BT5 End of Life Battery Preparation and Environmental Disposal

BY THE FARADAY INSTITUTION AS A DELIVERY PARTNER OF THE FARADAY BATTERY CHALLENGE BY INNOVATE UK

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THE FARADAY INSTITUTION

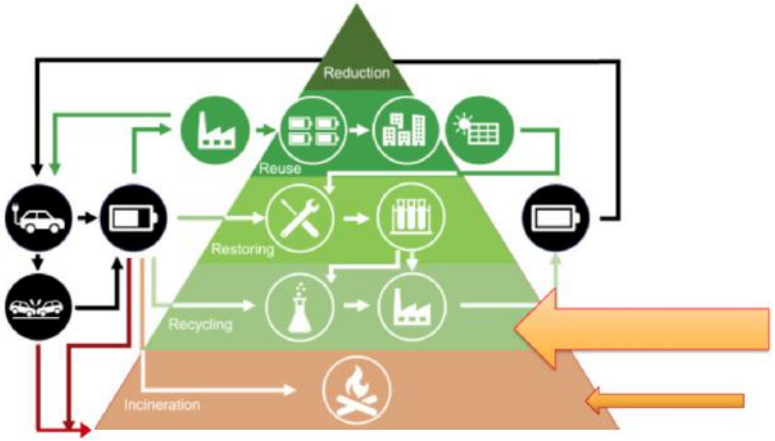
BT5 End of Life Battery Preparation and Environmental Disposal

Image: Freepik.com

Contents

1. Understand the safe handling and risk management around end-of-life preparation.
2. Understand the waste refuge process for batteries.
3. Understand the key recycling operations for low voltage batteries.
4. Understand the key recycling operations for high voltage batteries.
5. (Practical) Demonstrate the disassembly of a battery pack.

Notes:



Why Would You Still Need an Incineration Process?

Notes:

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Conforming to Battery Regulations and Standards

WEEE Regulations
(EC) 2006/66/EC on batteries and accumulators and waste batteries and accumulators
(this regulation covers - battery packs, modules and cells only.)

Notes:

(EC) 2006/66/EC – Portable Batteries

Portable batteries are:

- Sealed
- Under 4Kg and carried by an average person without difficulty
- Not an automotive or industrial battery
- Not designed exclusively for industrial or professional use

Notes:

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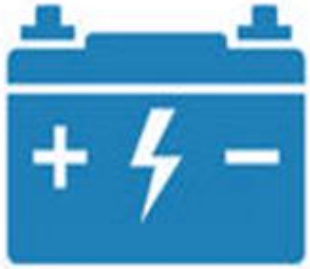

Notes:

(EC) 2006/66/EC – Industrial Batteries

Industrial batteries are:

- Designed only for industrial/professional use
- Used as a source of power for propulsion in an electric or hybrid vehicle
- Unsealed, but not an automotive battery
- Sealed and not a portable battery

Notes:

(EC) 2006/66/EC – Automotive Batteries

Automotive batteries are:

- Designed for vehicles, including those used off road, such as racing cars and tractors
- Any battery used in vehicles, such as in the key fob/remote

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Waste Refuge Centres

All local authorities (waste refuse centres) in the UK will collect and process household and ‘low voltage’ automotive batteries.

Automotive ‘waste collectors’ (sometimes referred to as car scrapyards) will buy (plus test for safety), then either sell on or move to an ‘ABTO’ approved battery treatment operator a larger ‘HV’ battery pack from a vehicle.

Notes:

Image: Freepik.com

Waste Refuge Centres cont.

Manufactures also have a collection scheme and storage area for a return to base system for the ‘HV’ battery packs. (The manufacturer is still responsible for safe repair, recycling or disposal of its products.)

Notes:

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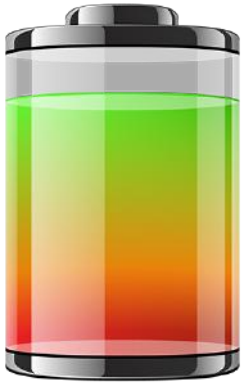

Battery Waste which can be Processed at Refuge Centres

All household batteries including 'button' batteries from watches.

Battery packs from laptops, mobile phones, power tools and remote-control units.

Car batteries can also be recycled but only at designated collection points, not in your home recycling.

Notes:

Form: Delegation of approved/appropriate person

This form is for packaging/battery companies to delegate their document signing function

January 2017

An approved/appropriate person must sign applications for approval and registration, data submissions (including data template submissions and changes to registration details and data) and statements of compliance/declaration of compliance. The approved/appropriate person is responsible for submitting data either to

- the Compliance Scheme acting on its behalf the appropriate authority*
- the Secretary of State (Regulatory Delivery)

The approved/appropriate person must be one of the following

Legal entity	Approved/Appropriate person
Company registered in UK	A Director or the Company Secretary*
Partnership	A Partner
Sole Trader	Individual
Other	A person who has control or management of the business

*According to Companies House registration

If you are an approved/appropriate person of an operator and you want to delegate your function for signing documents or information to another person you must sign a statement confirming you wish to delegate your function and return it to the relevant environmental regulator or Secretary of State. If you are a member of a compliance scheme, you may choose to submit your request via them. We have 28 days to assess your application from when we receive it.

If you are not a member of a compliance scheme, you must ensure that the proposed delegate is given the appropriate access to NPWD by your SuperUser. If you do not know your NPWD number, you can find this on the public registers on NPWD at:
https://npwd.environment-agency.gov.uk/

* Environment Agency for England, National Resources Wales for Wales, SEPA for Scotland and Northern Ireland Environment Agency for Northern Ireland.

Approved Battery Treatment Operator (ABTO) – Licence and Approval

To apply for approval you must have:

- At least one UK site for treating and recycling waste batteries
- An ’environmental permit’.

Notes:

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NPWD code:	
Appropriate person: position held in company (please tick as appropriate)	☐ Director ☐ Company Secretary ☐ Company Owner/Sole Trader ☐ Partner
Email address	
Regime delegation is for (please tick all that apply)	☐ Packaging ☐ Batteries
Proposed delegate's name	
Position in company and level of seniority (if applicable)	
If this person is not a member of your company, what is the nature of this person's relationship with you (as appropriate person)	
Please confirm if the proposed has: (please tick as appropriate)	☐ Suitable knowledge of the relevant regulations ☐ Access to all the information needed to carry out this function

I confirm that I am the "approved/appropriate person" for the above in respect of the Packaging /Batteries Regulations and request that I delegate my document-signing function.

Signed: Name (please print):

Date:

If you are a member of a compliance scheme, please ensure you inform your scheme of any changes you make to your registration, including delegation of authority.

Approved Battery Treatment Operator (ABTO) – Licence and Approval cont.

An approved or appropriate person is:

- A director or company secretary of a registered company
- A partner or member of a partnership, including limited liability partnership
- The obligated person if providing information as an individual
- A person who has management of that body (the producer is a company not registered in the UK)

Notes:

Battery packs, Modules or cells.

WEEE

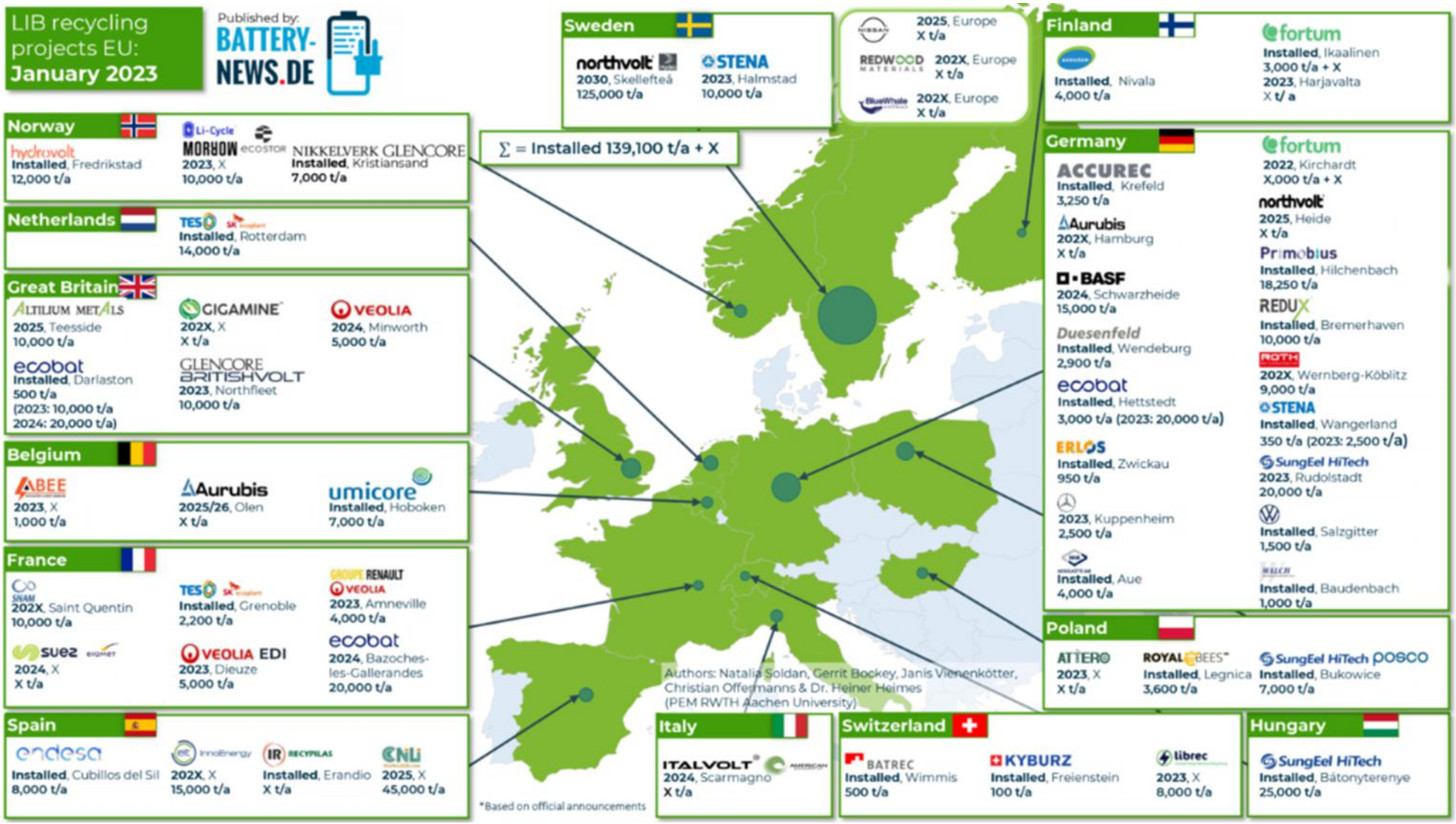
Compliance: Labelling and Packaging

WEEE Labelling needs to be clear on products, and separated into:

- Waste Electrical and Electronic Devices (Right Symbol)
- Waste Batteries (Left Symbol)

Notes:

Lithium-Ion Battery Recycling Projects



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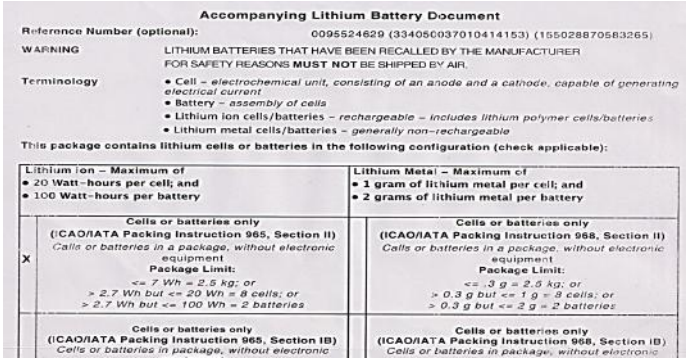
Battery Passports

Traceability information across the supply chain

- Country of origin
- Raw materials
- Quantities present

There are environmental considerations that relate to the mining of battery materials. The extraction of lithium from Salars can divert hundreds of thousands of gallons of water from agricultural operations. Also, chemicals can find their way into the water supply, harming wildlife.

Notes:



Accompanying Lithium Battery Document

Reference Number (optional): 0095524629 (33405003701041415 3) (155028870583265)

WARNING LITHIUM BATTERIES THAT HAVE BEEN RECALLED BY THE MANUFACTURER FOR SAFETY REASONS **MUST NOT** BE SHIPPED BY AIR.

Terminology
- **Cell** – *electrochemical unit, consisting of an anode and a cathode, capable of generating electrical current*
- **Battery** – *assembly of cells*
- **Lithium ion cells/batteries** – *rechargeable – includes lithium polymer cells/batteries*
- **Lithium metal cells/batteries** – *generally non–rechargeable*

This package contains lithium cells or batteries in the following configuration (check applicable):

	Lithium Ion – Maximum of • 20 Watt–hours per cell; and • 100 Watt–hours per battery	Lithium Metal – Maximum of • 1 gram of lithium metal per cell; and • 2 grams of lithium metal per battery
X	**Cells or batteries only (ICAO/IATA Packing Instruction 965, Section II)** *Cells or batteries in a package, without electronic equipment* **Package Limit:** *<= 7 Wh = 2.5 kg; or > 2.7 Wh but <= 20 Wh = 8 cells; or > 2.7 Wh but <= 100 Wh = 2 batteries*	**Cells or batteries only (ICAO/IATA Packing Instruction 968, Section II)** *Cells or batteries in a package, without electronic equipment* **Package Limit:** *<= .3 g = 2.5 kg; or > 0.3 g but <= 1 g = 8 cells; or > 0.3 g but <= 2 g = 2 batteries*
	Cells or batteries only (ICAO/IATA Packing Instruction 965, Section IB) *Cells or batteries in package, without electronic*	**Cells or batteries only (ICAO/IATA Packing Instruction 968, Section IB)** *Cells or batteries in package, without electronic*

EU Legislation

EU legislation will require batteries to have minimum amounts of recycled content, lowering the environmental burden, but also reducing Europe's dependence on raw materials.

By 2035, EV battery recycling could provide at least 22% of the lithium and nickel and 65% of the cobalt necessary for European production.

Notes:

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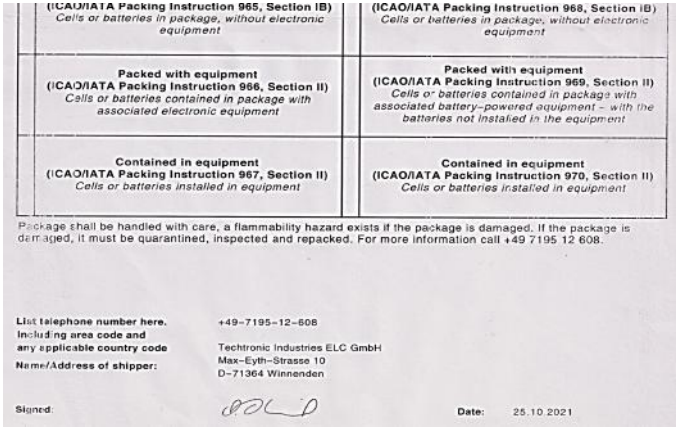

(ICAO/IATA Packing Instruction 965, Section IB) *Cells or batteries in package, without electronic equipment*	(ICAO/IATA Packing Instruction 968, Section IB) *Cells or batteries in package, without electronic equipment*
Packed with equipment **(ICAO/IATA Packing Instruction 966, Section II)** *Cells or batteries contained in package with associated electronic equipment*	**Packed with equipment** **(ICAO/IATA Packing Instruction 969, Section II)** *Cells or batteries contained in package with associated battery-powered equipment – with the batteries not installed in the equipment*
Contained in equipment **(ICAO/IATA Packing Instruction 967, Section II)** *Cells or batteries installed in equipment*	**Contained in equipment** **(ICAO/IATA Packing Instruction 970, Section II)** *Cells or batteries installed in equipment*

Package shall be handled with care, a flammability hazard exists if the package is damaged. If the package is damaged, it must be quarantined, inspected and repacked. For more information call +49 7195 12 608.

List telephone number here, including area code and any applicable country code: +49-7195-12-608

Name/Address of shipper: Techtronic Industries ELC GmbH
Max-Eyth-Strasse 10
D-71364 Winnenden

Signed: Date: 25.10.2021

EU Legislation

Most car manufacturers offer eight-year, 100,000 mile battery warranties, which – in simple terms – batteries recycled today first hit the road in 2010.

By the 1st January 2026, each industrial battery and electric vehicle battery placed on the EU market or put into service and whose capacity is higher than 2 kWh shall have an electronic record ('battery passport').

Notes:

Proposed Digital Tesla Battery Passport

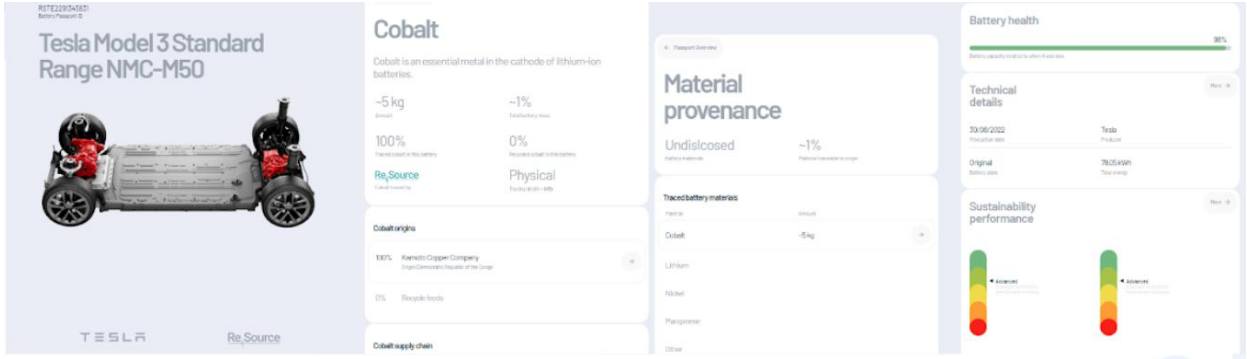

Image Source: resource.batpas.com

Notes:

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Conforming to Health & Safety and Legislation

There are a number of legislations which are relevant to battery preparation and disposal. These include:

- (UN) ECE – R100 Rev 2
  https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/2013/R100r2e.pdf
- Electricity at Work Regulations (EAWR-89)
  https://www.hse.gov.uk/pubns/books/hsr25.htm
- (HSE) Electric and Hybrid Vehicles
  https://www.hse.gov.uk/mvr/topics/electric-hybrid.htm
- (HSE) Using Electric Storage Batteries Safely
  https://www.hse.gov.uk/pubns/indg139.pdf
- GS38 (Electrical Test Equipment)
  https://www.hse.gov.uk/pubns/books/gs38.htm
- Health & Safety at Work Act
  https://www.hse.gov.uk/legislation/hswa.htm
- (HSE) Managing for Health & Safety
  https://www.hse.gov.uk/pubns/priced/hsg65.pdf
- Reporting of Injuries, Diseases and Dangerous Occurrences (RIDDOR)
  https://www.hse.gov.uk/pubns/indg453.pdf
- Control of Substances Hazardous to Health (COSHH)
  https://www.hse.gov.uk/coshh
- Personal Protective Equipment (PPE)
  https://www.hse.gov.uk/pubns/indg174.pdf

Notes:

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Health & Safety at Work Act (HAWA)

- This act is called an Enabling Act.
- The majority of prosecutions are made under the Health and safety at Work act 1974.
- It sets out the basic principles by which health and safety is regulated.
- It outlines duties that employers have to their employees and vice versa.
- The act covers regulations that explain the practical details of maintaining a safe working environment, Safe Place of Work, Safe Systems of Work.

Notes:

Image: Freepik.com

Health & Safety at Work Act (HAWA) cont.

The Health and Safety at Work Act (HASAWA) is the primary piece of legislation covering occupational health and safety in Great Britain.

The Health and Safety Executive, along with local authorities (and other enforcing authorities) is responsible for enforcing the Act.

Notes:

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Image: PNGMart.com

Notes:

Health & Safety at Work Act (HAWA) cont.

The Act sets out the general duties:

- employers to their employees
- employers and self-employed to persons other than their employees
- employees at work

Image: PNGMart.com

Health & Safety at Work Act (HAWA) cont.

Notes:

The main requirement of employers is to carry out a risk assessment.

Employers with five or more employees need to record the significant findings of the risk assessment and do the following:

- Make arrangements to resolve the health and safety risks identified
- Appoint a capable person to put in place any health and safety arrangements
- Set up emergency procedures
- Provide clear information and training to employees

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Health & Safety at Work Act (HAWA) – Duties of Employees.

- Employees have a duty to comply with certain provisions of the appropriate health and safety legislation
- Take reasonable care while at work for his or her own health and safety and for that of persons who may be affected by his or her acts or omissions at work
- To cooperate with the employer on safety matters

Notes:

Control of Substances Hazardous to Health (COSHH)

Control of Substances Hazardous to Health Regulations (COSHH). This legislation covers substances that are hazardous to health.

Substances can take many forms which includes:

- Chemicals
- Products containing chemicals
- Fumes
- Dusts

Notes:

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Control of Substances Hazardous to Health (COSHH) cont.

Every year, thousands of workers are made ill by hazardous substances, contracting lung disease such as asthma, cancer and skin disease such as dermatitis. These diseases cost many millions of pounds each year to:

- Industry, to replace the trained worker
- Society, in disability allowances and medicines
- Individuals, who may lose their jobs

Notes:

Control of Substances Hazardous to Health (COSHH) – Hazard Statements

A hazard statement is a phrase that describes the nature of the hazard in the substance or mixture. A hazard statement will be determined by the application of the classification criteria.

Examples of battery hazard statements include:

- Hazardous voltage inside
- Toxic if swallowed
- Corrosive, if the battery is leaking
- Explosive, risk of explosion if damaged, punctured or pierced

Notes:

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Control of Substances Hazardous to Health (COSHH) cont.

The Control of Substances Hazardous to Health Regulations (COSHH) requires the employer to consider:

- Preventing exposure to hazardous substances
- Replacing with a safer alternative
- Changing the process to limit exposure

If this cannot be achieved then assess the risk from the substance.

Notes:

Control of Substances Hazardous to Health (COSHH) cont.

Identify the substances

- Their use
- Where used?

Identify who is at risk

- Who comes into contact?

Assess the risk

- What is the hazard?
- The likelihood of harm occurring
- The seriousness of injury that may occur

Notes:

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Training Requirements for COSHH

The employer must provide information, instruction, training and supervision on:

- Risks from the hazardous substances
- Control measures used
- Spillage procedures
- How to report problems or faults
- Emergency procedures

Notes:

Control of Substances Hazardous to Health (COSHH) – Control Measures

As an employer, if control measures for the hazard are not possible then you should:

- Enclose the process
- Reduce the duration of exposure
- Provide ventilation
- Provide a safe system of work
- Ensure correct and appropriate PPE
- Provide training on all of the above

Notes:

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Notes:

Control of Substances Hazardous to Health (COSHH) – Control Measures cont.

Hazardous substances can enter the body via:

- Inhalation
- Ingestion
- Injection
- Absorption
- Instilled (eye)

Notes:

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations. Employers are required to report any work-related incidents, injuries and diseases to the Health and Safety Executive (HSE), or to the local authority environmental health department.

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Report Number (consecutive)

Report Number (consecutive)

Accident Record

1 About the person who had the accident

Name

Address

Postcode

Occupation

2 About you, the individual filling in this record

If you did not have the accident write your address and occupation

Name

Address

Postcode

Occupation

3 Details of the accident (Continue on the back of this form if you need to)

When it happened: Date / / Time

Where it happened: Exact location

How did the accident happen?

Give the cause if possible

If the person who had the accident suffered an injury, give details

Sign the record and date it

Print Name Sign Date / /

4 For the employer only

Complete this box if the accident is reportable under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR).

How was it reported?

Print Name Sign Date / /

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) cont.

Notes:

The employer is required to record any work-related incidents, injuries and diseases in an accident book with:

- date and time of the incident
- details of the person affected
- the nature of their injury or condition
- their occupation
- the place where the event occurred
- a brief note on what happened

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) cont.

Notes:

An employee must report any of the following to the employer:

- Accidents
- Injuries
- Near misses

These events must be recorded in the accident book and the employer must investigate the incident.

BT5 End of Life Battery Preparation and Environmental Disposal

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) cont.

The following injuries or ill health must be reported:

- The death of any person;
- Specified injuries requiring immediate medical attention.
- 'Over-seven-day' injuries, relieving someone of their normal work
- For more than seven days as a result of injury caused by an accident at work.
- Reportable occupational diseases.
- Near misses, described as 'dangerous occurrences'.

Notes:

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) cont.

Timescales for notification of accidents to the Incident Contact Centre or enforcing authority:

- Immediately – deaths, major injuries and dangerous occurrences.
- Over 7 day absence – within 15 days.
- Over 3 day absence – record but do not report.

Notes:

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Health & Safety Enforcement

Health and Safety Executives and Environmental Health Officers (working for the local authority) have the following enforcement powers and duties:

- Gain entry to premises at any reasonable time
- Give instructions
- Take samples, photographs and seize dangerous equipment
- Ask questions
- Advise employers and safety
- Be representatives

Notes:

Enforcement Actions

Enforcement actions can include:

- Give verbal or written advice
- Serve an improvement notice
- Serve a prohibition notice
- Commence a prosecution

Notes:

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RIDDOR – Penalties for Breaking the Law

Notes:

The penalties applicable to the Reporting of Injuries, Diseases and Dangerous Occurrences are as follows:

- Magistrates court:
  - Maximum fine £20,000
  - Maximum 6 months in prison
- Crown court:
  - Unlimited fine
  - Maximum 2 years in prison

Safety Issues – HV Battery Packs

Notes:

When removing and storing any HV system components, it is vital that all safety precautions and recommendations are followed.
You must have the required qualification and licence to work on an EV and remove the High Voltage battery pack.
Some of the safety precautions and recommendations are:

- Cutting corners
- High voltages
- Risking lives
- PPE
- Correct tooling

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Typical Hazards from a Lithium-ion Battery – Thermal Runaway

- Abuse / Stress leads to thermal runaway / fire.
- Rapid exothermic reaction – catastrophic decomposition and fragmentation (flying debris)
- Very high temperature (1300°C+)
- Very high gas flow rates (100's litres/second)
- Toxic gases and particulates.

Notes:

Typical Hazards from a Lithium-ion Battery – Leakage

- Damage or abuse leads to leaking electrolyte (potentially toxic chemicals).
- Potential for HF (Hydrofluoric Acid) to be present.
- Hydrofluoric acid is a serious systemic poison. It is highly corrosive. Its severe and sometimes delayed health effects are due to deep tissue penetration by the fluoride ion.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Typical Hazards from a Lithium-ion Battery – Cell Venting

- Abuse or Stress leads to gas build up and venting.
- Potential for flammable gas build up, leading to explosive atmosphere.

Notes:

Battery Safety Issues

Battery failure can be caused by:

- Impact damage puncturing the cell wall
- Cell degradation and impurities in the cell during manufacturing
- Over discharging and charging
- Water ingress into the cell modules
- Overheating because of a cooling system failure

Notes:

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Battery Safety Issues – Cell Degradation

When Li-ion cells charge and discharge over a long time, deposits form around the anode. Cell manufacturing is normally done in a cleanroom to stop additional materials being added to the anode and cathode layers.

If these materials are allowed to become embedded in the layers then puncturing of the separator becomes inevitable which leads to a direct short between the anode and cathode.

Notes:

Battery Safety Issues – Cell Pressuring/Venting

Charging above 4.2 V or the failure of the cell charging system leads to increased heat and swelling of the Li-ion cell.

If the pressure is too high depending on the cell structure, a release valve is incorporated into the cell casing, however this pressure release can also lead to thermal incidents inside the battery housing.

Notes:

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Battery Safety Issues – Overcharging

The sole purpose of a battery/cell is to store energy and release this energy at the desired time. The energy batteries supply stay high during most of its charge and then drops away rapidly as the charge depletes. If the discharge is allowed to continue (as the charge is rapidly depleting) then irreversible damage is caused to the battery.

Notes:

Battery Safety Issues – Overcharging cont.

This may cause the electrolyte to dry up and the separator to breakdown. Battery life and stability is directly related to the amount and length of stress the battery is subjected too. The stressing of the battery is directly related to charge and discharge rate along with temperature.

Notes:

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Battery Safety Issues – Impact/Puncture Damage

Impact damage is one of the main causes of extreme temperature leading to a fire of the battery and case.

Impact damage that penetrates the cell module housing but not the cell modules leads to the ingress of water. This leads to overheating or shorts in the battery housing.

Impact damage that penetrates the cell modules generally leads to damage to the separator allowing a direct short between the anode and cathode.

Notes:

Battery Safety Issues – Potential Injuries

Potential injuries from batteries include:

- **B**urns
- **S**hocks
- **A**rc
- **F**ire
- **E**xplosion

BSAFE – Keep safe and know how to control electrical hazards.

Notes:

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Battery Safety Issues – Hydrogen Fluoride (HF) Electrolyte Burns

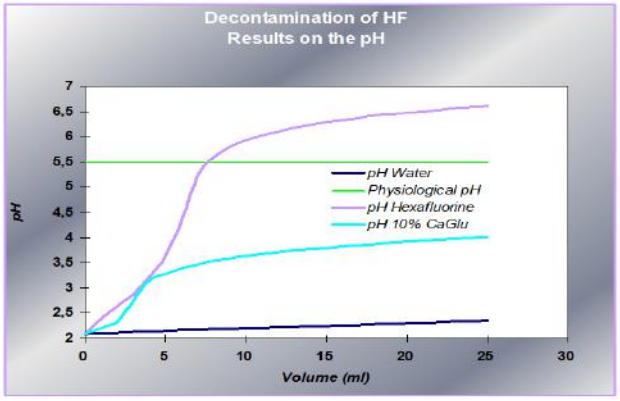
Some materials are vulnerable to moisture due to their chemical properties.

$LiPF_6$ (Lithium Hexafluorophosphate) is contained in the electrolyte of a lithium-ion battery.

When hydrolysed, $LiPF_6$ releases HF (Hydrogen Fluoride) that causes serious damage to a human body when in contact with the skin, eyes or if ingested.

Hydrogen Fluoride causes necrosis from within the skin and must be treated immediately.

Notes:



Battery Safety Issues – Hydrogen Fluoride (HF) Electrolyte Burns

- Liquid: retains the mechanical effect.
- Absorption capacity:
  - Stops the corrosive action of H^+ ions *(3 ions fixed by each molecule)*
  - Stops the toxic action of F^- ions *(6 ions fixed by each molecule)*
- Hypertonicity: stops the penetration.
- Application: on the eye and the skin.

Notes:

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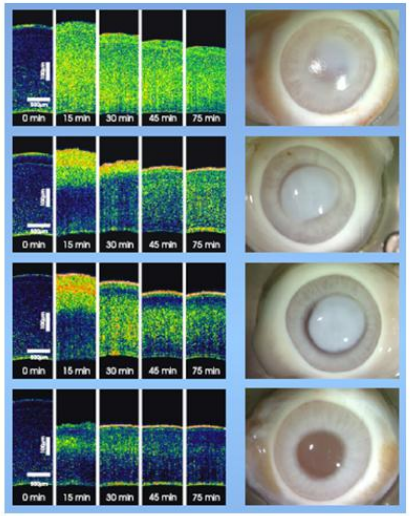
Influence of different washing solutions on HF penetration through the cornea.

- 20s of contact,
- 25ml of 2.5% HF,
- 15 minutes of washing



Without washing

Using water

1% Calcium Gluconate Solution (C-Gel)

HEXAFLORINE® No Burn

Source: *Schrage F, Frentz M, Spöler F, Först M, Kurz H. Accepted for publication in Burns*

Notes:

AC and DC – The Effect of Current (Ref IEC 60479-2)

DC current will make a single continuous contraction of the muscles compared to AC current, which will make a series of contractions depending on the frequency it is supplied at.

In terms of fatalities, both kill but more milliamps are required of DC current than AC current at the same voltage.

The severity of the electric shock depends on the following factors: body resistance, circuit voltage, amplitude of current, path of the current, area of contact, and duration of contact.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

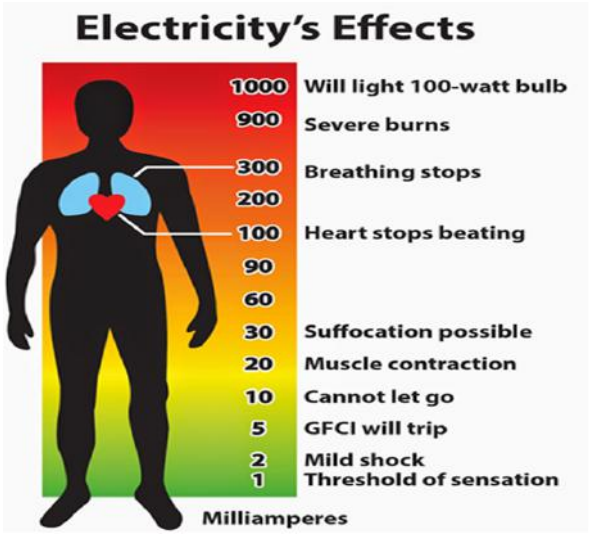
AC and DC – The Effect of Current (Ref IEC 60479-2)

Though both AC and DC currents and shock are lethal, more DC current is required to have the same effect as AC current.

For example:
If you are being electrocuted or shocked 0.5 to 1.5 milliamps of AC 60 Hz current is required and up to 4 mA of DC current is required.

For the let-go threshold in AC a current of 3 - 22 mA is required, against 15 - 88 mA of DC current.

Notes:



AC current (mA) @230V	Effect on Human body
1mA	Slight tingling sensation
1-3mA	Small shock
3-22mA (15-88mA DC)	Muscles contract, causing you to freeze. Known as the Let go threshold.
22-40mA	Respiratory muscles can become paralysed; pain; exit burns often visible
40-100mA	Usually fatal; ventricular fibrillation; entry & exit wounds visible
>100mA	Death almost certain; if survive will have badly burnt organs and probably require amputations

Notes:

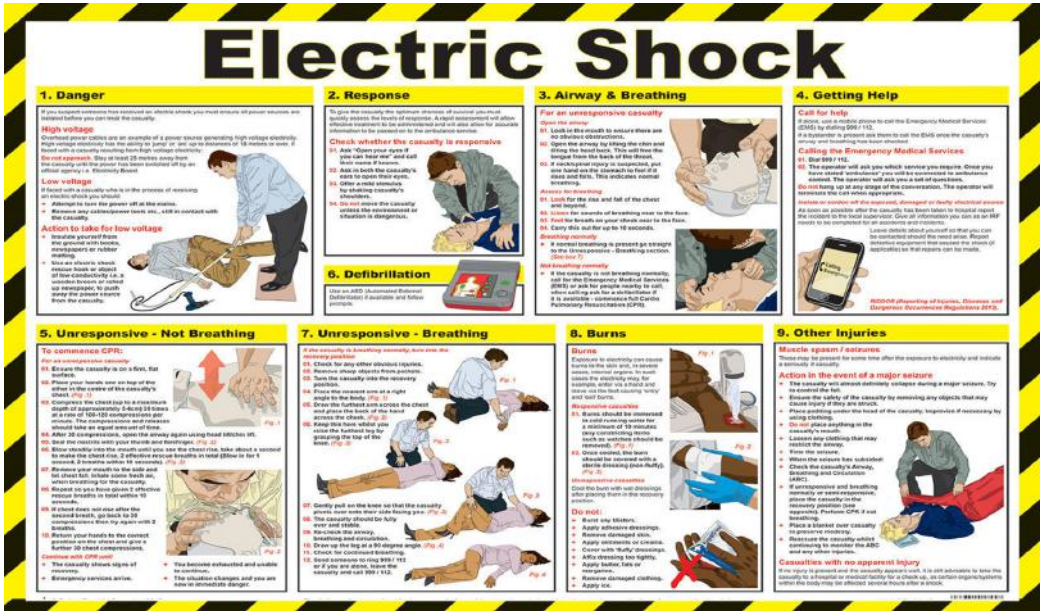
BT5 End of Life Battery Preparation and Environmental Disposal

Emergency Procedures - The Effect of Current (Ref IEC 60479-2)

The best way you can help somebody is to disconnect them from the power.
If 15-88mA (DC) or above they may be unable to free themselves.

If the power cannot be disconnected try and remove the person from the power source with a non-conducting item (Electrical Safety Hook).
Once the situation is safe administer First Aid and wait for the ambulance / paramedic.

Notes:



Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Working Practices

- Employers must carry out a Risk Assessment for each task or operation.
- SOPs: Standard Operating Procedures / Safe Operation Practices must be adhered to.
- When the hazards and risks are identified Safe Schemes of Work (SSW) must be introduced.
- SSWs may include: No lone working or handling of machinery, calibration of test equipment, protective methods and protective equipment.

Notes:

Reporting Electrical Incidents

Report all electrical shocks and near misses
RIDDOR:2013 legal responsibility to report to the HSE

- Electricity is invisible – this in itself makes it dangerous
- It has great potential to seriously injure or kill
- Every company has a duty of care to its employees and contractors
- Everyone is exposed to electrical hazards, not just electricians

All employees can be exposed to electrical hazards. They should receive electrical hazard training at the commencement of their employment and regular refresher training.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

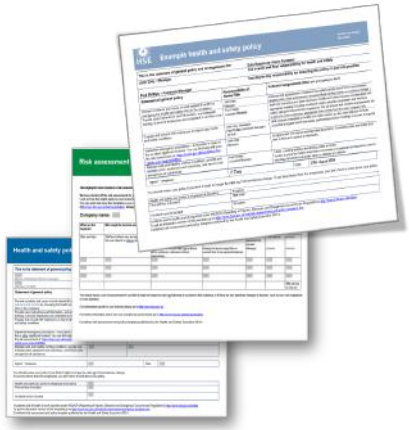
Notes:

Health & Safety Toolbox

The health and safety toolbox is a comprehensive guide from the HSE on 'how to control risks at work'.

It contains guidance on how small to medium-sized businesses can put measures in place to control the risks and includes:

- Case studies
- Simplified advice
- Helpful lists/do's and don'ts
- Updates on legal changes
- Detail information / sources of advice



Notes:

Health & Safety Policy Documents

- Workplace General Policy documents
- Safe Schemes of Work (SSW)
- Health and Safety Policy documents
- Risk Assessment / Risk Management documents
- Electrical / PAT / Gas Safe testing records
- Standard Operating Procedures (SOPs)
- Staff training / CPD records
- Accident book - records
- Incident or near miss reporting forms
- Layout map of fire evacuation / escape route plans

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ID	Date raised	Risk description	Likelihood	Severity	Risk	Owner	Mitigation action
001	17/02/22	Main HSO is absent who will cover the role?	Possible	Moderate	6	Management	Have a 2nd person trained? IOSH

Example

Health & Safety Workplace Training

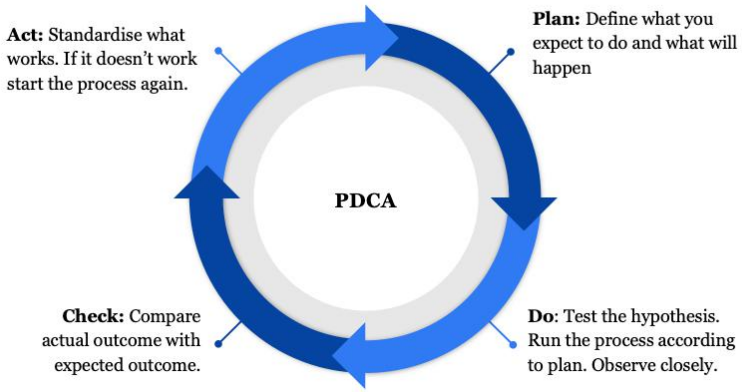
Who is needed and what are their titles?

- The Health and Safety Officer (HSO)
- Fire Wardens
- Fire Marshalls
- Anti-terrorism - trained personnel
- First Aiders

Additional to staffing:

- H&S Communications / Bulletins
- H&S Risk Management

Notes:



Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Risk Assessment

Identify hazards and risk factors that have the potential to cause harm (hazard identification). Determine appropriate ways to eliminate the hazard or control the risk when the hazard cannot be eliminated (risk control).

Notes:

Identify the Hazard

- Check manufacturers' instructions or data sheets / SDS sheets / battery passports for chemicals and equipment as they can be very helpful in spelling out the hazards and putting them in their true perspective.
- Look back at your accident and ill-health records - these often help to identify the less obvious hazards.
- Take account of non-routine operations (e.g. maintenance, cleaning operations or changes in production cycles).
- Remember to think about long-term hazards to health (e.g. high levels of noise or exposure to harmful substances).

Notes:

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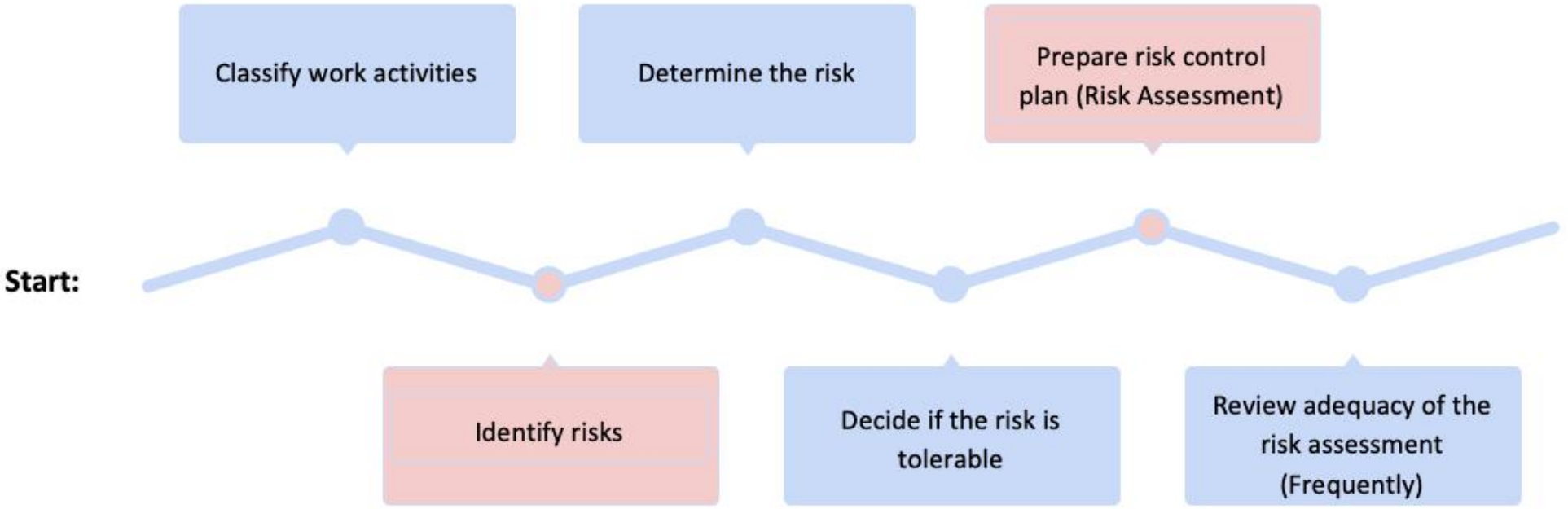
Risk Identification



Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

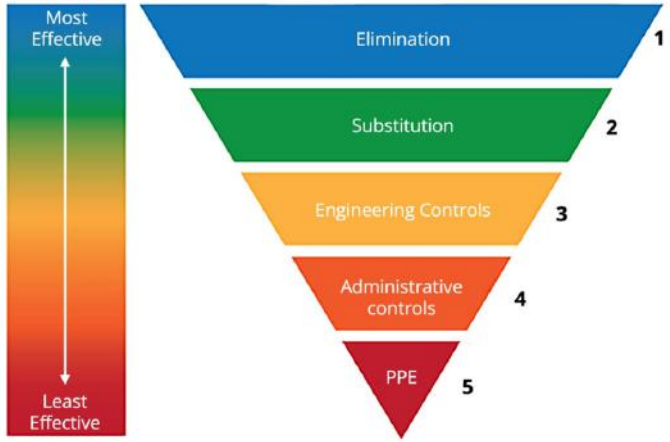
High Voltage Workplace Observations

Additional safety measures must be taken when working with HV components / parts and assemblies.

Measures should be in place to identify:

- The space around a HV designated component / part or assemblies
- The cleanliness of the area
- All tools, equipment and PPE

Notes:



Personal Protective Equipment (PPE)

Personal Protective Equipment at Work Regulations require employers to ensure that suitable personal protective equipment (PPE) is provided free of charge.

However, in electrification activities it is our first line of defence, ultimately the most important factor that will keep you alive when carrying out activities on HV.

Notes:

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Class zero (0) or double zero (00) rubber gloves, which you have checked for damage before wearing

A cotton inner glove and a protective outer glove

Non-conductive face shield.

Overalls made from natural materials (e.g. cotton).

Non-conductive footwear, with Electrical Hazards (EH) protection.

Notes:

IMPORTANT: Use a rubber (electrical) mat at all times.

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Safety Issues Relating to Tools & Equipment

Make sure the equipment you are using:

- Has the correct CAT rating for the vehicle you are working on.
- Has a CAT III rating of 1000 V DC and leads rated at 1000 V DC these would be suitable for most electric vehicles.
- Has a CAT III rating of 600V DC and leads rated at 600 V DC this equipment would not be suitable for a system delivering at 720V DC.
- Are fully insulated tools (1000 V DC) - spanners, screwdrivers, pliers, cutters and socket sets etc.

IMPORTANT: Do not rely on the CAT rating alone, please check the safety voltages of the equipment and the output voltage of the HV system.

Notes:

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Civilian Protection Equipment (CPE)

Protection equipment to protect civilians when working on high voltage batteries includes:

- Barriers
- Signage
- Fire extinguishers
- Electrical safety hook
- AED
- Burns kit
- First aid kit
- Spill kit

Notes:

High Voltage Battery – Effective Segregation

The removed HV battery needs to be secured from mechanical damage and should be stored out of the working area and regular commuting ways. If required a collision protection should be installed.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

High Voltage Battery – Effective Segregation cont.

Consideration needs to be given to:

- Correct lifting of the battery using the lifting eyes or mountings
- Placing the battery on a level ground
- Ensuring the working area is sufficiently ventilated
- Having a Class D L2 powder fire extinguisher in the work area
- Correctly marking out the work area

Notes:

Data Sheets

A data sheet is created by the manufacturers and summarises the performance and other characteristics of a product.

A safety data sheet (SDS) lists the information relating to occupational safety when using the substance or product. This can include listing potential hazards and providing spill handling procedures.

Notes:

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HV Battery - Anchor Points

Manual Handling Operations Regulations (MHOR)

The main provisions of these Regulations require employers to:

- Avoid the need for employees to undertake any manual handling activities involving risk of injury.
- Assess risks of the task, load and individual to carry out a manual handling tasks to try to reduce the risk of injury.
- Provide employees with information on the weight of each load (object, person or animal).

Where an employee is required to carry out a manual handling task, appropriate training of how to lift, carry and replace the load should first be given.

Notes:

Lifting and Slinging

Steps for safe lifting and slinging:

- Pre-use checks (inspecting the equipment)
- Select the correct lifting equipment
- Make sure the load is secure
- Lifting and slinging angles
- Check the area (hazards / collision)
- Moving the load (pre-warnings / observations)
- Lowering loads
- Post operational checks.
- Storage of the lifting and slinging equipment

Notes:

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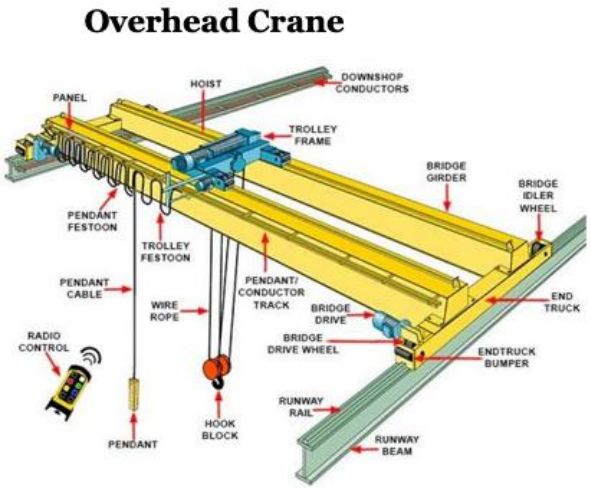
Pre-use Checks

Before any **lifting** and **slinging** takes place a pre shift check must be carried out on the equipment used. This includes checking for, rips, tears, cracks, stitching coming loose, wear, clasps, discoloration, tags, to name just a few.

Report any faults immediately.

Notes:



Select the Correct Lifting Equipment

Before lifting a load make sure the weight, size, material, shape etc of the load is taken into account before selecting the correct lifting equipment.

Notes:

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(Colour Coded / Weight Rated) Sling

Crane Hoist

Lifting Chains / Sling Hooks

Make Sure the Load is Secure

The correct method of securing the load when Lifting and Slinging is essential. ALWAYS double check the load is secure and will not come loose in transport. REMEMBER a choke hitch reduces what the sling can lift by 20%.

Notes:

Lifting and Slinging Angles

The best way to lift any load is vertical/straight up. Sometimes multi connection points are needed to secure the load, especially on long/wide loads.

REMEMBER that the lifting angle (including/working angle) will decrease what the sling can lift as the angle gets bigger. The recommended including angle between the two legs of a sling is 90 degrees. Always read the slings tag Lifting and slinging recommended angles.

Notes:

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Check the Area

Before moving the load, check the route to make sure all precautions are taken to reduce the risk of an accident.

E.g. securing the area, doorways are blocked, making sure pedestrian are safe and clear etc.

Notes:

Moving the Load

The Make sure loads are carried at ground level. Under NO circumstances must loads be carried over people's heads. Hand signals can be used if necessary.

Notes:

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Lowering Loads

Always ensure the load has a destination location before moving. Lower loads carefully ensuring the load is stable once in place.

Never drag material slings or chains from underneath a load, place on runners/skids if necessary.

Notes:

Post Operational Check

A check should be completed once the Lifting and Slinging is done.

This is to so you are confident that everything is functioning as it should. Make sure no damage has occurred while using the equipment and report any faults immediately.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Storage of the Lifting and Slinging Equipment

All of the equipment should be stored correctly when the job has been completed.

Firstly when the equipment is stored correctly it is easily found when you need it again.

Secondly, it ensures the equipment is not damaged. Store all equipment in the correct locations. Furthermore it also prevents slipping and tripping accidents in the workplace.

Notes:

Premises Controls – Safety Signs/Signage

All '(ABTOs) Authorised Battery Treatment Operators' – Plant and Facilities are subject to the HASAWA 1974 regulations as well as those specific to battery accumulator treatment operations.

For e.g., Safety systems could include a sprinkler system in a common warehouse premises, why would / could this be a problem in a LV/HV Battery processing facility?

Notes:

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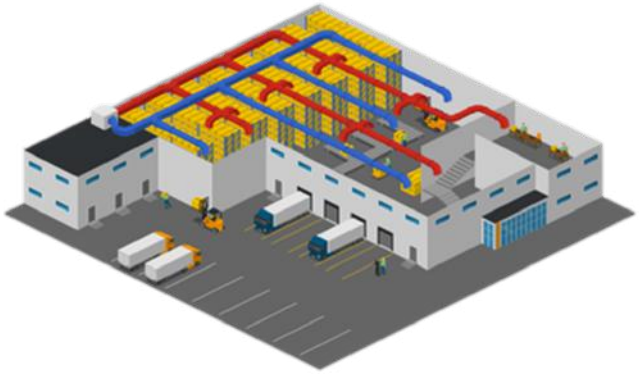
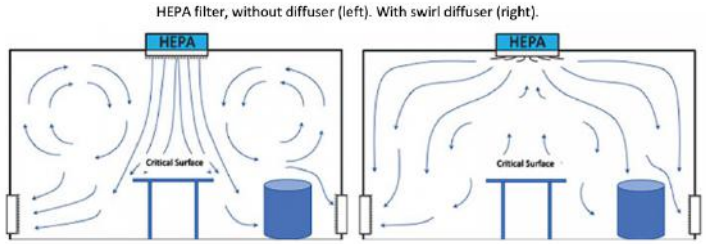


Premises Controls – Temperature Control/Ventilation

Heating, Ventilation, and Air Conditioning (HVAC) is the use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space. Its goal is to provide thermal comfort and acceptable indoor air quality for the facilities operations. Simplified it is controlled by:

- Supply
- Extraction

Notes:



Premises Controls – Temperature Control/Ventilation cont.

When working with batteries, plants and facilities use a variety of 'clean rooms' and 'air movement' protocols.

For example:
Laminar Flow - The air travels smoothly for both supply and change.
Positive pressure environments - The air in the building has an increased pressure forcing e.g. dust and other contaminants to go to ground or an exit flow.

Notes:

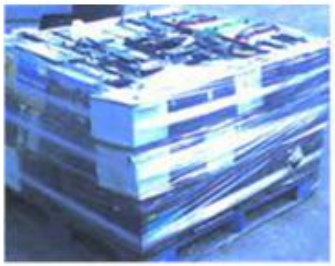
BT5 End of Life Battery Preparation and Environmental Disposal

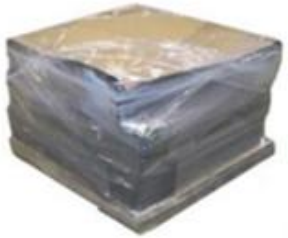
Arrival/Palletising – 12V Batteries from Waste Collectors

Forklifts are a common method of moving the received batteries around.

Safety 1st Approach:

- Safe Containment
- Safe Collection
- Secure when being moved





To improve safety ensure batteries are stacked correctly and are appropriately palletised.

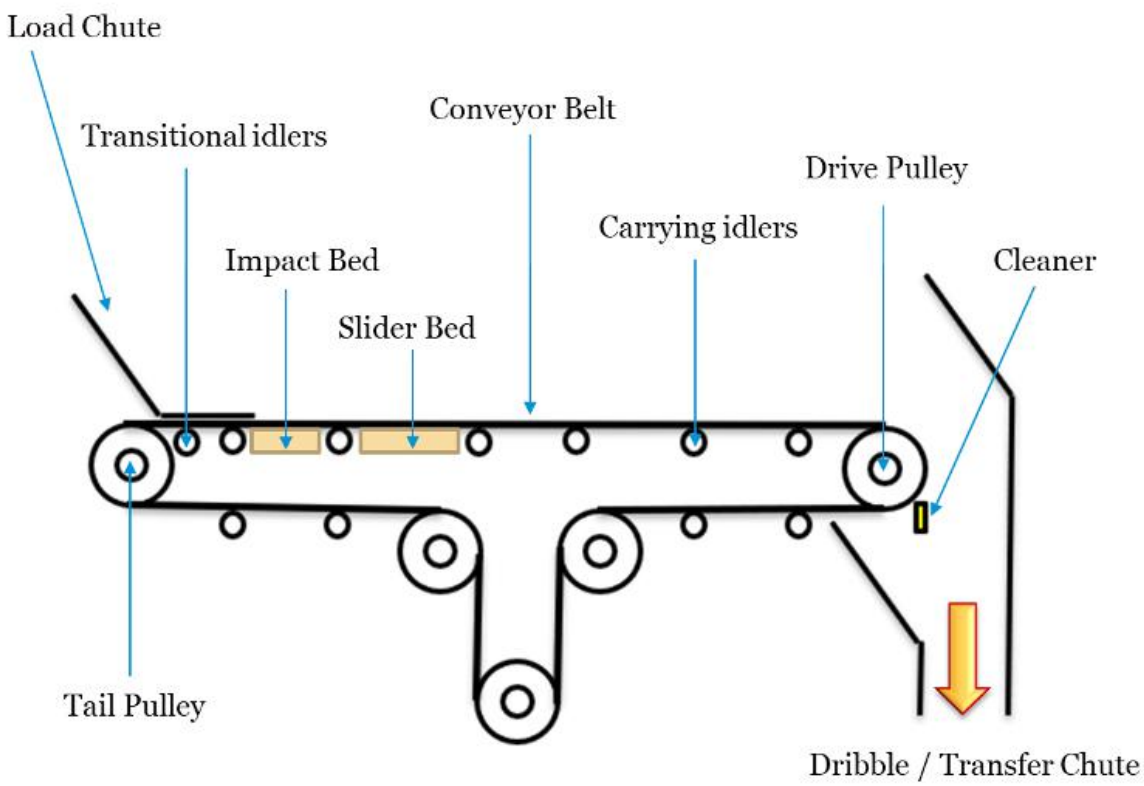
Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Sorting Lead Acid/Lithium-ion Batteries – Manual and Visual Inspections

Notes:

Conveyor Belt System – Moving the Product/Material



Notes:

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Battery Cutting/Rotating Hammers – Hammer Mills

The Hammer mills rotate to break up the batteries.

It needs to be consistent in its attack, so the same results are achieved with every battery that enters the process.

The process separates the battery into plastic chippings and a metallic paste, containing the lead.

Notes:

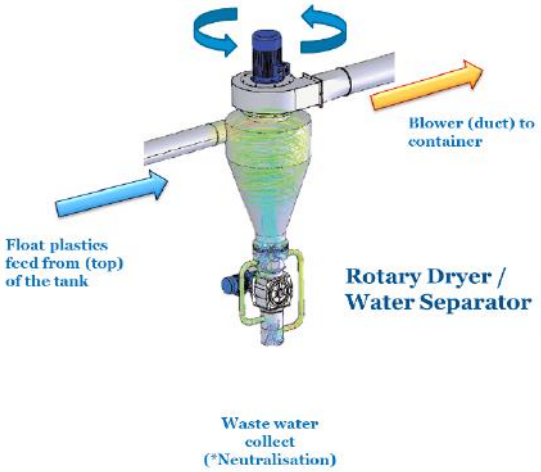
Float/Sink Tanks – Hydro-separation of Lead and Plastics

Plastic particles are suspended in the water, some floating to the top.

The Lead sinks and is removed using an Archimedes screw.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal



Washing/Drying - Plastics

Plastic particles are then dried using air and rotary forces to separate the water from the plastic.

Notes:

Washing/Drying – Plastics cont.

The blower is fed into a container where the plastic chips are then stored until the container is full.

(A second life processor will further process the chips into granules to be re-used in manufacturing / processing)

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Lead Waste – Collection and Processing

After removal from float-sink tanks the Lead waste is processed.

Water is added to form the correct slurry consistency for drying and to neutralise the acidic liquid.

The Lead paste is then held in a mixing tank.

Notes:

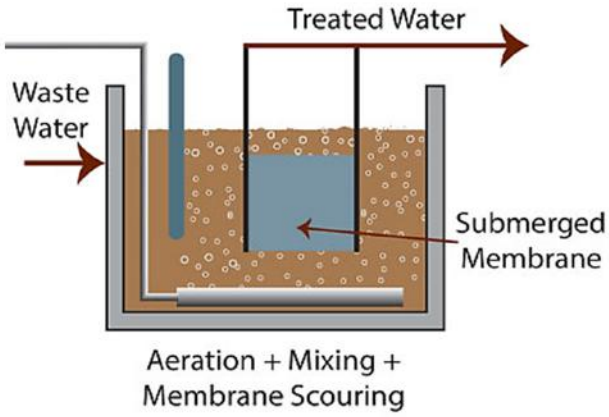
Lead Waste – Collection and Processing cont.

Once mixed correctly moisture is removed using a drying oven.

The dry Lead paste is then removed from the oven and collected to be re-utilised.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal



Contaminated Water – Holding and Chemical Neutralisation

Once removed from Lead waste contaminated water is collected in a holding tank. pH neutralisation is then carried out to reduce pH level to between 6.5 and 8.5.

The water is then filtered and sediment removed.

Once treated and quality assured, the water is then returned to the national water systems.

Notes:

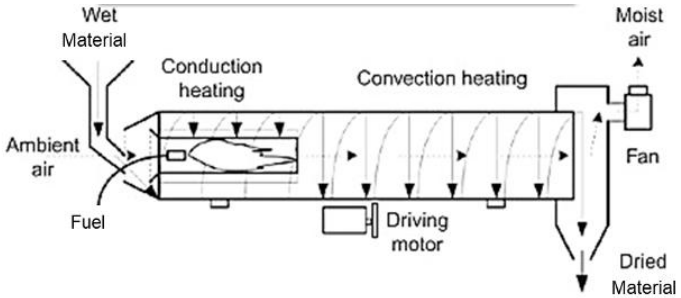
Processing the Dried Lead – Collection/Movement

- An Excavator is used to move the collected Lead waste.
- At this point refined coal is added to assist in the furnace smelting process.
- The mix is loaded onto a conveyor system via the load chute.

Notes:

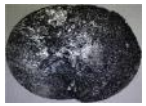
BT5 End of Life Battery Preparation and Environmental Disposal

Processing the Refined Lead – Revolving Dryer



Notes:

Smelting the Lead – Further Reducing Impurities



1. 10 hours in the furnace
2. Pour to holding kettle
3. Caustic Soda added for final purity standards
4. The top surface impurities are then removed - this is known as the ‘slag’.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Final Pour - Casting

The holding kettle is poured into the casting moulds.

Further ‘scraping’ is carried out for final impurity removals and visual QC checks.

The lead is then verified as a standardised ingot.

Notes:

End of Life (EoL)

Batteries at the End of their ‘automotive’ life which are not suitable for a pack repair, or re-life will eventually be processed as ‘scrap’.

By 2035 EV battery recycling could provide at least 22% of the lithium and nickel and 65% of the cobalt necessary for European production.

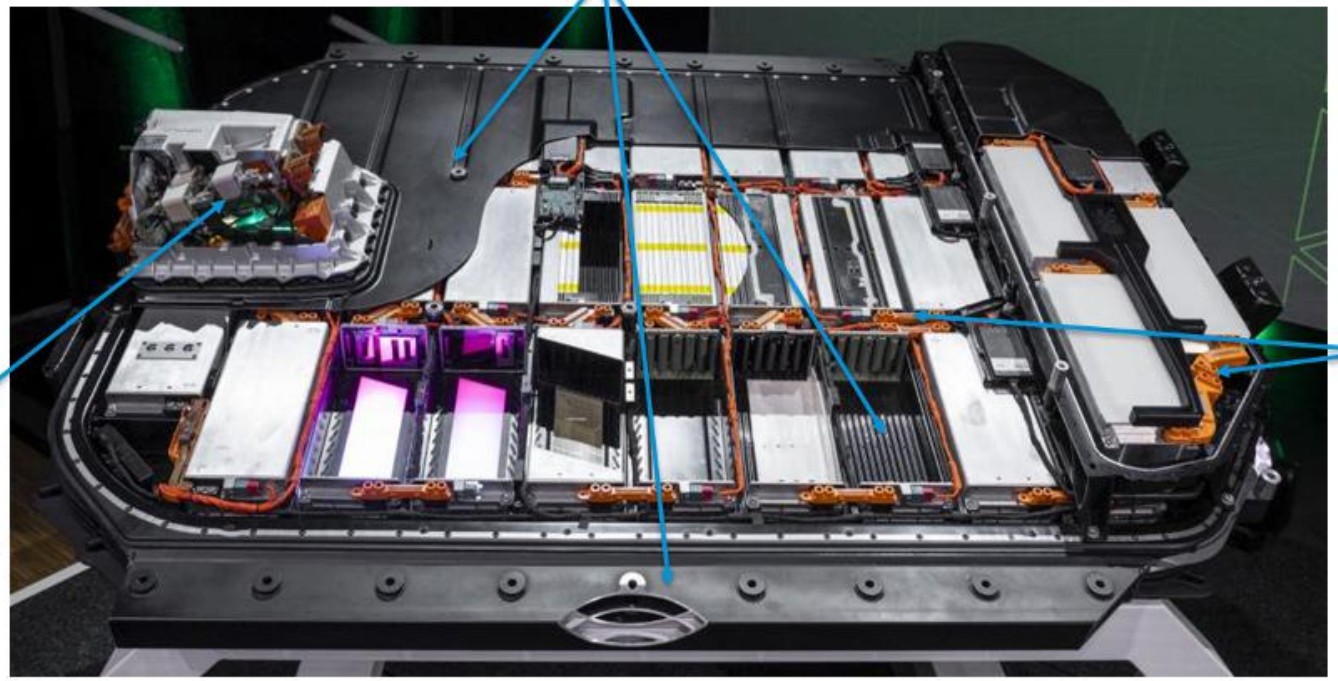
Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

High Voltage Battery Recycling

The Crash shell, Lid and Base – Steel Alloy, Aluminium = Widely recycled (Composite is harder to recycle).
(Recycled separately to the battery)

The BMS / BMU Is removed, this would come under regulation **(EU) 2012/19/EU** waste electrical and electronic equipment. *(Recycled separately to the battery)*



The HV Cabling, (PVC, Copper multi-core) and the Busbar links (PVC, Copper or Nickel) = Widely recycled. *(Recycled separately to the battery)*

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Inbound Logistics – Unpacking/Checking

When unpacking and checking high voltage batteries always ensure you:

- Wear the correct electrification PPE
- Check that the battery is 'locked out'
- Check and qualify the battery passport

Notes:

Inbound Logistics – Lifting and Handling

When using an overhead hoist or crane, always ensure the battery anchor points are securely connected to the hoist/crane prior to any lifting.

Please note: Specific qualifications are available for lifting and slinging, in addition to a range of training courses.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Inbound Logistics – Weighing

The battery weight is a good indicator for its integrity / identity.

The listed weight can also indicate the batteries designation in kWh in packs that use similar housings etc.

Please note: Most high voltage automotive batteries can weigh in excess of 300kg.

Notes:

Inbound Logistics – Positioning the Battery

When positioning/lowering the high voltage battery always ensure it is level and central to the device it is being lowered onto.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Inbound Logistics – Battery Management System Diagnosis and Discharge

The Battery Management System (BMS) diagnosis takes place on a diagnosis read machine with specific OEM software.

Note: Manual Service Disconnect (MSD)/Service Disconnect Switch (SDSW) to be replaced**.** Pack needs to be re-energised for the battery to be discharged.

Notes:

Inbound Logistics – Disconnect/Test for Dead (MSD/SDSW)

Follow the OEMs guidance on lockout (each vehicle is slightly different) in general the guidance is:

- Put on your PPE.
- Remove the MSD / SDSW / 12v HV lockout
- Wait the mandatory 10mins *(on 400v systems)* can be up to 15mins *(on 800v systems)* for de-energising.
- Test your meter (Proving unit, x2 times)
- Test for dead - COM to ground point, then positive lead to each side of the socket (done separately) to confirm 0v (Zero volt)
- Lockout the socket with the dummy plug.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Battery Cover Removal

The removal of the high voltage battery cover is a mechanical process involving the removal of all of the cover bolts, in line with the OEMs dis-assembly instructions.

Notes:

Series and Parallel Links Removal

This is the removal of the series or parallel high voltage links, to break the modules down.

E.g. if the battery is 300v and has 10 modules, removing the series links makes them 30v each to work with. This is further reducing risks.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Battery Module Removal – Assisted Lifting

A high voltage battery module can be removed and manoeuvred by one person when using assisted lifting and slinging equipment.

Please note: The use of this equipment will require specialist training.

Notes:

Battery Module Removal - Manual

A two-person lift is required by law under MHOR for an object in excess of 25kgs. Many battery modules will exceed 25kgs and therefore will require two people to lift and move them if lifting and slinging equipment is not available.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

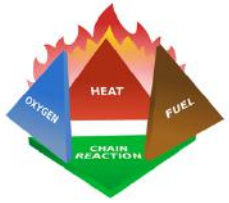
Conveyor Belt Systems

Conveyor belts are used to move the battery modules from one location to another. Many conveyor systems are modular and can be placed in series to provide a solution for moving between workstations.

Notes:

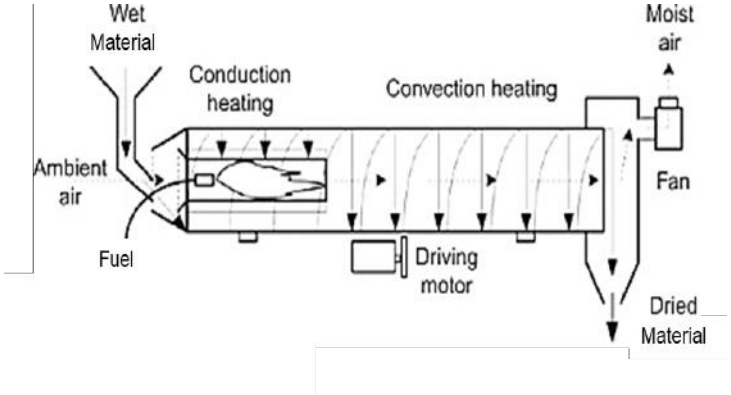
Shredding

Some shredding processes are being done in a Nitrogen inert gas environment. With the air (21% oxygen) removed there is no oxygen, therefore reducing the risk of fire (air is replaced with nitrogen gas).



Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

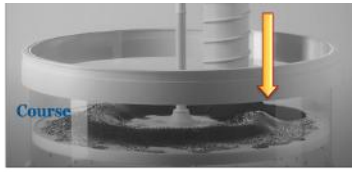


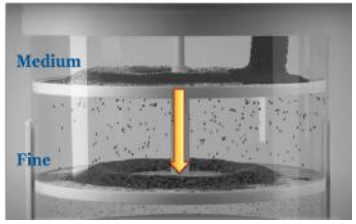
Dryer – Electrolyte Extraction

Electrolyte removal processes are being done in Nitrogen inert gas environments.

This lowers the risk of fire and also lowers the boiling point of the electrolyte for heat removal / electrolyte extraction.

Notes:



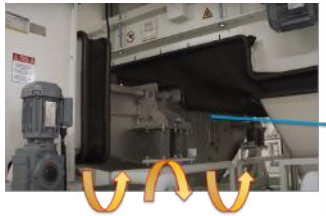


Sieving – Electrolyte Extraction

Large sieves are used during this process. The membrane sieves work based on grain size. This allows for complex separation of the materials.

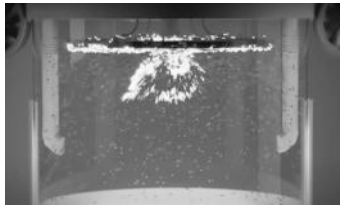
Notes:

BT5 End of Life Battery Preparation and Environmental Disposal



Electro-Magnetic Separator

The electromagnet is an overhead operation and allows for the removal of ferrous metal particles from the process.



Notes:

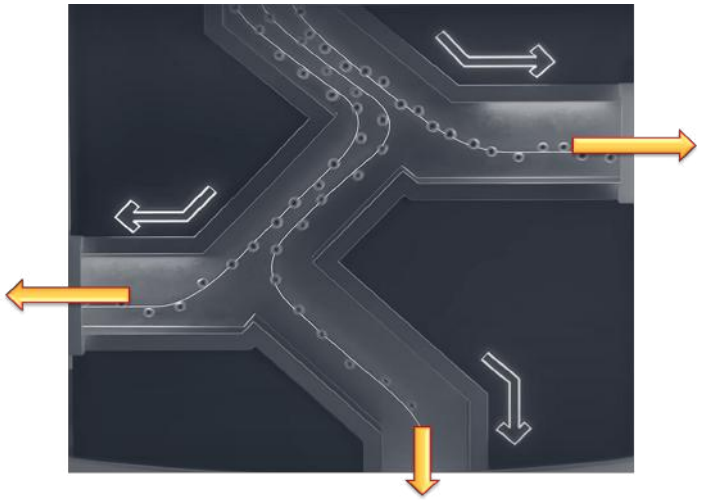
Vibration (Vibro) Plates

Prior to an electromagnet removing any ferrous metal from the mixed material grind, a 'vibro' plate is used to separate any material clumping or settling.

It does this by shaking the material vigorously on a transfer plate, once separated the material can then be moved to the next stage - use of the electromagnet.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal



Further Separation - Chutes

Compressed air is blown at a constant speed/at specific junctions within the chutes. The lighter material is fed one way, the heavier material will then drop to the next level.

Notes:

Bagging the Material

The next stage is that the sorted materials are bagged, according to their classification, along with being quality checked.

This re-claimed material can now be used again in the manufacturing/production process.

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Image: PNGArts.com

Black Mass Recovery (Graphite)

Black mass recovery (graphite) is what the industry is focussing on currently. The quality of the air purity in the process is paramount to the quality/grade for re-use.

Air moisture content in the processing needs to be kept at around 40% humidity throughout the controlled environment. (Ideal conditions)

Notes:

Collected Materials

The materials that are reclaimed include:

- Cobalt Sulphate
- Nickel Sulphate
- Lithium Carbonate / Lithium hydroxide
- Black Mass (Graphite)
- Metal

Notes:

BT5 End of Life Battery Preparation and Environmental Disposal

Glossary of Terms

Term/phrase/abbreviation	Explanation
BMS	Battery Management System
BPS / BPU	Battery Protection System / Battery Protection Unit
CAT ratings	Multi-meter category https://www.digikey.co.uk/en/blog/what-are-multimeter-cat-safety-ratings
Cell	An individual power source - cylindrical, pouch, prismatic or blade.
CMR	Convention on the Contract for the International Carriage of Goods by Road
DGSA	Dangerous Goods Safety Advisor
EDU	Electric Drive Unit
FA & T	Formation, Ageing & Testing
ICE	Internal combustion engine
KIB	Potassium Ion Battery
LAB	Lead Acid Battery
LBC	Lithium Battery Controller (same as BMS - different term)
LFP	Lithium, Iron Phosphate (Cells)
LIB	Lithium Ion Battery
MCU	Motor Control Unit

Glossary of Terms Cont.

Module	An arrangement of cells makes up a module
MRP - ERP	Manufacturing Requisition Planning / Enterprise Resource Planning
MVIB	Multi Valiant Ion Battery
NMC	Nickel, Manganese & Cobalt (Cells)
NMP	N-methyl-2-pyrrolidone (NMP) is the most common solvent for manufacturing cathode electrodes in the battery industry; however, it is becoming restricted in several countries due to its negative environmental impact.
Pack	An arrangement of stacked cells or modules joined in series and/or parallel, makes up a pack.
PVDF	Polyvinylidene fluoride more commonly known as (PVDF) polymers, are widely used as binders in lithium-ion batteries. It can be injected, moulded or welded and is commonly used in the chemical, semiconductor, medical and defence industries, as well as in lithium-ion batteries.
SAP	Systems Application and Products (Planning)
SEI	Solid Electrolyte Interphase
SIB	Sodium Ion Battery
TMS / TMU	Thermal Management System / Unit