Safety implications of ‘re-cycling’ electric vehicles batteries

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1 INTRODUCTION

This paper is one of three related published papers which look at current EV technology, issues around recycling batteries used for motive power in electric vehicles and, in more detail, issues surrounding the recycling of lithium-ion batteries in the wider industrial and commercial sectors.

In the first paper in this trilogy we outlined the current technology around batteries used in electric vehicles. This paper now moves into the field of recycling itself and discusses the options and the safety related implications.

2 CURRENT RECYCLING STRATEGY

Current environmental recycling strategy and theory to reduce usage, re-use, re-purpose and re-cycle, in part or in full, does not fully apply for electric vehicle (EV) batteries used for motive power. This is because of the statutory impact in many countries, including the UK, which will limit or stop completely in total manufacturing production and importation of petrol and diesel (fossil fuel) vehicles is not currently clear, fully developed and communicated to consumers. In terms of actions to limit climate change this essentially means the expansion and further technological development of alternative technologies for road transport. Examples include expansion of development of hydrogen powered vehicles. However, presently, at the front of this drive is the development of electric vehicles for the domestic market and, in a short while, for heavy commercial vehicles.

Currently, this now proposes significant safety, environmental and commercial issues in the strategy to recycle EV batteries. EV batteries have a limited operational life, and while technologists and engineers are extending the life progressively, we need chemists and materials scientists to discover new materials and physicists and engineers to develop new applications to improve battery functionality. Consequently, although these aspects of using alternative technologies are not impact free in commercial, cost and environmental terms there are inevitable environmental impacts the commercially driven need to reclaim precious and expensive elements and materials which go into a modern high performance EV battery. These materials include Cobalt, Lithium, Nickel and Copper. Available data (The Times, 17 January 2020) suggests that demand for cobalt for EV battery production will rise from 27,000 tonnes in 2019 to 100,000 tonnes in 2025. Similarly, data for nickel mining will rise from 95,000 tonnes in 2019 to 425,000 tonnes in 2025. Consequently, the need is there to re-cycle manufactured materials within the battery itself.

The purpose of 'recycling' used EV batteries is fundamentally commercial driven and reflects current problems globally for manufacturers and suppliers in sourcing batteries for vehicles in production. Reflecting on a global manufacturing issue, it is reported in The Sunday Times on 9 February 2020 that Jaguar Land Rover is halting production in Graz, Austria, of is best-selling i-Pace electric car due to a shortage of batteries. The lithium-ion batteries are supplied by the south Korean manufacturer LG Chem to Europe from its manufacturing plant in Wroclaw, Poland.

3 REUSE OPTIONS FOR BATTERIES

To make up for shortages in supplies of batteries, the re-use or reconditioning of batteries has to be considered, even though with an 8 year or 100,000 mile 'life', as a driver one would not be expecting to upgrade the battery in the vehicle for some time if the vehicle was bought new.

A review of present options suggests that re-use is not generally possible. By definition, the end of life of the battery is either due to its operational efficiency dropping below a safe operating threshold or due to an internal battery fault. This may include activation of an internal engineering safeguard or thermal trip device in a cell which protects against fire and explosion as a result of overcharging. In re-purposing the battery for another function, a similar situation exists and in general terms units would not be expected to be interchangeable or useful for an alternative purpose. Partial recycling could be possible in that casings, connectors, mounting brackets and fixings and control units and associated electronics modules could be re-used when the battery is removed. Finally, in terms of full-recycling the EV battery AND the integral materials which store and convert the chemical energy into electrical energy can be removed by specialists. The recovered components and materials may be introduced again to the product stream to add to existing raw materials that go into the manufacture of EV batteries.

3.1 Waste management protocols

The generally accepted hierarchy for waste management of materials comprises:

- Avoid: prevent or minimise the demand for materials
- Re-use or re-purpose the product
- Re-cycling, in whole or in part
- Reprocessing and / or recovery
- End-of-life disposal for non-recyclable or biodegradable materials.

4 WHY PARTIALLY RECYCLE EV BATTERIES?

Stockpiling waste batteries is potentially unsafe and environmentally undesirable, if direct re-use of the lithium or other valuable metals in batteries is not possible. If end-of-life disposal to landfill is correctly to be avoided, recycling in some form MUST be undertaken at some stage even if the battery has, as an interim position, a second useful life. Principally for economic reasons, but also significantly due to the currently scarce mineral and elemental resources used in batteries, and the limitation of raw materials, some recycling has to be considered. This is especially so in re-using elements such as lithium (LI), cobalt (Co) and silver (Ag) used in manufacturing.

4.1 Safety concerns

While there are many commercial considerations on reusing materials or in partially recycling EV batteries, and there are a few environmental concerns due to enhanced energy use and emissions in manufacturing, there are virtually no reported concerns regarding **the safety implications** to operators, companies and users from this re-use or re-cycling process.

5 WHAT IS THE SAFETY RELATED RISK?

In recycling a petrol or diesel fuelled vehicle the hazards, which are actions, conditions or energies that have the potential to cause harm, and the complementary risks which outline how probable or likely it will be for the harmful consequences to occur, are well understood. Looking to the future, it is anticipated that safety risks associated with dealing with the end-of-life of fuel cell technology or hydrogen powered vehicles potentially will be a routine industrial activity. But, dealing with the intrinsic safety hazards in EV technology poses safety related risks which need careful management today.

5.1 Hazards in EV battery technology

Intrinsic hazards in EV battery technology are focussed on the fire and explosion safety risk in the processing or disassembly operation. Harper et al in Nature, Volume 575, 7 November 2019 report in their paper 'Recycling lithium-ion batteries from electric vehicles' at least three major fires in metal recovery facilities world-wide between 2016 and 2018.

However, before we arrive ultimately at the fire risk there are fundamental hazards facing operatives engaged in dismantling work, down to a modular or component level. These hazards revolve around traditional industrial hazards in this type of dismantling work. The hazards comprise *inter alia*:

- Mechanical
- Electrical and the intrinsic potential energy in the battery, electrocution, short circuits and release of energy leading to fire and explosion
- Stored energy, thermal runaway and overheating
- Physical, manual handling issues with the mass of the battery
- Chemical
- Ergonomic
- Ejected materials
- Respiratory hazards in occupational health, including potentially liberation of HF, (highly reactive) hydrogen fluoride
- Carcinogenic materials, in electrode materials and electrolytes.

However, while these hazards are not unique the severity of the consequences each hazard proposes are peculiar to this type of work. Examples include the high electrical energies involved in modern battery technology and the toxicity of some of the materials used.

For the above reasons, the often-used hierarchy of controls in safety must be adopted before planning any work activity focussed on dismantling used batteries. The hierarchy of controls comprises:

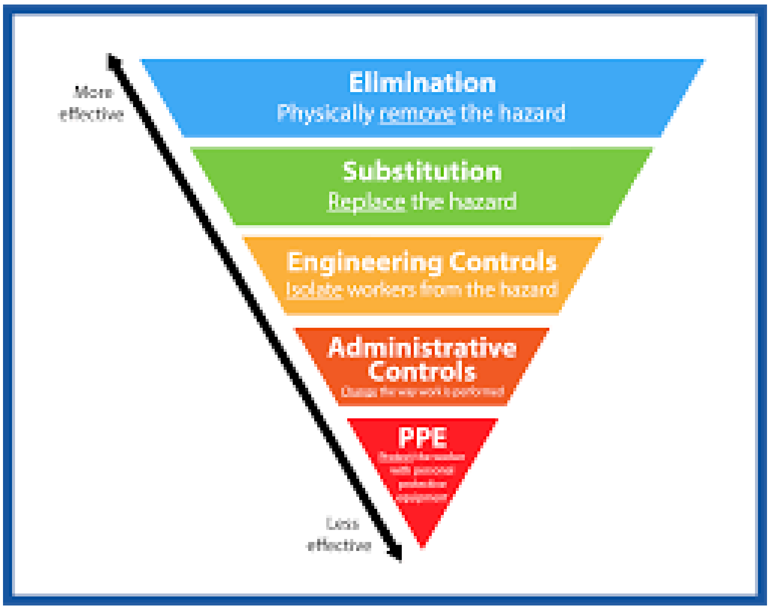

Figure 1: Hierarchy of controls

In this line of work elimination of hazards is stubborn and substitution for less hazardous materials and processes is not overtly viable. Consequently, this hierarchy shows that engineering controls are vital in choosing a method to isolate the hazards from the operators. This essentially means automating to some degree the disassembly process, potentially in using robotics and certainly in designing work areas around remote operations. Remote operations essentially focus on keeping **people** physically away from hazards and well understood principles are seen in remote handling of harmful, hazardous, dangerous and toxic materials including:

- Explosives and energetic materials
- Pathogens and infection agents
- Highly toxic substances
- Certain carcinogens including cytotoxic substances
- Radioactive substances and nuclear materials.

Various levels of 'remoteness' can be utilised, depending on the quantum of risk and the perceived outcome from simply using long-handled tools to an energy and barriers approach with a Monte Carlo analysis of dose and time, with design and implementation of strong blast deflecting structures, labyrinth walls, gravel engulfment, fire resisting structures, total isolation with segregation and separation and interlocked key access systems.

6 FIRE RISKS ASSSOCIATED WITH BATTERIES

Since the Battery Directive came into force, batteries are being stored on premises prior to recycling. Recycling stops batteries going to landfill and helps recover thousands of tonnes of metals, including valuable metals like nickel, cobalt and silver. This reduces the need to mine new materials, cutting CO_2 emissions and saving resources.

Recent advances in electronic technology have been accompanied by demands for enhanced battery performance, resulting in increased energy stored within the battery casing. There have been reported battery fires in kitchen drawers, shop recycling bins and electric vehicles during charging.   Shipments of lithium batteries have been suspected of contributing to two Boeing cargo aircraft incidents since 2006.

There have been several incidents in recent months involving lithium type batteries stored in battery recycling boxes. The most likely cause of these incidents is that the terminals of a lithium battery have caused a short circuit. The subsequent heat build-up in the battery and ultimately the thermal runaway can be responsible for fire development.

6.1 Storing new & waste batteries

There are no specific health and safety requirements for storing batteries, but normal health and safety rules, backed-up by realistic risk assessments, should apply. These rules include that the responsible person should be appointed to plan and oversee the work and should be responsible for assessing health and safety risks and for training operatives. Fundamental golden rules for high-voltage battery handing are in common with working with high-energy materials: **DO NOT inadvertently or unduly contaminate, confine or combust batteries, battery waste or packaging or extracted / recycled materials.**

6.2 Duty holders

In a defined workplace or building, the ‘responsible person’ is the employer or duty holder, or the person who occupies or owns the premises. In all other locations, where work with batteries is undertaken, including roadside repairs or at a remote open-air location the ‘responsible person’ will be the person or people in control of the work area or the employees working there.

The Health and Safety Executive considers the risks from storing small quantities of low voltage portable batteries to be very low, **if sensible common-sense precautions are taken.** But these precautions must be considered in a business’s health and safety risk assessment for normal operating conditions AND for abnormal events and emergency conditions such as the outbreak of fire, the release of energy in a short circuit or a thermal explosion.

7 RECORDING THE RISKS

7.1 The risk assessment process

In the UK safety legislation requires the employer to detail and record the hazards and risks that employees, contractors and the public faces from his undertakings. One is required to formally undertake an assessment of the risks, and to record the assessment in writing. It must be shared with workers and contractors, where relevant, and people must be trained in safe methods of working. There are many examples of good risk assessment pro-forma. But the 5 steps method to risk assessment from the HSE, in document INDG 163, is fundamental and easy to follow. This is referenced below:

https://www.hse.gov.uk/pubns/indg163.pdf

The steps in the process are illustrated below.

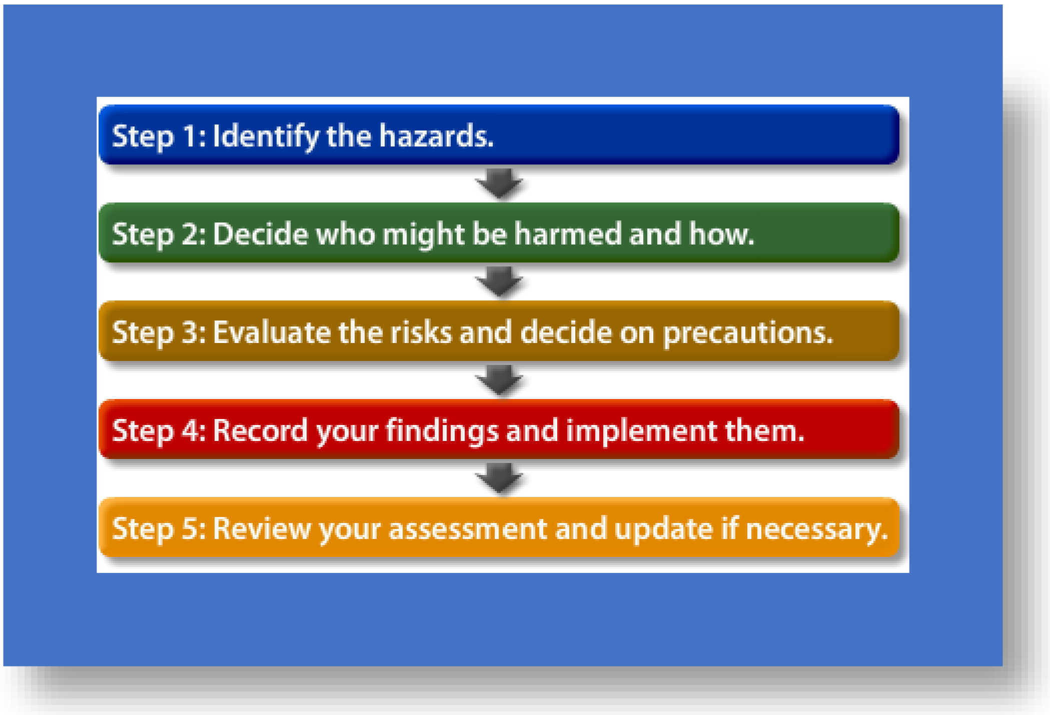

Figure 2: Steps in the risk assessment process

After establishing the best safety precautions or risk controls other operational documents should be written such as processes and procedures, including some safe working rules.

Examples of these rules include:

- Be fit for work. Take work seriously, look after yourself and your workmates by working safely and considerately.
- Always receive a briefing. Know what you are going to do today, or for the shift, or the next task.
- Report any incidents to your supervisor or manager. There may be something amiss with the process or the safe methods of working which were identified in the risk assessment and everyone would benefit from learning about what you have seen.
- Stop work if anything changes. Be alert and conscious of working conditions and if there are any aspects that change, which could impact on your safety or the safety of others. Know the emergency drills and what to do, where to go and how to get there if there is an incident.
- Be safe, and wear the right type of personal protective equipment (PPE) for the job.

8 WORK PLANNING AND WORKPLACE DESIGN

Plan and arrange the workplace and the workstations carefully with a view to safety in the event of a serious incident. Appoint and train first-aiders and fire marshals.

8.1 Planning operations

Plan and arrange the workplace and the workstations or workshops carefully with a view to safety in the event of a serious incident.

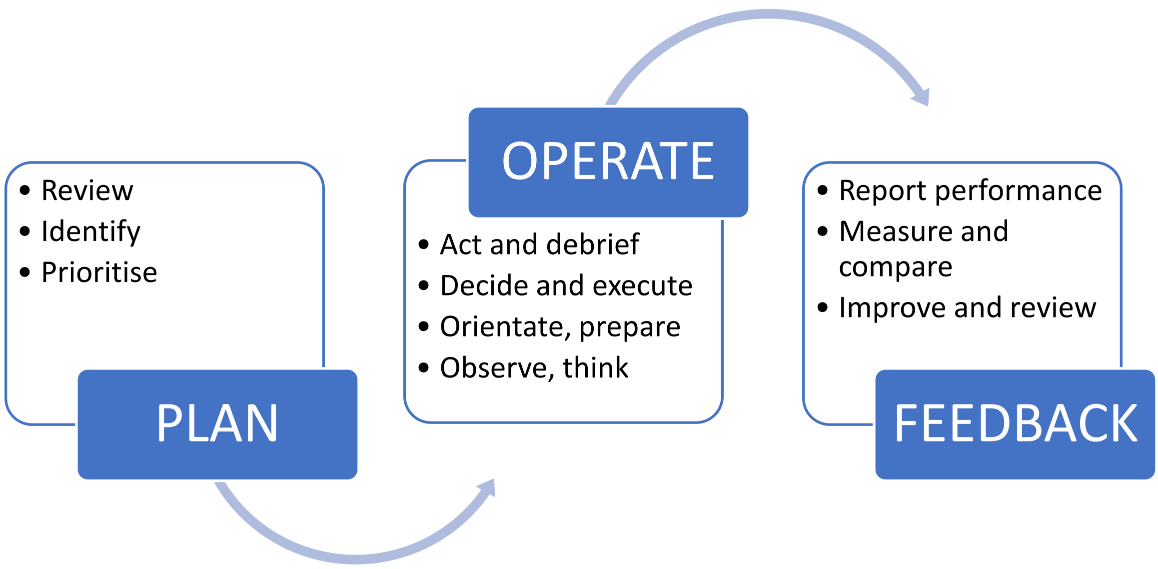

Figure 3: Management planning models and the OODA loop

8.2 Plan operations

Consider throughput:

- The number of units to be processed
- The number of operatives to be recruited and trained
- Time they will be required to work for
- Levels of competency and experience required etc.

8.3 Design the workplace

Particularly with respect to the tasks to be undertaken:

- And the complementary hazards
- Avoid changes of level, lifting, carrying, putting down etc.
- Design the workstations for safety in the event of fire and explosions
- Have workstations separated and segregated from each other and arranged in order that one incident or event is not going to communicate to an adjacent work cell etc.
- Place similar work hazards and risks together, keep opposite and non-complementary hazards and risks well apart!
- Integrate a design which separates people from hazards and allows 'an event' to vent freely, allowing people to escape unharmed and not affected by the incident immediately.
- Adopt an 'egg-box' design for workstations: Separation + Segregation = Safety

8.4 Implement the design(s)

- Both with physical layouts and work areas with job and process design and conceptual design. Discuss the requirements with operatives, and train them to undertake the operations safely.

8.5 Trial the physical facilities and the processes

- Operate the facilities on a trial basis at 'slow-speed' to see how all the elements fit together and how the workflow processes perform.

8.6 Review how the activities work

- Do all the process work safely? Have there been any incidents and unforeseen hazards, pinch-points in the process or potential difficulties in terms of undertaking the tasks safely?
- Is the design, procurement and provision of PPE correct?
- Does it limit dexterity?

8.7 Process modification

- Modify any difficulties found in the review to smooth out processes.
- Close-out the actions.

9 RECOMMENDATIONS

The following recommendations should be followed:

- Design should NEVER compromise safety.
- People must be competent in undertaking their work in terms of KATE, knowledge, approach, training and experience.
- Engineers and technicians working on electrical systems should be 'Appointed Persons' and hold a relevant tested and certificated professional skill or experience as an authorised person.
- Batteries should be stored and disposed of in accordance with the manufacturer's instructions.
- Where possible a battery should be returned to the manufacturer or supplier for disposal.
- Before handling, ALWAYS visually inspect a battery for physical damage, especially any signs of impact, fire damage or overheating or cracking of the outer casing. If a battery appears to be damaged, segregate it from stock and inform the supervisor for a decision on future remote handling and processing.
- Where 'processing' is undertaken, in that a battery is removed from a device, appliance or a vehicle, this should be undertaken in a clean, well-lit and tidy area with a minimum inventory of combustible materials. The number of people involved in any dismantling or dis-assembly operation MUST be minimised.
- Pay attention to planning the work and the workplace ergonomics. Do not dismantle vehicles for example in the centre of a building or work area but in a secluded part of the structure where, if a fire breaks-out, the damage may be contained or limited. The workplace design MUST allow people to literally step-back from the work in the event of an incident and must allow them to retreat to a place of safety. A means of escape should NEVER be 'on the opposite side' to the work undertaken and the person cannot run-around a vehicle or workbench to reach a place of safety. The ergonomics of the design should NEVER mean that a person must walk past an object on fire to reach a place of safety.
- If a fire is expected to break-out all staff must be trained in the safe use of fire extinguishers. Appropriate fire extinguishers should be to hand, or the dis-assembly work undertaken in a bay with substantial walls and an overhead fire sprinkler or water drench system.
- Batteries should be separated from other materials and stored in a non-combustible, well ventilated structure with enough clearance between walls and battery stacks to prevent sympathetic communication of fires or explosions.
- If possible, lithium batteries should be stored outside the premises.
- Do not place batteries near heating equipment, nor expose to direct sunlight.
- Tape terminals or provide plastic covers for lithium batteries to prevent short circuits between terminals of a positive terminal and earth.
- Ensure waste batteries are regularly removed from premises to avoid significant accumulations.
- Protect batteries against being damaged, crushed or punctured.
- Do not store batteries on fire escape routes or near offices, mess rooms or welfare facilities.

REFERENCE

https://www.360environmental.co.uk/legislation/producer_responsibility/batteries/