Is Lead Dead?

By David Hrivnak, Knoxville EVA

What would you say if I just replaced my 600 lb lead battery pack with a 170 lb lithium pack, and saw my range increase from 22 miles to 55 miles? What if I told you I kept my same lead battery chargers and can do the pack replacement for $2400, just $600 more than "discount" lead batteries. You may, like I, be saying "lead is dead".

While I am only a hobbyist, I wonder if the new generation and pricing for lithium batteries will very soon make lead obsolete.

Over the past four years I have been designing and building a hybrid conversion of my 2004 Avalanche using an Engine Motor Interface System (EMIS) kit from Lockport, Illinois-based NetGain. See *http://www.go-ev.com/EMIS-Desc.html* The EMIS connects into the trucks computer through the OBD port and then will power the electric motor that is connected between the transmission and differential.

The system is an electric assist that fools the gas engine to think you are driving downhill on the level and on the level when going uphill.. [Ed: You can watch a short video on this technology at work here: *http://www.electric-cars-are-for-girls.com/hybrid-cars.html*] During this time I have come to realize the huge benefits of Li-FePO4 batteries and how much better they were for my project. I am using 12V format lithium batteries for a simple drop in replacement of my first set of lead batteries. In a later article currently planned for Current Events, I plan to detail more about my use of the EMIS kit.

Because of where I needed to store the batteries I could not use the common flooded lead batteries and needed lead AGM. These batteries can be freely mounted in any position as they have no liquid electrolyte. The batteries also needed to be maintenance free since they are inaccessible under the vehicle. While I would have liked initially to use Lithium batteries, my price quote back in 2006 was $13,000, far out of my price range. My first lead battery was $85 for a 50 AmpHr Werker brand ($1.70/Ah). After testing and building my battery boxes I installed my first string of 6 batteries and found the price of the Werker batteries increased to $100. I have two parallel packs of 72V for 12 total batteries. Due to many complications in getting the right parts, it took me over two years before the conversion was really on the road. During those two years I did keep the batteries charged and performed a few test runs.

When I really started to use the system I found that after only 8 months of hard use my Werker batteries were essentially dead; my range was a pitiful 3 miles of assist. Because my batteries were purchased 14-26 months earlier the warranty had already expired. I was out of luck. When I looked to replace the Werkers the price had now gone up to $145 a battery or $1750 for the pack. That was $2.90/Ah. I thought that was outrageous given my poor experience so I looked at moving to Optima Yellow tops, but with a pack price of $1920, I was starting to have thoughts of scrapping my project all together. Then I checked Lithium batteries one more time and found that the price had dropped DRAMATICALLY. They claimed they could sell me a set of 12 batteries for under $2600 and lithium would last much longer than lead batteries. That worked out to be $5.41/Ah, since I have two parallel strings delivering the same voltage.

I found the claims hard to believe but I decided at that price to buy a battery and run my own tests. Those tests are documented here; I was amazed with what I found. I tried a simple run down test where I put the truck on jack stands and connected a single battery to the electric motor and recorded the voltage over time. I stopped the test when the batteries were down to about 10.5 volts. For lead cells, that is 1.75 volts per cell, a standard "dead threshold".

At this point the wheels were still spinning at about 15 mph but I did not want to destroy the batteries. My old Werker batteries were out of juice in 2 minutes, which was not surprising, as I knew they were shot. The Optima were lighter (at about 36 lbs versus 50 lbs for the Werkers), and those Optima would run about 10 minutes before reaching the threshold. But when I tried the Lithium battery it ran for over 28 minutes! Nearly 3 times the run length and they weighed a scant 13 lbs each. It seemed too good to be true! Three times the run length at 1/3 the weight was more than worth the price premium to me. The Werker batteries died after 150 cycles, and Optima claims 400 cycles, but the Li-FePO4 claim was 2000+ cycles!

I decided I had to give them a try. I drove 550 miles to pick up the batteries as I still thought the story too good to be true and wanted to look the seller in the eye. I found the seller to be sincere and honest.

The batteries have been installed and tested for 8 months now and while they were not perfect, I am pleased. With the Werker batteries I could get electric assist for about 22 miles, I now get assist for 55 miles. I use the same 12V charging system (one for each battery) and I am told I could even get more range if I would splurge new chargers with a higher float voltage, as these Lithium's can go to 16V (which is 4.0 volts per cell). But by not fully charging them, the Lithiums should last even longer than 2000 cycles. Of note, I did have one cell fail but it was replaced promptly with no problem.

The savings of more than 420lbs over the Werker batteries made a noticeable difference in performance and mileage.

The two drawbacks I have seen with the lithium are at temperatures at less than 40°F when their range drops off. At 20°F the range is a scant 4 miles but lead batteries have a

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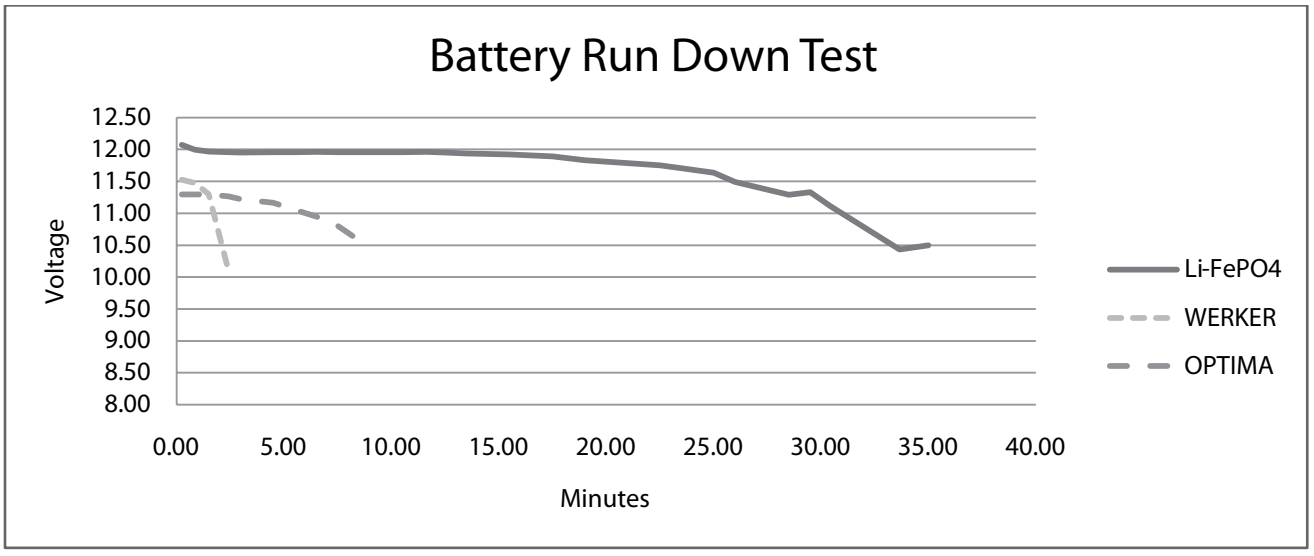
similar problem with cold. I have not yet identified if the batteries are solely at fault, and have been told that the controller electronics may come into play. I will have to perform tests next winter to validate that notion, as spring has already sprung.

Fortunately as temperatures warmed back into the 50's (Fahrenheit) my range is back to normal. Another negative is, at least with this smaller size (40 amp-hr) lithium batteries, they do not like high current draws. I would not expect they could supply much more than 250 amps per string. However with the two parallel strings that I use and a 450 amp controller I cannot really use more amps now.

Below is a chart from a series of "run down" tests. I put the truck on jack stands and placed the transmission in neutral. I would then hook up a single battery to the electric motor and allow the wheels to spin at about 15 MPH. I estimate the current draw at 80 amps. I would then measure the battery voltage over time and switch the system off when the battery voltage dropped to 10.5 V.

Nominal Pack voltage 72V (6 batteries in series)
Config (two parallel strings of 6 batteries each, for 12 batteries total)
The 6 batteries in series are tied together at the controller.
Chargers – 4 Dual Pro 3 chargers (each charger has 3 leads to independently charge 3 batteries).
Lithium config: Each "battery" is composed of 4 cells that arrived preassembled.



Li-FePO4 TS-LFP40AHA,	40 amp Hr,	13 lbs	($200 10+)	– Average of 10 tests
Optima D51,	38 amp Hr,	36 lbs	$159	– Average of 3 tests
Werker (after 8 months of use)	50 amp Hr,	50 lbs	$125	– Average or 2 tests

So in summary I would look hard at Lithium for any EV conversion. From my testing they seem to be a far better option than lead batteries.

For more details please see *http://webpages.charter.net/dhrivnak/hybrid_conversion.htm* for details of the project or *www.hrivnak.com* For a electrical schematic see: *http://webpages.charter.net/dhrivnak/wiring_diagram.htm*