What Takes Place Inside Lithium Batteries?

Lithium-Ion and Lithium-Polymer cell technology, possesses a fantastic gravimetric power-to-weight ratio, making it particularly attractive to aero-modellers . It is for this reason that it is especially well suited to the latest electric models, because although motors have become more efficient, the current required to power the models, particularly when performing 3D aerobatics has steadily increased. The expectations of the user to access this energy safely, is behind many of the problems being experienced today.

In the 1970s and 1980s, cell manufacturers introduced commercial rechargeable cells based on metallic Lithium. Unfortunately, some of these batteries quickly earned a dubious reputation for safety. Metallic Lithium in rechargeable batteries has now been replaced by Lithium kept in its ionic state, usually in the form of Lithium-Cobalt-Oxide. In this way most of the electrochemical benefits of Lithium-based cells can be reaped without the safety issues associated with the volatile metallic Lithium.

In order to maintain safety, the present Lithium-Ion technology must still be treated responsibly and with respect. It appears that many users of this technology are being lulled into a false sense of security, for it is perfectly possible to implement this technology poorly, resulting in a potentially dangerous battery. To this effect, and with past history behind it, the International Civil Aviation Organisation (ICAO) has introduced stringent regulations that preclude the transportation of Lithium-Ion and Lithium-Polymer batteries without a Manufacturer's Air Transportation Certificate. The certificate attests that the product being transported meets those regulations (false declarations incur severe penalties). In addition, batteries with more than 8g 'Lithium Equivalent Content'*, are considered by the International Air Transport Association (IATA) as 'Class 9 Dangerous Goods' and must be transported in a specific way if transported by air.

Potential Dangers

Despite the aforementioned advances in electrochemical structure, Lithium-Ion and Lithium-Polymer batteries remain inherently intolerant of overcharge, over-discharge, high current abuse and excessive temperatures, and all reputable batteries in other industries contain electronic protection circuits that are designed to protect both the battery and the user if these conditions are brought about.

Overcharge

The target charging voltage of a Lithium-Ion cell is 4.2V +/- 0.05V per cell, with +0.150V being the extreme at which most protection circuits will operate to prevent over-volting the cell, as consistent overcharging can cause the plating of metallic Lithium within the cell. Bringing metallic Lithium back into the equation will cause instability, especially if the cell is of lower manufactured quality, and especially if any moisture has been introduced inadvertently during the production process.

Over-discharge

Over discharging can cause copper plating that leads to internal shorting within the cell. The protection circuits should stop discharge well before the battery gets below 2.5V per cell. Some protection circuits permanently disconnect if a voltage below 1.5V is observed, rendering the pack permanently inoperable for safety reasons.

High Current Abuse

If the battery is discharged at an excessive rate, the excessive transition of Ions can bring about a breakdown in the crystalline-layered structure of the plates of a cobalt oxide Lithium-Ion or Lithium-Polymer cell. This can lead to a sudden rise in temperature that could possibly ignite the organic solvent of the electrolyte (which will not self extinguish).

High Temperature Abuse
As with high current abuse, if the battery reaches excessive temperatures, an excessive transition of Ions can occur, bringing about a breakdown in the crystalline-layered structure of the plates of a cobalt oxide Lithium-Ion or Lithium-Polymer cell. This can lead to a further rise in temperature, eventually leading to 'Thermal Runaway' igniting the organic solvent of the electrolyte (which will not self extinguish).

Quality Considerations

Quality
Quality, branded cells are a vital prerequisite to the creation of a safe Lithium-Ion or Lithium-Polymer battery. Poor quality cells may develop internal shorts, or their electrolyte may be contaminated, giving rise to further problems. It is rather concerning to note that such products are potentially being imported into the model market at present.

A quality product, is designed around safety protection at every level. As the electronic protection circuits are vital for the safe operation of a Lithium-Ion battery, it is essential that they, in turn, should be protected by correct layout. The top manufacturers use conformal coating on their circuit boards for an even higher level of protection. The electrolyte is a highly corrosive and conductive organic solvent. If the electrolyte were to be liberated for whatever reason, perhaps as the result of impact or a manufacturing defect, an electrical potential between them, such as the voltage across the battery terminals or two points on a pcb can result in a conductive path being built-up through the electrolyte, this can then lead to ignition.

Summery
If a Lithium-Ion or Lithium-Polymer battery cuts out, behaves strangely, or becomes excessively hot consider why this may have happened. Check the state of charge of each cell and ensure the load applied is not unsuitable. It is not good practice to draw excessive current over extended periods routinely. Operating a Lithium-Ion battery within its correct rating will enable the battery to achieve its expected cycle life and capacity. Always operate within the manufacturers rating but be aware that some manufacturers like to exaggerate the rating of their products. Whatever the subtleties of chemistry employed, all Lithium-Ion or Lithium-Polymer batteries remain similar in that they can be potentially dangerous or designed and manufactured to be safe.

* The revised version of the 44^{th} edition of the IATA Dangerous Goods Regulations, Section 2, (effective Jan 2003) states that the maximum lithium equivalent content for conventional air transportation of rechargeable lithium batteries must not exceed 8g. If the lithium equivalent content exceeds 8g then the battery must be transported as 'Class-9 Dangerous Goods', with the appropriate approved packaging, and clearly marked as such. The battery also has to be tested and approved by an independent test house. To calculate the lithium equivalent content of a lithium battery the following formula is used: n x C x 0.3, where n = the number of cells, and C = the Ah rating of each cell.

Let's take an example, a 4Sx4P (4-in-series x 4-in-parallel) battery pack made up of 2.0Ah Li-Po cells would be (n)16 x (C) 2.0 x 0.3 = 9.6g lithium equivalent content, making our example a 'Class-9' battery. So as you can see, it only takes a 14.8V 8Ah (118Wh) battery to enter the 'Class-9' classification.