Understanding the hazards associated with lithium-ion battery (LIB) manufacturing

The growing **commercialisation** of LIBs emphasises the need to better understand the **risks** linked to their manufacturing process and **end of life handling**.

Introduction

Improvements in lithium-ion battery (LIB) technology have helped to transform the design of energy storage systems and electric vehicles. Enhanced storage densities and reductions in manufacturing cost, alongside an increasingly urgent shift towards greener energy, mean that LIBs are now more ubiquitous than ever.

This growing commercialisation of LIBs, however, emphasises the need to better understand the risks linked to their manufacturing process and end of life handling.

DEKRA Reaction Safety Consultants and Testing teams are experienced in helping our clients to gain a deeper understanding of the hazards associated with the production of lithium-ion batteries.

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Hazards associated with lithium-ion battery manufacture

The manufacture of batteries can be broadly divided into the following stages:

- Electrode manufacturing
- Electrolyte production
- Cell assembly
- Cell finishing
- Battery module assembly
- Packaging and transportation
- Raw material and product storage
- Finished battery storage

Throughout the process, toxic, flammable, and reactive materials are used, and it is crucial to fully understand the potential hazards involved.

Fire and Explosion

Li-ion batteries are known to be particularly susceptible to fire and explosion hazards – the same is true of the manufacturing process. The chemicals used in the production process can be flammable, such as organic solvents, and highly reactive, such us electrolyte solutions, which under certain circumstances can generates flammable gases (H2, CO, C2H4, CH4, etc) that are easily ignitable. These characteristics significantly increase the risk of fires and explosions.

During certain stages of manufacture and recycling, these **harmful chemicals** may be released, posing risks to the **health and safety** of workers

Thermal Runaway

The manufacturing process involves several stages, including mixing of chemicals, formation of electrodes and electrolyte solutions which can create unstable conditions. The liquid electrolytes used in mainstream LIBs become unstable at higher temperatures, potentially leading to a chain of violently exothermic reactions known as a thermal runaway (TR). During a TR event this released exothermic energy can fuel further reactions, creating a self-sustaining cycle of uncontrolled heat generation.

These unchecked temperature rises can be accompanied by the generation of various gases, formed as products of the different chain reactions. The gases formed here will typically include acids (e.g. HF), inorganics and volatile organic compounds. The toxicity and/or flammability of these evolved gases pose additional safety concerns.

Toxicity

The solvents and electrolytes present in Li-ion batteries are frequently irritating, some may even be toxic. Salts, overcharge protection additives, and flame-retardant additives are responsible for most of the toxic components in electrolyte solutions. During certain stages of manufacture and recycling, these harmful chemicals may be released, posing risks to the health and safety of workers.

Additionally, the gases released during an undesirable scenario, such us decomposition or fire, may present flammable or toxic hazards (for example, fluorides, carcinogens and other hazardous compounds).

It is important to **carefully assess** any potential hazards arising from process **contamination**

Contamination

Due to the high reactivity of some of the materials involved in the manufacturing process for LIBs avoidance of any contamination is advisable. For example, the introduction of water (atmospheric humidity or process water) to the liquid electrolyte will have a destabilising effect, lowering the onset of decomposition and thus increasing the likelihood of thermal decomposition. Additionally, the presence of water can also lead to the formation of hydrogen fluoride (HF), highly toxic as a gas and as hydrofluoric acid, which is also highly corrosive to metals.
Like water, interaction with other materials used in the process - such as acids, utility streams or cleaning chemicals – or the presence of corrosion in process equipment, could introduce hidden risks that are sometimes overlooked. Therefore, it is important to carefully assess any potential hazards arising from process contamination.

Compatability

The material properties of all equipment involved in battery manufacture must be carefully considered to avoid any unwanted interactions with the process materials. The products arising from TR or the presence of impurities may lead to further incompatibilities not necessarily considered during an initial assessment and so should be understood and accounted for, too.

Collecting **data** from undesirable situations is **essential** to establish a solid basis of safety and effectively address any **unexpected events**

DEKRA Services

From the manufacturing of the electrolyte solution to the end battery cell production, our DEKRA experts are supporting our clients through chemical reaction hazard assessments, using our reaction calorimetry techniques, thermal stability testing and kinetic modelling capabilities to gain valuable insights into the potential risks that may arise at any stage of the production process.

Reaction Calorimetry

Normal process operation may be replicated with the use of isothermal reaction calorimetry, offering valuable insights into the thermodynamic and kinetic behaviour of the reactions involved in the manufacture of electrode coatings and electrolytes. The heat flux and gas generation data obtained here may be used to inform process design decisions, ensuring safe and efficient operation.

DEKRA also provide adiabatic reaction calorimetry to investigate the behaviour of a reactor under a credible maloperation scenario. Collecting data from undesirable situations is essential to establish a solid basis of safety and effectively address any unexpected events.

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Thermal Stability Testing

DEKRA can offer thermal stability testing on any materials involved at any stage of manufacturing, so that the hazards across the entire process may be assessed. Testing is not limited to the final products but may also consider the behaviour of any intermediates and the influence of any likely contaminants too.

Samples undergo a heat-wait-search programme, wherein the temperature of material tested is incrementally increased until exothermic behaviour can be detected. Once self-heating has been determined the runaway event may be tracked pseudo-adiabatically, keeping heat losses to a minimum.

The data generated in this manner provides insights into the onsets of both thermal runaway and any subsequent gas generation, maximum temperatures reached in the event of a runaway reaction, and the quantity of gas generated in such an event.

By gaining an understanding of the conditions leading to TR, manufacturers will be able to implement the appropriate process controls and safety measures necessary to ensure they are never met.

Decomposition Product Analysis

After thermal stability testing, DEKRA offers a variety of analysis methods to identify the decomposition products formed during thermal runaway.

Mass spectrometry, GC-MS, GC-TCD and other techniques may be performed to identify any gases generated during decomposition. The remaining sample may then undergo NMR spectroscopy to determine the composition of any residual material.

Understanding the composition of the gas formed during decomposition is crucial for effectively managing the consequences of any potential release, ensuring that proper safeguards and protocols are in place to minimise or eliminate the risks they pose.

Our team can **collaborate** with you in **identifying** and addressing potential **hazards** in your processes

Kinetic Modelling

Kinetic modelling may be performed on any thermal adiabatic data to determine the kinetics of the decomposition reaction, providing a better understanding of the thermal and gas generation profiles. Additionally, the kinetic model may be used to investigate the behaviour of the material in plant equipment under various credible scenarios, such as storage at low temperature, behaviour at a particular temperature, consequences during a fire, etc.

Consultancy Services

Our consultancy team consists of process safety experts with extensive experience in tackling complex challenges. With a deep understanding of the battery manufacturing and testing industry, our team can collaborate with you in identifying and addressing potential hazards in your processes.

DEKRA provides the following consultancy services:

- **Chemical Reaction Hazards Assessment**: Evaluate the risks associated with handling of chemical materials
- **Consequence Modelling**: Quantify fires, explosions, gas release, health effects. Design & analyse lab tests
- **Safeguards Selection and Design**: Design reliable safety barriers: pressure relief, fire protection, gas detection, Safety Instrumented Systems
- **Explosion Risks and Major Hazards**: Compliance to regulations (ATEX, SEVESO, OSHA, NFPA), best practices and beyond
- **Process Safety Management (PSM)**: Implement, monitor, audit & sustain programmes
- **Process Hazard Analysis (PHA)**: Identify failure scenarios and assess risk using risk assessment and process safety methodologies including HAZOP, LOPA, ALARP Demonstration, Occupied Building Risk Assessment (OBRA), Functional Safety (SIL)
- **Incident Investigation/Testimony**: Ensure the understanding of technical and root causes to prevent re-occurrence

Hazard analysis should be **prioritised** in every manufacturing process to ensure **high levels of safety** are achieved

conclusion

Hazard analysis should be prioritised in every manufacturing process to ensure high levels of safety are achieved, reducing or preventing the potential impact of any incidents.

By offering both testing and consultancy services, we provide a comprehensive and high-quality assessment of your process. Our consultancy team works closely with our lab experts to create a tailored approach that aligns with your specific needs, ensuring that every aspect of the project is carefully considered and addressed. This collaborative approach enables us to deliver more robust solutions to meet your requirements.

Our team is dedicated to delivering high-quality results with exceptional efficiency. We understand the importance of timely solutions, and we ensure that our ultrafast turnaround service meets your needs without compromising on quality.

DEKRA Organisational & Process Safety **Contact**

DEKRA Organisational and Process Safety are a behavioural change and process safety consultancy company. Working in collaboration with our clients, our approach is to assess the process safety and influence the safety culture with the aim of making a difference.
In terms of behavioural change, we deliver the skills, methods, and motivation to change leadership attitudes, behaviours, and decision-making among employees. Supporting our clients in creating a culture of care and measurable sustainable improvement of safety outcomes is our goal.
The breadth and depth of expertise in process safety makes us globally recognised specialists and trusted advisors. We help our clients understand and evaluate their risks, and we work together to develop pragmatic solutions. Our value-adding and practical approach integrate specialist process safety management, engineering, and testing. We seek to educate and grow client competence in order to provide sustainable performance improvement. Partnering with our clients, we combine technical expertise with a passion for life preservation, harm reduction and asset protection.
We are a service unit of DEKRA SE, a global leader in safety since 1925 with over 48,000 employees in 60 countries and five continents. As a part of the world's leading expert organisation DEKRA, we are the global partner for a safe world. We have offices throughout North America, Europe, and Asia.

For more information visit
www.dekra-uk.co.uk

Would you like more information?

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