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Electric and Hybrid Vehicle Testing

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ABSTRACT

Today's advanced-technology vehicles (ATVs) feature hybrid-electric engines, regenerative braking, advanced electric drive motors and batteries, and eventually fuel cell engines. There is considerable environmental and regulatory pressure on fleets to adopt these vehicles, resulting in high-risk purchase decisions on vehicles that do not have documented performance histories. The Department of Energy's Field Operations Program tests ATVs and disseminates the results to provide accurate and unbiased information on vehicle performance (http://ev.inel.gov/fop). Enhancing the fleet manager's knowledge base increases the likelihood that ATVs will be successfully and optimally placed into fleet missions.

The ATVs are tested using one or more methods - Baseline Performance, Accelerated Reliability, and Fleet Testing. The Program and its 10 testing partners have tested over three-dozen electric and hybrid electric vehicle models, accumulating over 4 million miles of testing experience. The Program has initiated the additional testing of neighborhood, urban, and hybrid electric vehicles and hydrogen-powered vehicles.

INTRODUCTION

The Field Operations Program provides fleet managers and other potential advanced technology vehicle (ATV) users with accurate and unbiased information on vehicle performance. This allows the purchaser to make informed decisions about acquiring and operating ATVs. Vehicle information is obtained by testing ATVs in conjunction with industry partners and disseminating the testing results. The ATVs are tested using three methods - Baseline Performance Testing, Accelerated Reliability Testing, and Fleet Testing. The testing results are disseminated via Program's Website in the form of vehicle fact sheets, summary reports, and survey results (http://ev.inel.gov/fop). Additional information on the Website includes testing specifications and procedures, as well as general information about ATVs, such as how they work and their histories.

The Field Operations Program signed a 5-year testing agreement in 1999 with the following group of Qualified Vehicle Testers (QVTs):

- Electric Transportation Applications (lead partner)
- American Red Cross.
- Arizona Public Service
- Bank One of Arizona
- Potomac Electric Power Company
- Salt River Project
- Southern California Edison (SCE)
- Southwest Airlines
- Virginia Power.

DOE's Office of Transportation Technologies (under the Office of Energy Efficiency and Renewable Energy) manages the Field Operations Program. The Program works with commercial and government fleets, and industry groups to support the testing and deployment of ATVs in today's evolving transportation market. Test procedures are developed jointly with industry stakeholders to measure real-world performance. The Program's activities comprise four areas:

- Light-Duty Electric Vehicles (EVs)
- Light-Duty Hybrid Electric (HEVs) and Fuel Cell Vehicles
- Light-Duty Alternative Fuel Vehicles
- Medium- and Heavy-Duty Advanced Technology Vehicles.

The Idaho National Engineering and Environmental Laboratory manages the first two program areas. These testing activities and the results are discussed below.

LIGHT-DUTY ELECTRIC VEHICLE TESTING

The Field Operations Program, in conjunction with its QVT partners, uses several testing methods to validate light-duty electric vehicle (EV) performance. The testing results are discussed by testing method.

EV BASELINE PERFORMANCE TESTING METHODS - The Field Operations Program has traditionally used two Baseline Performance testing methods, EVAmerica and Pomona Loop testing.

EVAmerica Testing Results - The EVAmerica testing is conducted by Electric Transportation Applications on closed tracks and dynamometers and the results are highly repeatable.[1] The test parameters include acceleration, three types of range tests, gradeability, handling, charging, maximum speed, braking, and minimum safety standards that the vehicles must meet.

The Program and its testing partners have conducted EVAmerica Baseline Performance testing on 21 vehicle models since 1994. Test vehicles include the Chevrolet S-10, Chrysler EPIC, Ford Ranger, General Motors EV1, and Toyota RAV4. These vehicles were equipped with nickel-metal-hydride (NiMH) battery packs. The test results provide a good characterization of vehicle performance. The testing has documented range increases of up to 150% when comparing the 1998 test vehicles to the 1994 test vehicles (Figure 1). The 1998 results include a drive-cycle[2] range of 225 kilometers (km) for the General Motors EV1 (Figure 2). (For all classes of EVs, the basis for drive cycle dynamometer testing is SAE J1632).

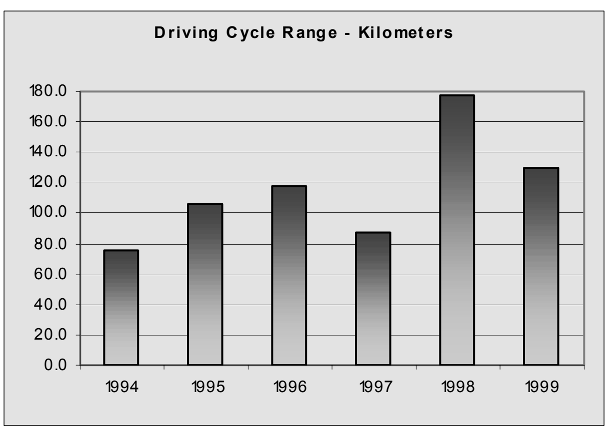

Figure 1. EVAmerica drive cycle (SAE J1634) average (mean) annual testing results.

All three of the range tests (Driving Cycle, Constant Speeds at 72 and 97 km/h) exhibit similar trends – an overall continuing improvement in EV performance. The 1997 decreases in range can be attributed to the type of vehicles tested that year. Both of the 1997 test vehicles were pickups, with lead-acid batteries and high payloads, intended for use in utility types of fleet applications.

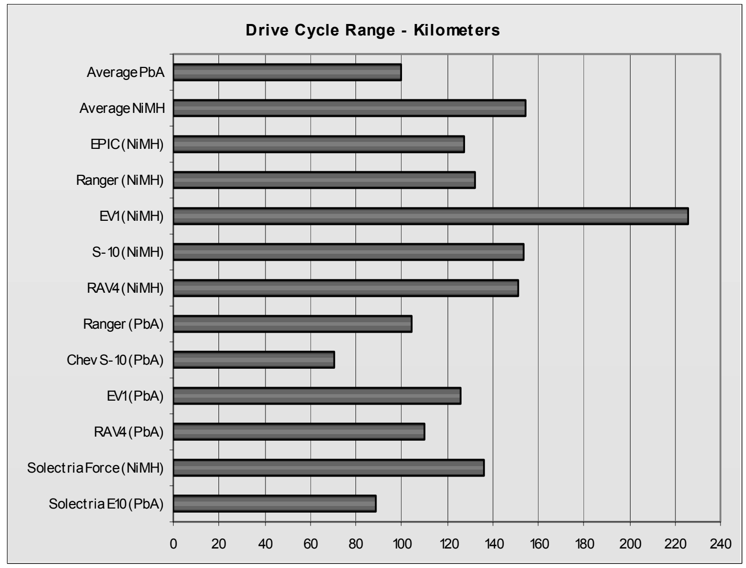

Figure 2. EVAmerica individual testing results for SAE J1634 drive cycle tests. (Not all vehicles shown).

The 1998 results were driven by the nickel-metal-hydride (NiMH) equipped EV1 from General Motors. The EV1 has the highest test results to date, going 356 km in the 72-km/h constant speed test and 259 km in the 97-km/h constant speed test. The two pickups tested during 1999 were also equipped with NiMH batteries and they averaged 143 km for the drive-cycle test, 198 km in the 72 km/h constant speed test, and 130 km in the 97-km/h constant speed test. The 1999 results did not increase compared to the 1998 tests; vehicles other than the EV1 with NiMH batteries could not replicate the 1998 results.

The average annual acceleration tests (performed at 50% state-of-charge) show an overall increase in vehicle performance (Figure 3). The average time to accelerate from 0 to 80 km/h has decreased from 24 seconds recorded during 1994 to 12 seconds for the 1999 test vehicles. The lead-acid EV1, tested during 1996, had a 0 to 80-km/h acceleration time of 6.7 seconds at a 50% state-of-charge. At 100% state-of-charge, the EV1 accelerated from 0 to 80 km/h in 6.3 seconds.

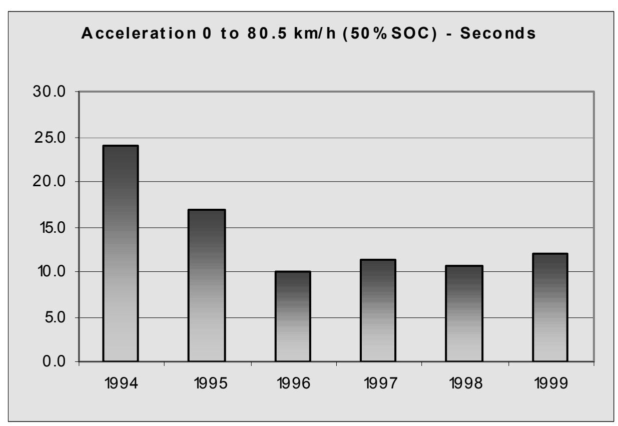

Figure 3. Mean EVAmerica acceleration testing results.

The single most important factor for increasing vehicle range is the amount of kWh stored in a vehicle's battery. Increasing the kWh can be accomplished by increasing the number of batteries onboard or using a higher-capacity battery technology. NiMH batteries were used on seven vehicles to increase range. The higher specific energy of NiMH batteries is evident when looking at Figure 4. During 1995, two out of the three test vehicles were equipped with NiMH batteries, as were all five vehicles tested during 1998 and 1999. During 1994, 1996, and 1997, lead-acid batteries were used in 12 of the 13 vehicles tested (one 1994 vehicle used nickel-iron batteries). The watt-hours per kilogram of the two NiMH battery packs used in the 1999 test vehicles is 130% greater than the lead-acid battery packs in the two 1997 test vehicles.

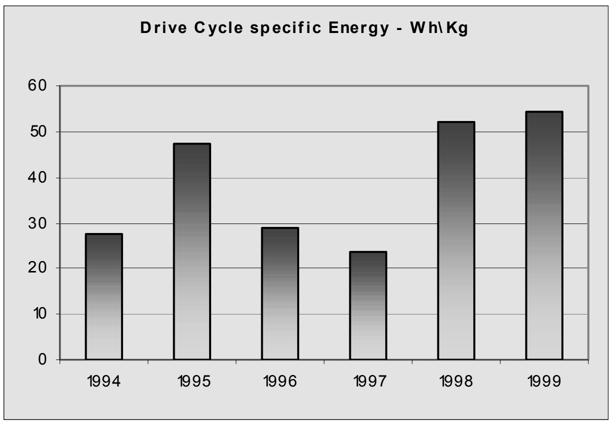

Figure 4. Average (mean) specific energy (watt-hours per kilogram) of the EVAmerica test vehicles.

Pomona Loop Testing Results - The Field Operations Program also supports the Urban and Highway Pomona Loop Baseline Performance testing conducted in Southern California. In addition to confirming EVAmerica test results, the Pomona Loop testing sometimes provides access to vehicles that are only available in California. In contrast to the "closed track" nature of the EVAmerica Baseline Performance tests, the Pomona Loop tests are performed on Southern California urban streets and area freeways. Some fleet managers prefer the nature of the Pomona Loop on-road testing rather than the dynamometer evaluation of the EVAmerica methodology.

The Urban Loop test is 31.1 km long and its elevation varies from 274 to 457 meters above sea level and it includes 50 stop signs and traffic lights. The Freeway Loop is 59.9 km long and its elevation varies from 213 to 351 meters above sea level.[3] The loops are fair representations of "typical" Southern California driving patterns. The tested vehicles are driven on each loop in four scenarios (Table 1). Each trip is driven with either the minimum or maximum payloads, and either with or without auxiliary power loads (such as air conditioning).

Table 1. Definition of the Urban and Freeway Pomona Loop testing scenarios. (Min – minimum, Max – Maximum, A/C – air conditioning)

Urban Loops	
UR1	Minimum payload, no auxiliary loads
UR2	Min payload, A/C high, headlights low, radio on
UR3	Maximum payload, no auxiliary loads
UR4	Max payload, A/C high, headlights low, radio on
Freeway Loops	
FW1	Minimum payload, no auxiliary loads
FW2	Min payload, A/C high, headlights low, radio on
FW3	Maximum payload, no auxiliary loads
FW4	Max payload, A/C high, headlights low, radio on

The Pomona Loop testing results displayed in Figure 5 include the minimum and maximum testing results for all eight Urban and Freeway tests. The graph ranges include the four testing scenarios for each Loop.

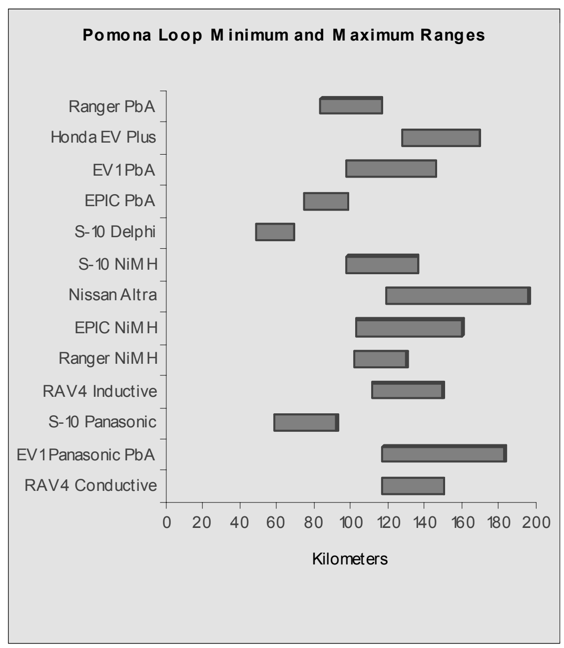

Figure 5. Range test results for the 13 vehicles Pomona Loop tested. Includes all eight driving tests conducted on the Urban and Freeway Loops.

Generally, the Pomona Loop testing results show lower ranges than the Baseline Performance test results. The Urban Loop test includes over 50 stop signs and traffic lights, while the EVAmerica Constant Speed tests do not include stops and reacceleration. The Freeway Loop can include many stops, depending on traffic conditions. The lowest range results for the Baseline Performance test vehicles occurs during the EVAmerica 97-km/h Constant Speed testing. The highest range results for the Baseline Performance test vehicles occurs during the EVAmerica 72-km/h Constant Speed testing.

EV ACCELERATED RELIABILITY TESTING[4] - The Accelerated Reliability testing is similar to the Fleet Operations testing with the important difference that the vehicles are operated in an accelerated mileage mode. That is, the QVTs operate each vehicle up to 40,000 km per year (48,000 km for vehicles equipped with advanced batteries). The goal is to obtain several years of traditional fleet-use operations data within a single year. The information collected includes energy use, maintenance requirements, and the effects of accumulated driving on vehicle performance and range. Energy use is collected with kWh meters mounted onboard the vehicles conductively charged or mounted on dedicated chargers for vehicles that are inductively charged. Several other parameters are calculated, including km per kWh and charging profiles, not only for entire fleets, but also for single model types and individual vehicles. Toyota RAV4s and Chevrolet S-10s were Accelerated Reliability tested. As an example of the Accelerated Reliability testing activities, some of the RAV4 testing results are discussed below.

Three RAV4s were range tested when they were delivered to SCE and later during Accelerated Reliability testing. Testing was conducted on the Urban Loop with minimum payload (driver only) and no auxiliary loads. Most of the tests were conducted with all three vehicles following each other to minimize the effects of varying ambient conditions, traffic, and driving style. The ranges listed in Table 2 are the mileage readings when reaching the "stop condition" (flashing charge light). As seen in the Table, the range for all three vehicles varied from 141 km to 173 km. The reasons for the variation in range are not completely clear. However, the most obvious possibilities are declining battery capacity, the effect of ambient temperature on battery capacity, and the so-called "memory effect." Although the range appeared to vary directly with ambient temperature (Figure 6), the data was not clear enough to make a definite conclusion.

Table 2. Range testing results for the three RAV4s.

Odometer (kilometers)	Average Temperature (C°)	Range (Kilometers)
Vehicle 1		
13	29	155
9,226	30	164
13,592	17	142
25,338	26	159
32,277	24	147
	Average Range	153
Vehicle 2		
16	29	173
14,500	14	141
28,217	26	163
39,525	24	150
	Average Range	157
Vehicle 3		
27	29	168
15,578	15	142
18,440	26	147
30,977	26	159
41,268	24	155
	Average Range	154
	Overall Average Range	155

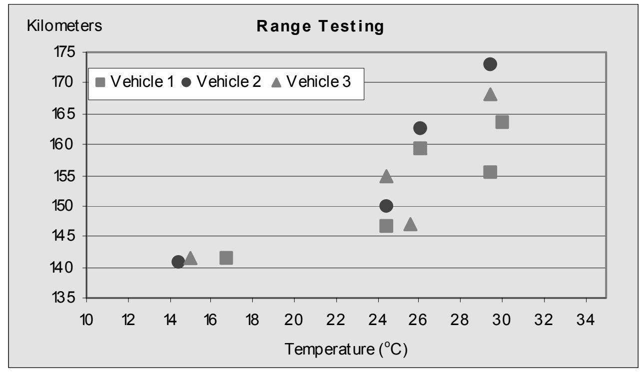

Figure 6. Range testing results of Toyota RAV4s at various temperatures.

EV FLEET TESTING - In this testing process, the QVTs collect data on EVs used in normal fleet operations within their respective commercial fleets. The data collected includes energy use, mileage, and maintenance requirements. While vehicles placed in Fleet testing do not normally accumulate vehicle data as quickly as during accelerated reliability testing, the Fleet testing is as "real world" as it gets. In addition to providing non-controlled testing data, it also acts as a reality check against Baseline Performance and Accelerated Reliability testing results. Fleet testing is dichotomous to laboratory testing, in that the test vehicles are exposed to variables that are often unanticipated. However, this is the reality of how drivers use the vehicles and the best measure of how well a vehicle performs.

Figure 7 highlights how fleet-testing results can differ from dynamometer and track testing. All three bars for each of the four vehicles measure km driven per kWh charged. (The charging efficiency was not measured for the Nissan Altra). As measured in km driven per kWh, the least efficient energy use occurred during fleet testing with the four vehicles averaging 2.7 km per kWh (Table 3). The average energy use for the four vehicles during the drive-cycle dynamometer testing (SAE J1634) was 5.4 km per kWh. The average EVAmerica charging efficiency results for the three vehicles was 3.5 km per kWh. The average fleet energy use results were 50% lower than the average drive cycle efficiency results and 23% lower than the EVAmerica charging efficiency results. Generally, hotel loads while on charge in fleet use contributes to lower energy efficiencies. These hotel loads can include heating and cooling vehicle battery packs and passenger cabins. Extended time left on charge, such as over weekends, will also lower energy efficiencies.

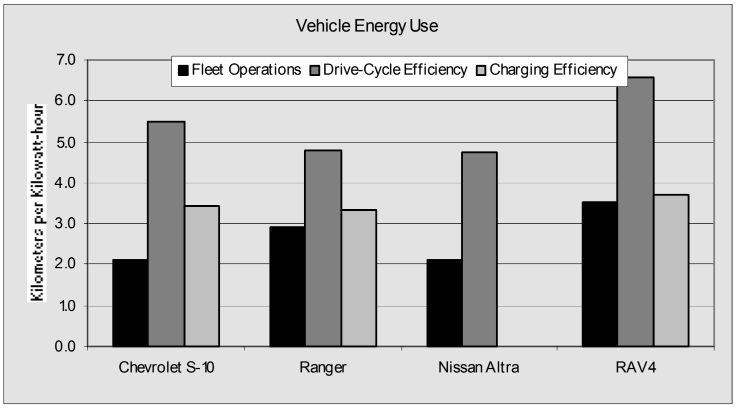

Figure 7. Energy efficiency based on kilometers traveled per kilowatt-hour of energy.

Table 3. Energy use (kilometers per kilowatt-hour) measured during Fleet, EVAmerica Drive Cycle (SAE J1634) and EVAmerica Charging Efficiency tests. The Nissan Altra drive cycle data is the average efficiency for the eight Pomona Loop tests. N/A - Not available.

Vehicle	Fleet Operations	Drive Cycle	Charging Efficiency
Chevrolet S-10	2.1	5.5	3.4
Ford Ranger	2.9	4.8	3.3
Nissan Altra	2.1	4.7	N/A
Toyota RAV4	3.5	6.6	3.7
Average	2.7	5.4	3.5

Fleet testing can also generate energy use information that cannot be collected during controlled testing. For instance, the average charge load profile for 18 Toyota RAV4s was plotted for 24 hours and averaged as 1-hour energy use periods (Figure 8). The highest average energy use occurs at 5 p.m. and the lowest at 7 a.m. The maximum energy used in any 15-minute period was 1.41 kWh and the total quarterly energy used for the 18 RAV4s was 7,343 kWh.

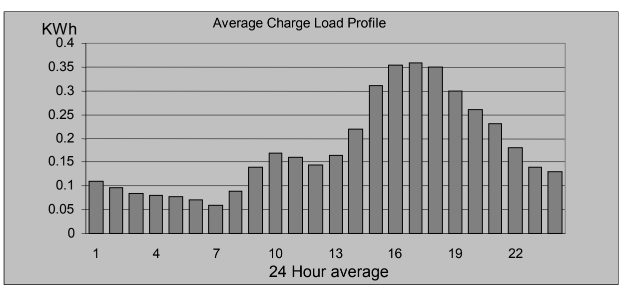

Figure 8. Average charge load profile for 18 Toyota RAV4s

NEIGHBORHOOD ELECTRIC VEHICLE TESTING

A neighborhood electric vehicle (NEV) is 4-wheeled, generally larger than a golf cart, but smaller than most light-duty passenger vehicles. NEVs are configured to carry two or four passengers (Figures 9–11), or two passengers with a pickup bed.

NEVs are defined by the United States National Highway Traffic Safety Administration as subject to Federal Motor Vehicle Safety Standard (FMVSS) No. 500 (49 CFR 571.500). Per FMVSS 500, NEVs have top speeds between 32 and 45 km/h and are defined as “Low Speed Vehicles.” While “Low Speed Vehicle” is technically the correct term, “NEV” has become the term used by industry and fleets to refer to passenger vehicles subject to FMVSS 500.

FMVSS 500 requires that NEVs be equipped with headlamps, stop lamps, turn signal lamps, tail lamps, reflex reflectors, parking brakes, rear view mirrors, windshields, seat belts, and vehicle identification numbers. About 30 states have passed legislation or regulations allowing NEVs to be licensed and driven on roads that generally are posted at 56 km/h or less.

Figure 9. NEV from Ford/Th!nk.

Figure 10. NEV from Global Electric Motor (GEM).

While NEVs were initially used in gated communities, they have been increasingly used by the general public for applications such as transporting kids to school, shopping, and general neighborhood trips. NEVs are very cost efficient, in terms of initial capital costs, fuel costs, and overall operating expenses.

Figure 11. NEV from Frazier Nash.

As part of its 2003 zero emissions mandates for full-size light-duty and sport utility vehicles, the California Air Resources Board (CARB) approved 4 credits for NEVs used in California during the years 2001 and 2002, with decreasing credits after 2002. Many expect that NEVs will be used by original equipment automotive manufacturers to meet at least part of their zero emission mandates by 2003.

In addition to the above uses, many federal, private, and public fleets are increasingly using NEVs at military bases, national parks, and commercial airports, and for local government activities.[5] NEVs are reducing petroleum use and simplifying fueling requirements by decreasing or eliminating the need for gasoline infrastructure. For federal fleets, NEVs can significantly decrease petroleum use, helping the federal fleets comply with Executive Order 13149 (Greening The Government Through Federal Fleet and Transportation Efficiency) which requires a 20% decrease in annual petroleum use by fiscal year 2005.

To better understand how fleets are using NEVs, and if and how the Field Operations Program should be testing NEVs, fifteen fleets were surveyed concerning their use of NEVs. The fifteen fleets operate a total of 348 NEVs in a variety of missions. The fleets service military, commercial, municipal, rental, and transportation organizations. The mean size of the fifteen NEV fleets is 23 NEVs and the median size is 10 NEVs. The NEV fleets range in size from 2 to 82 NEVs. Thirty percent of the 348 NEVs were purchased as replacement vehicles. Fifty-six percent of the NEVs are used only on private roads, 32% are used only on public roads, and 12% are used on both public and private roads. The fleets reported that 91% of the 348 NEVs did not have any problems; 4% of the NEVs have had their battery packs replaced. The fleets are charging 99% of their NEVs at 110 volts.

The NEVs' contribution to petroleum avoidance and cleaner air can be estimated based on the miles driven information provided by the fleets, and by assuming gasoline use and air emissions values. Gasoline and emissions data for a Honda Civic are used as the Civic has the best fuel efficiency for a gasoline-powered vehicle and has very clean emissions.[6] The 348 NEVs are being driven a total of about 1.9 million kilometers per year. This equates to an average of 5,200 km per NEV annually or 14 km per day. It is estimated that 110,515 liters of petroleum use is avoided annually by the 348 NEVs. This equates to 320 liters of petroleum use avoided per NEV, per year. Using the 348 NEVs avoids generating at least 352 kilograms of smog-forming emissions annually.

Because of the increasing use of NEVs, the CARB mandates providing for NEV credits, that all of the large companies manufacturing vehicles in the United States have made investments to build NEVs, and the contribution NEVs make to decreasing petroleum use and air emissions, the Program has initiated NEV testing.

The first step was to develop Baseline Performance test procedures based on the EVAmerica test procedures. These are being adapted with active input from NEV manufacturers. The EVAmerica Baseline Performance test procedures require vehicle performance capabilities that the NEVs are not capable of, nor are they designed for. For instance, NEVs are not capable of coast-down testing from 101 km/h as required for calibration of the drive cycle dynamometer testing. The NEV EVAmerica procedures in final form will likely include one or more drive range tests on closed tracks, but certainly not the 72- and 97-km/h constant speed testing used with the original EVAmerica tests. In addition, the performance goals will be significantly lower than EVAmerica goals.

The emerging NEV industry has many new entrants, and the testing activities will also document if the NEVs comply with the FMVSS No. 500 standards. The Field Operations Program will be NEV EVAmerica Baseline Performance testing up to fifteen NEV models, starting late 2001. In addition, the Program will also initiate NEV fleet testing starting late 2001; four fleets with 85 NEVs will participate.

URBAN ELECTRIC VEHICLE TESTING

Urban electric vehicles (UEVs) have been developed (Figures 12 and 13) for use in urban applications, with

Figure 12. Toyota e-com UEV.

top speeds of approximately 85 km/h. Similar to the NEVs, the UEVs are not capable of being tested with the EVAmerica test procedures for full-size EVs. The UEVs cannot attain 101 km/h for the coast-down tests, nor operate at the required 97 km/h for one of the constant speed tests.

Figure 13. UEV from Ford/Th!nk.

Some of the new Urban EVAmerica performance goals include acceleration times of 0 to 48 km/h within 8.5 seconds, a minimum top speed of 72 km/h within 1.6 km, and a minimum range of 48 km when tested to the Urban Drive Cycle. The newly developed Urban EVAmerica technical specifications[7] and test procedures[8] are available on the Field Operations Program Website.

The Program will initiate Urban EVAmerica Baseline Performance testing early in 2002. Five models of UEVs will likely be Urban EVAmerica Baseline Performance tested. In addition, fleet testing on three UEV models (100+ UEVs) will start during January 2002, and accelerated reliability testing will be started on at least one UEV model about the same time.

HYBRID ELECTRIC VEHICLE TESTING

Hybrid electric vehicles require new test procedures given their various operating scenarios. For instance, should HEVs be tested in pure electric modes, combined modes, or only in drive cycles when internal combustion engines provide energy and power? The Program is developing Hybrid EVAmerica testing procedures[9] that incorporate these and other operating scenarios while it performs initial Pomona Loop testing on the Honda Insight (Figure 14) and Toyota Prius (Figure 15). These initial tests will be used to refine the Hybrid EVAmerica testing procedures to incorporate the lessons learned.

Testing changes will include testing the HEV when it is operated in the “rechargeable energy storage system” (RESS) mode if it is capable of being driven in RESS mode only, so an HEV’s “pure electric” range can be measured. HEVs will also be tested in the manufacturer-specified normal operating (combined) mode with testing to commence at 100% state-of-charge. When applicable, both km-per-liter of fuel and the km-per-kWh will be captured as well as the HEV’s range when operated in pure electric mode.

When this paper was submitted, the Honda Insight and Toyota Prius HEVs had just completed the Pomona Loop testing. Both vehicles, as well as two additional HEV models, will be Hybrid EVAmerica Baseline Performance tested starting the spring of 2002. One Insight and one Prius will also be Accelerated Reliability tested for 1 year. In addition, a combination of 10 Insights and Priuses will be tested in four fleets.

Figure 14. Honda Insight HEV.

The Pomona Loop testing of the Insight demonstrates that the testing method (Table 1) can significantly impact the energy consumption results. When the vehicle is tested in urban driving with the air conditioning turned on maximum, the fuel economy dropped to 17.6 km per liter. With the air conditioning off and a minimum payload, the fuel economy was 22.3 km per liter in urban driving. The highest fuel economy obtained during the urban driving tests was 26.9 km per liter. The overall average fuel economy for the eight urban tests (Scenarios UR1 - UR4 were each driven twice) was 21.6 km per liter.

Figure 15. Toyota Prius HEV.

For the Toyota Prius, the highest average fuel economy obtained during a single freeway test was 26.5 km per liter and the lowest result was 20.3 km per liter with a full payload and the air conditioning turned on. The overall average fuel economy for freeway driving for the Prius was 21.9 km per liter.

Acceleration (Table 4) and braking performance tests were also performed on the Honda Insight and Toyota Prius during the Pomona Loop testing. From an adjusted speed of 40.23 km/h (25 mph), the Insight required an average of 8.8 meters to stop and the Prius required an average of 8.3 meters to stop.

Table 4. Performance testing results for the Honda Insight and Toyota Prius.

	Honda Insight	Toyota Prius
Acceleration (seconds)		
0 to 48 km/h	4.2	4.5
0 to 97 km/h	12.7	13.1
48 to 89 km/h	7.2	7.0
Acceleration - 0.4 km		
Time – seconds	19.1	19.4
Speed – km/h	115.9	119.1

HYDROGEN VEHICLE TESTING

The Field Operations Program will also be conducting operations and fueling evaluations on three hydrogen-powered vehicles. One vehicle will be a 100% hydrogen-fueled Mercedes van, and the other two vehicles will be blended compressed natural gas (CNG) Ford F150 pickups using 30% and 15% hydrogen fuel, respectively. The vehicles will be driven in some fleet applications as well as with dedicated drivers to gain experience with the vehicles and the hydrogen/CNG refueling structure that supports them. These activities will commence by the end of 2001. Testing these vehicles will help prepare for future fuel cell vehicle testing activities.

USPS ELECTRIC VEHICLE TESTING

The Field Operations Program is supporting the U.S. Postal Services' (USPS) purchase of 500 light-duty electric delivery vehicles by providing testing and technical support to demonstrate the capabilities of these vehicles (Figure 16). The drive train, batteries, and electric components are all based on Ford Motor Company's electric Ford Ranger. The testing and demonstration activities include Baseline Performance testing, accelerated reliability testing, onboard data collection, field testing at three USPS locations in California and New York, and a final analysis of the entire 500 vehicle deployment.

Figure 16. USPS light-duty electric delivery vehicle being charged at SCE.

BASELINE PERFORMANCE TESTING - Southern California Edison has performed Baseline Performance tests on two USPS vehicles.[10] The testing includes gradeability (the maximum grade the vehicle can ascend), maximum speed on various grades (Table 5), maximum speed, several range tests, energy consumption, water hazards, and overcharging rates.

Table 5. Gradeability test requirements for the USPS (column marked "USPS") and testing results for the two test vehicles. The maximum achievable speed on four grades was measured, as was the maximum grade achieved. [11] The speed units are in km/h.

	USPS	Vehicle 3	Vehicle 4
Speed at 2.5% Grade	N/A	93.5	94.1
Speed at 3% Grade	88.5	90.4	90.6
Speed at 6% Grade	72.4	76.8	75.8
Speed at 20% Grade	16.1	33.6	35.9
Maximum Grade	25%	26.2%	26.6%

The highest dynamometer testing range results have been achieved during city drive cycles; the highway portion of the dynamometer testing lowers the range results. The city drive-cycle portion of the dynamometer testing and the Pomona Urban Loop testing more closely resemble how the USPS vehicles will be used. Payload also impacts range-testing results. When tested with the minimum payload, Ford reports a combined city/highway range of 85 km. When tested with the full maximum payload of 567 kg, the dynamometer results are 50 km (Table 6).

Table 6. Southern California Edison's Dynamometer testing results using SAE recommended practices (SAE J1634) for range testing (combined two Urban Driving Schedules followed by two Highway Fuel Economy Test Procedure runs). The range tests were performed at the maximum payload of 567 kilograms.

Maximum Payload	DC kWh Out	Dynamometer km
Vehicle 3	16.2	49.9
Vehicle 3	16.2	50.7
Vehicle 4	16.2	50.4
Vehicle 4	15.7	49.2
Combined city (91.7 km) and highway (69.2 km) range at minimum payload – 84.8 km		

ACCELERATED RELIABILITY TESTING - Southern California Edison has also been performing accelerated reliability testing on two additional USPS vehicles; each will be driven 32,000 km within 1 year. To date, the two vehicles have each been driven an average of 31,413 km (Table 7).

Table 7. Accelerated Reliability testing results as of mid-September 2001.

	Vehicle 1	Vehicle 2	Average
Km Driven	30,516	32,309	31,413
AC kWh used	11,727	12,555	12,141
AC kWh/Km	0.38	0.39	0.39

Range, energy use, and ambient temperatures are collected whenever the vehicles are driven. The two vehicles have averaged 0.39 AC kWh per km (2.6 km/kWh). The vehicle ranges are periodically tested on the Pomona Urban Loop at maximum payload, with no auxiliary loads. Results have ranged from 63 to 80 km per charge, with an average of 72 km per charge (Table 8).

There has been some vehicle maintenance issues, as would be expected with a new production vehicle, including two pack replacements in Vehicle 1 and four modules replaced in Vehicle 2. Several changes have also been made to the battery management algorithm, so the testing has included several variables. Based on a 7-day week, Vehicle 1 has had an availability rate of 96.3% and Vehicle 2 has had a 99% availability rate.

USPS FLEET TESTING - To capture “real world” energy efficiency for the USPS vehicles, the energy use of 28 USPS electric vehicles was collected at the Fountain Valley, California post office.[12] The 28 odometers were read on June 1, 2001 and again on July 2, 2001. A single ABB kWh meter was used to collect energy use for all 28 charging stations. The 28 vehicles logged 13,926 km during the study period and they used 9,446 kWh, yielding 0.68 kWh per km energy efficiency (1.47 km/kWh) for the Fountain Valley fleet.

Table 8. Range tests conducted during Accelerated Reliability testing.

Date Tested	Odometer (km)	Tested Range (km)	Battery Pack Installed ON
Vehicle 1			
08-30-00	420	74	Original
10-12-00	2,337	68	Original
12-06-00	6,140	66	Original
03-28-01	15,294	72	03-13-01
06-18-01	22,227	76	04-06-01
09-18-01	30,833	68	04-06-01
09-19-01	30,930	71	04-06-01
Average #1		71	
Vehicle 2			
08-31-00	338	74	Original
10-12-00	2,549	63	Original
12-06-00	6,168	68	Original
03-27-01	15,931	80	Original
06-15-01	23,134	79	Original
09-18-01	32,671	76	Original*
09-20-01	32,806	68	Original*
Average #2		73	

* Four modules replaced.

Conclusion

The Field Operations Program supports the deployment of advanced technology vehicles by demonstrating vehicle performance and fleet suitability. The Program has evolved in step with industry to ensure the latest generation of vehicles are tested and the results disseminated in a timely manner. In continuing this progression, the Program has initiated the testing of NEVs, HEVs, and UEVs.

The initial EVAmerica testing of full-size pure EVs demonstrated the capabilities, and sometimes the lack of capabilities, of these early products. The resizing of pure EVs to fit niche markets should result in greater market penetration. The NEVs are lower priced than the earlier full-size EVs, providing greater economic utilization while meeting the mission requirements of many fleets; most of the NEVs should provide vehicle range capabilities (30+ km) that exceed most mission requirements. The manufacturing barriers to enter the NEV market are less than the full-size EV market, with the result that there is a greater need to ensure that the products are safe and perform as advertised. The Field Operations Program has developed a testing program that supports NEV purchasing decisions.[13]

While UEVs, with their higher advertised range capabilities (50+ km) and top speeds, should be able to successfully function in station car and other urban missions, there is no historical record of their performance characteristics and life-cycle costs. As with the NEVs, the Field Operations Program has also developed testing procedures and initiated the testing of several UEV models.

With the advent of commercially available HEVs, the Program has designed test procedures specifically for them. Testing will answer questions concerning their true fuel-use rates and the life of their propulsion batteries. Groups such as the Partnership for New Generation of Vehicles (PNGV) have battery-life goals of 15 years; the Program will document the life of HEV battery packs with their advanced materials. The Program will also document HEV operational issues and life-cycle costs.

The Field Operations Program and its testing partners will continue to ensure that fleet managers and others have unbiased information to support their transportation technology decisions.

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