Lithium-Ion Battery (LIB) Systems: *Risks* and *Accident Prevention*

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White Paper DEKRA Advisory and Training

Lithium-ion battery (LIB) technology has been instrumental to the development of energy storage systems (ESS) and electric vehicles (EVs). However, associated fire and explosion risks need to be recognized and addressed so that this technology can be safely deployed.

Promising Technology—With Risks

In response to climate change and global commitments to low-carbon energy sources, lithium-ion battery technology has rapidly developed and provided many new opportunities for consumer electronics, ESS, and the EV markets. Lithium-ion batteries (LIBs) have become attractive energy storage solutions because of their high-storage capacity and ability to be recharged. At the same time, thermal runaway (TR), fire, and explosion risks associated with this type of high-energy battery technology have become a major safety concern.

Understanding LIB Risk

When maintained properly, and according to their operational boundaries, LIBs are usually safe and reliable. However, a TR event or fire can result from battery manufacturing defects, charging system malfunctions, improper use, traffic accidents, or faulty end-of-life handling. Physical mishandling involving crushing or penetrating the battery, for instance, could cause an internal short-circuit leading to a TR. Likewise, exposure to excessive heat or overcharging represent hazard risks, among other conditions (see figure 1).

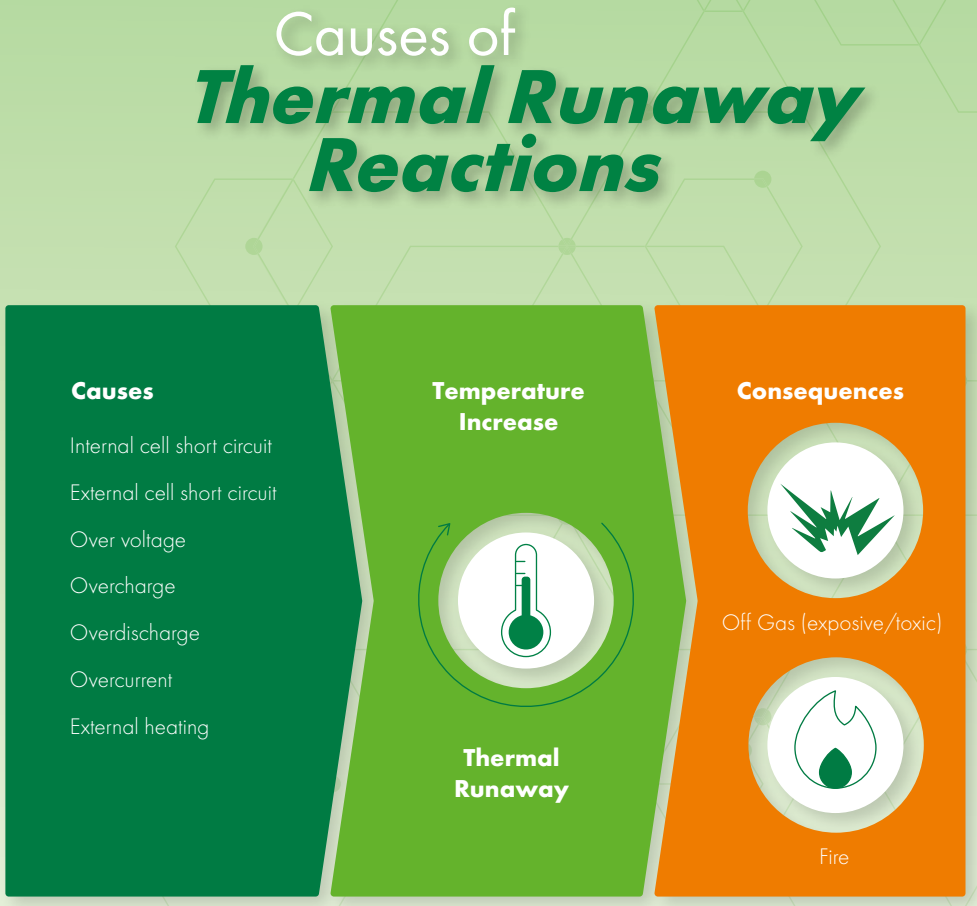

Figure 1. Causes of thermal runaway reactions

Preventive Actions for Thermal Runaways

Facility Design:

- Robust Construction Features
- Ventilation Systems
- Fire Protection
- Early Warning Gas and Smoke Detection
- High Capacity and Duration Automatic Sprinkler Systems
- Battery Management Systems

Safety Standards:

- UN 38.3
- UL 9540 and 9540 A
- NFPA 855
- German Insurance Association (GDV)
- VdS Schadenverhütung GmbH:
  - Pamphlet 3103 - Lithium Battery Hazards
  - Pamphlet 3856 - Sprinkler Protection of Lithium Batteries
- Fire Industry Association (UK) -
  - Guidance on Li Ion Battery Fires

Once the TR mechanism begins and the associated chain reactions take place, enormous heat energy and various toxic, flammable gases are released. As the thermal runaway event progresses, it may produce high-temperature fires involving ignitable liquids and vented gases. These fires are difficult to extinguish and present an array of exposures to workers and emergency response personnel. Jet fires, explosions, and battery reignitions may occur. Vast amounts of water applied over several hours or days will be necessary to extinguish the fire and prevent reignition.

LIB Safety and TR Prevention

The regulatory framework covering safe LIB storage, handling, and use varies from country to country, but there is emerging consensus on best practices to put in place when working with LIBs. Generally, prevention strategies include a robust battery-pack quality assurance program, including comprehensive inspection procedures so that mechanical damage and other anomalies are detected in a timely manner.

The battery management system (BMS) is a crucial component when it comes to LIB safety. The BMS is a set of hardware and software systems that monitor and manage the battery's performance, ensuring that it operates within its safety margins. For example, a well-designed BMS can prevent overcharging and overdischarging, two abuse scenarios that can lead to a TR event. It also calculates a battery's remaining charge, monitors its temperature and health, and checks for loose connections and internal shorts. When it detects unsafe conditions, it shuts down battery operation. Effective hazard prevention, therefore, includes proper homologation of the BMS to ensure its ability to carry out its protective functions.

Maintaining TR Preparedness When Working With LIBs

Hand-in-hand with LIB safety is TR emergency preparedness. Should a thermal runaway event occur, safety hazards can be properly managed. Unfortunately, there is little consensus on the best response to an LIB thermal runaway. But the topic is receiving more research attention, as the advantages and applications of lithium-ion batteries expand.

Fire suppression systems play a key role in absorbing heat and curbing propagation by limiting the number of battery cells involved in a fire—the more that cells succumb to fire, the more severe the TR event will be. Automatic sprinkler systems can also help prevent thermal runaways by cooling battery modules and packs or shielding them, in the case of non-battery fires.

When designing facilities to house or utilize LIBs, it is important to keep in mind that extinguishing an LIB fire requires much more water applied over a much longer duration than a typical fire, so the water discharge capacity should be commensurate with these requirements. In addition, it is imperative to address and manage the control of off-gassing and smoke, which contain both flammable and toxic materials.

Battery Safety Is in Our DNA

With our legacy in automotive and energy markets, DEKRA can share our unique insight to help clients safely design, use, and implement LIB technology. We look forward to helping you address your challenges and concerns. Contact one of our LIB experts now!

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Snyder earned a bachelor's degree in chemical engineering from Cornell University and a master's degree in occupational safety and health from Columbia Southern University. He is a registered professional engineer in Michigan, a Certified Safety Professional (CSP), a Certified Fire and Explosion Investigator (CFEI), and a Certified Fire Protection Specialist (CFPS).

Process Safety Advisory and Training Services

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