Migrating from Sealed Lead Acid to Li-ion

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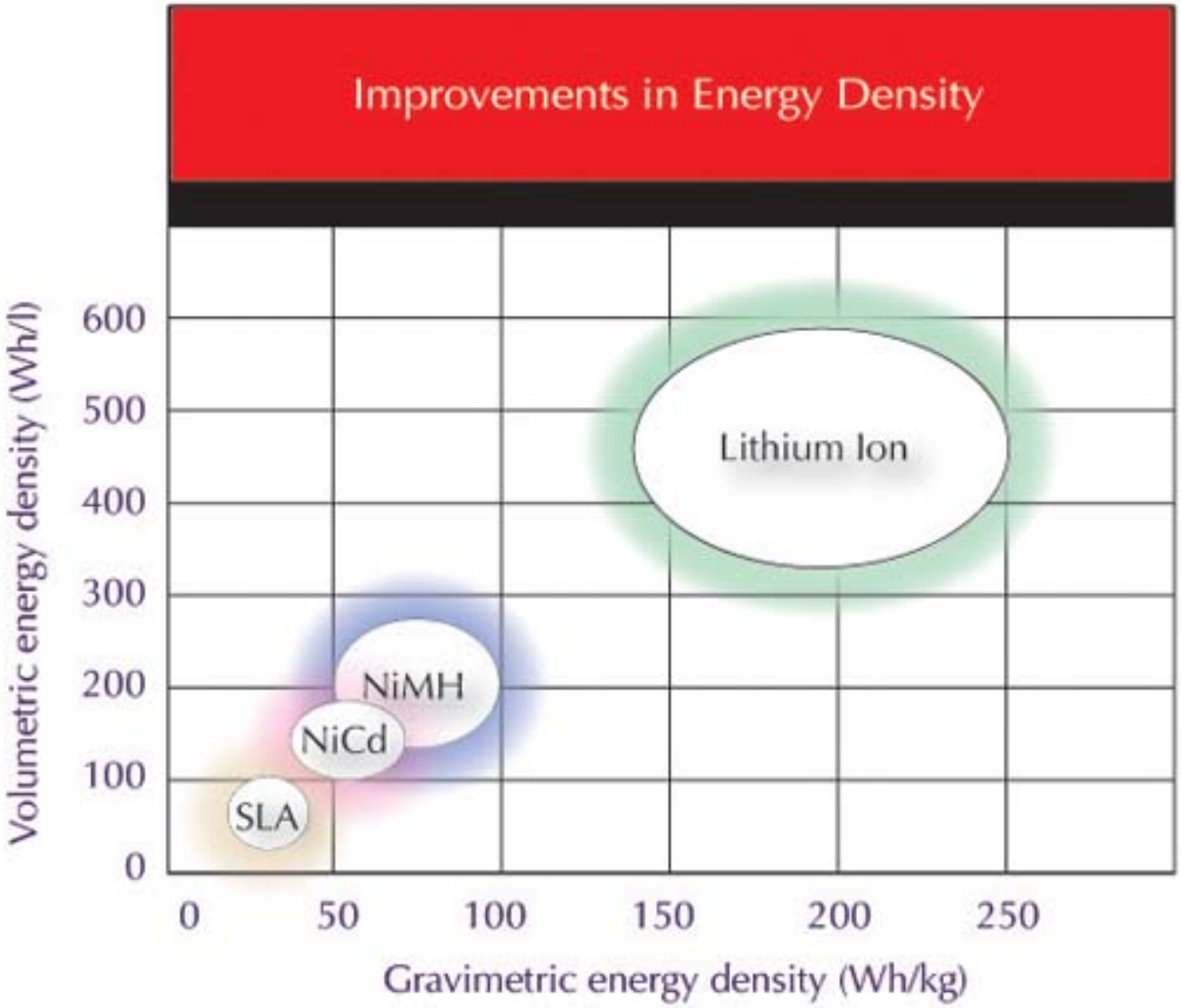
Applications with high voltage and capacity requirements are adopting Lithium-ion (Li-ion) technology because of its many advantages- especially the high energy density, small size and low weight that this technology provides. Historically, Sealed Lead Acid (SLA) batteries have had a few superior technical traits, in addition to their extremely low cost, that have kept them leading the majority of the overall battery market. However, recent innovations in Li-ion chemistry has made it extremely competitive in markets that are weight sensitive and inconvenienced by SLA's need for frequent maintenance. Many devices have required batteries for power back-up and these are primed for direct Li-ion replacement of SLA.

Li-ion battery systems are a good option when requirements specify lower weight, higher energy density or aggregate voltage, or a greater number of duty cycles. This accompanying graph illustrates that Li-ion technology offers a pronounced energy density advantage by both volume and weight. It’s also important to note the size of the Li-ion bubble; it represents the many flavors of Li-ion available on the market. The specific characteristics of each Li-ion cell chemistry, in terms of voltage, cycles, load current, energy density, charge time, and discharge rates, must be understood in order to specify a cell that is appropriate for an application. Conventional Li-ion chemistry, designed for portable applications like lap-tops and cell phones, is designed to offer the highest energy density by size and weight. Typically, these applications do not have high current requirements and are relatively price sensitive, so conventional Co-based Li-ion cells are appropriate for applications that need to be smaller and lighter.



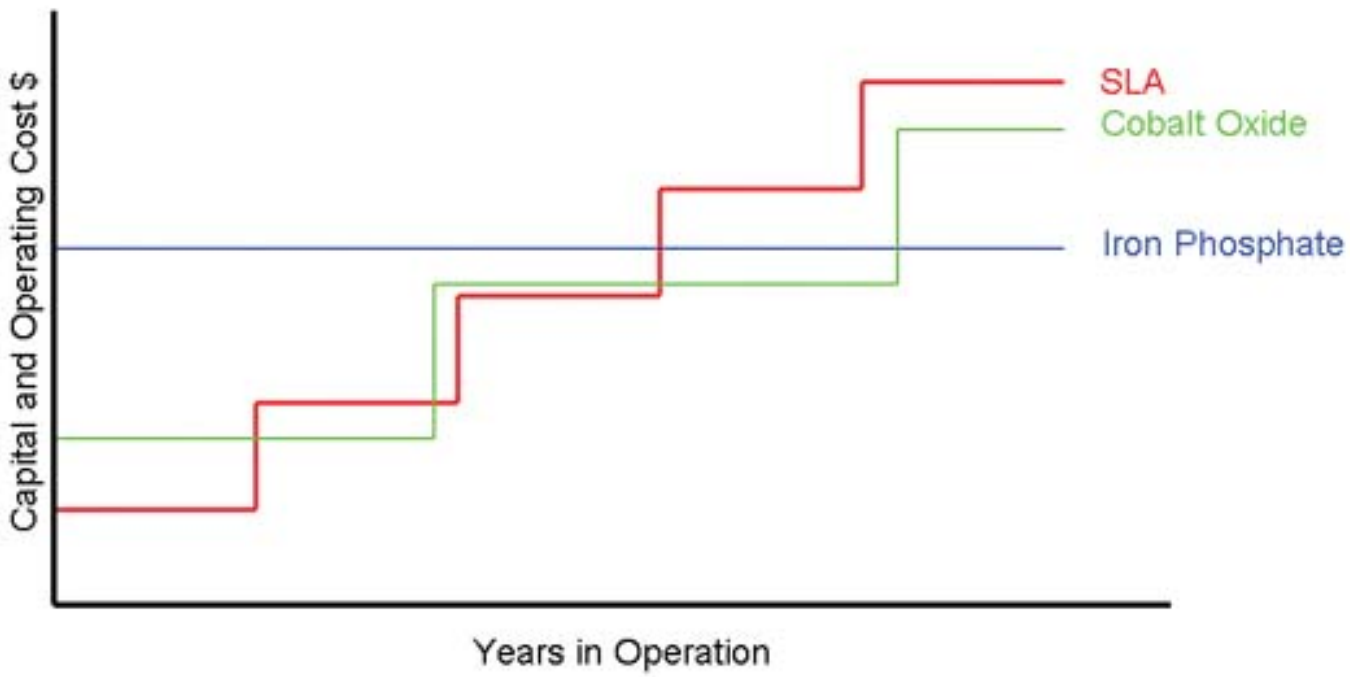
The three primary functional components of a Li-ion battery are the anode, cathode, and electrolyte, for which a variety of materials may be used. Depending on the choice of material for the anode, cathode, and electrolyte, the voltage, capacity, life, and safety of a Li-ion battery can change dramatically. The cathode is generally one of three materials: a layered oxide (such as cobalt oxide), one based on a polyanion (such as iron phosphate), or a spinel (such as manganese). The electrochemical reaction produces about three and a half volts depending on the chemistry and brand, so four cells in series can produce a range of nominal voltages from 12.8 to 14.8. Battery packs made with Li-ion are not a simple configuration of cells. They are carefully engineered products with many safety features. The main components of a battery pack include; the cells, which are the primary energy source, the printed circuit board, which provides the intelligence of the system, the plastic enclosure, external contacts, and insulation.

SLA batteries are stressed the most if discharged at a steady load to the end-of-discharge point. An intermittent load allows a level of recovery of the very chemical reaction that produces the electrical energy. The advantage is a simple voltage measurement can be used for fuel gauging. Traditional fuel gauges for Li-ion either monitored the voltage or the capacity, and the accuracy was quite limited. This is

due to that flat discharge curve we saw earlier. New gas gauges monitor the number of coulombs being transferred and opportunistically calibrate with the open circuit voltage of the Li-ion pack. These features allow the end-user to intelligently manage device use and avoid unexpected failures or shutdowns.

Direct Replacement of SLA with Li-ion, Fe-phosphate Chemistry
Newer Li-ion chemistries are optimized around the power tool and electric vehicle markets. These Fe-phosphate based cells have remarkable cycle life and current delivery capability, but their volumetric energy density is less and upfront cost is greater. The benefits of new high rate Fe-phosphate cell chemistries include; increased safety, low impedance and high discharge rates and a voltage that matches well with SLA at 12 and 24V increments. These design features allow use of a conventional SLA charger. Fe-phosphate chemistry also yields the longest cycle life, which can be as many as thousands of cycles and several years of operation.

Figure 2



There are several charging methodologies for SLA batteries. Due to the versatility of the SLA battery chemistry, charging electronics are simple and cheap, and numerous options exist. For Li-ion batteries, constant current - constant voltage, or CC/CV, is the only universally accepted Li-ion charging method. A constant current equal to or lower than, the maximum charge rate is applied to the battery until the maximum charge voltage is reached. A Li-ion battery is fully charged when the maximum charging voltage has been reached and the falling value of the charge current is below a certain fraction - usually 1/30 to 1/10 - of the battery's maximum charge rate. When a device manufacturer considers migrating from SLA to Li-ion battery, they have several options for placement of charge control electronics. The simplest option is to totally replace the SLA charge electronics with Li-ion charge

electronics within the charging bay. The new Li-ion charger is backwards compatible with the SLA batteries, but the old SLA charger is not forward compatible with the new Li-ion battery. Lithium iron phosphate provides a nice compromise for migration from SLA, as it will operate with most of the SLA charging methods.

This final graph conveys the economic tradeoff between SLA and 2 Li-ion chemistry solutions. One might imagine an SLA battery for a product with a 10 year lifetime. Over this lifetime the SLA would need to be replaced 5 times. A cobalt oxide pack with similar capacity would cost roughly twice as much but its cycle life is almost twice as much also. The upfront cost would be more, but over the lifetime of the product the total cost may be lower. With an iron phosphate Li-ion pack would likely be about 3 to 4 times the upfront cost, but the cycle life is so long that the solution will almost certainly have a lower cost over the life of the product. The Fe-phosphate cells are more amenable to direct use of an SLA charger and are appropriate for replacement of SLA when total cost of ownership and weight reduction are the primary objectives.

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