**EXPLORATORY TECHNOLOGY
RESEARCH PROGRAM
FOR
ELECTROCHEMICAL ENERGY STORAGE**

**EXECUTIVE SUMMARY REPORT
FOR 1993**

Energy & Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Edited by Kim Kinoshita, Technical Manager

September 1994

This work was supported by the Assistant Secretary for Energy Efficiency
and Renewable Energy, Office of Transportation Technologies, Electric & Hybrid
Propulsion Division of the U.S. Department of Energy under
Contract No. DE-AC03-76SF00098.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EXECUTIVE SUMMARY

The U.S. Department of Energy's Office of Propulsion Systems provides support for an Electrochemical Energy Storage Program, that includes research and development (R&D) on advanced rechargeable batteries and fuel cells. A major goal of this program is to develop electrochemical power sources suitable for application in electric vehicles (EVs). The program centers on advanced systems that offer the potential for high performance and low life-cycle costs, both of which are necessary to permit significant penetration into commercial markets.

The DOE Electrochemical Energy Storage Program is divided into two projects: the Electric Vehicle Advanced Battery Systems (EVABS) Development Program and the Exploratory Technology Research (ETR) Program. The EVABS Program management responsibility has been assigned to Sandia National Laboratories (SNL); Lawrence Berkeley Laboratory* (LBL) is responsible for management of the ETR Program. The EVABS and ETR Programs include an integrated matrix of R&D efforts designed to advance progress on selected candidate electrochemical systems. The United States Advanced Battery Consortium (USABC), a tripartite undertaking between DOE, the U.S. automobile manufacturers and the Electric Power Research Institute (EPRI), was formed in 1991 to accelerate the development of advanced batteries for consumer EVs. The role of the ETR Program is to perform supporting research on the advanced battery systems under development by the USABC and EVABS Program, and to evaluate new systems with potentially superior performance, durability and/or cost characteristics. The specific goal of the ETR Program is to identify the most promising electrochemical technologies and transfer them to the USABC, the battery industry and/or the EVABS Program for further development and scale-up. This report summarizes the research, financial and management activities relevant to the ETR Program in CY 1993. This is a continuing program, and reports for prior years have been published; they are listed at the end of this Executive Summary.

The general R&D areas addressed by the program include identification of new electrochemical couples for advanced batteries, determination of technical feasibility of the new couples, improvements in battery components and materials, establishment of engineering principles applicable to electrochemical energy storage and conversion, and the development of air-system (fuel cell, metal/air) technology for transportation applications. Major emphasis is given to applied research which will lead to superior performance and lower life-cycle costs.

The ETR Program is divided into three major program elements: Exploratory Research, Applied Science Research, and Air Systems Research. Highlights of each program element are summarized according to the appropriate battery system or electrochemical research area.

* Participants in the ETR Program include the following LBL scientists: E. Cairns, K. Kinoshita, F. McLarnon and J. Newman of the Energy and Environment Division; and L. DeJonghe, J. Evans, P. Ross and C. Tobias of the Materials Sciences Division.

EXPLORATORY RESEARCH

The objectives of this program element are to identify, evaluate and initiate development of new electrochemical couples with the potential to meet or exceed advanced battery and electrochemical performance goals. Research was conducted on new versions of the Zn/NiOOH cell, a novel Na/polymer cell, and an all-solid state Li/Mn oxide cell. Each of these cells is considered to be an attractive candidate for EV applications, and should provide high performance at ambient or near-ambient temperatures. A Zn/NiOOH battery would exhibit higher performance and lower costs, compared to the MH/NiOOH battery; and a Na/polymer battery would be lower cost, compared to a Li/polymer battery.

- LBL has applied X-ray photoelectron spectroscopy (XPS) and found that the NiOOH electrode in Zn/KOH/NiOOH cells does not react chemically with Zn species under cell cycling conditions with a KOH-KF-K₂CO₃ electrolyte.
- The Advanced Energy Systems Division of Acme Electric Corporation has completed 175 charge/discharge cycles with a 20-Ah starved-electrolyte Zn/NiOOH cell that contains the KOH-KF-K₂CO₃ electrolyte developed at LBL.
- LBL has found that the most promising manganese oxide so far in Na/polymer cells is Na_{0.44}MnO₂, first synthesized by Parant and Hagenmuller in 1971. Tests on Na/polymer cells with Na_{0.44}MnO₂ positive electrodes indicate that this material can insert 0.55 Na/Mn over a voltage range of 3.4-2.0 V at 0.1 mA/cm² (x ranges from 0.2-0.75 in Na_xMnO₂). This corresponds to a capacity of 160 mAh/g, a theoretical specific energy of 440 Wh/kg and theoretical energy density of 1450 Wh/L.
- Oak Ridge National Laboratory (ORNL) has fabricated all-solid-state Li/Li_xMn₂O₄ cells that contain a solid electrolyte of amorphous lithium phosphorus oxynitride (1-mm thickness). These cells can be cycled between 4.5 and 2.8 V at current densities of 10-20 mA/cm² at room temperature. Efforts are underway to reduce the impedance of the cell to operate at higher current densities.
- PolyPlus Battery Co. was awarded a subcontract on the basis of a Request-for-Proposals (RFP) to demonstrate the viability of Na/organosulfur (Na/SRPE) cells as practical components in batteries for EV applications. Components for Na/SRPE cells have been fabricated and evaluated in preliminary cycle-life tests.

APPLIED SCIENCE RESEARCH

The objectives of this program element are to provide and establish scientific and engineering principles applicable to batteries and electrochemical systems; and to identify, characterize and improve materials and components for use in batteries and electrochemical systems. Projects in this element provide research that supports a wide range of battery systems — alkaline, metal/air, flow, solid-electrolyte and nonaqueous. Other cross-cutting research efforts are directed at improving the understanding of electrochemical engineering principles, minimizing corrosion of battery components, analyzing the surfaces of electrodes, and electrocatalysis.

Electrode Characterization studies are an important research element for the successful development of rechargeable electrodes for advanced secondary batteries. Efforts are underway to determine the role of surface morphology on mass transport which may affect the morphology of electrodeposits and to evaluate the performance of cells utilizing Li intercalation electrodes. Advanced spectroscopic techniques are utilized to investigate the chemical state of electrode materials during charge/discharge cycling.

- LBL has designed and constructed new cells and improved experimental facilities for the study of the effect of protrusions on mass transport to electrodeposited surface layers, and the coalescence of electrolytic gas bubbles which may affect the morphology of electrodeposits. A hemispherical protrusion as small as 50- μ m radius was successfully attached to the surface of a micromosaic electrode. A mathematical model has been completed that uses the Boundary Integral Element Method (BIEM) to understand the hydrodynamics of flow over protrusions. Improvements in the experimental apparatus have led to the observation of the coalescence of electrolytic gas bubbles (about 0.1-cm diameter) with a resolution of 10^{-5} s.
- A new thrust was initiated at LBL to identify the physicochemical properties of carbonaceous materials that control the intercalation of Li in nonaqueous electrolytes. Analysis of existing data suggests that no unified theory that links the physicochemical properties of carbon to the reversibility and amount of Li intercalation that occurs is available.
- Brookhaven National Laboratory (BNL) has used extended X-ray absorption fine structure (EXAFS) and X-ray absorption near-edge spectroscopy (XANES) to study nickel oxide electrodes that were cycled in Zn/NiOOH cells at LBL. EXAFS showed a substantial amount of Zn is present in the nickel oxide electrodes, and the Zn EXAFS was different for the electrodes obtained from three vendors. Doping of manganese oxides with Group VIB metal oxides (CrO_3 , MoO_3 , WO_3) was found to improve the rate capabilities of the electrode in an electrolyte consisting of $\text{LiClO}_4/\text{PC-DME}$.

- Lawrence Livermore National Laboratory (LLNL) is evaluating the performance characteristics of Li-ion cells manufactured by Sony Corporation. Using the USABC Dynamic Stress Tests (DST), the capacity and specific energy of cells charged to 4.2 V were observed to be about 1 Ah and >94 Wh/kg, respectively. The cell voltage at the DST high-power-step (150 W/kg) decreased approximately linearly with cycle number and run time from about 250 to 200 minutes after 310 cycles.

Corrosion Processes in High-Specific-Energy Cells are under investigation, and the aim is to develop low-cost container and current-collector materials for use in nonaqueous, alkali/sulfur and molten-salt cells.

- Illinois Institute of Technology (IIT) has undertaken a theoretical study of the evaporation process of $\text{Mo}(\text{CO})_6$ to improve the quality of Mo_2C coatings obtained by plasma-enhanced chemical vapor deposition. The kinetic-gas theory was used to derive an equation that correlates the evaporation rate and the equilibrium pressure of $\text{Mo}(\text{CO})_6$.
- The Environmental Research Institute of Michigan (ERIM) has prepared TiN-coated Al containment materials by sputter-deposition techniques which were corrosion-resistant for 500 h in Na_2S_4 at temperatures up to 390°C. Another series of coatings, applied by ion plating, showed no evidence of corrosion after 500 h in Na_2S_4 at 345°C.

Components for Ambient-Temperature Nonaqueous Cells, particularly metal/electrolyte combinations that improve the rechargeability of these cells, are under investigation.

- Case Western Reserve University (CWRU) has used *in situ* spectroscopic techniques and thermal analysis to study the Li/organic electrolyte interface. Temperature programmed desorption (TPD) studies with Li exposed to propylene carbonate (PC) suggested that the thermal desorption peaks are characteristics of a reaction that produces Li carbonate. Evidence was also found by TPD to indicate that Li hydride may be formed with deuterated PC.
- Northwestern University (NU) was awarded subcontracts on the basis of a RFP to synthesize polymer electrolytes based on aluminosilicate-polyether hybrid electrolytes with improved low-temperature performance and to apply molecular dynamics and Monte Carlo simulations to understand the conduction process in polymer electrolytes. A new hybrid polymer electrolyte has been synthesized and will be tested shortly. Theoretical models are being developed to determine the influence of temperature, ion species, polymer chain basicity, and interionic correlations on conduction and Li transport number in polymer electrolytes.

- CWRU was awarded a subcontract on the basis of a RFP to develop novel polymeric materials for polymer electrolytes in rechargeable Li batteries. Effort is underway to synthesize sulfonated and phosphonated polybenzimidazole (PBI) polymers, and poly(4,5-dimethyleneimidazole and hydroxy imidazole) polymers.
- The University of Dayton was awarded a subcontract on the basis of a RFP to synthesize and characterize new polymer electrolytes that contain crown ethers which could have a fundamentally different mode of ion transport than those currently under investigation. The systems proposed are doped polymers with side chains that are terminated with crown ether groups which will complex with a Li salt. It is hypothesized that these materials will create highly ordered structures, thereby forming paths through which ions can move easily. The synthesis of the three polymers involving a seven-step procedure has been initiated. A common monomer intermediate is produced at step four; synthesis of this intermediate has been started following published procedures.
- Rutgers University was awarded a subcontract on the basis of a RFP to optimize the synthesis of polymer electrolytes by sol-gel processing of alkali silicate components. Various lithia-silicate compositions have been prepared which were found to have ionic conductivities over the range from room temperature to 400°C that show some promise for testing in Li batteries.
- The State University of New York (Binghamton) was awarded a subcontract on the basis of a RFP to synthesize molybdenum oxides for positive electrodes in rechargeable Li cells. Molybdenum oxides ($M_xMoO_{3+x/2}$, where M = cation) were synthesized using the hydrothermal method at 150-200°C. Layered structures were obtained which should allow for rapid diffusion of Li ions.
- SRI International was awarded a subcontract on the basis of a RFP to develop high-performance hexathiobenzene-based organosulfur electrodes for Na cells. Electrodes and polymer electrolytes for Na/PEO/ polyorganosulfide cells have been fabricated.

Cross-Cutting Research is carried out to develop mathematical models of electrochemical systems and to address fundamental problems in electrocatalysis and current-density distribution; solutions will lead to improved electrode structures and performance in batteries and fuel cells.

- The important physical processes taking place in the galvanostatic charge and discharge of a Li/polymer/insertion cell have been identified by LBL. A mathematical model has been developed that elucidates the dynamic changes in the cell with charge or discharge, and this model has been extended to examine the behavior of the "Rocking Chair" configuration, which is based upon two materials which insert Li at different potentials. A thermal model has been developed which predicts the rate of heat generation of a Li/polymer battery during cycling.

- A new LBL project was started on mathematical modeling of heat transport in Li/polymer batteries. A two-dimensional mathematical model for the thermal behavior of Li-polymer batteries was developed, and the results demonstrate that thermal management may not be a serious problem for these batteries under low discharge rates. However, under high discharge rates, the temperature of a battery may increase significantly if the thickness of a cell stack exceeds a certain value.
- A newly developed technique at LBL for low-energy ion implantation known as Metal Plasma Immersion Ion Implantation (MPIII) was used to implant Co, Zr and Pb in nickel oxide electrodes. Co-implanted Ni electrodes appear to have a higher coulombic storage capacity than comparable electrodes without the addition of Co. However, a similar beneficial effect of doping with Zr or Pb in nickel oxide was not observed.
- LBL utilized low-energy ion-scattering spectroscopy (LEIS) and Auger electron spectroscopy (AES) to study the composition of sputtered and ultrahigh vacuum (UHV)-annealed polycrystalline Pt-Ru bulk alloys that were used for methanol electrocatalysis. Annealing at 800°C in UHV causes a strong surface enrichment in Pt for equilibrated Pt-Ru alloys. The alloy with a hcp bulk lattice (9.5 at% Pt) exhibited a larger segregation than the fcc alloys (>35 at% Pt), which was rationalized with the lattice mismatch between the bulk and the surface face structure, resulting in a loosely packed surface. The Pt surface enrichment of annealed bulk alloys was contrasted with the segregation observed for bimetallic supported clusters of Pt and Ru.
- LBL has observed that the highest activity for the methanol electrooxidation on Pt-Ru alloys shifts from a surface composition of 10 at% Ru at 25°C to about 30 at% Ru at 60°C. This change is attributed to the change in the adsorptive nature of the Ru sites with temperature.
- LBL is exploring the use of nuclear magnetic resonance (NMR) to obtain information about surface poisoning on Pt-based electrocatalysts for electrochemical oxidation of methanol. Experiments are underway to detect and characterize the signal from ^{13}CO adsorbed on the electrodes from ^{13}CO -saturated 0.5 M aqueous H_2SO_4 under open-circuit cell conditions.

AIR SYSTEMS RESEARCH

The objectives of this program element are to identify, characterize and improve materials for air electrodes; and to identify, evaluate and initiate development of metal/air battery systems and fuel-cell technology for transportation applications.

Metal/Air Cell Research projects address bifunctional air electrodes that are needed for electrically rechargeable metal/air (Zn/air, Fe/air) cells; and novel alkaline Zn electrode structures that could be used in either electrically-recharged or mechanically-recharged cell configurations.

- Eltech Research Corporation is investigating the viability of bifunctional air electrodes that contain two electrocatalysts – one for oxygen evolution and the other for oxygen reduction. Electrodes with a graphitized acetylene black for the support and NiCo_2O_4 and either CoTMPP or $\text{La}_{0.6}\text{Ca}_{0.4}\text{CoO}_3$ as electrocatalysts have operated for over 100 cycles in 35 wt% KOH at room temperature.

Fuel Cell Research at Los Alamos National Laboratory (LANL) includes research in several areas of electrochemistry, theoretical studies, fuel-cell testing, fuel processing, and membrane characterization. Major achievements of the fuel-cell program during 1993 are listed below:

- LANL was awarded U.S. Patents describing the developments in membrane catalyst layers for fuel cells (No. 5,211,984, issued May 18, 1993, and No. 5,234,777, issued Aug 10, 1993) and the use of the thermoplastic (TBA⁺) form of the ionomer (No. 5,234,777, issued Aug 10, 1993).
- The first licensing agreement has been signed with a U.S. industrial company to utilize LANL technology for membrane/electrode assemblies in polymer electrolyte fuel cells (PEFC).
- LANL has investigated the use of Pt-Ru anodes and their tolerance to CO and CO_2 . The study showed that the advantage of Pt-Ru is not to enhance the oxidation of CO, but rather to minimize the extent of the CO_2 reduction process(es).
- Freeze-thaw cycle tests of proton-exchange membrane (PEM) fuel cells at LANL demonstrated no deleterious effect on performance. These results suggest that the direct application of a thin-film catalyst to the membrane generates a very good bond between catalyst and membrane to effectively prevent delamination under the demanding freeze-thaw cycling conditions.
- A new flow-field design was introduced by LANL for PEM fuel cells which contains a macroporous flow field for the reactant gases. Higher limiting currents were obtained than in cells with ribbed flow fields.
- LANL observed that removal of the gas diffusion anode backing layer dramatically improved the performance of a direct-methanol fuel cell (DMFC) at 80°C, with both liquid and vapor feeds.
- BNL is utilizing X-ray absorption spectroscopy (XAS) to study the adsorbed Pb on Pt catalysts. The results suggest that the electrocatalysis of small organic molecules on Pb-modified Pt cannot be attributed to adsorption of oxygen species on Pb, rather it must be attributed to the disordered nature of the Pb adlayer.

MANAGEMENT ACTIVITIES

During 1993, LBL managed 20 subcontracts and conducted a vigorous research program in electrochemical energy storage. LBL staff members attended project review meetings, made site visits to subcontractors, and participated in technical management of various ETR projects. LBL staff members also participated in the following reviews, meetings, and workshops:

- USABC/DOE Review Meeting, Dearborn, MI, January 12-13, 1993
- CALSTART Strategic Planning Meeting, Sacramento, CA, February 5, 1993
- Project California Planning Meeting, Irvine, CA, February 11, 1993
- Zinc/Air Review Meeting, Washington, D.C., February 18-19, 1993
- IAPG Chemical Working Group Meeting, White Oak, MD, March 23-25, 1993
- 183rd Meeting of the Electrochemical Society, Honolulu, Hawaii, May 16-21, 1993
- Fuel Cells for Transportation Strategic Planning Meeting, Leesburg, VA, April 6-8, 1993
- Lithium Polymer Battery Meeting, Washington, D.C., June 22-23, 1993
- 28th IECEC, Atlanta, GA, August 8-13, 1993
- 144th International Society of Electrochemistry Meeting, Berlin, Germany, September 5-10, 1993
- Progress in Electrocatalysis, Ferrara, Italy, September 12-15, 1993
- LANL Exploratory Fuel Cell and Capacitor Research for Transportation Review Meeting, Washington, D.C., October 6, 1993
- 184th Meeting of the Electrochemical Society, New Orleans, Louisiana, October 10-15, 1993
- Annual Automotive Technology Development Contractors' Coordination Meeting, Dearborn, MI, October 18-21, 1993
- US/DOE Fuel Cell Microgeneration Workshop, Alexandria, VA, October 21-22, 1993
- Symposium on the Science of Advanced Batteries, CWRU, Cleveland, OH, November 8-9, 1993
- Zn/Air Battery Review and Strategic Planning Meeting, Albuquerque, NM, December 1-2, 1993

ACKNOWLEDGMENT

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Propulsion Systems, Energy & Hybrid Propulsion Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. The support from DOE and the contributions by the participants in the ETR Program are acknowledged. The assistance of Ms. Susan Lauer for coordinating the publication of this report and Mr. Garth Burns for providing the financial data are gratefully acknowledged.

ANNUAL REPORTS

1. Exploratory Technology Research Project for Electrochemical Energy Storage – Annual Report for 1992, LBL-34081 (October 1993).
2. Exploratory Technology Research Project for Electrochemical Energy Storage – Annual Report for 1991, LBL-32212 (June 1992).
3. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1990, LBL-30846 (June 1991).
4. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1989, LBL-29155 (May 1990).
5. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1988, LBL-27037 (May 1989).
6. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1987, LBL-25507 (July 1988).
7. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1986, LBL-23495 (July 1987).
8. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1985, LBL-21342 (July 1986).
9. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1984, LBL-19545 (May 1985).
10. Annual Report for 1983 – Technology Base Research Project for Electrochemical Energy Storage, LBL-17742 (May 1984).
11. Technology Base Research Project for Electrochemical Energy Storage – Annual Report for 1982, LBL-15992 (May 1983).
12. Technology Base Research Project for Electrochemical Energy Storage – Report for 1981, LBL-14305 (June 1982).
13. Applied Battery and Electrochemical Research Program Report for 1981, LBL-14304 (June 1982).
14. Applied Battery and Electrochemical Research Program Report for Fiscal Year 1980, LBL-12514 (April 1981).

LIST OF ACRONYMS

AES	Auger electron spectroscopy
ATR	attenuated total reflectance
BIEM	Boundary Integral Element Method
BNL	Brookhaven National Laboratory
CRADA	Cooperative Research and Development Agreement
CV	cyclic voltammetry
CVD	chemical vapor deposition
CWRU	Case Western Reserve University
DME	dimethoxyethane
DMFC	direct methanol fuel cell
DOD	depth of discharge
DOE	Department of Energy
DST	Dynamic Stress Test
EIS	electrochemical impedance spectroscopy
EMD	electrolytic manganese dioxide
EMF	equilibrium electromotive force
EPRI	Electric Power Research Institute
ERIM	Environmental Research Institute of Michigan
ETR	Exploratory Technology Research
EV	electric vehicle
EVABS	Electric Vehicle Advanced Battery Systems
EXAFS	extended X-ray absorption fine structure
fcc	face centered cubic
FIDAP	finite element package, Fluid Dynamics International
FT	Fourier transforms
FTIR	Fourier transform infrared reflectance
hcp	hexagonal close packed
HTB	hexathiobenzene (C_6S_6)
HREM	high-resolution electron microscopy
IAPG	Interagency Power Group
IECEC	Intersociety Energy Conversion Engineering Conference
IIT	Illinois Institute of Technology
ISE	International Society of Electrochemistry
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory

LEED	low energy electron diffraction
LEIS	low-energy ion-scattering spectroscopy
LLNL	Lawrence Livermore National Laboratory
MEEP	polybis(methoxyethoxyethoxide) phosphazene
MES	Mossbauer Effect Spectroscopy
MPIII	Metal Plasma Immersion Ion Implantation
NSLS	National Synchrotron Light Source
NMR	nuclear magnetic resonance
NU	Norwestern University
ORNL	Oak Ridge National Laboratory
PBI	polybenzimidazole
PC	propylene carbonate
PDS	photothermal deflection spectroscopy
PEEK	polyether ether ketone
PEFC	polymer electrolyte fuel cells
PEM	proton-exchange membrane
PEO	poly(ethylene oxide)
PFSA	polyfluorosulfonic acid
PPE	polypropylethylene
PTFE	polytetrafluoroethylene
RFP	Request for Proposal
SEM	scanning electron microscopy
SERS	surface-enhanced Raman spectroscopy
SFUDS	Simplified Federal Urban Driving Schedule
SNL	Sandia National Laboratories
SPE	solid polymer electrolyte
SPL	Silent Power Ltd., Salt Lake City
TBA	tetrabutyl ammonium
TDF	perdeuterated tetrahydrofuran
THF	tetrahydrofuran
TPD	temperature programmed desorption
UHV	ultrahigh vacuum
UPD	underpotential deposition
USABC	United States Advanced Battery Consortium
XANES	X-ray absorption near edge spectroscopy
XAS	X-ray absorption spectroscopy
XPS	X-ray photoelectron spectroscopy

SUBCONTRACTOR FINANCIAL DATA - CY 1993

Subcontractor	Principal Investigator	Project	Contract Value (K\$)	Term (months)	Expiration Date	Status in CY 1993*
EXPLORATORY RESEARCH						
<i>Advanced Zn/NiOOH Cells</i>						
Acme Electric Corp.	M. Anderman	Secondary Zn/NiOOH	193	12	6-94	T
<i>Solid-State Cells</i>						
Oak Ridge National Laboratory	J. Bates	Rechargeable Li Batteries	150	18	9-94	C
PolyPlus Battery Company	M.-Y. Chu	Na/SRPE EV Batteries	184	12	10-94	C
APPLIED SCIENCE RESEARCH						
<i>Lawrence Berkeley Laboratory</i>						
	E. Cairns, L. Defonghe, J. Evans, K. Kinoshita, F. McLarnon, J. Newman, P. Ross and C. Tobias	Electrochemical Energy Storage	1865	12	9-94	C
<i>Electrode Characterization</i>						
Brookhaven National Laboratory	J. McBreen	Battery Materials	105	12	9-94	C
Lawrence Livermore National Lab.	S. Mayer	Li-Ion Battery Testing	55	12	6-94	T
Corrosion Processes in High-Specific Energy Cells						
<i>Illinois Institute of Technology</i>						
	R. Selman	Corrosion Resistant Coatings	132	12	5-93	T
<i>Environmental Research Institute of Michigan</i>						
	T. Hunt	Secondary Batteries	100	13	1-94	T
Components for Ambient-Temperature Nonaqueous Cells						
<i>Case Western Reserve University</i>						
	D. Scherson	<i>In Situ</i> Studies	125	12	9-94	C
<i>Northwestern University</i>						
	M. Ratner	Polymer Electrolytes	145	12	9-94	C
<i>Northwestern University</i>						
	D. Shriver	Polymer Electrolytes	121	12	9-94	C
<i>Case Western Reserve University</i>						
	M. Litt	Polymer Electrolytes	158	12	9-94	C
<i>University of Dayton</i>						
	G. Glasgow	Polymer Electrolytes	95	12	9-94	C
<i>Rutgers University</i>						
	L. Klein	Sol-Gel Electrolytes	95	12	9-94	C
<i>SUNY at Binghamton</i>						
	S. Whittingham	Cathode Materials	125	12	9-94	C
<i>SRI International</i>						
	S. Smedley	Na/Polymer Cells	156	12	9-94	C
AIR SYSTEMS RESEARCH						
<i>Metal/Air Cell Research</i>						
Eltech Research Corporation	E. Rudd	Oxygen Electrodes	104	18	3-94	T
Fuel Cell R&D						
<i>Los Alamos National Laboratory</i>						
	S. Gottesfeld	Fuel Cell R&D	1000	12	9-94	C
<i>Brookhaven National Laboratory</i>						
	J. McBreen	Fuel Cell Research	0	12	9-93	T

* C = continuing, T = terminating