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Electric and Hybrid Vehicles Program

14th Annual Report to Congress for Fiscal Year 1990

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PREFACE

This fourteenth annual report on the implementation of the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (Public Law 94-413, as amended by Public Law 95-238 and Public Law 96-185), referred to as the Act, complies with the reporting requirements established in Section 14 of the Act. In addition to informing Congress of the progress and plans of the Department of Energy's (DOE) Electric and Hybrid Vehicles Program, this report is intended to serve as a communication link between the Department and all of the public and private interests involved in making the program a success.

During FY 1990, significant progress was made toward fulfilling the intent of the Congress in the Act. There has been increasing interest shown by both the automobile manufacturing and supply sectors of our economy in electric and hybrid vehicles. The three major domestic automobile manufacturers have all initiated efforts directed toward commercialization of electric vehicles. Research and development efforts continue to show steady progress in advancing the technologies for batteries, fuel cells, and propulsion components. The results of the ongoing activities will provide industry with technology options for vehicles that will be more economically competitive and publicly acceptable.

Introduction

The Department of Energy's Electric and Hybrid Vehicles Program is conducting research, development, testing and evaluation activities to encourage the use of electricity and alternative fuels for transportation.

The transportation sector is the single largest user of petroleum; it consumed 63 percent of all petroleum used in the U.S. last year. Only a small fraction (5 percent) of electricity is generated from petroleum. Electric vehicles, which are themselves virtually pollution-free, could play a key role in helping to reduce both urban pollution and our dependence on petroleum imports. It is the program's goal to develop the technology, in cooperation with industry, that will lead to the production and introduction of pollution-free electric vehicles into the Nation's transportation fleet and substitute domestic sources of energy for petroleum-based fuels.

Public Law 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, was intended to, inter alia, "...encourage and support accelerated research into, and development of, electric and hybrid vehicle technologies...." Congress provided an appropriation for the Electric and Hybrid Vehicles Program of $17.7 million in FY 1990. The FY 1991 appropriation is $25.1 million.

The current program structure and principal responsibilities of the organizational units are shown in Figure 1. The Electric and Hybrid Propulsion Division within the Office of Propulsion Systems manages the program. Some supporting battery research has been conducted by the Office of Advanced Utility Concepts.

The major participants in the Electric and Hybrid Vehicles Program are listed in Table 1. They include a major automotive company, battery companies, component and propulsion system companies, universities, and electric vehicle users from the public and private sectors. Table 1 also provides the cost-sharing commitment of the participants.

The Electric and Hybrid Vehicles Program in FY 1990 continued to emphasize battery, fuel cell, and propulsion systems development up to the level of the testing and evaluation of proof-of-concept vehicles in the laboratory and in fleet operations. Progress made in developing electric and hybrid vehicle technologies is described beginning with highlights of recent accomplishments in FY 1990. Detailed descriptions of the program activities during FY 1990 is given on battery, fuel cell, propulsion system developments, and the testing and evaluation of new technology in fleet site operations and laboratories. In accordance with the reporting requirements of the Act, the Annual Report contains a status report on incentives and use of foreign components and concludes with a List of Publications resulting from the DOE program.

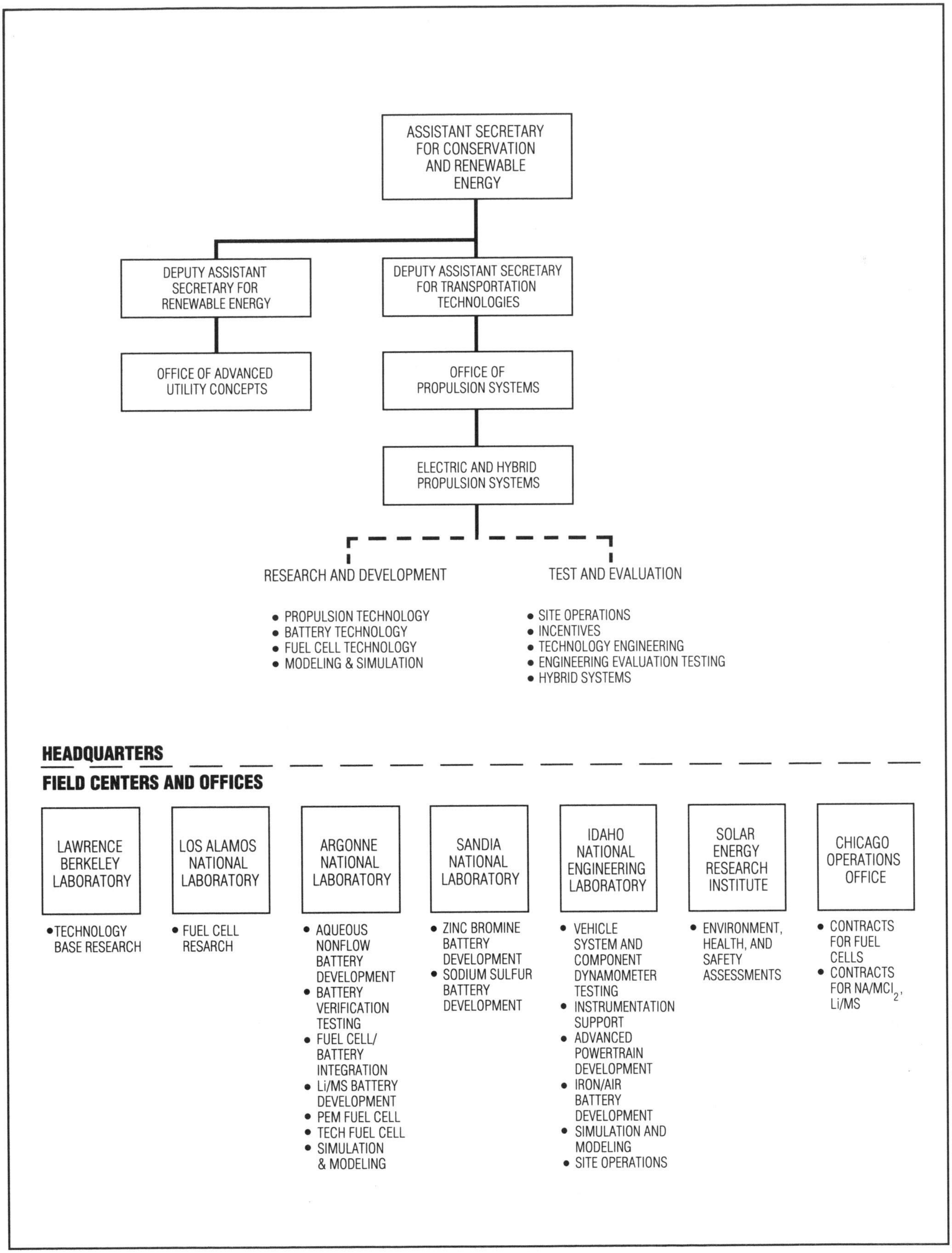

Figure 1: EHP Program Structure

Table 1

Major Participants in the Electric and Hybrid Vehicles Program

	Cost Share of Contract*
Automotive Companies	
Ford Motor Company	20%
Component and Propulsion System Companies	
Delco/GM	50%
A.D. Little	20%
Booz-Allen & Hamilton	32%
Energy Research Corporation	27%
General Electric	20%
Battery Companies	
Beta Power, Inc.	25%
Chloride Silent Power	19%
Eagle-Picher Industries	5%
Johnson Controls, Inc.	18%
Saft America, Inc.	20%
Westinghouse Electric Corp.	10%
Electrosource, Inc.	20%
Universities	
Georgetown University	14%
York Technical College	20%
University of Hawaii	10%
University of Alabama	
University of Florida	
Fleet Testing Site Operators 1/	
GTE Service Co.	50%
Detroit Edison (DECO)**	54%
Arizona Public Service (APS)	65%
United States Navy	80%
Southern California Edison (SCE)	93%
Los Angeles Dept. of Power & Water	54%

1/ The variance in the cost-share percentage by site operators is due to the different activities and contractual arrangements with the site operators. The United States Navy is using its own operation and maintenance funds to operate the electric vehicles transferred at no cost by the Department of Energy from completed site operator contracts. Therefore, the cost share from the Navy is relatively high (80%).

* All contracted efforts are with fee waiver.

** Operations completed in FY 1990

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FY 1990 Accomplishments

Significant progress occurred in each of the Electric and Hybrid Vehicles (EHV) Program areas during FY 1990. The following are highlights of those achievements.

- Two versions of sodium-sulfur battery systems were designed and fabricated by Chloride Silent Power, Limited (CSPL) for use in the ETX-II electric van. Both batteries were delivered to Ford Motor Company for performance evaluation. Results for each were similar and showed that the battery would power the vehicle for 21 Federal Urban Driving Schedule (FUDS) cycles (equivalent to > 150 miles range) and provide 65 kW of peak power for acceleration of 50 mph and 35 kW of continuous power for adequate hill climbing. Comprehensive in-vehicle testing will be performed by Idaho National Engineering Laboratory (INEL) in FY 1991.

- A cost-shared contract was awarded in July 1990 to Beta Power, Inc., to design a universal sodium-sulfur cell that can be used effectively in four U.S. electric vans: ETX-II, 75-hp Modularized Electric Vehicle (MEV), G-Van, and TEVan. This program will follow an evolutionary approach by designing a cell suitable for development of a battery system for these near-term EV's.

- DOE awarded a multi-year, 20 percent cost-shared contract to SAFT America, Inc., in April 1990 to develop and deliver two full-size, proof-of-concept lithium-iron sulfide EV batteries for evaluation in electric vehicles in 1993. These batteries are projected to possess performance capable of providing a 130-mile range in a light-duty van on the Simplified Federal Urban Driving Schedule (SFUDS). A more advanced disulfide cell will be developed which could extend the range to 400 miles.

- Johnson Controls, Inc., fabricated the first successful 1 kWh zinc-bromine battery. This battery utilizes a stack fabricated by vibration welding of the plastic flow frames. The adjacent flow frames are directly welded to each other to seal in the working fluids. The design and fabrication of the flow frames are being improved to assure mechanical ruggedness and to obtain the desired electrochemical performance from the battery system.

- The Fuel Cell/Battery Powered Bus System Project successfully completed Phase I, which demonstrated proof-of-feasibility. All sponsors agreed to proceed to Phase II to build three fuel-cell-powered test-bed urban buses.

- DOE initiated a multi-year, 20 percent cost-shared contract with Allison Gas Turbine Division of General Motors for R&D on proton-exchange membrane (PEM) fuel cells for transportation applications. The work includes the conceptual design of a PEM-based propulsion system, R&D on limiting components, and testing of a complete 10-kW PEM fuel cell system. Also, the Delco Remy and Hughes Aircraft Divisions of General Motors Corporation completed the first year of a feasibility effort on the development of a novel thermo-electrochemical (TECH) power source.

- The single-shaft electric propulsion system program (ETX-II) was completed and the vehicle with a CSPL sodium-sulfur battery was turned over to DOE during the final hardware review at the Ford Motor Company in Dearborn, Michigan. This completes a 4-year effort that has resulted in the development of an advanced AC propulsion system considered to be the standard for the industry. Also, DOE awarded a four-year, 20 percent cost shared, contract in September 1990 to the Ford Motor Company to develop a modular electric vehicle propulsion system that will be suitable for a wide range of vehicles from a small passenger car to a full-size van. This effort is based on the powertrain technology developed in the ETX-I and ETX-II programs and is the next step to bringing this technology closer to commercialization.

- The Los Angeles Department of Water & Power (LADWP) and York Technical College became new participants in The Site Operator Program during FY 1990. Closeout of long time participant Detroit Edison was completed with the transfer of 6 Griffon Vans to York Tech for continuation of testing and evaluation.

- Testing and evaluation of 15 pre-production G-Vans has been completed by Southern California Edison. Major and minor problems were identified and corrected. Solutions to the design problems will be corrected in the production edition vehicle due to start production in the first quarter of FY 1991.

- Preliminary field testing of the Dual-Shaft Electric Propulsion (DSEP) vehicle at Detroit Edison Company (DECO) is complete. The vehicle performance was satisfactory with the exception of the prototype Ni/Fe batteries. The vehicle will be altered for use of sealed lead-acid batteries and tested in comparison with two new Unique Mobility Vans at LADWP during the first half of FY 1991.

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Research and Development

Research and development activities are conducted to advance the technology to the point that transfer to the automobile industry, or component supplier industries, for application-oriented R&D becomes feasible. The functions are carried out in the following program elements: Battery Technology, Fuel-Cell System Technology, and Propulsion System Technology. The activities conducted in FY 1990 within each program element are described below.

BatteryTechnology

The objective of the Battery R&D program is to advance promising battery technologies to levels of maturity that will encourage industry to utilize them as foundation technologies for commercial product development. To this end, research and development was conducted on advanced lead-acid, nickel-iron, lithium aluminum/iron sulfide, sodium-sulfur, sodium-metal chloride, zinc-bromine, and iron-air battery technologies during FY 1990. Major multi-year R&D contracts exist with industrial firms to develop these technologies for electric vehicle propulsion. Each industrial contract is scheduled to deliver full-size EV modules and/or battery systems. Table 2 summarizes the current status and goals for these battery technologies. In addition, ultracapacitor and zinc-air battery technologies are under evaluation for electric vehicle applications. Based on promising test results, an ultracapacitor Request for Proposals (RFP) was issued.

Advanced Lead-Acid Battery

Johnson Controls, Inc.(JCI), has continued development of an advanced lead-acid battery under a five-year, $3.3 million contract in which JCI provides an 18 percent cost share. The objective is to close the gap between the performance capabilities of conventional lead-acid batteries and the mission-directed requirements for electric vans. Toward this end, JCI has investigated forced electrolyte flow by the porous lead and lead-dioxide electrodes as a

Table 2

Electric Vehicle Battery R&D Technology Status

Battery	Developer	Designation	Status*	Specific Energy (Wh/kg)	Specific SFUDS Requirement	Power (W/kg) Peak at 50% DOD	Projected OEM Cost (1990 $/kWh)	Life (Cycles to 80% DOD**)	Cost (1990$/Cycle/kWh)
Advanced Lead/Acid (Pb/A)	JCI	C472	M	47		104		130 ***	
			BG	56	79	—	72	450	0.20
Nickel/Iron (Ni/Fe)	EPI	NIF220	M	56		94		438	
			BG	56	79	—	162	1125	0.18
Zinc/Bromine (Zn/Br2)	JCI	SNL499	M	69		79		140	
			BG	75	79	—	96	600	0.20
Lithium Aluminum/ Iron Sulfide (Li Al/FeS)	ANL/ SAFT America	36V	M	90		86		130 ***	
			BG	100	106	—	96	600	0.20
Sodium/Sulfur (Na/S)	CSPL	ETX-II	B	86		92		230	
			BG	100	106	—	96	600	0.20
Iron/Air (Fe/Air)	Westinghouse	9001	C	57				260	
			BG	100	106	—	96	600	0.20
Sodium/Metal Chloride (Na/MC12)	TBD	BP-1	CD	134		170		—	
			BG	150	150	—	128	800	0.20

* Status: C, Cells; M, Modules; B, Battery; CD, Conceptual Design; BG, Battery Goal (Mission-Directed Goal for IDSEP van on SFUDS).
** Depth of Discharge.
*** Current R&D Core Program is aimed at improving cycle life while maintaining specific energy & power.

Note: SAFT America is the new industrial developer, but the status for this technology is based on hardware developed in a prior contract with Westinghouse Ocean Systems.

means of enhancing utilization of the active materials. The flow-by concept has increased specific energy to 47 Wh/kg, a 40 percent improvement over conventional technology and within 20 percent of the programmatic goal. The life goal of 450 cycles has proved to be more challenging. Recent flow-by cell designs with lower energy capacities have achieved only 50 to 100 cycles when discharged on the SFUDS. The limited life has been attributed to irreversible changes in the lead-dioxide particle matrix. This degradation appears to be precipitated by the high power steps in SFUDS, especially at increasing depth-of-discharge. The JCI program has placed increasing emphasis on characterizing the factors that promote this failure mode and identifying ways to ameliorate its effects. This research has included a matrix of 32 test cells that quantified the effects and interaction of nine design variables on specific energy and cycle life. Denser lead-dioxide electrodes, lower electrolyte densities, and constant-stress compression of the cells benefited cycle life and had minor impacts on specific energy. Forced electrolyte flow was determined to be essential for performance maintenance on SFUDS but much less critical for constant current testing. Detailed analyses have also been conducted on lead-dioxide electrodes to identify the fundamental changes that occur within this electrode. These basic insights are being engineered into new cell designs that seek to improve reaction uniformity within the lead-dioxide electrode.

Nickel-Iron Batteries

Development of high-performance nickel-iron batteries is continuing with Eagle-Picher Industries, (EPI) Inc., under a six-year, $2.9 million, cost-shared contract. This technology has already achieved many of the mission-directed performance targets, and renewed emphasis has been placed on meeting the goals set for cost and cycle life. In FY 1990, several technology-related issues were resolved that have a bearing on these issues. An EPI cost study determined that sintered nickel powder substrates are more cost effective for positive electrodes than fiber-based substrates. In evaluations performed at ANL, modules based on the powder substrate have also demonstrated superior energy, power, and cycle life. Thus, an extensive effort is in progress to minimize the cost of each electrochemical step in the formation of nickel electrodes without sacrificing performance. In earlier modules, substandard iron electrodes obtained from a vendor caused excessive capacity loss and premature failure. Eagle-Picher has worked closely with the vendor to avoid a reoccurrence of this problem. In addition, EPI has installed its own production line for the manufacture of iron plates. A measure of this technology's maturation is the July agreement between the Electric Power Research Institute and EPI to build a pilot plant for battery production. Initial capacity is to be 500 electric vehicle batteries per year (1500 modules). DOE is concluding their R&D efforts with the EPI nickel-iron battery and is supporting the pilot plant by underwriting the cost of the engineering activities needed to make the new production equipment operational.

Two exploratory efforts have also been undertaken to lower the cost of advanced nickel-iron batteries. First, Westinghouse has developed a nonelectrochemical method of making nickel electrodes, and this process has the potential for significantly reducing the cost of this component. Construction of a five-cell Westinghouse module was funded in order to assess the capabilities of their technology. The technology assessment module has been completed, and performance characterization and life evaluation is underway at ANL. Second, the costs of using nickel-iron batteries can be lowered if energy efficiency can be improved. To this end, Electrotek Laboratories was awarded a small contract to investigate active-material ratios, cell additives and new charging techniques.

Lithium-Aluminum/Iron Sulfide Battery

A cost-shared contract was placed with SAFT America, Inc., in April 1990 to develop lithium-iron sulfide batteries for EV applications. ANL provides the technical management of this 3-year $4.2 million contract, while DOE Chicago provides contract administration. This new industrial contract is jointly funded by DOE and EPRI. It is designed to advance the lithium-iron monosulfide technology previously developed in R&D efforts at ANL and Westinghouse Electric Corp. and to initiate the transfer to industry of lithium-iron disulfide technology currently being developed at ANL. By the end of the contract, SAFT is scheduled to fabricate three full-size, lithium-iron monosulfide batteries; one for laboratory testing and two for in-vehicle testing. The performance and life goals for these batteries are 100 Wh/kg, 106 W/kg, 150 Wh/L, and 600 cycles on the SFUDS. The second generation lithium-iron disulfide technology offers the prospect of achieving double the performance achievable with the monosulfide.

In the early stages of this contract, ANL provided significant technology transfer to SAFT on both the lithium/iron monosulfide and lithium-iron disulfide technologies. The technology transferred on the lithium-iron monosulfide was used by SAFT as the basis for developing baseline cell and module designs, as well as the framework for organizing and planning their R&D efforts to advance this technology. The technology transferred on lithium-iron disulfide was used by SAFT to design a scaled-up prismatic bicell. This bicell will be used to verify the high performance and long- cycle life achieved in smaller prismatic disulfide cells at ANL. Cell hardware of both technologies is scheduled for fabrication and evaluation in the first quarter of FY 1991.

Sodium-Sulfur Battery

A cost-shared contract was placed by Sandia National Laboratories (SNL) with Chloride Silent Power Limited (CSPL) in September 1986 to advance the sodium-sulfur technology specific to EV applications. This program was modified in 1987 and again in 1990 to specify that two sodium-sulfur batteries be designed, fabricated, and qualified that are suitable for evaluation in the ETX-II experimental electric vehicle. The latest battery design is being tested in the cargo bay of the vehicle. The sodium-sulfur battery designed for the ETX-II vehicle is shown in Figure 2. During FY 1991, mechanical and electrical improvements will be made to permit the next generation battery to be located and tested under the vehicle floor.

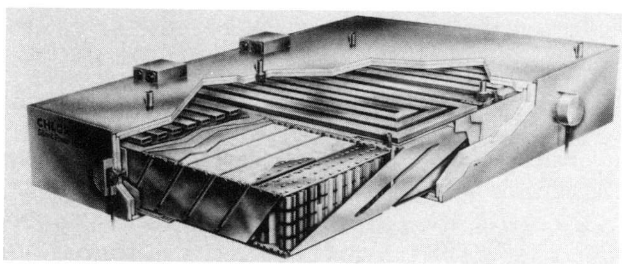

Figure 2: ETX-II Sodium-Sulfur Battery

This program uses the qualified CSPL cell technology developed under a complementary core-technology program. Battery service life of > 600 cycles and up to one year is expected. Weight reduction of the battery is the major goal of the activity for the next generation system. Other important battery level component advancements include cell and battery interconnects, the thermal enclosure, and the control electronics. Satisfaction of the defined activities will result in an EV power system that will allow a definitive proof-of-concept demonstration to be conducted.

During FY 1990, two versions of the current generation battery were delivered to Ford Motor Company for evaluation in the ETX-II vehicle. The first version was packaged into a single enclosure. During shipping, a ground fault developed. Ford performed limited testing to identify its operational characteristics. Then because the enclosure could only be destructively removed to correct the ground fault, the battery was returned to CSPL, repackaged into three separate enclosures with less vulnerability to shipping, shock, and vibration and returned to Ford. The evaluations of both batteries at Ford have shown that they satisfy the performance and physical goals for the ETX-II program: a capacity of 300 Ah at a voltage of 200 V; attainment of 21 full FUDS cycles on a single discharge (> 150 mile range); peak power of 65 kW; and the ability to sustain a 35 kW discharge for over an hour before reaching the upper temperature limit of 3700C.

A second sodium-sulfur program was placed by SNL in late FY 1990 to design a universal sodium-sulfur cell and battery module that can be used effectively in four electric vans: ETX-II, 75 hp Modularized Electric Vehicle (MEV), G-Van, and TEVan. Because the specifications for advanced, purpose-built, EV's has not been defined by industry, this program will take an evolutionary approach and design a common cell suitable for these near-term EV's. But, importantly, the analytical models and information needed to initiate a similar effort for advanced EV's is being developed. The specific activities to be completed by Beta Power Inc., in this one-year program include the following: (l) identification and analysis of battery requirements; (2) cell design; (3) battery system design (specified for MEV), and (4) analysis of the applicability of the design to electric passenger vehicles.

A number of supporting activities are also performed within SNL to improve the safety and commercialization potential of the sodium-sulfur technology and to evaluate the performance of deliverable cells and modules. During FY 1990, accomplishments in three specific areas were made: (1) a ternary eutectic salt with a very high heat-of-fusion value and a desirable melting temperature was identified and characterized, (2) the design of a thermal cut-off fuse has been completed that will prevent internal short circuiting in the worst-case situation when major cell failures occur, and (3) ongoing evaluations of cells and modules have demonstrated many of the excellent characteristics (e.g., efficiency, power, energy, versatility) of the sodium-sulfur technology and have identified or confirmed some of its remaining problems (e.g., service life, charge acceptance, temperature, and sensitivity).

Sodium-Metal Chloride Battery

The technology for sodium-metal chloride batteries is much less mature than that of sodium-sulfur but has the potential to offer the same high performance, and if successfully developed provide benefits in the areas of improved safety, lower operating temperature, and higher reliability. DOE awarded a one-year cost-shared contract to Beta Power, Inc., in August 1989. The objectives of this one-year study were to: (1) define and evaluate conceptual designs of low-cost, high-performance sodium-metal chloride batteries for electric vehicles, (2) develop battery cost estimates for assumed production levels of 1,000, 10,000 and 100,000 full-size batteries per year, (3) identify R&D needs, and (4) prepare a plan for developing modules and full-size batteries. On July 31, 1990, Beta Power, Inc., successfully completed the contract developing the information described below.

Two equally promising cell designs were identified: a central cathode multitube and a bipolar flat plate. Batteries built with the multitube design are projected to have a specific energy of 124 Wh/kg, a volumetric energy density of 247 Wh/L and a specific power of 150-185 W/kg depending on the state of discharge. Batteries built using the bipolar flat-plate design are projected to possess a slightly higher specific energy (134 Wh/kg) and specific power (150-200 W/kg).

A study of the manufacture and cost of the batteries indicate that at production levels of 10,000 to 100,000 batteries per year, the cost would change very little. For example, for the central cathode type cell design, the projected materials cost per kWh of battery would be $38.80 with a selling price of $147.90 per kWh. This compares to a battery materials cost of $36.60 and a selling price of $158.10 per kWh for the bipolar flat-plate design. An artist's concept of the multitube type battery is shown in Figure 3.

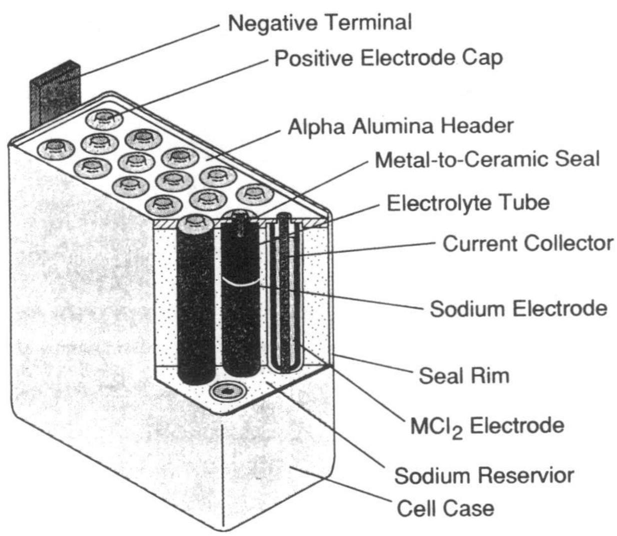

Figure 3: Sodium-Metal Chloride Battery

The proposed plan for developing the advanced battery modules (15 kWh) involves three key steps. The first is the selection of the preferred cell design (multitube vs. bipolar), the second will address the design and development of the cell selected, and the third step will be the design and development of the battery modules.

Zinc-Bromine Battery

Sandia National Laboratories placed a cost-shared contract with Johnson Controls, Inc. (JCI), in December 1986 to design, fabricate, and evaluate zinc-bromine batteries for EV applications. The three-year program was modified in 1989 to allow the final contract deliverables to be fabricated and to extend core development activities including research into materials of construction and methods of fabrication. This phase of the program is scheduled to be completed in December 1990. The new V-design battery stack was developed to address the characteristic problems of the bolted Z-design battery stack. The new stack design incorporates thermal welded electrodes and separator inserts into individual bipolar frames which are then welded together to form the battery stack. Progress has been made on the uniformity of the battery parts and the welding operation parameters which are critical to achieving a leak-free stack. The main features of the new cell stack consist of injection molded bipolar flow frames, dual electrode inserts made of extruded, reinforced carbon plastic, IR welded electrodes and separator inserts, and a vibration welding technique to assemble the battery stack. In any flow battery system with common electrolyte manifolds, there is the possibility of shunt currents that reduce the overall energy efficiency. The JCI zinc-bromine system incorporated a "tunnel" type shunt current protection system developed by Exxon under an earlier contract. The shunt current protection system has been successfully implemented on several 8-cell stacks; however, the effectiveness of the system on larger stacks has not yet been determined. The final battery deliverable of the program was fabricated and evaluated at JCI. Preliminary data indicate that the scale-up from an 8-cell battery stack to an 68-cell stack was successful. The battery package incorporates a single 68-cell stack, two reservoirs, pumps, controls, and electrolyte.

Zinc plating studies were carried out in laboratory flow-by test cells to evaluate the effect of various parameters on the quality of the zinc deposits. Within the experimental range investigated, the electrolyte flow rates had a minor effect on zinc plate deposits while charging current density, zinc loading level, and electrolyte composition had larger effects. A package of additives that smoothed the deposits was developed, but due to time constraints, it has not yet been tested in batteries to determine the effectiveness. Testing of two Toyota zinc-bromine batteries was completed. Although both batteries eventually failed, the batteries were found to have good energy efficiency performance but would have insufficient power to meet the ETX-II battery goals. A severe leak was the cause of failure in one battery, and in the other, a failed pump motor resulted in overheating of the stack.

Iron-Air Battery

INEL manages and administers the engineering development of iron-air batteries at Westinghouse Electric Corporation. This $5.5 million cost-shared (8 percent) contract was initiated in January 1987. The contract emphasizes the development of high performance, long-lived, bifunctional air electrodes and hardware scale-up to a full-size laboratory EV battery. During FY 1990 Westinghouse scaled up their $40 cm^2$ improved air electrodes, which were routinely achieving 300 or more operating cycles, to full size $400 cm^2$ units. The resulting full-size iron-air cells have not yet attained the current 300 cycle goal, and most of the FY 1990 effort was devoted to investigating the causes of this scale-up behavior. Comparative testing of the Westinghouse bifunctional air electrodes and similar devices built by other developers indicates significant superiority of the Westinghouse electrodes, particularly at higher power levels appropriate for EV operation. Figure 4 shows an iron air cell under test at INEL. Evaluation is in progress to determine the desirability of using this electrode as part of other electrochemical couples, such as zinc-air.

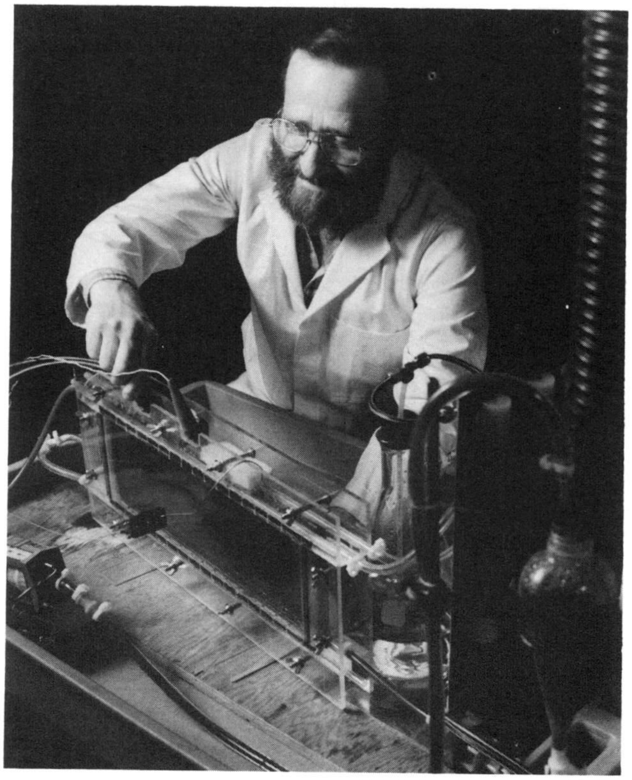

Figure 4: Laboratory Testing of Iron-Air Cell

Zinc-Air Batteries

Lawrence Berkeley Laboratory (LBL) is actively involved in research and development of several designs of zinc-air cells. This project is part of the technology base to support the Electric and Hybrid Propulsion Division on the development of batteries for electric vehicles. LBL is investigating various methods to extend the lifetime, including taper charging, the use of mildly alkaline electrolytes, calcium zincate electrodes, and cells that use a combination of approaches. These studies are conducted on laboratory-scale 1.35 Ah cells as shown in Figure 5. A computerized system for SFUDS testing of laboratory mechanically rechargeable zinc-air cells was set up. The recent test results completed on zinc-air cells with packed-bed zinc anodes and monofunctional air cathodes indicated a specific energy of 110 Wh/kg and a peak specific power of 97 W/kg, with an end-of-discharge cell voltage of 0.92 volts.

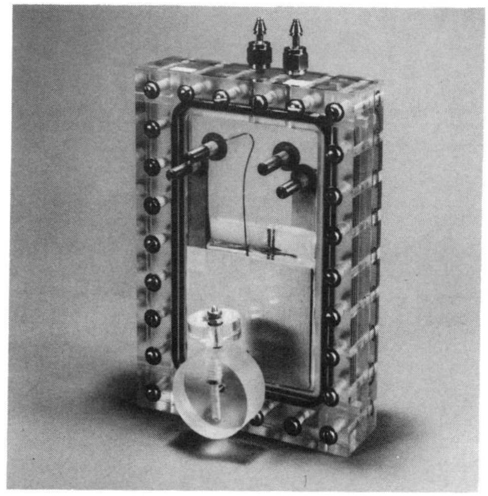

Figure 5: Zinc-Air Cell

Ultracapacitors

The application of high power density storage devices to reduce peak power demands on the traction battery in electric vehicle propulsion systems was studied at INEL in FY 1990. Computer simulations of hybrid power sources coupling conventional batteries and high energy capacitors indicated that the peak power required from the battery could potentially be reduced by a factor of two or more, which could permit batteries to achieve longer life or higher energy output or both. State-of-the-art ultracapacitors having a specific energy of about 1 Wh/kg were obtained for evaluation in the INEL battery laboratory in order to validate this concept. A Request for Proposals for an engineering development effort to increase the specific energy of ultracapacitors to 5 Wh/kg or greater in order to allow for a system-level evaluation was issued at the end of FY 1990. Proposal evaluation is underway, and it is anticipated that a contract will be signed in early FY 1991.

EV Battery R&D Evaluations

Laboratory testing and post-test analyses were conducted at ANL in support of the EV battery R&D activities. These activities provide insight into those factors that limit performance and life of advanced battery technologies and help identify the most promising R&D approaches for overcoming these limitations. Battery performance and life characterizations were performed under uniform test conditions that simulate driving cycle load profiles. Evaluations were conducted on a 22 kWh sodium-sulfur (Na/S) battery, a 2.4-kWh Na/S module, a 5-kWh zinc-bromine (Zn/Br) battery, 4.4 Wh nickel-metal hydride (Ni/MH) C-size cells, and developmental hardware from the nickel-iron (Ni/Fe) battery R&D program. The results of these evaluations are summarized in Table 3. Post test examinations include

Table 3

Battery Evaluation Summary Test Results

Battery Description			Battery Weight (kg)	Battery Capacity 3-h Rate (Ah)	Energy Density 2-h Rate		Peak Pwr for 30s 50% DOD (W/kg) (Wh/L)	Battery Efficiency		IDSEP Van SFUDS Range* (miles)
Manufacturer	Model	Type			Gravi-metric	Volume-tric (Wh/kg)		Coulombic (%)	Energy (%)	
Powerplex	B-11	Sodium/Sulfur	253	238	81	83	151	100	91	154
CSPL	PB-MK3	Sodium/Sulfur	29.2	292	79	98	94	100	88	150
SEA	ZBB-5/48	Zinc/Bromine	81	126	75	56	53	93	75	93
Ovonics	C-cell	Nickel/Metal Hydride	0.081	3.6	54	186	182	92	80	97
Eagle-Picher	NIF220	Nickel/Iron	25	231	56	136	94	74	55	76
	NIF200	Nickel/Iron	25	203	51	118	112	74	58	87

* Based on projection to 695 Kg battery with appropriate burdens.

physical and chemical analyses from which the degradation and failure mechanisms are determined. The results of these evaluations provide a measure of the success of the battery development efforts and insights into the direction the research programs should take.

A half-size 22 kWh Na/S EV battery from Powerplex Technologies Inc., has been under test since May 1990. The 240 Ah 90 V battery was shipped at operating temperature (310°C) and came complete with thermal and safety management systems. The battery has completed a set of EV performance characterization tests and is presently undergoing life evaluation using simulated driving profile discharges. Test results show that all of the cells are operating with uniform capacity. A maximum capacity of 238 Ah (20.5 kWh) was achieved at the 3-h rate, and no degradation in battery performance has been observed after successfully completing 166 test cycles to 100 percent depth-of-discharge (DOD). Results of simulated driving profile discharges indicate ranges of 154 miles for an electric van (IDSEP) on a SFUDS.

An 8 V 300-Ah Na/S module from Chloride Silent Power Limited (CSPL) has been under test since June 1990. EV performance characterization tests have been completed, and the module is presently under life test using SFUDS discharges to 100 percent DOD. A maximum 3-h rate capacity of 304 Ah (2310 Wh) was achieved at an operating temperature of 350°C. Results of driving profile discharges indicate that the IDSEP van would have a range of 150 miles on a SFUDS. At the end of FY 1990, the module had successfully completed 141 cycles and still retained 100% of its initial 292 Ah capacity.

A third-size 19 kWh Na/S EV battery from CSPL completed 241 cycles during a life-cycle evaluation at ANL in FY 1989. During FY 1990, a joint CSPL/ANL effort was conducted to determine the cause(s) of failure. The failure analysis revealed that 51 of the 960 cells in this battery had failed. The predominant failure mechanism was fracture propagation through the glass seal between ceramic components. Improper glazing procedures increased the susceptibility of these seals to attack by sodium. CSPL has since developed alternative glazing procedures to help eliminate this form of premature failure.

A 5 kWh 48 V Zn/Br module from the Studiengesellschaft fur Energiespeicher und Antriebssysteme (SEA), Research Group for Energy Storage and Propulsion Systems in Austria, is presently on life test. Evaluation of this technology was started in November 1989, and the results will be compared with those of the Exxon Zn/Br technology developed under the DOE Electric and Hybrid Vehicle Program. The SEA battery has good specific energy (72 Wh/kg at 3-h rate), but low power capability (53 W/kg at 50 percent DOD). The low power is due to a high internal battery resistance. A maximum power of only 67 W/kg was obtained at full charge. The battery has completed >270 cycles and shows no decline from its initial performance.

Performance and life characterization tests are being conducted on 3.5 Ah (C-size) Ni/MH cells from Ovonic Battery Company (Troy, MI). These cells are viewed as replacements for commercial Ni/Cd batteries, and Ovonics proposes to scale up to larger cell sizes and fabricate a full-size 175 Ah, 175 V (30 kWh) battery for EV applications. The ANL tests are to determine the suitability of this technology for EV propulsion. Performance characterization tests have been completed, and life tests are continuing. The results show that these small Ni/MH C-size cells with relatively heavy, sealed metal cases attain comparable performance to that of the larger Ni/Cd modules. An impressive specific energy of 54 Wh/kg (3-h rate) and peak power of 182 W/kg (50 percent DOD) were attained. Three cells have been life tested and the longest life achieved was 289 cycles.

Two types of advanced Ni/Fe modules (NIF220 & NIF200) from Eagle-Picher Industries (EPI) are being evaluated. Both have sintered-powder nickel electrodes. The NIF220 design provides a capacity of 220 Ah in the same module package as the 170-Ah module developed for the Eaton DSEP program. Several NIF220 modules were tested and all exhibited a rapid capacity loss (0.1%/cycle) with cycling. The maximum NIF220 life achieved at ANL was 370 cycles. Post-test analyses on a failed NIF220 cell showed that its capacity was limited by the Ni electrode, but severe deterioration of the Fe plates had contaminated the Ni plates. The causes of the Fe electrode problem in the NIF220 design were corrected by EPI in their later NIF200 design, and good results have been obtained to date. The NIF200 design provides a capacity of 200 Ah in the same module package as the NIF220. Performance tests were completed and life evaluation is ongoing. These modules exhibit a self-discharge capacity loss of 2 percent for a 1-h open-circuit stand after charge and 6 percent loss for a 24-h stand time. The module on life test still retains 96 percent of its initial 200-Ah capacity after >130 cycles.

Fuel Cell Technology

Fuel cells, operating on non-petroleum fuels, can potentially provide an alternative power source for transportation with nearly twice the fuel economy and greatly reduced emissions/noise compared with the internal combustion engine. A fuel cell is an electrochemical device that combines hydrogen with oxygen and converts their chemical energy into electricity. The waste product from the process is water; fuel cells emit essentially no carbon monoxide, nitrogen oxides, or particulates. The objective of the DOE Fuel Cells for Transportation Program is to advance fuel cell technologies from the R&D phase, through optimization and scale-up, to demonstration in cars, vans, and buses that could provide future energy savings, fuel flexibility, and air quality improvements.

Near-term efforts are directed at phosphoric acid fuel cells (PAFC) as the only suitably developed technology for transportation at this time. The result will be a methanol-fueled, fuel-cell-powered bus system with performance equivalent to diesel buses but with exhaust emissions reduced by more than 99 percent.

For cars and vans, the program is directed at proton-exchange-membrane (PEM) fuel cells for mid-term introduction and monolithic solid-oxide fuel cells (MSOFC) for long-term application and greater capability. PEM fuel cells can achieve the power density required for cars and vans, but much additional R&D is required for cost reduction, performance optimization, and engineering scale-up.

The hydrogen used in fuel cells can be produced from many sources such as methanol, ethanol, or natural gas. The hydrocarbons are converted into hydrogen and carbon dioxide through a thermal chemical process in a reformer. Advanced reformer technology is being developed to improve the competitiveness of PAFC and PEM fuel-cell-powered vehicles by reducing system size and cost, reducing start-up times, and increasing transient response capability. Fuel flexibility will be attained with the capability of reforming methanol, ethanol, or natural gas into hydrogen for use in fuel-cell-powered vehicles.

The MSOFC system may offer the best long-term prospects because it operates with internal reforming and does not require a separate reformer or peaking power source, but it is at the earliest stages of development. A feasibility study to evaluate the applicability of MSOFC for transportation applications is planned for FY 1991.

The DOE programs in fuel cell technology are described in the following paragraphs. ANL provides technical management and support for DOE/EHP's fuel cell activities, while DOE/Chicago Operations Office provides contract administration for cost-shared contracts with industry.

Proton Exchange Membrane (PEM) Fuel Cell Technology

The proton exchange membrane (PEM) fuel cell, when fully developed, will offer significant advantages over the phosphoric acid fuel cell for transportation applications. These include reduced size and weight, faster start-up, better transient response, increased reliability, and potentially lower cost. Accordingly, DOE has established a four-phased development with a go/no-go decision point between each phase. Phase I, Feasibility Evaluation, will lead to the demonstration of a 10-kW breadboard PEM system. Phase II, Proof-of-Feasibility, will be directed at proving feasibility by means of a 25-kW brassboard system. Phase III, System Scale-Up, will result in the laboratory evaluation of a full-scale 50-kW propulsion system. In Phase IV, Proof-of-Concept, this full-scale system will be installed and evaluated in a test-bed vehicle.

Following a competitive procurement during FY 1990, Phase I of the PEM Fuel Cell R&D Program was initiated. DOE awarded a 2-year, 20 percent cost-shared contract to

Allison Gas Turbine Division of General Motors in September 1990. Allison plans to utilize Los Alamos National Laboratory, Dow Chemical Company, Ballard Power Systems, and General Motors Research Laboratories as subcontractors. The work includes the conceptual design of a PEM-based propulsion system, R&D on limiting components to advance the technology to meet transportation needs, and integration and testing of a complete 10-kW PEM fuel cell system. The expected outcome of this effort is a demonstration of the feasibility of PEM fuel cells for transportation, thereby laying the groundwork for a potential future engineering scale-up.

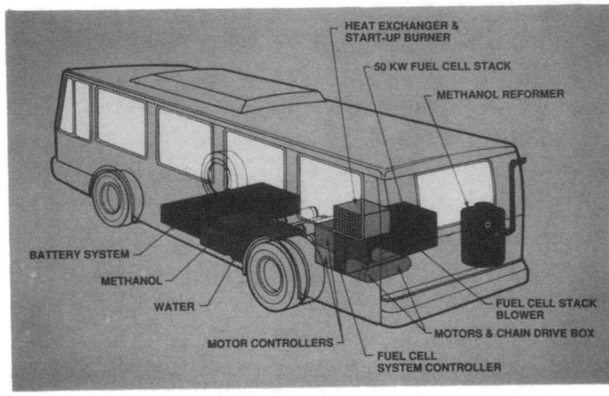

Figure 6: Fuel Cell/Battery Powered Bus

Thermo-Electrochemical (TECH) Power Source

During FY 1990, the Delco Remy and Hughes Aircraft Divisions of General Motors Corporation completed the first year of a feasibility effort on the development of a novel thermo-electrochemical (TECH) power source. The TECH system converts heat into electricity by the reaction of an acid and a base across a cation-exchange-membrane in an electrochemical cell, with thermal regeneration of the resulting salt into the initial reactants to form a closed-loop system. The TECH system can use almost any fuel as the heat source and provides power for electric propulsion with much lower emissions than internal combustion engines because the external combustion of fuel is much cleaner. This project is supported on a 50/50 cost-shared basis by DOE and Delco Remy, with matching funds provided by General Motors.

During FY 1990, Hughes completed a conceptual design for a TECH-based propulsion system and conducted component design and development studies which quadrupled the cell operating current density. In the second year of this two-year feasibility effort, Hughes will scale-up the cell size and fabricate and test a laboratory-scale TECH demonstration system. This unit is expected to supply the information needed for an engineering assessment of overall system efficiency. A major emphasis in this development effort is on demonstrating high overall efficiency at low system cost.

Phosphoric Acid Fuel Cell/Battery Powered Bus System

The objective of this program is to develop a methanol-fueled, phosphoric acid fuel cell/battery propulsion system for an urban transit bus, as illustrated in Figure 6. An urban bus was selected as the initial test vehicle because its larger size can readily accommodate the packaging of a first-generation fuel-cell-powered propulsion system, and because the present-day acquisition cost of fuel cell systems can be amortized over a longer service life in a bus than in passenger cars. Methanol was selected as the fuel of choice for this program because it can be derived from non-petroleum sources (e.g., coal, natural gas, biomass), it is readily transportable, and it can be processed for fuel cell use at relatively low temperatures. The phosphoric acid fuel cell was selected for this program because of its more mature state-of-development and because its operation on reformed methanol has been demonstrated. The use of a battery in parallel with the fuel cell minimizes the size of fuel cell required; the fuel cell provides the average power required and the battery, which is recharged by the fuel cell during bus idle periods, provides the supplemental power needed during vehicle acceleration. For maximum energy efficiency, the energy released during vehicle braking can also be used to charge the battery.

This program is co-sponsored by DOE, the Department of Transportation/ Urban Mass Transportation Administration (DOT/UMTA), and the California South Coast Air Quality Management District (SCAQMD). During FY 1990, Energy Research Corporation completed a 29-month, Phase I contract ($2.8 million, 23 percent cost-shared) to develop an air-cooled phosphoric acid fuel cell/battery system; and Booz-Allen & Hamilton completed a 29-month, Phase I contract ($3.0 million, 30 percent cost-shared) to develop a liquid-cooled phosphoric acid fuel cell/ battery system. Argonne National Laboratory provided technical management for this work, and Georgetown University provided additional support under a cost-sharing (14 percent) contract with DOE.

During FY 1990, both industrial contractors completed laboratory evaluation of a brassboard propulsion system that is one-half the size needed for the bus. The team of Booz-Allen & Hamilton, Chrysler Pentastar Electronics, and Fuji Electric built and tested a liquid-cooled phosphoric acid fuel cell/battery power source; this 68-kW system consists of a 25-kW fuel cell and 43-kW lead-acid battery, a power conditioner (dc chopper) to step up the fuel cell output voltage to match that of the battery, and overall system controls. The team of Energy Research Corporation (ERC), Los Alamos National Laboratory, and Bus Manufacturing, Inc., built and tested a 62-kW power source consisting of a 32-kW fuel cell and 30-kW nickel/cadmium battery connected in parallel. In both systems, the test results verified the performance predicted by the design analyses and confirmed the feasibility of the fuel cell bus concept.

Based on the successful proof-of-feasibility results in Phase I, all sponsors (DOE, DOT, and SCAQMD) agreed to proceed to Phase II which is directed at installing full-size fuel cell/battery propulsion systems into three 27-30 ft. test-bed buses. A system design and integration contractor for the 30-month Phase II effort is being sought through a competitive procurement. The work will also include the design of a full-size 40-ft urban transit bus.

Fuel Flexibility in Fuel Cells

During FY 1990, ANL conducted a study on reformers to assess the present state of technology for converting alternative fuels (methanol, ethanol, and compressed and liquefied natural gas) to a hydrogen-rich gas mixture for powering fuel cells in automotive applications. The objective of this study was to identify the R&D needs for developing reformers that achieve the thermal, chemical, and hydrodynamic performance required to supply the anode gas for fuel-cell-powered vehicles.

The study included a literature search to identify the different types of reformers that have been or are being developed; an analysis of the available data on these reformers to evaluate their expected performance in automotive applications; investigation of the potential for reformer/fuel cell systems integration; and recommendations for further research and development. Specifically, it was found that the reformers developed to date lack adequate start-up and dynamic response capability to permit their use in stand-alone fuel cell power systems for automotive applications. Based on the heat transfer characteristics and the desired small size and low weight, the study recommends that a catalytic partial oxidation reformer be developed. The desirable features for such a reformer would include:

- a small catalyst bed for a quick-starting, light, and compact reformer;
- multiple catalysts for optimum operation of the different reforming steps;
- direct heat transfer partial oxidation for rapid response to fluctuating loads; and
- fuel processing scheme thermally independent of the rest of the fuel cell system.

In a related project, the State of Illinois has agreed to co-sponsor with DOE the development of an ethanol reformer suitable for application on a fuel-cell-powered bus. In the first year of this project, ANL will determine the optimum reaction conditions (temperature, pressure, water injection, etc.) required to carry out the conversion of ethanol to a hydrogen-rich gas mixture. Commercially available catalyst materials will be evaluated for this purpose. In the second year, a prototype ethanol reformer will be designed, built, and tested to determine its projected performance in a fuel cell system.

Propulsion System Technology

The objective of the Propulsion System Technology Development Activity is to concurrently advance battery and powertrain technologies in a mission- oriented, integrated fashion within the context of a total propulsion system for electric vehicle applications. In order to enhance the transfer of these technologies to potential manufacturers of derivative commercial products, contracts for development of the technologies have been placed with industrial teams that not only have the necessary development expertise but also have the capability to manufacture related products should it become in their business interests to do so.

Second Generation Single-Shaft Electric Propulsion System Program (ETX-II)

The Ford Motor Company was under contract to DOE to develop the Single-Shaft Electric Propulsion System (ETX-II). This research effort is concentrating on technologies that will adapt the ETX concept to a small commercial van and take the electrical and mechanical subsystems a step closer to production. General Electric (GE) is a major subcontractor and is responsible for the electric subsystem, which includes the motor, its controls, and the inverter, including the power modules. Technological advances that have been accomplished include: a new interior permanent magnet (IPM) motor for the transaxle assembly, which is integrated into the rear axle of the van, development of the control algorithms required for control of the interior permanent magnet motor, further development of the unique power modules, improvements to the inverter to reduce its size and weight, and integration of the vehicle controls and the electric subsystem controls to provide a system controller that is in command of the entire propulsion system. In addition, specification and integration of an advanced sodium-sulfur traction battery is included in the program to assure that this important portion of the propulsion system is included in all of the system design trade-offs. Powerplex Technologies Inc. (Powerplex), a subcontractor, supplied a sodium-sulfur traction battery for the program. In addition, Chloride Silent Power Limited (CSPL) supplied a sodium-sulfur traction battery, built to ETX-II specifications under a separate contract with DOE, for test in the ETX-II propulsion system.

During FY 1990 system integration, development, test and demonstration were completed by Ford. The test program was conducted in Dearborn, Michigan at the Ford facility using a lead-acid battery. Preliminary examination of the component efficiency data indicated good correlation with the ETX-II computer simulations. The test program included a series of FUDS cycles, constant speed tests, and SAE J227a/C and D cycles on a vehicle dynamometer and tests for gradeability, acceleration, coastdown, and top speed performance at the Ford test track. The test results are shown in Table 4 and indicate all the performance goals for the program have been met.

Table 4

ETX-II TEST RESULTS SUMMARY

		Goal	Achieved
Energy Consumption (kWh/km): (Over FUDS)		0.250	0.247
Top Speed (km/h)		96	105
0 - 80 km/h time (secs)		<20	17.35
Gradeability (%)		30	30
Range (km):	Na/S battery (Powerplex)	>160	166
	Na/S battery (CSPL)	>160	240

Both the Powerplex and CSPL sodium-sulfur batteries were also tested in FY 1990. Acceleration and FUDS tests were conducted on Ford's vehicle dynamometer using Powerplex/Asea Brown Boveri (ABB) B-11 sodium-sulfur battery modules rated at 42 kWh in the ETX-II test bed vehicle. Several complete discharge tests (FUDS cycles) were undertaken resulting in a range of 166 km (103 mi.) in each instance.

Tests were also conducted using CSPL's sodium-sulfur battery. Initially the battery was tested with Ford's load simulator on the FUDS and a constant power test. A total of three separate FUDS tests were conducted, with each FUDS test run for twenty complete cycles, equivalent to 240 km (150 miles). Subsequent tests were conducted with the battery connected via an umbilical cord to the ETX-II test bed vehicle. These included discharges on the FUDS regime and at constant speeds of 30 and 40 mph to 80 percent DOD. The battery is rated at 52 kWh and performed with no problems during the discharge and charge cycles.

In FY 1990 GE delivered three types of inverters for the ETX-II propulsion system although the program originally planned for only two types of inverters. The first type is a bipolar transistor-inverter, which uses the Darlington transistor developed in the ETX-I program. The second type is the more advanced MCT-based inverter which utilizes the MOS-(Metal Oxide- Semiconductor) -Controlled-Thyristor (MCT) technology developed at GE, and a high voltage multi-layer ceramic (MLC) capacitor available from Olean Advanced Products and is "plug-compatible" with the base program ETX-II inverter. Because of several unresolved failures in one of the phase legs of the Darlington inverter, an additional more rugged inverter was provided by GE with their own funds as a replacement for the Darlington inverter. This third type inverter was developed by GE for fan drives and uses Insulated-Gate Bipolar Transistors (IGBT's). It was repackaged to fit the vehicle and also interface directly to the ETX-II controls. The IGBT transistor inverter is expected to be a viable contender for use in EVs.

Initially, two of the advanced MCT inverters were planned; however, program cost constraints and availability of hardware only allowed for a single MCT inverter to be built and functionally tested on the dynamometer at GE. The advanced MCT inverter has significant advantages over the other transistor inverters. These advantages include: eliminating the driver circuits and the power supplies that are required for bipolar switching devices; reducing snubber circuits and a reduction in operating losses; and permitting greater power efficiency and better thermal management. The use of the ceramic capacitor permits a large reduction in required volume for the dc bus capacitor and a reduction in energy loss as heat. These improvements allow the MCT inverter to be 50 percent smaller, 50 percent lighter, and more efficient than the other transistor inverters for the same power rating. All three types of inverters are shown in Figure 7 along with the first generation ETX-I inverter. Tests on the MCT-based inverter, conducted at GE under full power operation, indicated very high (95 percent) efficiencies, as evidenced by the absence of a temperature rise of the coolant (water at 1 gpm). The inverter was subjected to intensive testing, including regenerative operation. Notable goals achieved include 81 hp at 7000 rpm and 30 ft-lbs of regeneration torque at 5000 rpm.

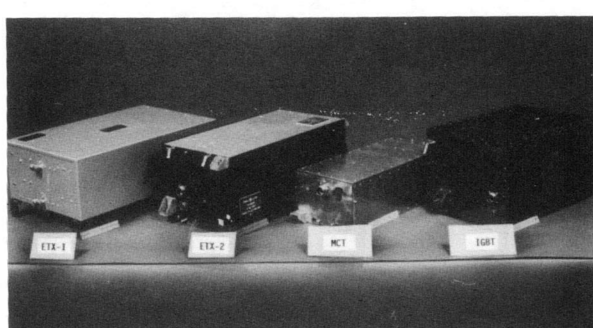

Figure 7: Inverters Used in ETX Programs

This program was completed in FY 1990 and initial test results indicated that it has met or exceeded all its performance goals. The DOE took delivery of the ETX-II (as shown in Figure 8), and it has been shipped to the Idaho National Engineering Laboratory where more extensive laboratory testing will be done with the CSPL sodium-sulfur battery in FY 1991.

Figure 8: Delivery of the ETX-II Vehicle

Modular Electric Vehicle Program (MEVP)

The Department of Energy awarded a contract to the Ford Motor Company on September 18, 1990, for development of a new generation of electric vehicle propulsion systems building on the technology developed by Ford and General Electric in the ETX-I and ETX-II programs. The four-year research and development effort will be cost-shared between Ford and DOE. The contract was awarded in response to Ford's unsolicited proposal.

Under the project, Ford will design and develop three modular propulsion systems that will be suitable for a varity of vehicles ranging from a small passenger car to a full size van. The project's goal is to make the production of electric propulsion systems more commercially viable, allowing electric vehicles to enter the marketplace sooner than through traditional design programs.

The MEVP program will be conducted in two phases. In the first phase, trade-off design studies will determine the optimum propulsion system design using the modular approach. During phase two, detailed designs of all components will be completed. These component designs will be implemented in hardware and tested, and the developed components will be integrated into test bed vehicles and evaluated. Ford will complete its contract by delivering three vehicles in different weight classes to DOE for testing.

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Test and Evaluation

Test and Evaluation (T&E) activities are performed on newly developed and existing technologies to characterize their performance potential in laboratory and field environments. The functions are carried out in three separate elements: Site Operations, Technology Engineering, and Engineering Evaluation Testing. The activities conducted in FY 1990 within each of these T&E elements are described below.

Site Operations

FY 1990 was a year of transition for the Site Operator Program. During the year, one of the long time participants in the program withdrew for internal reasons not related to the Electric Vehicle Program. Two new participants were added, one in the private sector and one in the public sector. Through a combination of factors, the most significant being a renewed interest in improving the air quality in our urban areas, the public awareness of the EV alternative to the internal combustion engine (ICE) has greatly increased. This has created renewed interest in the Site Operator Program, both in the public and private sectors. In response to this interest, and in an effort to make the program management more efficient, steps were begun to revise the participant selection to a more equitable process. All existing subcontracts will be allowed to expire at the end of FY 1990 and new participants selected from a fully competitive bidding cycle, open to all interested organizations and individuals starting in FY 1991.

Emphasis among the participants during the past year was concentrated on the new vehicles becoming available and upgrading older vehicles to more closely match the newer technologies.

The database developed during FY 1989 was sent to program participants for the collection of operating and maintenance data. It has proved to be a significant improvement over the previous manual collection method. Feedback from the users has provided direction for expanding and refining the system to allow the tabulation of additional data not previously collected. This additional data will allow a more detailed analysis of vehicle, component, and battery performance, taking into consideration such variables as driving type (freeway, delivery route, etc.) and payload. These modifications and enhancements are being made and will be implemented in early FY 1991.

The program begins FY 1991 with four private sector and four public sector participants. These are shown in Table 5.

Table 5

Electric and Hybrid Vehicle Program Site Operators

(Operating During FY 1990)

Private Site Operators
GTE Service Company
Honolulu, Hawaii
Pomona, California
Irvine, Texas
Arizona Public Service Company
Detroit Edison Company (DECO)*
Southern California Edison Company (SCE)
York Technical College
Public Site Operators
Sandia National Laboratories
University of Hawaii
Los Angeles Department of Water & Power
U.S. Navy

*Operations completed in FY 1990

Interest in the program has been expressed by organizations from across the country including Federal, State and local Government agencies, colleges and universities, private sector utilities, and other companies. In order to determine the most qualified among these for participation in the program, a Request For Proposal (RFP) was sent to more than 40 organizations and individuals expressing interest in the program. In order to obtain the maximum distribution, an announcement of the RFP was placed in the Commerce Business Daily. The RFP asks that proposals be submitted to DOE in early FY 1991 with the expectation of awarding contracts by the end of the first quarter. The RFP requests the proposer to submit a plan for a five-year program. It is anticipated that the subcontracts awarded will be for one year with one-year extensions for the following four years, contingent on site operator performance and available funding.

FY 1990 activities included the introduction of the first next generation vehicles. Fifteen preproduction G-Vans were delivered and put into service during the year. The G-Van is an electric powered version of the GM Vandura van. It is manufactured by Vehma International, Inc., (a subsidiary of Magna International, Inc.), with support from General Motors Corporation and Chloride EV Systems. The vehicle has a top speed of over 50 mph with a range on the order of 60 miles. It is available in either cargo or passenger configuration with available payloads of approximately 1500 and 1000 pounds, respectively. Standard equipment includes power steering and brakes with AM/FM stereo radio and air conditioning available as options. Vehicle use studies indicate the G-Van has the capacity to replace up to 60,000 ICE fleet vehicles in the Los Angeles area alone.

The Dual-Shaft Electric Propulsion (DSEP) van, developed by Eaton Corporation under contract to DOE, is one of the new generation of vehicles. It is built on the body and chassis of the Chrysler Corporation T-115 Mini-Van and incorporates an AC traction motor, a new nickel-iron (Ni/Fe) battery design, and state-of-the-art controls. Two prototype vehicles were built and delivered for preliminary testing, one to the INEL and the other to Detroit Edison Company (DECO) as part of the Site Operator Program. The decision by DECO to end their entire Electric Vehicle Program, including participation in the Site Operator Program, halted the field testing of the vehicle assigned to them. This vehicle has had several small problems of the type typical for a prototype design which have required some maintenance. It has been transferred from DECO to the INEL where it will be repaired and reassigned to a new site. The second vehicle is located at the INEL and is in the final stages of laboratory testing, which will be concluded in early FY 1991.

At the conclusion of these tests, it is planned that this vehicle will be assigned to several Site Operators for periods of one to three months. Locating one of the vehicles at a single site while rotating the other through several sites will allow the program to establish baseline performance data which can be compared with shorter term data from a group of operators, maximizing the effectiveness of the two vehicles.

The Sonnenschein 6V160, a sealed cell lead-acid battery first put into use in the Site Operator Program in late FY 1989, has now been installed in several vehicles by other participants in the program. Results to date support the findings of laboratory testing which indicated the battery provided good performance with long life. As a result, it has become the battery of choice among the Site Operators. Sonnenschein is currently completing installation of a manufacturing plant in the U.S. so future batteries will be domestically manufactured.

Vehicles in the EV fleet at Arizona Public Service (APS) are loaned to various operating organizations within the company and community for evaluation as to suitability for missions normally performed by those organizations. They also provide routine transportation for personnel within the EV program. During FY 1990, work at APS was directed toward improving the performance of the existing fleet. These activities included replacing battery packs in vehicles which had reached the end of their useful life and updating electronics to bring the vehicles closer to state of the art. APS collects data on significant operating parameters and maintenance activities which are included in the Site Operator Program data base.

Before withdrawing from the Site Operator Program in FY 1990, Detroit Edison Company (DECO) was continuing the over the road evaluation of the Griffon Electric Van. During the course of this evaluation seven vehicles have been used in both commercial and commuting applications. Collectively they have been driven over 125,000 miles, ranging from a low of 1,400 miles to a high of 43,000 miles per vehicle. They have averaged 28 mi./charge and 0.98 kWh/mi, and have demonstrated the ability to replace ICE vehicles for a range of applications. Prior to termination of the program the vehicles were retrofitted with several new components, including a new generation of battery chargers, traction motors, motor controllers, and a second generation battery heating system. The vehicles were transferred to York Technical College to continue the testing.

GTE Service Company continues its participation in the program with one experimental vehicle (a Mercury Lynx developed by Eaton Corporation) and a fleet of seventeen Jet 750 (Ford Courier) pickups operating in California and Hawaii. The Lynx is a new design featuring a dc powertrain and two speed transmission. The vehicle is performing well in a daily commuting capacity. Fleet operations in California and Hawaii continue to concentrate on battery test and evaluation. They are involved in the testing of five new battery types, including two gelled and three flooded electrolyte types. Preliminary results on at least one of the gelled electrolyte types indicate a much longer life expectancy than has been observed in the past.

York Technical College (York) now has a fleet of seventeen vehicles, including five Griffon vans from DECO. York will complete the testing of the updated Griffon vans started by DECO. The school has cooperative agreements with several organizations within the area, including Duke

Power and the City of Rock Hill, and is actively involved in bringing EV capabilities to the attention of the public in addition to its test and evaluation activities.

Southern California Edison (SCE) began the test and evaluation of fifteen preproduction prototype G-Vans. The SCE program includes an outside loan program whereby one of the vans is loaned to an organization outside SCE. The loan is for a period of several weeks and is intended to allow the organization to assess the ability of the vehicle to perform to the organizations requirements. To date over 50 organizations have participated with approximately that many more on the waiting list. Comments from the users have been generally favorable with three consistent negatives. These are lack of range, unreliability, and high noise levels inside the vehicle.

Sandia National Laboratories currently operates a fleet of eleven Jet Electrica sedans. All eleven of the vehicles are in routine use with missions ranging from daily commuting to travel to and from remote construction sites. Since the beginning of the EV program at Sandia in the early 80's, the vehicles have accumulated a total of over 80,000 miles with no significant maintenance problems. The vehicles have replaced ICE vehicles and demonstrated a capability to perform an assigned mission and provide operator satisfaction. Activities for FY 1990 included upgrading the appearance and performance, including new paint and new electronics.

The EV program at the University of Hawaii continues to center around the field testing of traction batteries. The island location provides a unique opportunity for testing batteries and vehicles in an environment with limited range requirements.

The Navy is completing work on the installation of a solar powered battery charging station on Bermuda, combining two inherently clean technologies. Construction is scheduled for completion in early FY 1991.

Negotiations with the Los Angeles Department of Water and Power (LADWP) to participate in the Site Operator Program were completed in late FY 1990. LADWP currently operates a fleet of six preproduction G-Vans which are used both by Department personnel and on loan to outside organizations. Participation in the Site Operator Program will include test and evaluation of three mini-van vehicles. Two of these are being built by Unique Mobility Inc., one of which is a hybrid with a small ICE powered generator on board, the other is pure electric. The third is one of the DSEP vehicles built by Eaton Corp. for DOE, which will be loaned to LADWP. The testing will allow a comparison of three different technologies in a common environment.

Technology Engineering

Technology Engineering activities undertake the development and evaluation of improved-technology components that are likely to enhance the capabilities of early state-of-the-art EVs in site operated fleets. These components are evaluated in laboratories; on test tracks in vehicles; and in sheltered (outdoor laboratory) on-the-road vehicles to verify their suitability for incorporation into site-operated EVs. Factors such as temperature, road shock, moisture, electromagnetic interferences, durability, and safety are evaluated along with the actual performance measurements for the component under test. Battery technology improvements discovered through integrated independent testing of new process components offer the greatest opportunity for enhancing EV performance.

A project was initiated with the Jet Propulsion Laboratory (JPL) to evaluate the viability of integrating photovoltaics into terrestrial electric vehicles. The study used computer modeling techniques to define the payback period for adding a solar array to a standard EV. The modeling included variables for vehicle usage, geographic region, time of year, electric utility energy cost, and battery, vehicle, and array types. The study concluded that the payback periods are shortest (less than 2 years) where the vehicles are consistently driven to their range limits. The short payback is the result of using the photovoltaics to reduce the battery depth of discharge (DOD) as a means of extending the overall battery life.

The University of Alabama at Huntsville (UAH) continued work on a computer controlled output charging system. Two vehicles have been prepared for operation at a photovoltaic charging station under construction by the Navy in Bermuda. The vehicle systems have been completed with the exception of an electrical converter that will allow charging directly from the stations main storage battery. UAH has also separately demonstrated the data collection portion of the charging system at the battery laboratory at INEL. This data collection system greatly reduces the hardware requirement that would prohibit such a capability to be included in a production vehicle.

Engineering Evaluation Testing

Under the Engineering Evaluation Testing activity, dynamometer and laboratory tests are conducted to evaluate technology outputs in circumstances that duplicate or simulate actual EV operation and environments under repeatable and well defined conditions. For this reason, test and evaluation programs are in process that (1) subject batteries to the actual electrical loads of high-technology EVs on a dynamometer and in test bed vehicles; (2) integrate advanced EV drive systems in vehicles and test them on the track, road and dynamometer; (3) test and characterize auxiliary systems, such as battery chargers, state-of-charge indicators, and battery monitoring and thermal management systems in a realistic EV environment; and (4) test advanced batteries by electrically loading them with complex driving cycle power profiles in a controlled laboratory environment over a range of operating temperatures from -20°C to +80°C.

DOE selected the Idaho National Engineering Laboratory (INEL) in FY 1984 to perform these testing activities, and dynamometer and battery test laboratories were established for this purpose. The present laboratory facilities permit the testing of vehicles and complete battery subsystems under simulated load conditions which closely approximate the demands of EV operation, including the performance of the FUDS.

In FY 1990, the component test capabilities added to the INEL dynamometer laboratory at the end of the previous year were qualified through functional testing. The INEL chassis dynamometer was also extensively overhauled and

Figure 9: Dynamometer Testing of DSEP

determined to be nearing the end of its service life, and procurement of a new generation dynamometer system controller was initiated. Procurement was also initiated for a new integrated dyno laboratory data acquisition system (LDAS) to be installed in early FY 1991, which should substantially increase the reliability and automation of data processing and analysis activities. An additional tester for repetitive driving cycle tests was added to the battery

Table 6

Vehicle & Power Train Engineering Evaluation Testing Results

Vehicle Specifications Vehicle Designation	(For Reference Only) **Chrysler/GE ETV-I** (Passenger Vehicle)	**DSEP** (Utility Vehicle)
Test Weight (kg)	1723	2614
Battery Mass Fraction	0.31	0.31
Battery Manufacturer/Type	JCI Phase III Gel/cell lead-acid	Eagle Picher NiFe 170
Transmission (no. speeds)	single-speed	two-speed
Road Load Power required at 88 km/h (kW)	9.60	16.03
Acceleration, 0-80 km/h (seconds)	23.6	22.3
Energy Consumption (Wh/km)		
48 km/h (vehicle net dc)	94	150
72 km/h (vehicle net dc)	108	180
88 km/h (vehicle net dc)	129	215
C-Cycle (vehicle net dc)	163	300
Federal Urban Driving Vehicle (vehicle net dc)	174	296
Range (km)		
48 km/h (km)	172	200[a]
72 km/h (km)	126	161[a]
88 km/h (km)	97	125[a]
C-Cycle (km)	85	103[a]
Federal Urban Driving Schedule	75	100[a]
Powertrain System Efficiency at 88km/h	84	80

a – with the battery capacity at its normal 170 Ah rating.

laboratory along with an automatic monitoring and test shutdown system for off-shift battery charging. The increased emphasis on environment, safety, and health concerns at DOE facilities caused a substantial reduction in the amount of testing performed while regulatory and compliance issues were reviewed and addressed.

An extensive series of track and dynamometer performance tests (as shown in Figure 9) were conducted on the final test bed vehicle delivered to DOE by the Eaton Corporation at the completion of the DSEP program. These tests confirmed the generally excellent performance projected for the DSEP propulsion system in a small van, including acceleration to 50 miles/hour in about 20 seconds and energy consumption in urban driving less than 0.5 kWh/mile. Table 6 summarizes the results of the DSEP-TB2 vehicle tests conducted by INEL in FY 1990.

As part of a continuing effort to monitor the state of near-term battery development for DOE site operators and other potential EV users, the INEL battery laboratory tested a number of commercially available batteries for potential EV application. Sealed lead-acid batteries from Johnson Controls and GNB proved to have good performance but short life. The Johnson Controls batteries were tested in a parallel string configuration proposed by one EV manufacturer, with the anticipated result that the capacity of the strings became unbalanced over time when a single charger was used. Nickel-cadmium batteries manufactured by Saft were found to have excellent performance (for near-term batteries) at a high cost; their life expectancy is not yet known. Nickel-iron batteries built by Eagle Picher Industries were subjected to comparative testing using modules with and without flame prevention modifications developed in a previous DOE program by Johnson Controls; no deleterious effects of the modifications were found on the operation of the batteries, but fabrication difficulties have thus far kept such improvements from reaching commercial application. Table 7 shows the results from each of the batteries tested.

A battery charger manufactured by Sonnenschein for its sealed lead-acid batteries was tested because of the growing number of site operators using these batteries. The charger functioned well but was expensive, and its design made it unlikely that it would maintain maximum battery capacity over life in EV applications. Several other storage devices were tested in support of development programs and other DOE activities, including an iron-air cell built by Westinghouse Electric and high energy ultracapacitors which have the potential to be used with batteries to reduce the effects of high peak power demands in EV powertrains.

Table 7

Battery Description	Battery Type	Module Weight (Kg)	Battery Capacity 3Hr. Rate (Ah)	Specific Energy 3Hr. Rate (Wh/Kg)	Volumetric Energy Density (Wh/L)	Peak Power 50% DOD 15 sec (W/Kg)	Battery Coulombic Efficiency (%)
Electrosource 22 & 23E	Sealed Lead-Acid	10.18	29.2	35	59.32	—	95.7
Johnson Controls GC-12V100	Sealed Lead-Acid	30.48	138	27	60.12	—	98.2
Saft SEH-5-200	Nickel Cadmium	24.9	204	49.8	94.65	202	83.1
GNB Bipolar	Sealed Lead-Acid	9.93	25	30.1	47.95	66.5	97
Eagle Picher NIF-200-5	Nickel Iron	25.1	203	51	—	—	73

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Incentives

The major incentives-related activities included the Corporate Average Fuel Economy (CAFE) and Loan Guarantee activities.

Cafe Regulations

Section 13(c)(1) of Public Law 94-413 directed the Department of Energy

"—to conduct a seven-year evaluation program of the inclusion of electric vehicles in the calculation of average fuel economy—" to determine the value and implications of such inclusions as an incentive for early initiation of industrial engineering development and initial commercialization of electric vehicles in the United States.

This seven-year evaluation program was conducted by DOE, and a final assessment report on this activity was completed in February 1987. DOE's final recommendation was that the EV CAFE provision be continued, to the extent that the CAFE regulation remains intact, in the average fuel economy calculations under the Motor Vehicle Information and Cost Savings Act.

DOE has initiated action to revise 10 CFR 474 (Equivalent Petroleum-Based Fuel Economy Calculation) dated April 21, 1981, to provide a means of publishing the petroleum equivalency factor on an annual basis. The new action further extends the calculation methodology to cover range extender equipped electric vehicles.

Planning Grants

There was no activity in this incentive program during FY 1990.

Loan Guarantees

DOE authority for making principal and interest assistance contracts under the Electric and Hybrid Vehicle Loan Guaranty Program expired on September 17, 1983, as provided for by the notice of final rulemaking published in the Federal Register on May 31, 1979 (44 FR 31510).

Since inception of this program in FY 1979, ten formal applications were provided to DOE, and two loan guarantees were issued, both of which were terminated due to default. The assets of one company were liquidated in 1982 recovering approximately $83,000, which resulted in a loss to the Government of $2,363,000. A workout agreement was negotiated in January 1983 with the second company (Jet Industries) providing for full payment of the $2,170,000 principal outstanding pending liquidation of real estate and other assets.

In FY 1990, Jet Industries continued their efforts to sell the real estate and pay off the remaining balance of the loan but an acceptable offer has not been obtained. The workout agreement provision that gave Jet Industries the exclusive right to sell the real estate expired on September 1, 1990. DOE is currently examining options for disposing of the property and recovering the assets.

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Other Activities

Studies and Assessments

National Laboratory Project Review Meeting

For the purpose of enhancing the coordination of program activities being performed at ANL, INEL, LANL, LBL, SERI, and SNL, a National Laboratory Project Review Meeting was held at ANL on September 6-7, 1990. The meeting was attended by 30 representatives from these laboratories, DOE, and EPRI. The meeting provided the opportunity for participating laboratory personnel to better appreciate the type and scope of program activities being conducted and managed by the other laboratories. Consideration is being given to holding meetings of this type at six-month intervals.

Alkaline Zinc Battery Evaluations

ANL initiated two alkaline zinc battery evaluations during FY 1990. A survey of domestic industrial firms indicated that at least three firms were still interested in nickel-zinc batteries for EV applications. Of these, only one firm possessed an active R&D project. Cells of this technology in the 60 Ah and 17 Ah size were obtained for evaluation at ANL. These cells are scheduled for test and evaluation in the first half of FY 1991. Also, 20 Ah cells under development at LBL are scheduled for evaluation at ANL in FY 1991.

In the area of Zn-air battery technology, battery design concepts were solicited from developers. Seven design concepts, two mechanically- rechargeable versions and five electrochemically-rechargeable versions, are being evaluated. The electrochemically-rechargeable batteries require a long-lived, high-performance bifunctional air electrode, which has proven to be a major technical barrier. The mechanically-rechargeable batteries employ commercially-available monofunctional air cathodes but require the establishment of a refueling infrastructure. Thermal analyses indicate that both versions will require active thermal management systems for poor efficiency. The advantages, disadvantages, and prospects for successful development of both types of Zn-air systems are being evaluated.

Battery Test Task Force

The EHP Battery Test (Working) Task Force was formed in 1983 to coordinate the battery evaluation work at several DOE and EPRI funded laboratories. Present member laboratories are ANL, INEL, LANL, SNL and Electrotec. The group has met twice each year since then to discuss testing procedures, results, reporting methods, and special techniques.

During FY 1990, the key accomplishment was the agreement of the DOE laboratories on a standardized procedure for initial characterization testing of batteries. The task force is planning to address life testing and post operation evaluations in future meetings.

Assessment of Fuel Cells for Transportation Applications

ANL conducted a study of the suitability of four different types of fuel cells for vehicle propulsion applications. The fuel cell types studied were phosphoric acid, proton exchange membrane, molten carbonate, and monolithic solid oxide; alkaline fuel cells were not included because they are not compatible with methanol or other reformed fuels. Simplified process flow diagrams were constructed for each system to carry out quantitative thermodynamic analyses. All of these fuel cell systems were found to offer the potential for fuel efficiencies significantly greater than that of the internal combustion engine. ANL prepared a technical report entitled, "An Assessment and Comparison of Fuel Cells for Transportation Applications," which presents a review of the current status of fuel cell technologies, provides a conceptual system design for each fuel cell type to evaluate it in a transportation application, identifies the critical R&D needs for each fuel cell system, assesses the merits of each fuel cell type for transportation applications, and provides recommendations regarding research and development programs.

EV Air Conditioning Study

Arthur D. Little performed a study of the effects of vehicle design features (insulation, glazing properties, ventilation, etc.) on cooling and heating requirements for electric vehicles for both transient and steady-state load conditions. A significant improvement in the vehicle range reduction due to climate control energy demands was found to be possible through judicious application of design changes in these areas. A second phase of this study evaluated the potential for application of advanced thermal cycles for EV climate control; results will be available in early FY 1991.

Environmental Study

In FY 1990, a project was initiated at the Solar Energy Research Institute (SERI) to assess the environmental, health, and safety (EH&S) aspects of four advanced battery technologies including, sodium-beta, nickel-iron, lithium-metal sulfide, and zinc-bromine. The assessment will examine the total fuel cycle of these technologies with emphasis on cell and battery manufacturing, battery shipment, in-vehicle use, and recycling of spent batteries. For cell and battery manufacturing, the assessment will identify and evaluate EH&S issues in areas, such as cell design and assembly, interconnections, thermal management, and physical integrity of the battery container. In the shipping area, the assessment will review applicable Department of Transportation and United Nations requirements and regulations to provide the necessary information to submit an application. For in-vehicle use, the assessment will review the applicable Federal Motor Vehicle Safety Standards as well as EH&S issues, such as recharging and emergency response to accidents involving electric vehicles. For recycling spent batteries, the assessment will identify, classify, and, where possible, quantify the materials that need to be treated, recycled, or disposed of; and examine the techniques, costs of, and develop guidelines to conform to recent Environmental Protection Agency regulations.

Computer Modeling

In support of the DOE Electric and Hybrid Propulsion Program, ANL has developed software packages for technical analysis and modeling of batteries and electric vehicles. During FY 1990, the battery performance simulation model (DIANE) developed by ANL was upgraded, documented, and distributed to battery and EV developers. Additional battery datasets were incorporated into the software package to reflect recent progress attained in battery technologies. This model, which operates on a personal computer, enables an accurate prediction of EV performance by modeling the battery's second-by-second current/voltage relationship as a function of battery usage.

In support of the validation of Engineering Evaluation Testing results, the development of EV-specific test standards, and the need to accurately predict the results of propulsion system development efforts, INEL developed a personal computer-based electric vehicle simulation program based on data from developers and INEL laboratory tests. This program, called SIMPLEV, is used to project the performance characteristics of various types of electric vehicles using a wide variety of driveline components and batteries. It has largely obviated the need to utilize older mainframe computer simulation programs, such as ELVEC which are difficult to maintain and use.

Database Development

ANL developed a battery and fuel cell systems database on DOE-sponsored research and development programs and related activities. Included in this database is information on the technical, programmatic, budget, and technology transfer aspects of lead-acid, iron-air, lithium-iron sulfide, nickel-iron, zinc-bromine, sodium-metal chloride, and nickel-metal hydride battery systems as well as the fuel cell/battery hybrid bus system program. The database uses hypertext tools to link numerous text-based information files for menu-driven, user-friendly retrieval of information on these subjects. In addition, the hypertext operating shell makes available other, unrelated, databases from within the master menu. These include contacts information, programmatic milestones, and a compilation of current and recent research highlights from the various R&D programs. This PC-based database is maintained at ANL with regular monthly updates provided to DOE/EHP.

INEL constructed a personal computer-based database for storing the physical characteristics and actual charge/discharge data for various batteries tested for EV application at DOE laboratories. This database, to be released for trial use in FY 1991, will permit improved access by DOE and the EV user community to the results of battery technology testing and evaluation efforts over the past several years.

Impact Studies

Public Law 94-413, section 13, requires a continuing assessment of material demand and pollution effects from electric and hybrid vehicles (EHVs). No new studies of material demand were conducted in FY 1990 because earlier studies indicated that the availability and production of materials for EHV production could be readily increased to meet any plausible level of EHV production during this century.

Section 13 of the Act also requires a statement of activities related to research on incentives to promote broader consumer acceptance of EHVs. No new activities were initiated in this area during FY 1990.

Hybrid Vehicle Evaluation

The Department of Energy continues to monitor domestic and foreign developments in hybrid vehicles. Improvements in batteries, powertrains, engines, motors, and computers modeling, etc., are monitored for possible effective use toward consideration of future hybrid systems. In-house studies of energy storage systems have been conducted. Flywheels, hydraulic accumulators, and small-range extender heat engines were evaluated for possible use in hybrid vehicle consideration.

Range extender concepts are under evaluation by several manufacturers. A small number of individual hybrid vehicles have been built which demonstrate the feasibility of this concept. However, none of these vehicles have been evaluated to the level of detail that DOE requires in our Engineering Evaluation Testing.

Use of Foreign Components

Section 14 (2) of Public Law 94-413 requires the Department to examine "the extent to which imported automobile chassis or components are being used, or are desirable, for the production of vehicles under Section 7.0, and of the extent to which restrictions imposed by law or regulation upon the importation or use of such chassis or components are impeding the achievement of the purpose of the Act."

No further vehicle purchases are being made under the provisions of Section 7.0 of the Act. Activities following the development progress of foreign made batteries, drivetrain components, and vehicle systems are continuing.

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Recommendations for Initiatives

The Department of Energy is not considering any new legislative initiatives to further the purpose of the Act. The current legislation provides sufficient flexibility to the program to stimulate the advancement of EHV technologies to the point where the private sector can determine their viability as transportation options and continue their development into marketable products. The President's FY 1992 budget request incorporates a restructuring of the Electric and Hybrid Vehicles R&D Program, with a significant increase in funding (and a further increase planned for FY 1993), but no new legislation will be needed to accomplish this.

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