Safe conversions: Battery Thoughts

10/30/2009 Version 1 David Kerzel

I look at converted vehicles and see a wide range of safety consciousness and workmanship. These vehicles are being converted for a number of reasons and with wide expectations. Most conversions are done by an individual at home who is learning as they go.

These projects are high power electrical systems that need to be respected. Please always wear Safety Glasses. If something happens at these energy and current levels, metal that makes up tools, batteries, wires, and other components melts and is often splattered from the explosive arc that may happen.

All electrical connections need to be done with care, using proper size wires and appropriate terminal lugs. All connections and devices need to be electrically touch safe, either by insulation or by being located in a secondary protective enclosure.

Warning decals are needed to remind people of the hazards even at the batteries where the hazard may appear obvious and the connections are tough safe.

The batteries need to be securely mounted in the vehicle. It is the second thing I notice when I look at a converted vehicle, just after I look at the wiring workmanship. Most builders make frames that prevent the batteries from moving and have clamps or straps to keep them in the frame and to reduce vibrations. These battery supports not only need to keep the batteries in position in normal use but also if there is ever a collision. The battery supports need to be able to provide a minimum of 10G of restraint, left, right, forward, back, and up or down. If you have a battery that weighs 40Lb (18Kg), the 10G of restraint is 400LbF (180Kg or 1780Newtons). That is a lot of force and if there are 8 batteries in the rack it needs to restrain all 8 or 3200LbF (14KN). Most frames I have seen were flimsy and not mounted to the vehicle well enough for forces of this level.

One of the important things will be Gross Vehicle Weight. This is the weight of the vehicle, fuel, all passengers (150 LB, 68Kg each), and cargo. When the donor vehicle was designed, it was engineered to function at the original GVW. The breaks, the suspension, the energy absorbing parts of the car are based on this weight. If this weight is maintained the original car safety and handling should be maintained.

Many converters begin the project with the assumption the GVW will be significantly more after conversion. This is probably true for conversions with heavy lead based battery systems. There are a number of reasons to avoid these heavy batteries in addition to weight.

Everyone would prefer to use the highest energy density (KW/Lb) batteries like lithium Ion but the budget often won't allow it so flooded lead acid or AGM batteries are chosen.

Flooded lead acid has the lowest initial cost and probably the lowest energy density (KW/Lb). Using them will make maintaining the original GVW very difficult. There are 3 other serious problems with PbA (lead acid) batteries.

The acid is liquid, it can spill splash, and leak. It will cause severe chemical buns if it gets on a person. It will cause metal to corrode away rapidly, and electrical connections to corrode and self heat causing more problems. In a collision, the cases can rupture and it can spill acid into the environment. They need maintenance to the liquid acid. They absolutely should not be in the passenger cabin.

When charging, especially at the end of a charging cycle hydrogen gas is produced which is very flammable. Charging techniques like SAE J1772 have a provision for batteries that need ventilation. The problem is the ventilation is not fail safe and if it fails, there is a serious possibility of fire or explosion. The idea of putting the batteries in a box or enclosure and ventilating it actually increases the likelihood that the flammable gasses will accumulate in dangerous concentrations. If a battery box is used, nothing but batteries should be in it and the vents need to exit the vehicles side, not on the bottom, hydrogen is lighter than air so the accumulated gas will rise and disperse away from the vehicle and other enclosed spaces.

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The other problem is the number of charge cycles. Most PbA batteries used are rated at 300 to 400 charge discharge cycles before performance is lost. If they are not discharged too low and well maintained a few more cycles will result. Regardless, in less than 2 years the battery capacity will be significantly reduced. In the long run, these may be very expensive based on cycles or miles driven.

AGM batteries are sealed PbA batteries. They have a thin porous fiberglass mat between the lead plates and only enough acid to wet all the parts. They can still leak but there is very little acid. When they charge they still make hydrogen but it is stored in the cell. The pressure of the gas builds up in the cell, but when it discharges that same hydrogen gets reabsorbed in the acid. If they are significantly overcharged, a safety vent will open and let out some of the hydrogen. Most have a way to connect vent tubes to exhaust this gas but few people implement this safety feature. Finally, AGM normally have more charge discharge cycles in their life than flooded batteries but they are more expensive.

Lithium Ion batteries come in a lot of chemistry variations and configuration. All of them have high energy density (KW/Lb) and this introduces a new problem, so much energy in a small volume. Some of the chemistry like ____ often used in lap top computers have positive temperature coefficients and if there is a short or over load, they continue to self heat until they burst, burn and smoke. Other chemistry like Lithium Iron Phosphate (LiFePO4) has slightly lower energy density but will fail more gracefully if abused or damaged. Abuse or damage is a real possibility in a vehicle in traffic.

Lithium Ion batteries are sealed, but many have a safety vent. The metals and chemicals in them are not as toxic as in a lead based battery. They need no maintenance and they typically have 2000 to 3000 discharge cycles before performance is lost

Comparing different chemistries for cost per cycle for a system of 148 volts, based on about 88 Amps:

Type	Voltage	Number	Price Each	Total Price	Total weight	Cycles	Cost per Cycle
Flooded PbA	13.5	11	$134.95	$1485	517 Lb	300	$4.95
AGM	13.5	11	$185.00	$2035	727 Lb	400	$5.08
Lithium Ion	3.2	46	$180.00	$8280	303 Lb	2000	$4.14

Flooded are Trojan 24TMX 12V 85Ah, Group 24, Flooded Deep Cycle Battery
AGM is a CSB Group 27, 12V 88Ah, Sealed Lead Acid Battery
Lithium Ion is a Thundersky LFP 90. 3.2V, 90Ah

The cost per cycle is the cost of using the battery pack. It is the cost for a full cycle. If you only use half of the battery packs capacity it is reasonable to assume you have used half cost per cycle. The numbers used above are manufactures data sheet numbers and probably represent a deep discharge cycle.

If you are being honest, when you tell people how you drove 100 miles on under $3 of electricity should you figure in the cost of the battery cycle?

Limiting the depth of discharging and resisting the need to charge back to 100% will extend battery pack life. Everyone want maximum range but is it worth it if never going below 30% charge and never charging above 95% increases battery life by 50% of the cycles or reduces the cost of each cycle by 33%?

The lithium Ion batteries have the lowest cost per cycle so they should end up, at the end of their life, having the lowest cost of ownership. 300 cycles for a daily driver is not a long time.

References:

United Nations Regulation 100, Amendment 99 *"Uniform Provisions Concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the construction and Functional Safety"* , 1996.

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Australian National Code of Practice for Light Vehicle Construction and Modification, Bulletin 14, *"Guidelines for the Installation of Electric Drive in Road Vehicles"*, 2006.