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Fleet Testing - (Task 4)
Final Report

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Electric Transportation Applications

in conjunction with

APS
Commitment. Innovation. Energy.

PEPCO
Electric Vehicles
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1. INTRODUCTION

In 1996 the U.S. Department of Energy (DOE) established its Field Operations Program with the purpose of evaluating production electric vehicles for use in federal fleets. To implement the Field Operations Program, DOE selected two Qualified Vehicle Testers (QVT's) through competitive bids. One of the QVT's selected is the Southern California Edison Company. The other QVT selected is a consortium of Electric Transportation Applications (ETA), Arizona Public Service (APS), Salt River Project (SRP) and Potomac Electric Power Company(PEPCO).

Task 4 of the Field Operations Program is designed to evaluate production vehicles in an actual fleet environment. Driving is done on public roads in a random manner based on the fleet mission. Data is collected and reported through the DOE.

Vehicles were driven in the fleets of Potomac Electric Power Company (PEPCO) in Washington D.C., Arizona Public Service Company (APS) in Phoenix, AZ, Salt River Project in Phoenix, AZ, and Electric Transportation Applications (ETA) in Phoenix, AZ. This report summarizes Task 4 fleet test results of vehicles as shown in Table 1.

TABLE 1: Task 4 Test Vehicles and Fleets

Vehicle Type	Arizona Public Service Fleet	Potomac Electric Power Fleet	Salt River Project Fleet
Chevrolet S-10	2	3	-
Ford Ranger	2	17	2
Toyota RAV 4	-	10	-

Two of the Potomac Electric Power Company (PEPCO) Ford Rangers (#337 & #338) were operated in the ETA fleet after completing Accelerated Reliability Testing. Two of the Chevrolet S-10 vehicles (#36009 & #39011) experienced winter driving range below that acceptable for any mission in the PEPCO fleet. As a result, these vehicles were moved to Arizona for fleet testing. In the ETA fleet, the vehicles were successfully operated more carefully controlled missions.. One Toyota RAV 4 vehicle (#808t) was deleted from the test as it was located at a remote location making data collection impossible.

2. TEST PROTOCOL

In Task 1 of Cooperative Agreement DE-FC07-96ID13475, procedures were developed to govern the conduct of the Field Operations Program. Specifically, "Fleet Testing Procedures" were issued by QVT Southern California Edison Company in October, 1997. These procedures define the specific requirements for operation, maintenance and ownership of fleet electric vehicles. Input to the test procedures was provided by the Idaho National Engineering and Environmental Laboratory (INEEL) and by Electric Transportation Applications.

3. TEST OVERVIEW

Vehicles were introduced into their home fleets on dates as shown in Table 2. Vehicles were equipped with meters to monitor and record charging energy use as shown in Table 3. Installation instructions used for meter installation in the Toyota RAV 4 vehicles are contained in Appendix 10. These meters were read monthly along with the vehicle odometer. Vehicles were operated through the dates shown in Table 2, accumulating a total of 176,418 miles. As shown in Table 3, the vehicles consumed a total of 95,056 kWh during their operation.

TABLE 2: Vehicle Test Dates and Test Mileage

Participant	Vehicle Number	Vehicle Type	Vehicle ID Number	Meter Number	Start Date	Start Miles	End Date	End Miles	Miles Driven
APS	08181	Chev S10	1gcde14h7v8200469	01 970 839	Dec-97	899	Nov-98	6181	5282
APS	08182	Chev S10	1gcde14hov8200412	01 619 238	Dec-97	2179	Feb-99	7365	5186
Pepco/ETA	36009	Chev S10	1gcde14hxv8198247	old 01 923 890 1/99 01 970 836 1/99(H) 01 970 842	Jan-98	209	Mar-99	7358	7149
Pepco	36010	Chev S10	1gcde14h6v8198133	01 923 892	Jan-98	1288	Sep-99	2576	1288
Pepco/ETA	36011	Chev S10	1gcde14h8v8197503	01 923 891 1/99 01 970 834	Jan-98	498	Mar-99	6393	5895
APS	8210	Ford Ranger	1ftzr1076wta43622	02 161 901	Jul-98	652	Sep-99	4812	4160
APS	8211	Ford Ranger	1ftzr1078wta43623	01 978 164	Jul-98	1616	Aug-99	12762	11146
SRP	1541	Ford Ranger	1ftzr1074wta41996	02 161 882	Jul-98	895	Jul-99	5610	4715
SRP	1542	Ford Ranger	1ftzr1079wta47518	02 161 899	Jul-98	600	Sep-99	12948	12348
Pepco	806f	Ford Ranger	1ftzr1078wta81031	02 161 898	Nov-98	345	Sep-99	3779	3434
Pepco	808f	Ford Ranger	1ftzr1079wta83287	02 161 900	Nov-98	35	Sep-99	1792	1757
Pepco	809f	Ford Ranger	1ftzr1074wta84671	02 161 888	Nov-98	70	Oct-99	3576	3506
Pepco	810f	Ford Ranger	1ftzr107xwta81032	02 161 890	Nov-98	224	Sep-99	1941	1717
Pepco	811f	Ford Ranger	1ftzr1078wta81033	02 161 894	Nov-98	378	Sep-99	3079	2701
Pepco	812f	Ford Ranger	1ftzr107xwta81029	02 161 895	Oct-98	543	Sep-99	3214	2671
Pepco	813f	Ford Ranger	1ftzr1070wta84490	02 161 891	Nov-98	35	Sep-99	1441	1406
Pepco	814f	Ford Ranger	1ftzr1076wta81030	02 161 898	Nov-98	326	Jul-99	3363	3037
Pepco	815f	Ford Ranger	1ftzr1074wta84492	02 161 883	Oct-98	35	Oct-99	3604	3569
Pepco	816f	Ford Ranger	1ftzr1072wta84491	02 161 887	Oct-98	250	Sep-99	2038	1788
Pepco	817f	Ford Ranger	1ftzr1073wta81034	02 161 892	Oct-98	133	Oct-99	5380	5247
Pepco	**801t**	Toy RAV 4	jt3gs10v6wooo1225	02 161 893	Oct-98	6123	Sep-99	15943	9820
Pepco	**802t**	Toy RAV 4	jt3gs10v0wooo1270	02 259 711	Feb-99	2920	Aug-99	6368	3448
Pepco	**803t**	Toy RAV 4	jt3gs10v2wooo1271	01 970 837	Feb-99	8258	Jul-99	12850	4592
Pepco	**804t**	Toy RAV 4	jt3gs10v7wooo1301	02 143 037	Feb-99	5265	Sep-99	9127	3862
Pepco	**805t**	Toy RAV 4	jt3gs10v5wooo1300	02 161 896	Feb-99	8091	Sep-99	15151	7060
Pepco	**806t**	Toy RAV 4	jt3gs10v6wooo1317	02 161 885	Mar-99	2983	Sep-99	7702	4719
Pepco	**807t**	Toy RAV 4	jt3gs10v6wooo1318	02 161 897	Feb-99	2024	Sep-99	7011	4987
Pepco	**808t**	Toy RAV 4	jt3gs10v0w0001429	01 970 835	Jun-99	4286		4286	0
Pepco	**809t**	Toy RAV 4	jt3gs10v5wooo1457	02 161 886	Feb-99	904	Sep-99	4555	3651
Pepco	**810t**	Toy RAV 4	jt3gs10v5wooo1460	02 161 902	Feb-99	2524	Sep-99	6678	4154
Pepco/ETA	338	Ford Ranger	1ftzr1070wta84859	old 01 978 166 9/99 02 161 882	Feb-99	1670	May-00	23217	21547
Pepco/ETA	337	Ford Ranger	1ftzr107xwta84867	02 161 889	Apr-99	3043	May-00	23619	20576
Total Miles									176418

TABLE 3: Vehicle Energy Use

Participant	Vehicle Number	Vehicle Type	Vehicle ID Number	Meter Number	Total Energy	Total Charges	Ave Energy/Charge
APS (TD)	08181	Chev S10	1gcde14h7v8200469	01 970 839	3394	245	13.85
APS (DV)	08182	Chev S10	1gcde14hov8200412	01 619 238	3394	233	14.57
Pepco/ETA-259	36009	Chev S10	1gcde14hxv8198247	old 01 923 890 1/99 01 970 836 1/99(H) 01 970 842	3105	235	13.21
Pepco	36010	Chev S10	1gcde14h6v8198133	01 923 892	1190	271	4.39
Pepco/ETA-258	36011	Chev S10		01 923 891 1/99 01 970 834	3253	227	14.33
APS	8210	Ford Ranger	1ftzr1076wta43622	02 161 901	3083	215	14.34
APS	8211	Ford Ranger	1ftzr1078wta43623	01 978 164	6522	358	18.22
SRP	1541	Ford Ranger	1ftzr1074wta41996	02 161 882	2950	247	11.94
SRP	1542	Ford Ranger	1ftzr1079wta47518	02 161 899	5910	485	12.19
Pepco	806f	Ford Ranger	1ftzr1078wta81031	02 161 898	1981	230	8.61
Pepco	808f	Ford Ranger	1ftzr1079wta83287	02 161 900	1397	199	7.02
Pepco	809f	Ford Ranger	1ftzr1074wta84671	02 161 888	2773	236	11.75
Pepco	810f	Ford Ranger	1ftzr107xwta81032	02 161 890	1640	197	8.32
Pepco	811f	Ford Ranger	1ftzr1078wta81033	02 161 894	2785	219	12.72
Pepco	812f	Ford Ranger	1ftzr107xwta81029	02 161 895	2733	150	18.22
Pepco	813f	Ford Ranger	1ftzr1070wta84490	02 161 891	1302	110	11.84
Pepco	814f	Ford Ranger	1ftzr1076wta81030	02 161 898	2138	218	9.81
Pepco	815f	Ford Ranger	1ftzr1074wta84492	02 161 883	2917	173	16.86
Pepco	816f	Ford Ranger	1ftzr1072wta84491	02 161 887	1889	180	10.49
Pepco	817f	Ford Ranger	1ftzr1073wta81034	02 161 892	4278	302	14.17
Pepco	**801t**	Toy RAV 4	jt3gs10v6wooo1225	02 161 893	3702	274	13.51
Pepco	**802t**	Toy RAV 4	jt3gs10v0wooo1270	02 259 711	1361	75	18.15
Pepco	**803t**	Toy RAV 4	jt3gs10v2wooo1271	01 970 837	2257	111	20.33
Pepco	**804t**	Toy RAV 4	jt3gs10v7wooo1301	02 143 037	1780	95	18.74
Pepco	**805t**	Toy RAV 4	jt3gs10v5wooo1300	02 161 896	3098	209	14.82
Pepco	**806t**	Toy RAV 4	jt3gs10v6wooo1317	02 161 885	1895	120	15.79
Pepco	**807t**	Toy RAV 4	jt3gs10v6wooo1318	02 161 897	2106	185	11.38
Pepco	**808t**	Toy RAV 4	jt3gs10v0w0001429	01 970 835	0	0	0.00
Pepco	**809t**	Toy RAV 4	jt3gs10v5wooo1457	02 161 886	1748	116	15.07
Pepco	**810t**	Toy RAV 4	jt3gs10v5wooo1460	02 161 902	1960	86	22.79
Pepco/ETA	338	Ford Ranger	1ftzr1070wta84859	old 01 978 166 9/99 02 161 882	8556	422	20.27
Pepco/ETA	337	Ford Ranger	1ftzr107xwta84867	02 161 889	7959	501	15.89
Total Miles					95056	6924	13.73

4. OPERATING RESULTS

Vehicles were operated in a variety of missions and fleets. The average monthly mileage for each vehicle, by vehicle type, is presented in Appendix 1. The average number of charges per month are presented in Appendix 2 for each vehicle type. The average monthly miles driven on each charge is presented in Appendix 3 for each vehicle type. The average energy used for each battery charge is presented in Appendix 4 for each vehicle type. Detailed monthly data for each Chevrolet S-10 are presented in Appendix 5, for each Ford Ranger in Appendix 6 and for each Toyota RAV 4 in Appendix 7.

4.1 Range

Range was a factor in finding suitable fleet missions for vehicles. From baseline test data, the range of the Toyota RAV 4 (using a nickel metal hydride battery) was significantly greater than either the Ranger or S-10 (using a lead acid battery). These vehicles were deployed randomly in the PEPCO fleet along with Ford Ranger vehicles. From data contained in Tables 2, 3 and 4, the average monthly use for the Toyota RAV 4 vehicles (as shown in Table 5) was 70 mi/mo, whereas the average monthly use for the Ford Ranger vehicles was only 30 mi/mo. The greater use of the Toyota RAV 4 vehicles is primarily a result of the greater available range. The greater range allowed the vehicles to be used in a wider range of missions. The greater range also allowed for more flexible vehicle use within the assigned mission. These factors combine to result in more extensive use of the Toyota RAV 4 vehicles in the PEPCO fleet.

Contrasting with the PEPCO fleet experience are results with the S-10 vehicles in the APS and ETA fleets. Chevrolet S-10 vehicles #36009, #36011, #08181 and #08182 were placed in carefully selected missions that matched the available range of the vehicle. As a result, the vehicle were used an average of 610 mi/mo. These results demonstrate that careful mission selection can overcome shortcomings of reduced range.

From the data in Tables 3, 4 and 5, it can be seen that the greater range of the Toyota RAV 4 also allowed its number of miles driven per charge to be greater. In the PEPCO fleet the Toyota RAV 4 vehicles averaged 36 miles/charge (as shown in Table 5), while the Ford Ranger vehicles averaged only18 miles/charge.

4.2 Energy Efficiency

From the charge data presented in Tables 4 and 5, it can be observed that the energy efficiency of each vehicle was highly dependent on the intensity of use for that vehicle. Vehicles used frequently and for long distances tend to offset the hotel loads when the vehicle is connected to the charger, resulting in a better overall energy efficiency. For example, the Chevrolet S-10 vehicles # 36009 and #36011 driven intensely in the ETA fleet achieved an efficiency of 0.487 kWh/mi, while Chevrolet S-10 vehicle #36010, driven infrequently in the PEPCO fleet required 0.924 kWh/mi. Similarly with the Ford Ranger, vehicles #337 and 338, driven in the ETA fleet, achieved an efficiency of 0.392 kWh/mi, while Ford Ranger vehicles driven in the PEPCO fleet averaged 0.701 kWh/mi. It is further noted that Ford Ranger vehicles #337 and #338 achieved the highest energy efficiency of all vehicles tested, while Ford Ranger vehicle #816f operated in the PEPCO fleet recorded the lowest energy efficiency of 1.056 kWh/mi.

With the energy efficiencies of these fleet vehicles, and an energy cost of 7¢/kWh, a fleet wide fuel cost of 3.77 ¢/mi can be anticipated. The lowest fuel cost was 2.74 ¢/mi and the highest fuel cost was 7.39 ¢/mi.

TABLE 4: Vehicle Energy Efficiency

Participant	Vehicle Number	Vehicle Type	Months Driven	Miles Driven	Energy (kWh)	Average Miles/Mo	Efficiency (kWh/mile)
APS (TD)	08181	Chev S10	12	5282	3394	440	0.643
APS (DV)	08182	Chev S10	14	5186	3394	370	0.654
Pepco/ETA-25	36009	Chev S10	8	7149	3105	894	0.434
Pepco	36010	Chev S10	21	1288	1190	61	0.924
Pepco/ETA-25	36011	Chev S10	8	5895	3253	737	0.552
APS	8210	Ford Ranger	15	4160	3083	277	0.741
APS	8211	Ford Ranger	14	11146	6522	796	0.585
SRP	1541	Ford Ranger	12	4715	2950	393	0.626
SRP	1542	Ford Ranger	14	12348	5910	882	0.479
Pepco	806f	Ford Ranger	11	3434	1981	312	0.577
Pepco	808f	Ford Ranger	11	1757	1397	160	0.795
Pepco	809f	Ford Ranger	11	3506	2773	319	0.791
Pepco	810f	Ford Ranger	10	1717	1640	172	0.955
Pepco	811f	Ford Ranger	10	2701	2785	270	1.031
Pepco	812f	Ford Ranger	10	2671	2733	267	1.023
Pepco	813f	Ford Ranger	11	1406	1302	128	0.926
Pepco	814f	Ford Ranger	9	3037	2138	337	0.704
Pepco	815f	Ford Ranger	13	3569	2917	275	0.817
Pepco	816f	Ford Ranger	12	1788	1889	149	1.056
Pepco	817f	Ford Ranger	13	5247	4278	404	0.815
Pepco	**801t**	Toy RAV 4	12	9820	3702	818	0.377
Pepco	**802t**	Toy RAV 4	7	3448	1361	493	0.395
Pepco	**803t**	Toy RAV 4	6	4592	2257	765	0.492
Pepco	**804t**	Toy RAV 4	8	3862	1780	483	0.461
Pepco	**805t**	Toy RAV 4	8	7060	3098	883	0.439
Pepco	**806t**	Toy RAV 4	8	4719	1895	590	0.402
Pepco	**807t**	Toy RAV 4	8	4987	2106	623	0.422
Pepco	**808t**	Toy RAV 4	0	0	0	0	0.000
Pepco	**809t**	Toy RAV 4	8	3651	1748	456	0.479
Pepco	**810t**	Toy RAV 4	8	4154	1960	519	0.472
Pepco/ETA	338	Ford Ranger	16	21547	8556	1347	0.397
Pepco/ETA	337	Ford Ranger	14	20576	7959	1470	0.387
Total			342	176418	95056	516	0.539

TABLE 5; Efficiency Summaries By Vehicle Type

Summary Factor	Overall	Monthly
All Vehicles		
Average miles/vehicle	5691	17
Average kWh/mile	0.539	
Average miles/charge	25	
S-10		
Average miles/vehicle	4960	79
Average kWh/mile	0.578	
Average miles/charge	20	
S-10 (less 36009 & 36011)		
Average miles/vehicle	3919	83
Average kWh/mile	0.969	
Average miles/charge	16	
Ranger		
Average miles/vehicle	6196	30
Average kWh/mile	0.577	
Average miles/charge	24	
Ranger (less 337 & 338)		
Average miles/vehicle	4213	24
Average kWh/mile	0.701	
Average miles/charge	18	
RAV 4		
Average miles/vehicle	5144	70
Average kWh/mile	0.430	
Average miles/charge	36	

5. Maintenance Requirements

Chevrolet S-10

Maintenance requirements for the Chevrolet S-10 vehicles are presented in Appendix 8. The vehicles experienced significant time out of service due to battery pack problems (mostly low range). Further time out of service was required to implement upgrades to the vehicles as part of Chevrolet's Customer Satisfaction Program. The changes included a switch from Delco batteries to Panasonic batteries and software upgrades to extend range. the switch to Panasonic batteries significantly increased range and reduced battery pack problems.

The Chevrolet S-10 vehicles experience numerous recalls as detailed in Appendix 8. After completion of the test program for the Chevrolet S-10 vehicles, a recall was implemented for replacement of charge ports. Unfortunately, Chevrolet did not have the new charge port available at the time of recall, resulting in vehicles being out of service for over six months. After return of the vehicles with new charge ports, both range and reliability problems were experienced with the vehicles and remain unresolved as of the writing of this report.

Ford Ranger

Maintenance requirements for Ford Ranger vehicles are presented in Appendix 9. Significant time out of service was required to diagnose battery problems and to replace batteries. Multiple packs of Delco and East Penn batteries were replaced in vehicles. Several vehicles were out of service for extended periods due to lack of available replacement batteries.

Battery charger failures occurred in several vehicles along with trans-axle failures and battery control module failures. Software was changed to eliminate charging failures and premature power cutback. This required several iteration of software and again resulted in extended out of service periods. The software changes eventually resolved issues with premature power cutback and failure to charge. However, battery pack failures continued after completion of the test program.

Toyota RAV 4

Maintenance requirements for Toyota RAV 4 vehicles are presented in Appendix 10. No significant maintenance was required for these vehicles.

6. CONCLUSIONS

The following conclusions have been drawn from operation of Chevrolet S-10, Ford Range and Toyota RAV 4 vehicles in fleet service.

- Mission selection is the most important aspect to successfully operating electric vehicles.
- Greater range makes mission selection easier and promotes greater vehicle use.
- Applications in areas with cold winters should be avoided when deploying lead acid vehicles.
- While the Chevrolet S-10 vehicles had problems related to the Delco batteries, the switch to Panasonic batteries stabilized vehicle performance and significantly reduced battery maintenance problems.
- Energy efficiency of fleet electric vehicles is strongly dependent on the intensity of use.

- Delco batteries in the Chevrolet S-10 and Ford Ranger vehicles were the source of significant down time for these vehicles.
- The Ford Ranger vehicles experienced significant software problems which appear to have been resolved as of the end of testing.
- The Chevrolet S-10 charge port recall, while potentially having a devastating effect on any fleet dependent on the reliable operation of its electric vehicles, has been resolved and recurrence of a similar event is unlikely.