Electric and Hybrid Vehicle Program

Site Operator Program

*Quarterly Progress Report
for April through June 1994
(Third Quarter of Fiscal Year 1994)*

*D. M. Kiser
H. L. Brown*

Published October 1994

*Idaho National Engineering Laboratory
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415*

MASTER

*Prepared for the
U.S. Department of Energy
Assistant Secretary for Conservation and Renewable Energy (EE)
Under DOE Idaho Operations Office
Contract No. DE-AC07-94ID13223*

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

plc

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

Executive Summary

Site Operator Program Quarterly Report

The DOE Site Operator Program was initially established to meet the requirements of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The Program has since evolved in response to new legislation and interests. Its mission now includes three major activity categories:

1. Advancement of Electric Vehicle (EV) technologies
2. Development of infrastructure elements needed to support significant EV use
3. Increasing public awareness and acceptance of EVs.

The 13 Program participants, their geographic locations, and the principal thrusts of their efforts are identified in Table ES-1. The EV inventories of each participant are summarized in Table ES-2.

Participants' experience with EV operation reflects three unrelated factors:

1. Operating climate and terrain
2. Current battery design and manufacturing technology, and charging/maintenance practices
3. Control and drive component technology and dependability

Factor 1 can noticeably influence the operating range of a vehicle. Factors 2 and 3, in that order, give rise to a great majority of the

problems encountered. The effects of vehicle age, weight, and accumulated service mileage are also factors, and are noted by the operators in their service records. To summarize:

- Ambient temperature extremes and other climatic variations decrease vehicle range through both reduced battery capacity and increased accessory usage.
- Battery pack life for a given type is not uniform and frequently much shorter than expected; identical modules may show substantially different service lives.
- Electronic control system and drivetrain components are critical to vehicle operation and failures are not uncommon.

An appraisal of the overall current status of EVs for transportation emphasizes the following:

- Zero-emission vehicles have been mandated to specified percentages of new vehicles sold, by California law.
- For successful use of electric vehicles, conditions must be favorable, typically involving short-range service and infrastructure (i.e., charging and service) availability. Climate and terrain also impose limitations.
- Evaluation and test activities to date reflect the need for technology advances. Improved battery chemistry, design, and manufacturing practices are needed if adequate dependability is to be achieved. Powertrain and control system design will

Site Operator Program Quarterly Report

necessarily reflect battery technology changes, although control and powertrain design philosophy is potentially flexible. Examples are AC versus DC drive power, and the use (and operational problems) of regenerative braking.

- The additional cost of an EV over conventional ICE vehicles is largely in purchase price. Operating costs appear to be competitive.
- Vehicles representing relatively new designs (e.g., Soleq EVcort and Chrysler TEVan) are presenting a variety of equipment and operational problems to the users. The design of the S-10 pickup conversions now on order is under discussion to resolve limitations on vehicle steering and load capacity, and charging plug location.
- Further effort is needed in hybrid vehicle development to achieve the necessary operating performance and overall dependability. The UNIQ hybrid minivan has been out of service for more than a year, awaiting essential design information and circuit diagrams from suppliers.
- Batteries and charging equipment continue to present generic problems, even in otherwise proven EV systems. Fast-charge technology is now under active investigation, and standardized testing protocols are being developed. A companion effort, the Rapid Battery Interchange Program, has been started at Pacific Gas and Electric Co.

Program Management covered a spectrum of activities:

- Reports of Program status.
- Public awareness activities.
- Purchase orders totaling 42 pickup conversions have been placed with two vendors subsequent to the Site Operator Users Task Force bid evaluations. These units will be factory-equipped with the current version of the Mobile Data Acquisition System (MDAS).

A Program Experience Overview, the result of analyzing Site Operator inputs, provides an insight into the variables that can affect electric vehicle performance and operating cost. These variables must be considered when making comparisons with conventional ICE-powered vehicles.

Graphic treatments of composite data for the reported G-Van, Escort, Chevrolet S-10, and VW Pickup, highlight the intrinsic differences among these vehicle types, as well as reflecting site-to-site differences attributable to operating requirements and environmentally seasonal influences. Separate presentations are made of (1) energy costs; (2) maintenance costs; (3) consolidated (all sites) energy costs; and, (4) service/repair costs for specified activity groups. The influences of vehicle type/weight, operating service requirements, operating environment, and vehicle age/cumulative usage are inherent in the results of the analysis.

It is noted that lighter-weight EVs (for example, the EVcort) have better performance and maintenance records. The apparent absence of such information from the graphic composite data reflects two factors:

1. Not all Site Operators report specific operating and maintenance data;
2. Some data are provided in a format that is not compatible with our analytical algorithm.

Conclusions

The conclusions reached from the overview results were:

- The larger, heavier G-Vans consume more energy than the smaller, lighter, Ford Escort, or the pickup trucks (i.e., Chevrolet S-10 or Volkswagen pickup).
- An electric vehicle that is used sporadically will use more energy/mile than one that is used more often. This is shown by the Ford Escort data.
- "Opportunity Charging" significantly affects the accuracy of the reported Site Operator data because energy added to the system during "opportunity charging" is often not recorded.
- Charging technology problems tend to impede effective utilization of EVs. These problems relate to:
 - Passenger comfort power demands

- On-board charging equipment rate limitations
 - Charging equipment incompatibility with infrastructure features governed by local ordinance.
- Routine maintenance costs are comparable for the four (4) types of vehicles reported, although major maintenance needs can make this difficult to detect.

Recommendations

The following recommendations are made as result of the data analysis:

- Use of in-vehicle data acquisition systems should be considered to eliminate the effect of unrecorded "opportunity charging," and reduce the labor required to edit data records containing errors.
- The area of charging technology should be surveyed to identify (and rank) its related problems and candidate approaches to controlling and minimizing their effects.
- More sites should report data utilizing the Site Operator Database. This would provide a larger data sample, give more reliable results, and reduce the amount of special handling required for data reported utilizing other media.

*Site Operator Program
Quarterly Report*

Table ES-1. Site Operator Program Participants.

Entity	Principal Thrusts of Program Effort a. Fleet evaluation, vehicle test b. Infrastructure development c. Technical education d. Public awareness
Arizona Public Service Co. Phoenix, AZ	a, b, d
Kansas State University Manhattan, KS	a, b, c, d
Los Angeles Dept. of Water & Power Los Angeles, CA	a
Orcas Power and Light Co. Eastsound, WA	a, b, d
Pacific Gas and Electric Co. San Ramon, CA	a, b, d
Platte River Power Authority Fort Collins, CO	a, b, d
Potomac Electric Power Co. Washington, DC	a, b, d
Sandia National Laboratory* Albuquerque, NM	a
Southern California Edison Co. Rosemead, CA	a, b, d
Texas A&M University College Station, TX	a, c, d
University of South Florida Tampa, FL	a, b, c, d
U.S. Navy Port Hueneme, CA	a
York Technical College Rock Hill, SC	a, b, c, d
* Information-sharing agreement	

*Site Operator Program
Quarterly Report*

Table ES-2. Site Operator Program active vehicle inventory.

Participant	G-Van	EVcort	Force	S-10	Jet*	Unique	Griffon	TEVan	Other	Total
APS	4	3	1	—	—	2	—	1	1 Solar Colt sedan; 1 Honda CRX; 1 Saturn	14
KSU	—	2	—	—	—	—	—	—		2
LADWP	6	—	—	—	—	1†	—	4		11
OPALCO	—	—	1	—	1	—	—	—		2
PG&E	3	1	—	—	—	—	—	—	2 Ford Ecostars	6
PRPA	—	2	—	—	—	—	—	—		2
PEPCO	1	—	1	—	—	—	—	—		2
SANDIA	—	—	—	—	—	—	—	—	12 Electrica (Escort conversion)	12
SCE	15	—	4	1	—	—	—		5 Ford Ecostars, 1 Tempo Sedan, 2 Ranger pickups, 1 bus, 1 Dodge Caravan)	30
TAMU	16	—	—	—	1	—	—	6	2 race cars	25
NAVY	5	—	—	6	42	—	11	—	2 Grumman	66
USF	2	—	1	6	—	—	—	—	1 Mirage	10
YORK	1	—	—	2	4	2			1 Solectria Force 1 Escort (Bearskin)	11
TOTALS	53	8	8	15	48	5	11	11	34	193
* = various manufacturers					† = hybrid					

Contents

Site Operator Program Quarterly Report

Executive Summary	iii
Introduction	1
Program Management	7
Program Experience Overview	9
Summary	19

APPENDICES

Program Activities	A-1
Site Operators	A-3
Arizona Public Service	A-3
Kansas State University	A-4
Los Angeles Department of Water and Power	A-5
Orcas Power and Light Company	A-6
Pacific Gas and Electric Company	A-7
Platte River Power Authority	A-9
Potomac Electric Power Company	A-10
Sandia National Laboratory	A-10
Southern California Edison	A-11
Texas A&M University	A-13
U.S. Navy	A-14
University of South Florida	A-14
York Technical College	A-17
Site Operator Data Tables	B-1 thru B-16

Introduction

Site Operator Program Quarterly Report

The Site Operator Program was initially established by the Department of Energy (DOE) to incorporate the electric vehicle activities dictated by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976. In the ensuing years, the Program has evolved in response to new legislation and interests. The Program currently includes thirteen sites located in diverse geographic, metrologic, and metropolitan areas across the United States (see Figure 1). Information is shared reciprocally with a fourteenth site, not under Program contract. The vehicles are operator-owned, except for two Griffon vans.

The Mission Statement of the Site Operator Program includes three major activities:

1. Advancement of electric vehicle technologies
2. Development of infrastructure elements necessary to support significant electric vehicle use; and
3. Increasing the awareness and acceptance of electric vehicles (EVs) by the public.

The current participants in the Site Operator Program are shown in Figure 1. Table 1 indicates the EVs in each of the Site Operator fleets. Table 2 provides baseline information on several EVs currently in use by the Site Operators, or which have evolved to the point that they may be introduced in the near future.

The Program is currently managed by personnel of the Electric and Hybrid Vehicle Program at the Idaho National Engineering Laboratory. The current principal management functions include:

- Coordination of Site Operator efforts in the areas of public awareness and infrastructure development (program-related meetings, and educational presentations).
- Technical and financial monitoring of programmatic activities, including periodic progress reports to DOE.
- Data acquisition, analysis, and dissemination. The data from the Site Operators are made available to authorized users through the INEL Site Operator Database.

The ultimate thrust of program activities varies among sites, reflecting not only the Operator's business interests but also geographic and climate-related operating conditions. These considerations are identified below for each Program Status entry.

This third quarter report (FY-94) will include a summary of activities from the previous three quarters. The report section sequence has been revised to provide a more easily seen program overview, and specific operator activities are now found in Appendix A.

*Site Operator Program
Quarterly Report*

Table 1. Site Operator vehicle fleet.

Arizona Public Service Company (APS)

1.	Unique sedan	2 ea.
2.	G-Van (cargo)	2 ea.
3.	G-Van (passenger)	2 ea.
4.	EVcort sedan	3 ea.
5.	Solar Colt Sedan	1 ea.
6.	TEVan	1 ea.
7.	Honda CRX	1 ea.
8.	Saturn	1 ea.
9.	Solectria	<u>1 ea.</u>
	TOTAL	14

NOTE: Does not include 3 vehicles donated to local organizations

Kansas State University (KSU)

1.	EVcort sedan	<u>2 ea.</u>
	TOTAL	2

Los Angeles Department of Water and Power (LADWP)

1.	G-Van (passenger)	4 ea.
2.	G-Van (cargo)	2 ea.
3.	Unique hybrid passenger	1 ea.
4.	TEVan	<u>4 ea.</u>
	TOTAL	11

Orcas Power and Light Company (OPALCO)

1.	Escort	1 ea.
2.	Solectria Force	<u>1 ea.</u>
	TOTAL	2

*Site Operator Program
Quarterly Report*

Table 1. (continued)

Pacific Gas and Electric Company (PG&E)

1.	G-Van (passenger)	2 ea.
2.	G-Van (cargo)	1 ea.
3.	Ecostars	2 ea.
4.	EVcort	<u>1 ea.</u>
	TOTAL	6

Platte River Power Authority (PRPA)

1.	EVcort sedan	<u>2 ea.</u>
	TOTAL	2

Potomac Electric Power Company (PEPCO)

1.	G-Van (passenger)*	1 ea.
2.	Solectria Force	<u>1 ea.</u>
	TOTAL	2

Sandia National Laboratory

1.	Electrica (Escort conversion)	<u>12 ea.</u>
	TOTAL	12

Southern California Edison Company (SCE)

1.	G-Van (passenger)	9 ea.
2.	G-Van (cargo)	6 ea.
3.	Ford Ecostar	5 ea.
4.	Solectria Force	4 ea.
5.	Electricar pickup (S-10)	1 ea.
6.	Sedan (Green Motor Works)	1 ea.
7.	Pick Up (Venus Motors) (Ranger)	2 ea.
8.	Sedan, Ford Tempo	1 ea.
9.	Bus (Clean Air Transit)	<u>1 ea.</u>
	TOTAL	30

* Not currently in service

*Site Operator Program
Quarterly Report*

Table 1. (continued)

<i>Texas A&M University (TAMU)</i>		
1.	G-Vans	16 ea. (Includes consortium vehicles)
2.	Jet	1 ea.
3.	TEVan	6 ea.
4.	Race Car	<u>2 ea.</u>
	TOTAL	25
<i>U.S. Navy (NAVY)</i>		
1.	Jet (various)	42 ea.
2.	Grumman Van	2
3.	S-10	6
4.	G-Vans	5
5.	Bedford Vans	5
6.	Griffon Van	<u>6 ea.</u>
	TOTAL	66
<i>University of South Florida (USF)</i>		
1.	G-Van (passenger)	2 ea.
2.	Chevy S-10 Pickup	6 ea.
3.	Solectria Force	1 ea.
4.	Mirage	<u>1 ea.</u>
	TOTAL	10
<i>York Technical College (YORK)</i>		
1.	G-Van	1 ea.
2.	Escort (Bearskin)	1 ea.
3.	Unique Sedan	2 ea.
4.	S-10 Pickup	6 ea.
5.	Solectria Force	<u>1 ea.</u>
	TOTAL	11

TOTAL - SITE OPERATOR PROGRAM

193

*Site Operator Program
Quarterly Report*

Table 2. Baseline vehicle information on selected electric vehicles.

VEH NAME	G-Van	EVcort	Force	S-10	TEVan	ECOSTAR
MFG	Conceptor	Soleq	Solectria	Solar Car	CHRYSLER	FORD
BODY	VAN-PSG/CRGO	SEDAN	SEDAN	PICK-UP	MINI-VAN	STAT. WAG.
NO. PASS	7/2	4	2+2	2	7	2
BATT TYPE	LEAD-ACID	LEAD-ACID	LEAD-ACID	LEAD-ACID	NI-FE	NA-S
MODUL VLT	6	6	12	6	6	
NO. MODUL	32	18	12	20	30	
SYST VOLT	216	108	144	120	180	336
CHARGER	OFF BOARD	ON BOARD	ON BOARD	ON BOARD	ON BOARD	
WEIGHT(GVW)	8600 lbs	3980 lbs	2450 lbs	3200 lbs	~6000 lbs	3950 lbs
WEIGHT(CURB)	7670 lbs(Pass) 7050 lbs(Cargo)	3560 lbs		3500 lbs		3200 lbs
MOTOR/HP	DC/60 hp	DC/42 hp	AC/25-DC/32	DC/28	DC/55	AC/75 hp
EST RANGE	60 MI.	60 MI.	46 MI.(FUDS)	40-70 MI	120 MI.	100 MI.
REGEN BRK	YES	YES	YES	OPTIONAL	YES	YES
Note: VW-Pickup curb weight = 3370 lbs; Griffon Van curb weight = 5513 lbs; Mitshubishi Mirage curb weight = 2590 lbs, Mitshubishi Mirage GVW weight = 3417 lbs.						

VEH NAME	IMPACT	LA 301	ELECTRON-TWO	FEV	RAM 50 TRUCK	E1
MFG	GM	CLN AIR TRNS	SOLAR ELECTR	NISSAN	EVA	BMW
BODY	SEDAN	SEDAN	SEDAN	SEDAN	PICK-UP	SEDAN
NO. PASS	2	4	2	2	2	4
BATT TYPE	LEAD-ACID	PB-A w/HYBRID	LEAD-ACID	NI-CAD	LEAD-ACID	NA-S
MODUL VLT	10	6	6		6	
NO. MODUL	32	32	18		20	
SYST VOLT	320	216	108		120	120
CHARGER	ON BOARD	ON BOARD		ON BOARD		
WEIGHT	2200 lbs	3894 lbs	3100 lbs	1984 lbs	3500 lbs	2600 lbs
MOTOR/HP	2 ea AC/57 hp	57	DC/23	2 ea	DC/38	DC/45
EST RANGE	80 MI	40-60 MI*	45-65 MI	100 MI	50-70 MI	155
REGEN BRK	YES	YES		YES		
*BATT. ONLY; 150+ MI AS HYBRID						

Program Management

The Program report for the second quarter of FY-94 was issued.

Work continued on the proposed Program reorganization. A draft proposal for data collection/reporting standards presented to DOE-HQ is under review.

The latest version of MDAS has been received from Sigma Tec and is being tested at the INEL.

Forty-two S-10 pickup conversions are now on order from GE/Spartan and Hughes/U.S. Electricar. Thirty of these vehicles (15 from each supplier) will be delivered with current-

model MDAS units installed. The MDAS permits automated real-time data acquisition for a ranged of pertinent operating parameters, as well as an uncomplicated data download for subsequent processing and storage.

The vehicle distribution to the ten Site Operator Program participants who have ordered them, and the type of operating environment for daily usage, are presented in Table 3.

Review of contract renewals for Program participants is essentially completed. Task recommendations will be based on funding availability.

*Site Operator Program
Quarterly Report*

Table 3. Recommended MDAS distribution for S-10 pickup conversions.

Site	No. Spartan	W/MDAS	No. Electricar	W/MDAS	EV Operating Environment
APS	6	4	—	—	warm-hot/flat/urban
KSU	4	2	—	—	warm-cold/flat-suburban
LADWP	—	—	5	3	warm-cool/mixed/urban
PEPCO	2	2	2	2	hot-cold/mixed urban
PRPA	5	3	—	—	warm-cool/mixed/suburban-rural
PG&E	—	—	5	3	warm-cool/mixed/urban-suburban
SCE	3	2	3	2	warm-cool/mixed/urban-suburban freeway
TAMU	—	—	3	3	hot-cool/flat/rural-suburban
USF	2	2	—	—	hot-cool/flat/urban-freeway
YORK	—	—	2	2	hot-cool/flat/suburban-urban
Total	22	15	20	15	

Program Experience Overview

Site Operator Program Quarterly Report

Because a principal interest, and corresponding activity, of the Site Operator Program is vehicle performance evaluation, various data acquisition and analysis methods and equipment are in use. Most recently, installation of the Mobile Data Acquisition System in 30 new Program vehicles is under way, and will provide real-time operating data. However, these vehicles will not be operated all at a single site, nor under closely similar conditions. It then becomes necessary to arrive at a sound basis for data comparisons, groupings, and statistical interpretations. The objective here is to determine how many vehicles must be tested, and for how long a time interval, to assure a 95% confidence level in the data.

A classical statistical analysis to determine this information was performed on manually gathered Site Operator Program operating data for seven Public Service Electric and Gas Co. (PSE&G) G-Vans (cargo). Similarly, multivariate analysis was carried out on MDAS data for a Virginia Power Corporation Solectria during testing at the INEL Vehicle Test Laboratory. The findings of the two different methods are in acceptable agreement.

In the case of the most common controlling event, premature battery pack failure, both statistical methods showed that three vehicles per site could be adequate for a 95% confidence level in the data. The final recommendation was for four vehicles per site, and at least 162 data samples for each vehicle. Since each sample represents a charge cycle of (generally) three or more days, the minimum sampling time period must be at least 486 days.

The principal vehicle types now used by the Site Operators, under this Program, are: G-Van, Griffon, EVcort, Ford Escort, Solectria Force, Unique Mobility, Chevrolet S-10, and Volkswagen Pickup. Site Operators that are reporting data utilizing the Site Operator

Database are: Kansas State University (KSU), Pacific Gas & Electric (PG&E), University of South Florida (USF), and York Technical College (YORK). The remaining Site Operators are reporting data utilizing spread sheets, a dBase II version of the database, or Apple Computer software. These data require special handling for which algorithms have been developed to import the data. The algorithms will be utilized for reporting data for the fourth quarter of FY-94. Vehicles for which data has been reported are: G-Van, Griffon Vans, Ford Escort, Chevrolet S-10, Ford Ecostar, Mitsubishi Mirage, and Volkswagen Pickup. For the reported vehicle types, at the sites reporting, data, this section provides composites of:

- Energy Costs (\$/mi) of Vehicle Operations for the Reporting Sites (Figure 2).
- Normalized Energy Costs (\$/mi/klb) of Vehicle Operations for the reporting Sites (Figure 3), where normalization is with respect to the vehicle curb weight in kilo-pounds (klb).
- Maintenance Costs (maintenance \$/mi) by Category of Vehicles for the reporting sites (Figure 4).
- Range of Energy Consumption (kW·h/mi) for reported vehicles (Figure 5).
- Normalized Range of Energy Consumption (kW·h/mi/klb) for reported vehicles (Figure 6), where normalization is with respect to vehicle curb weight in kilo-pounds (klb).
- Maintenance Costs (maintenance \$/mi) of vehicles for the reporting Sites (Figure 7).

Site Operator Program Quarterly Report

Furthermore, these data do not support unequivocal conclusions, although trends can often be identified:

- As with ICE-powered vehicles, maintenance requirements vary from one design to another and from one supplier to another. Further, increased requirements tend to accompany increased vehicle age, but the data analysis does not break out the age dependency.
- The program is just beginning to acquire new vehicles which may incorporate new technologies. At the very least, then, an initial period of defacto testing and/or debugging can be expected as these vehicles enter service.
- A restatement of power usage in terms of combined weight and mileage is a more realistic approach than mileage alone, but must, of course, be qualified by the actual weights of the vehicles compared. The results will then reflect mainly the differences in design, use, and operating environment.

A continuing overview of Site Operator Program activities, as well as outside factors which influence or impact these activities, reveals certain trends in EV technology and usage:

- Vehicle technology, both design and operational control, is showing definite improvement. The light vehicles (for example, EVcorts) in more modern designs, approach equivalent ICE vehicles in overall operating costs. (This conclusion is drawn from the overall Site Operator submissions, not all of

which, as stated earlier, are reflected in the graphic summaries presented in this report.)

- Increased EV usage is, to an extent, being encouraged by political and/or environmental mandates.
- The current principal interest in EVs is for utility vehicles; cargo (rather than just passengers) is the primary emphasis.
- Infrastructure development (e.g., curbside charging capability) is proceeding at an accelerating pace.

The raw data were supplied by the Site Operators. Energy costs are computed from the kilowatt-hour measured in charging the vehicle batteries and an assumed energy rate of \$0.07/kW·h. Maintenance costs include only the labor hours, and costs are computed assuming a labor rate of \$23.00/hr.

The figures present exemplary data from earlier Site Operator submittals. It should also be noted that DOE has recently requested that data for the G-Vans no longer be published.

The data scatter reflect a spectrum of service and assignment related variables, either separately or in combination. The principal variables are:

- The type of service, such as personnel and equipment transport, public demonstration, commuter service or laboratory testing.
- Operating conditions, such as terrain, climate, and ambient temperature.

*Site Operator Program
Quarterly Report*

- Vehicle weight and age.
- Component variability and age.
- Battery charging method.
- Accuracy of data input.

Tables of the data are shown in
Appendix B.

Figure 2. Energy costs (\$/mi) of vehicle operations for reporting sites.

Figure 3. Normalized energy costs (\$/mi/klb) of vehicle operations for reporting sites.

Figure 4. Maintenance costs (maintenance \$/mi) by category of vehicles for reporting sites.

Figure 5. Range of energy consumption (kWh/mi) for reported vehicles.

Figure 6. Normalized range of energy consumption (kWh/mi/klb) for reported vehicles.

Figure 7. Maintenance costs (maintenance \$/mi) of vehicles for reporting sites.

Summary

Site Operator Program Quarterly Report

The DOE Site Operator Program currently receives input from 14 sites in the U.S.A. The participants are public utilities, educational institutions, a National Laboratory, and the U.S. Navy. (No input was received from the Navy.) The number of electric vehicles now in use or undergoing test evaluations exceeds 175, ranging in age from new to twelve years. Body styles are mainly for utility (van or pickup) or passenger service.

Program participant efforts reflect varying combinations of day-to-day use, laboratory testing and evaluation, and successful promotion of public awareness by demonstrations, exhibits, and media dissemination of related activities and information.

The foregoing status entries provide more specific information concerning the Program participants and their overall interests, their programmatic activities, and their experiences with electric vehicles and accompanying problems.

The principal operating problem reported is a decrease in vehicle range, usually a direct result of battery pack problems, but also a function of the climate, especially the ambient temperature, in the operating environment.

The principal maintenance problems relate first to batteries and then to failures of electric components in the control systems and the powertrain.

Program management activities relate to issuance of reports, communication with sponsors (DOE) and cooperating institutions, determination of program goals/objectives, and evaluation of advanced EV-related components and systems.

An overview of Program experience, derived from the operator inputs, demonstrates unequivocally the differences in energy and maintenance costs for operating the principal types of electric vehicles used by the participants. A categorical breakdown of service/repair costs in \$/km identifies the principal problem groups associated with each vehicle type. This information, presented in Appendix A, is not all-inclusive of the Site Operators; for the others, the data were either not provided or were submitted in a form that is incompatible with the Program's data-handling algorithms.

It is for these reasons that in-vehicle automated data acquisition systems will be implemented in the near future. The DOE data requirements are currently being developed for automated data systems, and a summary of these developments will be presented in a future Site Operator Quarterly report.

Despite apparent commonalities of interests among the Program participants, their individual contributions have been adequately diverse, for a variety of reasons related to equipment, operating environment, operating philosophy, and the overall objectives of each participant. The three major categories of the Program Mission appear to be well served.

APPENDIX A

SITE OPERATOR PROGRAM PARTICIPANTS'
PROGRAM ACTIVITIES

Site Operators

Arizona Public Service (APS)

- maintains and operates 10 electric vehicles of various types in its Electric Vehicle (EV) Program, primarily in the Phoenix area (see Tables 1 and 2). Both passenger and cargo vehicles are represented. Much of the vehicle usage is demonstration, often under loan or lease arrangements. As a public utility, APS benefits from EV usage throughout its territory because of energy sales to meet the battery charging requirements. The APS EV Program activity summaries also cover EVs leased to or owned by the cities of Phoenix and Scottsdale. This program is supported by several APS subsections. Technical information is coordinated with Southern California Edison, the U.S. Department of Energy (DOE), the Idaho National Engineering Laboratory (INEL), and the Electric Power Research Institute (EPRI).

Technical

APS has logged over 531,000 miles on their electric vehicles since 1979 as part of the DOE EV Site Operator Program, and 7,297 miles in the first quarter of CY-94. The APS EVcorts consistently show the lowest operating costs, competitive with equivalent ICE vehicles.

A Chrysler TEVan was delivered to APS at the start of the reporting period, and is currently under evaluation by the APS Research Department.

Range problems in G-Van operation in cooler weather have been addressed by battery replacement (now a Sonnenschein gel electrolyte pack) and installation of an on-board SOLEQ charger in EV 103, followed by operating range tests. This G-Van has been returned to mail service, and its operating range currently exceeds

40 miles. Battery packs in three other G-Vans have been replaced with Trojan T-145 assemblies, and the vehicles returned to service. Battery packs were also replaced in the two Unique Mobility sedans and the Solectria and Solar sedans, using battery types of known effectiveness in APS vehicles. SOLEQ on-board chargers have also been upgraded. Improved performance is seen with the Sonnenschein packs.

Routine maintenance requirements were relatively low, except for the TEVan traction system. R&D Support manhours for vehicle modifications totaled 610 in this reporting period.

Public Awareness

APS hosted the 1994 APS Electric 500 competition which included 68 vehicle entries. Of these, 36 were part of the High School Electric Vehicle Competition. Attendance was approximately 3,000.

APS sponsored a regional IEEE Symposium on EV Technology in conjunction with the APS Electric 500 during the reporting period. In addition, APS provided sponsorship of Education Day at the Electric 500, by transporting over 1,000 students to the event to participate in a day of displays and competitions.

APS also sponsored several teams in the High School Electric Vehicle Competition. Co-sponsors were the U.S. Department of Energy and the Electric Power Research Institute.

Site Operator Program Quarterly Report

Through APS efforts, the "Safety of Electric Racing Vehicle" race safety plans for safe conduct of EV competitions, and several technical papers relating to vehicle safety, have been published.

Kansas State University - The Kansas State University (KSU) Site Operator Program is conducted at Manhattan, Kansas, in conjunction with the Kansas Electric Utilities Research Program. The latter effort is a contractual joint venture of six major electric utilities in the state; its mission is to undertake applied R & D to enhance reliability and minimize the cost of electric service in Kansas. Several industrial organizations within the state provide technical and financial support to the KSU Electric and Hybrid Vehicle demonstration program. The KSU Site Operator Program is currently based on three electric vehicles (See Table 1). The G-Van, maintained at the KSU campus, is available for demonstration purposes on short-term loan to interested utilities and other companies. Further use is routine transportation by the Program and the Engineering Technology Department under ambient weather and driving conditions.

Technical

Both Soleq EVcorts have performed during this reporting period without major incidents. Operating costs under every-day driving conditions and weather in the immediate city area appear comparable to those of a similar vehicle with ICE power. The on-board charger provides a definite advantage under the existing spectrum of operating conditions. Combined mileage to date on the EVcorts exceeds 3,600 miles.

- Non-regenerative braking, after system repair, is still not uniform, failing to operate at low vehicle speeds. Controller problems are suspected.
- The two air-conditioning compressors on EVcort 151 were rewired by Soleq to permit either series or parallel operation, because of a compressor "kickout" problem. The system operated properly in a service test when warmer weather returned.
- Electric operator-comfort heating for EV operation in this area appears relatively impractical. The heaters require 3 kW, a substantial battery drain. With the power limitations of most curbside charging stations, little battery charging can take place while the heater load is imposed. Fuel-powered heaters may be a feasible alternative.
- Both EVcorts have experienced a failure of the pre-heating and pre-cooling system. The cause, possibly a control relay, is being investigated by Soleq. Other intermittent electrical problems are noted.

Procurement of four Chevrolet S-10 conversions by Spartan Motors, to be placed with participating utilities in the Kansas Electric Utilities Research Program, is underway. These vehicles will demonstrate advanced AC drivetrain technology, including controller and motor systems, and may incorporate a thermal battery-management system to minimize the effects of outside temperature.

Site Operator Program Quarterly Report

Three potential problems are under discussion:

- The expected use of a manual steering system may not be effective with the added weight of batteries and conversion components.
- The proposed on-board charger is neither as advanced nor as light weight as current state-of-the-art equipment. As a result, the current S-10 conversion could be only a 2-person, no-cargo vehicle.
- The Meltric plug and receptacle for all S-10 conversions does not fit in the gas cap area on the 1994 model vehicles. Utility representatives would like it on the front of the vehicle, a potentially harsh environment. A satisfactory design for this location is sought.

Public Awareness

Professor Hague of Kansas State University (KSU) took a KSU electric vehicle on a 14-day, 13-site alternative fuels tour of junior and senior high schools. A similar tour, involving 32 Unified School Districts in Kansas, is planned for the Fall 1994 school semester. The effort is part of a demonstration program established by the Kansas Corporation Commission.

A KSU electric vehicle was shown to area junior and senior high school students by West Plains Energy, of Great Bend, KS. Brochures and other information were provided by the DOE Site Operator Program at KSU.

Innovatron Data System's advanced technology payment systems, used in the curbside charging station, and potentially

applicable to other KSU projects, were discussed with Innovatron.

KSU will host the Sunrayce '95 event. At the planning meeting, the KSU EVs were displayed, and test-driven by Sunrayce participants.

Los Angeles Department of Water and Power (LADWP) - currently operates eleven (11) electric vehicles (see Table 1). Its participation in the DOE Site Operator Program involves only a hybrid minivan (Unique Mobility, Englewood, CO.), for test and evaluation, ultimately as a candidate fleet vehicle, and a Chrysler TEVan.

Technical

The UNIQ hybrid minivan has consistently demonstrated severe range limitations since its 1990 delivery to LADWP. The range extender, the battery packs, and the electrical system components have all required excessive maintenance, without being able to solve the problems. The conversion design and the physical configuration of the converted vehicle make maintenance efforts difficult and slow. Unique Mobility and Soleq Corporation, the suppliers, have been requested to provide design information and wiring schematics to support LADWP in solving these problems, but the necessary information has not yet been received.

The UNIQ has been out of service since April 1993. Its current problems involve batteries, range extender, on-board electrical systems, damaged cables, and battery pack cover. Current status of the LADWP work on this vehicle is as follows:

Site Operator Program Quarterly Report

- Development of meaningful test and diagnostic procedures awaits further input from Soleq.
- Electrical system repairs and upgrades are likewise deferred until adequate technical documentation can be obtained.
- The vehicle's electrical systems are being rewired in a logical manner to eliminate unnecessary systems, partial systems, and interconnections, thereby simplifying the system diagnostic process.
- A pack of Sonnenschein DF8D gelled-electrolyte 225 A·h batteries was purchased, and minor chassis modifications needed for their installation have been identified. The DF8D units will replace the 160 A·h original equipment Sonnenschein 12 V-160 units.

Problems with the Chrysler TEVans are mostly repetitive and generic. They concern motor control units, auxiliary power control units, and on-board battery watering systems.

Public Awareness

As a participant in the CALSTART Electric Bus/Mass Transit Program, LADWP is working with suppliers, operators, and political agencies to develop and implement pollution-free public passenger transport systems, and demonstrate existing capabilities. In conjunction with LA's Harbor Department and Department of Transportation, LADWP is operating three trolley-style electric shuttles in the LA Harbor area on a three-year demonstration program. Service is eight hours daily, seven days weekly. Since this service began in November 1992, the

system has carried more than 30,000 passengers comprising a variety of interests.

Orcas Power and Light Company (OPALCO) - of Eastsound, WA, operates two (2) electric vehicles (see Table 1) as part of its participation in the DOE Site Operator Program. This electric utility serves customers in the islands of San Juan County, WA. The OPALCO territory presents some driving conditions and operating problems not encountered by other Program participants.

OPALCO is actively encouraging EV ownership/operation by both public demonstrations and enlarging the necessary infrastructure with additional EV charging stations.

Technical

The Solectria battery pack was found to have five monoblocks below acceptable voltage standards. These lead-acid units were exchanged for replacements through Sears, Roebuck & Co. at less than 50% of the original cost.

The timer on the Solectria kilowatt-hour recording meter failed and was replaced.

Public Awareness

The OPALCO manager described the Site Operator Program, both at OPALCO and nationally, to the annual meeting of the Rural Electric Management Development Council, representing 55 electric cooperatives. A similar presentation was made at the Annual Meeting of the Management Advisory Council, National Rural Electric Cooperative Association, at Charleston, SC.

A utility update by OPALCO has appeared in three San Juan County newspapers. The content concerns the impact of zero-emission vehicle standards and related legislation on EV technology.

Pacific Gas and Electric Company (PG&E) - a public utility based in California's Bay Area, operates three G-Vans as part of its participation in the Site Operator Program (see Table 1). The overall program effort relates to many broad areas of interest in addition to vehicle testing and performance evaluation:

- Infrastructure R&D is concerned with charging systems and their load and distribution impacts.
- Joint efforts with the Bay Area Rapid Transit (BART) District reflect the benefits of increased usage of public transportation in the Bay Area.
- Collaboration with EPRI and the Electric Vehicle Association of the Americas is directed toward increased public awareness of EV technology and benefits.
- Cooperative efforts with California universities and other utilities are studying demand-side load management.
- PG&E, other utilities, and EPRI are working to establish a test protocol for human exposure to electromagnetic fields.
- Jointly with two other utilities, PG&E has applied to the California Public Utilities Commission for approval of special EV billing rates.
- PG&E is actively involved in the California Electric Vehicle Task Force, concerned with issues affecting EV commercialization. Other task force members represent utilities, private industry, and state regulatory agencies.
- PG&E is also participating in the efforts of the Infrastructure Working Council, a subgroup of EPRI. The membership of this organization represents automakers, utilities, code specialists, and other EV stakeholders, with the goal of a standard, safe, and reliable EV charging infrastructure.
- PG&E is a member of CALSTART, a consortium of more than 40 public and private entities mobilized to create an electric transportation industry in California and address related issues.

Technical

The second Ford Ecostar was received during the reporting period; the first Ecostar has operated successfully in tests and demonstrations for more than 1,700 miles.

PG&E signed a contract with the Clean Air Vehicle Technology Center (CAVTC) in Hayward, CA., to establish a fast-charge test facility at CAVTC. The facility will evaluate equipment performance, identify utility load impacts and test mitigating measures such as energy storage devices, develop standardized test protocols and reporting formats, and establish a national data source for fast-charge technology. The principal emphasis will be technical and economic.

Site Operator Program Quarterly Report

The Fast-Charge Testing Advisory Panel held its kick-off meeting during the reporting period. A special subcommittee of the Infrastructure Working Council (IWC), the Panel represents utilities, automakers, and battery manufacturers, and will review testing and safety procedures and reporting formats. A draft of the EMF measurement protocol for EVs and EV charging systems has been submitted to the IWC for review.

Evaluations of CEN, Spegel, and Inductrans chargers were completed last year. Three Hughes chargers – two curbside "pop-up" modules and an opportunity charging module – remain under test.

The Rapid Battery Interchange Program, sponsored by PG&E, CALTRANS, and the California Energy Commission (CEC), demonstrates rapid automated exchange of EV battery packs. The first two phases, a comprehensive economic analysis and system/vehicle design, are in progress. Road testing will depend on funding availability.

As part of the Utility System Impact Evaluation Program, PG&E is participating in a demand-side management evaluation to determine the load impacts of EVs. Four interrelated studies are involved:

- Pre-production vehicle trials
- EV installation evaluations
- Charging load research and infrastructure analysis
- Distribution impact assessments.

Another objective of this program is to

develop consumer preference models based on the results of consumer and fleet surveys. A phone/mail survey of 1,000 fleet operators is ongoing.

Planning and preliminary design have begun on constructing or retrofitting full-size transit buses with hybrid propulsion systems, as part of the CALSTART project with Santa Barbara County Air Pollution Control District (SBCAPCD). Two full-size transit buses will be constructed with hybrid propulsion systems. One bus will be a conversion; the second will be purpose-built throughout. In addition, three military buses from Vandenburg AFB, in two different capacities, will be retrofitted with hybrid propulsion systems. Arizona Public Service (APS) was selected as retrofit contractor, and the buses were provided for engineering review. The project objective is to advance CNG and EV technology on heavy-duty vehicles.

Public Awareness

The year-long demonstration of an internodal all-electric commute and a Hughes inductive charger was completed. The all-electric commute concept will be further demonstrated with the station car project at eight BART stations. This project, co-funded by the Bay Area Air Quality Management District, and the Department of Defense Advanced Research Projects Agency, will demonstrate 45 "station cars" in 1994. Vehicle and fleet service specifications have been finalized, and a procurement package for 45 vehicles prepared.

The Fleet Electric Vehicle and Narrow Lane Vehicle (NLV) projects have been merged. The NLV, no wider than 52 inches, will permit CALTRANS to make two lanes in a single lane

of current width. Work is currently in the design phase. Motive, Inc., a division of International Auto Design, is the project contractor.

PG&E has agreed to participate in the General Motors Corporation PrEView customer evaluation program for the Impact IV passenger EV. Selection of 78 drivers is planned; infrastructure placement (electrical service and Hughes chargers) is being contracted.

Platte River Power Authority (PRPA) - operates two (2) electric vehicles (see Table 1) as part of its participation in the DOE Site Operator Program. PRPA, a political subdivision of the State of Colorado, maintains and operates facilities for generation and wholesale distribution of electrical energy to four Colorado municipalities: Estes Park, Fort

Collins, Longmont, and Loveland. The thrust of PRPA activities under this program is threefold:

- Conduct electric vehicle tests, evaluations, and demonstrations
- Investigate electric vehicle infrastructure issues
- In conjunction with Colorado State University, develop EV infrastructure components.

The vehicles are operated in a real-world environment, for personnel transport and public demonstrations.

Technical

Total mileage for the two vehicles during the reporting period was 1,102. Average trip

mileage was 12.6 and 13.1, respectively; maximum single-trip mileage, without opportunity charging, was 36 and 39, respectively. The vehicles were used primarily as pool vehicles within the PRPA fleet, but their limited range precluded the more frequent, longer than 40-mile trips. No maintenance was performed on either vehicle during the reporting period.

Five S-10 pickup conversions are on order from Spartan Motors, Inc.

The EVcorts are each equipped with an on-board load profile meter that automatically integrates AC energy used for charging, over 15-minute periods, and stores the load data for monthly download. Vehicle log sheets completed by the operator insure that no charge data are lost.

Public Awareness

Public demonstrations of the two vehicles during the quarterly reporting period included:

- Rocky Mountain Home Show (Denver)
- Rocky Mountain Technology Exposition (Denver)
- Fort Collins Department of Natural Resources
- Colorado Air Quality Control Commission
- Platte River Integrated Resource Plan public input forums
- A delegation of electric utility dignitaries from People's Republic of China

Site Operator Program Quarterly Report

- Earth Day activities

Presentations were made by the PRPA planning engineer as follows:

- "Fueling the Future Transportation Community, an Electric Utility Perspective," at the Rocky Mountain Technology Exposition.
- "Electricity as an Alternative Fuel," to the Colorado Air Quality Control Commission.

Potomac Electric Power Company (PEPCO) - At the present time, PEPCO in Washington, DC, operates three EVs in the Site Operator Program (see Table 1). The principal use is fleet service. PEPCO's primary interest in electric vehicles is sale of electric power for battery charging.

Technical

The Solectria Force was driven 191 miles during the reporting period (January through March). Energy measurements are not available because of extensive un-metered opportunity charging.

The G-Van was not driven during the reporting period due to a combination of bad weather and battery problems.

Public Awareness

The Solectria Force was demonstrated at three different schools, at the Minority Business Trade Show, and at the Government Services Administration Conference.

PEPCO supported two local area high schools in the Mid-Atlantic High School Electric Vehicle Challenge. The goal is to acquire and convert an ICE vehicle to electric and participate in a race, and to make a presentation on design and development of the conversion.

PEPCO is participating in an industry commercialization initiative, EV-America. The goals are at least 500 EVs to be procured for fleet and demonstration service by the end of 1995, and 5,000 by the end of 1997.

Sandia National Laboratory (SNL) - at Albuquerque, NM is no longer involved with the DOE Site Operator Program, but contact with the SNL Electric Vehicle Program continues, with reciprocal information sharing. The reporting period for SNL is Calendar Year 1993.

Seven "Electricas" (Ford Escort conversions) have been in service since 1981; four additional vehicles were obtained from the U.S. Navy, refurbished, and put into service in November 1987. A twelfth Electrica (1983 model) obtained from Public Service Company of New Mexico, was placed in service during September 1993. SNL has operated these vehicles on a daily basis in missions that vary from benign to very hard.

Technical

Cumulative mileage now exceeds 100,000, with an accident-free record. A preventative maintenance program for the fleet, implemented in CY-90, checks each vehicle at 6 to 8 week intervals. Repairs and replacements are made as needed. A survey shows the following problems, in decreasing order:

Site Operator Program Quarterly Report

- Failure of the 12-volt auxiliary battery from heavy accessory drain causes the speed controller to lose logic. A modified charging algorithm to maintain the traction and auxiliary batteries independently, coupled with an efficient DC-to-DC converter, appears to be needed.
- Failure of the state-of-charge system causes vehicle stranding. Original units by Anderson are no longer available, and a candidate replacement by Curtis Instruments requires modification before operation on the Electrica 96-volt system. Two such units have been ordered, for in-vehicle testing. Seven vehicles now have defective state-of-charge units.
- Exhaust fan failures are caused by corrosive vapors from the battery compartment.
- Logic board component aging causes shut-off failures in the charging cycle. Replacement boards are no longer commercially available. A Sandia-made replacement was not successful, but development work continues.
- Faulty micro-switch in the power brake pressure sensing unit fails in the "ON" position. Additional battery drain occurs, but no safety problem is involved.
- The consequences of vehicle aging and wear are becoming obvious.

Public Awareness

SNL has addressed environmental safety and health issues associated with EV operation in a document "ES&H Standard Operating Procedure for the Electric Vehicle - Electrica," and a supplement, "Electrica Operating and Safety Manual."

Southern California Edison Company (SCE) - an electric utility, currently operates and maintains 24 electric vehicles as part of its participation in the DOE Site Operator Program (see Table 1). The SCE effort involves major roles in electric vehicle and component testing/evaluation, battery technology development, recharge infrastructure development, demand-side management, and overall technological leadership in meeting the air quality and transportation requirements of the area.

In filling the final role, SCE shares its technical expertise and test results with two California regulatory agencies: The South Coast Air Quality Management District and the California Air Resources Board. The results of this continuing cooperation can be seen in the electric shuttle operated by several Southern California cities and technical assistance in feasibility studies of truck and bus conversions.

SCE also provides support at many levels to the CALSTART program, which is intended to position California "high tech" industries in a leadership role as developers and suppliers of EV-related products. In the Site Operator Program, CALSTART's participation ranges from battery recycling processes and vehicle/infrastructure testing to promoting public interest in zero-emission vehicles.

Site Operator Program Quarterly Report

The Research, Development, and Demonstration Department of SCE has the primary responsibility for carrying out the tasks covered by the Site Operator Program. In turn, it has access to the necessary corporate resources and facilities/manpower.

Technical

Cumulative EV mileage to date exceeds 240,000. SCE continues to expand its EV fleet. Thus far, G-Vans (15) constitute the majority of the current fleet and are the basis for most of the operating and experience data. A lease for six Ford Ecostars has been executed, with delivery of five to date. On-going discussions with Ford and the U.S. Postal Service concern an additional six Ecostars for mail service. SCE is also planning participation in school bus conversions to electric operation. As appropriate, the foregoing vehicles will be incorporated into the Site Operator Program.

Per DOE request, G-Van operating data will no longer be included in the Site Operator Program Quarterly Reports.

Existing vehicles are variously assigned, comprising company field operations, vehicle and component research, public events, and infrastructure development. SCE plans to loan vehicles to outside users on a continuing basis, when appropriate to SCE and program purposes. Loan agreements with several companies have been finalized.

Vehicle and component testing by SCE or on contract serves not only to identify technical advances and problems, but also provides essential input to planning and operating the electric utility system.

The current SCE report presents an overview of their planned and on-going EV evaluation program for the period 1993 through 1997. Preliminary characterization testing of the first Ford Ecostar, completed during the previous quarter, is a part of that program.

Four additional Ecostars were placed in service during this quarter, and have accumulated approximately 4,500 miles. Two are assigned to SCE field service, and two to the infrastructure program.

Performance characterization of an AC Propulsion ELX was completed in this quarter. The vehicle, owned by South Coast Air Quality Management District, was tested with both original and up-graded deep-cycle sealed lead-acid batteries.

Maintenance logs indicate a spread of mechanical and electrical operating problems with both vehicles and associated service equipment. However, the most common problems continue to be electrical, related to either the battery pack or the charger.

During FY-93, SCE participated in the "Group Buy" proposal evaluation for mini- and mid-sized converted pickup trucks. Two purchase orders have since been awarded for the program as a whole: GE-Spartan Motors, for 22 units, and Electricar-Hughes, for 20 units. Vehicle specifications require a manufacturer-installed Mobile Data Acquisition System (MDAS) from Sigma Tec Systems, Tampa, FL, in each. SCE has ordered three units from each supplier.

Public Awareness

SCE has loaned electric vehicles from its fleet to other companies and individuals operating within the SCE service territory, in order to determine what types of customers might buy EVs, how such EVs might be used and recharged, and how vehicle performance affects usage. This information will permit SCE to develop and implement the electric utility infrastructure needed for widespread commercial deployment of EVs. Four G-Vans are currently on loan:

- Federal Express (2)
- Miller Brewing Co.
- City of Fountain Valley

As part of the Infrastructure Program, SCE provides guest speakers for local organizations upon request. Electric vehicles and their benefits are a popular topic.

SCE is also involved with the EV fleet activities of other entities operating within the utility's service territory, and is currently participating with CALSTART in the conversion of two school buses to electric. These units are now in service in the Santa Barbara and Santa Monica areas.

Texas A&M University (TAMU) - conducts a Site Operator Program at its Center for Electrochemical Systems and Hydrogen Research, Texas Engineering Experiment Station, College Station, TX. The current complement of electric vehicles comprises 25 passenger and cargo vehicles (see Tables 1 and 2) and two zinc-bromine race cars. The ultimate thrust of the Program is education (i.e., graduate school support). The vehicles are in regular local fleet use except for two G-Vans

that are used as demos in Houston (by EPRI) and Austin (by Lower Colorado River Authority), respectively.

The South Central Electric Vehicle Consortium (SCEVC), based at TAMU, supports the TAMU Electric Vehicle Program and also brings together EV fleet owners and operators throughout Texas and Oklahoma.

Technical

Mileage accumulation to date on TAMU G-Van vehicles exceeds 132,000. Some of the G-Vans are not currently in service due to reduced range and other minor problems. A new maintenance contractor, Electric Transportation Services, Inc. (ETSI), with the help of EPRI, is providing parts, batteries, and service for G-Vans. ETSI claims that use of a high-frequency, low-current charging regimen has improved G-Van operating range from 40 to 60 miles. It is hoped that the ETSI capabilities and technical approaches will increase G-Van reliability and restore some now out of service to regular use.

TAMU has had a wide variety of problems, on a continuing basis, with the Chrysler TEVans and their operation. The principal problems relate to:

- Battery functions and maintenance
- Widely variable vehicle range
- Controller and APC failure rates
- Other vehicle operation and monitoring systems

Communication with Chrysler in an effort to identify and implement solutions to these problems is seen as less than successful. EPRI

Site Operator Program Quarterly Report

supports and subsidizes TEVan operations, and has attempted to mediate between Chrysler and the TEVan owners, without obtaining (to date) the necessary commitments from Chrysler.

Three S-10 conversions, with MDAS units installed, are now on order from U.S. Electricar. Delivery should start toward the end of the final quarter of FY-94.

Public Awareness

The Governor of Texas, Ann Richards, came to College Station on April 28 for the "Capital of the Day" event. Personnel of TAMU's Center for Electrochemical Systems and Hydrogen Research gave her an overview of EV activities at the Center and highlighted the DOE support through the Site Operator Program. The Center's G-Van was used by the Governor and her advisors to conduct their entire day's business in the area.

U.S. Navy (NAVY) - As noted in Table 1, the U.S. Navy installation at Port Hueneme, CA, has a large complement of electric vehicles, representing several manufacturers and body styles, and a broad span of vehicle ages. The principal thrust of this Navy operation is fleet evaluation. The current age span of their EV inventory contributes substantially to a vehicle experience (rather than test) data summary.

Technical

Initial contributions of fleet operating and maintenance data are reported in the Program Experience Overview section of this report. No other input was received for this quarter.

The University of South Florida (USF) - at Tampa, monitors and tests ten electric vehicles as a participant in the DOE Site Operator Program (see Table 1). The principal collaborating organizations are Florida Power Corp. (FPC), Tampa Electric Co., Hillsborough County, and the City of Tampa. The purpose of the USF effort is to determine EV efficiency under commuter and fleet conditions in Florida. A part of the effort is the development of a utility-interconnected photovoltaic EV charging system. Additional associations include Florida Power and Light Co., Florida Energy Office, Naval Weapons Center, GTE Mobilnet, and National Renewable Energy Laboratory.

Technical

The reported vehicle inventory comprises:

- Two G-Vans
- Seven Chevrolet S-10 conversions
 - One operated by Pinellas County Air Quality Office
 - One operated by Bruderly Engineering Associates of Gainesville.
 - One operated by Jacksonville Air Quality Division
 - Two in use at USF by the Electrical Engineering Department

Site Operator Program Quarterly Report

- One operated by Hillsborough County Environmental Protection Commission
- One operated by Orlando Air Quality
- One Mitsubishi Mirage conversion, in use at USF for light delivery and commuter service.
- One Solectria Force, received February 22nd.
- University of South Florida
- Bruderly Engineering
- City of Jacksonville
- City of Tampa
- Orange County
- Pinellas County
- Volusia County
- Hillsborough County
- Florida Power Corp.

Cumulative mileage exceeds 21,000. A Chevrolet S-10 pickup is on order, for EV conversion at Spartan Motors.

The overall USF plan is to locate site operators and participating vehicles throughout the State of Florida. Collection of performance data from such a widespread territory and a varied spectrum of driving cycles is greatly simplified by the Mobile Data Acquisition System (MDAS). Its hardware and software, while standardized, offer wide flexibility in measurement capability. As currently used in a G-Van, a Mirage, and three S-10s, it monitors main battery pack voltage, current, and temperature; and in addition, EV velocity, cab temperature, and ambient temperature, all relevant to optimum EV use in the Florida climate. Other options for specific EV types or models are being evaluated by the USF EV research group. An Automatic Data Retrieval System (ADRS) acquires the MDAS output via cellular or land-line telephones for processing and analysis by computers at USF, and subsequent distribution. To date, MDAS units have been installed in electric vehicles owned or operated by:

Data from additional EVs acquired and operated in the Tampa/St. Petersburg metro area by Florida Power Corp. will be included in the USF database. Other operators contributing to this database will be located in the counties of Alachua, Volusia, Pinellas, Dade, Polk, Duval, Brevard, and Orange.

An S-10 hybrid conversion, to be operated by Dade County, has been fitted with an MDAS, with independent back-up battery. The back-up, needed when the auxiliary generator is started, is diode-isolated, but can be charged by the on-board DC-DC converter. The vehicle is powered by sealed GNB lead-acid batteries.

An alternate fuel vehicle is also being monitored as part of the USF effort. A Dodge "Spirit," owned by Florida Power Corp., is equipped to burn either unleaded gasoline or compressed natural gas, under driver control. An MDAS and appropriate sensors have been installed, permitting a real-time comparison of fuel economy in each mode.

Development work is in progress on a second-generation MDAS design, substantially smaller, but also more rugged. This system will be installed in an S-10 conversion for Lee County Electric Cooperative.

Site Operator Program Quarterly Report

Four Automatic Data Retrieval Systems (ADRS) were installed, in a G-Van and in three S-10 pickup conversions.

On-going data processing activities relate to:

- Vehicle operation data for the past year, to find an optimal compression algorithm.
- Development of a standard data presentation interface.

An expanded version of EV-SOFT, featuring control by graphical interface, has been completed and is ready for release and use in EV operating data analysis.

The photovoltaic charging system is in operation. Four source circuits accommodate the DC-DC controller for direct charging the S-10 pickup batteries. All source circuits are interconnected to the electric utility grid, via a microprocessor-controlled inverter. An automatic photovoltaic data acquisition system acquires data (voltage, current, temperature, and irradiance) from the arrays to analyze and compare the performance and effectiveness of each array, as well as overall performance.

Reconfiguration of source circuit components now allows current control by 3.2 ampere multiples, up to 41.6 A. This arrangement provides for a relatively smooth charging curve, particularly in the current-controlled charging regimen for the last 20 to 30% of charge. The charging rate is maximized and the effects of irradiance fluctuations are minimized. Charging rate control is based on a calculated battery gassing voltage.

DC-DC sun-charging shows an overall efficiency exceeding 93%. However, the less efficient AC-DC operation may be required under conditions of low or no sunlight. The data acquisition system for the photovoltaic charging site has been integrated with the DC-DC charging software, and the resulting system will be referred to as DC-DAS. Analysis of the data permits an evaluation of the strengths and the deficiencies of DC-DC and DC-AC-DC charging methods.

Public Awareness

- A paper, "*Direct DC-DC Electric Vehicle Charging With a Utility-Interconnected Photovoltaic System*," was presented at the 12th European Photovoltaic Conference in Amsterdam, Netherlands.
- USF and Florida Power Corp. are involved in conceptual design efforts related to EV use and necessary infrastructure for the Disney Celebration project.
- USF personnel continue participation in efforts sponsored by Advanced Research Projects Agency, with the Southern Coalition for Advanced Transportation.
- The Solectria was displayed at schools and Polk County Earth Day Festivities.
- Representatives of several manufacturers toured the USF Clean Energy and Vehicle Research Center, and discussed potential joint development projects.

York Technical College (YORK) - at Rock Hill, SC operates 11 electric vehicles under the Site Operator Program (see Table 1). Interest in EV technology at YORK goes beyond the nominal Program scope and is well demonstrated by the school's growing Electric Vehicle Program and emphasis on public awareness. Programmatic associations and interchanges continue with local electric utilities, other Program participants, municipalities, South Carolina State Energy Office, regional secondary schools and colleges, and the Clean Air Transport Association.

Technical

- An order has been placed for two S-10 pickup truck conversions from U.S. Electricar.
- The VW pickup truck owned by Palmetto Electric Co-op has been repaired, tested, and returned to service at Hilton Head Island.
- Work continued on the nickel-cadmium powered Escort project:
 - Battery cycling and charger profiling
 - DC-DC converter replacement and rewiring
 - Accelerator control problems
 - Operating range tests.
- A variety of maintenance, repairs, and subsequent performance tests were made on other EVs within the YORK Program.

- Work began on installation of a 20 kW DC converter in the EV laboratory. The installation of line voltage transformer equipment in the lab has measurably increased traction battery charging efficiency.
- Preparation of electric vehicles for exhibit at various locations continued.

Public Awareness

- Two YORK employees participated as EV technical inspectors and judges at the EV Grand Prix in Richmond, VA. This high-school-level racing competition was sponsored by Virginia Power Co., the U.S. Department of Energy, and Edison Electric Institute.
- A number of EV-related presentations and vehicle displays took place, both on and off campus, at high-school and college levels. Several municipal and electric utility exposures of the YORK EV Program were achieved. A major public exposure of YORK's EV Program took place at North Carolina State University: the "*Powering a Cleaner Environment*" event. Electric vehicles, video tapes, and a static display were used.
- Discussions took place with Virginia Power Co. regarding deliverables for a four-day training workshop for electric vehicle technicians.
- Several presentations, demonstrations, and tours were given to junior high, high school, and college students in the area.

APPENDIX B

SITE OPERATOR DATA TABLES

Table A-1. Site Operator vehicle operations summary (assumed rate: \$0.07/kWh).

Site	Miles Traveled	kW·h Used	Mi/kW·h	kW·h/Mi	\$/Mi
G-Van Operations					
KSU	11,537.00	14,674.00	0.79	1.27	\$0.09
PG&E	11,048.60	10,649.60	1.04	0.96	\$0.07
PSE&G	30,659.00	29,124.00	1.05	0.95	\$0.07
USF	12,729.10	14,073.40	0.90	1.11	\$0.08
YORK	1,336.00	1,116.80	1.20	0.83	\$0.06
Total	67,309.70	69,637.80	0.97	1.03	\$0.07
Mean	13,461.94	13,927.56	.97	1.03	\$0.07
Maximum	1,336.00	1,116.80	1.20	0.83	\$0.06
Minimum	11,537.00	14,674.00	0.79	1.27	\$0.09
Escort Operations					
PG&E	1,077.00	576.60	1.87	0.53	\$0.04
YORK	467.00	263.00	1.78	0.56	0.04
Total	1,544.00	839.60	1.84	0.54	\$0.04
Chevy S-10 Operations					
USF	10,058.00	5,557.40	1.81	0.55	\$0.04
VW Pickup Operations					
YORK	1,002.00	932.70	1.07	0.93	\$0.07
Griffon Van					
YORK	4,650.00	10,512.30	0.44	2.27	\$0.16
Mitsubishi Mirage					
USF	1,605.00	1,314.30	1.22	0.82	\$0.06
Total	1,605.00	1,314.30	1.22	0.82	\$0.06
GRAND TOTAL	86,168.70	88,794.10	0.97	1.03	\$0.07

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
KANSAS STATE UNIVERSITY	150 G-Van-P			
Qtr 4		243.40	584.00	0.42
FY-91 Totals		243.40	584.00	0.42
Qtr 1		2,000.10	2,467.00	0.81
Qtr 2		1,804.80	2,283.00	0.79
Qtr 3		2,790.40	2,973.00	0.94
Qtr 4		1,924.00	2,314.00	0.83
FY-92 Totals		8,519.30	10,037.00	0.85
Qtr 1		1,109.60	1,384.00	0.80
Qtr 2		1,027.30	1,514.00	0.68
Qtr 3		637.40	1,155.00	0.55
FY-93 Totals		2,774.30	4,053.00	0.68
GRAND TOTAL FOR SITE		11,537.00	14,674.00	0.79
PACIFIC GAS & ELECTRIC	301 G-Van-P			
Qtr 1		372.00	761.00	0.49
Qtr 2		267.00	260.00	1.03
Qtr 3		393.00	562.00	0.70
Qtr 4		472.00	670.00	0.70
FY-92 Totals		1,504.00	2,253.00	0.67
Qtr 2		267.00	159.30	1.68
Qtr 3		124.00	46.30	2.68
Qtr 4		154.20	46.50	3.32
FY-93 Totals		545.20	252.10	2.16
Grand total for vehicle		2,049.20	2,505.10	0.82
	302 G-Van-P			
Qtr 2		240.00	270.00	0.89
Qtr 3		834.00	1,116.20	0.75
Qtr 4		413.00	946.00	0.44
FY-92 Totals		1,487.00	2,332.20	0.64
Qtr 2		224.00	15.00	14.93
Qtr 3		410.00	149.00	2.75

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
Qtr 4		678.00	1,015.30	0.67
FY-93 Totals		1,312.00	1,179.30	1.11
Qtr 1		334.40	312.00	1.07
FY-94 Totals		334.40	312.00	1.07
Grand total for vehicle		3,133.40	3,823.50	0.82
	303 G-Van-P			
Qtr 1		1,059.00	1,146.50	0.92
Qtr 2		852.00	743.00	1.15
Qtr 3		790.00	933.00	0.85
Qtr 4		911.00	1,139.00	0.80
FY-92 Totals		3,612.00	3,961.50	0.91
Qtr 2		771.00	247.00	3.12
Qtr 3		484.00	110.50	4.38
Qtr 4		658.30	2.00	329.15
FY-93 Totals		1,913.30	359.50	5.32
Qtr 1		340.70	.00	.00
FY-94 Totals		340.70	.00	.00
Grand total for vehicle		5,866.00	4,321.00	1.36
	304 Ford Ecostar			
Qtr 1		1,077.00	576.60	1.87
FY-94 Totals		1,077.00	576.60	1.87
Grand total for vehicle		1,077.00	576.60	1.87
GRAND TOTAL FOR SITE		12,125.60	11,226.20	1.08
PUBLIC SERV. ELEC. & GAS	454 G-Van-P			
Qtr 1		641.00	997.00	0.64
Qtr 2		963.00	1,131.00	0.85
Qtr 3		831.00	1,138.00	0.73
Qtr 4		548.00	541.00	1.01
FY-92 Totals		2,983.00	3,807.00	0.78
Qtr 1		191.00	196.00	0.97
Qtr 2		85.00	104.00	0.82

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
Qtr 3		1,139.00	1,058.00	1.08
FY-93 Totals		1,415.00	1,358.00	1.04
Grand total for vehicle		4,398.00	5,165.00	0.85
	455 G-Van-C			
Qtr 1		20.00	52.00	0.38
Qtr 2		182.00	298.00	0.61
Qtr 3		1,001.00	589.00	1.70
Qtr 4		1,606.00	861.00	1.87
FY-92 Totals		2,809.00	1,800.00	1.56
Qtr 1		387.00	265.00	1.46
Qtr 2		205.00	125.00	1.64
Qtr 3		983.00	873.00	1.13
FY-93 Totals		1,575.00	1,263.00	1.25
Grand total for vehicle		4,384.00	3,063.00	1.43
	456 G-Van-C			
Qtr 1		105.00	226.00	0.46
Qtr 2		371.00	494.00	0.75
Qtr 3		303.00	336.00	0.90
Qtr 4		1,198.00	912.00	1.31
FY-92 Totals		1,977.00	1,968.00	1.00
Qtr 1		773.00	1,129.00	0.68
Qtr 3		1,815.00	239.00	7.59
FY-93 Totals		2,588.00	1,368.00	1.89
Grand total for vehicle		4,565.00	3,336.00	1.37
	457 G-Van-C			
Qtr 1		183.00	221.00	0.83
Qtr 2		635.00	599.00	1.06
Qtr 3		396.00	289.00	1.37
Qtr 4		367.00	426.00	0.86
FY-92 Totals		1,581.00	1,535.00	1.03
Qtr 1		301.00	355.00	0.85

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
Qtr 3		479.00	940.00	0.51
FY-93 Totals		780.00	1,295.00	0.60
Grand total for vehicle		2,361.00	2,830.00	0.83
	458 G-Van-C			
Qtr 1		270.00	448.00	0.60
Qtr 2		529.00	909.00	0.58
Qtr 3		879.00	935.00	0.94
Qtr 4		1,198.00	1,052.00	1.14
FY-92 Totals		2,876.00	3,344.00	0.86
Qtr 1		217.00	411.00	1.43
Qtr 2		149.00	276.00	1.03
FY-93 Totals		366.00	687.00	0.53
Grand total for vehicle		3,242.00	4,031.00	0.80
	459 G-Van-C			
Qtr 1		288.00	272.00	1.06
Qtr 2		1,566.00	1,779.00	0.88
Qtr 3		297.00	327.00	0.91
Qtr 4		640.00	650.00	0.98
FY-92 Totals		2,791.00	3,028.00	0.92
Qtr 1		568.00	842.00	0.67
Qtr 2		473.00	642.00	0.74
Qtr 3		714.00	776.00	0.92
FY-93 Totals		1,755.00	2,260.00	0.78
Grand total for vehicle		4,546.00	5,288.00	0.86
	460 G-Van-C			
Qtr 1		171.00	55.00	3.11
Qtr 2		571.00	605.00	0.94
Qtr 3		627.00	207.00	3.03
Qtr 4		1,293.00	601.00	2.15
FY-92 Totals		2,662.00	1,468.00	1.81
Qtr 1		597.00	634.00	0.94

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW·h Used	Mi/kW·h
Qtr 2		151.00	240.00	0.63
Qtr 3		499.00	500.00	1.00
FY-93 Totals		1,247.00	1,374.00	0.91
Grand total for vehicle		3,909.00	2,842.00	1.38
	461 G-Van-C			
Qtr 1		24.40	55.00	0.44
Qtr 2		336.90	354.00	0.95
Qtr 3		701.00	581.00	1.21
Qtr 4		1,468.00	792.00	1.85
FY-92 Totals		2,530.30	1,782.00	1.42
Qtr 1		180.00	233.00	0.77
Qtr 3		544.00	254.00	2.14
FY-93 Totals		724.00	487.00	1.49
Grand total for vehicle		3,254.30	2,269.00	1.43
GRAND TOTAL FOR SITE		30,659.00	29,124.00	1.05
UNIV. OF SOUTH FLORIDA	650 G-Van-P			
Qtr 3		1,056.60	1,319.30	0.80
Qtr 4		648.00	1,002.00	0.65
FY-92 Totals		1,704.60	2,321.30	0.73
Qtr 1		988.00	829.00	1.22
Qtr 2		1,351.00	1,890.00	0.71
Qtr 3		981.00	635.00	1.54
Qtr 4		888.00	769.00	1.15
FY-93 Totals		4,208.00	4,123.00	1.02
Qtr 1		514.00	183.00	2.81
Qtr 2		526.00	240.00	2.19
FY-94 Totals		1,040.00	423.00	2.46
Grand total for vehicle		6,952.60	6,867.30	1.01
	651 G-Van-P			
Qtr 3		747.50	1,011.00	0.74
Qtr 4		582.00	959.00	0.61

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW·h Used	Mi/kW·h
FY-92 Totals		1,329.50	1,970.00	0.67
Qtr 1		1,073.00	1,393.70	0.77
Qtr 2		11.00	48.00	0.23
Qtr 3		924.00	1,313.00	0.70
Qtr 4		732.00	967.00	0.76
FY-93 Totals		2,722.00	3,706.10	0.73
Qtr 1		776.00	630.00	1.23
Qtr 2		949.00	900.00	1.05
FY-94 Totals		1,725.00	1,530.00	1.13
Grand total for vehicle		5,776.50	7,206.10	0.80
	652 Chevy S-10			
Qtr 4		640.00	538.00	1.19
FY-92 Totals		640.00	538.00	1.19
Qtr 1		403.00	351.00	1.15
Qtr 2		1,162.00	798.00	1.46
Qtr 3		726.00	290.00	2.50
Qtr 4		963.00	609.00	1.58
FY-93 Totals		3,254.00	2,048.00	1.59
Qtr 1		1,276.00	405.50	3.15
Qtr 2		810.00	420.00	1.93
FY-94 Totals		2,086.00	825.50	2.53
Grand total for vehicle		5,980.00	3,411.50	1.75
	653 Chevy S-10			
Qtr 4		155.00	187.00	0.83
FY-92 Totals		155.00	187.00	0.83
Qtr 1		1,298.00	1,043.90	1.24
Qtr 2		770.00	443.00	1.74
Qtr 3		883.00	472.00	1.76
FY-93 Totals		2,901.00	1,958.90	1.48
Qtr 2		1,022.00	.00	.00
FY-94 Totals		1,022.00	.00	.00

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
Grand total for vehicle		4,078.00	2,145.90	1.90
	654 Mitsubishi Mirage			
Qtr 3		35.00	6.00	5.83
Qtr 4		164.00	76.00	2.16
FY-93 Totals		199.00	82.00	2.43
Qtr 1		961.00	896.20	1.07
Qtr 2		445.00	336.10	1.32
FY-94 Totals		1,406.00	1,232.30	1.14
Grand total for vehicle		1,605.00	1,314.30	1.22
GRAND TOTAL FOR SITE		24,392.10	20,945.10	1.16
YORK TECHNICAL COLLEGE	402 Escort			
Qtr 1		87.00	104.00	0.84
Qtr 2		128.00	134.00	0.96
Qtr 3		82.00	.00	.00
Qtr 4		82.00	.00	.00
FY-93 Totals		379.00	238.00	1.59
Qtr 1		59.00	.00	.00
Qtr 2		29.00	25.00	1.16
FY-94 Totals		88.00	25.00	3.52
Grand totals for vehicle		467.00	263.00	1.78
	406 VW Pickup			
Qtr 1		22.00	13.90	1.58
Qtr 2		.00	.00	.00
FY-94 Totals		22.00	13.90	1.58
Grand totals for vehicle		22.00	13.90	1.58
	407 VW Pickup			
Qtr 2		228.00	196.00	1.16
Qtr 3		553.00	395.50	1.40
Qtr 4		127.00	267.30	0.48
FY-93 Totals		908.00	858.80	1.06
Qtr 1		72.00	60.00	1.20

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
FY-94 Totals		72.00	60.00	1.20
Grand totals for vehicle		980.00	918.80	1.07
	412 Griffon Van			
Qtr 2		77.00	79.00	0.97
Qtr 3		210.00	226.00	0.93
Qtr 4		6.00	.00	.00
FY-92 Totals		293.00	305.00	0.96
		837.00	768.90	1.09
FY-93 Totals		837.00	768.90	1.09
Qtr 1		204.00	.00	.00
FY-94 Totals		204.00	.00	.00
Grand totals for vehicle		1,334.00	1,073.90	1.24
	413 Griffon Van			
Qtr 3		199.00	189.00	1.05
Qtr 4		487.00	623.00	0.78
FY-92 Totals		686.00	801.00	0.86
Qtr 1		339.00	419.00	0.81
Qtr 2		238.00	334.00	0.71
Qtr 3		479.00	721.00	0.66
Qtr 4		77.00	1,186.00	0.06
FY-93 Totals		1,133.00	2,660.00	0.43
Grand totals for vehicle		1,819.00	3,472.00	0.52
	414 Griffon Van			
Qtr 2		70.00	3.00	23.33
Qtr 3		154.00	264.00	0.58
FY-92 Totals		224.00	267.00	0.84
Grand totals for vehicle		224.00	267.00	0.84
	415 Griffon			
Qtr 2		185.00	448.00	0.41
Qtr 3		175.00	370.00	0.47
Qtr 4		389.00	486.00	0.80

Table A-2. Operations breakdown by site and vehicle

Site Operator	Veh No.	Miles Traveled	kW-h Used	Mi/kW-h
FY-92 Totals		749.00	1,304.00	0.57
Qtr 1		286.00	858.00	0.33
Qtr 2		226.00	2,889.40	0.08
Qtr 3		12.00	648.00	0.02
FY-93 Totals		524.00	4,395.40	0.12
Grand totals for vehicle		1,273.00	5,699.40	0.22
	418 G-Van-P			
Qtr 4		567.00	641.00	0.88
FY-93 Totals		567.00	641.00	0.88
Qtr 1		295.00	107.00	2.76
Qtr 2		382.00	336.80	1.13
Qtr 3		92.00	82.00	1.12
FY-94 Totals		769.00	525.80	1.46
Grand totals for vehicle		1,336.00	1,116.80	1.15
GRAND TOTAL FOR SITE		7,455.00	12,824.80	0.58

Table A-3. Site Operator electric vehicle maintenance event summary.

Veh. Type	G Vans		Chevy S-10		Escort		VW Pickup	
Maint Code	No.	Lab Hr	No.	Lab Hr	No.	Lab Hr	No.	Lab Hr
00-07	7	13.20	—	—	1	1.50	—	—
10-18	4	4.20	—	—	—	—	—	—
20-27	—	—	3	11.00	—	—	1	5.00
30-39	3	2.70	1	2.00	—	—	—	—
40-49	17	35.40	2	4.00	7*	17.30*	4*	33.00*
90-93	33	26.80	—	—	1	1.50	—	—
Totals	64	82.30	6	17.00	9	20.30	5	38.00
Maintenance Codes: 00-07 Air Conditioning, Body, and Instrumentation 10-18 Chassis 20-27 Drivetrain 30-39 Electrical/Auxiliary 40-49 Electrical/Traction 90-93 Other (i.e., state-of-charge meter, watering system, data acquisition equipment)								

* Exceptional items deleted from the analyses and Figures 2 through 7.

Table A-4. Maintenance event breakdown by site.

KANSAS STATE UNIVERSITY								
Veh. Type	G Vans		Chevy S-10		Escort		VW Pickup	
Maint Code	No.	Lab Hr	No.	Lab Hr	No.	Lab Hr	No.	Lab Hr
00-07	4	0.60						
10-18	4	4.20						
20-27	—	—						
30-39	3	2.70						
40-49	10	10.40						
90-93	30	20.30						
Site Total	51	38.20						
UNIVERSITY OF SOUTH FLORIDA								
00-07	—	—	—	—				
10-18	—	—	—	—				
20-27	—	—	3	11.00				
30-39	—	—	1	2.00				
40-49	2	6.00	2	4.00				
90-93	—	—	—	—				
Site Total	2	6.00	6	17.00				
YORK TECHNICAL COLLEGE								
00-07	3	12.60	—	—	1	1.50	—	—
10-18	—	—	—	—	—	—	—	—
20-27	—	—	—	—	—	—	1	5.00
30-39	—	—	—	—	—	—	—	—
40-49	5	19.00	—	—	7*	17.30*	4*	33.00*
90-93	3	6.50	—	—	1	1.50	—	—
Site Total	11	38.10	—	—	9	20.30	5	38.00
GRAND TOTAL	64	82.30	6	17.00	9	20.30	5	38.00

* Exceptional items deleted from the analyses and Figures 2 through 7.