EXPLORATORY TECHNOLOGY DEVELOPMENT AND TESTING (ETD)

Sandia National Laboratories, Albuquerque, NM 87185 (U.S.A.)

The objective of the ETD project is to develop and evaluate high-performance, long-life, economical, and producible batteries for near-term and future mobile and stationary energy storage applications. The project is designed to fill the gap between basic research on promising electrochemical systems and the product engineering capabilities of industry. This is accomplished by sponsoring programs that have been declared Technology Base Research successes, developing multicell designs, evaluating batteries using uniform testing, and transferring the technology to industry. Continued ETD support is warranted in programs demonstrating steady or accelerated progress against advanced performance goals.

The ETD project consists of four major elements: aqueous nonflow batteries, nonaqueous batteries, flow batteries, and battery testing. Specific in-house accomplishments and status are detailed below.

Aqueous nonflow batteries

The objective is to develop aqueous batteries for both mobile and stationary applications. The main emphasis for mobile use is to increase energy density, while for stationary batteries the main thrust is to increase cycle life.

For mobile applications, the systems under investigation are lead–acid and nickel/iron. The lead–acid batteries feature an acid circulation system to reduce stratification, thus requiring less overcharge. This in turn results in less water loss and grid corrosion, significantly improving battery performance. The nickel/iron system is rugged and demonstrates long cycle life, but the generation of considerable hydrogen on charge remains a consideration.

Concerning stationary applications, lead–acid batteries are being improved for load-leveling application with long lives being achieved during accelerated testing. Sealed lead–acid batteries are being developed for deep discharge, solar applications with very encouraging cycle lives. The design of a nickel/hydrogen battery for terrestrial applications is under consideration.

Flow batteries

Three flow battery development programs and one supporting technology program are funded by this technology center. These are the Exxon Research and Engineering zinc/bromine battery, the NASA/Lewis Research

Center Redox storage system, the Lockheed zinc/ferricyanide battery, and a Sandia membrane research effort. Specific goals and accomplishments of each of these efforts are detailed in other sections of this document. These systems are currently being developed for solar applications. With Sandia's expanded role, broader application ranges for these technologies and new technologies are under review. One result of this effort to date has been the decision to institute a zinc/bromine electric vehicle battery development program. Contracting negotiations on this are currently underway.

Nonaqueous batteries

The objective of the nonaqueous battery program is to develop and evaluate high performance nonaqueous battery systems for electric vehicle and stationary storage applications. This element has responsibility for the technical management of the Ford sodium/sulfur program and the Argonne, Eagle–Picher, and Gould lithium/iron sulfide programs. These are both advanced, high-temperature battery systems with the theoretical capability of high energy and power performance. The major thrusts of the sodium/sulfur project are the completion of a cell design suitable for electric vehicle applications and the evaluation of a 100-kW h utility load leveling module. The goal of the lithium–aluminum/iron sulfide project is to bring the current program to an orderly conclusion so that future work can center on innovative battery engineering and higher energy couples.

Battery testing

The System Testing Technology Center provides independent testing and evaluation of state-of-the-art and prototype batteries. This effort supports and coordinates testing intended to identify basic and engineering development required for operation in actual system environments. The activity includes initial characterization of advanced systems, a limited amount of application-specific experiments associated with wind and photovoltaic systems, and technical support of other organizations sponsoring application-specific experiments.

During the past fiscal year, significant progress has been made in five major areas: test systems and techniques, sealed lead–acid battery testing, flowing electrolyte battery testing, full-scale photovoltaic battery system testing, and battery/wind energy system testing.

Computer-controlled battery test systems have been in operation at SNL since early 1981. These systems operate around the clock collecting data on various battery systems. The data are then condensed and transferred into a data base management system. Tests were developed that simulate battery operation in a photovoltaic system. One unique feature of these tests is a prolonged operation at partial states of charge. These tests have been run on both sealed and conventional lead–acid batteries.

Sealed lead–acid batteries developed under contract from Gould and Eagle–Picher have been tested. Some units from Gould have been on test since early 1981 and have accumulated over 700 cycles (80 percent depth of discharge at the C/5 rate). The Gould contract was renewed and at present 12 6-V, 100-A h units are on test. Data collected during these tests include coulombic and energy efficiencies, reference electrode data, cell pressure data, and charge and discharge performance characteristics.

Four flowing electrolyte battery systems have been tested during the past year. These include one iron/chromium redox battery from NASA, a 500-W h and a 1.2-kW h Exxon zinc/bromine battery, and a 6.4-kW h Gould zinc/bromine battery. The zinc/bromine systems have been exposed to a four-factor, two-level test plan. The factors varied were the charge rate, discharge rate, state of charge, and battery temperature.

A 40-kW h lead–acid battery system has been installed at the Photovoltaic Advanced Systems Test Facility located at SNL. This system consists of three strings of 44 6-V batteries. The strings can be paralleled or operated independently. Instrumentation and control equipment has been designed, installed, and is now operational. The battery strings are currently being routinely cycled using a.c.-powered charges and resistive load banks. Power conditioning equipment is being procured in conjunction with the photovoltaics group at SNL, which permits operation of the battery with full-sized photovoltaic systems.

In the battery/wind energy area, two programs have been in place during the past year. A 2-kW wind turbine is being tested with a 25-kW h lead–acid battery at the Small Wind Systems Test Facility at Rocky Flats. The second contract involved the design of a battery/wind energy system for the island of Molokai.

Plans and technical objectives for 1983

Battery and supporting development programs will be continued as appropriate to application goals and continued demonstrated performance. New technologies will be critically reviewed for applicability to ETD goals. Because of the expanded role of the ETD program, the requirements of load-leveling and electric vehicles will be emphasized.

Planned new activities for 1983 include reviews of zinc/chlorine, advanced molten salts, and aluminum/air programs for potential support, zinc/chlorine and high temperature battery testing, zinc/bromine electric vehicle battery development, and nickel/hydrogen battery cost reduction study.

Recent publications

1 A computer controlled test system for evaluating battery storage systems for solar applications, *SAND80-2145A*, Sandia National Laboratories, November 1982.

2 D. J. Anderson, E. R. Anderson and G. J. Collaros, *Solar Energy/Battery Storage*, The BDM Corporation, June 1981.
3 D. M. Bush, P. C. Butler, D. W. Miller and A. E. Verardo, Testing batteries for photovoltaic power systems, *SAND81-0226C*, Sandia National Laboratories, August 1981.
4 P. C. Butler, D. M. Bush, D. W. Miller and A. E. Verardo, Initial laboratory evaluation of batteries for solar applications, *SAND81-1223A*, Sandia National Laboratories, June 1981.
5 P. C. Butler, D. W. Miller and A. E. Verardo, Flowing electrolyte battery testing and evaluation, *SAND82-0381C, 17th Intsoc. Energy Conversion and Eng. Conf., August 1982.*
6 D. L. Caskey, E. A. Aronson and B. C. Caskey, SOLSTOR description and user's guide, *SAND79-2330,* November 1980.
7 D. L. Caskey, E. A. Aronson and K. D. Murphy, Parametric analysis of stand-alone residential photovoltaic systems and the SOLSTOR simulation mode, *SAND81-1130C*, Sandia National Laboratories, May 1981.
8 D. L. Caskey, J. Broehl and J. Skelton, Analysis of battery storage in wind energy systems for commercial buildings, *SAND81-7171*, Sandia National Laboratories and Battelle National Laboratory, September 1981.
9 J. L. Chamberlin, Batteries for solar energy, research and development program overview, *SAND81-1120,* Sandia National Laboratories, June 1981.
10 J. L. Chamberlin, Interim performance criteria for photovoltaic energy systems, SERI/TR-742-654, December 1980 (contributor).
11 J. E. Clifford and E. W. Brooman, Assessment of nickel–hydrogen batteries for terrestrial solar application, *SAND80-7191,* Sandia National Laboratories, February 1981.
12 Exide Management and Technology Co., Handbook of secondary storage batteries and charge regulators in photovoltaic systems, *SAND81-7135,* Sandia National Laboratories, August 1981.
13 FY81 Annual Operating Plan, Sandia batteries for specific solar applications, Project of the U.S. Department of Energy, *SAND80-2316,* December 1980.
14 A. Podder and M. Kapner, *Analysis of Batteries for Use in Photovoltaic Systems — Volume 1,* Hittman Associates, Inc., February 1981.
15 A. Podder, M. Kapner and T. Morse, *Data Base on Batteries, Power Conditioning Equipment and Photovoltaic Arrays — Volume 2,* Hittman Associates, Inc., February 1981.
16 G. R. Ramsay and Alan Edgecombe, *A Study of Battery Storage for Residential, Commercial, and Utility Photovoltaic Systems: Tasks 1 and 3,* Gould Inc. Federal Systems Laboratories through Research Triangle Institute, May 1981.
17 W. M. Resnik, *SOLPLT 2.0 — A Users Oriented Graphics Package for the SOLTOR Model,* The BDM Corporation, July 1981.
18 W. M. Resnik, *SOLSTOR Software Maintenance Manual,* The BDM Corporation, March 1981.
19 A. E. Verardo, Battery testing using desktop computer controlled test system, *SAND80-2330A,* Sandia National Laboratories, October 1980.