ELECTRIC AUTO ASSOCIATION NEWS

Dec. 1989 Vol. XXI No.12

BELIVE IT OR NOT

CALIFORNIA **DMV** Has **36,894** Electric Vehicles Registered out of total of **22,727,561** Vehicles in Ca.

September 12, 1989

Dear Mr. John Newell;

It has only been a short while since the American Solar Cup, (ASC), in Visalia but a lot has happened since then, solar car wise and of course with the environment. The GM race, the American Tour de Sol, Canadian Solar Cup, MIT's cross country run and numerous other vehicles around the country have begun to be constructed. I like to think in some way the ASC had something to do with this.

I'm currently recieving requests from interested parties to join a solar car group. The American Solar Car Assn. is in an early formative stage but should not try to fly on it's own, being that solar cars are still such an esoteric thing. But combining with a like minded group would assist both the solar enthusiast and the "parent" organization with some new membership and a great information network.

The thrust of the group is to educate and promote solarcars to the public and private sector, and to sanction solar car ralley's, races, symposiums, etc.

I have sent a similar letter to Ken Krutz of the EVA.

I value your input and look forward to your response.

sincerely,

Robert M. Cotter

Robert M. Cotter

Director, American Solar Cup
President, American Solar Car Assn.

AMERICAN SOLAR CUP

P.O. 158 Waldoboro ME 04572 (207) 832-6925

Uses of a "Clearinghouse"

(Mutual Self-Help in any Organization)

by Charles Smith, secretary, East Bay Electric Auto Association

In any organization there is a lot of untapped expertise, skill, knowledge or information which could be brought to bear on the problems, and needs of the persons involved in the group.

Supposedly the participants in an organization are there because of a shared interest, so they are to a certain extent "self selected."

Whether or not the people involved really do join in with a program of self-help and information exchange often depends upon the type of leadership and the forums which exist.

For instance, with an interest group there are several methods which could be used to allow and encourage members to communicate with each other:

A Clearinghouse card file could be established over a period of time which lists the sources of equipment the members need for their shared interest.

(After all, the members have come together because of this shared interest, what better way to strengthen this common interest than to make certain that all participants have the benefit of the very best and latest information on that common interest.)

Another approach is for the Newsletter to encourage members to feel willing to make known any problems they are having by making an appeal for help in the Newsletter.

Still another step which might be taken would be for the organization to set up a self-listed Directory of members. This Directory could include a run down on the education, work experience, and other pertinent points furnished by the individuals themselves. It might also include a statement of any areas of expertise where the person might be contacted for advice and help.

Any number of additional other channels of communication may occur to persons who have particular situations.

For instance, the Bulletin Board at a clubhouse, neighborhood or senior center can be used as an exchange of information of all sorts. A good, well-operated Bulletin Board can be make a community center into much more than just a gathering point. It can be a constant source of new or individual information which is not handled any other way in the organization or community.

(Part of a series by Chas. L. Smith, 61 San Mateo Road, Berkeley, CA 94707. May be copied. 11/89)

Fuel Cell Powered Electric Vehicles

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ABSTRACT

Fuel cell powered electric vehicles have the potential of replacing internal combustion powered vehicles if the problems of low power density and high cost can be overcome. Future cost and performance estimates for proton exchange membrane fuel cell power systems are compared with internal combustion power systems. Specific areas of research for fuel cell power systems are suggested.

INTRODUCTION

Transportation Today, is economical and effective but it has 3 major problems: 1) pollution, 2) inefficiency, and 3) inflexible source of fuel.

Air pollution is the direct result of fossil fuel combustion. Typical pollutants are hydrocarbons, by-products of combustion, and oxidants. These pollutants create health and property damage that have been estimated at $1.11 (U.S.) for each gallon of gasoline consumed (1)*.

Due to rising pollution in U.S. cities, legislation or plans for legislation are now in place (2) or being considered to bring about a change from fossil fuels to low emitting fuels. Rather than using an energy source directly as we do today, it is being proposed that we use energy carriers such as electricity, methanol and hydrogen. In each case, the energy carrier is *manufactured* from conventional energy sources such as natural gas, coal, nuclear and hydro, or, from future sources such as solar and fusion. Table 1 presents the energy density characteristics of each carrier and compares it to gasoline. Gasoline has advantages in energy density and ease of handling which make it and Diesel ideal fuels for transportation.

Table 1
Fuel Characteristics

	Gasoline	Methanol	Electricity (NaS Battery[1])	Hydrogen[2]
Energy Density[3]				
Wh/kg	13333	6300	105	39406
Wh/liter	9333	4977	116	2798
Specific Gravity	.70	.79	1.1	.07

Notes
1 Sodium sulfur battery module, (3).
2 Liquid hydrogen.
3 Higher heating value, Wh - Watt hours.

A fuel cell power system for transportation applications, must have a high power density (kW/kg) and a low specific cost ($/kW). The proton exchange membrane (PEM) and alkaline fuel cell (AFC) types, potentially have these characteristics. The PEM fuel cell may be used with methanol reformate but requires platinum electrocatalyst material. The AFC can be constructed without precious metal electrocatalyst but requires pure hydrogen for operation due to sensitivity to CO_2. The first fuel cell powered vehicles will probably be of the PEM type.

The high capital cost of future, mass produced, PEM fuel cell power systems (≈$270/kW) will necessitate hybridization with batteries. If fuel cell systems could decline further in the cost to power ratio, for example by future discoveries and the use of on-board storage of hydrogen, the hybridizing may not be necessary. The performance and cost goals for an electric vehicle fuel cell power plant need to be approximately: 1) 1 kg/kW (fuel cell stack weight), 2) $160/kW (fuel cell stack cost).

Specific areas that require research and development to reach these goals and make fuel cell power systems possible are:

1) Continued lowering of the amount of platinum necessary as an electrocatalyst material while maintaining high specific performance.
2) A cost effective light weight bi-polar plate material and design (must be electron conducting and corrosion resistant).
3) Light weight and low cost thermal and water management for low temperature high power fuel cells.
4) High cycle life, low cost, high power density batteries for hybridizing (power density larger then 200 W/kg).
5) Methanol fuel reformer weight reduction and response time improvement. Carbon monoxide clean up stage to reduce CO < 10 ppm.
6) Low cost and weight effective, on-board storage system for hydrogen. Pure hydrogen reduces fuel cell start up time, and allows the fuel cell to have rapid load response.
7) Testing and demonstration of a PEM fuel cell-battery hybrid vehicle. This test will provide a present day bench mark and the demonstration would provide impetus for this technology.

CONCLUSIONS

Air pollution is stimulating the transition from conventional vehicles to more efficient low emitting vehicles. The battery powered electric vehicle is clean and efficient but suffers from limited daily range, and long re-charge times. The fuel cell is an electrical power system that may overcome these problems. The fuel cell provides a path to future fuels by operating on reformatted methanol in the near term and pure hydrogen as it becomes available. The problems in fuel cell power systems today are low power density and high cost.

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Demonstration of Aluminum-Air Fuel Cells in a Road Vehicle

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ABSTRACT

This paper discusses recent progress in the application of aluminum-air fuel cell technology to road vehicles. Preliminary road tests were conducted to compare the performance of an aluminum-air/lead-acid hybrid battery energy source with that of a conventional lead-acid-only energy source. One of Unique Mobility's Electrek hatchback vehicles was converted into a highly instrumented testbed for testing the aluminum-air/lead-acid hybrid. Tests showed that at least a doubling of the range was achieved in an all-electric vehicle using the aluminum-air/lead-acid hybrid approach. The demonstration provided focus to necessary future developments in aluminum-air fuel cell engineering for vehicle applications. Test data are presented, as well as projections on future developments of the aluminum-air fuel cell as a vehicle power source.

INTRODUCTION

Refuelable aluminum-air batteries are a type of fuel cell that has significant potential for road vehicle applications. They overcome two of the classic deficiencies of electric power sources, in that they possess both high specific energy densities, and the potential for rapid refuelability. In an effort to assess the merits of these batteries for road applications, Alcan and Unique Mobility have formed a joint venture to integrate Alcan's aluminum-air battery technology with Unique's electric vehicle technology. This paper discusses the initial testing in this new area of aluminum-air battery powered electric vehicles.

Alcan has developed an aluminum-air battery that is currently being field-tested for standby reserve use by a telecommunications company (1). Though having a rather low power density, the battery has an energy density comparable to that of an internal combustion engine, with more than 350 Wh/kg based on a total battery weight. In addition, Alcan and Unique Mobility Inc. of Denver are engaged in a joint venture to develop high-efficiency high-power-density motors and controllers for advanced electric vehicles. Unique had previously built the Electrek, which was a commercially available all-electric vehicle, and which performed outstandingly well in D.O.E. tests (2).

As a first step in a program to develop an aluminum-air battery for road use, we decided to test a modified version of an existing telecommunications battery, which had been designed for 1.3 KW peak power, in an existing vehicle which had a history of successful track testing behind it (3). The concept was to replace eight of the sixteen lead-acid batteries used in the Electrek with two aluminum-air batteries, which would result in a net savings in weight. This would give an ideal combination of high power capability for short duration using the lead-acid batteries, and long operating time due to the high energy density of the aluminum-air batteries. This was done to allow normal vehicle acceleration and road speeds, since the aluminum-air batteries had a relatively low power capability. Thus the eight lead-acid batteries would provide the surge power, and the aluminum-air batteries would constantly trickle-charge the lead-acids, supplementing their power requirements, and recharging them during off-peak periods and when the vehicle was not being driven. The specifications for the Electrek vehicle modified for this experiment, now designated the Altrek, are shown in Table 1. The aluminum-air/lead-acid hybrid would give a 20% reduction in battery weight, and an expected increase in energy capacity to about 30 kWh from the 12.5 kWh afforded by the lead-acids alone.

Table 1. The Altrek Vehicle

Altrek Specifications

General:
Wheelbase: 95.5 in. (2.42 m)
Length: 171.5 in. (4.35 m)
Width: 67 in. (1.702 m)
Propulsion Motor: 32 HP (23.87 kW) Shunt wound
Controller: Hybrid Armature Field Transistor
Body: Glass and Carbonate

	Base Line System	AluPower Hybrid	
Batteries	Lead Acid	Al Air	Lead-Acid
Quantity	16	2	8
Weight Each	24.1 kg	71 kg	24.1 kg
Total Battery Weiqht	386 kg	335 kg	
Battery Capacity	14.2 kWh	41.1 kWh	
Gross Vehicle Weight	1,510 kg	1459 kg	
Estimated Range at 30 MPH	75 mi.	200+ mi.	

The test to compare the aluminum air/lead acid powered hybrid vehicle with the lead-acid-only powered vehicle consisted of running the same vehicle on the same track under similar conditions for as long as each would maintain the performance baseline, and logging the relevant data to allow quantitative analysis at a later time. The first tests were conducted in October 1988 and the second tests in March 1989 on a 0.9-mile closed-loop road track in Mead, Colorado.

THE ALTREK VEHICLE

The Altrek vehicle is pictured in Figure 1. It is a specially modified Electrek with a compartmentalized rear hatch area for the aluminum-air batteries, a DC-DC converter for boosting the aluminum-air battery voltage to the 96-volt lead-acid battery system bus, and a PC based data acquisition computer for data logging and controlling the batteries. A block diagram of the Altrek electrical system is shown in Figure 2.

The aluminum-air batteries are shown in Figure 3, and a typical performance curve for a stationary discharge of a single battery in Figure 4. These batteries were designed and built at Alcan's Research Centre in Kingston, Ontario, and are modified versions of the award-winning standby reserve battery. The modifications included a 50% reduction in electrolyte storage space, up-graded wiring, extra heat-exchange capability and improved seals. Each battery has a reservoir of caustic electrolyte which is pumped through the cell-stack between the aluminum anodes and air cathodes to generate electrical power. The battery by-product of aluminum hydroxide is gradually precipitated out and collected in the sump area. This non-hazardous by product can be recycled, thereby allowing clean, replenishable power. A stream of air is blown through the cell-stack to supply oxygen to the cathodes in order to maintain the electrochemical power-generating reaction.

FIGURE 1: THE ALTREK VEHICLE

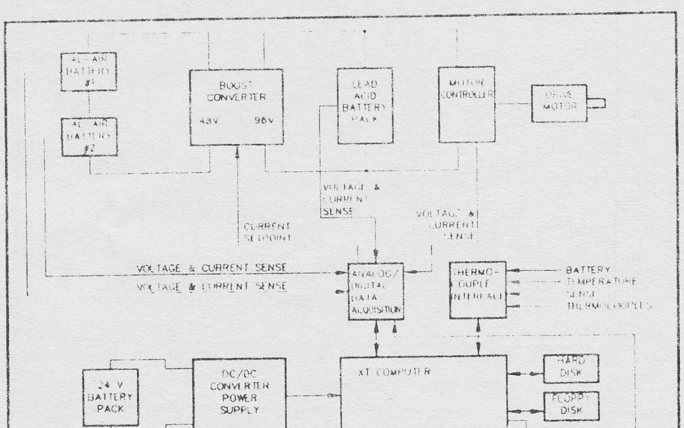

FIGURE 2: BLOCK DIAGRAM OF ALTREK ELECTRICAL SYSTEM

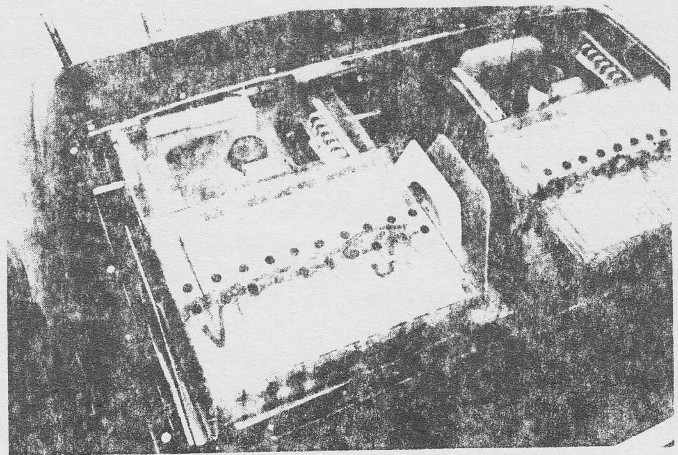

FIGURE 3: THE ALUMINUM AIR BATTERY

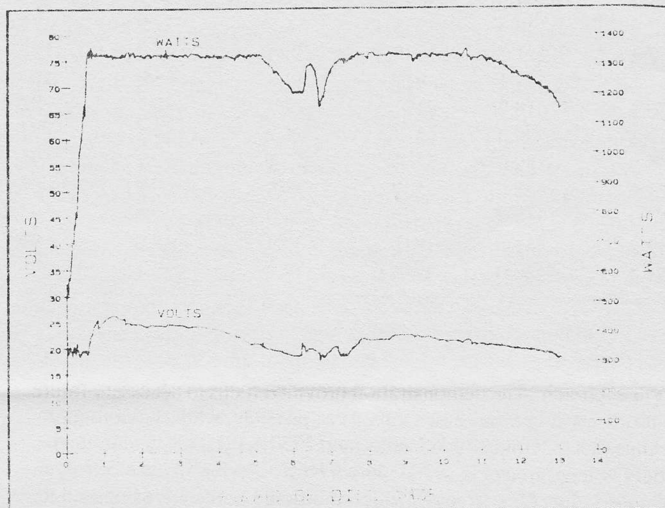

FIGURE 4: ALUMINUM AIR BATTERY PERFORMANCE CURVE

The lead acid batteries used were 12 volt Sears Die Hard™ (Johnson Controls) deep cycle marine batteries. One string of eight batteries was used to provide the 96 volt bus. For the lead-acid-only test, another string was connected in parallel to the first. For the aluminum-air/lead-acid hybrid test one series of eight lead-acid batteries was replaced with two aluminum-air batteries connected in series. The main specifications for the lead-acid battery are a capacity of 65 amp-hours at a one-hour rate and a weight of 55.5 pounds.

A DC-DC converter was used to interface the aluminum-air batteries to the lead-acid batteries. The voltage of each of the two aluminum-air batteries varied between 20 to 30 volts depending on load, together delivering a 40 to 60 volt output, which was then boosted by a DC-DC converter to the 96-volt bus voltage. This boost converter was capable of handling 65 amps input and had a current setpoint which allowed control of the actual current delivered by the aluminum-air batteries. The PC was used to monitor the various battery parameters and set the current limit.

The PC based data acquisition system was used to log data from the various systems, as well as perform the above-mentioned control functions. It was powered from its own set of two lead-acid batteries. The PC had a hard disk for data storage, and it used cumulative data tracking so that if the PC were powered off, it would restart with the previous run's data which allowed tracking the total cumulative battery outputs. A total of 23 parameters was logged at one minute intervals throughout the entire test. A sample of the raw data logged by this system is shown in Table 2.

Table 2: Sample of Data Logged by Computer

Al-Air Power	Lead-Acid Power	Motor Power	Al-Air Volts	Al-Air Amps	Lead-Acid Volts	Lead-Acid Amps	Motor Amps	Lead-Acid Amp-Hours	Al-Air kWHours	Test Time Hours
62.8	73.4	0.0	55.0	1.1	111.4	0.7	0.0	21.6	10.2	25.46
622.9	610.9	0.0	55.0	11.3	116.9	5.2	0.0	21.7	10.2	25.48
812.3	767.3	0.0	52.8	15.4	114.7	6.7	0.0	21.7	10.2	25.50
64.6	78.7	0.0	55.0	1.2	111.1	0.7	0.0	21.8	10.2	25.52
1581.0	-4050.5	5610.5	40.6	38.9	101.1	-40.1	55.5	21.7	10.3	25.53
1653.0	-5424.5	7026.0	39.4	42.0	96.2	-56.4	73.0	20.8	10.3	25.55
1679.5	-6214.0	7860.5	39.6	42.4	95.8	-64.9	82.1	19.8	10.3	25.57
1635.2	-4276.0	5896.3	40.8	40.1	98.2	-43.6	60.1	19.0	10.3	25.59
1630.1	-1934.9	3515.6	40.3	40.5	97.4	-19.9	36.1	18.0	10.4	25.60
1364.7	-3412.6	4767.2	30.6	44.7	97.5	-35.0	48.9	17.4	10.4	25.62
1581.7	-4599.7	6145.0	39.2	40.3	95.3	-48.3	64.5	16.4	10.4	25.64
1705.2	-6790.3	8424.5	38.4	44.4	95.2	-71.3	88.5	15.4	10.5	25.66
1665.2	-4064.6	5685.4	41.4	40.2	95.5	-42.6	59.5	14.6	10.5	25.67
1637.9	-6420.3	8023.3	41.1	39.9	95.6	-67.2	83.9	13.7	10.5	25.69
1762.5	-241.2	1918.5	38.4	45.9	102.4	-2.4	18.7	12.9	10.5	25.71
1734.1	731.1	917.0	37.8	45.9	100.2	7.3	9.2	12.1	10.6	25.73
1556.3	-7619.2	9127.5	43.6	35.7	92.2	-82.6	99.0	11.5	10.6	25.74
1649.1	-4779.3	6373.5	41.7	39.5	93.2	-51.3	68.4	10.5	10.6	25.76
1665.0	-6249.0	7881.9	41.4	40.2	93.7	-66.7	84.1	9.6	10.6	25.78
1778.5	-3143.0	4842.0	38.8	45.9	94.0	-33.4	51.5	8.8	10.7	25.80
27.9	-4918.7	4970.1	55.0	0.5	95.8	-51.4	51.9	7.9	10.7	25.81
1442.8	-351.6	1816.2	37.9	38.0	99.3	-3.5	18.3	7.2	10.7	25.83
1454.3	-2230.0	3735.6	38.2	38.1	96.8	-23.0	38.6	6.3	10.8	25.85

The algorithm for controlling the current drawn from the aluminum-air batteries was to pull as much current as possible, while satisfying the constraints of a maximum of 65 amps, and 2750 watts, and an aluminum-air battery voltage greater than 20 volts per battery, as well as an electrolyte temperature below 65 degrees Celsius. Additional limits were imposed to control the lead-acid batteries maximum float voltage at 114 volts, and to limit the total amp hours recharged to ensure high recharge efficiency.

VEHICLE TESTING AND RESULTS

The testing consisted of driving the vehicle for as long as possible while maintaining 48 km/hr (30 MPH) around a 0.9 mile closed-loop road course in Mead, Colorado. In addition to the vehicle driver, a second passenger was on board to observe the data acquired and radio results to observers at track-side. The run with lead-acid-only occurred on 10/24/88 and achieved a range of 51.3 miles. The 16 lead-acid batteries used for this test theoretically had 12.5 kWh energy capacity, therefore the energy consumed per mile was 243 Wh/mile (12,500/51.3). Since the average speed was 30 MPH, the average power from the lead-acid batteries was 7.3 kW (243 Wh/mile * 30 mile/h). This run provided a baseline for operation, and preceded the aluminum-air runs on 10/25/88 through 10/28/88.

ALUMINUM AIR TEST #1 – The tests on 10/25/88 through 10/28/88 with the aluminum-air batteries highlighted technical problems with both the batteries' reliability and the data acquisition system reliability. During these tests one of the two aluminum-air batteries, battery A, developed operational problems which prevented finishing the test with both aluminum-air batteries, so the DC-DC converter and PC control algorithms were modified to finish the test with one aluminum-air battery. The total energy delivered by battery A was 2.1 kWh, and that from battery B was 12.57 kWh for a total aluminum-air battery energy of 14.67 kWh. In addition the original eight lead-acid batteries had a full charge of 6.25 kWh of energy, for a total aluminum-air/lead-acid energy of 20.9 kWh. The total range achieved with this combination was 67.5 miles. This gives an energy per mile of 310 Wh/mi (20,900 Wh/67.5 mi). Since the 14.67 kWh from the Al-Air batteries achieved only an additional 41.9 miles, for an economy of 350 Wh/mi, the energy transfer efficiency was only 69%. This inefficiency was ascribed to the inefficiency of using a single aluminum-air battery, the low initial temperature of all the batteries each morning, particularly the lead-acids, and to a malfunctioning lead-acid battery. These initial results were nonetheless encouraging considering the problems encountered. Thus, it was decided that a second test of the aluminum-air batteries should be conducted.

ALUMINUM-AIR TEST #2 – The second test occurred on 3/27/89 through 3/30/89. This test consisted of six separate drive cycles over a four-day period, which achieved a total range of 105 miles. Figure 5 shows the cumulative aluminum-air battery energy delivered as well as the net energy delivered to the motor. Since the lead-acid batteries were initially charged, the cumulative energy delivered to the motor is greater than the aluminum-air energy delivered. From the detailed data logged during this run, the total motor energy delivered was measured to be 26.07 kWh, which gives a

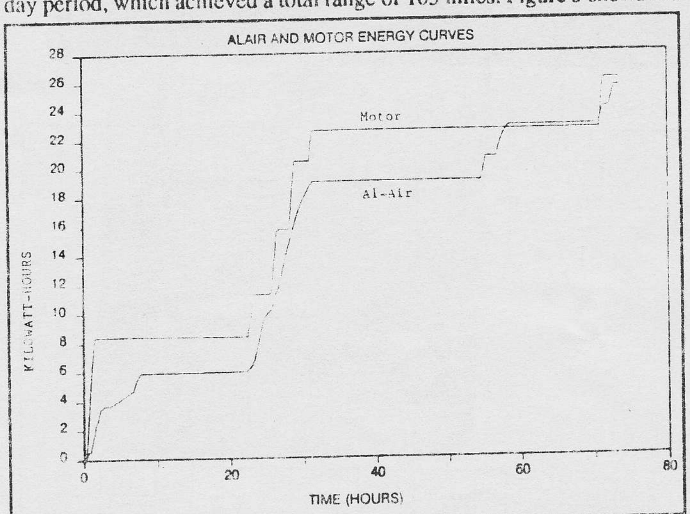

FIGURE 5: ALUMINUM-AIR AND MOTOR ENERGY CURVES FOR TEST RUN

motor energy per mile of 248 Wh/mi (26,070 Wh/105 mi). This then shows the average power consumption over the 105 miles at 30 MPH average to be 7.44 kW (248 Wh/mi * 30 mi/h), which is comparable to the value calculated for the lead-acid-only run. This was quite a respectable economy when one took into account the undulating nature of the course, and its several sharp corners, along with the sometimes wet condition of the surface.

Integration of the initial lead-acid power for the first cycle of this test shows the lead-acid batteries had 4.9 kWh of energy in their initial charge. Thus, of the total aluminum-air energy delivered, the net amount delivered to the motor was 21.17 kWh (26.07 - 4.9), based on the difference between the total energy supplied to the motor and the initial energy content of the lead-acid batteries. Furthermore the data acquisition system measured a total aluminum-air energy delivered of 25.5 kWh. Thus the net efficiency of transfer of energy from the aluminum-air batteries to the drive motor is found to be 83% (21,170/25,500). This is substantially better than the first run, due partly to the presence of both aluminum-air batteries which provided a higher voltage input to the DC-DC converter, and thus higher voltage boost efficiency, as well as the warmer operating conditions and fully functional lead-acid batteries.

This delivery of 21,170 Wh from the aluminum-air batteries to the motor demonstrates over three times the energy content of the heavier lead acid batteries they replaced. As can be seen from Figure 6, this is conservative since some energy was transferred from the aluminum-air batteries to the lead-acid batteries and not discharged by driving the vehicle.

Also of interest is the lead acid amp-hours versus time which dramatically shows the individual drive cycles and their associated recharge cycles, as shown in Figure 6. The lead acid amp-hours data were cumulatively updated relatively fast, approximately every second, whereas the data logger only sampled and stored data every minute, thus there is more continuity in the amp-hours measurement than in the other data sampled.

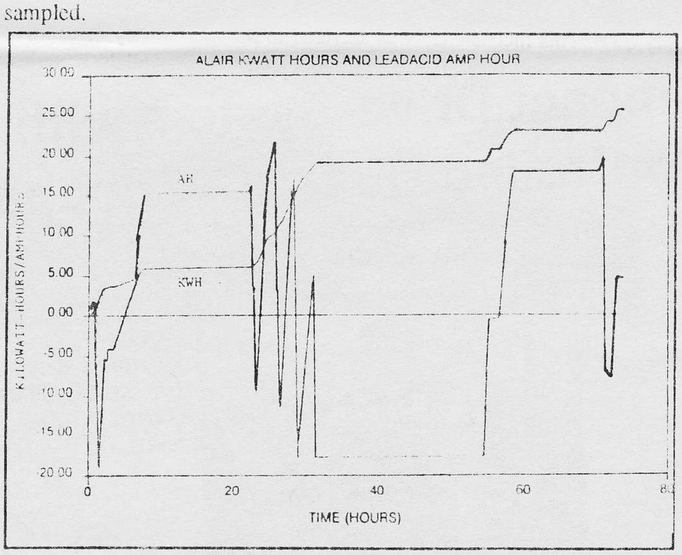

FIGURE 6: LEAD-ACID AMP-HOUR AND AL-AIR KWATT-HOUR CURVES

The recharging of the lead-acid batteries requires some discussion to explain the approach used. It was determined that recharging the lead-acid batteries to a 100% state of charge was inefficient. It was found that charging the lead-acid batteries to around 75% state of charge was a reasonable upper limit. Also fully discharging the lead-acid batteries completely should be avoided since it can cause cell reversal. Thus it was decided that the lead-acid batteries should be charged and discharged somewhere between about 10% and 75% state of charge. Testing of the charging algorithm prior to the final tests showed by trial and error that putting in about 35 amp hours resulted in a return of about 35 amp hours, and thus the charge algorithm was to nominally replace 35 amp hours at each charge.

The second series of tests also brought to light areas which needed further improvement, mainly in the battery engineering to enhance its roadability. Nevertheless the tests did show a marked improvement over the first series of tests, and gave encouraging results, especially since the 100 mile range barrier was broken.

DISCUSSION

While this is not the first attempt to separate the electrochemical power sources on a road vehicle into the "energy" source and the "power" source, it is the first such trial of an aluminum-air battery on a road licensed vehicle. Used as a range extender the aluminum-air system allows the user the option of recharging his secondary battery with regular utility company electricity. If the mission is short one may never need to turn on the aluminum-air system. In the current tests, the 2.6 kW aluminum system could only sustain the vehicle at a continuous speed of around 20 Km/hr (12.5 mi/hr). The vehicle's full performance is only obtained while the lead-acid power battery retained some charge.

This same vehicle with a 6KW aluminum-air range extender would be able to run continuously at around 40 km/hr (25 mi/hr) and would be capable of broader use. It is our intention to build a rapidly refuelable 6 kW unit for a vehicle test in 1990. Simultaneously we are working on lower cost anodes and cathodes. At this time we can identify that the 1990 vehicle battery will use smelter-grade metal.

We can expect to get around 3.5 kWh from a kilogram of aluminum in a practical battery, with a metal cost around $2.50 a kg. Clearly this is a high cost for energy, since taking the economy of 248 Wh/mi and 83% efficiency gives 300 Wh/mi from the aluminum-air batteries, and therefore 21 cents per mile cost, thus it is only justified if used infrequently. Fortunately with the typical distribution of mileage between short and long trips of the average consumer this is the case and it is possible that our anode costs will make some markets for environmentally benign electric vehicles feasible. Cathode costs have been viewed in the past as a barrier to the use of aluminum-air batteries. Our present cathodes for communications reserve systems cost as little as $200/m^2. We have every expectation that costs will fall for a vehicle battery also.

We were gratified that the communications reserve batteries did withstand the rigours and demands of the vehicle tests as well as they did. The new system being designed will be specially adapted to the vehicle - unlike the self-contained cubic shape of the present battery which was designed for an entirely different application - and will utilize the vehicle space in a manner that will not impose a constraint on passenger or luggage space.

CONCLUSIONS

An aluminum-air battery that is activated only as needed has been shown to be roadworthy. The vehicle range was doubled, and thus the aluminum-air battery remains a viable contender for a long range vehicle though further cost reduction is necessary.

ACKNOWLEDGEMENTS

Mike Schoeneweiss and John Dawson from Alcan and Craig Carnbier, Kevin Barnes and Roger Thornton from Unique Mobility participated in the tests, and their cooperation is gratefully acknowledged. We are especially appreciative of the efforts of Nancy Van Camp of Alcan in ensuring that the correct documentation accompanied each and every shipment across the international border which can otherwise pose a severe barrier to successful international collaboration.

The authors wish to thank Hugh Wynne-Edwards for advice and encouragement during the long period of development that led up to this demonstration.

The Zinc/Bromine Battery: Recent Advances for Electric Vehicle Applications

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Johnson Controls, Inc.

ABSTRACT

The advanced Battery Business unit of Johnson Controls, Inc. (JCI) is developing the Zinc/Bromine Battery for electric vehicle applications. The battery's potential for good energy density, low manufacturing cost, and long life make it a particularly attractive candidate. Other advantages include ambient temperature operation, a modular design which facilitates design flexibility, and minimal maintenance.

In December of 1986, JCI was awarded a cost-share contract from the Department of Energy. Its main objectives are: (1) to continue research and development of the Zinc/Bromine Battery core technology, and (2) to conduct the necessary battery engineering and testing to develop the battery for a proof-of-concept Zinc/Bromine electric van battery. The design specifications for the final contract deliverable battery correspond to application in the Ford ETX-II van. Advances in the core technology, including electrode substrate, separator, cathode activation layer, and electrolyte, have significantly improved the systems's life and performance capabilities.

CONCLUSION

The development of the zinc/bromine battery has reached the point where complete proof-of-concept batteries will soon be ready to be checked out in a real or simulated electric van. In 1989, JCI will first deliver an 8-cell and then a 63-cell module to a site specified by the DOE for testing.

SUMMARY

Sodium-sulfur batteries for electric vehicles is promising as a result of improvements in electrochemical performance, battery design, and cost. Because of the potential hazards associated with reactive compounds under elevated temperature, battery transport safety and disposal issues will need to be addressed before widespread commercialization is possible. Important issues identified are: 1) hazardous material shipment regulations and procedures, 2) safety in motor vehicles, and 3) EPA hazard classification, decommissioning, and disposal procedures. A combination "top-down" and "bottom-up" relative risk assessment would provide information for developing performance standards, test procedures, and rulemaking proposals.

A New Compact Drive-System with a Microcomputer Controlled Dual DC-Chopper

Hans Kahlen and H. Thomas Drumm
VDE

Abstract

Different forms of integration between motor, gear and controller are discussed. By using gear-shifting, the drive can be optimised. A good performance for a separately excited dc motor is given by splitting in two parts fed by a dual dc chopper. The design of a motor and controller system for a passenger car is shown.

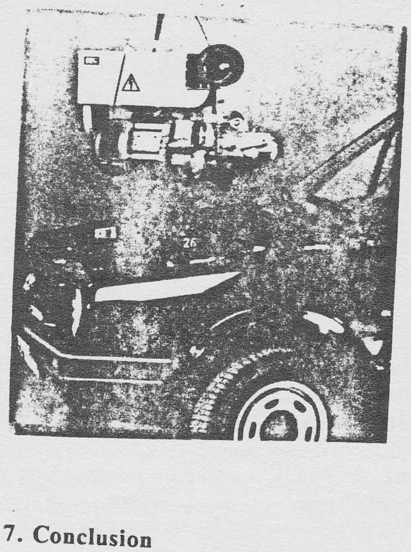

Fig. 1: Complete drive unit for the CitySTROMer (Photo: ABB)

1. Introduction

Until now, many different drive-systems have been developed for electric vehicles. The drive components can be used universal if they work as separate units. The separate mounting of each unit and the necessary and numerous electrical and mechanical connections (electric wires, shaft-connections, cooling devices) are disadvantageous.

2. Integrated drive-systems

A concentration of different electronic components, including the board power supply and an on-board-charger (components which are not part of the drive), in one component carrier has made an approved system in prototype cars. With this strategy the VW-Golf "CitySTROMer" (Figure 1) was as well fitted as the Chrysler Van T115 (1,2,3).

7. Conclusion

Drive systems for electric vehicles have been choosen up to now with a large field weakening range to keep the additional battery losses in the armature control range small. But the drive motor is not well utilised in this case. In a higher speed range (weakened field) the efficiency drops. With the dual chopper, the total efficiency will be better in the armature control range. The base speed can be choosen optimally

Electric Vehicle Design and Performance Using Advanced Batteries[a]

ACKNOWLEDGMENT

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EG & G, Inc.
Idaho Falls, ID

ABSTRACT

Series of designs of compact and full-size passenger cars and minvans were formulated using state-of-the-art electric driveline components and battery modules/cells. The performance of each of the designs was simulated using the ELVEC. Computer runs were made for constant speeds between 40 and 88.5 km/h and the J227D and FUDS driving cycles as well as maximum effort accelerations. The simulations indi-cated for the three vehicle types the target ranges and acceleration times could be met for both the near-production and advanced batteries. The targets were consistent with those established for the various batteries by the DOE Battery Goals Task Force in 1988. The energy consumption values calculated for vehicles utilizing DC drivelines were consistently lower by 15–25% than those for vehicles using AC drivelines primarily due to the higher efficiency of the transmission in the DC powertrain system. The attractive performance of the formulated electric vehicle designs emphasizes the need to give greater attention in the future to battery cost, life, and maintenance issues than they have often received in the past. Successful marketing of electric vehicles now depends to a large extent on these issues about which there is presently considerable uncertainty.

INTRODUCTION

Recent advances in DC and AC motors and the associated electronics have resulted in electric drivelines that are smaller, lighter, and more efficient than those previously available. Progress has also been made on advanced batteries having significantly higher energy and power densities than the lead-acid batteries presently being used in electric vehicles. This paper is concerned with the assessment of the effect of these advances in electric vehicle technology on the performance and utility of various types of electric vehicles, including compact and full-size passenger cars and minivans. The advanced powertrain components and batteries can be characterized in considerable detail using data from various DOE supported programs. These characterizations permit one to formulate designs (powertrain layout and size, vehicle weight and utility) for various types of electric vehicles and then to simulate their performance (range and acceleration) on the computer with considerable confidence. The advanced batteries considered in the paper are sodium/sulfur (Na/S) and zinc/bromine (Zn/Br) with the baseline batteries being sealed gel/cell and flooded tubular lead-acid and nickel/iron (Ni/Fe). The major uncertainty concerning all the batteries considered in this study is not in their performance in electric vehicle applications, but in their life and initial cost.

CONCLUSIONS

The proposed GSFUDS battery discharge cycle is representative of the duty cycle of an electric vehicle traction battery over the Federal Urban Driving Schedule.

The GSFUDS cycle is much simpler a FUDS power versus time cycle yet produces the same estimate of battery performance in an electric vehicle.

The manner in which the GSFUDS cycle is defined increases its utility in that the cycle applies to any traction battery in any electric road vehicle.

Application of Solar Cells to the Automobile

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Electronics Engineering Dept.
Mitsubishi Motors Corp.

ABSTRACT

This paper is a summary of the applications of the solar cell to automobiles. The solar cell, which generates electric power using solar energy, has become more efficient for electric power generation. As the result, a higher electric power output has been able to be obtained with a smaller cell.

Therefore, for internal combustion engine powered vehicles, the solar cell is being applied to an auxiliary charger for prevention of battery-running-down, to a ventilation system, etc.. However, the ultimate application of the solar cell is for the vehicle power source. One application is for the auxiliary battery charging of electric vehicles and the other is for solar powered vehicles for which solar energy itself is utilized as the power source.

We made several solar powered vehicles as an experiment using silicon cells(which are the most popular type of solar cell) applied to conventional techniques used in electric vehicles. One of them ran the whole distance in the Pentax World Solar Challenge Race held in Australia in 1987. The technique may be practically applied to commuter cars and will be useful for improving the performance of electric vehicles.

CONCLUSIONS

The application of the solar cells to the car is not yet practical because of the limitation of generating power. However, viewing from the good results of the solar-car-race run, the solar car has been improved to the point where it has enough performance to allow operation on a road.

Fig.14 shows a single seater commuter car which employs the aforementioned techniques, and it is capable of practical use on the street.

However, in case of the application to the car, the usable surface area is the limiting factor or requiring an improvement in solar cell efficiency for this concept to be practical. We expect the development of more efficient solar cells soon, along with more effective techniques that improve power conversion efficiency.

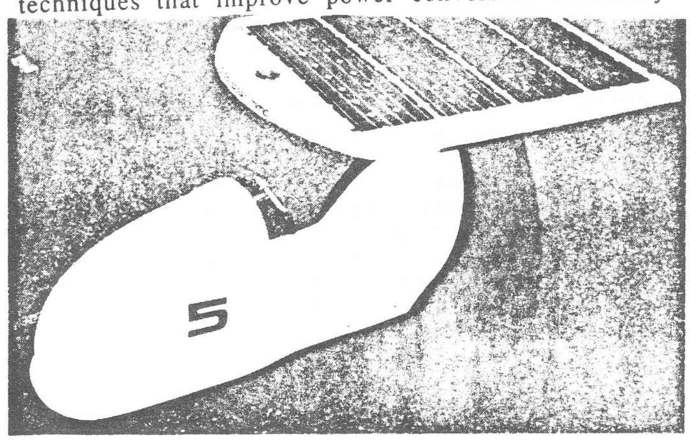

Fig. 14 Commuter car

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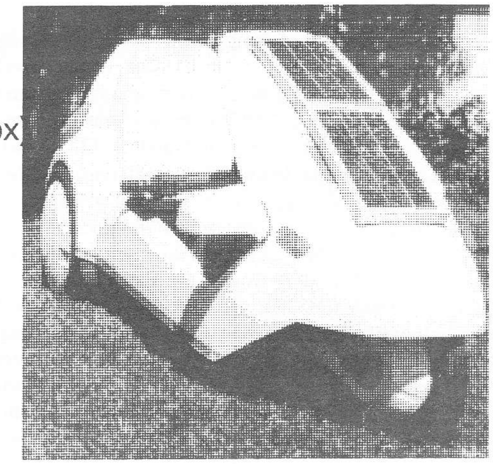
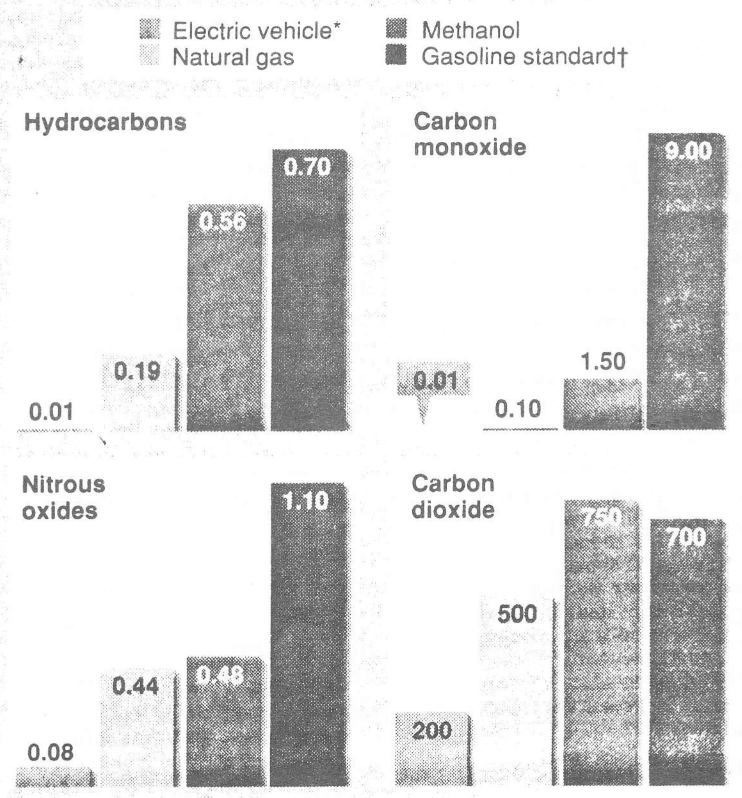


At Last, a Practical Electric Vehicle?

Speed: 72 M.P.H.;
Range: 100 Miles

Comparing Vehicle Emissions

Emissions of pollutants in vans using different forms of energy, in grams per mile.



* Figures represent power-plant emissions, based on mix of coal, oil, hydro and nuclear plants in current use.
† Assuming 17 miles per gallon

Source: Electric Power Research Institute

SANTA CLARA EAA RALLY

September 16, 1989 was cloudy as we assembled at Mc Candless Moffat Park for a 10Am start. We had a 500 watt inverter to power the time clock. Roy Poulsen conducted video interviews with most of the EV drivers while we were setting up. The inverter would not start without a continous load, so a 30 minute delay was caused by a trip to the electrical store to get a 25 watt lamp!
In the driver's meeting we decided to run as fast as the speed limits would permit. The course was 4.4 miles long, and the fastest lap time was just over 8 minutes.
We ran 1½ hours before lunch, and another 1½ hours after lunch. The intermittant rain became so heavy by 2:30PM that we stopped the run. Some drivers continued to run laps with an impartial witness as passenger. The drivers who did this received credit for the extra laps.
The rally results were as follows:

L. Wenzel	Honda	15laps	68 miles
C. Olson	Saab	13 "	57 "
B. Williams	Honda	13 "	57 "
S. Skokan	Escort	12 "	53 "
S. Cornell	Carman Ghia	10 "	44 "
L. Hemstreet	VW...	10 "	44 "
L. Burriesci	Plymouth	7 "	31 "
G. Hargraves	Aquilla	7 "	31 "
J. Wasylina	Renault	7 "	31 "
<u>2&3 wheel vehicles</u>			
B. Schneeveis	Homemade	2 "	9 "
R. Poulsen	Homemade	1 "	4.4 "

Submitted by L. Hemstreet, Pres. SC Chapter

San Jose Mercury News ■ Tuesday, June 7, 1988

Hydraulic fluid

Revolutionary substance could put car technology on new roac

By Thomas Maugh
Los Angeles Times

AUTOMOBILE clutches with no moving parts. High-performance shock absorbers that adjust instantly to changing road conditions, yet cost no more than conventional shocks. Robotic arms that are much more sensitive and responsive than those now in use.

Those are but a few of the potential applications of a revolutionary new hydraulic fluid patented last week by University of Michigan researchers.

The fluid solidifies when an electric field is applied, then returns to its liquid form when the field is released. This ability would allow fluid switching devices, clutches, transmissions and other devices to be controlled directly by a computer without intermediate mechanical components.

The first such fluid was developed 40 years ago, but neither it nor others developed since have had practical applications, primarily because they break down at the temperatures encountered in cars and other machinery. The Michigan material is the first to overcome that problem. Experts say that potential applications of the technology represent a $20 billion annual business.

The new fluid represents "real product innovations that are very feasible very soon," said David D. Hunter, vice president of Acustar Inc., a Chrysler Motor Corp. subsidiary that has licensed the technology for use in four-wheel-drive vehicles.

Fluids like the new material are called electro-rheological fluids because they thicken in the presence of an electrical field. Those developed in the past typically consisted of a fine powder such as baking soda, glass or even corn starch dispersed in an electrically non-conductive fluid such as kerosene or silicone oil. They always contained water, which limited their operating temperature.

In the absence of an electrical field, such fluids typically look like milk. As an increasing electrical field is applied, the fluid thickens to the consistency of cream, then of butter. At very high fields, the congealed solid can withstand large forces of shear, tension and compression, said physicist Frank E. Filisko, the new material's inventor.

Although a field of several million volts is required to congeal the fluids, virtually no current passes through the material. Thus, if the fluids could be used in an automobile, for example, its battery could furnish the required power. When the field is turned off, the material instantly reverts to its fluid form.

Filisko's discovery was that a family of materials called aluminosilicates — made from aluminum, silicon, and oxygen — would work in such fluids in the absence of water.

Scientists are not really sure about how the electro-rheological fluids work. "We have a new theory that helped us select the aluminosilicates, but I am not going to talk about it until we study it more and publish a paper," Filisko said.

He noted that his group was fortunate that the aluminosilicates were one of the first materials they tried; other materials they have tried since do not work as well as predicted by the theory.

Filisko estimated that the new materials could cost as little as $3 per quart, compared to $40 or more for existing electro-rheological fluids.

One potential use of the new fluids might be in shock absorbers where they could change from normal to viscid and back again in a fraction of a second under the control of a microcomputer. It would thus be possible to alter the damping effect of individual shock absorbers independently in response to changing road conditions.

Such shock absorbers could be built for a fraction of the cost of conventional independent suspension systems, Filisko said. Used in brakes, the fluid would allow smooth braking with no lockups because the brake on each wheel could be controlled independently by microcomputers, he said.

In hydraulically powered robotic arms, use of the new fluid would eliminate the need for solenoids — mechanical switches for controlling the fluids — and would greatly decrease the response time of the devices, he added.

The primary licensee of the new technology is Tremec Trading Co. of Farmington Hills, Mich., which manufactures manual automobile transmissions and which supported Filisko's research.

The company is already studying the fluid's use in a variety of mechanical devices, said Ed Kaiser, Tremec's manager of technical sales, but he could not predict which products would be first to market.

"It's completely changing the way we think about products, so we're not sure yet which is going to be best," he said.

One potential use of the new fluids might be in shock absorbers where they could change from normal to viscid and back again in a fraction of a second under the control of a microcomputer. It would thus be possible to alter the damping effect of individual shock absorbers independently in response to changing road conditions.

CALENDAR

ASME Dec. 10-15 Winter Anual Meeting, San Francisco, Ca. (212)705-7795

ASME Dec. 11-13 Ninth Miami Intrtnational Congress on Energy and Envionment, Miami, Fla. Contact T. Nejat Veziroglu, Clean Energy Research Institute, College of Engineering, Box 248294, Coral Gables, Fla. (305)284-4666

ASME Dec. 12-14 Winter National Design Engineering Conference and Show, Anaheim, Calif. Administered by Cahners Exposition Group (203)964-0000

ASME Jan. 14-18 Energy Sources Technolgy Conference and Exhibiton, New Orleans, La. ASME-Dallas (214)437-1194

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