

ME 495

Professor Joyce Cooper

Winter 2005

Aaron Cooper

Nick Lancaster

Nick Stadnicky

Ryan Stutesman

Nichole Thomas

Jill Williams

Abstract

The original goal of this project was to create a conversion kit that would allow owners of the Ford Ranger Electric Vehicle to use off the shelf batteries in the truck instead of the stock battery pack that was provided with the vehicle. This kit would be useful to owners of the Ranger EV because Ford no longer supports the vehicle, and the stock battery pack does not allow the user to replace individual batteries within the pack. The conversion kit is to be designed in order to provide the same performance (voltage, operational time, etc.) as the stock battery pack, fit within the space allocated under the vehicle, and within the team's budget of three thousand dollars.

Several design options for the case have been explored, in an attempt to make the conversion kit as simple and as cost effective as possible. The first attempt involved replacing the stock 8-volt batteries with off the shelf deep cycle batteries; however, this was not a practical solution as there are no commercially available 8-volt batteries that meet the design requirements: fit into the current case with little or no modification and provide equal power (312 V). The team also determined that it would not be possible to use two 4-volt batteries wired in series to simulate a single 8-volt battery, as this configuration would not provide sufficient amp hours to run the vehicle and would be much larger than the allotted space. The two final possibilities that we considered for converting the vehicle are to farm-out the conversion through BatteryMD, or completely redesigning the stock control system and battery pack. The focus of the design project is based on overhauling the controller and battery pack of the vehicle because this design will offer a more permanent solution to current owners of the Ford Ranger EV.

Table of Contents

Introduction	4
Design Goals and Constraints	5
Design Concepts	6
Timeline	11
Conclusion	12
Appendix A (References)	13
Appendix B (Calculations)	15
Appendix C (Goals and Constraints)	16
Appendix D (Battery Specification)	17
Appendix E (BatteryMD information)	18
Appendix F (Morphological Chart)	19

Introduction

The Ford Motor Company introduced the Ranger EV in order to meet the demand of the environmentally conscious consumer. In 1999, they were one of the first vehicle manufacturers in the nation to either sell or lease electric vehicles. During the first year, Ford sold or leased hundreds of these vehicles throughout the United States and Canada, claiming that they had met the demands of the consumer and that the Ranger performed comparably to its internal combustion counterpart.

Individuals who have driven the Ford Ranger EV find that the truck is significantly quieter and easier to handle than its internal combustion alternatives. With zero emissions during operation, the vehicle provides excellent performance with little environmental impact. The driving force for this model is a 90 horsepower, three-phase AC motor with single speed transaxle connected to a robust rear-wheel drive train. A heavy-duty frame and suspension support the truck; the charging of the vehicle is easily accomplished using an inexpensive conductive charging system.

After several years of production, Ford abandoned the Ranger EV project as competing automakers began to introduce the new generation of energy efficient vehicles: electric-gas hybrids. After the introduction of the hybrids, the driving distance limitations and the awkwardness of the massive battery pack left the Ranger EV less desirable for some consumers of the energy efficient vehicles. Ford then requested that the leased vehicles be returned immediately without the option to buy. When returned, the Rangers were destroyed.

However, a number of the vehicles still do exist and are owned by private parties or serve as corporate fleet vehicles for various entities, such as, the Detroit Zoo. Because there is no longer Ford-based repair support for the vehicles, battery packs that go bad leave the owners with very few options to get their vehicles running again.

Recently, Vashon Island began a project called “Sustainable Vashon.” The goal of the program is to eliminate the island’s reliance on outside sources of energy. Rita Schenck, a project member, began looking into electric vehicles that would be available for use to the islanders. Rita Schenck

purchased a 1999 Ranger EV through the Internet auction site eBay. Because the island is only thirty miles long, the Ranger was ideal for the short trips related to the project activities.

After several months of use, the vehicle lost power during operation and was unable to recharge. Options for diagnosis and repair of the vehicle were limited, as Ford had eliminated the EV project, its team members, and company-sponsored support for vehicle owners. Schenck approached Professor Joyce Smith Cooper of the University of Washington Mechanical Engineering Department for help in learning more about the vehicle design and repair options.

Design Goals and Constraints

The Ranger EV is powered by a 312V battery pack that contains thirty-nine individual, custom 8V batteries. Ford is no longer providing support for these vehicles or batteries. Thus, replacement batteries are no longer available to the owners. The goal of this project is to create a conversion kit that allows vehicle owners to modify the existing battery pack into one that can support off the shelf batteries. The next phase of the project will be to determine modifications necessary to the case that will house and secure the new battery configuration. The final phase of the project will be the creation of the instructions, packaging details for the conversion kit, a business plan for manufacturing necessary components, and distribution of the product.

In order for our design to properly power the vehicle, we must be within the constraints that are imposed by the current battery pack. Our final design must be able to provide voltage and current to the truck at a rate equivalent to the stock battery pack. It could provide slightly less voltage and current, but this would mean that the truck and battery pack would have to weigh less to compensate, which is not desirable because of the added work and cost. This means that the final design should have a net voltage of 312 V and an Amp hour rating of approximately 75 Amp-hours. Since the suspension of the truck was designed around the stock battery pack, we will have to keep the total weight and weight distribution of our design as close as possible to the stock battery pack. This is important, because the weight of the truck is directly proportional to how long the truck will be able to go between charges, and by keeping the weight the same, we don't have to worry about changing any of the shocks or suspension. In addition, we are limited by the amount

of space that is available for the battery pack underneath the truck. We would like to reuse the stock case in our design if possible, but making a new case to accommodate our design is a possibility. The final design limitation that our team faces is that we cannot exceed the project budget of three thousand dollars. A ranking of goals and constraints can be found in Appendix C.

Design Concepts

This section of the report will include an explanation of all of the design concepts that were generated and explored by the 495 group, up to our current proposed design. Previous work on the design of an alternative battery pack was conducted during Autumn quarter of 2004 in conjunction with ME 395 at the University of Washington under Professor Joyce Smith Cooper. The focus was on designing a new battery pack that could be installed into the vehicle, using readily available batteries. The first phase of the design was selecting an off the shelf deep cycle battery. Based on an operational analysis of the existing battery pack, the 395 group determined that twenty-six Optima d31a batteries would provide the vehicle with the required 312 V and 75 Amp hours. The next phase of this conceptual design was to create a custom made battery pack that would be able to house the new batteries; the stock battery case would not be an acceptable solution due to the dimensions of the Optima batteries. The new case was designed to fit within the space available underneath the truck and to use the existing battery pack mounts present on the truck. All of the design decisions that were made by the ME 395 team were made using Dieter's Design Process. A more detailed description of the methods and results from the ME 395 project can be found at:

<http://students.washington.edu/njs/395home.shtml>. A copy of the morphological chart used can be found in Appendix F.

Replacement of 8V batteries with other 8V batteries with existing controller

Due to the complexity of creating the custom battery pack in the conversion kit that was proposed by the ME 395 group, the initial intent was to replace the stock 8V batteries that came with the truck. This was the ideal solution because all that it would require is a set of off the shelf 8-volt batteries with similar performance specifications and dimensions to the stock batteries. In addition, this design was the least likely to require any modifications to the stock controller.

The primary goal was to find 8-volt batteries that would fit within the stock case, and the secondary goal was that the batteries have an equivalent amp hour rating as the stock batteries. The search was prioritized in this order because the design team was willing to sacrifice some of the vehicles operational time for the added convenience of using off the shelf batteries. After several hours of research, it became apparent that there were no batteries that would come close to meeting either of the search criteria that the team had settled on. The closest off the shelf battery that was found in the search process had an equivalent amp hour rating to the stock batteries but was almost double the volume of the stock battery (see appendix D for battery specifications). The team also considered the option of having the batteries for the case custom made. After contacting Interstate Batteries, a company that makes custom battery packs, we learned that that amount of time and money that was needed to engineer a battery that met our needs was prohibitive. In addition, they did not believe they were capable of making such a battery and could not provide any recommendations for a company that might be capable of creating the desired battery.

Replacement of 8V batteries with two 4V in series with existing controller

Voltage is additive in series, which provided us with another option for replacing the stock batteries. This is where the team began with the next concept: finding 4-volt batteries that would fit our vehicles needs, i.e., batteries that would provide a sufficient amp hour rating within our size constraints. We would, however, need to double the number of battery cells in order to achieve our desired voltage. We were unable to find a 4V battery that would have an amp hour rating large enough to move the truck more than a few feet before needing a recharge (see appendix D for battery specifications). The highest amp hour rating we could find for 4V batteries was 10 AH, and at least 60 AH are needed for satisfactory operation.

Repairing the existing 8V batteries with existing controller

An alternate option for replacing the batteries is simply to repair the existing cells. BatteryMD is the official battery pack refurbishing company for Ford Ranger EVs and services several other electric vehicle battery packs as well. For a fee of four thousand dollars, BatteryMD will exchange

a customer's old battery pack with a refurbished one (the contact info for BatteryMD can be found in Appendix E). The cost includes the labor required to remove the old batter pack and replace it with a refurbished one, and a complete diagnostic inspection of the truck. Because the company was authorized to work on Ford Ranger EVs, they had, therefore, stockpiled the standard issue cells. This concept has been put on hold due to the fact that it does not offer a permanent solution to current owners of Ford Ranger EV's, as the BatteryMD has a limited quantity of stockpiled batteries. Additionally, the company is currently not authorized to sell individual cells to customers who are not authorized Ford technicians.

Replacement of 8V batteries with 12V batteries with existing controller

The concept of replacing 8-volt batteries with fewer 12-volt batteries was initially thought to be the superior design in the embodiment phase of this project, which took place in Autumn quarter's Introduction to Mechanical Design course. After discussions with members of SEVA (Seattle Electric Vehicle Association) at their monthly meeting, it was confirmed that the design should work.

However, after finding the Owner's manual, our concept was abandoned. The manual states that the battery control system performs an equalizing battery charge every three weeks. This procedure is done to ensure optimum performance of the battery pack by ensuring that each cell is equally charged. This indicates that the system will seek to recognize thirty-nine batteries and equalize the voltage during a charge. With the conversion to the twelve-volt battery design, leads will have to be capped and abandoned. We are currently unsure how the controller will react to this configuration.

Replacement of 8V batteries with 12V batteries and a new controller

Due to the fact that the controller will try to identify 39 batteries in the case, and it is unknown how the controller will react to capped leads, a new controller would be required to convert the truck to 12-volt batteries. The 12-volt batteries provide significant improvements to the vehicle (see appendix D for battery specifications). The total weight of the battery pack is decreased by

approximately 500 pounds, thus increasing the payload of the vehicle. Additionally, the batteries can be replaced individually should they fail in the future. The 495 group has selected this as the final design option.

The first phase of the design is the new battery pack. There are currently no 12-volt batteries available on the market that fit into the current battery pack. The 495 group revisited the conceptual design of the 395 group and used that battery case (see Figure 1) as the design.

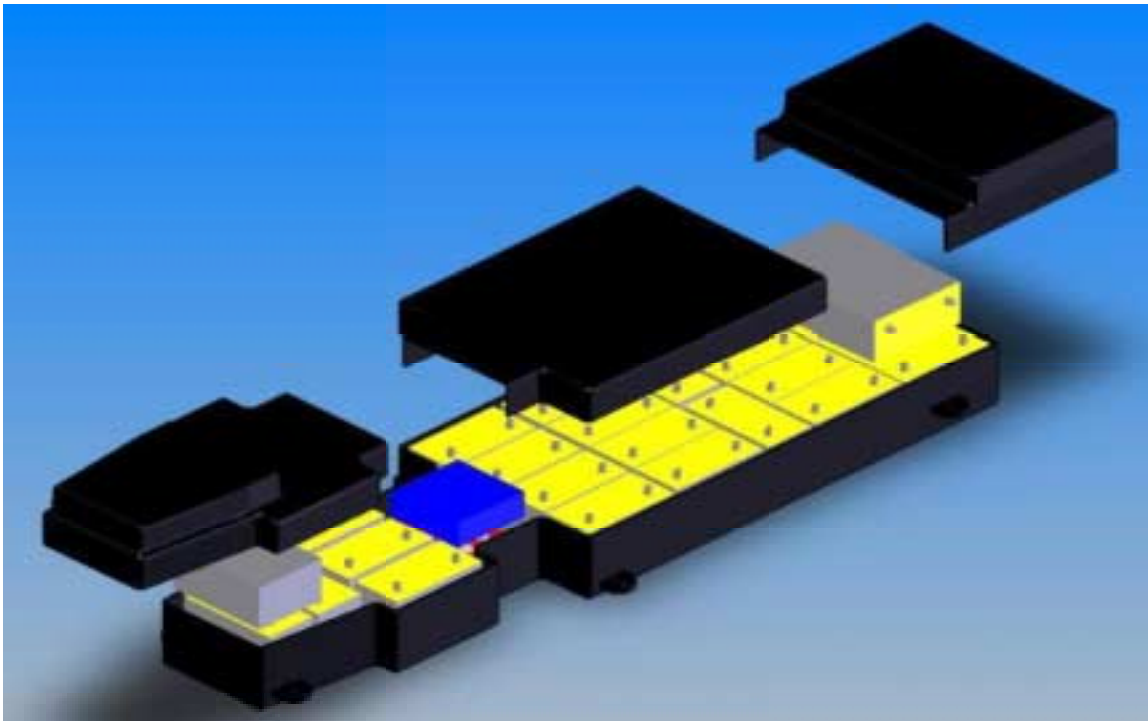


Figure 1: Conceptual design for new battery case with 12-volt batteries

The case was designed to fit in the space currently available in the truck. Further, the case utilizes the same six mounting brackets as the existing case. Therefore, no modifications to the truck frame are required.

The next phase of the design is to determine the manufacturing method for the new battery pack case. The existing case consists of two halves. The upper half is entirely molded fiberglass, while the lower portion is welded metal covered in fiberglass. The fiberglass is necessary to contain battery acid in the event of a battery rupture. This material is ideal because it does not react with the battery acid, but it is water resistant and durable. The 495 group is currently exploring options

for manufacturing the new case. Finite element analysis of the case is being utilized to determine the best material based on performance and cost.

The final phase of the new battery pack design is interfacing with the truck. The 495 group has identified two options to accomplish this task. The first is a complete conversion of the Ford Ranger EV electrical system to implement the use of the battery pack. This transformation would be similar to the conversion process used in changing internal combustion vehicles to electric vehicles. This design option is being researched, but is not preferred due to the impact it would have on the vehicle. This conversion would likely result in a loss of some of the safety systems and interdependence installed by Ford. The second option is the creation of a controller for the battery pack similar to the current controller. The main difference would be that the new controller would be programmed to recognize twenty-six 12-volt batteries as opposed to thirty-nine 8-volt batteries. The 495 group is in communication with the University of Washington Electrical Engineering Department to construct this controller.

Updated Timeline

Task	Date
SEVA meeting	1/11/05
Safety meeting with Russ Noe	1/11/05
Design Proposal, Safety Plan and Presentation	1/13/05
Contact information for EV maintenance	1/13/05
Possible battery choices	1/14/05
Battery choice evaluation	1/23/05
Battery selection	1/25/05
Determine battery configuration	2/1/05
Midterm report	2/10/05
Finite element analysis (FEA) of battery case	2/16/05
Determine case material from results of FEA	2/18/05
Complete budget breakdown for battery purchase	3/3/05
Complete budget breakdown and suppliers list for manufacture of the battery case	3/7/05
Determine manufacturing method for case	3/7/05
Complete website	3/14/05

Conclusion

The Ford Ranger EV is a widely celebrated member of the electric vehicle community. The truck is still in use by a few private owners. Additionally, several organizations operate small fleets of these vehicles, including the Detroit Zoo, the Tulsa Zoo, and the University of Berkeley Facility Site Services. Due to the abandonment of the electric vehicle program, Ford is no longer available to service these vehicles. Currently, BatteryMD is the only location available to repair or refurbish these battery packs. Due to the popularity of the vehicle among its owners, there is a niche market available for new battery packs to replace the aging models.

The 495 group has decided to create a new battery pack and controller to replace the existing system. This decision was based on the current technology available on the market and the available options for restoration of the vehicle. The battery case has been designed and a Solidworks document has been created. The next phase of the project will consist of two separate paths. The first will be to determine the material and most suitable manufacturing method for the case. This will be done following a finite element analysis of the case utilizing a variety of inexpensive and durable materials. Following selection of these processes, an economic plan will be developed to determine the cost of the construction. The second path will be developing the new controller to interface with the vehicle. This step will be performed with the assistance of the University of Washington Electrical Engineering Department.

Completion of the design will occur over the next several weeks. At the completion of the 2005 Winter Quarter, the 495 group will present a public website that provides all information gathered during the research phase of the design. Additionally, instructions on how to manufacture the necessary components for conversion of the battery pack will be provided along with a list of suppliers.

Appendix A - References

Schenck, R. (2004, October 14). Lecture presented in Mechanical Engineering 395. University of Washington, Seattle, Washington.

Dieter, G. (2000). Engineering Design: A Materials and Processing Approach. Boston: McGraw-Hill.

Deep Cycle Batteries - Calculation Worksheet. (1998). Retrieved October 25, 2004, from http://www.cyb.com.au/automotive/prod_info/deepcycle_calc.htm.

Batteriesareus - Optima Batteries. (2004). Retrieved October 25, 2004, from <http://www.batteriesareus.com/index.htm/optima-specs>.

Ford Ranger Electric Vehicle. (2002). Retrieved October 25, 2004, from <http://www.herelectricvehicle.com/fordranger.html>.

Ford Ranger Electric Vehicle. (2001). Retrieved October 25, 2004, from http://www.autoworld.com/news/Ford/Ranger_Electric.htm.

Electric Vehicle. Retrieved October 25, 2004, from http://www.brainyencyclopedia.com/encyclopedia/e/el/electric_vehicle.html.

The History of Electric Vehicles. (2004). Retrieved October 25, 2004, from <http://inventors.about.com/library/weekly/aacarselectric2a.htm>.

Valvoline - Electric Vehicle Overview. (2004). Retrieved October 25, 2004, from <http://www.valvoline.com/carcare/articleviewer.asp?pg=dsm20011001af>.

October Ford Global News. (1997). Retrieved October 25, 2004, from http://www.autoweb.com.au/cms/A_50153/newsarticle.html.

Electric Vehicle Performance and Battery Cost Comparison. Retrieved October 25, 2004, from http://www.electrcauto.com/hist_comp_01.html.

Jump Start Ford. Retrieved February 1, 2005, from <http://www.jumpstartford.com/action/rangerEVpressRelease.html>.

“Electric Rangers to Join Lab Fleet.” *Facilities Quarterly* (April 1999). Retrieved January 19, 2005 from http://fac.lbl.gov/Facilities/Planning/Publications/FacQ/archive/FQ_4_99.pdf.

Battery Specifications. (2005). Retrieved March 13, 2005, from http://www.exide.com/products/golf_car/spec_golf_car.html.

Battery Mart. (2005). Retrieved March 13, 2005, from <http://www.batterymart.com/p-SLA-4V9.html>.

Technical Specs. (2004) Optima Batteries. Retrieved March 13, 2005, from http://www.optimabatteries.com/publish/optima/americas0/en/config/product_info/automotive/deep_cycle/technical_specs.html.

ICS-200 User's Guide. (2002). Retrieved November 23, 2004, from <http://www.etecevs.com/pdf/004a2%20ICS-200B%20Users%20Guide.pdf>.

Appendix B - Calculations

For this project, the total energy supplied by the existing batteries and any new possible batteries needed to be calculated. The following are the equations used to determine the amp hours and watt hours for this project, with the calculations for the stock batteries.

$$(\text{Watt-Hours}) / (\text{volts}) = \text{AH}$$

$$(23 * 10^3) / (312) = 73.7 \text{ AH}$$

$$\text{AH} * \text{Volts (total)} = \text{Watt-Hours}$$

$$(73.7) * (312) = 23 * 10^3$$

Appendix C – Goals and Constraints

Constraint	Score
Voltage	7
Current	7
Size	6
Budget	9

Goals	Score
Provide comparable range	8
Limit required modifications	7

The scores are based on a scale of 1-10, 1 being not important, and 10 being critical. The scores were tabulated by taking a poll within the group and deciding which constraint or goal was most important.

Appendix D - (Battery Specifications)

Current Battery

- Model BXE-202
- 8 Volt
- 70 Amp-hour rating per individual battery
- 23 kWh rating for the pack
- 39 individual batteries
- 15.25" L x 4.5" W x 6.625" H
- Total weight = 2000 lbs.

8V Replacement Battery

- Exide Golf Cart Battery: E-4800 8V
- 40.9 AH
- 10.375" L x 7.1875" W x 11.4375" H3

4V Replacement Battery

- Sealed Lead Acid 4V Battery
- 9 AH
- 3.98" L x 1.73" W x 3.74" H

12V Replacement

- Optima d31a Deep cycle Battery
- 12V
- 75 AH
- 12.81" L X 6.50" W X 9.31" H

The 8V batteries are too big (and could provide a power concern), while the 4V batteries aren't powerful enough.

Appendix E – (BatteryMD contact information)

Battery MD

- www.batterymd.com
- Contact: Kitty Rodden at batterymd@aol.com or 916-641-1807
- Official remanufacturer of all Ford EV battery packs
- Individual batteries not available
- Offer qualified used “refurbished” battery pack purchased with trade-in of your existing battery pack for approximately \$4000 (quoted as \$3928.56). This includes parts and labor, and they will perform a complete diagnostic test of your vehicle. Price does not include transporting your vehicle to and from there Sacramento offices

Pack is only guaranteed to have a range of 30 miles when it leaves their facility, as compared to the original 50 mile range from the factory. The pack is not warranted. There is no guarantee on how long the new pack will last.

Appendix F – (Morphological Chart)

Subfunction	Concept Number			
	1	2	3	4
1.0 Store Energy				
1.1 Electric	Deep Cycle	Standard Automotive		
1.2 Kinetic	Flywheel	Gyro		
2.0 Deliver Energy				
2.1 Power Transformation	Transformer			
	Equivalent Amp			
2.2 Provide Adequate Duration	Hours			
3.0 Provide Housing and Support				
3.1 Protect Batteries				
3.1.1 Overcharge Protection	Provided by battery	Provided by On-Board computer system		
3.1.2 Provide Thermal Control				
3.1.2.1 Cooling	Air	Liquid		
3.1.2.2 Heating	Electrical	Insulation		
3.1.3 Resist Impact	Shock Absorbers	Resistant Case	Integrated Skid Plate	
3.2 Provide Structure				
3.2.1 Chemical Resistant	Case Material	Case Coating	Sacrificial Material	
			Increase the number of mount points	
3.2.2 Low Flex	Internal framing	Rigid Material		
	Sliding Battery			
3.3 Access to all Batteries	Trays	Minimize Stacking of batteries	brackets	
4.0 Provide User Interface				
4.1 Fastening Hardware	Base Clamps	Tie Straps	Pressure Fit	
4.2 Provide Connections				
4.2.1 Battery Connections	Alligator Clip	Clamp On	Push On	Hardwire
4.2.2 Wires	Silver	Lead	Gold	Silver
4.3 Allow for Easy Maintenance				
4.3.1 Top Case Easily Removable	Top Case Sectioned	Solid Top Case		
4.3.2 Contaminant Infiltration	Weather Stripping	Silicon		