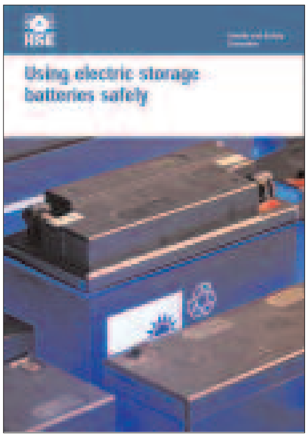
Health and Safety
Executive

Using electric storage batteries safely



Every year, at least 25 people are seriously injured when using batteries at work. If you or your staff work with large batteries, this booklet is for you. It gives a basic introduction to working safely with batteries and minimising the risks involved.

Work safely!

Remember

When working with or near batteries, and also when moving or handling them:

Do…

- Wear gloves and suitable eye protection, preferably goggles or a visor.
- Wear a plastic apron and suitable boots when handling battery chemicals such as sulphuric acid or potassium hydroxide.
- Empty your pockets of any metal objects that could fall onto the battery or bridge across its terminals.
- Keep sources of ignition – such as flames, sparks, electrical equipment, hot objects and mobile phones – well away from batteries that are being charged, have recently been charged, or are being moved.
- Use suitable single-ended tools with insulated handles.
- Fit temporary plastic covers over the battery terminals.
- Charge batteries in a dedicated, well-ventilated area.
- Share the load with a workmate when lifting batteries – they can be very heavy. Use insulated lifting equipment and check there are no tools, cables or other clutter you could trip on.
- Wash your hands thoroughly after working with batteries, especially before eating, smoking or going to the toilet.

And don't…

- Work with batteries unless you have been properly trained.
- Smoke.
- Wear a watch, ring, chain, bracelet or any other metal item.
- Overcharge the battery – stop charging as soon as it is fully charged.

Introduction

This booklet contains straightforward advice on how to use rechargeable batteries safely. Following it can greatly reduce the risks involved. The advice is aimed at supervisors, technicians, safety professionals and others involved in:

- motor vehicle repair and maintenance;
- IT and telecommunications;
- uninterruptible power supply (UPS) systems;
- warehousing and materials-handling;
- stand-by electricity generation;
- using or repairing electric or hybrid vehicles.

Batteries are used to store electrical energy. Many of the things we use every day rely on the instant power provided by batteries. However, the larger batteries found in workplaces can be dangerous and may explode if used incorrectly.

Injuries from batteries include serious chemical burns to the face, eyes and hands, and wounds from flying pieces of metal and plastic. Burns from metal objects that have become very hot or have exploded after short-circuiting the battery's terminals occur frequently. Serious electric shocks and burns are common in accidents involving high-voltage battery packs.

Types of battery

There are two main classes of battery: those that can be recharged and those that cannot. This booklet gives advice about how to reduce the risks of using rechargeable batteries.

The two most important types of rechargeable battery are lead/acid and alkaline. **Lead/acid batteries** are the most common large-capacity rechargeable batteries. There is one in almost every car, motorcycle and wagon on the road. They are often used in electric vehicles, such as fork-lift trucks, and in the UPS of computer/communication, process and machinery control systems.

Alkaline rechargeable batteries, such as nickel-cadmium, nickel-metal hydride and lithium ion, are widely used in small items such as laptop computers. Large-capacity versions of these cells are now used in transport and UPS applications.

There are two different types of lead/acid and alkaline rechargeable batteries: valve-regulated ('maintenance-free') and vented. In **valve-regulated batteries**, any hydrogen and oxygen produced during charging does not escape but is converted back into water. You cannot add water to these batteries, as they do not need topping up.

In contrast, **vented batteries** allow any hydrogen and oxygen produced to escape into the surrounding atmosphere. They require regular topping up with water.

Hazards

Chemical

Batteries are usually filled with solutions (electrolytes) containing either sulphuric acid or potassium hydroxide. These very corrosive chemicals can permanently damage the eyes and produce serious chemical burns to the skin. Sulphuric acid and potassium hydroxide are also poisonous if swallowed.

The lead, nickel, lithium or cadmium compounds often found in batteries are harmful to humans and animals. These chemicals can also seriously damage the environment.

If you own a battery, it is your job to dispose of it properly and without causing unnecessary pollution when it is no longer useful. Many battery-suppliers and scrap metal dealers will do this for you. Transporting scrap batteries by road is subject to certain rules. At the time of publication, these apply when more than six scrap batteries are being moved to a disposal site. You can get up-to-date advice on the proper way to dispose of batteries from your local council or from the Environment Agency.

Explosion

Hydrogen and oxygen are usually produced inside a battery when it is being charged. A source of ignition – for example, a flame, a spark, a cigarette or any hot object, electrical equipment, a mobile phone – will often cause mixtures of these gases to ignite and explode. The explosion is often so violent that it shatters the battery and produces a highly dangerous shower of fragments and corrosive chemicals.

Hydrogen and oxygen are produced more quickly as the battery gets close to being fully charged. If you continue charging after the battery is fully charged, a lot of gas will be produced, greatly increasing the risk from explosion.

During charging, gas bubbles often become trapped inside the battery. The mixture of two parts hydrogen to one part oxygen produced is perfect for an explosion. When a vented battery is moved, the trapped gases are released into the air around the battery. A tiny spark is all that is needed to ignite the gases. If this happens in a confined space (eg inside the battery, or in an enclosure or a poorly ventilated battery room), a violent explosion is likely.

The gases that come out of a vented lead/acid battery during charging often contain a fine mist of sulphuric acid. Take care to avoid breathing these fumes, and wear suitable eye protection.

Valve-regulated ('maintenance-free') batteries are much less likely to release hydrogen than vented batteries. However, it is still important to take care when charging them. Gas pressure may build up inside the battery if it is charged too quickly or for too long. If this happens, the pressure relief valves in the battery may open and let the gases escape. An explosion is likely if this happens close to an ignition source.

Electrical

Batteries contain a lot of stored energy. Under certain circumstances this energy may be released very quickly and unexpectedly. This can happen when the terminals are short-circuited, for example with an uninsulated metal spanner or screwdriver.

When this happens, a large amount of electricity flows through the metal object, making it very hot very quickly. If it explodes, the resulting shower of molten metal can cause serious burns and ignite any explosive gases present around the battery. The sparks can give out enough ultra-violet (UV) light to damage the eyes.

Most batteries produce quite low voltages, and so there is little risk of electric shock. However, some large batteries produce more than 120 volts DC. To protect people from the real danger of electric shock,[1] you should:

- Ensure that live conductors are effectively insulated or protected.
- Display suitable notices/labels warning of the danger.
- Control access to areas where dangerous voltages are present.

Making and breaking connections

Many explosions happen when batteries are being connected or disconnected. The sparks produced when this is done incorrectly may cause the battery to explode, especially if it has just been charged. The correct way of making and breaking connections to batteries is as follows:

- Isolate the battery by turning off all the switches in the circuit. If the battery is in a vehicle, turn off the ignition switch as well.
- If the battery consists of a number of smaller connected batteries (cells), shroud the other terminals to prevent short circuits or flashovers when disconnecting the cells.
- **Disconnect the earthed terminal of the battery first.** On most vehicles, this is the terminal attached to the chassis, usually by a short, thick wire. In modern vehicles, the negative terminal (-) of the battery is earthed, but always check to make sure.
- Ensure that the connectors and terminals are clean and secure. Reconnect the earthed terminal last.

  Remember. Do not rest metal tools on or near the battery. If they fall across the battery terminals, they will cause a short circuit.

Charging batteries

Explosive gases are given off when batteries are charged. The risk of an explosion is great if the gases are allowed to collect. When charging batteries, follow the procedure below, together with the advice in the Work Safely! list on page 1.

Getting ready

- Make sure you understand the battery manufacturer's instructions on charging.
- Always use a dedicated, well-ventilated charging area.
- Do not smoke, carry out hot work (eg welding, brazing, grinding), or use a mobile phone in the charging area.
- Do not charge batteries below electric lights or other equipment that could be an ignition source.
- Check that the charging equipment is suitable for the battery, eg correct voltage and charging rate.

Charging

- Raise the lid or open the doors of the battery compartment **before** starting to charge the battery. This will help to prevent an explosive mixture of gases building up.
- Before starting to charge a vented battery, check that the electrolyte level is just above the tops of the plates in all the cells. Top up the cells with distilled or deionised water if the level is too low.

- Make sure the charger is switched off before connecting the charging leads to the battery (unless the charger manufacturer specifies a different procedure). Connect the charger's positive **(+)** lead to the battery's positive terminal and the negative **(-)** lead to the negative terminal.
- Check that the charging leads are securely clamped in position before switching on the charger.
- Never charge the battery faster than the battery manufacturer's specified maximum charging rate.
- Do not remove or adjust the charging leads while the charger is switched on. Always switch it off first.
- Switch off the charger before disconnecting the charging leads from the battery (unless the manufacturer's instructions specify otherwise).
- Allow a vented battery to stand for at least 20 minutes after disconnecting it from the charger. Carefully top up the electrolyte with distilled or deionised water to the manufacturer's recommended level.
- Store the charging leads so that the uninsulated parts do not rest against each other or any earthed metalwork. This will prevent short circuiting if the charger is switched on suddenly.

Details of the working life of each battery must be recorded: eg installation date, charging performance, volume of water added to which cell.

Some equipment is capable of carrying out 'fully controlled charging'. Here, the charging current is automatically reduced as the battery gets near to being fully charged. This type of equipment greatly reduces the risk of overcharging and so makes charging much safer.

Jump-starting

Jump-starting uses the charged (good) battery of one vehicle to start the engine of a second vehicle with a discharged (flat) battery. Whenever possible, follow the manufacturer's instructions for jump-starting a vehicle. If these are not available, use the procedure described in this section.

First of all, find out whether the negative or positive terminal of each vehicle's battery is connected to the chassis. This is known as the vehicle's earth polarity. Usually the negative terminal of the battery is connected to the chassis. In this case, the vehicle is said to have negative earth.

If the two vehicles have different earth polarities, the chances of error are much greater, and only competent people with suitable experience should carry out jump-starting.

Preparation

Follow the steps below:

- Check that the vehicles use the same voltage, eg 12 or 24 volts. If you are not sure that the vehicles have the same voltage, do not proceed.
- Ensure that the two vehicles are not touching.
- Ensure that each handbrake is securely applied and that the two vehicles are in neutral (or in park if fitted with automatic transmission).
- Turn off each ignition switch.
- Use appropriate, colour-coded (red for positive, black for negative) jump leads. These should be suitable for the expected electrical current and have insulated handles.

Connection (for vehicles with the same earth polarity)

Follow the steps below:

- Use the red jump lead to connect the non-earthed terminal of the good battery to the non-earthed terminal of the flat battery. (The non-earthed terminal is the terminal that is not connected to the vehicle's chassis.)
- Use the black jump lead to connect the earthed terminal (the terminal connected to the vehicle chassis) of the good battery to a suitable unpainted metal part of the chassis or engine of the dead vehicle. The point of attachment should be at least 15 cm from the battery and away from fuel and brake lines.

Connection (for vehicles with different earth polarities)

Do not attempt this unless you are competent to do so and have suitable experience. Follow the steps below:

- Use the **black jump lead** to connect the earthed terminal of the good battery to the non-earthed terminal of the flat battery.
- Use the **red jump lead** to connect the non-earthed terminal of the good battery to a suitable unpainted metal part of the chassis or engine of the dead vehicle. The point of attachment should be at least 15 cm from the battery and away from fuel and brake lines.

Starting the vehicle

Follow the steps below:

- Check that each handbrake is firmly applied and that each vehicle is in neutral or park.
- Make sure that all the leads are clear of anything that might start to move or rotate.
- Start the engine of the good vehicle and increase the engine revs a little to a fast idle (about 1500 rpm) for about one minute.
- Start the engine of the dead vehicle.

Disconnection

Follow the steps below:

- Stop the engine of the good vehicle and turn off the ignition. Leave the engine of the other vehicle running – the battery is still flat, so you will need to drive several miles before it has enough energy to restart the engine.
- Disconnect the leads in the reverse order to the one used to connect them.
- Do not allow the exposed metal parts of the leads to touch each other or other metal parts of the vehicles until both leads have been disconnected.

  Remember. If the metal parts of the leads are hot, do not handle them until they have cooled down.

Electric vehicles

Electric vehicles such as fork-lift trucks have large, specifically designed traction batteries. These provide large amounts of electrical power and use substantial electric currents during recharging. Many batteries and charger units have special fittings to reduce the chance of poor or incorrect connections.

As well as the advice in the Work Safely! list, remember the following points:

- Use a charging unit recommended by the manufacturer of the vehicle/battery.
- Raise the lid or open the doors of the battery enclosure to aid ventilation before starting to charge the battery.
- Switch off all electrical circuits before connecting or disconnecting the battery.
- Leave the battery to stand for at least 20 minutes after charging to allow any flammable gases to disperse.

Calculating ventilation requirements

This section gives detailed technical advice on how to reduce the risk from fire and explosion when batteries are charged.

Once the maximum charging current is known, the rate at which hydrogen is released during charging can be calculated. With this information it is possible to determine the airflow needed to provide effective ventilation and avoid a flammable atmosphere forming in the charging area. This approach may enable all but the immediate vicinity of the battery to be identified as non-hazardous when a hazardous area classification is carried out.[2,3]

In most situations, a zone 1 hazardous area (flammable atmosphere likely to be present) should be considered to exist for up to one metre in all directions around batteries under charge. All equipment present within the hazardous zone should be suitable and should be constructed and maintained to an appropriate standard.

Guidance on how to calculate the extent of the hazardous zone is available in BS EN 50272-2: 2001 *Safety requirements for secondary batteries and battery installations.*[4]

There is detailed information on hazardous area classification and the selection and use of appropriate electrical equipment in BS EN 60079-10: 2003: *Electrical apparatus for explosive gas atmospheres*.[2] Additional advice is also from available from publications by the Energy Institute (formerly the Institute of Petroleum) and the Institution of Chemical Engineers.[5,6]

Calculating the ventilation necessary for safe charging

Mixtures with air containing from 4% hydrogen (lower explosion limit – LEL) to 75% hydrogen (upper explosion limit – UEL) will readily ignite and explode.[7] Consequently, providing effective ventilation is one way of preventing a flammable mixture of hydrogen and air/oxygen accumulating.

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) require that 'adequate ventilation should maintain the average concentration of dangerous substances during normal operation to below that which could form an explosive atmosphere'.[8] Sufficient ventilation should be provided to ensure that the concentration of hydrogen is diluted well below the LEL.

The size of the 'margin of safety' provided by dilution ventilation should reflect the risk to people. In charging areas that people enter (workrooms) the concentration of hydrogen should not exceed 0.4% vol/vol (10% of the LEL). When charging takes place in an enclosure that people do not enter, the concentration of hydrogen should not exceed 1% vol/vol (25% of the LEL).

Effective dilution depends on several factors. These include the rate of hydrogen production; the location of the battery within the area; the shape and size of the area; and anything that would impede the natural circulation of air. However, in relatively uncongested areas natural ventilation is often sufficient to provide effective dilution.

The buoyancy of hydrogen causes it to rise from the battery and accumulate against ceilings or bulkheads. Consequently, charging areas and battery compartments or enclosures should be equipped with appropriate air vents, ie inlets at low level and outlets at high level. These should be located in two opposing exterior walls or in a door and an opposing exterior wall.

So long as the velocity of the airflow through these ventilation openings is at least 0.1 m/s, the minimum area of both the inlet and the outlet necessary to achieve the required airflow is given by the equation shown below.[9]

Minimum area of inlet/outlet needed = 0.3 x N x I x S cm^2

Where
N = number of cells in the battery(ies)
I = the overcharging current (amps)
S = the appropriate dilution factor; 10 for workrooms, 4 for enclosures

If natural ventilation is insufficient to achieve the required level of ventilation, suitable mechanical means should be used. The ventilation air must be drawn from and discharged to a safe place. An alarm system should be installed to detect build-up of hydrogen or failure of mechanical ventilation and to isolate electrical equipment in the area.

Worked example

Four batteries, each containing six cells, are located in a charging area (workshop) that people can enter. The batteries could receive an overcharging current of 20 amps. What is the minimum size of the ventilation openings needed to prevent a dangerous concentration of hydrogen forming in the charging area?

Calculation:

Minimum area of inlet/outlet needed = 0.3 x N x I x S cm^2

In this example:

N = number of cells in the battery(ies) = 4 x 6 = **24**
I = the overcharging current (amps) = **20**
S = the dilution factor for workrooms = **10**

Substituting the values for the example into the equation:

Minimum area of inlet/outlet needed = 0.3 x 24 x 20 x 10 cm^2

= 1440 cm^2

In this example, the inlet (low level) and outlet (high level) would **each** need to have a minimum area of 1440 cm^2 to ensure effective dilution of the hydrogen produced during charging.

Glossary

Charging current
The current supplied to the battery during the charging process. When calculating the ventilation requirements, the maximum current likely to be supplied by the charger during malfunction should be used so as to include a suitable safety margin.

Cell
Discrete voltage-producing part of a battery comprising a pair of electrodes and electrolytes.

Dangerous substance
Materials, such as hydrogen, petrol and natural gas, that can harm people through fire or explosion.

Earth polarity
Term describing which terminal (+ ve or - ve) of the battery is connected to the body of the vehicle.

Flammable
Capable of burning with a flame.

Flammable range
The concentration of a flammable vapour in air falling between the upper and lower explosion limits (see also below).

Fully controlled charging
Control of the charging process so as to prevent significant overcharging at the end. In addition, constant monitoring of the battery's behaviour for faults, and terminating the charging process if any are detected.

Hazard
Anything with the potential for causing harm. The harm may be to people, property or the environment, and may result from substances, machines or methods of work or work organisation.

Lower explosion limit (LEL)
The minimum concentration of vapour in air below which a flame will not be propagated in the presence of an ignition source. Also referred to as the lower explosive limit or the lower flammable limit (LFL).

Upper explosion limit (UEL)
The maximum concentration of vapour in air above which a flame will not be propagated in the presence of an ignition source. Also referred to as the upper explosive limit or the upper flammable limit (UFL).

Valve-regulated battery (maintenance-free battery)
A battery in which the gases produced during charging are contained within the electrolyte compartment and recombined to produce water. Flammable mixtures will only be released to the atmosphere if the battery malfunctions.

Vented battery
A battery in which the gases produced during charging are free to escape into the surrounding atmosphere.

References

1 *Memorandum of guidance on the Electricity at Work Regulations 1989. Guidance on Regulations* HSR25 HSE Books 1989 ISBN 0 7176 1602 9

2 BS EN 60079-10: 2003 *Electrical apparatus for explosive gas atmospheres. Classification of hazardous areas* British Standards Institution

3 PD 60079-14: 2000 *A guide to the application of BS EN 60079* British Standards Institution

4 BS EN 50272-2: 2001 *Safety requirements for secondary batteries and battery installations. Stationary batteries* British Standards Institution

5 IP Model code of safe practice in the petroleum industry Part 15: *Area classification code for installations handling flammable fluids* The Energy Institute 2005 ISBN 0 85293 418 1

6 Cox A W, Lees F P and Ang M L *Classification of hazardous locations* Institution of Chemical Engineers 1990 ISBN 0 85295 258 9

7 ISO/TR 15916: 2004 *Basic considerations for the safety of hydrogen systems*

8 *Control and mitigation measures. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance* L136 HSE Books 2003 ISBN 0 7176 2201 0

9 prEN 50276 *Gaseous emissions produced by traction batteries – ventilation and general safety requirements for closed charging areas* 1997

Further information

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This leaflet contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

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