BATTERY FAILURES –
PREVENTION, DETECTION, & CORRECTION
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As cold weather arrives, we have received calls regarding a significant decrease in range. Typically, a lead acid battery will lose 50% or more of its capacity at 0F; and a greater decrease at lower temperatures. But batteries also fail; so the questions become how to prevent failures and how can a failed battery be indentified?

In fact, this paper will cover:

- Prevention
- Detection
- Correction

Although this paper is written for lead acid batteries, the principles apply also to lithium cells.

Prevention

How can we prevent battery failures?

Step 1 - Choose wisely
This is critical; there are many different battery labels, but only a few good manufacturers. Major manufacturer are Trojan, U.S. Battery, Deka (East Penn), and Optima. The EV Album identifies 1147 wet lead acid battery users; these manufacturers provide the majority of batteries with Trojan at 372 users; U.S. Battery at 182 users; Optima 147 users, and Deka 103 users. (www.evalbum.com November 12, 2012)

A general rule of thumb is that battery weight should be 30% of the finished weight of the EV. So a 4000 lb truck should have ~1300 lbs of lead acid batteries. If you put in a light-weight battery pack (i.e. 10 – 12v (630 lbs) , the current will be greater than the battery's plates can handle, causing premature failure.

We have found that the typical life of lead acid batteries are:

12V batteries - 10,000 miles
8V batteries - 15,000 miles
6V batteries - 20,000 miles

Our customers with Sam's Club, Costco or other box store brands have not achieved the same performance as Trojan or U.S. Batteries; but they also paid quite a bit less. So remember, you get what you pay for.

One customer called and stated that he got 28,000 miles out of his 6V Trojan battery pack. When asked how? He basically said that he took care of them.

EVA has sold Trojan batteries for more than 20 years; we work with the Trojan Master Distributors across the country. We can help you identify your range and help you with pricing.

This year, we sold two systems to two brothers who converted identical S10s. One brother bought T-145 Trojan Batteries from us; the other bought a battery pack from a local manufacturer who claimed his batteries were better than Trojans. Well, the brother with the Trojans gets 70 miles on a charge; the other brother gets only 30 miles. To verify that the increase was due to the Trojan batteries, these brothers put the Trojan batteries in the poorly performing S10. The range increased to 70 miles! So Buyer beware! And don't always believe battery salesmen.

Step 2 - Proper Installation

Once the proper batteries are purchased, it is essential to install them properly. We recommend a non-conductive box with 1 inch of polystyrene insulation on a metal frame. We never recommend placing the batteries directly on metal, because metal is not only a great electrical conductor, but it is also a great thermal conductor. The worst case I ever saw was batteries inside an aluminum battery box. The purpose of the insulation is to utilize the amperage when you drive to increase in battery temperature. With 100-200 amps going through the batteries, they will heat up 20-30 F, if insulated. Locate the batteries adjacent to each other with the 1 inch of polystyrene around the perimeter and on the bottom. Polystyrene is sold in 2 ft x 8 ft sheets at any building supply.

Our recommendation for years has been to use a lock washer or wave washer under the nut on the battery terminal. The purpose is to maintain tension against the nut, so as the lead post relaxes, the nut does not become loose. It is still necessary to re-tighten the nut to manufacturer's torque setting 1-2 weeks after the initial tightening. Trojan Battery does not recommend the lock washer; they recommend a flat washer and periodic checking. I will let you make the decision.

Step 3 - Proper Break-In & Use

Once the vehicle is operational, it is necessary to break in the new batteries. It will take 30-50 cycles to maximize range. We recommend that your first drive be 5 miles for 12V batteries and 10 miles for 6V batteries. Then add 5 miles (12V) or 10 miles (6V) each

time you drive. Do not drive your EV until the batteries are totally exhausted; this will shorten their life.

The ammeter, voltmeter, and fuel gage are all necessary instruments to help you keep from damaging your batteries, controller, or motor. The ammeter identifies the current from the battery to the motor. If it is always high (> 200 amps), the motor can be damaged and your batteries will be depleted faster. If you cut the current in half, the available time doubles plus you gain 10 percent for fewer losses. So operating at 100 amps vs 200 amps, more than doubles your operating time.

The voltmeter is the most important instrument to protect your batteries. The battery voltage should never go below 1.75V/ cell under load. So for a 120V pack, the voltage should never go below 105V (60 cells x 1.75V/cell) with your foot on the accelerator. Driving with the pack voltage below 1.75V/ cell, you will shorten the life of your batteries substantially. It is recommended that you use red construction paper to cover the voltage on the voltmeter below 1.75V/ cell. This will alert all operators.

The voltmeter can also be used as a fuel gauge. For example, when fully charged a 120V pack is at 130V. Two-thirds (2/3) of your energy is above the nominal voltage, so 1/3 is below 120V. If the no-load voltage is 115V, then your 120V batteries are essentially done. For 144V pack, full is 156V and empty is 138V. Simply take your foot off the accelerator when driving and you will see the status of your battery pack on the voltmeter.

The fuel gage is important to provide confidence that you will be able to make it home. The voltmeter is good, but the fuel gauge provides extra confidence. Many fuel gauges have a bell-shaped curve. So the first bar may only be 2-3 miles while the middle bars are 10+ miles.

While you are breaking in the batteries, it is important to establish the baseline performance of the battery charger. See http://evamerica.com/chargertesting.html Then we recommend quarterly testing to verify continued performance. Occasionally, a customer will call and say the charger sounds different. I always ask him to take the data, so that a comparison can be done, so the baseline is critical.

Step 4 - Proper Maintenance

I like wet lead acid batteries for two reasons: (1) they require maintenance which means I have to look at terminals, etc. and (2) they are more forgiving than other batteries from abuse. I recommend that you set aside the 1st day of the month as the day to inspect your EV and water the batteries. Remember to use only distilled water and check all your terminals.

Centralized Watering systems were not very successful in the 1990s, but there are newer systems available today. In rare cases, it may make sense to use. You can minimize the

frequency of watering by using water miser caps. http://www.flowsystemsusa.com/water-miser-vent-cap.html

Detection

Battery failure is pretty obvious in most cases. Typical symptoms are:

- EV won't operate or can only operate at slow speed.
- EV has limited range – significant decrease in a short period of time.
- Fire – very rare – but it can occur.

In addition, the fuel gage will read high while voltmeter drops substantially. This is a great indicator.

The real question is which battery has failed. Often mechanics and battery shops use a battery discharge meter to detect failures. Usually this method is only good for starting batteries, because deep cycle batteries can sustain higher loads for longer periods of time than the discharge meters can measure.

On the Troubleshooting Section of our website, the following procedure is provided to identify a bad battery:

- Charge all batteries
- After one hour record the voltage of each battery, using a digital voltmeter.
- Do close to the maximum range miles
- Quickly take the voltage of each battery with digital voltmeter.
- Compare the voltages - the bad battery should be 1-2 volts lower.
- Charge the batteries again.
- Bypass the bad battery so that it is not in circuit
- Drive again and see if range increases. This confirms that you have identified the bad battery.
- Put bad battery back in circuit
- Recharge
- Then replace bad battery.

If you have an infrared thermometer, the bad battery will be 15-30F hotter after the first run at maximum range. This is a nice confirmation.
Ref: http://evamerica.com/batterytesting.html

Correction

Once the bad battey or batteries have been clearly identified, it becomes easier to correct the problem. Then the question becomes what is the best method of replacement. If the batteries are new, then it is a warranty problem. If they are 1-2 years old, then warranty replacement may not be a consideration. If the battery pack itself is in very good

condition with some loss in range, then I recommend replacement with a new battery of less capacity. For example, a less expensive Trojan T-105 might go into an older T-145 battery pack. If the battery pack is only capable of 30-50% of its original range, then I recommend buying a good used golf cart battery for $10-$20.

When your battery pack finally requires replacement because they no longer meet your range requirements, consider selling them to someone who needs less range or for a golf cart owner at a camp ground, etc. where range is not important.

Conclusion

Batteries are key to great performance! Without great batteries, you will not get great performance. So we encourage you to:

- Buy the best batteries to meet your needs
- Install them properly
- Break them in gently
- Maintain them monthly
- Use your instrumentation

Your batteries are your greatest investment. With TLC, you can maximize their life and performance.

Additional Resources

"Battery Essentials" by Electric Vehicles of America, Inc.

Trojan Battery User's Guide
http://www.trojanbattery.com/pdf/TRJN0109_UsersGuide.pdf

Battery University **http://batteryuniversity.com**