Dynamometer Testing of USPS EV Conversions

P. T. Jones (PI)
Oak Ridge National Laboratory

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Lee Slezak
Vehicle Technologies Program
U.S. Department of Energy

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

• Timeline
  – Project start date: Nov. 2010
  – Project end date: May 2011
  – 100% complete

• Barriers
  – Unique vehicle mission, drive cycle
  – Standardized test development
  – Charging infrastructure
  – Vehicle readiness

• Budget
  – New project, FY10 funding
  – FY10 funding: $200k
  – USPS Provided Vehicles
  – FY11 (current) funding: $0k project completed

• Partners
  – Oak Ridge National Laboratory
  – Idaho National Laboratory
  – United States Postal Service
  – Ecotality NA
Objectives

- Perform benchmark dynamometer testing on USPS Electric Vehicle Conversions

- Quantify vehicle performance using both “standardized” test methods and project specific test methods.

- Characterize vehicle performance in various driving modes
Vehicle Technology Program (VTP) - Relevance

- VTP Multi-Year Program Plan (2 key goals from VSST Subprogram)
  - Demonstrate market readiness of grid-connected vehicle technologies by 2015.
  - Support the laboratory and field evaluations of large-scale demonstration fleets of advanced commercial and passenger PHEVs and EVs.

- Barriers
  - Public acceptance of electric drive as central vehicle choice
    - Government to show leadership in usage of advanced vehicle technologies
  - Battery cost and durability
    - Though not directly evaluated in this program, right sizing components for mission design is critical – consumer behavior and understanding
Background USPS Fleet - Relevance

Largest non-military fleet in the world*

- Range of ‘Road’ vehicles T3 to Windstar to Class 8
- Various Technology Applications
  - Air, Rail, and Marine & 44K Alternative fuel vehicles
    - Bio-, LNG, CNG, Electric Vehicles
- Huge fleet operation costs/logistics

Fuel used in 2010 – 650 Million gallons (street, highway and air)
Cost of fuel impact – 1 cent/gallon increase ~$6.5M
2008 record prices ($4.11/gallon) – increase equates to $31M/month**
Driven distance in 2010 – 4+ million miles per day

** Steve Masse, VP USPS Finance and Planning
USPS Electric Vehicle History* - Relevance

- Previous electric vehicles

Cleveland, Ohio, 1899
22 miles route 2 ½ hr previously powered by horse taking 6 hrs.

Cupertino, California, 1978.
Used thru 1982, Cupertino converted its entire 30 vehicle fleet.

- 2000-2003 Ford Based EV

500 EV Ranger based delivery vehicles
Predominantly in California, few in Washington D.C, and NY
Replaced with Gasoline Windstars when Ford ended their EV program

Project Focus Area - Relevance

Long Life Vehicle (LLV)

Grumman Aluminum body
Modified Chevrolet S-10 Chassis
4 cylinder 2.5 and 2.2L 3spd Auto
Rear Wheel Drive

142,000 Vehicles in service
EPA Rated at 18 MPG
‘Real’ mail delivery MPG* ~ 10 MPG

Opportunities to Meet VTP Goals - Relevance

"Real" Mail Delivery Driving

* Modified chart; original chart source: http://avt.inel.gov/pdf/fsev/costs.pdf
USPS EV Conversion Project - Relevance

United States Postal Service (USPS)

- **Key Vehicle Requirements** -
  - Project Management - First article acceptance, infrastructure, field test and evaluation
  - Vehicle Conversions meet numerous FMVSS and SAE EV safety specifications
  - USPS Basic requirements for EV LLV
    - 0 – 15 mph within 5 seconds
    - 0 – 55 mph within 35 seconds
    - 110V recharge @ 15 amps
    - 25 mile range over described route
    - Maintain 1000 lb cargo carrying capacity
    - Heater/Power steering – no Manual shifting
    - Maintain 40 foot turning radius

5 Awards – Convert a vehicle (provided by USPS), 1 year evaluation

Idaho National Laboratory (INL)

- PI - Jim Francfort and Richard “Barney” Carlson
  - Field data collection and analysis (VSS033)

Ecotality – Vehicle Prep, baseline test and vehicle characterization
Approach

- Test Procedure development and selection (INL & USPS)
  - SAE original J1634: Electric Vehicle Energy Consumption and Range Test Procedure
  - Develop USPS “worst-case” Delivery cycle based on ‘bin’ data

- Vehicle track characterization (INL & Ecotality NA)
  - Perform vehicle coast down testing
  - Establish vehicles meet minimum performance criteria and instrument:
    - Performance
    - Energy consumption, charging requirements
    - Emissions

- Conduct Dynamometer Testing (ORNL)
  - Utilize AC motoring chassis dyno and instrumentation to capture energy usage data

- Compare and Validate (INL and ORNL)
  - Field usage data with dyno results
Test Procedure - Strategy

- **J1634 type testing**
  - based on the Federal Emission Test Procedure using the Urban Dynamometer Driving Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HFEDS)
  - Complete usable ESS capacity used in transient drive cycles

- **C/3 Range Testing**
  - Based on vehicle battery rated capacity
  - Steady state cruise at speed determined
  - Complete usable ESS capacity used in three one hour drives

- **USPS Simulated Delivery Cycle (worst case scenario)** – next slides
**Test Procedure Development - Approach**

**USPS Delivery cycle (worst case)**

<table>
<thead>
<tr>
<th>Cycle Name</th>
<th>Distance (mi)</th>
<th>Top speed (mph)</th>
<th>Number of stops</th>
<th>Time [sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td>3.96</td>
<td>35</td>
<td>11</td>
<td>835</td>
</tr>
<tr>
<td>Freeway</td>
<td>3.07</td>
<td>55</td>
<td>1</td>
<td>270</td>
</tr>
<tr>
<td>Delivery #1</td>
<td>2.77</td>
<td>11</td>
<td>175</td>
<td>4380</td>
</tr>
<tr>
<td>Delivery #2</td>
<td>2.77</td>
<td>11</td>
<td>175</td>
<td>4380</td>
</tr>
<tr>
<td>Lunch</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1800</td>
</tr>
<tr>
<td>Delivery #3</td>
<td>2.77</td>
<td>11</td>
<td>175</td>
<td>4380</td>
</tr>
<tr>
<td>Delivery #4</td>
<td>2.77</td>
<td>11</td>
<td>175</td>
<td>4380</td>
</tr>
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</tr>
</tbody>
</table>

**total:**  
25.14          724          21530 seconds 5.98 hours

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**Graphical Representation:*

- **Speed (mph)**
  - Range: 0 to 800 mph
  - Data points indicating varying speeds throughout the cycle.

- **Time (sec)**
  - Range: 0 to 4500 seconds
  - Highlighted sections indicating specific time intervals.

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Test Procedure Development - Approach

- USPS Delivery cycle (worst case)
Milestones - Progress

- Milestone #1, February 28, 2011:
  - Benchmark testing on all 5 EV conversion vehicles completed
  - Final vehicle leaves for USPS Engineering

AOP Project Objective:
The purpose of this task is benchmark up to five (5) United States Post Office delivery vehicles that have been converted to operate as battery electric vehicles (BEV). This task was funded late in FY2010, and benchmarking dynamometer work will be carried out in FY2011.
## Vehicle Architecture Summary

<table>
<thead>
<tr>
<th></th>
<th>Vehicle A</th>
<th>Vehicle B</th>
<th>Vehicle C</th>
<th>Vehicle D</th>
<th>Vehicle E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FWD or RWD</strong></td>
<td>RWD</td>
<td>RWD</td>
<td>RWD</td>
<td>FWD</td>
<td>RWD</td>
</tr>
<tr>
<td><strong>Drive system</strong></td>
<td>DC Brushless</td>
<td>AC Induction</td>
<td>DC Brushless</td>
<td>DC Brushless</td>
<td>DC Brushless</td>
</tr>
<tr>
<td><strong>ESS type</strong></td>
<td>Li-Ion liquid cooled</td>
<td>Li-Ion, air cooled with A/C</td>
<td>LiFePO$_4$ prismatic cells - air cooled</td>
<td>Na-NiCl$_2$ battery (hot) +500$^\circ$F</td>
<td>Li-Ion liquid cooled</td>
</tr>
<tr>
<td><strong>Rated capacity [DC kWh]</strong></td>
<td>13.3</td>
<td>23.2</td>
<td>19.5</td>
<td>55.7</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>Voltage [V]</strong></td>
<td>333</td>
<td>374.4</td>
<td>345</td>
<td>371</td>
<td>267</td>
</tr>
<tr>
<td><strong>Capacity [Ah]</strong></td>
<td>40</td>
<td>62</td>
<td>56.5</td>
<td>150</td>
<td>80</td>
</tr>
<tr>
<td><strong>Curb Weight (lbs)</strong></td>
<td>3310 lbs</td>
<td>3408 lbs</td>
<td>3598 lbs</td>
<td>4366 lbs</td>
<td>3500 lbs</td>
</tr>
<tr>
<td><strong>Additional features</strong></td>
<td>Solar panels on roof</td>
<td>Vehicle-2-Grid (up to 80A)</td>
<td>-</td>
<td>4 wheel disc brakes</td>
<td>-</td>
</tr>
</tbody>
</table>
# Vehicle Test Results Summary

<table>
<thead>
<tr>
<th></th>
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<td>3408 lbs</td>
<td>3598 lbs</td>
<td>4366 lbs</td>
<td>3500 lbs</td>
</tr>
<tr>
<td>USPS Composite Test Efficiency (AC Wh/mile)</td>
<td>**</td>
<td>1160</td>
<td>842</td>
<td>1217</td>
<td>939</td>
</tr>
<tr>
<td>UDDS / HWY (J1634) Efficiency (AC Wh/mile)</td>
<td>**</td>
<td>446</td>
<td>503</td>
<td>599</td>
<td>506</td>
</tr>
<tr>
<td>C/3 Range Efficiency (AC Wh/mile)</td>
<td>**</td>
<td>284</td>
<td>328</td>
<td>508</td>
<td>311</td>
</tr>
<tr>
<td>Level1 USPS Recharge Time</td>
<td>**</td>
<td>22 hours</td>
<td>14 hours</td>
<td>40 hours*</td>
<td>17 hours</td>
</tr>
</tbody>
</table>

* Duration of charge due to ESS and USPS requirements

** Testing complete and data supplied to Program management, under review with Supplier
Vehicle Graphical Comparison - Progress

Energy Consumption Rates for Various Drive Cycles

Lower is Better

Energy Consumed (DC Wh)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDDS/HWY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USPS comp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commute only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Vehicle Testing Summary - Progress

Regenerative Braking Effectiveness

- Percentage of Propulsive Energy Recovered

Higher is Better

UDDS/HWY | USPS City/HWY | USPS Delivery
---|---|---
A | B | C | D | E
A stable fuel/energy price, which for the tested EV architectures, yields significant fuel savings over the current LLVs, though conversion cost are high.
Accomplishments – Vehicle and Data Sharing

- Transfer of vehicles to ORNL for testing in route to USPS field deployment
- Evaluated using new project specific drive cycle (worst case scenario)
- Quantified vehicle initial vehicle performance using “standardized” tests
- Summarized vehicle information for field data comparison and future test procedure modifications
Collaboration and Coordination with Other Institutions

United States Postal Service (USPS)
- Vehicle Engineering and Evaluation – Han Dinh, Joseph McGrath and J. Smith
- Overall Program Management
  - Field deployment
  - Statement of Work
    - Key Vehicle Requirements - Performance, safety, charging
    - First article testing, Infrastructure, Overall test and Evaluation

Idaho National Laboratory (INL)
- Project Management
- PI - Jim Francfort and Richard “Barney” Carlson
  - Vehicle preparation and project leads
  - Field data collection and analysis (VSS033)

Ecotality - baseline test and vehicle characterization
Summary

- Benchmark dynamometer testing was performed on five USPS Electric Vehicle Conversions at Oak Ridge National Laboratory

- ORNL used “standardized” test methods and specific program test methods to quantify vehicle performance and report to INL (Lead Project Lab).

- Analysis was performed on vehicle test results to identify areas of interest in various driving modes
Future Work

• Obtain in-use delivery drive cycle information and access test drive cycle impacts

• Establish baseline vehicle model to identify architecture sensitivity to drive cycle

• Use vehicle modeling to identify maximum regeneration possible from vehicles
Acknowledgements and Contacts

DOE Vehicle Technologies Program:
- Lee Slezak, Vehicle Systems Manager

Oak Ridge National Laboratory (ORNL)
- David E. Smith, Advanced Vehicle Systems Program Manager

Smithde@ornl.gov

ORNL Investigators:
- P.T. Jones – Jonespt@ornl.gov
- Paul Chambon – Chambonph@ornl.gov

INL Investigators:
- Richard “Barney” Carlson – Richard.Carlson@inl.gov

USPS Vehicle Engineering and Evaluation
- Han Dinh and Joseph McGrath