EVA TECHNICAL PAPERS

Enclosed are the following tech papers to help you make decisions regarding an Electric Vehicle (EV):

I hope you enjoy these tech papers. These papers will give you confidence as you decide to pursue or not pursue an EV.

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EVA - " Customer Service is No. 1! "

"ELECTRIC VEHICLES - THE CLEAN ALTERNATIVE" ©

BY
BOB BATSON

(Note: The purpose of this paper is to show the benefits of Electric Vehicles. The data is 10 years old - but the concept and conclusion remains valid. In the last 10 years we have seen little progress in on-road EVs. The automobile manufacturers take the research dollars, build a few prototypes, and then cancel the EV claiming that it does not meet the publics needs. It is important to realize that the automakers have billions invested in the internal combustion engine and make millions on repairs and replacements parts. They will do everything to protect that investment.)

Electric Vehicles are appearing in newspapers, magazines, and television. They are the future mode of transportation! The following three fundamental questions answer the question why?

1. Why do we need an alternative fuels for transportation ?

2. Why Electric Vehicles (EVs) ?

3. When ?

Each of these is discussed below:

Question No. 1 - Why are Alternative Fuels being discussed?

There are two main reasons: (1) the environment and (2) oil dependence.

Air pollution affects everyone! The average person drinks no more than 2 liters (2 quarts) of water per day; but that same person inhales 10,000 liters or 350 cu ft of air each day. If our water supply is contaminated, we can purchase bottled water, but if our air is contaminated; there is no alternative! (1)

More than 100 areas of our country will be required to control air pollutants; 27 cities including Boston have severe ozone pollution and have 10 years to come into compliance. More than 120 million people live in these areas, and 30 million people are affected. Many of our citizens are elderly who are severely affected by the air in the summer.

More than 50% of the U.S. population live in areas which exceed the ozone standard. Approximately 30 percent of the population are sensitive to ozone. Of the 12 million people who live in New England, 11 million people live in areas that exceed the ozone standard.

Cambridge Massachusetts is limiting parking spaces to control air pollutants; consequently, some businesses may look elsewhere in order to expand.

Global Warming

The U.S. is the major contributor to global warming. Recent facts support the incidence and impact of Global warming:

- *1980's were the hottest decade on record.*

- *The British Journal "Nature" reported that the thickness of the polar ice cap has decreased 15 percent between 1976 and 1987. The area was the size of Nevada.*

Recently, Shell Norway added one meter to the height of an offshore drilling platform to accommodate the rising height of sea level due to Global Warming. The additional cost was $2 million!

A comparison of the total emissions from various sources in New England is as follows:

	VOC (1)	*NOx (2)*
Mobile Sources (automobiles, trucks)	*40 %*	*66 %*
Factories and Industrial Sources	*5 %*	*34 %*

(Source: EPA Region 1)

(1) Volatile Organic Compounds also known as hydrocarbons.
(2) Nitrous oxides

The above table clearly illustrates that the major cause of our air pollution problem is mobile sources (automobiles, trucks, etc.) due to the internal combustion engine.

Imported Oil

Our consumption of imported oil has increased 60 percent during the past 5 years. In 1979, we imported 8.5 million barrels /day. In 1985 we had reduced our imports to 5 million/day. Now we are back to 8 million/day.

In Massachusetts, 70% of the energy consumption is met with oil; a major portion of this is transportation. Domestic oil production is decreasing every year; Alaskan oil production decreased for the first time in 1989. So clearly, Massachusetts, New England and the nation must seek other alternative fuels.

Question No. 2 - Why EVs?

EVs are energy independent; many different sources of energy can be used. Therefore, the EV is inherently fuel flexible so that any source of electricity can be used and many new sources will be developed in the coming decade.

While an EV operates there are no emissions. However, it requires electricity to recharge the batteries. If the source of electricity is photovoltaic, then the EV generates no emissions. However, the EV typically uses electricity from electric generating plants which use multiple sources of generation. These sources could be fossil fueled units, nuclear units, hydro electric, or any other source.

Two methods of minimizing the air pollution from automobiles are:

- *Cleaning up the fuel or source of energy.*

- *Improving their efficiency to minimize the pollutants per mile.*

Electric Vehicles (EVs) use both methods. It is more efficient to clean up the emissions at a single power plant than thousands of automobile exhausts. In addition, EVs are more energy efficient when compared to their internal combustion engine (ICE) counterpart:

		Fuel Efficiency	Energy Consumption
General Motors	*ICE*	*10 mpg*	*14,400 Btu/Mi*
	EV	*1 mi/kwh*	*10,800 Btu/Mi*
Chrysler	*ICE*	*16 mpg*	*9,000 Btu/Mi*
	EV	*2 mi/kwh*	*5,400 Btu/Mi*

(Source: EPRI)

Question No. 3 - When?

The economics have also changed recently due to the high cost of gasoline. The G-Van by Vehma International is the first commercially available production van. The G-Van selling price is $50,000 compared to the $16,000 ICE. For comparison, a pickup truck conversion similar to my own has been added. Its principal advantage is that it was converted at about 50,000 miles when many of the components start to require replacement and when engine efficiency starts to decrease.

G-Van

	ICE(1)	*EV(1)*	*Pick-up Conversion*
Vehicle	*15.2*	*14.6*	*4.0*
Battery		*12.2*	*5.4*
Vehicle Maint	*7.7*	*5.8*	*5.8*
Battery Maint -		*2.7*	*1.2*
Fuel	*15.*	*8.0*	*4.0*
	-----	-------	--------
Cost(cents/mile)	*37.9*	*43.6*	*20.4*

Assumes $1.50/gal gas and 8 cents/kwhr

Detroit Edison has done extensive testing of the G-Van; they have found that the maintenance has decreased from 2.5 hrs/month to 1.4 hrs/month due to the learning curve.

In the U.K. there is significant experience in EVs for retail delivery vehicles. The EV cost/mile is only 60 percent of the cost of an ICE.

In the late 1970s the United States Postal Service in California used EVs as postal vehicles. At that time, the cost was 2.5 cents/mile for an EV vs 5.6 cents/mile for a gasoline jeep. The principal advantage of the EV in this type of stop and go service is that an EV does not use any energy when it is stopped. The ICE jeep got only 6.5 mpg.

We can also look at a more developed industry; that of lift trucks. Initial cost for an electric is $10,000 more because of the batteries and charger. However, there is substantial saving in fuel and maintenance costs.

Fuel cost Electric	*$1.25/day*
ICE	*$ 7-9/day*

Electric trucks have 20% less driving time but 25% greater service life; annual maintenance cost is only $1700. The maintenance cost for an ICE truck ranges from $3,000 - $7,500 depending on whether it operates for one or two 2 shifts per day.

EVs are fully capable of different types of service, although the present range is limited to 50-80 miles daily. Current application for EVs include service at universities, municipal government vehicles, postal vehicles, and National Parks vehicles.

LEGISLATION

Frequently, legislators discuss penalties for large cars or an additional gas tax. But this only penalizes a majority of the tax payers which they are supposed to represent. A better way to address automobile pollution is to provide incentives. Incentives for EVs can include:

- Special Parking Areas for "EVs Only" with photovoltaic charging and reduced parking rates. These parking areas can be at train stations, commuter parking lots, and shopping centers.

- Tax breaks at the state level

- Reduced EV electric rates

- Reduced insurance rates for EVs

- Reduced registration and excise tax rates for EVs

In addition, there are more than eight pieces of federal legislation that is directed at EVs. With the support for EVs growing at the national, state, and local level, the 1990s will be the decade of the EV.

CONCLUSION

The EV is inherently fuel flexible so that any source of electricity can be used and many new sources will be developed in the coming decade. In addition, it is environmentally beneficial because it will help clean our air.

Everyone can benefit from EVs:

- *The individual benefits because it reduces air pollution.*
- *Businesses benefit due to reduced operating costs.*
- *The States benefit because a new industry is creating new jobs.*
- *The Nation benefits because of reduced imported oil.*

Yes, the 1990s will be the DECADE OF THE EV !!!

ELECTRIC VEHICLES - " THE CLEAN ALTERNATIVE " ©

(1)Reference unknown

Electric Vehicles – Our Only Alternative

By
Bob Batson
Electric Vehicles of America, Inc.

In 1991, I wrote [1] that Electric Vehicles (EVs) would:

- *Clean our air*
- *Decrease our demand for imported oil*

Thirteen years have passed. We have cleaner air but our oil imports have increased to more than 56% of our oil consumption.

My paper also stated that EVs are Energy Independent because many different sources of energy can be used to generate the electricity used to recharge the batteries. And that EVs utilize both methods of minimizing air pollution:

- *EVs are a cleaner source of energy.*
- *EVs are more efficient.*

At that time, I thought the 1990s would be the decade of the Electric Vehicle.

In 1992, President George Bush signed the Energy Policy Act [2](EPAct) to decrease our demand for imported oil. EPAct required all municipal, state, federal, and utility fleets to purchase Alternative Fueled Vehicles (AFVs) starting at minimal levels and increasing to 70% of all fleet purchases in 2003. There are token AFVs being used today. President Clinton did not enforce the 1992 EPAct.

In October 1998, Design News [3] reported that "Federal and state agencies have failed miserably in adding EVs to their fleets…. Of the 585,000 vehicles in the federal fleet, only about 200 are electric…..A battery pack for a Ford ranger EV cost more than $30,000, and Ford sells the truck for $32, 795. The battery pack for GM's EV1 costs about $45,000…..Of course these prices reflect very low volume and would come down if many more vehicles were sold." One engineer asked "Who are the 100,000 soldiers who will sacrifice themselves to drive EV prices down?"

Daniel Sperling wrote "A Case for Electric Vehicles" [4] for Scientific American magazine in 1996. This article discusses battery operated EVs as well as EVs powered by ultracapacitors, flywheels, and fuel cells. The article further states that "Although automakers worldwide have spent perhaps $1 billion on electric vehicles during the 1990s, … this investment is relatively small. The auto industry spends more than $5 billion a year in the U.S. alone on advertising".

The article further states "Much of the investment made so far has been in response to governmental pressure. In 1990, California adopted a zero-emission vehicle (ZEV) *mandate requiring that major automakers make at least 2 percent of their vehicles emission free by 1998…. The major automakers aggressively opposed the ZEV mandate but rapidly expanded the electric-vehicle R&D programs to guard against the possibility that their regulatory counterattacks might fail…..California regulators gave in to the pressure from both the automobile and oil industries and eliminated the quotas." The Bush Administration sided with the automakers in opposing the California Regulations in 1992.*

So the bottom line is that we know that EVs are an answer to our pollution and imported oil problem; yet the very people (the automakers) who can solve the problem oppose the solution. They automakers claim that EVs cost too much money. And in order to prove their point, they make them expensive. General Motors made the EV1 which they leased. The EV1 proved to be so popular that GM recalled all of them and crushed most of them to prevent their engineering and design from being used.

The true reason is that the automakers make their money from the internal combustion engine and all of the maintenance requirements it imposes (tune-ups, oil changes, exhaust system replacements, cooling system repairs, etc.). Asking the automakers to develop EVs is like asking IBM in the late 1970s to develop a personal computer. IBM made their money in mainframes; if the government funded PC development, PCs would be expensive with limited capabilities. The only reason we have PCs today is because of small businesses that had a vision!

Our federal government continues to fund transportation development with the major automakers. Haven't we learned our lesson; isn't there a better way?

In the 2003 State of the Union President George W. Bush declared his support for the hydrogen economy and the fuel cell vehicle.[5] The President stated "With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen, and pollution free."

In the report "Carrying the Energy Future" [6] it is stated "Those obstacles are considerable, in significant measure because they involve creating an entirely new system of energy production and delivery on the scale of today's power grid. The cost in the United States alone has been estimated at between US$200 billion and US$500 billion." In this report they compared the hydrogen option to the use of the existing electrical option with advanced batteries (Li-ion, NiMH). Some of their conclusions are:

- *Direct Electricity (92%) is far more efficient to transport than Renewable Hydrogen (ReH) (45-63% pipeline).*

- *Advanced batteries is a more efficient means of energy storage than ReH by a factor of 1.6. That is 60% more efficient in storage.*

- *EVs can provide twice the useful work for the same energy when compared to ReH – fuel cell vehicles.*

A National Research Council report [7] on the hydrogen fuel cell for automotive application identified many problems and the impact on oil imports and carbon dioxide emissions are likely to be minor over the next 25 years. The report also stated "If battery technology improved dramatically ….. all-electric vehicles might become the preferred alternative."

Let's look at all of these conclusions of these various reports to understand where we are:

- *EVs will decrease oil imports.*
- *EVs will clean our air.*
- *Electricity is a more efficient means of transporting energy.*
- *Batteries are a more efficient means of energy storage.*
- *Fuel Cell vehicles will have a <u>minor</u> impact on oil imports or air pollution for the next 25 years.*
- *The automobile manufacturers are opposed to EVs.*

In 1991, I was optimistic about EVs for the coming decade because we had EPAct and eight other pieces of proposed legislation. ***And we had time.*** *That time has now disappeared and we will soon be faced with another oil crisis. On November 16, 2004 the Oil Depletion Analysis Centre in London reported that oil supplies will remain tight through the rest of this decade.[8] It is worse that that – Peak oil production (world supply) will not meet demand!*

Hubbert's Curve developed in 1956 by M. King Hubbert identified when peak oil production would occur. For the U.S the curve predicted 1972. Peak oil production actually occurred in 1970. Do you remember the gasoline lines in 1973? At that time, we in the U.S only imported 36% of our oil. Now we import 56% of our oil.

Hubbert's Curve for peak world oil production is now! And world demand for oil is increasing. That means that demand will quickly exceed supply. China once an exporter is now an importer. In fact, there are only four countries that will not reach their peak for 20 years: Abu Dhabi, Kuwait, Iraq, and Saudi Arabia.

So here's the problem: *Our current means of transportation is based on solely on oil. The automakers want us to wait 25 years for possible fuel cell vehicles, but the demand for oil is now exceeding supply. We must act now!*

And here's the only immediate solution: *The federal government must encourage conversion of existing internal combustion vehicles to EVs. They can do that by providing a $4000 tax credit (not deduction) for conversions!*

Most conversions cost $6000 - $10,000. If EV owners can receive a $4000 federal tax credit that decreases the cost to $2000 - $6000. This completely changes the economics in favor of EVs over internal combustion vehicles. As identified in my letter to President George W. Bush, $8 billion can put 2 million EVs on the road. This will decrease our demand for oil, clean our air, and create a market for better batteries!

References:

1. "Electric Vehicles – The Clean Alternative" by Bob Batson, Electric Vehicles of America, Inc. 1991.
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5. Bush, President George W., State of the Union Address 2003, January 28, 2003.
6. "Carrying the Energy Future – Comparing Hydrogen and Electricity for Transmission, Storage, and Transportation", Patrick Mazza and Roel Hammerschlag, Institute for Lifecycle Environmental Assessment, June 2004. (www.ilea.org)
7. "The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs", National Research Council, Board of Energy and Environmental Systems. Washington DC, National Academy of Sciences. 2004. ES-2.
8. Solar Quest iNet News Service, November 16, 2004. http://www.hubbertpeak.com/news/article.asp?id=8228

Other links:

www.eia.doe.gov
www.financialsense.com/series3/part1.htm
http://wolf.readinglitho.co.uk/mainpages/hubbert.html
www.oilcrisis.com/ summary

Use search "Hubbert's curve"

Books

The End of Fossil Energy, John Howe, McIntire Publishing, 2004.
Hubbert's Peak: The Impending World Oil Shortage, Kenneth S. Deffeyes, Princeton Press, 2003

EVs – CONVERSION ECONOMICS

By
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Electric Vehicles (EVs) are the future!   My research indicated that 18 years ago before I started Electric Vehicles of America, Inc (EVA). It still indicates it today.

Parameter	Used Gasoline Commuter	Used Electric Commuter	Used Gasoline Truck	Used Electric Truck
Vehicle, less battery				
Price (Used)	$12,000.00	$3,000.00	$15,000.00	$6,000.00
Life / miles	10000	10000	20000	20000
Use (miles/ year)	5000	5000	10000	10000
Life, years	2	2	2	2
Salvage Value	$8,000.00	$2,000.00	$12,000.00	$4,000.00
Cost/ Mile	$0.40	$0.10	$0.15	$0.10
Conversion Cost				
Price		$6,000.00		$8,000.00
Life / miles		10000		20000
Use (miles/ year)		5000		10000
Life, years		2		2
Salvage Value		$4,000.00		$5,500.00
Cost/ Mile		$0.20		$0.13
Vehicle Summary				
Initial Cost	$12,000.00	$9,000.00	$15,000.00	$14,000.00
Salvage Value	$8,000.00	$6,000.00	$12,000.00	$9,500.00
Cost /mile	$0.40	$0.30	$0.15	$0.23
Vehicle Summary (with Tax Credits)				
Federal Tax Credit		$4,000.00		$4,000.00
State Tax Credit		$0.00		$0.00
Initial Cost		$5,000.00		$10,000.00
Salvage Value		$6,000.00		$9,500.00
Cost /mile		($0.10)		$0.03

Assumptions

Let's start with just the vehicle costs. Our basic assumptions were comparing a used gasoline vehicle to a conversion. The gasoline vehicle was assumed to be about 3 years old with about 40,000 miles, so it depreciated to about 60% of its original cost. The used electric vehicle was an older gasoline vehicle with about 100,000 miles. The vehicle has more miles on it, but most of the internal combustion parts were going to be removed anyway. We even made the Electric Commuter and the electric Truck vehicle costs high. Most of our customers spend a lot less for their vehicles – but we want to look at worst case.

We assumed the commuter is used only 5,000 miles a year; the equivalent of commuting 25 miles a day to work or to the train station. The truck is assumed to be used more – 10,000 miles per year. After 2 years, we assumed that the vehicles had lost 30 percent of their value. We also assumed that the EV components had lost 30 percent of their value.

Parameter	Used Gasoline Commuter	Used Electric Commuter	Used Gasoline Truck	Used Electric Truck
Battery Cost				
Price		$1,000.00		$2,000.00
Life / miles		10000		20000
Use (miles/ year)		5000		10000
Life, years		2		2
Salvage Value		$0.00		$0.00
Cost/ Mile		$0.10		$0.10
Fuel use				
miles/gal	20		16	
$/gal	$2.00		$2.00	
Fuel Cost/ mile	$0.10		$0.13	
miles/ kw-hr		3		2
$/ kw-hr		$0.10		$0.10
Fuel Cost/ mile		$0.03		$0.05
Summary (without tax credits)				
Vehicle cost	$0.40	$0.30	$0.15	$0.23
Fuel Cost	$0.10	$0.13	$0.13	$0.15
Life Cycle Cost/ Mile	$0.50	$0.43	$0.28	$0.38
Summary (with tax credits)				
Vehicle cost	$0.40	($0.10)	$0.15	$0.03
Fuel Cost ($2/gal)	$0.10	$0.13	$0.13	$0.15
Life Cycle Cost/ Mile	$0.50	$0.03	$0.28	$0.18
Summary (with tax credits)				
Vehicle cost	$0.40	($0.10)	$0.15	$0.03
Fuel Cost ($3/gal)	$0.15	$0.13	$0.19	$0.15
Life Cycle Cost/ Mile	$0.55	$0.03	$0.34	$0.18
Savings		$0.52		$0.16
per Year		$2,583.33		$1,625.00
5 years		$12,916.67		$8,125.00

Conclusions

I must admit that even I was surprised by the savings! Without the tax credit, the commuter vehicle saves $0.07/mile. I agree that is only $350. But we did not even consider the cost of tune-ups, oil changes, exhaust system replacement, and cooling system repairs associated with the gasoline vehicle. When you consider the tax credit, *the savings is substantial! $0.47/mile ! At $6000 to convert with a $4000 tax credit, the savings pays for the conversion in less than 1 year!*

The Electric Truck is not as economical. It savings is only $0.10/mile at $2.00/gal for gasoline and $0.16/mile at $3.00/gal gasoline. But at 10,000 miles per year those numbers represent $1,000 and $1,600 per year savings!

There are many other benefits to EV conversions, including:

- *EV conversions are the ultimate in recycling. You are taking a vehicle and recyling its use.*
- *The EV minimizes air pollution. Each gasoline vehicle put out its weight in pollutants annually!*
- *EVs eliminate the need for oil changes.*
- *EVs do not have a cooling system – no antifreeze.*
- *EVs allow you to do most of your own vehicle maintenance.*

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"Anyone can build an EV - but building great EVs requires experience and engineering. That is the advantage of an EVA Component Package. "

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"SAFETY FIRST"

by
Bob Batson of Electric Vehicles of America, Inc.
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INTRODUCTION

Although Electric Vehicles (EVs) have been in existence for more than 100 years, their recent interest and development has occurred faster than the ability to establish industry standards. The purpose of this technical paper is to present the authors' experience in building an EV that can be safely operated and maintained as well as being crashworthy. The authors have extensive experience in building EVs and automotive testing.

A good design results only from careful consideration of the specific EV being built. Each component and each modification to an existing vehicle must be considered relative to its impact on the conversion design and the safety of the overall vehicle. Therefore, any EV project should make use of a qualified engineer for critical decisions.

The specific recommendations are intended to represent a conservative design for the protection of the driver, vehicle occupants, and the general public. There is no intention to supersede or negate any existing codes, standards, or governmental regulations.

CRITERIA

It is important to first identify the criteria for a safe design, these are:

- The assumption of a "Single Failure" There should be no single component that is critical to safe operation. One must assume that any single component may fail and ensure that safety is maintained, even in the event of a crash or rollover. For example, if a circuit is protected by a fuse, consider what would happen in an overcurrent situation, if the fuse failed to "blow". Safety must still be maintained, perhaps by the inclusion of an additional fuse.

-The assumption of a single failure leads naturally to "redundancy" of safety components. A second fuse should ensure that at least one fuse blows. Redundant contactors, activated by separate power sources, should also be considered to ensure that high voltage power sources can be interrupted, if necessary.

-"Separation" between high voltage components is also critical for a safe design. Batteries, contactors, or other components that have a significant voltage difference should not be located near each other. For example, in a 120 volt power system, the first and last battery should not be located beside each other. Similarly, the negative side contactor should not be located adjacent to the positive side contactor, if used.

CONSTRUCTION

It is essential that an EV operate safely to protect the drivers, passengers, and pedestrians. The following design practices are recommended:

Electrical System Recommendations

All control and power circuits should be fused. The fuse should be located near the source of power.

As a minimum, the power system should be protected by at least one fast-acting fuse; however, two fuses should be considered based on the "single failure" criteria.

The wire size should be adequate for the intended load. In addition, the wire should be automotive wire. Wire designated as "THHN" or "TEW" or is marked "oil and gas resistant" is not automotive wire. This wire should not be used because its insulation will crack and contribute to ground faults.

Wiring should be protected against mechanical damage. Wires penetrating metal surfaces, such as the firewall, should use grommets or other protective barriers to protect against chafing of the wire. Other wires in proximity to metal edges or other objects which cause fraying should also be protected.

The power system should not be grounded through the vehicle frame. Although this is acceptable on the 12 volt system, it is unacceptable and unsafe for voltages greater than 24 volts.

Upon actuation by the key "switch", a voltmeter or indicator light should indicate that the power system is connected. Putting the key "switch" in the "off" or "stop" position should disable the power system.

Opening any vehicle front door with the key "switch" in the "on" position should activate an audible alarm. This indicates a potentially "live" power system.

A contactor is recommended as an electrical disconnect when the power system is turned "on" through a key "switch". Circuit breakers are not designed or recommended for this service.

Flexible wire is recommended in place of solid buss bars for the battery interconnects. Flexible wire doesn't transmit vibration between batteries and provides greater protection from short circuit.

All EVs require an auxiliary battery (12V), even if a DC-DC converter is in use. This ensures operation of the warning flashers, brake lights, headlights, etc. if the DC-DC converter fails.

If the regenerative braking system is actuated on throttle release, the brake lights on the vehicle should be lit.

The wiring system in the vehicle should be protected from the effects of high humidity, salt and water spray.

The accelerator potbox should not be placed in a crush zone of the vehicle. This is to prevent the possibility of causing full power to the motor if the potbox lever is pushed to wide open position.

The power system should be automatically disconnected in the event of a crash; this can be accomplished by connecting an inertia switch to the contactor(s) control circuit.

The controller, motor, and other large components should be located such that they do not penetrate or significantly damage the passenger compartment in the event of a crash or rollover.

Battery System Considerations

In a vehicle with flooded lead acid batteries, contactors and other components that can create an arc should not be located above or near batteries where they might cause a hydrogen gas explosion.

In a vehicle with flooded lead acid batteries, the battery box should be vented to ensure that the buildup of hydrogen gas is prevented.

A warning signal should alarm or a fuel gauge should indicate when the battery is at minimum state of charge.

The batteries should be located in enclosed compartments designed to prevent any electrolyte leakage into the passenger compartment during a crash or rollover.

The battery compartment should prevent the batteries from exiting the vehicle or entering the passenger compartment in the event of a crash or rollover event. Welding a restraint system is preferred if the vehicle has a frame. For a unit body vehicle, the requirements are more complex and may involve a combination of welding and bolting to carefully selected attachment points.

The batteries should be restrained inside the battery compartment sufficiently to prevent their leaving the compartment during a crash or rollover event.

Vehicle Handling Recommendations

The vehicle center of gravity should be kept low. Locating the batteries high will adversely affect vehicle handling.

There is considerable flex in a vehicle frame or unit body, so it is essential to allow for differential movement between components.

The Gross Vehicle Weight Rating (GVWR) as identified on the door jam placard should not be exceeded. If this rating is exceeded, one should evaluate the impact on the vehicle including brakes, wheel bearings, axle strength, and fatigue of the unit body. Decreasing the vehicle payload capacity (e.g., passenger, cargo, etc.) will be required in most EV conversions.

The weight distribution of the EV should be considered and remain within the limits set by the manufacturer to ensure proper vehicle handling.

MAINTENANCE

The EV will require periodic maintenance. Therefore, the design should accommodate ease of maintenance as well as safety from electric shock. The following practices are recommended:

It should be possible to disconnect mechanically both electric poles of thebattery pack from the motor and controller. These maintenance disconnects are in addition to the electrical disconnects used for operation. The installation of maintenance disconnects provides positive separation of battery voltage from the motor and controller.

Components should be arranged to allow accessibility for testing and removal.

Segregating the batteries into three or four battery boxes will minimize exposure to high voltages when maintenance is performed on the batteries.

The distance between first and last battery, contactors, etc. should be maximized in order to prevent an accidental short circuit. Dielectric barriers can be used to assist in this separation.

Protective barriers over batteries or protective covers over the battery terminals should be used to protect personnel and reduce the possibility of a short circuit condition.

The battery box should be labeled to alert users of the potential dangers. In addition, if the EV is designed for a specific type of battery, this should be identified.

The direct contact with live parts of an electrical circuit whose voltage is greater than 50 VDC or 30 VAC should be prevented by housings, covers, or other types of protection.

Harnesses carrying cables with voltages greater than 50 VDC or 30 VAC should be *easily identifiable by color or a "warning" designation. Individual cables routed separately should also be easily identifiable as power cables.*

CONCLUSION

Safety is essential in any vehicle. We accept the explosive risk associated with gasoline vehicles because manufacturers have designed the vehicle to minimize the risk and everyone is aware of the risk. Similarly, everyone should be aware of the risk of electrical shock in an EV.

If you have questions, comments, or have experienced EV safety problems, please contact:

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"Meeting the needs of Electric Transportation"

"SELECTING A VEHICLE FOR CONVERSION"

by Bob Batson

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INTRODUCTION

The decision to convert my first EV in 1987 was very simple. It was a 1973 VW which was in the process of being converted to electric. I helped its owner complete the conversion, and then I purchased the vehicle from him. After I purchased the vehicle, I invested $1500-$2000 into the vehicle for new brakes, tires, PMC controller, and paint job. My purpose for the VW was to demonstrate the feasibility of EVs and to learn from the experience.

Later, I found the VW limiting because of the space available for batteries and the location of batteries within the passenger compartment. Consequently, after a couple of years of driving the VW Beetle, I was itching to try another vehicle And this time I was going to select the vehicle based on an engineering evaluation.

After proceeding through the selection process, I determined that "selecting a vehicle" to convert to an Electric Vehicle (EV) can be as simple as 1 - 2 - 3 :

1. Define your requirements for the vehicle.

2. Evaluate the vehicles classes that meet your requirements.

3. Select one or two specific vehicles models.

STEP 1. DEFINE THE PURPOSE OF THE VEHICLE

This is the major decision. Ask yourself the following questions:

Why do you want an EV?
Where will you drive it?
Who else will drive it?
How many miles do you require on a daily basis?
How often will you drive the vehicle?
With or without passengers?
Will your employer allow me to charge at work?
How much do I want to spend?
How much time do I have for the conversion?

These are important questions that must be answered.

My purpose for my second vehicle was finally selected: To demonstrate that EVs can be larger vehicles which serve a useful function. And my criteria became:

A vehicle designed for the extra battery weight. Battery weight represents fuel weight; the more fuel you carry, the greater your range.

A vehicle that allowed all batteries to be located outside the passenger compartment. This makes it easier to restrain the batteries in designing for an accident. I felt it was a safer design.

A vehicle that allowed components to be easily replaced for testing new EV components. I did not want to bury components in inaccessible places.

A small passenger compartment to limit the heating requirements in the New England winter.

STEP 2. EVALUATE THE VEHICLES MANUFACTURED

Once you start to evaluate the different vehicles you find there are three classes:

1. Sports cars,
such as the Honda CRX, Pontiac Fiero, Toyota MR2, Porsche 914, Fiat X-19, Nissan Pulsar, MGB or MG Midget. Sports cars have limited space and minimal payload capacity.

2. Passenger cars and vans,
such as the Ford Escort, VW Rabbit, VW Beetle, Saturn, Honda Civic, Geo Metro, VW Vanagan, and Dodge Caravan. Vans are considered herein as a passenger car because they require the batteries inside the passenger compartment. The payload capacity within this class varies considerably from Geo Metros with a payload of 600 lbs to the VW Vanagan with a payload capacity of almost 2000 lbs.

3. Trucks,
such as the Chevrolet S-10, GMC S-15, Ford Ranger, Dodge Ram and Rampage, and VW Rabbit Truck. Trucks have the advantage of locating batteries outside the passenger compartment and typically have a frame which permits a higher payload capacity.

Each of these classes have their own characteristics with respect to aerodynamic drag, curb weight, Gross Vehicle Weight Rating (GVWR), passenger compartment, and available space for batteries.

Table 1 lists typical vehicles under each of these classes and their range using various lead acid battery packs (6V and 12V). Range is a function of battery weight because the battery represents the fuel. Typically it takes 15-20 lbs of lead to achieve 1 mile in range. A Rule of Thumb is that 1/3 of the EVs weight should be batteries; the other 2/3 represents dead weight (i.e. frame, suspension, body, motor, etc). If you could decrease this dead weight to 1/2 leaving 1/2 for fuel, you would have superior performance.

TABLE 1 - CLASSES OF VEHICLES

VEHICLE	*ICE CURB WEIGHT*	*VOLTAGE OF EV*	*BATTERY MODELED*	*CURB WT (LBS)*	*AVG RANGE (MILES)*	*MAX RANGE (MILES)*
SPORTS CARS						
Pontiac Fiero	*2530*	*120*	*5SHP*	*3360*	*44*	*68*
Honda CRX	*2175*	*120*	*5SHP*	*3060*	*47*	*72*
Toyota MR2	*2695*	*144*	*SCS225*	*3430*	*40*	*62*
Nissan Pulsar	*2025*	*144*	*SCS225*	*2863*	*46*	*68*
PASSENGER / VANS						
Ford Escort	*2300*	*96*	*T-145*	*3457*	*59*	*91*
Geo Metro	*1695*	*120*	*SCS225*	*2451*	*38*	*53*
Honda Civic	*2260*	*144*	*SCS225*	*3063*	*40*	*59*
Saturn	*2300*	*120*	*5SHP*	*3165*	*42*	*63*
VW Rabbit	*1930*	*96*	*T-105*	*2967*	*48*	*71*
VW Vanagan	*3460*	*120*	*T-145*	*4731*	*53*	*81*
Dodge Caravan	*3605*	*120*	*T-145*	*4854*	*52*	*80*
TRUCKS						
Chevrolet S-10	*2700*	*120*	*T-145*	*4100*	*61*	*92*
Dodge Ram	*2565*	*96*	*T-145*	*3682*	*51*	*76*
Ford Ranger	*2750*	*120*	*T-105*	*3908*	*44*	*64*
VW Rabbit P/U	*2200*	*96*	*T-145*	*3372*	*60*	*92*

Notes:
1. Calculations based on spreadsheet developed by Electric Vehicles of America, Inc.
2. Typically curb weight increases each model year
3. Average range based on 1 percent grade at 50 mph - representing some traffic.
4. Maximum Range based on 0 percent grade at 50 mph.

Other Considerations

Of course, there are other considerations, including:

Front Wheel Drive(FWD) vs Rear Wheel Drive (RWD).
A FWD vehicle has the advantage of being more efficient; which improves range. However, front wheel drive vehicles typically have smaller engine compartments which limit the location of batteries. Also, the front -wheel drive vehicle requires more weight (typically 60 percent) on the front axle. If you locate batteries in the trunk, the tail can wag the dog in rain or snow. This is a problem with many Geo Metros with batteries in the trunk.

In addition, the high voltage, high amperage EV controllers and motors can produce greater torque and horsepower than the original engine in the smaller FWD vehicles. This can produce a problem. There are two distinct limitations for FWD vehicle. During "launch"(initial take-off from a standing start) all cars tend to pitch up (front rotates up relative to back.) This is because the center of mass is above the force being exerted by the tires against the road. In a RWD, this pitch tends to plant the driven tires more firmly against the road, thus enhancing traction. In a FWD the effect is opposite. The force pressing the drive wheels against the road is reduced because of the pitch. If power is applied while the car is in a turn, RWD is much more stable. If the rear wheels spin, the car over-steers. If the front wheels spin, the car under-steers and may easily spin out.

Availability of Spare Parts / Age of Vehicle
Spare parts should be available. This availability is related to the production of that specific vehicle and which part of the country in which you live. Also the availability of after market parts for suspension upgrades can be important.

Manual Vs. Automatic Transmission
Most EV conversions are manual transmissions because they are more efficient than automatic transmissions and provide greater range, require less motor torque, require no transmission cooler, and are easier to convert. The problem with an automatic transmission is that it shifts at about 2000 rpm; the electric motor is usually designed to operate efficiently between 4000-5000 rpm. Consequently, the automatic transmission is a poor choice which results in decreased range. If you buy a vehicle with an automatic transmission, you can replace it with a manual transmission. The additional cost is $150 and up depending on the transmission and used auto parts dealer. Consider trading the automatic transmission.

Power Steering
Power steering is not recommended because of the continuous power required of the battery system. Even on many of the trucks that we converted, we eliminated the power steering. The cost to change from power steering to a manual steering box is under $100 and less than 1 hour of work. The equal weight distribution allowed reasonable manual steering.

<u>Power Brakes</u>
Power brakes are a definite advantage as you increase the weight of the vehicle approximately 800-1200 lbs with the EV components. In many cases, this represents an increase of 20 25 percent in the curb weight of the vehicle. Your goal should always be to have a safe vehicle. Power brakes unlike power steering are only an intermittent energy demand. A typical system requires a vacuum pump and a vacuum switch.

<u>Curb Weight</u>
Curb weight is the weight of the vehicle parked at the curb. No passengers and no payload. If you want to have 1/3 to 1/2 of the finished weight in fuel; then the initial curb weight of the vehicle should be less than 3000 lbs. The Geo Metro is one one the lighter vehicles with a curb weight of 1695 lbs. Consequently, an 800 lb battery pack seems ideal, except that GVWR and weight distribution become a major problem.

<u>GVWR and Distribution</u>
This is the most important consideration in any vehicle, because this directly affects the safety of the vehicle (Refer to "Safety First" in the September 1997 issue). As previously stated, converting an existing vehicle to an EV will add 800 - 1400 lbs in curb weight. Check the Gross Vehicle Weight Rating (GVWR) of the vehicle including the tires presently on the vehicle to see if it is designed for this increase. The GVWR and each axle rating are located on the drivers side door jamb. If the GVWR of the vehicle is exceeded, then the vehicle frame, suspension system, and braking system may be beyond their design value.

Although the Geo Metro can perform with an 800 lb battery pack, the payload capacity of the vehicle is 600 lbs. Payload equals GVWR minus curb weight. With two people in the Geo, the available payload decreases to 300 lbs. Consequently, an 800 lb battery pack can lead to braking and handling (See FWD vs RWD above) as well as a long term fatique problem with the unibody. Therefore, the lightest vehicle is not always the best vehicle.

You must also consider where the EV components will be located. Where will the batteries be located; they are the bulk of the additional weight. Will the charger be carried on board or off board? How will this change in weight distribution affect the vehicles handling? In the 1973 VW, the majority of weight was on the rear wheels; this was great for snow.

This further defined my requirements to:

A light-weight truck about 5 years old because it met my criteria developed in Step 1.
A manual transmission
No power steering
Power brakes

If my criteria was different, a different type of vehicle may have been selected. For example, if the most important criteria was acceleration to 50 mph. Then, the selection would be based on a vehicle with minimum weight and a low drag coefficient, i.e. a sports car.

STEP 3. SELECT ONE OR TWO MANUFACTURERS

It actually became easier as each decision was made. Here I searched through the available literature (Consumer Reports, Changing Times, Motor Trend, etc.) that provided detailed information on the weight and features of the different light-weight trucks available. Much of this information is now available on the internet.

These trucks varied in weight from 2555 lbs to 2900 lbs for the standard bed model; the long bed models add another 200 lbs. The lowest weight was the Dodge Ram 50 at 2555 lbs and the Toyota at 2565 lbs. Both of these trucks had an excellent reputations.

When I considered light-weight trucks, I evaluated the VW Rabbit P/U Truck, an oversize Rabbit. It had the advantage of being light-weight (2200 lbs) as well as front wheel drive to minimize drive train losses. It's disadvantage was that it had not been in production for 10 years and body rust was a problem in New England.

By doing this evaluation, my search was clearly focused. This eliminated time wasted looking at vehicles that did not meet my criteria.

My second EV conversion was a 1987 Dodge Ram 50 pickup converted in 1990 to 96V. This truck had a 5-speed overdrive transmission, power brakes, and rear wheel drive. The batteries are beneath the bed of the vehicle and the weight is over the drive wheels. This significantly improves their handling in snow. Its maximum range is 50 - 70 miles. Its maximum speed is about 65 mph.

My third EV was a Bradley GT II originally built as an EV. Surprisingly, this vehicle met my requirements developed in Step 1. This EV has been upgraded to the FB1-4001A Advanced DC Motor and Curtis 1231-8601 controller so that it will perform as a sports car.

My fourth EV was a GMC S-15 truck (same as the Chevrolet S-10). The advantages of the S series are:

1.The frame rails are further apart; this allows the battery box to be located under the bed between the drive shaft and the frame.

2. Both rear shocks are aft mounted so that you can 4-6 batteries forward of the rear axle. The number of batteries depends on the bed length and model year.

3. The front radiator area can easily accommodate 4 batteries.

4. The open channel frame is more to corrosion. Box frames can rust from the inside out.

We have since converted a number of vehicles (Dodge Caravan, Saturn , and more S-10s for electric utilities, U.S. Air Force, and Curtis Instruments.

CONCLUSION

In conclusion, consider the long term use of your EV. Here is a vehicle that you are going to invest thousands of dollars and approximately 100-200 hours of your time. Don't buy a vehicle just because it is available at a cheap price. You want to enjoy the vehicle and be proud to show it. Consider value not just initial cost.

It is important to state that a good conversion even after used for a few years can be sold, usually at a price greater than the cost of the components. A number of my S10 customers sold their EVs for $10,000 - $12,000 after driving them for a few years. How many internal combustion vehicles actually retain their value?

EVA's   1991 S-15
STILL ON THE ROAD !

We sold our S15 GMC for $20,000 after showing and driving it for 4 years! However, this EV was a really sharp vehicle and the workmanship was outstanding. It is still on the road with a very happy owner after many years!

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"DO IT RIGHT THE FIRST TIME ! "

Bob Batson - Electric Vehicles of America, Inc.
Presented with
Seth Murray - Student, Worcester Polytechnic Institute
at
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Building an EV takes Time and Money. It requires 100-200 hours of labor and $5000 - $9000 in components. That is a major commitment, so why not do it right the first time?

That is exactly what Seth Murray did as a high school student. Electric Vehicles of America, Inc. (EVA) worked with him to ensure that his Electric Vehicle (EV) was right for him.

But first, we must define "what is right?". What is right for one individual and one application may not be right for another individual with a different application. So we must define the process, which consists of four major steps:

1. Identifying your requirements.
2. Selecting the vehicle.
3. Selecting the EV systems.
4. Installing and testing the systems.

Let's look at each one in detail.

1. IDENTIFYING YOUR REQUIREMENTS

This is the major decision. Ask yourself the following questions:

Why do you want an EV?
Where will you drive it?
Who else will drive it?
How many miles do you require on a daily basis?
How often will you drive the vehicle?
With or without passengers?
Will your employer allow you to charge at work?
How much do I want to spend?
How important is safety and reliability?
How much time do I have for the conversion?

These are important questions that must be answered.

Seth's criteria was to build an EV to compete in the 2002 American Tour de Sol (ATdS) Race sponsored by Northeast Sustainable Energy Association (NESEA). The race was from Washington, D.C. to New York City with some days requiring a range of 70 miles. This was a difficult challenge for many high schools, colleges and EV businesses. Seth was only a high school student, and his funding was from his part-time job cutting lawns and family donations and gifts.

In addition to the range, Seth was looking for an EV that could be used every day, so it had to be reliable, practical, and simple using proven technology. In the final analysis, the criteria became:

Range - Minimum 50 miles with the ability to go 70 miles if needed.
Acceleration - Reasonable; keep up with traffic.
No. of passengers - one
Safety - Maximum possible, at least as good as the original vehicle
Technology & Innovation - Use proven technology

Now the difficult step of translating those requirements into a specific vehicle and system.

2. SELECTING THE VEHICLE

Basically, there are three classes of vehicles: (1) Sports cars, (2) passenger cars and vans, and (3) trucks.

(1) Sports cars,
such as the Honda CRX, Pontiac Fiero, Toyota MR2, Porsche 914, Fiat X-19, Nissan Pulsar, MGs, Datsun 240Z. Sports cars have limited space and minimal payload capacity.

(2) Passenger cars and vans,
such as the Ford Escort, VW Rabbit, VW Beetle, Saturn, Honda Civic, Geo Metro, VW Vanagan, and Dodge Caravan. Vans are considered herein as a passenger car because they require the batteries inside the passenger compartment. The payload capacity within this class varies considerably from Geo Metros with a payload of 600 lbs to the VW Vanagan with a payload capacity of almost 2000 lbs.

(3) Trucks,
such as the Chevrolet S-10, GMC S-15, Ford Ranger, Dodge Ram and Rampage, and VW Rabbit Truck. Trucks have the advantage of locating batteries outside the passenger compartment and typically have a frame which permits a higher payload capacity.

Each of these classes have their own characteristics with respect to aerodynamic drag, curb weight, Gross Vehicle Weight Rating (GVWR), passenger compartment, and available space for batteries.

Before we select a vehicle, one must consider the battery system. Lead acid batteries typically cost $2000 or less. Many types of batteries and energy sources are being promoted, including Nickel Cadmium (NiCd) , Nickel Metal Hydride (NiMH), Lithium Ion, and even fuel cells. But the price for these batteries can be prohibitive, and many require special chargers. For a 20 kw-hr pack, the price can vary from $10,000 for NiCd, $30,000 forNiMH, and $100,000 or more for a fuel cell.

I prefer wet batteries vs sealed lead acid because (1) they typically provide more miles/ pound (2) they can take more abuse and (3) they cost less per mile (~10 cents/mile).

Most people use lead acid batteries, so there are two important considerations:

Weight of Fuel - Range is a function of lbs of fuel whether the fuel is gasoline or lead acid batteries. It takes 15-20 lbs of lead to achieve 1 mile in range. The lower number is for sportscars; the higher number is for trucks and vans. So if you want a range of 70 miles, then you will require a battery pack weighing 1050 - 1400 lbs.

Ratio of Battery Weight to Total Vehicle Weight - A Rule of Thumb is that about 30% of the EVs weight should be batteries; the other 70% represents dead weight (i.e. frame, suspension, body, motor, etc.). Naturally the greater the percentage of battery weight to total weight, the greater the range.

This clearly shows that the three most important considerations in selecting a vehicle are (1) curb weight, (2) Gross Vehicle Weight Rating (GVWR), and (3) available space.

(1) Curb Weight
Curb weight is the weight of the vehicle parked at the curb. No passengers and no payload. If you want to have 30-50% of the finished weight in fuel; then the initial curb weight of the vehicle should be less than 3000 lbs. The Geo Metro is one of the lighter vehicles with a curb weight of 1695 lbs. Consequently, an 800 lb battery pack seems ideal, except that GVWR and weight distribution become a major problem.

(2) GVWR and Distribution
This is the most important consideration in any vehicle, because this directly affects the safety of the vehicle (Refer to "Safety First" tech paper). As previously stated, converting an existing vehicle to an EV will add 800 1400 lbs in curb weight. Check the Gross Vehicle Weight Rating (GVWR) of the vehicle including the tires presently on the vehicle to see if it is designed for this increase. The GVWR and each axle rating are located on the drivers side door jamb. If the GVWR of the vehicle is exceeded, then the vehicle frame, suspension system, and braking system may be beyond their design value.

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(3) Available Space
You must also consider where the EV components will be located. Where will the batteries be located; they are the bulk of the additional weight. How will the weight distribution affect the vehicles handling?

Of course, there are other considerations, including:

Manual Vs. Automatic Transmission
Most EV conversions are manual transmissions because they are more efficient than automatic transmissions and provide greater range, require less motor torque, require no transmission cooler, and are easier to convert. The problem with an automatic transmission is that it shifts at about 2000 rpm; the electric motor is usually designed to operate efficiently between 4000-5000 rpm. Consequently, the automatic transmission is a poor choice which results in decreased range. If you buy a vehicle with an automatic transmission, you can replace it with a manual transmission. The additional cost is $150 and up depending on the transmission and used auto parts dealer. Consider trading the automatic transmission.

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Power Steering
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Power Brakes
Power brakes are a definite advantage as you increase the weight of the vehicle approximately 800-1200 lbs with the EV components. In many cases, this represents an increase of 20 25 percent in the curb weight of the vehicle. Your goal should always be to have a safe vehicle. Power brakes unlike power steering are only an intermittent energy demand. A typical system requires a vacuum pump and a vacuum switch.

Availability of Spare Parts / Age of Vehicle
Spare parts should be available. This availability is related to the production of that specific vehicle and which part of the country in which you live. Also the availability of after market parts for suspension upgrades can be important.

It pays to do your research using old Consumer Report, Motor Trend, and other publications. Over the last 15 years, I have been surprised at some vehicles. For example, a high performance Mustang II (8 cyl) had a GVWR of 4000 lbs while having a curb weight of less than 3000 lbs. Not much different than a truck.

For Seth, his requirements defined the following type of vehicle:

- *A light-weight truck*
- *A manual transmission*
- *No power steering*
- *Power brakes*

Seth selected an S10 because it has more space between the frame rails and the drive shaft. This allows more space for battery boxes under the bed when a tilt bed is used.

3. SELECTING THE EV SYSTEMS

First, lets look at the major EV components and their relationship between each other. They are all related.

Vehicle Design => Battery Weight => Controller Voltage & Amperage =>
Controller Voltage & Amperage => Motor hp => Vehicle Performance

The selection of the motor and controller is a major decision when building any EV. These two components help establish the performance of the vehicle as well as the cost. The motor and the batteries establish the voltage, horsepower, vehicle weight.

These components or systems are the foundation for the EV. The decision on any one component prematurely can affect adversely the performance of the final product. For example, one customer had purchased a bargain motor which was to be used even though it was undersize. After he burned up the small motor, he bought the correct motor for his application.

To ensure that components are sized correctly for the application, Electric Vehicles of America Inc. (EVA) performs detailed calculations based on:

Vehicle Description System Design
- Initial Curb Weight -Motor
- Drag Coefficient - Battery
- Frontal Area - Voltage

But let's look at the output:

- The required horsepower
- The estimated amperage
- The horsepower under various terrain and speeds.
- The estimated range

For the S-10 truck which is one of our specialties, the results based on 50 mph are:

		RANGE	
HP REQUIRED	*MINIMUM*	*AVERAGE*	*MAXIMUM*
26	*45*	*61*	*92*

The calculation also identifies the hp, amperage, and range at various grades and speeds. The use of engineering calculations allow you to size components and compare the performance of different battery packs and voltages before you ever make a purchase.

We believe that this type of analysis is essential in selecting the right components. There are a number of other systems for an EV, including

Drive system
Battery system
Instrumentation
Power Brakes
Safety Systems

Let's look at the Safety System in a little more detail. The principal concern is personal safety and the prevention of damage to EV components; safety techniques include:

High Voltage components mounted on a non-conductive material
Multiple fuse within the battery pack
Use of a primary and a secondary contactor
Anderson Disconnects between batteries & controller
Battery covers over terminals

Batteries located in crush zones so they take the impact
First Inertia Switch to shutdown the systems on impact.

For more on safety, see EVA "Safety First" tech paper.

It is important that Safety personnel (i.e. Police, Fire, EMTs, etc.) know that your vehicle is an "Electric Vehicle" before they start cutting the body to extract occupants. This can be as simple as an "Electric Vehicle" emblem or decal. In addition, the Emergency Disconnect should be identified.

Seth incorporated many safety features into his S10 which he attributes to minimizing any injuries when his father and he were hit by a full size truck going substantially faster.

4. INSTALLING AND TESTING THE SYSTEMS

Installation and testing is the final step in doing it Right!

As we previously discussed, layout of the batteries is critical for weight distribution. Each component needs to be evaluated for its best location in relationship to the other components as well as how it will be tested and easily removed. Design for maintenance.

Layout of the high voltage components is critical for safety. If you use the control board concept, you can run the cable thru drilled holes in the board. You can also mount components on the bottom of the board.

We recommend that you use pieces of welding cable to see how the cable will be routed between components. Also how will the small wiring be routed. Will it look like a professional job? Or will it be haphazard? Appearance is the critical.

Testing the vehicle ensures that each system operates correctly and shows how to troubleshoot a component or system. Once the vehicle is road worthy, we encourage:

Testing to determine the maximum speed in each gear
Testing to establish a baseline as well as to compare to calculations.

Our EV Installation Manual identifies the test procedures in detail.

CONCLUSION

Your EV can meet your objectives - it can be Right For You! Take the time to understand the process.

Seth achieved success because the vehicle meet the following:

Affordability - Seth Murray, while in high school, converted an S-10 using his money with help of gifts from parents and grandparents.

Design Features - Seth's S-10 passed the technical testing at the ATdS the first time, receiving one of the highest scores.

Performance Criteria - The S-10 did 80 miles on his longest run before being rear-ended by a larger truck. More range was available.

Safety Features - The S10 was in a major accident with a full size truck, but Seth and his father received minimal injuries because the S-10 took the impact.

Maintainability - Components are easily replaced. Most components can be replaced in less than 30 minutes!

Success was achieved because it was done Right The First Time!

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See Seth's Truck at [Seth Murray's '85 Chevrolet S-10]

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"Meeting the Needs of Electric Transportation"

"Do It Right The First Time"
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"BATTERIES ESSENTIALS"

by
Bob Batson
Electric Vehicles of America, Inc.
EVAmerica Newletter

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 (specifically wet lead acid). 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 or expensive to find a charger that will charge the sealed battery properly at higher voltages. (The Zivan Charger has solved this problem.)

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 of only 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 terminal (UT), 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 not 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>
1. Visually inspect battery connections, etc. Note any burn marks.
If a cell has been a problem (excessive watering, etc.), check it!

<u>*Monthly*</u>

1. 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.

2. Clean the surface of the batteries with a damp cloth. Do not remove caps. Do not allow foreign matter to enter battery cells.

3. Remove caps and inspect a few batteries internally.

4. Take voltage readings for each battery and compare against previous readings. The batteries should be fully charged, and allowed to sit 4-8 hours for the voltage to stabilize.

Annually

1.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.

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.

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EVA - " Customer Service is No. 1! "

EVA "CLUTCHLESS DESIGN"

*Electric Vehicles of America, Inc. (EVA) provides a "**Clutchless Design**". Our design eliminates the flywheel and the pressure plate, weighing approximately 30 lbs, which are required for an internal combustion vehicle, but not for an Electric Vehicle (EV). Think about it. The EV motor does not rotate when the vehicle stops; the internal combustion engine did rotate. Why keep the extra parts?*

EVA has used a clutchless design since 1987 and it works successfully. With more than 15 years experience, our customers have 1,000,000 miles using the clutchless design. One customer had more than 50,000 miles on his EV. So simply consider the facts - lighter weight, more efficient.

Our design could be called a "clutch pedal-less design". We eliminate the need for clutch pedal but not the clutch disk. The clutchless design is a direct connection between the motor and the transmission. We mount your clutch disk on an aluminum coupling; therefore it matches the input shaft of your transmission and the springs in the clutch disk absorb the initial shock from the motor. Very simple; very unique - just like an EV.

The clutch disk (provided by the customer) is critical. And we use the existing clutch disk to connect the motor output shaft to the input shaft of the transmission.

Advantages

The advantages of the clutchless design are:

*1. **More efficient design!** One racing customer stated that for every 7 lbs in rotational weight is equivalent to 100 lbs of vehicle weight So by eliminating the flywheel and pressure plate (~30lbs); it could be the equivalent to removing 400 lbs of vehicle weight. That makes the clutchless design about 10% more efficient in rolling resistance! The same goes with aluminum wheels vs steel wheels; less rotational weight - less energy required.*

*2. **It allows the conversion** of vehicles for which a clutch design is not available or affordable. A manual transmission is recommended because it allows you to operate the motor at higher rpms but you do not have to add a clutch pedal assembly. This makes it easier to convert vehicles that have an automatic transmission to a manual transmission.*

*3. **It eliminates the potential of overspeeding the motor** with different EV Users. If new drivers step on the accelerator and rev the motor before popping the clutch, there is the possibility of overspeeding the motor. This is a concern here in New England because of the hills. With the clutch pedal-less design, you simply put the transmission in gear and step on the accelerator. This helps many high school drivers who may not have* *experience with driving with a clutch.*

*4. **The design is simple.** We need only three dimensions and the clutch disk and we can make the adapter plate and coupling.*

*5. **It allows the conversion of vehicles that once were automatics** without having to install the hydraulics etc. We have converted existing S10s for the U.S. Air Force; they were automatics. We just replaced the automatic transmission with a manual transmission and used our design We did not have to install a clutch pedal and all of the other hydraulics. this allows greater flexibility when looking for a potential EV. The manual transmission is only $150.-$300*

*6. **Shifting is accomplished because of the minimal inertia of the motor** (no flywheel or pressure plate) and the synchromesh.*

Disadvantages

The disadvantage of the clutch pedal-less design are:

1. It takes a little longer (1-2 seconds) to shift. You cannot speed shift. However, an EV may drive in 2nd gear in town and 3rd gear on the highway. An S10 can be driven in 2nd gear from 0 -45 mph. So you don't need to shift very often. With your car standing still and engine off. Shift gears without pressing the clutch pedal. Notice how you can go from one gear to the next without using the clutch. Why? Because there is no inertia. It is the same way with the electric motor, there is no huge mass of inertia. That is how the clutchless design works.

2. Downshifting takes 1-2 seconds longer because the speeds have to match. I usually downshift only at a stop sign coming off a highway. Remember you shift an EV very infrequently. Usually only 2nd and 3rd gear are used.

The synchros in the transmission make it smooth. Some people have suggested that the synchros wear out quickly, but some of our clutchless customers have more than 30,000 miles total on their vehicles. For more information on clutchless, refer to ttp://www.geocities.com/CapeCanaveral/Lab/4429/cl3.htm This is a customer in Norway. This includes pictures of the installation of clutchless, the clutch installation is similar.

Once we asked someone on the West Coast (1) why they thought a clutch was required and (2) how that myth got started. He stated that a clutch was required on the old voltage switching and resistance controllers in order to allow one to park without banging the others cars. This problem was solved with PWM controllers.

Our S-15 truck used a clutchless design and aluminum wheels - it has great range *because we eliminated about 70 lbs in rotational weight. Using the rule of thumb above - this represents about 1000 lbs of vehicle weight. WOW! That is about a 20 % decrease in rolling resistance - better than low rolling resistance tires!*

As always, we just want to give the facts.

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"Why buy a component when you can buy a system?"

That is the advantage of an EVA Drive System Package. "

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EVA - " Customer Service is No. 1! "

EVA "Clutchless Design"

REGEN THOUGHTS

Although we have installed a couple of the Curtis regen systems for customers, we are not an advocate of regen unless you are looking for additional braking capacity. Curtis no longer makes a Regen Controller and other high voltage regen controllers (120V +) in DC systems have not proven effective.

Regen should be activated by the brakes and should not come "on" when you take your foot off of the accelerator. You have paid for that energy - now coast.

Now. if we look at the additional range via regen; it appears that you would multiple the:

(%Time Foot is on the brake) x (Regen Efficiency) = (% additional range)

Let's say (5% on brake) x (25 % regen eff) = 1.25% additional range

I think then you have to evaluate that additional range and braking benefit to the additional cost of regen. In our opinion, you are better spending you money on decreasing the aerodynamic drag and rolling resistance in most cases.

To back up the above, an S-10 built by EVA for the USAF was in the Great Truck Race in Smuggler's Notch VT in 1993. Ours was the only older EV with a DC system and no regen. All of the others were 1992 or 1993 trucks. In a 20 mile efficiency run through the valleys, we tied Solectria for 3rd place. Another Solectria truck won 1st place and one was in 5th place. There was also US Electricar truck and others. Although a Dodge truck with a Westinghouse system did not make to the starting gate and a SMUD vehicle from Europe broke a motor mount. Now, please remember this was an efficiency run. Naturally, we were pleased with our performance against AC system costing 3 times as much.

Something to think about. Evaluate incremental cost vs incremental benefit. It is called economic analysis.

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