

August 1995



RECEIVED

NOV 21 1995

OSTI

**Electric and Hybrid Vehicle Program
Site Operator Program
Quarterly Progress Report for
January through March 1995
(Second Quarter of FY-95)**

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

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, makes 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.

*Electric and Hybrid Vehicle Program
Site Operator Program*

*Quarterly Progress Report
for January through March 1995
(Second Quarter of Fiscal Year 1995)*


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

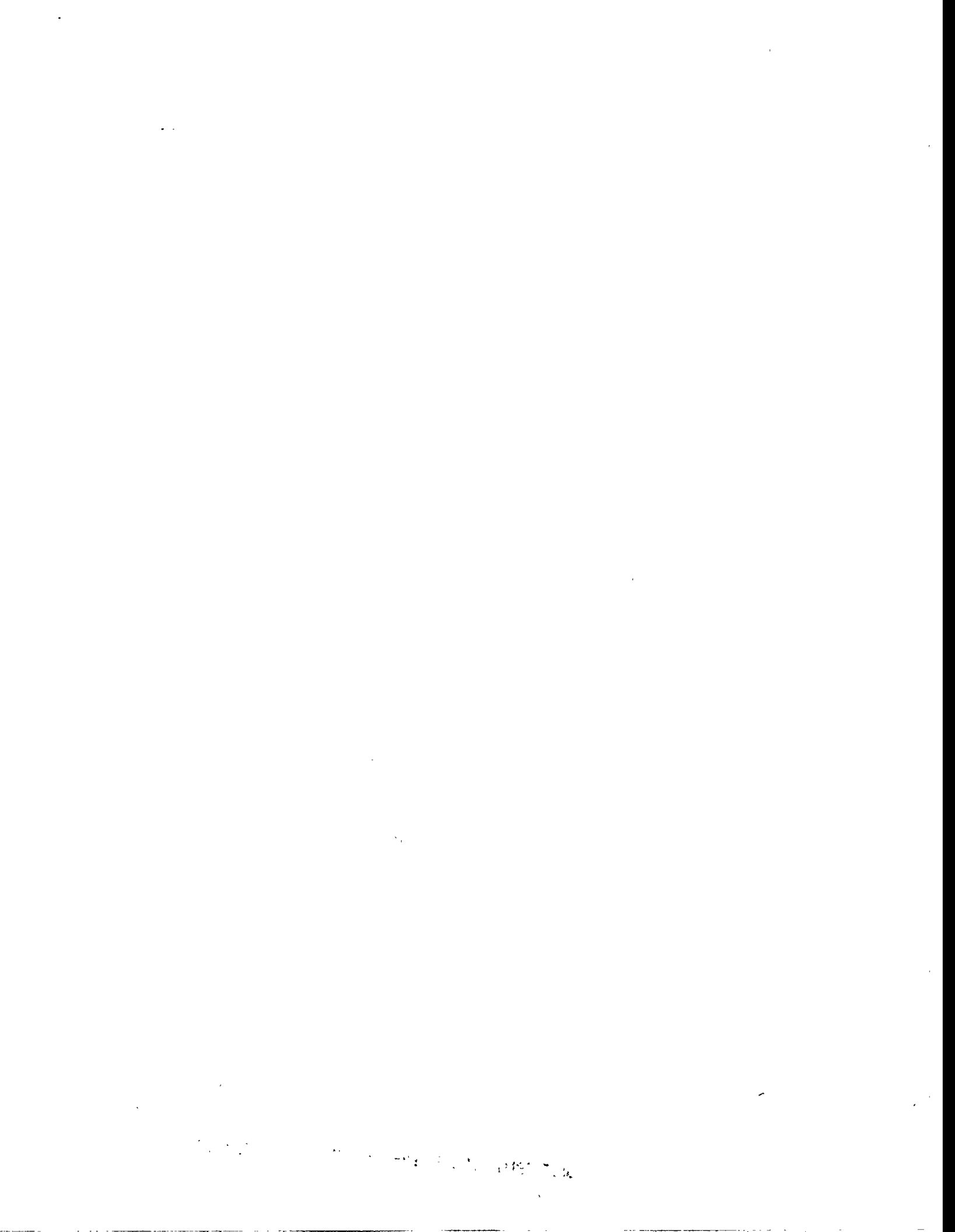
Published August 1995

*Idaho National Engineering Laboratory
Lockheed-Martin Idaho Technology
Idaho Falls, Idaho 83415*

*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*

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED 



Executive Summary

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.
- Conversion of conventional ICE-powered vehicles for electric vehicle usage imposes excessive loads on frames, suspensions, brakes, and tires. The consequence is a substantially reduced service life and increased maintenance requirements.

*Site Operator Program
Quarterly Report*

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. Similar laws have been adopted by Massachusetts and New York and are under consideration in other states.
- 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 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. Some problems with weight overload when converting a chassis designed for ICE power have begun to surface. In particular, the vehicle

frame and running gear components are often not adequate to carry the substantial load of batteries required, much less a usable payload in routine service. A redesign, from the ground up, of the basic vehicle appears necessary before EV service life will begin to approach that of conventional ICE vehicles.

The DOE "Group Buy" effort for S-10 pickup conversions fell short of completion. Approximately half of the 42 units ordered were delivered to Site Operator Program participants before orders were canceled and production discontinued by the two manufacturers. At this writing, no alternative source is available to fill existing demand for EV conversions within the Program.

- 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., Solectria and US Electricar) are presenting a variety of equipment and operational problems to the users.
- Further effort is needed in hybrid vehicle development to achieve the necessary operating performance and overall dependability.

- Batteries and charging equipment continue to present generic problems, even in otherwise proven EV systems. Fast-charge technology is now under active investigation with several options available, 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.

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, EVcort, and Chevrolet S-10 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
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) generally have better performance and maintenance records with the exception of the KSU vehicles. 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).

*Site Operator Program
Quarterly Report*

- An electric vehicle that is used sporadically will use more energy/mile than one that is used more often, and for longer trips at uniform speeds. 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.
 - Effective solar charging has regional limitations, but may be economically feasible when surplus power can be sold via a grid connection.

- Routine maintenance costs are comparable for the four (4) types of vehicles reported, although major maintenance needs can make this difficult to detect.

Recommendations

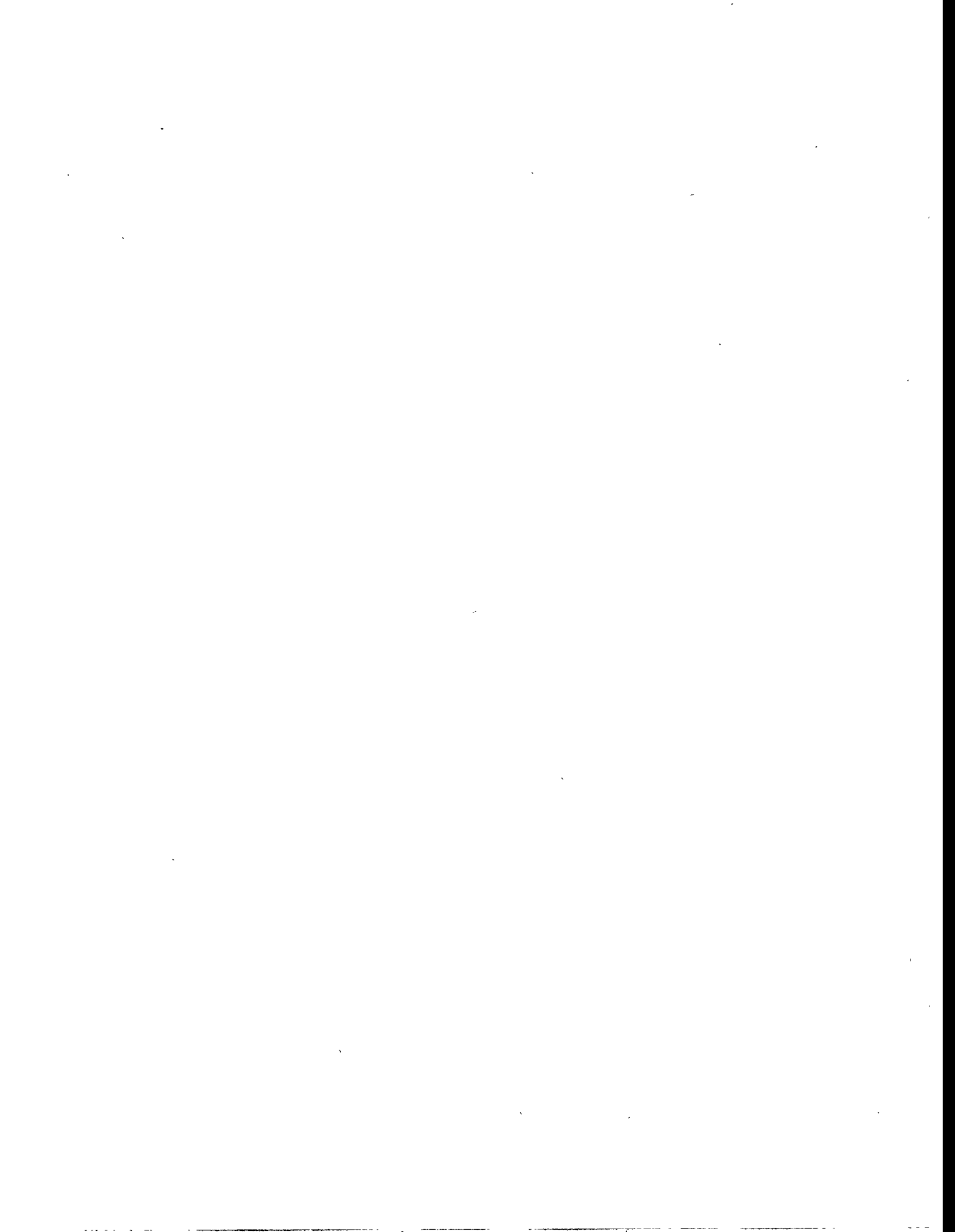
The following recommendations are made as result of the data analysis:

- Use of in-vehicle data acquisition systems will be used 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	





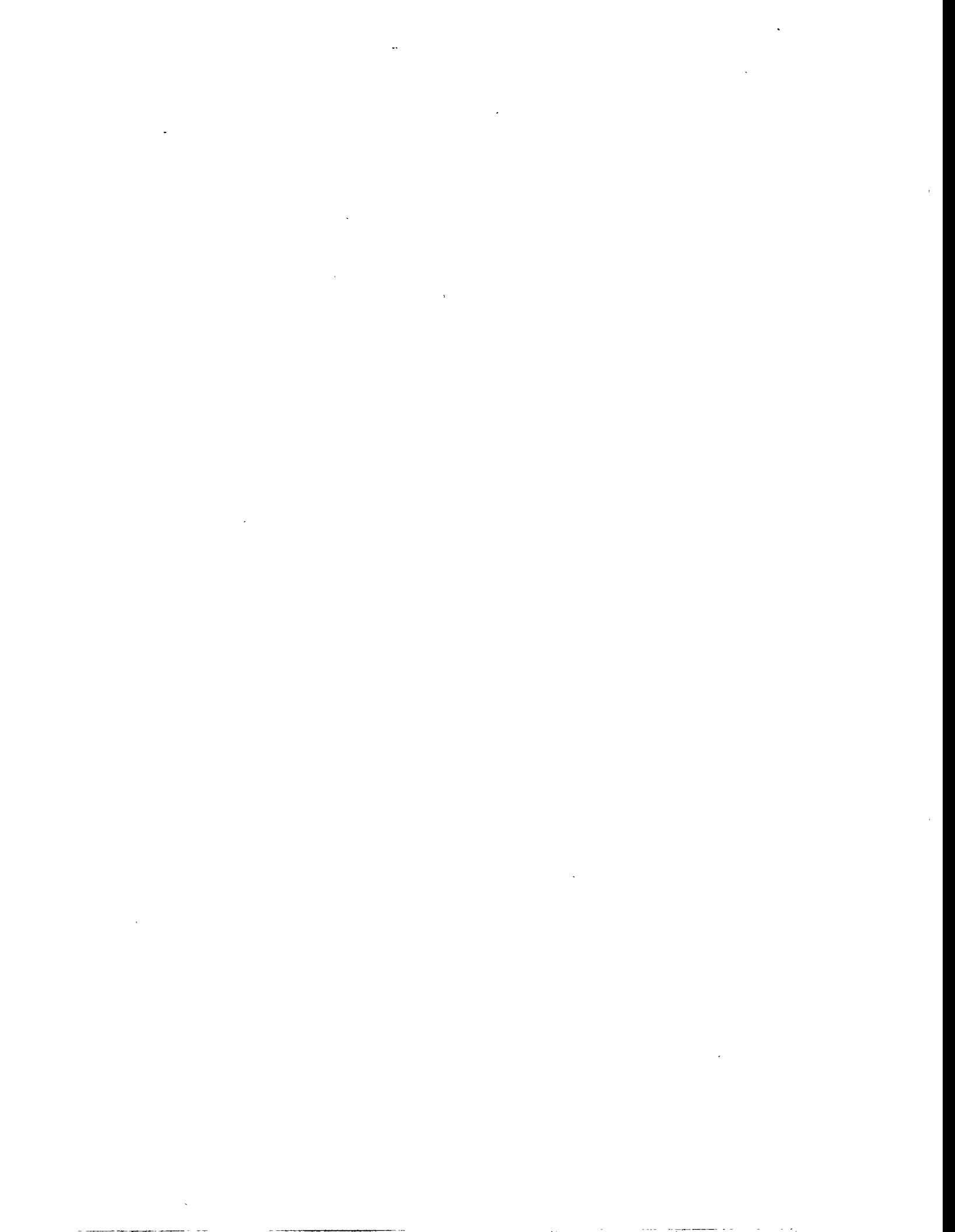
Contents

Site Operator Program Quarterly Report

Executive Summary	iii
Introduction	1
Program Management	11
Program Experience Overview	13
Summary	15

APPENDICES

Program Activities	A-1
Site Operators	A-3
Arizona Public Service	A-3
Kansas State University	A-3
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-8
Potomac Electric Power Company	A-8
Sandia National Laboratory	A-9
Southern California Edison	A-9
Texas A&M University	A-11
U.S. Navy	A-12
University of South Florida	A-12
York Technical College	A-15



Introduction

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 twelve sites located in diverse geographic, metrologic, and metropolitan areas across the United States (see Figure 1). Information is shared reciprocally with a thirteenth site, not under Program contract. The vehicles are operator-owned.

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.

Operator Program are shown in Figure 2. 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 (INEL). 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 current participants in the Site

*Site Operator Program
Quarterly Report*

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.

*Site Operator Program
Quarterly Report*

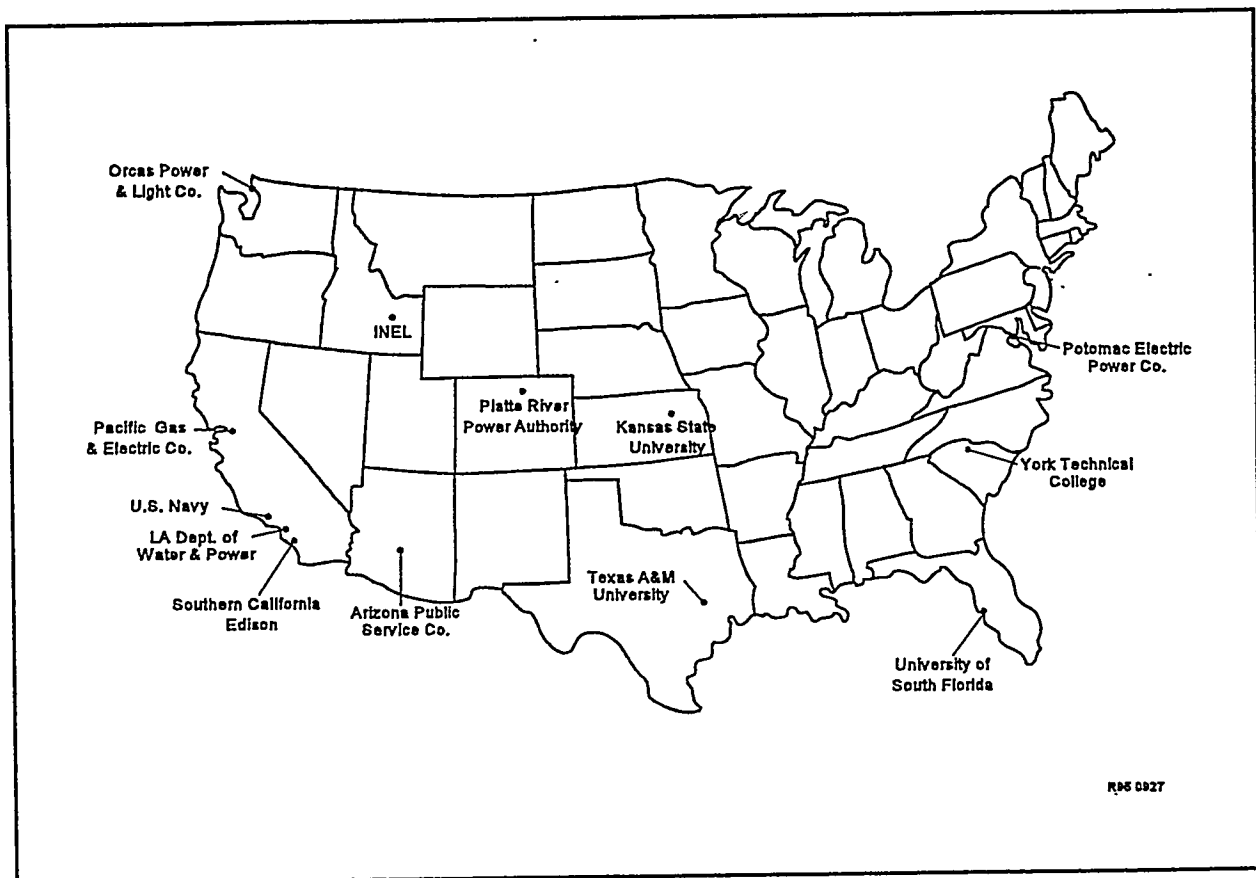


Figure 1. DOE electric vehicle Site Operator Program participant locations.

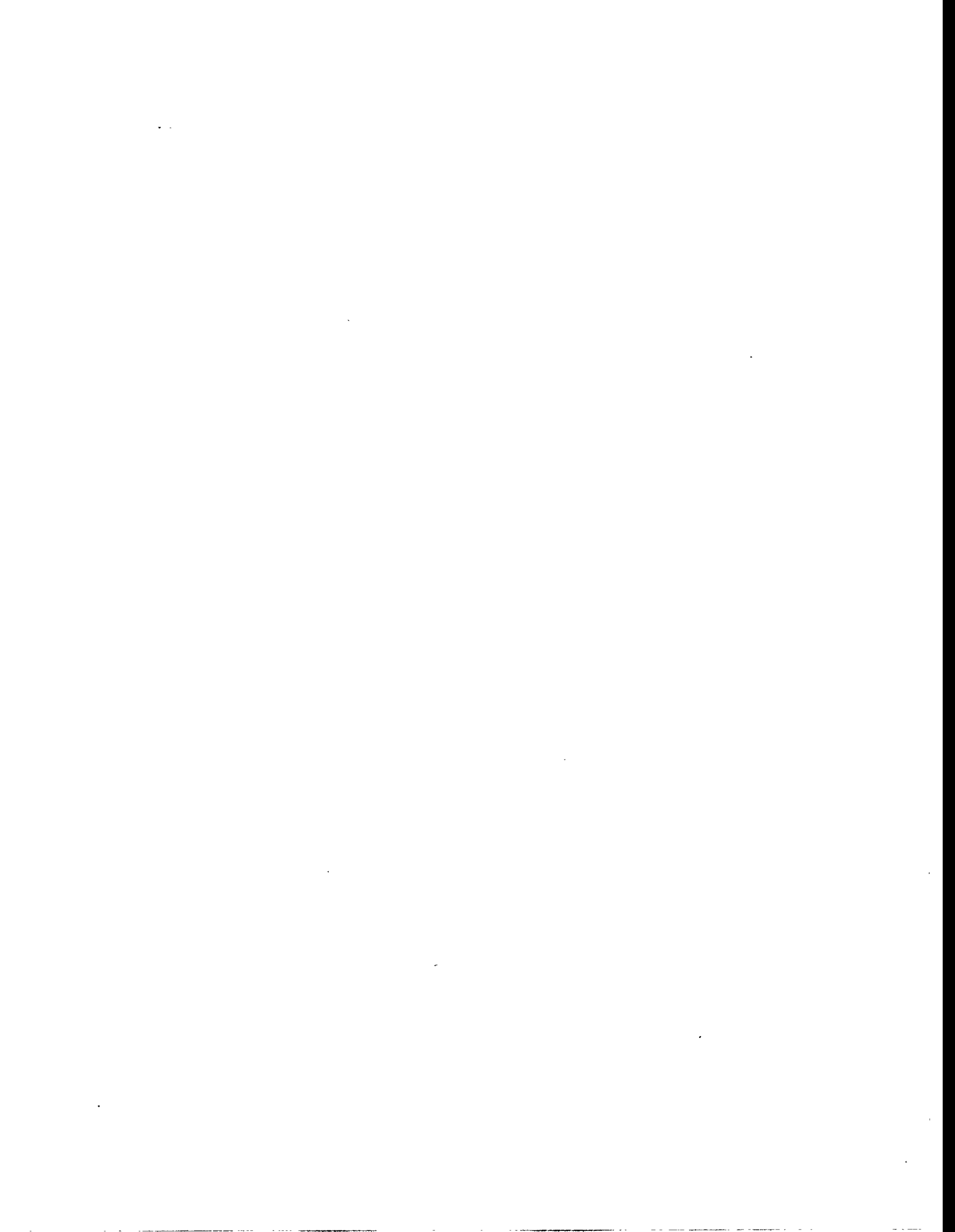


Table 1. Site Operator vehicle fleet.

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.	Bus	1 ea.
8.	Solectria	1 ea.
9.	S-10	<u>9 ea.</u>
	TOTAL	22

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	4 ea.
5.	S-10 pickup	4 ea.
6.	Prizm sedan	<u>5 ea.</u>
	TOTAL	20

Quarterly Report

Table 1. (continued)

Orcas Power and Light Company (OPALCO)

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

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	1 ea.
3.	EVcort	<u>1 ea.</u>
	TOTAL	3

Sandia National Laboratory

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

* Not currently in service

Table 1. (continued)

Southern California Edison Company (SCE)

1.	G-Van (passenger)	9 ea.
2.	G-Van (cargo)	6 ea.
3.	Ford Ecostar	12 ea.
4.	Solectria Force	6 ea.
5.	Electricar pickup (S-10)	4 ea.
6.	BAT sedan	1 ea.
7.	Pickup (Venus Motors) (Ranger)	1 ea.
8.	Sedan, Prizm	4 ea.
9.	TEVan	2 ea.
10.	Bus (Clean Air Transit)	1 ea.
11.	Honda sedans	3 ea.
12.	Van, Dodge Caravan	<u>1 ea.</u>
	TOTAL	50

Texas A&M University (TAMU)

1.	G-Van	15 ea. (Includes consortium vehicles)
2.	Jet	1 ea.
3.	TEVan	8 ea.
4.	Race Car	2 ea.
5.	S-10 Pickup	<u>3 ea.</u>
	TOTAL	29

U.S. Navy (NAVY)

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

*Site Operator Program
Quarterly Report*

Table 1. (continued)

University of South Florida (USF)

1.	G-Van (passenger)	2 ea.
2.	Chevy S-10 Pickup	10 ea.
3.	Dakota	1 ea.
4.	Mirage	<u>1 ea.</u>
	TOTAL	14

York Technical College (YORK)

1.	G-Van	1 ea.
2.	Escort (Bearskin)	1 ea.
3.	Unique Sedan	2 ea.
4.	S-10 Pickup	8 ea.
5.	Solectria Force	<u>1 ea.</u>
	TOTAL	13

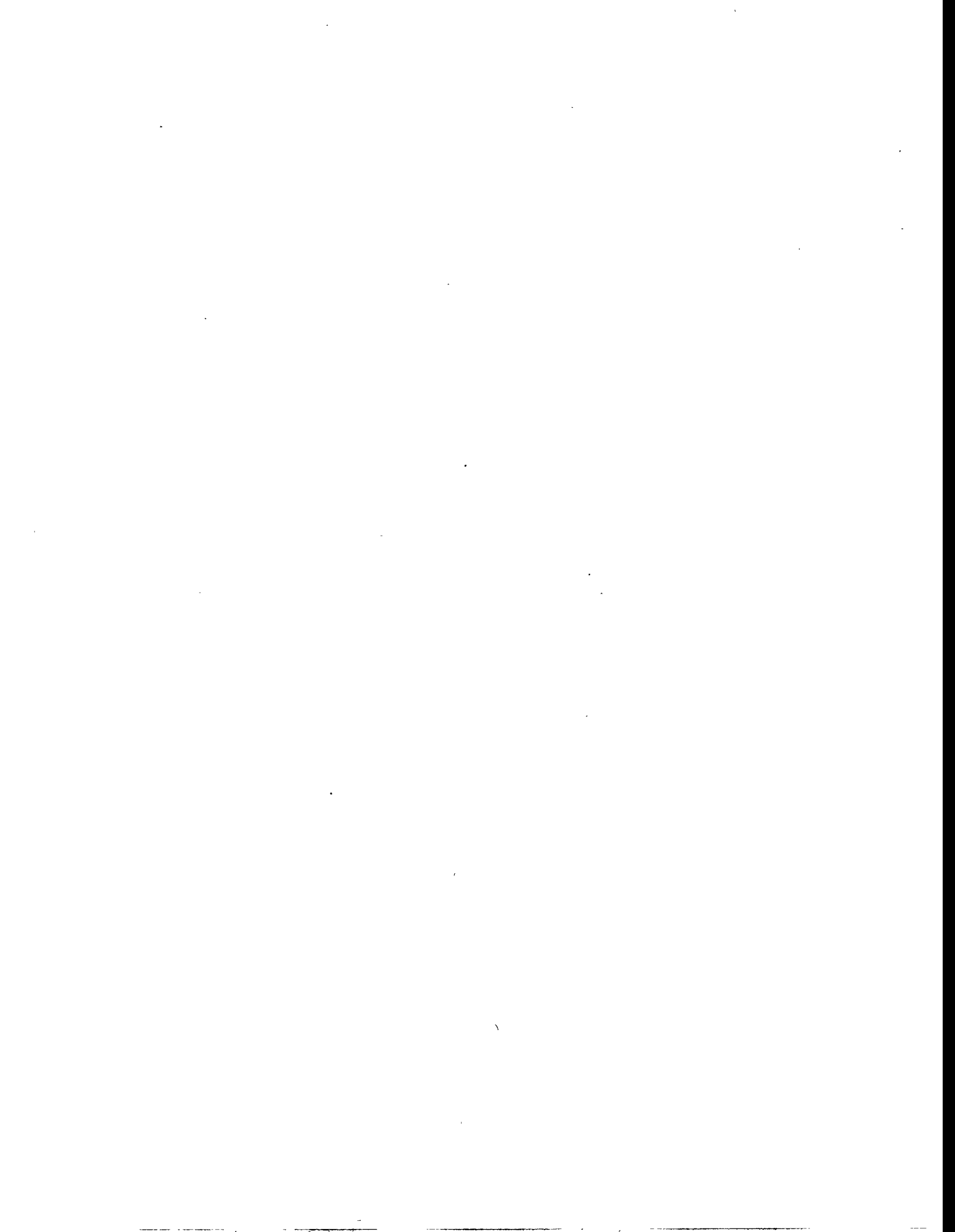
TOTAL - SITE OPERATOR PROGRAM 242

*Site Operator Program
Quarterly Report*

Table 2. Baseline vehicle information on selected electric vehicles.

VEHNAME	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

VEHNAME	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 first quarter of FY-95 was issued.

Work continued on the proposed Program reorganization. A draft proposal for data collection/reporting standards presented to DOE-HQ has been finalized.

Two versions of the Mobile Data Acquisition System (MDAS) received from Sigma Tec Systems, Inc. have been tested at the INEL. Critical comparisons were made with the Laboratory Data Acquisition System. The later version of the MDAS seems to be better suited to operational and data-gathering needs.

At present, no supplier is available to meet the existing demand for EV conversions within the Site Operator Program. The DOE "Group Buy" effort for S-10 pickup conversions was not carried to completion. Of the 42 units ordered, U.S. Electricar delivered roughly half before shutting down production and reorganizing its operations geographically. GE-Spartan delivered at least one unit before canceling all outstanding

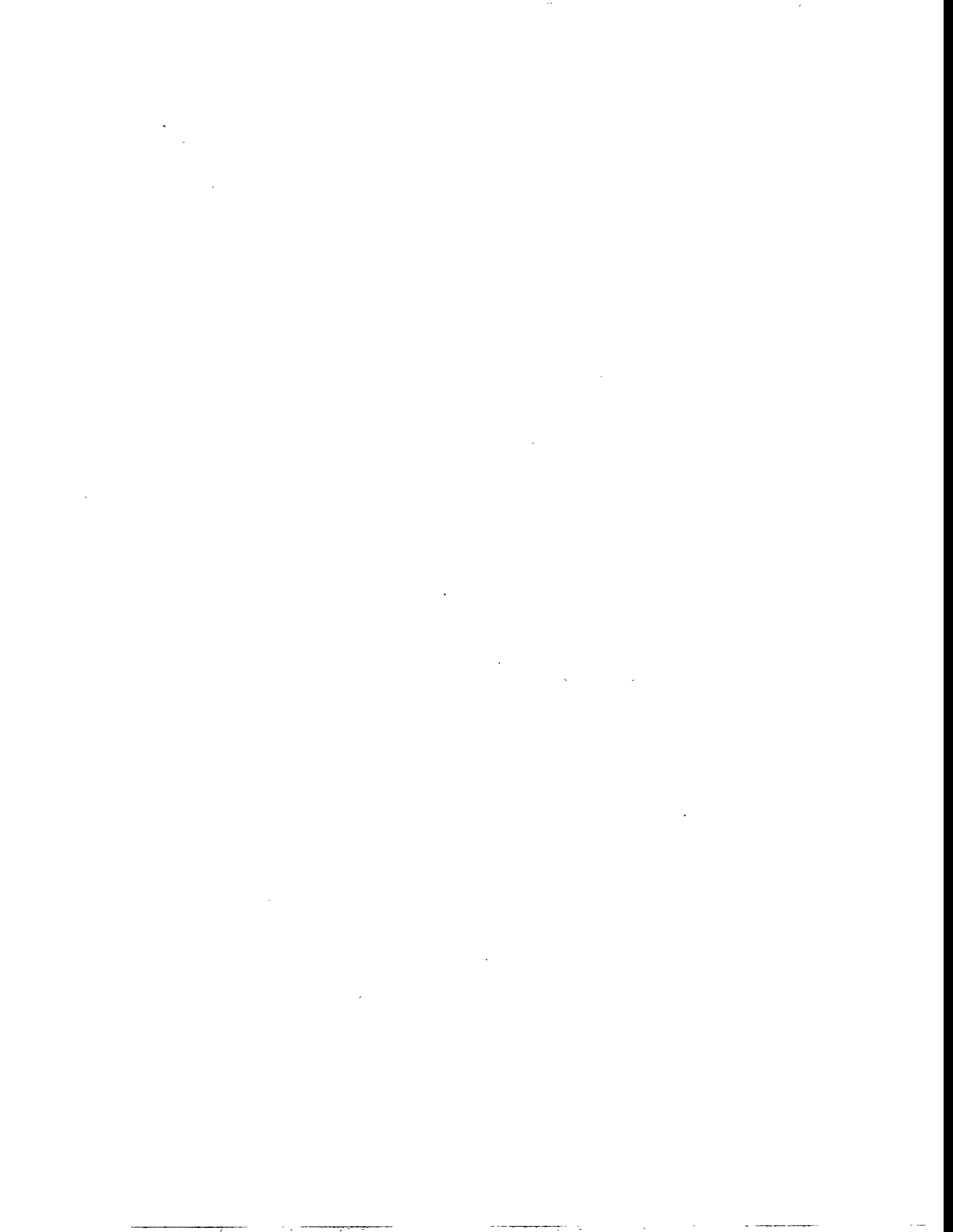
orders. Furthermore, the delivered products largely failed to meet the purchase and performance specifications, and the manufacturers have been slow to remedy identified problems.

Ten MDAS units were ordered for use in the EV America Test Support effort involving testing at Virginia Electric Power Company.

Review of contract renewals for Program participants is essentially completed. Task recommendations will be based on funding availability. The PEPCO contract has been renewed; others will be renewed as they expire.

The Site Operator Users Task Force meeting was held January 19 and 20, 1995 in Kansas City, MO.

The Interface Agreement between the Site Operator Program and EV America has been finalized.



Program Experience Overview

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 several new Program vehicles 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.

Two reports were transmitted to DOE on September 9, 1994:

1. *"Application of the Technique for Estimating the Number of Electric Vehicles and Length of Time Necessary for a Field Test to G-Van-C Data"*
2. *"Technique for Estimating the Number of Electric Vehicles and Length of Time Necessary for a Field Test."*

Report 1 presents a classical statistical analysis of field test data for G-vans operated by Public Service Electric and Gas Company. Report 2 applies multivariate statistical methods to operating data from a Mobile Data Acquisition System installed in an electric vehicle from Virginia Power Corp. and tested at the Idaho National Engineering Laboratory.

The method, data, and the consequent calculations are presented in these two reports, and are available from the INEL Vehicle Database(s) within the Automotive Systems and Technology Department. The MDAS, combined with the multi-variate data analysis techniques will provide about 7 times better precision than the manual data acquisition method used to acquire the PSE&G, G-Van-C data. This improvement will allow the average vehicle efficiency to be measured with 95% confidence with the number of samples computed as 649.

Thus, with three vehicles per site as the lower limit recommended in Report No. 1, the classical analysis presented herein predicts that 216 samples are required; and with four vehicles per site, 162 samples are required. This result appears consistent with the trend of the results presented in Report No. 1, which demonstrated that for three similar vehicles, the results were just beginning to converge to the 95% confidence interval within 50 samples per vehicle.

MDAS units were tested at the INEL to compare with the Laboratory Data Acquisition System (LDAS). The MDAS was limited to 16 channels, a substantially increased flexibility as needed. The precisions are eight binary bytes for the MDAS and 16 for the LDAS. Sampling frequencies are adjustable for both systems; the data from either system can be normalized to give comparable results. The reports of this investigation are in publication.

*Site Operator Program
Quarterly Report*

At this time, there exists no comprehensive data to define the battery life for the seven vehicles analyzed, either in terms of the life of modules within the battery pack or in terms of the life of the battery pack as a whole. However, the INEL Energy Storage Test Laboratory has acquired limited data for a wide range of vehicle applications while advising the Site Operators concerning replacement of battery pack modules that failed prematurely. Based on this experience, it seems reasonable to estimate that some lead-acid battery modules, in a fleet operation

environment, will begin to fail prematurely within 200 charge cycles. Thus, to assure that 95% confidence results can be achieved within the test time interval, and within the life of a battery module or pack, then four similar vehicles, tested for 162 charge cycles, must be recommended. As both MDAS and maintenance data are acquired, showing battery life cycle information, this estimate of battery life can be revised, as necessary.

Summary

The DOE Site Operator Program currently receives input from 14 sites in the U.S. The participants are public utilities, educational institutions, a National Laboratory, and the U.S. Navy. The number of electric vehicles now in use or undergoing test evaluations exceeds 230, ranging in age from new to fifteen 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.

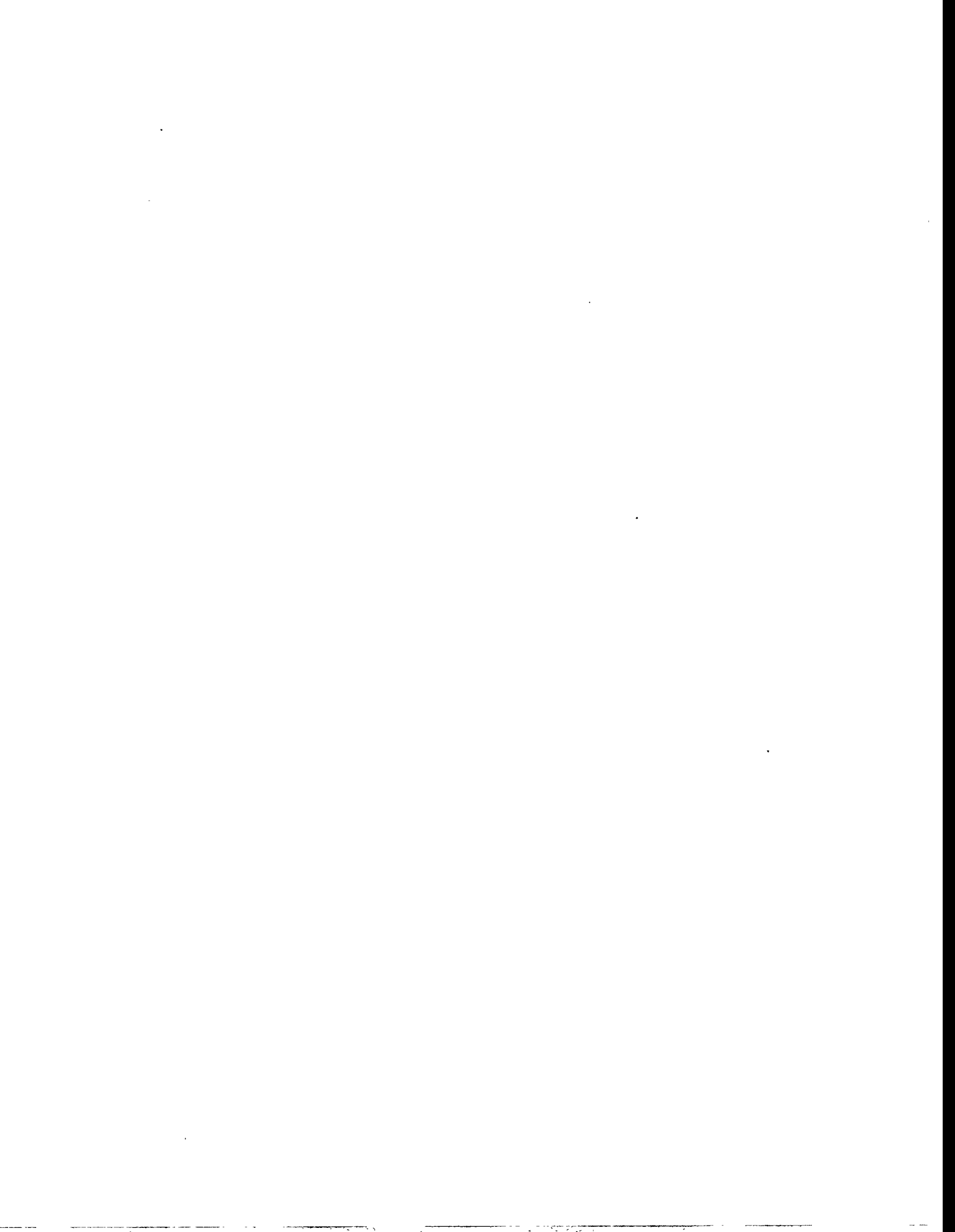
Program management activities relate to issuance of reports, communication with sponsors (DOE) and cooperating institutions,

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 the Site Operator Quarterly report for the fourth quarter of FY-95..

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 about a dozen 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 600,000 miles on their electric vehicles since 1979 as part of the DOE EV Site Operator Program. Total mileage for all vehicles for CY-95 was 33,611. The APS Evcorts consistently show the lowest operating costs, competitive with equivalent ICE vehicles.

A Chrysler TEVan continues under evaluation by the APS Research Department. The mileage for CY-94 on this vehicle was 3,505 using a nickel cadmium battery.

Three Solectrias, being tested for EV America, and four S-10 conversions required no maintenance during the current reporting period.

The summary of APS battery pack life experience reveals a wide spread of service life capabilities. Pack deaths (32 reported) have occurred anywhere from 62 miles (for a mixed pack) and 513 miles to 22,796 miles, all for lead-acid batteries. Low-mileage failures (less than 1,000 miles) were about 15%, and high-mileage (over 10,000 miles) were about 9%.

Public Awareness

No submittal was received for this period.

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

Site Operator Program Quarterly Report

currently based on two electric vehicles (see Table 1), maintained at the KSU campus and 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 were again returned to the manufacturer for warranty service during the reporting period. A variety of minor problems contributing to limited operational range required resolution by the manufacturer. Return to operational status is expected within the next quarter. Combined mileage to date exceeds 8,600 miles.

KSU experience with these two EVs emphasize significant continuing problems in several areas:

- Passenger comfort and preheat systems
- Regenerative braking
- Unavailability of standard repair manuals and essential technical information because manufacturers want to protect their developing technology. In the absence of proper documentation, the operator is forced to perform even minor repairs through a "reverse engineering" process, which is both time-consuming and expensive.

In general, the spectrum of problems would cause potential customers to view these vehicles as other than proven technology.

Previously reported effects of battery weight overload on the EVCORT suspension, brakes, and tires continue to mount. Increasing the wheel size to accommodate larger tires is complicated by associated brake replacement problems and is therefore cost prohibitive. KSU concludes that accelerated road use will result in premature wear and fatigue of other structural components of the vehicle, and that overall vehicle quality must be improved if EVs are to be marketable. A complete review/evaluation of the structural design, particularly frame and running gear, appears vital.

KSU and its Program associates are looking into the purchase of several new technology electric pickup trucks. Earlier commitments have fallen through: U.S. Electricar no longer provides vehicles to the utility industry, and GE Spartan canceled all orders. Definitive evaluation of alternatives is in progress, and a proposal will be submitted to DOE for necessary concurrence.

Public Awareness

Operating problem remediation with both vehicles precluded any public demonstrations during the reporting period. Movement of these vehicles, for either display or factory warranty service, has been greatly facilitated by availability of a tandem-axle steel-bed transport trailer. Acquisition of this unit was sponsored by the Kansas Electric Utilities Research Program.

In the area of infrastructure development, KSU provided financial support for Underwriters Laboratory testing of the EDD-7 charge station. Twelve of these stations have been deployed recently through the Electric Vehicle Research Network as part of an Electric Power Research Institute electric vehicle demonstration program. The utility companies receiving these stations are:

- Boston Edison Co. Boston
- Centerior Energy Cleveland
- Duke Power Charlotte, NC
- Georgia Power Atlanta
- NY State E&G Binghamton, NY
- Salt River Project Tempe, AZ
- TVA Chattanooga, TN

In conjunction with their evaluations of both inductive and conductive charge stations, these companies are also evaluating advanced billing systems, including microprocessor-based "chip cards."

As part of the KSU program, EHV Corp. Provided EDD-7 charge stations for the 1995 Arizona Public Service Race. This is the fourth consecutive year that APS has placed an order for these units, reflecting steadily increasing demand during race events.

KSU will serve as a host site for the DOE National Solar Electric Car Race (Sunrayce 95) to be held June 25-26, 1995.

Professor Hague made EV presentations to:

- Manhattan Area Amateur Radio Society
- Advanced Manufacturing Institute Conference
- Kansas Rural Electric Cooperative

Many of the Radio Society members will serve as volunteers for the Sunrayce '95 event on the KSU campus.

A round-table discussion of electric vehicle events took place at a joint meeting of the DOE Site Operators Users Task Force and EV America held at Kansas City, MO. on January 19-20, 1995.

Los Angeles Department of Water and Power (LADWP) - currently operates twenty (20) 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

Five S-10 conversions from U.S. Electricar were received during the first quarter of FY-95. Because of many unresolved design and operational problems, these vehicles are only partially operable and are not yet suitable for designated fleet applications. LADWP intends to obtain the

*Site Operator Program
Quarterly Report*

necessary engineering design fixes and/or parts from the supplier and make the required modifications and upgrades in-house.

MDAS units have been installed in three of the S-10 units, and data are being collected. A potential problem involving the voltage sensor connection to the vehicle battery pack has been discovered. The MDAS manufacturer, Sigma Tec., Inc. is working on a fix to totally isolate the battery pack from the vehicle.

Public Awareness

No information was received for this period.

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

One vehicle accounted for 85% of the 209 miles driven during the reporting period. The reduced usage and increased energy

requirements during the winter months reflects inadequacy of vehicle heating and defrosting equipment. The potential for problems with regenerative braking on icy roads also tends to discourage EV usage when these conditions exist.

No new vehicles, components, or batteries were added during this quarter. Modifications to the heating/defrosting systems of both existing vehicles are under consideration.

Five signed EV charge stations now serve the current total of 11 electric vehicles (nine privately owned and driven) on the islands that make up San Juan County. These stations are intended for limited (30-60 minutes) recharging of vehicles with 1 to 2 kW on-board chargers, although primary charging (6 to 8 hours) is possible, if needed. The installed cost of a station, between \$2,000 and \$2,500, is DOE-funded.

Public Awareness

Businesses in the vicinity of the signed EV charge stations for public usage have been given fact sheets about these facilities for public distribution. The sheets summarize the technical and economic aspects of the stations and invite further inquiries. The current ratio 1 to 750 of electric to internal combustion vehicles in San Juan County is the highest in the United States.

The replacement sales and activities representative for Solectria is also located on Orcas Island. This arrangement insures continuing service and technical assistance to

OPALCO as needed, as well as a synergistic working relationship with OPALCO and its customers who may be interested in electric-powered transportation.

Meetings with DOE, EV America, and the Site Operator Users Task Force have focused on EV specifications and service testing of fleet vehicles.

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 PERI 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

No information was received for this period.

Site Operator Program Quarterly Report

Public Awareness

No information was received for this reporting period.

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 730. 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. One vehicle was out of service for converter repair, under warranty, during February.

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.

The purchase order to Spartan Motors for five S-10 conversions was canceled on January 26, 1995 for lack of performance. The unconverted vehicles are now for sale by PRPA.

Public Awareness

The PRPA Planning Engineer discussed EV-related issues with a member of the Fort Collins Air Quality Advisory Board and participated in the "Alternative Fuels '95, conference for Fleet Managers and Operators in Larimer County."

There were no public demonstrations of the two vehicles during this reporting period.

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

No information was received for this reporting period.

Public Awareness

No information was received for this period.

Sandia National Laboratory (SNL) - located 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.

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. The SNL has operated these vehicles on a daily basis in missions that vary from benign to very hard.

Technical

No new information was received for this period.

Public Awareness

No information was received for this reporting period.

Southern California Edison Company (SCE) - an electric utility, currently operates and maintains 50 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 for 35 vehicles, other than G-Vans, now in operation exceeds 107,000. 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 previously reported operating and experience data. A 30-month lease for twelve Ford Ecostars has been executed; all are now in service. Six Ecostars are assigned to the Huntington Beach Post Office for mail service. Additional EV procurement is being pursued.

The US Electricar vehicles delivered in 1994 all require retrofit on some key systems, but are driveable and are now in service.

A BAT pickup truck remains on order; a Solectria S-10 conversion was received during the quarter.

Level 2 field testing data have been collected for many of the fleet units, using a variety of systems, some proprietary. During the reporting period, additional systems, comprising the "Silent Witness" operating data collection system and a "smart" ac kilowatt-hour meter, were installed on several of the remaining vehicles. The data output will be similar to that of the Sigma Tec

MDAS, originally planned for some of the SCE "DOE Group Buy" vehicles, but now limited to one SCE vehicle in the near term.

SCE continues active in Level 3 activities (vehicle and component development and testing). During this quarter, an investigation concerned a problem with the Hughes Dolphin charging system when used on the US Electricar vehicles. A temporary fix by Hughes has reduced, but not completely eliminated, the lengthy initial trickle charge requirement.

Vehicle maintenance during the quarter was primarily for electrical problems. Controller repairs on the Ecostars were the most common activity.

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 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.

SCE is participating in workshops to revise procedures for the planned EV America performance testing efforts, co-funded by DOE.

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.

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. In addition, SCE is participating in the demonstration and field tests of the General Motors Impact EV.

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 24 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

The three S-10 conversions received from US Electricar were not equipped to the Site Operator Program Specifications. As received, the vehicles had a variety of problems and deficiencies; some were remedied by TAMU personnel. To date, the supplier has not taken any action on the other deficiencies. MDAS units have been retrofitted to two of the three, but are not yet trouble-free. On-board charging has been replaced by inductive charging on two of the vehicles. These trucks are now in service with SCEVC member fleets in Austin, Dallas, and Oklahoma City.

Inductive charging provides a major saving in required charging time over the presently used direct charging method (110 V only). A minor drawback is that inductive charging efficiency appears to decrease when battery depth-of-discharge (DOD) is less than 50%. In addition, because the MDAS does not have the capability to monitor charging energy input, this information must be taken from the grid-to-charger connection. As a

*Site Operator Program
Quarterly Report*

consequence, the energy per mile figures reflect the efficiency of the charger. (This situation also applies to direct charging.)

During this quarter, two of the TEVans required 1 hour and 2 hours of unscheduled maintenance, and 120 hours and 42 hours of scheduled maintenance, respectively. One S-10 required 4.3 hours of unscheduled maintenance.

Reported mileage for the quarter was 2,361 for two TEVans and 1,314 for two S-10 pickups. Ineffective heaters in the S-10s tended to discourage their use during cold weather. Operating data for the third S-10 unit were not reported.

Public Awareness

The TAMU Electric Vehicle Team successfully completed an electric race car, based on a Porsche, Model 959, kit. The project sponsor, DAX Industries (a member of SCEVC) plans to use this vehicle as a test bed for development of their high-power EV controller.

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

No input was received for this quarter.

The University of South Florida (USF) - at Tampa, monitors and tests 14 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 Col, 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 the National Renewable Energy Laboratory.

Technical

The reported vehicle inventory comprises:

- Two G-Vans
- Ten Chevrolet S-10 conversions, one a hybrid vehicle
 - One operated by Pinellas County Air Quality Office
 - One operated by Bruderly Engineering Associates of Gainesville

*Site Operator Program
Quarterly Report*

- One operated by Jacksonville Air Quality Division
 - Two in use at USF by the Electrical Engineering Department.
 - One, a hybrid, operated by Dade County.
 - 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 Dakota pickup

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 MDAS. Its hardware and software, while standardized, offer wide flexibility in measurement capability. As currently used in a G-Van, a Mirage, and two S-10s, it monitors main battery pack voltage, current, and temperature; and in addition, EV velocity, cab temperature, and ambient temperatures, 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:

- University of South Florida
- Bruderly Engineering
- City of Jacksonville
- City of Tampa
- Orange County
- Pinellas County
- Volusia County
- Hillsborough County
- Florida Power Corp.

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.

Tests of Hall Effect sensors used for measurement in MDAS units show significant current drift with increasing temperature. It was concluded that separate Hall Effect sensors are needed for accurate measurement of the low-range charging currents and the higher discharge currents. Other Program operators are expressing interest in the results of these tests.

Site Operator Program Quarterly Report

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 effect 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. Preliminary evaluations of the fixed tilt angles (isolation) of the three photovoltaic arrays indicate that the 15° angle is more efficient for year-round use in the Tampa area. During

this quarter, the system generated in excess of 2,968 kW·h above that needed for the USF EV fleet.

A comparison of a 1992 model DC-driven S-10 and a 1995 AC-driven S-10 was made under real-world driving conditions. The purpose was twofold:

- To evaluate technology advances
- To investigate charger efficiency versus miles driven between charges.

Gross overall vehicle AC energy efficiency appeared to improve slightly, but DC energy efficiency, based on manufacturer specifications for charger efficiencies, decreased slightly. An increase in operating efficiency is likewise seen as miles between charges increase, but operator driving characteristics may obscure this effect.

An interchange format for the AFV-Soft data analysis program has been defined. A new Program, HFORMAT, developed to convert MDAS vehicle files to EV/NDC format, has automatic install routine, and runs under MS Windows.

A Florida Power Corporation hybrid natural-gas/gasoline pickup was received for MDAS installation. Sensor requirements have been investigated and specified.

An IC Sensors accelerometer was tested for applicability to electric vehicle operating data collection. Its usefulness is questionable because maximum acceleration

is a relatively small fraction of the instrument range, thereby increasing the percentage error. The sensitivity to inclination may prove to be of value in some situations.

Maintenance during the quarter included:

- Replacement of failed current sensors on two vehicles.
- Installation of a new speed sensor in another vehicle.

Two vehicles suffered controller and battery pack failure, respectively. Repairs will be made in the next quarter.

Public Awareness

Details of two electric bus projects were further developed during this quarter:

- A project with Hillsborough Area Regional Transit, including a photovoltaic system in downtown Tampa.
- A project with Pinellas Suncoast Transit Agency for a circulator bus in Pinellas Park.

USF personnel continued participation in efforts sponsored by Advanced Research Projects Agency, with the Southern Coalition for Advanced Transportation.

USF was represented at a number of meetings:

- The 1995 Winter Board Meeting and Annual Membership Meeting of the Southern Coalition for Advanced Transportation.
- The 1995 Winter Meeting of ARPA and the Regional Consortia Technology Program Review.
- EV America/DOE Site Operator meeting held in Kansas City
- The Southcon Conference held in Fort Lauderdale, FL.
- The Hillsborough Area Regional Transit pre-proposal meeting for electric bus procurement.

Technical displays/vehicle demonstrations were made at six different locations.

York Technical College (YORK) - located at Rock Hill, SC operates 13 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

*Site Operator Program
Quarterly Report*

utilities, other Program participants, municipalities, South Carolina State Energy Office, regional secondary schools and colleges, and the Clean Air Transport Association.

Technical

No information was provided for this reporting period.

Public Awareness

No Information was provided for this period.