RELi^{3}ON®

SAFETY OF RELiON® LITHIUM IRON PHOSPHATE ($LiFePO_4$) BATTERIES

I. Introduction

The news media, internet and battery marketplace is filled with misinformation regarding the safety of lithium batteries. RELiON has always placed safety as the highest priority in all their lithium battery products. This document has been created by RELiON to assist customers, distributors, OEMs and the engineering community to better understand the differences in lithium battery technologies.

The early models of rechargeable lithium batteries, made with metallic lithium, were highly unstable and were the subject of many highly publicized recalls, due to batteries exploding or catching fire. To address these real safety issues, industry development shifted to non-metallic lithium using lithium ions. Today lithium ion batteries are one of the most successful chemistries in the market. [1]Hundreds of millions of lithium-ion batteries are produced each year, and catastrophic failure, such as explosion or melting, is rare. However, when any type of lithium battery does ignite or explode, it gets significant public attention and highlights the need for a safe lithium battery technology, like the type found in RELiON.

A common misunderstanding is that all lithium ion batteries are the same. There are different chemistries available that provide various advantages and disadvantages. Lithium Iron Phosphate ($LiFePO_4$) batteries cannot be made in the small sizes required for most consumer electronics, however when it comes to safety, $LiFePO_4$ technology is by far the safest chemistry available.

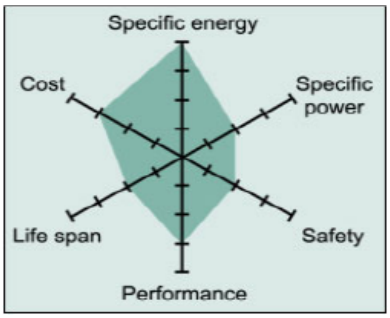
RELiON Battery's customer's needs can be satisfied by its unique drop-in replacement sizing and larger format batteries. This proprietary RELiON design allows for the use of the safest Lithium ion chemistry, Lithium Iron Phosphate ($LiFePO_4$). Additionally, RELiON incorporates many safety features into their systems. RELiON also tests its product to widely recognized standards to ensure the ultimate safety for the customer.

[1]http://www.livescience.com/50643-watch-lithium-battery-explode.html

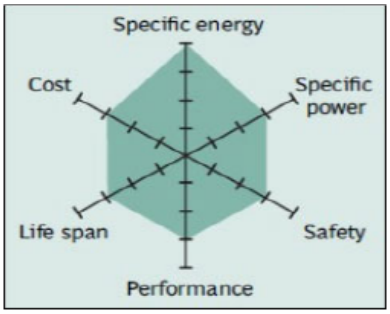
II. Lithium Chemistries

There are three main lithium chemistries.

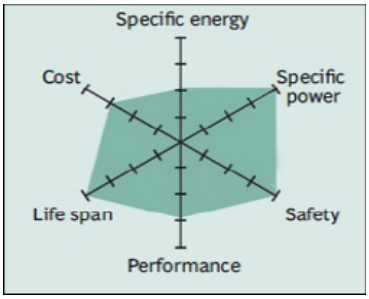
Lithium Cobalt
$LiCoO_2$



Lithium Nickel-Manganese Cobalt Oxide (NMC)
$LiNiMnCoO_2$



Lithium Iron Phosphate
$LiFePO_4$ (LPF)



Source: Battery University

As shown in the diagrams above $LiFePO_4$ is the safest lithium chemistry.

III. Why do Lithium Ion batteries explode or catch fire?

The main cause of fire or explosion of a lithium ion battery is excessive overheating during charging, which causes a perpetuating reaction called thermal runaway. Without proper management, thermal runaway may result in fire. The initial source of this excessive heat is the instability of most lithium ion chemistries.

RELiON uses lithium iron phosphate (LiFePO4), which is an inherently safe chemistry. The structural stability of LiFePO4 results in significantly less heat generation compared to other lithium chemistries.

As with any battery chemistry, including lead-acid, proper installation is necessary, as a loose terminal connection can cause a spark which may ignite.

IV. Chemical and Thermal Stability of Lithium Iron Phosphate ($LiFePO_4$)

The $LiFePO_4$ technology that is built into every RELiON battery possesses superior chemical and thermal stability over other lithium chemistries, which means better battery safety. $LiFePO_4$ is an intrinsically safer cathode material than cobalt oxide or manganese oxide cathode. Technically speaking, the fully "lithiated" and "unlithiated" states of $LiFePO_4$ are physically similar, which means it's structurally stable. The iron phosphate oxide bond is stronger than the cobalt oxide bond, so when it is subjected to overcharge it maintains its physical structure, while other lithium chemistries expand producing excessive heat, which leads to thermal runaway.

$LiFePO_4$ chemistry is highly robust during the oxygen loss that accompanies the charge cycle, thereby significantly reducing the exothermic reaction that is associated with other lithium chemistries. The heat produced by the chemical reaction in a $LiFePO_4$ battery during overcharge is only 5.5% of the heat that is produced by a lithium cobalt chemistry. Unlike other lithium chemistries, $LiFePO_4$ batteries can operate at temperatures up to 65°C (150°F) and thermal runaway temperature is at a high 270°C (518°F).

[2]When abuse does occur, the phosphate based cathode material will not burn and is not prone to thermal runaway. Lithium phosphate cells are incombustible in the event of mishandling during charge or discharge, they are more stable under overcharge or short circuit conditions and they can withstand high temperatures without decomposing. [3]From the viewpoint of safety performance, a $LiFePO_4$ battery is similar to a lead-acid battery.

V. Cell Design for Ultimate Safety

RELiON's cells are all designed with the following safety features.

1. Explosion-proof stainless steel
2. Built-in Safety Fuse
3. High Pressure Safety Vent
4. Over-Temperature Protection
5. Strong Spot-Welded Connections

Note: While submerged in diesel fuel engulfed in flames, these cells did not explode.

[2]http://www.newcastlesys.com/blog/lithium-ion-vs-lithium-iron-batteries
[3]http://www.powerstream.com/LLLF.htm

VI. Battery Management System Provides Extra Protection

RELiON's batteries are all equipped with an internal or external BMS which protect against the following potentially damaging circumstances:

1. Over-Voltage
2. Under-Voltage
3. Over-Current
4. Over Temperature
5. Short Circuit
6. Cell Imbalance

The BMS will disconnect the battery from the circuit if any of these events occur.

VII. Safety Test Protocols

RELiON's cells are UL1642 certified and have been tested per IEC62133 standards.

Test Criteria/Standard	UL1642	IEC62133
External Short Circuit	•	•
Abnormal Charge/Over-charge	•	•
Forced Discharge/Over-discharge	•	•
Crush	•	•
Impact	•	
Shock	•	•
Vibration	•	•
Heating	•	•
Temperature Cycling	•	•
Low Pressure (altitude)	•	•
Projectile Fire/Internal Fire	•	
Drop		•
Continuous Low Rate Charging		•
Forced Internal Short Circuit		•

RELiON's batteries are UN38.3 certified.

Test Criteria/Standard	UN38.3
Altitude Simulation	•
Thermal Test	•
Vibration	•
Shock	•
External Short Circuit	•
Impact	•
Over-charge	•
Forced Discharge	•

VIII. Use in Confined Spaces

During normal operation RELiON LiFePO4 lithium batteries are safe for human use in confined areas as they do not emit hazardous gasses like a lead acid battery. Any gasses generated during operation are recombinant and remain sealed within the cell. The combined cells are paired with a battery management system (BMS) to ensure the battery operates within specified voltage, current, and temperature conditions. The BMS monitors operation and will open the circuit to prevent unsafe conditions and or damage to the battery.

In extremely rare critical failure scenarios (i.e. severe physical damage from a crash or abuse of the battery in extreme applications for which it was not intended) LiFePO4 batteries may experience a thermal runaway event. During a thermal runaway event individual cells vent gasses as a failsafe to reduce the chance of conflagration and or spontaneous disassembly of the entire battery. The triggering of failsafe's in a critical failure event end the life of the battery.