LITHIUM-ION BATTERY SAFETY - PERILS AND PROMISES

With the recent incidents of Chevrolet Bolt unattended fire and Hyundai's recall of Kona EV, battery safety in electric vehicles is now glaring headline news. With increasing demand towards higher energy density and faster charging, battery safety is indeed the need of the hour. The cells and the BMS are central to this safety.

Lithium-Ion Batteries (LIBs) mainly consist of the cathode, anode, separator, and electrolyte. The malfunction of these parts, together or individually, can negatively affect LIB safety. When operating, the electrodes produce heat, which can become uncontrollable during battery malfunction. If a separator is damaged, LIB processes transition from controlled to uncontrolled electrochemical reactions, resulting in significant heat generation. In such cases, the electrolyte acts as a fuel for further heat generation leading to **thermal runaway**.

LIB Safety

Among the different LIB form factors, cylindrical cells generally come in smaller sizes and lower energy capacity. Also, the gap between the individual cells, when forming a module, enables better heat dissipation. The metallic shell casing of cylindrical and prismatic cells can withstand higher pressures. In contrast, the aluminium-plastic composite film in the pouch cell's casing deforms easily and withstands less pressure.

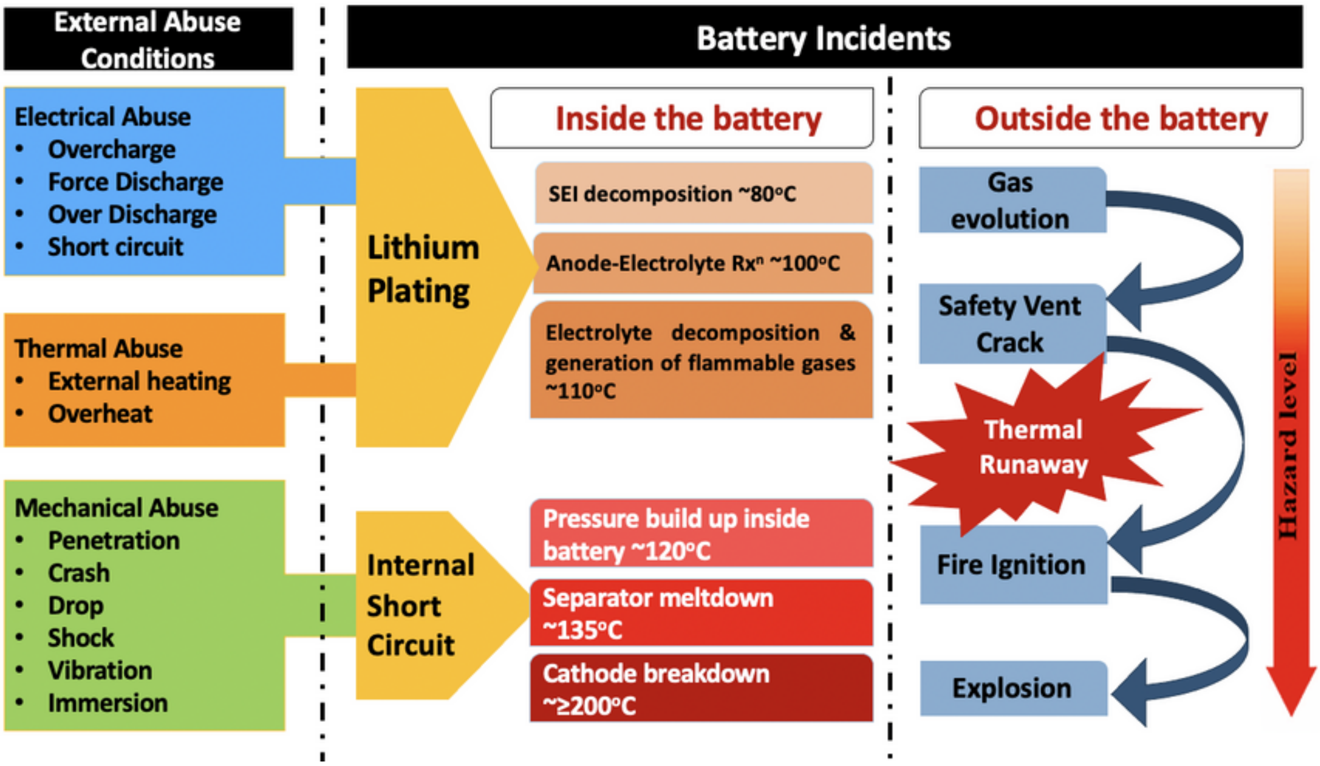
Lithium-ion batteries have electrolytes that are typically a mixture of organic solvents, salt and various additives. Unfortunately, they are highly volatile and flammable. In combination with an oxidant and an ignition source, they can potentially cause fires and explosions.

The damages in a LIB is generally classified as:

a) electrical - overcharge/discharge and short circuit

b) thermal shock and local heating

c) mechanical - damage to shell casing, crash, shock, penetration, and drop of battery packs



Understanding LIB performance in unsafe conditions is critical.

Thermal Runaway

Thermal runaway in a battery defines a situation where an increase in temperature changes the conditions in a way that causes a further rise in temperature, often leading to a destructive result. It is a kind of uncontrolled positive feedback. The leading causes of thermal runaway are:

- **Uncontrollable internal heat generation**, which causes oxygen release from the cathode material, leading to numerous side reactions, resulting in thermal runaway.
- **Separator defects** (either thermally-induced or mechanical damage) creating short circuits in the battery and rapid discharge of the energy stored in it and release of massive amounts of heat.
- **Electrical abuse**. Electrolyte decomposition occurs at the cathode interface, especially in a high state of charge (SOC). This leads to heat accumulation and consequently release of oxygen from the cathode and damage to the separator.
- **Electrochemical side reactions caused by local thermal abuse**. If the heat generated during normal LIB operations cannot be dissipated quickly enough, the separator in that specific place will shrink or rupture.
- **Mechanical battery damage**, which causes short circuits and/or air to penetrate the battery.

Battery Thermal Management

Good battery thermal management controls battery temperatures and minimizes the formation of localized hot spots. Depending on the method of heat transfer, typical battery thermal management systems include one of the following:

- traditional air cooling systems
- liquid-cooling systems containing water, glycols, etc.
- phase-change material (PCM) based
- heat pipe-based thermal management systems

Natural cooling simply relies on the temperature difference between a battery and ambient air to cool the battery. If convection is insufficient to dissipate the internal heat of the battery at its maximal charge and discharge rates, then forced air cooling is required.

PCM with a suitable melting temperature absorbs the heat during the phase change to cool the battery. A suitable PCM to wrap the batteries with thermally conductive sheets between the batteries, enhances the heat removal and significantly improves the uniformity of the battery pack temperature.

Cell Balancing

Cell balancing in a Battery Management System (BMS) is extremely critical to LIB safety. In the absence of an appropriate balancing system, the voltage differences between the individual cells will amplify, severely compromising battery safety. To achieve a high-performance battery system, the cells need to be continuously balanced to minimise the variations between them.

Thermal differences in a battery can cause different self-discharge rates in its cell components. Passive equalization technology is currently widely used, but active equalization technology is becoming more and more popular for larger battery packs.

The main type of passive balancing is switch resistance, in which equalizing resistance of the access circuit consumes some of the battery energy through heat generation. Passive equalization can release the electrical energy of the over-charged high-capacity cells in the battery pack, but it cannot supplement the energy for the low-capacity cells.

Safety Standards

Safety standards such as Chinese standard GB/T 31485, International Electrotechnical Commission (IEC) standard IEC62133 Edition 2.0, United Nations (UN) standard UN38.3 for Hazardous materials transport and Underwriters Laboratories (UL) standard UL9540 are most common. While there are several industry standards regarding battery safety, there isn't a set baseline summarizing expected performance for given applications or form factors. Also, successfully passing the nail penetration, crash, and other tests does not guarantee a vehicle battery's safety in real-life performance conditions.

Summary

The growing demand for higher energy density, faster charging and more powerful EV battery systems, is bound to pose greater challenges to battery safety. LIB thermal runaway and the presence of flammable components are the root causes of battery fires and explosions. The most effective way to dissipate excessive heat is to protect batteries from thermal and mechanical abuse by improving their outer shells. A well-designed battery pack along with an advanced Battery Management System can meet much-needed safety requirements.

India is on the cusp of EV adoption. Battery failures can appear suddenly, and without warning, with the potential of severe injuries, product recalls, and loss of reputation. Hence the EV industry must invest in good battery design with advanced battery intelligence that can predict and prevent the user from unsafe batteries before they lead to any untoward incident. When it comes to Lithium-ion batteries, an ounce of prevention is far better than a pound of cure!

Venkat Rajaraman is the Founder/CEO, and **Dr Mayank Vyas** is the Lithium Battery expert at **Cygni Energy**. Cygni is a leading storage technology company with cutting-edge expertise in EV Batteries (2W & 3W) and Energy Storage Systems. They have deployed over 75MWh of storage solutions. Cygni battery packs come with advanced cell balancing features and provide useful data on ageing and prognosis on battery safety. It supports multi-stage charging to avoid over-charge conditions, and superior thermal management ensures battery safety and prevents thermal runaway.