they do not require any special ventilation to clear hydrogen gas. There are end-of life disposal issues, i.e. low recycling rate, toxic material leaching and damaged batteries can catch fire in landfills.
- **Lithium Phosphate Batteries** are generally safer and more environmentally friendly during use than cobalt-based batteries. However, their end-of-life (EOL) management presents significant challenges, including fire risks, and environmental contamination.

NB: In the UK, there are strict regulations which apply to industrial battery disposal. Not following these rules can lead to significant fines from the Environment Agency.

7.10 Costs

Lithium batteries generally cost 2 to 3 times more than lead-acid batteries upfront, but they offer a significantly lower total cost of ownership (TCO) over their lifetime due to longer lifespans, higher efficiency, and no maintenance.

7.11. Opportunity Charging

Provide supplementary charges during a working day/shift to extend the working period of the battery, by charging it when periods of idle time are available. This is not free power and every period of opportunity charge chips away at the cycle life expectation and will reduce overall cycle life. Frequent opportunity charging can elevate battery temperatures, and this also can have an impact on battery life.

7.12 Partial State of Charge (Opportunity Charging)

Opportunity charging involves partially charging electric batteries during short, frequent intervals. Batteries are charged during breaks, lunch periods, or shift changes to maintain a continuous mid-level state of charge, typically between 20% and 80% (State of Charge).

Although lead-acid batteries can operate in a Partial State of Charge (PSoC), prolonged operation in this condition is generally not recommended because it promotes sulfation, leading to premature battery failure. To reverse sulfation and maintain battery health, the battery should be fully charged to 100% on a regular basis (typically at least once every 30 days). Extended PSoC operation reduces battery capacity by allowing irreversible lead sulfate crystals to form on the plates, increasing internal resistance and causing permanent capacity loss

Note: Partial State of Charge (PSoC) operation is a specialised application and should only be implemented following consultation with the OEM. The OEM can advise on the suitability of the application, the electrical infrastructure requirements necessary to support the charging regime, and the appropriate battery management practices to ensure alignment with operational requirements.

Table 1. Comparison of battery types.

Feature	Lithium Phosphate (LiFePO4 / LFP)	Other Lithium-ion (e.g., NMC)	Lead-acid
Safety	Superior thermal and chemical stability; non-combustible and highly resistant to thermal runaway, even if damaged or overcharged.	Higher energy density makes them more volatile and prone to overheating and fire in case of damage or overcharging.	Generally safe but can emit hazardous gases (hydrogen, acid mist) if overcharged or poorly maintained; risk of acid leaks and spills.
Lifespan	Significantly longer lifecycle, often exceeding 2,000 to 4,000 cycles, and in some cases up to 6,000 cycles, with minimal degradation.	Shorter lifespan, typically 500 to 1,000 cycles.	Typically, 500–1,500 cycles depending on depth of discharge and maintenance; capacity fades more rapidly over time.
Energy Density	Lower energy density (90–120 Wh/kg) than NMC, meaning they	Higher energy density (150–260 Wh/kg), making them ideal for applications	Lowest energy density (30–50 Wh/kg); much heavier and bulkier for equivalent power.

	are bulkier for the same power output.	where weight and space are critical (laptops, phones).	
Opportunity Charging	Thrives on opportunity charging during breaks without damage (no memory effect), which increases operational uptime.	Benefits from opportunity charging, but high charge rates generate more heat and require more complex cooling measures.	Cannot opportunity charge without negatively impacting lifespan; requires full charge/discharge cycles and long cool-down periods.
Maintenance	Zero maintenance; no watering, acid handling, or required cool-down periods.	Requires a Battery Management System (BMS) for safety, but still generally maintenance-free compared to lead-acid.	Requires regular watering, acid checks, cleaning, and equalisation charging; periodic maintenance is essential for safe operation and longevity.
Cost	Higher initial cost than lead-acid, but generally less expensive to produce than other Li-ion chemistries (no cobalt/nickel).	Can have a higher upfront cost than LFP.	Lowest upfront cost; however, higher total cost of ownership due to frequent replacements and ongoing maintenance.
Environmental Impact	Uses iron and phosphate, which are abundant, non-toxic, and easier to recycle.	Often contain cobalt and nickel, which are hazardous and raise ethical sourcing and disposal concerns.	Lead and sulphuric acid content pose significant environmental risks; recycling is possible but requires strict handling and is less environmentally friendly.

8. Storage and Handling Requirements

Manufacturers/suppliers are obliged to include the procedure for safe handling of the battery, including installation, removal, and secure mounting on the truck, within the instruction handbook. These instructions must be communicated to employees and should form part of your internal safe operating procedures.

8.1 Lead-acid Batteries are the most common type of batteries used in FLT's. They are affordable, durable, and reliable. However, lead-acid batteries also have specific handling and storage requirements. When working with lead-acid batteries, they should:

- **Be stored** in cool (10°C-25°C), dry, well-ventilated, and covered areas to prevent hydrogen gas buildup, fire, or freezing. Avoid direct sunlight and temperatures above 60°C or below freezing (unless fully charged). Separate different types of batteries and do not store new and used batteries together.
- **Labelling:** All containers must be properly labelled identifying the battery type.
- **Keep batteries** in an upright position to prevent electrolyte leaks.
- **Fire prevention:** Keep away from heat, sparks, and combustible materials. This includes avoid using electrical devices near lead-acid batteries.
- **Avoid tipping.** Keep containers closed when not in use, with vent caps on, and terminals covered.
- **Always wear protective clothing and equipment**. Handling requires acid-resistant PPE (gloves, goggles, apron, and boots) to protect against sulfuric acid.
- **Provide ventilation**. The charging area should be well ventilated to avoid hydrogen gas explosion risks.
- **Charge correctly**. Do not overcharge or undercharge lead-acid batteries, as this can reduce their lifespan and performance. Use the appropriate charger and settings for your battery type and check the water level and specific gravity of your battery regularly. Check electrolyte levels only when fully charged.

- **Switch off**. Before detaching any circuit connection, you should check that power to the charger is off. Never disconnect a charger while it is still running.
- **Dispose of lead-acid batteries properly**. Follow the local regulations and guidelines for recycling or disposing of your batteries.
- **Do not alter packaging**. Do not open or tamper with the original packaging of the batteries, as this can expose the electrodes and electrolytes to air and moisture, which can cause a short circuit or fire.
- **Spill response:** In case of skin contact, immediately flush with large amounts of water.
- **Prevent short circuits** by keeping terminal covers on. Inspect cables and connections periodically for damage.

8.2 Lithium-ion Batteries used in trucks are valued for their efficiency and minimal maintenance requirements, but they demand careful storage and handling to ensure safety. Lithium-ion batteries should:

- **Be stored** in cool (10°C–25°C), dry, and well-ventilated locations, away from direct sunlight and temperature extremes. Avoid stacking or storing damaged batteries and ensure new and used batteries are kept separate.
- **Labelling** should clearly mark containers to indicate battery type and chemistry.
- **Keep batteries upright** to prevent physical damage and leaks.
- **Fire prevention:** Keep away from heat sources, sparks, and flammable materials. Avoid the use of electrical devices near batteries.
- **Avoid tipping.** Keep terminals covered and containers closed when not in use.
- **Wear appropriate PPE** such as gloves and safety goggles to protect against possible leaks or fire hazards.
- **Provide ventilation** Charging areas should be well-ventilated to disperse any gases and minimise explosion risk.
- **Charge correctly** using the designated charger and settings for your battery type; avoid overcharging or deep discharging to maintain battery health.
  - **Switch off**. Ensure power is off before disconnecting chargers or any circuit connections.
  - **Dispose of lithium-ion batteries properly.** Follow local regulations for recycling or disposal, as improper handling can pose environmental and fire risks.
  - **Do not alter packaging**. Never open or tamper with battery casings, as this can lead to exposure of hazardous materials or cause a fire.
  - **Spill response:** In the event of a leak, evacuate the area and follow emergency procedures for hazardous materials.
  - Prevent short circuits by keeping terminal covers in place and regularly inspecting cables and connections for damage.

8.3 Lithium Phosphate Batteries ($LiFePO_4$) are increasingly popular in trucks due to their safety, longevity, and environmental benefits. Their storage and handling requirements are like other lithium-ion batteries, but with a few distinctions:

- **Labelling:** Clearly mark containers to indicate $LiFePO_4$ chemistry.
- **Keep batteries upright** to avoid damage and leaks.
- **Fire prevention:** Keep away from heat, sparks, and combustible materials. $LiFePO_4$ batteries are less prone to thermal runaway, but caution is still required.
- **Avoid tipping.** Keep terminals covered and containers closed when not in use.
- **Wear appropriate PPE** such as gloves and safety goggles when handling batteries.
- **Provide ventilation**. Ensure charging areas are well-ventilated to prevent gas buildup.

- **Charge correctly.** Use the correct charger and settings; avoid overcharging or excessive discharge. Regularly inspect battery management systems for faults.
- **Switch off.** Always ensure the charger is powered down before disconnecting.
- **Dispose of lithium phosphate batteries properly** Adhere to local recycling and disposal guidelines.
- **Do not alter packaging.** Never tamper with battery casings; this may lead to exposure to hazardous materials.
- **Spill response:** In the event of a leak, follow emergency procedures and evacuate if necessary.
- **Prevent short circuits** by keeping terminal covers on. Inspect cables and connections regularly for signs of damage.

9. Charging

9.1 Lead-acid batteries charging requires using a charger matched to the battery type (flooded, GEL, or AGM). Key safety measures include charging in well-ventilated areas to prevent hydrogen gas buildup, monitoring temperature to avoid overheating, and using, 14.4–14.7V for charging and 13.2–13.8V for float.

Note: The difference between Bulk / Absorption and Float / Trickle voltage limits is Bulk / Absorption is used to actively charge a battery quickly, while Float / Trickle is used to maintain a full charge without damaging the battery.

In all cases you must always follow the specific, manufacturer charging instructions for your battery model.

9.2 Lithium batteries must be charged via the Battery Management System (BMS). The BMS should never be bypassed or disabled. The charge unit and BMS must be compatible. Never connect a charger of unknown or incompatible type to a lithium battery.

9.2.1 The charger may be specific to a particular equipment model even where different models are produced by the same manufacturer. Overcharging is not possible if the correct charger and BMS are used.

9.2.2 Connection/disconnection of the charge equipment/power supply should be done with no current flow, e.g. by ensuring the charger is switched off. The procedure detailed in the equipment manual must be followed. For safety and compliance, all charger isolators should be fitted with power disconnection switches.

9.2.3 The charging of any type of battery poses a fire risk and should only be completed in a designated fire segregated battery charging area.

9.2.4 Where possible, outdoor or segregated charging is preferred. If charging indoors, employers must ensure the charging area meets fire separation, ventilation and protection requirements consistent with BS EN IEC 62485-2 and fire authority recommendations.

9.2.5 Ensure the area has good ventilation to prevent the accumulation of flammable gases that could result in a vapour cloud explosion.

9.2.6 Battery charging areas should be located adjacent to an exterior wall, which can be accessed from the outside and has easy egress in the event of an emergency.

9.2.7 The area should be separated from the rest of the warehouse or production area by a fire-resistant compartment, providing at least 60 to 90 minutes of fire resistance, particularly where multiple trucks are charged.

9.2.8 Always maintain a clear space of at least 2 metres around the charging units and the FLT's on charge. Ensure there are no combustibles within the vicinity. Hatched floor markings can assist to define the charging area.

9.2.9 Automatic fire detection (preferably smoke) should be provided within the FLT charging area, in addition to portable fire extinguishers. It is preferable for extinguishers to be Aqueous Vermiculite Dispersion (AVD) e.g. Lith-Ex, as they are specifically designed to combat lithium battery fires.

9.2.10 Safety signage should be provided to identify the area where lithium-ion FLT battery charging is undertaken.

9.2.11 Install fixed metal barriers or bollards to protect charging equipment from accidental damage by FLT's and secure chargers to non-combustible walls or stands, at least 0.5 metres off the ground to avoid water damage.

9.2.12 Provide recoil units to automatically retract the charging leads and prevent mechanical damage to the leads.

10. Fire Hazards

Employers are legally obliged to review both lead-acid and lithium batteries as part of undertaking fire risk assessments under The Regulatory Reform (Fire Safety) Order 2005, and The Dangerous Substances and Explosive Atmospheres Regulations 2002.

When undertaking a fire risk assessment, consideration should be given to the following.

10.1 Fire Risk Assessment Ensure whoever is conducting the risk assessment is competent. Competent is defined as someone who has a combination of relevant training, skills, experience, and knowledge that enables them to identify workplace hazards and implement appropriate, safe, and effective control measures. They must have practical and theoretical knowledge of specific equipment or tasks to ensure compliance with health and safety legislation.

10.2 Lead-acid Batteries while they do not pose the same high-risk thermal runaway threat as lithium-ion batteries, (see 10.3.2). They are considered dangerous because they release highly flammable hydrogen gas during charging and can cause severe chemical fires and explosions if mishandled or damaged. If charged in an unventilated or poorly ventilated space, this gas can accumulate and create an explosive atmosphere, easily ignited by a spark or flame.

- **Overcharging or short-circuiting** lead-acid batteries can cause excessive heat buildup, causing the casing to rupture or ignite.
- **Electrolyte hazards:** the sulfuric acid within the batteries is highly corrosive, and when damaged, they can release flammable gases.
- **Short circuits:** damaged or improperly stored batteries (e.g., metal objects falling on terminals) can cause short circuits, resulting in fire.

If you are responsible for a building (employer, owner, or occupier), you must include battery storage and charging areas in your fire risk assessment.

10.2.1 Control Measures. A comprehensive fire risk assessment should include measures such as:

- Using ventilated areas or specialized charging cabinets for large battery banks.
- Installing fire detection and suppression systems in battery rooms.
- Ensuring proper training for staff handling or maintaining battery systems.

10.3 Lithium-ion Batteries pose a fire risks because of the large battery packs. It is well known that fires involving these batteries are notoriously hard to put out. The larger the battery pack, the greater the danger and impact of a fire. It is important to note that, while the forklift itself may not always start a fire, it can fuel one if it occurs.

10.3.1 Vapor Cloud Explosions can occur when toxic and flammable gases released by the failing battery ignites or find an ignition source, leading to an explosion. This kind of explosion can cause widespread damage, even breaching firewalls when larger battery packs are involved. Additionally, when these batteries fail, they release hydrogen fluoride (HF) gas, a toxic substance that poses a serious inhalation hazard. The volume of dangerous gases produced in a lithium-ion battery fire can significantly exceed that of a typical fire, highlighting the need for specific safety measures and awareness.

10.3.2 Thermal Runaway in lithium-ion batteries is a dangerous condition where the battery's temperature increases uncontrollably due to a chain reaction of exothermic (heat-producing) chemical reactions. This runaway heat can lead to battery failure, potentially causing fires, explosions, and the release of toxic gases.

10.3.3 Causes of thermal runaway include:

- **Overcharging:** Exceeding the battery's maximum voltage can cause internal reactions that generate heat.
- **Short Circuits:** Internal or external short circuits can lead to a sudden surge in current and temperature.
- **High Temperatures:** Both high ambient temperatures and internal heat buildup from other factors can exacerbate the problem.
- **Mechanical Abuse:** Physical damage like punctures or crushing can cause internal shorts and trigger thermal runaway.
- **Manufacturing Defects:** Imperfections in the battery's construction can also increase the risk.
- **Rapid Charging:** Charging at high currents can lead to excessive heat generation.
- **Improper Charging:** Using incompatible chargers or leaving batteries charging unattended, especially overnight.
- **Storage Conditions:** Storing at high temperatures or in direct sunlight.
- **Defective Battery Management System:** A malfunctioning BMS fails to stop overcharging, increasing fire risks.

10.3.4 Thermal Runaway Consequences:

- **Fire and Explosion:** The high temperatures and flammable gases released during thermal runaway can lead to fires and even explosions.

- **Toxic Gas Release:** Many gases, including carcinogens, can be released during the process.
- **Physical Damage:** The battery can rupture and release molten metal or other debris.
- **Damage to Surrounding Materials:** The intense heat can damage surrounding equipment and structures.

10.3.5 Thermal Runaway Prevention:

- **Proper Charging:** Follow manufacturer guidelines for charging voltage and current. Use approved, compatible chargers.
- T**emperature Monitoring:** Use BMS to monitor battery temperature and prevent overheating.
- **Proper Storage:** Store batteries in cool, dry conditions and avoid exposure to extreme temperatures.
- **Avoiding Mechanical Abuse:** Handle batteries with care to prevent punctures or crushing. If a battery is damaged or swells, it should be removed and disposed of properly.

10.4 Lithium Phosphate Batteries despite having a significantly lower fire risk compared to other lithium-ion batterie, including a higher thermal runaway threshold, they can still catch fire if misused, damaged, or overcharged.

When these types of batteries fail it is more likely to create an explosive atmosphere, off-gassing large amounts of hydrogen quickly, rather than just burning, which poses a risk in confined spaces. Battery fires can release toxic gases like hydrogen fluoride.

10.5 Emergency Procedures

- Review fire detection systems and check emergency procedures.
- Lithium battery fires are known to be more difficult to extinguish than fires from other sources. Toxic gases and vast quantities of smoke can be released almost immediately. Where a fire may involve a lithium battery, raise the alarm and immediately evacuate the area. Firefighting should only be conducted by trained personnel.
- Fires involving lithium-ion batteries can also be extinguished with water with fire suppression additives. This is a skilled and specialist fire-fighting technique. A large and continuous supply of water may be required at both high and low pressure. The possible environmental impact of additives should be assessed.
    a) Do **NOT** attempt to tackle battery fires with water unless appropriately trained to do so; exposed lithium in damaged cells may react violently on contact with water.
    b) Ensure the fire service knows about your charging arrangements and ask them for advice on training staff to deal with lithium battery fires.
    c) Communicate your pre-fire plan with the fire service.

Appendices

Battery Safety and Compliance Checklists Supporting Guidance for Lithium and Lead-Acid Batteries in Workplace Vehicles.

NB: These are not exhaustive checklists but should be used as a starting point for further development.

i). Appendix A: Storage and Handling Checklist

Item	Requirement	Completed
Battery Type Identification	All batteries are clearly labelled with type (lithium-ion, lithium phosphate, lead-acid).	[ ]
Dedicated Storage Area	Batteries are stored in a designated, secure area away from heat sources and direct sunlight.	[ ]
Ventilation	Storage area is well ventilated to prevent build-up of hazardous gases.	[ ]
Separation	Lithium and lead-acid batteries are stored separately to avoid chemical interactions.	[ ]
Handling Procedures	Staff are trained in safe handling, including use of appropriate PPE such as gloves and safety glasses.	[ ]
Spill Response	Spill kits and instructions for acid or electrolyte leaks are available and accessible.	[ ]

ii). Appendix B: Fire Risk Checklist

Item	Requirement	Completed
Fire Risk Assessment	Fire hazards related to battery storage and use have been assessed and documented.	[ ]
Fire Suppression Equipment	Appropriate fire extinguishers (Class D for lithium, CO_2 for lead-acid) are installed and regularly inspected.	[ ]
Emergency Procedures	Clear fire evacuation and response plans are in place and communicated to all staff.	[ ]
Alarm Systems	Fire detection and alarm systems are operational and routinely tested.	[ ]
Isolation of Batteries	Faulty or damaged batteries are promptly isolated and disposed of in accordance with regulations.	[ ]
Access for Fire Services	Storage and charging areas are accessible to emergency services.	[ ]

iii). Appendix C: Charging and Maintenance Checklist

Item	Requirement	Completed
Charging Protocols	Charging is carried out in designated areas with suitable ventilation and fire protection measures.	[ ]
Inspection Routine	Regular inspection of batteries for damage, leaks, or corrosion is documented and actioned.	[ ]
Maintenance Records	Maintenance activities and checks are recorded for each battery and vehicle.	[ ]
Charging Equipment	Charging equipment is compatible with battery type and maintained in good condition.	[ ]
Supervision	Charging is supervised or monitored to promptly address incidents.	[ ]
End-of-Life Disposal	Procedures for safe disposal or recycling of depleted batteries are followed.	[ ]

iv). Appendix D: General Compliance Checklist

Item	Requirement	Completed
Risk Assessment	Comprehensive risk assessments are completed for all battery types and vehicle operations.	[ ]
Staff Training	All relevant staff receive training on battery hazards, safe handling, fire risks, and emergency procedures.	[ ]
Legal Duties	Policies and procedures comply with UK health, safety, and fire safety legislation.	[ ]
Record Keeping	Documentation of inspections, maintenance, incidents, and training is maintained and regularly reviewed.	[ ]
Continuous Improvement	Procedures are reviewed and updated following incidents or changes in legislation.	[ ]
Consultation	Staff are consulted on risk controls and encouraged to report hazards or suggestions for improvement.	[ ]

Further Information Additional sources of information can be found at:

Health and Safety Executive – https://www.hse.gov.uk/mvr/topics/electric-hybrid.htm
FLT Association - https://nationalforkliftsafetyday.co.uk/wp-content/uploads/2023/06/UKMHA-GN69-Lithium-Ion-V1.pdf
Allianz- https://www.allianz.co.uk/news-and-insight/insight-and-expertise/lithium-ion-batteries-how-to-reduce-risk-of-fire.htmlhttps://forklift-training.london/lithiun-ion-battery-fire-risk/