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FINAL REPORT

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**PARTICIPATION IN THE U.S. DEPARTMENT OF ENERGY'S ELECTRIC
& HYBRID VEHICLE SITE OPERATOR'S PROGRAM**

Submitted by

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INTRODUCTION

The Center for Electrochemical Systems and Hydrogen Research (CESHR), a department of the Texas Engineering Experiment Station (TEES) at Texas A&M University (TAMU), has been involved in education, demonstration, research development, and testing of EVs and their components since 1988. CESHR's participation in the US Department of Energy (DOE) Electric Vehicle and Site Operators' Programs (SOP) started in August 1991. The South Central Electric Vehicle Consortium (SCEVC), a CESHR-led group of utilities and private companies in Texas and neighboring States, was organized at about the same time. The SCEVC has helped bring together electric vehicle (EV) fleet owners and operators in the south-central region of the country (Texas, Oklahoma, and Louisiana). The DOE, the SCEVC, TEES and the State of Texas Governor's Energy Management Office supported the demonstration and field testing of EVs in the region.

CESHR was, and continues to be, actively involved in the research in new materials for advanced batteries and in proton exchange membrane fuel cells for transportation applications. The above efforts at CESHR have been carried out by a dedicated team of engineering and electrochemical staff and graduate and undergraduate students in chemical, electrical, and mechanical engineering. The projects were supported by a cost share of 40%.

The laboratory facilities available at CESHR are fully equipped for testing EV batteries of different technologies on programmable load profiles and other EV components.

OPERATIONS AND ACTIVITIES

In the first two years of the SOP, two vehicles converted to electric drive by Jet Industries Inc. (Austin, TX) and 16 GMC G-Vans were field tested in the region. In the following years, nine Chrysler TE Vans were added to the fleet. In the final year of the program, three Chevrolet S-10 pick-up trucks converted to electric drive by US Electricar (San Francisco, CA) were included in the field tests. These three trucks were also equipped with Mobile Data Acquisition Systems (MDAS). These vehicles were tested in fleet applications by the utility members of the SCEVC. The vehicles logged a cumulative total of more than 150,000 miles. The operational data were collected, analyzed, and forwarded to DOE and to state agencies participating in this activity.

The CESHHR EV team participated in electric vehicle races, e.g., in the Arizona Public Service 500 (APS 500) in Phoenix, Arizona in 1991, 1992, and 1993, and the Tour de Sol (a five day east coast rally) in 1992 and 1993. The CESHHR EV team won second position twice at the Tour de Sol and third position in the APS 500 in 1993. The team also won the highest DOE award in its class in the Tour de Sol for the student teams in 1991. The vehicles used in these races were a 1981 General Motors Opel Kapitän (the former General Motors nickel-zinc battery test car) and a 1991 Geo Metro. Each had a 22.5 kWhr Zinc Bromine battery supplied by SEA Inc. (Graz, Austria), which weighed 370 kg and had a recharge time of 5 hours. The best range was achieved by the Geo Metro, which obtained 150 miles on a single charge at an average speed of 50 mph, and 119 miles in 2 hours on the Chrysler proving grounds in Phoenix, AZ.

EDUCATION AND INFORMATION

Public education and dissemination of information about EVs have been carried out since the inception of the EV program at CESHHR. After the SOP was established, it became possible to greatly increase this educational effort. During the course of the five-year field test program, CESHHR personnel made more than 150 presentations and demonstrations on electric vehicles to public and private organizations nationally and internationally. Nearly half of these presentations were followed by "Ride and Drive" events in electric vehicles. CESHHR personnel have given demonstrations in the local schools to children of all grades and hosted "Ride and Drives" on Earth Day celebrations and other community events to inform the general public about EVs.

Some highlights are as follows:

1. Mr. William Craven of CESHHR was asked to participate in the Texas Energy Policy Alternative Fuels Committee. This committee helped develop alternative fuel policies for the State of Texas. This legislation was also used in the planning of the 1992 National Energy Policy Act.
2. Mr. Craven and Mr. Imran Kakwan of CESHHR were invited to make a presentation on electric vehicles to a Texas Public Utility Commission panel in 1993. This panel was to study the effects of EVs on the utilities.
3. Dr. A. John Appleby of CESHHR briefed Texas Governor Ann Richards on the CESHHR electric vehicle program during her visit to College Station in April 1994. The CESHHR electric G-Van was used to drive her to her engagements during the visit.

4. In July 1994, Vice President Al Gore and Secretary of Transportation Federico Peña invited Dr. A. John Appleby of CESHHR to a White House conference on fuel cells for EVs (Partnership for a New Generation of Vehicles, PNGV). Dr. Appleby presented a key-note introduction to fuel cell technologies.

5. To draw further attention to EVs, CESHHR organized annual Electric Vehicle Symposia to educate the members of public, private, and government organizations. CESHHR also actively participated in numerous electric vehicle and alternate fuel seminars and expositions.

The SOP has also had other less visible but important benefits as well. The program has helped the research programs and theses of graduate students performing work on EVs, EV batteries, and fuel cell/battery hybrid topics. Some of these students, after graduation, are working in the EV industry. The program also enabled CESHHR to produce research papers on EV related issues. These papers were presented at conferences and published in various journals. This effort also promoted the emergence of specially trained personnel, the EV mechanics along with specialized EV tools. It also helped devise safety procedures for EV operation, maintenance, and repairs. CESHHR developed a technique to identify defective monoblocks in a battery pack before a battery monitoring system was developed and marketed. CESHHR graduate students also developed a micro-processor based advance control system for the Zinc Bromine battery used in the race cars.

CONCLUSIONS

The five-year SOP program at CESHHR has now ended, but its fallout benefits are expected to be evident for a long period of time. CESHHR personnel and students feel very privileged to have been given the opportunity to be a part of this important project. Its success and failure can only be measured by examining the desired objectives set at the initiation of the project. Two major objectives, were EV education and awareness and the evaluation of currently available electric vehicles. During the course of the project, activity in education and awareness was a total success. Today, EV awareness (both nationally and internationally) is much higher than at the beginning of this program in 1991, especially among the younger children and students up to high school level. The evaluation of currently available EVs was not as great a success. The vehicles themselves need more sophistication, but the power source (i.e., the battery) must be greatly improved for the EV to be acceptable and affordable by the general public.

During the period of the program, it became apparent that human errors and attitudes have adversely affected the commercialization of EVs. Quality control by the EV manufacturers and converters of the vehicles tested was poor. After-sales service and and after-sales treatment of EV owners and operators left even more to be desired. This experience deterred potential first-time and repeat EV buyers, who started with enthusiasm but rapidly became disenchanted with the products and product support available.

APPENDICES

Selected Publications prepared by Center Personnel are attached.

They include:

William R. Craven, *Status Report and Houston Lighting and Power G-Vans*, August 1992.

David H. Swan, Muralidharan P. Arikara, and Alton D. Patton, *Battery Modeling for Electric Vehicle Applications Using Neural Networks*, International Congress and Exposition, Detroit, MI, March 1993. *removed + cycled separately*

Blake E. Dickenson, David H. Swan, and Thomas R. Lalk, *Comparison of Various Battery Technologies for Electric Vehicles*, Presented at Future Transport Technology Conference, San Antonio, TX, August 1993.

Muralidharan P. Arikara, Blake E. Dickenson, and Brian Brannum, *A Smart Control System for Electric Vehicle Batteries*, Society of Automotive Engineers, Future Technology Conference, San Antonio, TX, August 1993.

*Central and South West Services
Public Service Company of Oklahoma
Southwestern Electric Power Company
City of Austin Power and Light
Collmer Semiconductor, Inc.
Electric Power Research Institute
Electrosource, Inc.
Texas Engineering Experiment Station*

*Houston Lighting & Power
Central Power and Light
West Texas Utilities Company
Lower Colorado River Authority
Southwestern Public Service, Co.
VEHMA International, Co.
Texas A&M University
Texas Utilities Company*

South Central Electric Vehicle Consortium

MEMO

August 21, 1992

To: Ed Riddell, Jim Janasek

From: William Craven *WBC*

Subject: Status report on Houston Lighting and power G-vans

The people at Houston Lighting and Power Company (HL&P) and Texas A&M University (TAMU) thank the rapid response by Ed Riddell and Jim Janasik to the crisis at hand concerning the electric G-Van. On August 10th, William Craven (TAMU) called Jack Compton (HL&P) to see how many Chrysler TE-Vans he was going to commit to purchasing. Jack Compton replied that he did not plan on buying any TE-Vans, in fact, they were planning for next year's budget and were seriously considered purchasing several internal combustion engine vans to replace the G-Vans that were no longer functioning in his fleet. He then stated that all six G-Vans that were in operation at HL&P were now parked and inoperable. The main problem was lack of range per charge rendering them unacceptable for any application. Craven immediately called Jim Janasik at EPRI and stated the problem HL&P was having. Jim said he would call Conceptor and get back to me. The following day, I called Jack Compton and he stated that he had to call the President of HL&P the next day to approve of their plan to displace the G-Vans due to lack of range and necessary parts. Craven then tried to call Janasik, who was not in the office, and then called Ed Riddell and explained the situation.

Craven stated that there was a range problem with one of the A&M vehicles and was corrected by balancing of the battery pack. Ed stated there were long-term solutions being worked on in California by EPRI. Ed agreed that A&M personnel should go and assist HL&P in trying to increase their vehicle range, and get them back into service. Ed also agreed to pay for all necessary expenses related to this exercise. I called Jack Compton and arranged to meet with them Friday, August 14, 1992.

The first memo in attachment C shows how the relationship between Conceptor and HL&P was severely strained at this time.

The following is a result of this trip to Houston Lighting and Power on Friday August 14.

TRIP REPORT
To Houston Lighting and Power
August 14, 1992
for
Electric G-Van Battery Pack Balancing

On August 14, 1992, William Craven and Imran Kakwan from Texas A&M University went to Houston Lighting and Power Company (HL&P) to help resolve battery problems occurring with the G-Van. We arrived at 9:00 a.m. at the main HL&P offices in Houston, Texas. We were met by E.J. (Jack) Compton, Manager of Transportation, B.J. (Richard) Grasshoff, Division Manager of Transportation and Maintenance; Frank Morris, Supervisor; Robert Flemming, Crew Leader; and Roman Neitfeld, Crew. Two G-Van battery packs were fully charged and sitting on a dolly platform ready for diagnosis. However, we only had equipment to diagnose one pack at a time and each procedure takes about eight hours. The following procedure was conducted by Imran Kakwan and assisted by the HL&P personnel:

A resistor was hooked up to the battery pack and the pack was discharged at a rate of 50 amps (Picture 1). Every 30 minutes, the voltage was checked on each of the monoblocks (Picture 2). The bad monoblocks were eventually identified by their rapid decrease in voltage, compared to the rest of the battery pack. When a bad battery was identified, it was disconnected from the pack by drilling out of the posts to free the cable (Picture 3). An extension cable was used to re-connect the battery pack so the discharge could continue (Picture 4). The discharge of the complete pack took approximately four hours since the batteries are rated at 205 amp hours and we were discharging at 50 amps. At the end of four hours, six monoblocks had been identified as being sub-standard. At this time, the replacement of the monoblocks occurred (Picture 5). Some replacement batteries had to be outfitted with flame arrestors (Picture 6);

then they replaced the separators between the monoblocks (Picture 7). Finally, the cables were welded to the battery posts (Picture 8). Silicon caulking was used to cover the cable connections (Picture 9). The replacement batteries were fully charged and had to be discharged down to a state equivalent to the rest of the battery pack. A bad motor and rear assembly was on the floor near the site of our operation (Picture 10). The job was complete by 7:30 p.m.

On Monday, the pack was placed back into the G-Van and charged at the lowest charger setting. The vehicle was fully discharged and charged everyday until Friday, August 21, at which time the vehicle obtained 61 miles on a single charge. This van is one of their vehicles that has the most useful applications for an EV. They transport magnetic records from their down town office to a storage facility just outside of town. The unloading of the tapes takes place inside the building requiring a zero emission transport vehicle (Picture 11).

In discussion with Richard Grasshoff and Robert Flemming, it was discovered that Conceptor was not responding, in a timely fashion, to the needs of their electric vehicle fleet. Attached is a list of parts that have been on order from Conceptor (Attachment B), some since April, with no resolve to date. Parts that were warranted and replaced by Conceptor have not been sent in a timely fashion; in some cases, when the failed parts were required to be sent back to Conceptor, the postage associated with the returned part has not been reimbursed. For example, four batteries returned at the expense of \$400 is still outstanding.

Every communication with Conceptor or any vendor concerning electric vans is written down in summary form and documented by the HL&P personnel. They have excellent records on all work that has been done, and work that is still needed. Two of the phone conversations between Robert Flemming and Ron Mitchell are enclosed (Attachment C) and should draw concern. One dated July 15 shows Ron Mitchell stating the vans were out of warranty, and because of this, he can no longer ship parts. Ron was only servicing vehicles that were still under warranty. If Conceptor is not going to assist the repair of these vehicles after the warranty, a parts listing with each of the vendors associated with parts should be published by Conceptor to allow G-Van users to purchase the necessary replacement parts.

In just the last two months HL&P has experienced the failure of two motors, one was replaced, under warranty, the other is out of warranty. One motor also failed last year.

In conclusion, the trip was successful for balancing one of the battery packs. The vehicle was reported as having a range of 35 miles and now is getting 61 miles as recorded on August 20 (Attachment A). HL&P is so pleased they are now considering buying two TE-Vans and are looking forward to getting all of their G-vans back in service. Several issues concerning the G-van still need to be addressed.

Action Items:

- (i) The *balancing of the G-Van battery pack does increase the capacity* leading to greater range of the vehicle per charge. A standardized battery pack balancing procedure should be recorded and disseminated to all G-van users
- (ii) There is difficulty in obtaining replacement parts that are no longer under warranty by Conceptor. *It is suggested that a detailed parts list be produced for the G-Van so vendors of the parts can be contacted directly.*
- iii) The traction motor has failed too often (three for HL&P) suggesting *an extended warranty should be offered on the motor.*
- iv) *A faster response for parts under warranty should be expected.* Six to eight weeks is not acceptable and in some of the documented cases, it is going on four months with no resolve.

1

Discharging battery
pack through
resistor bank.

From left to right:
Robert Flemming
Roman Neitfeld
Frank Morris
R.L. Grasshoff
Imran Kakwan

2

Checking the
voltage every
30 minutes

When identified, the bad
batteries would be
disconnected from
the pack.....

3

... and bypassed

4

When the whole pack
was discharged, the
bad batteries were
replaced.

5

Batteries needing flame
arrestors were made

6

Battery separators are
re-inserted

7

Cables are welded
to posts

8

Blue silicon caulking was used to cover connections

9

Bad motor - waiting for replacement

10

G-Van is used for transporting magnetic tapes from headquarters to storage facility. The G-Van is ideal since the van is driven into the building for unloading

11

Attachments

Attachment A

The Light company

Houston Lighting & Power

P. O. Box 1700 Houston, Texas 77251 (713) 228-9211

August 21, 1992

Mr. William B. Craven, Manager
Center for Electrochemical Systems & Hydrogen Research
Texas Engineering Experiment Station
Texas A&M University System
College Station, TX 77843-3402

Dear Bill,

We have just put our G-Van #5 back in service after replacement of the six (6) bad modules in our battery pack. Your assistance and technical expertise was invaluable to us and most appreciated. After equalizing the cells and recharging, the range has increased from 35 miles to 61 miles.

Thanks again for your time and technical assistance in helping HL&P solve the G-Van problem.

Sincerely,

Richard Grasshoff
Division Manager
Transportation Maintenance

RLG:bj

Attachment B

**The Light
company**

Houston Lighting & Power P.O. Box 1700 Houston, Texas 77001 (713) 228-9211

VEHICLE #	CONCERN	DATE REPORTED TO CONCEPTOR	PROBLEM RESOLVED YES/NO	FOLLOW UP DATES
All Vans	Alternator (no output)	05/08/92	yes	6/15/92
E4216-2	Vacuum Pump Broken	05/08/92	no	5/18/92, 8/1
	Charger Fan Broken	05/08/92	no	
	Charger output too high	04/07/92	no	
All Vans	Relocate Flame Arrestors	05/08/92	yes	kits arrived 8/1
All Vans	Harness for charging pack out of van	05/08/92	no	
All Vans	Burning Rings	05/08/92	no	
All Vans	Battery Terminal Sealant	05/08/92	no	
E4216-6	Watering Block	05/08/92	no	
E4216-2	Excessive water leaking during charging	05/18/92	no	6/8/92
E4216-5	Excessive water leaking during charging	05/18/92	no	6/8/92
E4216-6	Excessive water leaking during charging	05/18/92	no	6/8/92
E4216-3	Traction motor failure	06/03/92	yes	6/15/92
E4216-5	Traction motor failure	08/18/92	no	8/18/92

Houston Lighting & Power Company

OFFICE MEMORANDUM

To R.L. GRASSHOFF

From R. FLEMING

Subject E-VANS

JULY 15, 1992

On 7/15/92 I spoke with Ron Mitchel concerning the burnt out drive motor on E4216-5. I told Ron that this was one of the vans that leaks water excessively out of the vent tubes during charging. I reminded him of the fax that was sent to him on 5/18/92, with photos showing the water that had leaked onto the floor under the van. I told Ron that I felt this was why the batteries required so much water and that I did not want to return this van to service until the problem was resolved. I asked Ron when the technicians would be down to check the battery packs. Ron said that there was a problem between his company and EPRI and that until it was solved he could not send anyone. I asked Ron about the vacuum pump that I had been trying to get and reminded him about the fax 5/18/92 addressing the pump along with the name of a local GMC dealership as he had requested. I asked Ron if he could locate the pump and ship it to me as I do not have a good part number. Ron said that because our vans were out of warranty that he could no longer ship parts. He said that the only parts being shipped were for vehicle under warranty. I then told Ron that the least he could do was to get me a valid part number for the pump, he said he would look into it.

RF/wp 7_23_92

Attachment C

OFFICE MEMORANDUM

To R.L. GRASSHOFF

MAY 11, 1992

From R. FLEMING

Subject E-VANS

On 5/8/92 at 3:00 PM, I spoke with Ron Mitchell. I told him that five of the six vans had bad alternators. Ron said that both the ground and the 40 amp fuse should be checked before condemning the alternators. Ron said that he still didn't know if they would be covered under warranty. I asked if driving the van without the alternator would damage the power controller. Ron said that it would not. He said that it would only draw the auxiliary battery down.

I also asked if anything was being done about the leaking flame arrestors. Ron said that their engineers are working on redesigning the support plate that would relocate the arrestors away from the brake lines. He said they should be available in two to four weeks.

I asked if the battery terminal sealant was ever shipped. Ron said that he was waiting on Dan Utley to return the signed E.P.A. form.

The ground and the fuses are good and I'am sending the alternators to Tracy Electric to be repaired. Also Dan said that Ron had the E.P.A. form for the sealant but he would send me a copy.

RF/wp
file: 5_8_92

The Light company

Houston Lighting & Power P.O. Box 1700 Houston, Texas 77001 (713) 228-9211

June 25, 1992

TO: RON MITCHELL

IN REFERENCE TO: E4216-5 TRACTION MOTOR FAILURE

(VEHICLE SERIAL #3024) (MOTOR SERIAL #514978)

(VEHICLE MILEAGE 3219)

After our conversation on 6-23 I found A megger meter. I tested the isolation resistance and the reading came out to 3 Megohms on each cable to frame ground. Please let me know what you find ASAP when you will be able to send the traction motor and also the alternator that we had talked about.

Also Roman had talked to you about a Vacuum pump and some watering blocks. Can you give us the status of these parts.

I had the chance to talk to the driver of E4216-5. He informed me that he had no indication of failure. Failure occurred when he accelerated from an intersection and felt a vibration in rear of vehicle, at this time the battery light came on. The batteries were charged the night before. The conditions were hot and dry in the 90'S and the batteries had half charge when wrecker arrived.

Please call me if you have any questions (713) 945-6529

Sincerely,

The Light company

Houston Lighting & Power P.O. Box 1700 Houston, Texas 77001 (713) 228-9211

William B. Craven
238 Wisenbaker Engineering Research Center
Texas Engineering Experiment Station
College Station, Texas 77843-3402

Mr. Craven,

Enclosed you will find copies of the correspondence between myself and Conceptor that I forward to Richard Grasshoff. In addition I have attached a list showing the major repairs and outstanding problems concerning the G-Vans.

As we discussed Friday, we are still awaiting the shipment of the fan for one of our chargers. This charger puts out 41 amps with the taps on the lowest setting. During the time the fan was ordered, I asked for an adapter to charge the battery packs out of the van, also burnings for the terminals and two watering blocks. As of this date we have not received these items.

Again I would like to thank you and Imran for your help during your recent visit. If I can be of further assistance please call.

Thank You,
Robert Fleming

Houston Lighting & Power
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Fax # (713) 945-6637