IMPORTANT NOTICE – PLEASE READ CAREFULLY

Lithium-Ion Traction Battery Applications

(a) The recommendations and advice contained in this Guidance Note are based on specifications, procedures and other information which have been collected by the UK Material Handling Association Limited (UKMHA) from its members. They represent what is, so far as UKMHA is aware, the best available data at the time of publication on the construction and use of industrial trucks in the general conditions described, and are intended to provide guidance for such use.

(b) However, there are a wide variety of situations in which industrial trucks may be used, consequently in all cases the suitability and safety of this Guidance Note must be determined by the person seeking to apply it on the basis of his own judgement, in the light of the conditions in which use is envisaged and subject to all relevant statutory requirements.

(c) UKMHA accepts no responsibility for the recommendations, advice, statements, opinions and conclusions expressly or by implication set out below and gives no warranty or representation of assurance in respect of the accuracy or validity of the same.

This Guidance Note (GN) is Generic in content and does not refer to any individual battery or MHE manufacturer. The advice where provided is from the MHE industry and is endorsed by the UKMHA TPC members.

1 INTRODUCTION

Lithium-ion (Li-ion) battery technology is undergoing a period of intense development. There are a wide variety of solutions available, and potential adopters should seek detailed advice on their specific application to ensure an optimum solution.

2 SCOPE

This Guidance Note provides information on lithium-ion (Li-ion) traction batteries for Industrial Trucks.

This GN does not discuss the differences in the various technologies and chemistries available. Where specific details are required, the battery manufacturer should be contacted.

Lithium-ion batteries have important technical and safety differences from lead-acid (PbA) batteries which, along with all other battery chemistries and types, are excluded from the scope of this guidance note. Information on lead-acid traction batteries can be found in UKMHA Guidance Note GN68.

This Guidance Note does not provide information on batteries other than traction batteries.

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3 DEFINITIONS & USEFUL TERMS

3.1 Lithium-ion Cell

Some definitions do cross over from Automotive and Stationary applications and standards, and the following descriptions may prove useful when using this GN, if the product you have is used in such a manner.

3.2 Lithium-ion Battery Pack

One or more lithium-ion cells electrically connected and associated mechanical elements e.g. trays, mounting material.

3.3 BMS, Battery Management System

Electronic system associated with a battery which monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life and has the functions to cut off in case of overcharging, overcurrent and overheating. [SOURCE: BS EN 62620:2015, 3.11]

3.4 Lithium-ion Battery (hereafter battery)

System which incorporates one or more lithium-ion cells or battery packs, including a battery management system as well as disconnecting and/or isolating devices, e.g. contactors, disconnectors, fuses, etc. and mechanical elements. [SOURCE: BS EN 62620:2015, 3.10, modified]

3.5 Traction Battery

Collection of battery packs, which are electrically connected, for the supply of electric power to the electric drive and conductively connected auxiliary system, if any.

3.6 Critical Undervoltage Limit

Lowest discharge voltage of the battery cell below which the battery cannot be expected to be recoverable.

3.7 Opportunity Charging

Recharging a battery for short intervals during the work cycle, for instance during operator breaks, to reduce or remove the need for a dedicated longer charging period, eliminate battery change, and/or extend the operational shift.

3.8 Energy Density

Charge storage capacity per unit volume (alternatively, per unit weight).

3.9 Power Density

Maximum rate of power transfer, charge/discharge, per unit volume.

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4 OPERATOR TRAINING

4.1 Pre-shift Checks

Manufacturers/suppliers are obliged to provide details of the required pre-shift checks in the instruction handbook. However, the pre-shift checking of this type of battery is generally restricted to visual inspection (if applicable) and checking the state of charge. Pre-shift checks to the remainder of the truck will be as for other power sources.

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.

4.2 State of Charge

A state of charge (SoC) indicator shall be provided in plain sight of the operator. An additional SoC indicator may also be provided on the battery.

Warning signals (audible and/or visual) shall be provided before the BMS shuts down the lithium-ion battery due to a low state of charge.

Generally, Li-ion batteries do not show a declining performance during operation (discharge) and will shut-down when discharged. The operator should ensure that the equipment has sufficient remaining charge to complete the work activity and return to the charge station before commencing each task.

The rate of discharge has only a very minor effect on capacity (Peukert's law does not apply).

5 CHARGING

Charging of Li-ion batteries must be carried out 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 Li-ion battery. 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.

Note: on some equipment some BMS functions are carried out by the charge unit, e.g. charge profile.

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.

A safe location for charging should be identified where equipment and cables don't cause an obstruction. Lithium-ion batteries do not generate hydrogen gas during charging. The risk of potentially explosive gas mixture due to hydrogen evolution during charging is removed and reduced safety distances may be considered. No special ventilation is required.

5.1 Charge Time

Lithium-ion technology permits very fast charging. The time required to fully charge depends upon battery chemistry and capacity, charger characteristics, and available power supply. Full charge may be achievable in 1 to 2 hours. A cooling down period following charging is not required.

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The power supply to the charge unit must be appropriately sized to permit the fastest required charging. As a rough guide, charging in one hour will require approximately 8 times the current compared with charging over eight hours. The maximum number of trucks on charge at any one time must be considered when specifying site requirements.

The battery should be taken out of service if charging does not complete within the specified time as this may indicate an internal battery fault.

5.2 Opportunity Charging

Rapid charging and partial charging (partial charge and/or partial discharge, often referred to as 'opportunity charging' or 'interim charging') are not detrimental to Li-ion battery life or performance (no memory effect). However, performance optimisation can be achieved by tailoring the charge cycle profile to operational requirements. This may be an integrated function of the BMS or may be carried out by an appropriately trained technician during maintenance/inspection following interrogation of the battery data logs and diagnostic system.

The ability to apply high levels of charge over short periods, such as operator breaks and shift changeover, means that battery changeover, along with the associated space and handling requirements, is not generally required. However, this is application specific, and expert advice should be sought when determining operational requirements.

5.3 Balancing

Cell balancing is carried out by the BMS during charging and discharging. This ensures that the charge state of each cell is similar. The requirements for cell balancing may be equipment and application specific and should be discussed with the supplier.

Operator intervention is not required for cell balancing. However, optimisation of the balancing parameters and charge cycle profile may be carried out by an appropriately trained technician during maintenance/inspection following interrogation of the battery data logs and diagnostic system.

6 MAINTAINENCE

Lithium-ion batteries do not require 'watering' (topping up the electrolyte) and can generally be considered to be 'maintenance free'. However, visual inspection of battery casing, cables, connectors and charge equipment should be carried out as part of a regular maintenance regime. 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.

Charge units and some batteries may contain cooling fans and other equipment that requires servicing and/or cleaning. This may be included as part of the annual inspection detailed below. Refer to manufacturer's instructions for further details.

6.1 Inspection

Annual inspection by a specialist is recommended. Inspection may be carried out by connection of specialist diagnostic equipment to the BMS and will generally include interrogation of battery logs, testing battery protection systems and checking cell resistance and cell balancing function. An estimate of remaining battery life may be provided.

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6.2 Fault Finding

WBMS generally incorporate data logs recording activity, errors, faults and alarms. Data recorded may include charge and discharge cycles, temperatures, cell resistance.

Interrogation of the BMS is system dependant and may require specialist knowledge and equipment. However, many batteries have a status display, sometimes coded or accessed through the truck controls. Error messages may include 'internal short circuit', 'cell balancing failure', etc. These are not generally user repairable.

The BMS will shut down the battery before it is discharged below the critical undervoltage limit (deep discharge). If one of the battery cells is discharged below the critical undervoltage limit, the BMS will not permit charging until the battery is assessed, and the BMS reset, by a suitably qualified technician.

The BMS is usually designed to shut down the battery and to prevent charging when the battery is outside thermal limits. Reset is subject to specific battery/BMS design. See section 7 for further details.

The ability to recover a battery from a fault or shutdown condition is to some extent dependent on speed of response. Charge decay of a shut-down battery will continue, this may further damage the cells and increase the risk of the battery being irrecoverable or becoming unstable. It is important, therefore, that a battery specialist be notified promptly of any fault or shut down event.

6.3 Replacement

Lithium-ion cells, battery packs and battery management systems are not interchangeable at component level. Different systems and chemistries have different performance characteristics and operating voltages. Replacement with an incompatible cell or BMS may result in extreme hazard.

Batteries comprising multiple battery packs may have either a single BMS or multiple BMS. Communication between multiple BMS, for instance via a master controller, ensures common behaviour. Configuration of a multiple BMS system requires specialist knowledge to ensure safe and efficient operation of the battery. Whole battery replacement is generally preferred.

Battery replacement should be carried out by suitably trained personnel who can manage the environment and ensure that those close by do not pose a risk to themselves or others.

Where replacement batteries are not identical to those originally supplied the EMC test requirements may need to be assessed as the original truck EMC testing could be invalidated.

Replacement batteries must be compatible with the truck:

- Voltage
- Capacity
- Discharge rate
- Weight and centre of gravity, e.g. as part of counterbalance
- Electrical connector
- Mechanical fixing
- Regenerative braking (recuperation)
- Safety features, e.g. isolation
- Charging equipment

The above requirement can only be assured by using replacement batteries approved by the original equipment manufacturer for the specific piece of equipment.

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Generally, lithium-ion batteries are not directly interchangeable with either lead-acid (PbA) batteries or other battery designs, including alternative Li-ion batteries. Expert assessment is required to convert MHE between battery types and this must be carried out by the original equipment manufacturer. Changing battery technology may constitute substantial modification and invalidate manufacturers conformity assessment.

6.4 Handling

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.

- Isolate equipment and ensure loads are in a safe position before commencing work
- Do not wear jewellery made from conductive material while handling batteries
- Do not short circuit cells, packs or batteries
- Avoid mechanical shocks/impacts
- Do not expose to naked flames or high temperatures
- Do not open or destroy battery cells
- Never touch damaged batteries with bare hands
- Use insulated tools

6.5 Storage & Extended Idle Periods

Do not store discharged or damaged batteries. Inspect regularly (at least every 3 months) and maintain greater than 50% charge.

Batteries should generally be stored indoors, away from heat sources and direct sunlight, and within the temperature range 0°C to 40°C. Storage areas should be dry and well ventilated (max. 85% humidity).

Ensure sufficient protection against short circuit and mechanical damage.

Lithium-ion batteries may be stored installed to MHE or separately from it. Never separate the BMS from the battery pack or cells unless under repair/replacement by a competent person.

7 SPECIFICATIONS

7.1 Identification

Each battery shall have an identification plate stating the nominal voltage, energy storage capacity, weight and manufacturers details.

There is currently no single, internationally recognised, marking system identifying the cell chemistry of lithium-ion batteries. A European standard, EN 62902, Secondary batteries: Marking symbols for the identification of their chemistry, is under development.

7.2 Operating Limits

Operating temperature range will be defined by the battery manufacturer, stated in the operator's instruction handbook, and be monitored by the BMS. The temperature limits for charging and operation depend upon the battery chemistry and heating and/or cooling functions controlled by the BMS. Heating/cooling places an additional burden on the battery. The BMS may shut down the battery if temperature limits are exceeded or if insufficient charge remains to maintain temperature control functions.

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Operation close to the specified temperature limits may reduce performance. Batteries may become damaged or unstable if subjected to extreme temperatures. Battery life will be reduced and recovery to service may not be possible if the manufacturers recommendations are not respected.

Typically, the minimum temperature for charging is higher than the minimum temperature for operation. Where trucks are operated at below the minimum charging temperature they may need to be moved to a suitable area and the battery temperature allowed to recover prior to commencing charging.

The actual temperature limits depend on the manufacturer and the work activity, e.g. charging, operating, storing, etc. Where operation and/or charging is anticipated at below around 0°C the equipment manufacturer should be consulted.

Note: The battery temperature is determined by the BMS and may differ substantially from the ambient temperature.

7.3 Special Operational Conditions

7.3.1 Cold Stores

Do not leave MHE with Li-ion batteries in cold stores idle/parked for extended periods, e.g. overnight. Battery heating (where applicable) will drain the charge. At low internal temperatures the battery will not accept a charge and recovery to a warm environment may be required. If the battery does not recover and accept a charge after standing for sufficient time to warm up to a core temperature > 0°C then expert advice should be sought. Permanent and irrecoverable damage may have occurred.

7.3.2 Explosive Atmospheres (ATEX)

This is a subject too large and complex to be covered in a Guidance Note. It is important that anyone who encounters an ATEX battery must remember that it is designed for special operating conditions. Where it can be used will be displayed on the battery label, and on any truck it is designed to function on.

Only specially trained engineers are permitted to inspect and maintain ATEX certified batteries.

8 TRANSPORTATION & PACKAGING

Manufacturers/suppliers are obliged to include procedures for transporting both operative and inoperative batteries within the instruction handbook.

Transportation of lithium batteries (all types and chemistries) within the UK is regulated by The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG Regs). For road transport, CDG Regs implement “The European Agreement Concerning the International Carriage of Dangerous Goods by Road”, known as ADR 2017.

The following clauses provide a brief overview of the requirements for road transport within the UK. For full details of the requirements, and for all transportation by other than road, please refer to CDG Regs. Both the HSE and the Department for Transport provide free guidance on CDG (see bibliography).

Everyone involved in the transportation process of hazardous materials must be trained appropriately for their task and in relation to safety.

You may be required to appoint a Dangerous Goods Safety Advisor (DGSA). A DGSA will be necessary for loads exceeding 333kg.

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8.1 Identification

Except for case 8.2 below, shipments/packages containing lithium-ion batteries must be identified as ADR class 9A – miscellaneous – lithium batteries:

8.2 Istalled Equipment

Where Li-ion batteries are installed to MHE and they:

- Comply with the test requirements of UNECE for Transportation for Lithium batteries, part III, UN test 38.3 (refer to product documentation for certification),
- Have a functioning BMS,
- Have sufficient charge to ensure functioning of the BMS throughout the transportation process (generally > 50% charge),
- Show no errors, faults, leakage, or damage,
- Have not experienced conditions outside the permitted charge or environmental limits, e.g. not discharged to critical undervoltage limit and not exposed to high or low temperatures,
- Are protected from damage and accidental operation by the equipment in which they are installed, and,
- Have adequate protection against short circuit,

such trucks shall be identified as UN 3171 ELECTRIC TRUCKS and do not generally require further special arrangements under ADR (see special provisions 240 and 666 of ADR for further details).

The transport company shall be advised of the nature of the shipment and provided with appropriate documentation.

Note: the BMS log will record relevant errors and events outside operational limits.

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8.3 Separate Shipment

Where Li-ion batteries are being shipped separately from the MHE and they:

- comply with the test requirements of UNECE for Transportation for Lithium batteries, UN test 38.3 (refer to product documentation for certification),
- have a functioning BMS,
- have sufficient charge to ensure functioning of the BMS throughout the transportation process (generally > 50% charge),
- show no errors, faults, leakage, or damage, and
- have not experienced conditions outside the permitted charge or environmental limits, e.g. not discharged to critical undervoltage limit and not exposed to high or low temperatures,

such batteries may be:

- packed in the original packaging, or suitable packaging supplied by the battery manufacturer, or, if over 12kg with durable, shock proof housings, may be secured to a pallet with a protective enclosure and durable outer packaging, or, may otherwise be packaged in accordance with the relevant provisions of ADR 2017,
- packaged in a manner that ensures protection against short circuit
- labelled on the outer packaging as UN 3480 LITHIUM-ION BATTERIES with danger label 9A affixed.

  The transport company shall be advised of the nature of the shipment and provided with appropriate documentation.

8.4 Potentially Non-Compliant/Damaged Equipment

Damaged and faulty batteries may not be transported within the standard provisions of ADR. This includes batteries where there is doubt as to the condition, history or specification. Cases other than described in 8.2 and 8.3 above generally require specialist approval, containment and shipping. Refer to ADR 2017 special provision 376 for further details.

9 HEALTH & SAFETY INFORMATION & HAZARDS

Site owners, insurance providers and the local fire service should be advised that lithium-ion traction batteries are in use.

Where a fire may involve a lithium-ion battery, raise the alarm and immediately evacuate the area. Firefighting should only be carried out by trained personnel. Class D fires (burning metal) should be tackled with dry powder or sand.

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. 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.

Damaged batteries, including batteries deep discharged, without functioning BMS, should be treated as hazardous materials and moved to a segregated and well-ventilated area, e.g. outdoors and away from flammable materials. Expert advice should be immediately sought.

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10 END OF LIFE

The technology may have the potential to provide useful life beyond 15 calendar years and 8000 charge/discharge cycles. However, this is dependent on technology development, selected electro-chemical system and build quality. Over time and cyclic use battery efficiency will reduce, and currently little real-world data currently exists beyond 5 years operation.

Where batteries no longer meet the requirements for intensively used MHE, a 'second life' reuse may be considered, for instance on less intensively used equipment or for accumulation on energy supply systems. However, compatibility between systems must be confirmed before proceeding.

Lithium-ion batteries must not be disposed of via landfill. To comply with UK legislation and EU regulations manufacturers and suppliers must provide information on, and a service for, recycling at end of life. This information will be included within the instruction handbook.

Efficient re-cycling requires detailed knowledge of the specific battery chemistry. Batteries may contain valuable recoverable materials such as cobalt, manganese and nickel. It is important, therefore, that battery identification, e.g. labels, handbook, etc., is not damaged or lost.

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