BATTERIES ESSENTIALS"

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INTRODUCTION

The proper selection and care of the EV battery are essential for EV performance and economics. Batteries are a substantial investment and if the desired performance is not achieved or shorten life occurs, the investment is wasted.

The purpose of this paper is to discuss the hands on aspects of EV batteries. EVA has been very fortunate to be a supplier of Trojan batteries for more than 8 years. Trojan batteries and our customers have:

- *Achieved 143 miles/ charge*
- *A battery life of 20,000 miles*
- *High reliability*

Frequently, someone will say "that they can buy a battery for less". Our response is "How often do you want to replace it?"

SAFETY

Batteries contain sulfuric acid, hydrogen gas, and represent the energy equivalent of 1-3 gallons of gasoline. Therefore it is essential that you always consider safety, including:

- *Wear proper eye, face, and hand protection.*
- *Use terminal covers over each terminal .*
- *Use protective covers over sections of the battery pack. For example, if batteries are grouped together, overlap a cover such that only 12-24V of batteries are exposed when working on the batteries.*
- *Use short handled tools so that the tool cannot reach between battery terminals. Wrap the tool in electrical tape or some other insulating material.*
- *Remove vent caps only for inspection.*
- *Never smoke near batteries.*
- *Connect the DC charging connections first, then start the charger (AC input).*
- *Always disconnect the input side (AC) of the charge, before removing the output side (DC).*

SELECTION

The main criteria for selecting a battery are:

- *Performance Required - Range*
- *Size in order to fit within the EV*
- *Weight*
- *Cost*

Range is a function of pounds of lead - referred to as pounds of fuel. Therefore, a 1400 lb battery pack gives more range than a 800 lb battery pack. Acceleration is a function of voltage and current limit which equals Horsepower vs vehicle weight.

According to "Battery Book One" by Curtis Instruments, the manufacturer's battery capacity is given as 100 percent discharge; however, the recommended usable capacity is 80 percent of the rated capacity.

The amp hour rating of a battery, typically given at a 20 hr rate rates capacity. Most EVs operate at 100-200 amps. A more meaningful number by the manufacturers is the number of minutes at 75 amps. A Trojan T-105 is good for 105 minutes (recently upgraded to 107). That translates into 131 amp hrs. Notice the significant decrease in amp-hr capacity.

Sealed batteries sound promising. Our observation has been that sealed batteries have two significant problems. First, their range is typically 25-33 percent less than a wet battery. Second, it is difficult to find a charger that will charge the sealed battery properly at higher voltages.

The economics of batteries are based on :

1. The cost to charge ($/mile). This is based on the kw-hrs per charge, miles /charge, and the cost per kw-hr for electricity. Free electricity from an employer or off-peak rates decrease this cost substantially.

2. The life cycle cost of the battery ($/mile). This is based on the cycle life of the battery. Cycle life does not increase as the depth of discharge decreases. For example, if you only discharge the batteries 10 percent DOD, you do not get 8 times the cycle life of discharging it 80 percent. DOD The cycle life may increase by a factor ofonly 2-3.

INSTALLATION

There are many different battery connections, (automotive post, universal post, L post, etc).

On automotive posts and L posts the bolt is offset from the center of the lead post. This means that if excessive torque is applied it will break the seal between the polyethylene battery case and the lead post. This seal is designed for difference in thermal expansion between the two materials. Breaking this seal allows acid to rise and corrode the lug, etc. Less expensive batteries frequently have a poorer seal design.

We prefer the universal post, where the post allows the bolt to go through the center of the post. The advantage is that you are not applying torque offset from the center of the post and therefore, less likely to break the seal.

Some installation guidelines are:

1. Do not use a ratchet.

2. Use two wrenches where necessary.

3. Do not overtighten. Tighten until the lug is snug against the post, then tighten another 1/2 turn. Torque wrench use 70 inch-lbs.

4. Inspect and retighten after the first five battery charge cycles. The lead post may relax.

5. Pay attention -do not damage the post.

6. If you are interrupted while tightening the bolt, either finish tightening it or remove it. Do not leave it .

7. Do <u>not</u> lift the battery by its posts. Use the handle brackets.

Be extremely careful when tightening the battery connections. It is a critical task. Done incorrectly, batteries can be damaged and their life shortened.

INITIAL BREAK-IN

It is important to prepare batteries. One cannot expect to install batteries and immediately achieve maximum performance. To optimize the performance of deep cycle batteries:

1. Always! Always! Always charge the batteries before their first use. Do not drive the vehicle until the batteries have been charged; the charge that comes on the battery is only a surface charge

2. Start early in cycling the batteries. It takes 30-50 cycles to maximize range. If you are preparing for an endurance race, finish the vehicle 1-2 months early to optimize the battery performance. This also helps you optimize the vehicles and driver's performance. You can put two cycles a day on the vehicle by running it first thing in the morning and then charging the pack. Then run it again at night and recharge over night. This allows you to get 30 cycles on the batteries in a little over two weeks.

3. Break the batteries in slowly. Start at 10-20 percent of your estimated range and then gradually add 10-20 percent each cycle. Try to get the vehicle up to its rated performance in about 10 cycles. Think of your batteries as an athelete. Exercise them, to get them in shape but don't overdo it initially.

Also understand the design of your charger and what facilities will be available for AC power. If your charger is designed for 240 V, but only 208 V is going to be provided; your pack will require longer to recharge. We use a buck booster to increase our voltage and current for charging.

Also some chargers with automatic shut off will not operate until the battery pack is cycled 5-10 times. So initially turn the charger off when you think the pack is charged.

USE

Frequently, there is the question regarding charging after some minimal miles (5-10 miles) vs charging after some greater distance (30-60 miles). There are a number of considerations to optimize the performance (range) of deep cycle batteries and to minimize the life cycle costs. Typically, we recommend that the battery be discharged 30-50 percent before being recharged.
Deep Cycle (Lead Acid) batteries develop a memory! Their performance is a function of their previous cycle. If they saw very little range or no range in their previous cycle, the next cycle will be affected. If they receive a shallow discharge, they may not provide the maximum range when required. Batteries must

be exercised in order to perform. If they are not exercised, they will lose performance.

Inactivity decreases performance. If the batteries sit for any length of time, they lose capacity and must be broken in again. EVs that sit idle over a weekend have less performance on Monday - than they did on the previous Friday. If the EV sits idle for a week, it may lose 25-50 percent of its range. Even if you do charge it the night before.

Never use an additive. There are claims that additives increase battery life. One additive was found to decrease performance in proportion to the electrolyte that had to be removed to allow its addition.

Proper charging is critical to maximize life. Batteries should be charged near their optimum rate (amperage). This rate is usually the 20 hr rate divide by 10. So the T-145 battery should be charged near 25 amps. The SCS225 (12V) should be charged at about 13 amps. The purpose of this charging rate is to increase circulation between the plates. If the amperage is too low, stratification will occur between the plates, and the range will slowly decrease. This is long term degradation.

BATTERY FAILURE MECHANISMS

*Premature battery failure is due to**:***

1. Repeated Deep Discharges (Improper battery sizing).

2. Improper battery charging

3. High temperatures. Every 10C (18F) above 70F reduces battery life by a factor of 2.

STORAGE

If batteries are stored for any period of time, it is important to remember to keep them charged. The optimum storage temperature is 40F. Cold weather minimizes the chemical activity within the battery. At 40F, charging is required every 4-6 months. Whereas, if the storage temperature is greater than 60F, the battery must be charged monthly. Remember batteries freeze if they become discharged. The temperature at which they freeze varies with the amount of charge. A fully charged battery will freeze at -40F. At 0F, a 45 percent charged battery (S.G. 1150) will freeze.

MAINTENANCE

Our tendency is to think of our EVs as Zero Maintenance Vehicles. However, it pays to start good inspection habits early.

<u>Weekly</u>

- *Visually inspect battery connections, etc. Note any burn marks.*
- *f a cell has been a problem (excessive watering, etc.), check it!*

Monthly

- *Check the water level. Add distilled water only. Water should be added if the level is 1/2 inch below the full level. Add water after charging. Use a battery jug for proper filling. Do not overfill.*
- *Clean the surface of the batteries with a damp cloth. Do not remove caps. Do not allow foreign matter to enter battery cells.*
- *Remove caps and inspect a few batteries internally.*
- *Take voltage readings for each battery and compare against previous readings. The batteries should be fully charged, and allowed to sit idle for 4-8 hours for the voltage to stabilize.*

Annually

- *Remove the batteries from their battery boxes and clean thoroughly. A solution of bicarbonate of soda (1 cup) per pail of water can be used to wash the batteries. Thoroughly rinse with clean water after washing. Do not allow this solution or the rinse water to enter cells.*

TESTING AND REPLACEMENT

Numbering of Batteries
At EVA we number our batteries from negative to positive, this allows us to multiply the battery number by the battery voltage to obtain the theoretical voltage. Therefore, the10th battery (6V) has a nominal voltage of 60 volts (10 x 6V). This system of numbering is effective when doing the following:

Recording Specific Gravity or Voltage
When we measure specific gravity or voltage for each battery, we identify the cells as A, B, C, etc. The third cell is on the 5th battery is 5C. We usually develop a table for a history of specific gravity readings, as follows:

Specific Gravity/ (or Voltage Readings)

Battery No.	*Cell*		
	A	*B*	*C*
1	*1.300*	*1.299*	*1.300*
2	*1.300*	*1.300*	*1.299*

Typically there should be minimal voltage difference between batteries. Our T-145 batteries would read 6.48-6.51 when new. As they got older, the voltage would decrease, but there would be consistency between batteries. If one battery is lagging behind the others, charge it separately using a 6V or 12V charger after the battery pack has been charged. Repeat this a number of times, trying to bring the battery back in line.

If the specific gravity of one cell in a battery varies by 0.030 or more, it may indicate a bad cell. Try charging the battery separately.

Replacement

As batteries age, deposits will build up between the plates. New batteries have clean plates. Also the battery voltage will drop. The batteries should not be discharged below 1.75 V per cell (5.25V for a 6 V battery) under load. If a T-145 is 6.5V initially, that allows 1.25V to be used. If the voltage decreases to 6.25V, then more than 20 percent range has been lost.

As batteries age, they will require frequent watering. It is time to consider new batteries, especially if winter is coming. Because winter temperatures will decrease performance. At 32F, a battery loses about 50 percent of its capacity.

Recently, we have heard about batteries at their end of life shorting out and exploding. This did not create a major problem in our truck design, but would create a problem if the batteries were within the passenger compartment.

CONCLUSION

Our conclusions from our own experience and our hundreds of EV customers are:

1. Performance (range) requires exercise. The EVs that utilize the capacity of the battery have better range.

2. Use of the battery to 50-80 percent DOD decreases life cycle costs. If your EV has a range of 50 miles, this means you should charge after 30-50 miles in order to maximize battery life.

3. Equalization to 2.55-2.58 volts/ cell will increase performance and life. If the batteries are constantly undercharged, their life and performance will decrease. Equalization must be done once every 5-10 cycles. If done every cycle, the cost per charge increases.

4. Batteries are tough. If they have been under utilized, exercising will bring them back. Most batteries are discarded before they fail. Frequently batteries are replaced when their capacity is less than 80 percent of their original capacity. However, these batteries can be sold or given to someone else who requires less range.

So use your batteries and consider how their life can be maximized - it will decrease your EV cost.

BIBLIOGRAPHY

1. "Battery Book One" by Curtis Instruments, Inc..
2. "Deep Cycle Battery Maintenance" by Trojan Battery Company.
3. "More Power" Application Manual, by Eagle Picher.
4. Battery Service Manual, Battery Council International, Chicago, IL, 1987.