Boulder Electric Vehicle Field Validation Project 2012

Task # 3 Deliverable Report

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Submitted by:

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Abstract/Executive Summary

Boulder Electric Vehicle (BEV) will produce, deploy and field validate 18 all electric, zero NO_x, advanced zero emissions new vehicle 11,500 gross vehicle weight rating (GVWR) delivery trucks with a patent pending ultra-light-weight aluminum honeycomb composite vehicle frames, a top speed of 65 miles per hour (mph) and a range of 120 miles. BEV will deploy them in three metropolitan non-attainment areas in Texas for a full calendar year. FedEx and UPS will deploy and test a combined total of nine trucks in the cities of Dallas, Houston, and San Antonio. The Cities of Dallas, Galveston, and San Antonio will deploy and test three vehicles each. The validation of the top speed, range, and carrying capacity as well as the heating and cooling of the battery pack will all be validated under real world conditions and duty cycles. BEV has reduced the curb weight of a standard delivery truck from 9,000 pounds (lbs) down to near 5,000 lbs. by incorporating patent pending composite aluminum frame technology. Due to the reductions in weight, the size of the battery pack is also greatly reduced, thus lowering the cost of the vehicles and increasing economic viability. Because the ultra-light-weight aluminum honeycomb composite vehicle frames are a departure from the standard steel frame rails, field validations will greatly accelerate the market acceptance and commercialization of this new technology, thereby reducing the NO_x in Texas metropolitan non-attainment areas. The data logged and published from this field validation project will greatly accelerate the market adaptation of this zero emissions vehicle technology as well as validate the potential for great pollution reduction in Texas non-attainment cities.

Introduction/Background

There are three major issues with the performance (and therefore market acceptance) of large format electric vehicles:

- The vehicles weigh too much and therefore require very large and expensive battery packs.
- The batteries will not perform as well when it is cold (noticeable degradation of range starts at 40 degrees Fahrenheit (F)), and when the temperature goes over 120 F the pack starts to "bake" drastically reducing cycle life. The later issue has been greatly publicized by a major original engine manufacturer (OEM) having their range reduced in their first offering of electric cars deployed in Phoenix, Arizona.
- No one is making a commercially available electric truck that goes faster than 50 mph.

BEV has addressed all of these issues in our first prototype 11,500 lbs. GVWR vehicle.

Vehicle Weight

BEV has filed patents on the ultra-lightweight composite aluminum frame which we think will be a key component in the automotive industry for making vehicles lighter while retaining strength.

Aluminum honeycomb composite is well known in the aerospace industry but has never been used in the automotive industry until now. Our primary invention is the placement of key stringers of tubing inside the honeycomb core in order to stiffen and spread out the load inside the vehicle frame and where it attaches to key suspension points. There are three primary advantages in our frame design over the typical steel frame rail truck design.

First is lightness of the vehicle. Batteries for electric vehicles have such a high cost, that a gain in the efficiency of the vehicle pays for itself through a smaller battery pack and less initial costs. On smaller vehicles such as the Nissan Leaf or the GM Volt the batteries might be 20-30% of the price of the vehicle. On larger trucks the battery pack can be fully 50% or more of the costs of materials in the manufacturing of the vehicle. Especially in the delivery market where there is a great deal of stop and go driving, the reduction in weight offers a tremendous increase in efficiency.

Second is safety. By bringing the battery pack to the center of the vehicle it protects the battery pack from accidents, thus protecting the investment in the high cost battery packs and increasing the factor of safety. This also places the weight of the battery pack (1,400 lbs. or over) in the center of the vehicle, increasing the stability and drivability of the vehicle. Third is the reduced energy needed to manufacture the frame itself. Costs, energy, and ease to manufacture the frame are all better than a typical steel frame rail truck. The process is vacuum bagging six parts instead of plasma cutting, welding and bolting 30 parts or more. Thus costs and energy to manufacture is dramatically decreased.

Battery Thermal Management System

This is different from the usual Battery Management System (BMS) in that the usual BMS is involved in managing the battery cells during charge and discharge in order to keep track of any over or under voltage conditions outside of normal parameters. Our Battery Thermal Management System (BTMS) allows us to use the same heating and cooling system that we use on the cab of the truck and heat and cool the battery pack. We have spent the last 18 months in Colorado testing the system in the summer and winter. At 40 F the range of the battery pack is already being reduced without heating the pack. In minus 20 F conditions the range is reduced by 80% without heating the pack. Although it is a much more difficult parameter for a customer to quickly quantify, cooling the pack in the heat of the summer is equally important by keeping cycle life in line with manufacturer's spec. Over 102 F the pack is being baked. The cycle life can be reduced by up to 80% just by a few weeks of operations at this higher temperature. The problem is compounded by the necessary placement of the battery pack about one foot above the black pavement. Therefore we cool the battery pack. No one else has implemented this in electric trucks.

Highway Capable Electric Trucks

BEV's top speed is 71 mph. We are the only electric truck OEM that offers this speed. From a department of transportation legal perspective any vehicle that gets on an interstate highway *must* be capable of going at least 10 mph less than the posted speed limit. Since many states have speed limits of 75 mph this dictates a 65 mph speed. For large format electric vehicles this means either a motor/controller with a greater amount of torque and power, or a transmission. This is not hard to do, but the market dictates that this *must* be done. The only reason we can speculate as to why neither Smith nor Navistar has done this is that both of their designs were finalized in England where this is not a market driven necessity. We have also observed through our own extensive testing of our prototype truck that higher speeds will decrease range and therefore make the trucks either more expensive to produce or lower in range.

Project Objectives/Technical Approach

The objectives for this project are:

1. Build all electric, zero-NO_x delivery trucks with a top speed of 65 mph and a range of 120 miles.
2. Demonstrate for a period of up to one year the 18 electric delivery trucks in the Dallas, Houston-Galveston, and San Antonio areas with both public and private entities, collecting data on vehicle durability and performance and customer acceptance.
3. Evaluate the durability of vehicle components and battery packs in three of the demonstration vehicles after demonstration is complete.

Tasks

The tasks for this entire project are as follows:

- Task 1: Demonstration preparation and vehicle design adjustments,
- Task 2: Vehicle production,
- Task 3: Vehicle deployment,
- Task 4: Vehicle demonstration,
- Task 5: Post-demonstration vehicle durability analysis, and
- Task 6: Reporting.

This specific report is the report for *Task 3 – Vehicle Deployment* and will address delivery methods, records driver training, field validation partner's infrastructure for charging the vehicles, and maintenance.

Task 3 – Vehicle Deployment

From the Grant Activities (Scope of Work):

> ***"****Task 3: Vehicle deployment*
>
> *2.3. Task Statement: The PERFORMING PARTY will deliver the electric vehicles to demonstration partners and provide a driver and vehicle maintenance training for the demonstration fleet drivers and mechanics.****"***

Task 3.1 Demonstration Fleet Training

Task 3.1.1 Driver Training Course

From the Grant Activities (Scope of Work):

> *"2.3.1.1 The PERFORMING PARTY will develop and perform a driver training course for the primary fleet drivers to use the demonstration vehicles*

We have developed a driver training course which we have implemented from the very first vehicle delivered. This driver training course has developed with subsequent round of deliveries and with additional driving training sessions for fleets which have had some turnover in drivers. The course is a two hour power point presentation followed by two hours of ride and drives so that the drivers actually have a chance to become familiar with the vehicles in an intense, hands-on session. The final two pages of the driver training course are a test for basic knowledge of the differences in driving an electric vehicle (EV) and how to get the most range and consistent performance from the vehicle. The final step is making the drivers familiar with the owner's manual and its contents.

Task 3.1.2 Electric Vehicle Fleet Maintenance

From the Grant Activities (Scope of Work):

> *"2.3.1.2 The PERFORMING PARTY will develop, offer, and implement a course in electric vehicle fleet maintenance for designated mechanics within each demonstration partner fleet."*

We have developed a rudimentary basic maintenance course but at the present time we feel it will be necessary to fly in fleet managers for training at our Colorado facility as the danger of working with 400

volts of direct current poses such a liability risk that a full day of training in our facilities is needed. Since the nature of the field validation is that BEV services the vehicles for the first year of operation before handing it off to the fleets on the ground, no one has yet taken us up on the offer to fly in to Colorado for the training for high voltage electric vehicles. The basic maintenance course is attached as Appendix-B

Task 3.2 Vehicle Delivery and Site Prep

Once charge stations were delivered to the specific cities and commercial fleets we performed on site visits to make sure that the charge stations were properly wired and working correctly. After that initial step was performed we scheduled delivery, transportation and driver training. Many fleets consider an EV a "new toy" and want to drive it right away. We have developed a policy of not handing over the keys until driver training has been performed. Before this policy was implemented one of the city fleets actually took delivery from our transport driver, proceeded to drive the vehicle down to 0% state of charge and then leave it without plugging it in as their charge stations were on the other side of the city from where they had designated delivery. This necessitated a service call on our part.

Task 3.2.1 Transportation

From the Grant Activities (Scope of Work):

> *"2.3.2.1 The PERFORMING PARTY will arrange for transport of electric demonstration vehicles to demonstration partner sites in Dallas, Houston-Galveston, and San Antonio."*

Basic flatbed transportation was arranged with trucks going two and sometimes three per trailer. We have found one consistent carrier who is very reliable and has been trained with our delivery methods. Records were kept of deliveries and sign offs. These included the dates our Chief Financial Officer signed off for the outgoing transportation, the last three digits of the vehicle identification numbers (VIN) (which correlate to our serial numbers), and the receiving party and date. The following table indicates the last three digits of the VIN, the fleet validation partner, the location and use, as well as the month and year of delivery.

Table 1. Vehicles by fleet, location, and delivery date.

VIN #	Fleet Validation Partner	Use Location	Delivery Date
003	City of San Antonio	Utility repair	Sept 2012
004	City of Dallas	Code Enforcement	Sept 2012
005	City of Galveston	General Services	Sept 2012
007	FedEx Express	Houston Station	Jan 2013
008	FedEx Express	Houston Station	Jan 2013
009	FedEx Express	Dallas Station	Jan 2013
010	FedEx Express	Dallas Station	Jan 2013
011	FedEx Express	San Antonio Station	Jan 2013
012	FedEx Express	San Antonio Station	Jan 2013
013	City of San Antonio	Parks & Recreation	Nov 2012
014	City of Dallas	Parks & Recreation	Dec 2012
015	City of Galveston	General Services	Dec 2012
018	City of San Antonio	Utility Services	Dec 2012
019	City of Dallas	Utility Repair	Dec 2012
020	City of Galveston	General Services	Dec 2012
023	UPS	Houston Depot	Jan 2013
024	UPS	Dallas Depot	Jan 2013
025	UPS	San Antonio Depot	Jan 2013

Task 3.2.2 Vehicle Charging

From the Grant Activities (Scope of Work):

> *"2.3.2.2 The PERFORMING PARTY will ensure that demonstration partner fleet sites have proper outlets and power for charging vehicles at their primary base of operations."*

We have performed on site visits to make sure the demonstration partners have their charge stations installed and wired correctly and are operational. We have developed a company policy of not sending a vehicle from our plant until we are sure the end user has their charge station installed.

Task 3.3 Schedule

From the Grant Activities (Scope of Work):

> *"2.3.3 The PERFORMING PARTY shall complete this task within 18 months of the signed Notice to Proceed Date as issued by TCEQ."*

This was performed timely for the city fleets but was somewhat delayed in the commercial fleets due to internal corporate delays. We were somewhat amazed that the commercial entities were actually performing more slowly than the city governments with internal implementations and controls.

Task 3.4 Deliverables

From the Grant Activities (Scope of Work):

> *"2.3.4 The PERFORMING PARTY shall submit a report to the TCEQ upon completion of this task. This report will include but is not limited to a driver training book, an electric vehicle maintenance book, a description of all training sessions, vehicle transportation records, and demonstration site charging outlet implementation records"*

Driver Training Book

We have developed a driver training course which we have implemented from the very first vehicle delivered. This driver training course has developed with subsequent round of deliveries and with additional driving training sessions for fleets which have had some turnover in drivers. The course is a two hour power point presentation followed by two hours of ride and drives so that the drivers actually have a chance to become familiar with the vehicles in an intense, hands-on session. The final step is making the drivers familiar with the owner's manual and its contents. The full document is attached as Appendix A. For proprietary reasons the driver training book is designated as confidential.

Electric Vehicle Maintenance Book

We have developed a rudimentary basic maintenance course but at the present time we feel it will be necessary to fly in fleet managers for training at our Colorado facility as the danger of working with 400 volts of direct current poses such a liability risk that a full day of training in our facilities is needed. Since the nature of the field validation is that BEV services the vehicles for the first year of operation before handing it off to the fleets on the ground, no one has yet taken us up on the offer to fly in to Colorado for the training for high voltage electric vehicles. The basic maintenance course is attached as Appendix-B. For proprietary reasons the maintenance book is designated as confidential.

Training Session Descriptions

A basic sign in sheet was developed so that we would have each of the driver's names and cell phone numbers on record. The basic sign in sheet format is attached in Appendix C but for reasons of keeping the driver's names and private cell phone numbers secure this has been designated confidential.

Vehicle Transportation Records

Delivery sheets for the vehicles were kept. The basic delivery format is attached as Appendix D but for reasons of key contact confidentiality and private contact cell numbers being on the actual delivery sheets the full documentation is designated confidential.

Demonstration Charging Outlets

We have performed on site visits to make sure the demonstration partners have their charge stations installed and wired correctly and are operational. We have developed a company policy of not sending a vehicle from our plant until we are sure the end user has their charge station installed.

Discussion/Observations

Objectives vs. Results

The objectives of this particular task which was to deliver the vehicles, perform a driver training and to develop maintenance procedures were met, albeit in a fashion that incurred some delays. The maintenance and repair training would be best performed at the same time as driver training. There exists a real fear of working on electric vehicles without proper training. In our opinion this is very well justified as there is potentially dangerous voltages that could be harmful to the maintenance technician.

Critical issues

One critical delivery issue we had was with one of the city fleets which kept their vehicles in an "acceptance" area for almost a month before deploying them. The acceptance area did not have charge stations, only the operational staging area had the charge stations. Therefore the battery packs died from internal loads over the course of a month and an unscheduled maintenance visit had to be performed by our staff. One of the key rules is that an electric vehicle needs to be plugged in every night and this was grossly ignored. A possible solution is to have a master kill switch so that the vehicle can sit for a month without discharging. The staff at the acceptance center also felt it was acceptable to "see what they can do" with the electric vehicles (top speed 91 mph) and therefore put some miles on them before letting them sit for a month. This exacerbated the issue. We have also considered a small solar panel for keeping the 12 volt battery on a trickle charge. We have also installed a low voltage barrier mechanism on the 12 volt battery so that it can go to low but no further thus protecting the auxiliary battery from failure.

Technical and commercial viability of the proposed approach

The goals of this task were technically achievable. The commercial viability of flying in a service technician just to make sure the charge stations are installed and working is of dubious merit. Long term this approach might be the responsibility of the delivery agent of the vehicle or possibly even put onto the diagnostics of the vehicle itself. However delivering an electric vehicle without a way to charge the vehicle is building failure into the process and thus undesirable. In five years we do not anticipate this being a problem however at this time it adds significant expense to a sure fire launch. Hopefully this will be reduced so that each fleet only has the initial experience managed by BEV and then they will be able to implement a "train the trainer" approach to electric vehicle implementation.

Scope for future work

Future development of the EV infrastructure would benefit by having online, webinar style training for the installation and testing of EV charge stations. Company-wise, BEV would benefit by having repair manuals, part numbers and ordering information available online. This could possibly be accomplished through password enabled portions of a customer portal web site.

Intellectual Properties/Publications/Presentations

No inventions or patents were developed in the execution of this task.

Summary/Conclusions

The biggest obstacle to implementing electrification of transportation is changing the human behavior of the end user. When cell phones first came on the market people were not used to having to plug their phone in every night. People soon learned that plugging in your cell phone every night was the only way it would perform reliably the next day. It is the same with electric vehicles.

People are used to being able to park a vehicle “down the street” or in a side area of a fleet parking area and coming back a week later when they need that specific vehicle. However electric vehicles need to be plugged in every night. This determines both the performance for the following day’s use as well as longevity of the battery pack.

Contact Information

For further information about this project please contact:

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Appendices

Appendix A: Driver Training Book

The information in this appendix was claimed by the grantee as Proprietary and/or Confidential. To view this information please contact the New Technology Research and Development program at:

(512) 239-4950

Or

ntrd@tceq.state.tx.us

Appendix B: Electric Vehicle Maintenance Book

The information in this appendix was claimed by the grantee as Proprietary and/or Confidential. To view this information please contact the New Technology Research and Development program at:

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Appendix C: Training Session Descriptions

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Appendix D: Vehicle Transportation Records

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