Electric Vehicle Fleet Operations in the United States

Jim Francfort

Presented to:
31st International Symposium on Automotive Technology and Automation
Dusseldorf, Germany – June 1998
Field Operations Program Members

- **U.S. Department of Energy**
  - Office of Technology Utilization

- **Idaho National Engineering and Environmental Laboratory**
  - Lockheed Martin Idaho Technologies Co.

- **Qualified Vehicle Testers**
  - Southern California Edison
  - Electric Transportation Applications (Arizona Public Service, Potomac Electric Power Co., Salt River Project)
Field Operations Program Mission

- Demonstrate the validity of operating electric vehicles in commercial fleet applications by documenting
  - Performance
  - Costs
  - Support requirements
Field Operations Program Testing Methods

• **Baseline Performance Testing (EV America)**
  – Initial performance
  – Periodic checks
• **Fleet testing**
  – Viability as fleet vehicle
  – User acceptance issues
• **Accelerated reliability testing**
  – High mileage
  – Performance over life-cycle
  – Infrastructure support
Baseline Performance (EV America) Testing

- Utilities, domestic and foreign car manufacturers, Department of Energy
- Stringent testing procedures
- Minimum qualification standards
- Allows vehicle-to-vehicle and year-to-year comparisons
Baseline Performance (EV America) Testing

- Testing parameters
  - Driving cycle range (SAE J1634)
  - (2) constant speed range
  - Maximum speed
  - Acceleration
  - Charge time
  - Charge efficiency
  - Vehicle specifications
  - Braking
  - Handling
Baseline Performance (EV America) Testing

- **1998**  - Toyota RAV4 (NiMH)  
  - Other OEM vehicles
- **1997**  - Ford Ranger 
  - Chevrolet S-10
- **1996**  - GM EV1 
  - Toyota RAV4 (lead prototype)
- **1995**  - 2 Solectria conversions 
  - 1 Baker conversion
- **1994**  - 1 Dodge van 
  - 2 U.S. Electricar conversions 
  - 2 Solectrica conversions
  - 1 Unique Mobility conversion
### GENERAL MOTORS EV1

#### PERFORMANCE STATISTICS
- **ACCELERATION 0-50 mph**
  - At 100% SOC: 6.3 sec
  - At 50% SOC: 6.7 sec
  - Max. Power: 116.4 kW
  - Performance Goal: 13.5 sec at 50% SOC
- **MAXIMUM SPEED @ 50% SOC**
  - At 1/4 Mile: 78.9 mph
  - At 1 Mile: 80.4 mph
  - Performance Goal: 70 mph in one mile
- **CONSTANT SPEED RANGE @ 45 mph**
  - Range: 135.2 miles
  - Energy Used: 15.58 kWh
  - Average Power: 5.19 kW
  - Efficiency: 11.5 Wh/mile
  - Specific Energy: 31.9 Wh/kg

#### VEHICLE SPECIFICATIONS

<table>
<thead>
<tr>
<th>Purpose-Built Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Vehicle:</strong> 1997 EV1</td>
</tr>
<tr>
<td><strong>VIN:</strong> 4gLip225060100009</td>
</tr>
<tr>
<td><strong>Seating Positions:</strong> Two</td>
</tr>
<tr>
<td><strong>Standard Features:</strong> Heat Pump Climate Control System Cruise Control Power Door Locks Dual Air Bags Power Windows Front Disc Brakes Power Steering Anti-Lock Brakes Front Wheel Drive Regenerative Braking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Battery</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pack Location:</strong> T-Pack Integral</td>
</tr>
<tr>
<td><strong>Nominal Module Voltage:</strong> 12 V</td>
</tr>
<tr>
<td><strong>Nominal System Voltage:</strong> 312 V</td>
</tr>
<tr>
<td><strong>Nominal Capacity (1C):</strong> 53 Ah</td>
</tr>
<tr>
<td><strong>Weights:</strong></td>
</tr>
<tr>
<td><strong>Design Car Weight:</strong> 2970 lbs</td>
</tr>
<tr>
<td><strong>Delivered Car Weight:</strong> 2922 lbs</td>
</tr>
<tr>
<td><strong>Distribution F/R:</strong> 53/47%</td>
</tr>
<tr>
<td><strong>GVWR:</strong> 5410 lbs</td>
</tr>
<tr>
<td><strong>GAWR F/R:</strong> 1705/1705 lbs</td>
</tr>
<tr>
<td><strong>Payload:</strong> 440 lbs</td>
</tr>
<tr>
<td><strong>Performance Goal:</strong> 400 lbs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Dimensions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheelbase:</strong> 98.9 inches</td>
</tr>
<tr>
<td><strong>Track F/R:</strong> 57.9/49.0 inches</td>
</tr>
<tr>
<td><strong>Length:</strong> 189.7 inches</td>
</tr>
<tr>
<td><strong>Width:</strong> 69.5 inches</td>
</tr>
<tr>
<td><strong>Height:</strong> 50.5 inches</td>
</tr>
<tr>
<td><strong>Ground Clearance:</strong> 4.2 inches at GVWR</td>
</tr>
<tr>
<td><strong>Performance Goal:</strong> 5.0 inches at GVWR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Charger</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong> Off-Board</td>
</tr>
<tr>
<td><strong>Type:</strong> Delta Electronics Inductive 6.6 kW Input Voltages: 156 to 260 VAC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tires</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong> Michelin</td>
</tr>
<tr>
<td><strong>Tire Model:</strong> Primax RR Radial</td>
</tr>
<tr>
<td><strong>Tire Size:</strong> P175/65R14</td>
</tr>
<tr>
<td><strong>Tire Pressure F/R:</strong> 50/50 psi</td>
</tr>
<tr>
<td><strong>Spares Installed:</strong> No, Self Sealing Tires</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Test Notes:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. At various during these range test the Battery Life, Reduced Performance. Service Soon, and Service Now icables illuminated.</td>
</tr>
<tr>
<td>2. Charging time was extended due to high temperature conditions.</td>
</tr>
<tr>
<td>3. Specific Energy values were calculated using the number of modules times the module weight.</td>
</tr>
<tr>
<td>4. The battery pack data collection voltage signal was reduced 100:1 through a voltage divider installed by General Motors. This was for personnel protection.</td>
</tr>
<tr>
<td>5. The Standing Water Test was conducted with a water depth of six inches versus eight inches.</td>
</tr>
</tbody>
</table>

Values in bold indicate the Performance Goal was not met. * All Power and Energy values are DC unless otherwise specified.

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A98 0585
Baseline Performance (EV America) Testing

Drive Cycle Range

- Ford Ranger: 65.1 Miles
- Chevrolet S-10: 43.8 Miles
- General Motors EV1: 78.2 Miles
- Toyota RAV4: 68.2 Miles
- Solectria Force: 84.5 Miles
- Solectria E10 Pickup: 55.1 Miles
- Baker EV100 Pickup: 56.6 Miles

Performance Goal: 60 Miles
Baseline Performance (EV America) Testing

**Constant Speed Range @ 45 mph**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Range (Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Ranger</td>
<td>86.9</td>
</tr>
<tr>
<td>Chevrolet S-10</td>
<td>60.4</td>
</tr>
<tr>
<td>General Motors EV1</td>
<td>135.2</td>
</tr>
<tr>
<td>Toyota RAV4</td>
<td>81.7</td>
</tr>
<tr>
<td>Solectria Force</td>
<td>105.9</td>
</tr>
<tr>
<td>Solectria E10 Pickup</td>
<td>80.8</td>
</tr>
<tr>
<td>Baker EV100 Pickup</td>
<td>61.2</td>
</tr>
</tbody>
</table>

Performance Goal: 60 Miles*

*60 Mile range is based on the driving cycle range performance goal.
Baseline Performance (EV America) Testing

Vehicle Acceleration
0-50 mph
50% State of Charge

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Time (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Ranger</td>
<td>12.3</td>
</tr>
<tr>
<td>Chevrolet S-10</td>
<td>10.35</td>
</tr>
<tr>
<td>General Motors EV1</td>
<td>6.7</td>
</tr>
<tr>
<td>Toyota RAV4</td>
<td>13.3</td>
</tr>
<tr>
<td>Solectria Force</td>
<td>18.5</td>
</tr>
<tr>
<td>Solectria E10 Pickup</td>
<td>17.4</td>
</tr>
<tr>
<td>Baker EV100 Pickup</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Performance Goal: 13.5 seconds
Baseline Performance (EV America) Testing

Recharge Time

- Ford Ranger: 8.85 hours
- Chevrolet S-10: 5.25 hours
- General Motors EV1: 5.3 hours
- Toyota RAV4: 8.48 hours
- Solectria Force: 8.95 hours
- Solectria E10 Pickup: 11.18 hours
- Baker EV100 Pickup: 7.83 hours

Performance Goal: 8 Hours
Baseline Performance (EV America) Testing

Maximum Speed @ 50% State of Charge At 1 mile

- Ford Ranger: 74.5 MPH
- Chevrolet S-10: 69.3 MPH
- General Motors EV1: 78.9 MPH
- Toyota RAV4: 77.9 MPH
- Solectria Force: 69.9 MPH
- Solectria E10 Pickup: 67.9 MPH
- Baker EV100 Pickup: 71.1 MPH

Performance Goal: 70 MPH
Baseline Performance (EV America) Testing

General Motors EV1 Vehicle Performance Compared to Performance Goals

- Charge Efficiency
- Energy Cost @ 10 cents/kWh (cents/mile)
- Vehicle Acceleration 0-50 50% SOC (seconds)
- Gradeability Time on 3% Grade (minutes)
- Constant Speed Range @ 45mph (miles)
- Constant Speed Range @ 60mph (miles)
- Maximum Speed @ 50% SOC At 1 mile (mph)
- Driving Cycle Range (miles)
- Recharge Time (hours)

A98 0591
Baseline Performance (EV America) Testing

Ford Ranger Pickup Vehicle Performance Compared to Performance Goals

- Vehicle Acceleration 0-50 50%SOC (seconds)
  - 12.3 seconds
- Gradeability Time on 3% Grade (minutes)
  - 15 minutes
- Constant Speed Range @ 45mph (miles)
  - 86.9 miles
- Constant Speed Range @ 60mph (miles)
  - 60 miles
- Driving Cycle Range (miles)
  - 60 miles
- Maximum Speed @ 50% SOC At 1 mile (mph)
  - 74.5 mph
- Charge Efficiency Energy Cost @ 10 cents/kWh (cents/mile)
  - 4.8 cents/mile
- Recharge Time (hours)
  - 8.86 hours

A98 0592
Baseline Performance (EV America) Testing

Acceleration at 50% SOC - 0 to 50 mph

- 1994:
  - Seconds: 30
- 1995:
  - Seconds: 24
- 1996:
  - Seconds: 18
- 1997:
  - Seconds: 12
Baseline Performance (EV America) Testing

<table>
<thead>
<tr>
<th>Year</th>
<th>Time to Recharge (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>9</td>
</tr>
<tr>
<td>1995</td>
<td>8</td>
</tr>
<tr>
<td>1996</td>
<td>7</td>
</tr>
<tr>
<td>1997</td>
<td>6</td>
</tr>
</tbody>
</table>
Baseline Performance (EV America) Testing

Driving Cycle Range

Miles


0  10  20  30  40  50  60  70  80
Fleet Testing Activities

• Data acquisition
  – kWh meter onboard, for onboard conductive chargers
  – kWh meter offboard, for inductive chargers
  – kWh data stored in 15 minute segments
  – Odometer readings
  – Location, vehicle identification, time/date
Fleet Testing Activities

• Information Calculated
  – Charging profiles for 24 hours by fleets, models, and individual vehicles
  – Average and maximum charging rates
  – Range in miles per kWh
  – Daily distance based on charging patterns
  – Range per charge
  – Energy efficiency; mileage; and energy use by fleet, model, and vehicle
Fleet Testing Activities

Average Monthly Mileage per Vehicle

- **Toyota RAV4**
- **Chev S-10**

Miles

- Oct '96
- Nov '96
- Dec '96
- Jan '97
- Feb '97
- Mar '97
- Apr '97
- May '97
- Jun '97
- Jul '97
- Aug '97
- Sep '97
- Oct '97
- Nov '97
- Dec '97
- Jan '98

Oct '96: 800 miles
Nov '96: 900 miles
Dec '96: 700 miles
Jan '97: 600 miles
Feb '97: 500 miles
Mar '97: 400 miles
Apr '97: 300 miles
May '97: 200 miles
Jun '97: 100 miles
Jul '97: 0 miles
Aug '97: 100 miles
Sep '97: 200 miles
Oct '97: 300 miles
Nov '97: 400 miles
Dec '97: 500 miles
Jan '98: 600 miles
Fleet Testing Activities

Average Charge Load Profile
Max energy used in 15 minute period = 1.41 kWh
Total quarterly energy used = 7,343 kWh
18 Vehicle profile
Accelerated Reliability Testing

- Chrysler EPIC (lead acid) 4,000+ miles
- Chevrolet S-10 - several vehicles, 12,000+ miles per vehicle
- Toyota RAV4 and Ford Ranger now entering testing
- KWh, mileage, and maintenance requirements collected
- Topical reports
Infrastructure Development

- Infrastructure Working Council
  - Health and Safety
  - Load Management, Distribution, and Power Quality
  - Data Interface
  - Bus/Non Road
  - Connector & Connecting Stations
    - Defining Level 1, 2, and 3 charging standards
    - Developing connector hardware
Charging Connectors

- **Conductive** - direct wire-to-wire “traditional” connection. Both offboard and onboard chargers.
  - Chrysler, Ford, Honda, Toyota
- **Inductive** - transfer power by magnetic coupling between the windings of two separate coils, one in the paddle and one in the vehicle receptor. Offboard charger.
  - General Motors, Nissan
Chargers - Level of Power Classification

• **Level 1** - Common household type of circuit, rated to 120 volts/AC and rated to 15 amps, standard household 3-prong connection, portable equipment, often results in low miles/AC kWh efficiencies

• **Level 2** - Permanently wired EVSE used specially for electric vehicle charging, rated up to 240 volts/AC, up to 60 amps, and up to 14.4 KW

• **Level 3** - Permanently wired EVSE used specially for electric vehicle charging, rated greater than 14.4 KW
Chargers - Fast Charging

- Fast chargers are rated as Level 3 chargers. However, not all Level 3 chargers are considered as fast chargers. This depends on the size of the battery pack to be charged and how much time is required to charge the battery pack. A charger generally can be considered a fast charger if it is capable of charging an average electric vehicle battery pack in about 20 to 30 minutes or less.
Summary

• Leaving vehicles charging over weekends/night results in low miles/AC kWh efficiencies
• Early vehicles often failed to meet performance goals
• Average annual performance results are improving
• New vehicles are OEM manufactured and include warranties
• Performance test results suggests that vehicle quality is significantly increasing as OEMs provide vehicles
Summary (cont’d)

- **Vehicles in fleet and reliability testing**
  - *Chevrolet S-10s (Lead acid)*
  - *RAV4s (NiMH)*
  - *Ford Rangers (Lead acid)*
  - *Chrysler EPIC (Lead acid)*

- **Vehicles in baseline performance testing (1998)**
  - *Toyota RAV4 (NiMH)*
  - *3 OEM vehicles with advanced (NiMH) battery packs*
Field Operations Program - Web Homepage

- Operations, performance, and maintenance results disseminated through formal reports and the World-Wide-Web

http://ev.inel.gov/sop/