SODIUM/SULFUR BATTERY DEVELOPMENT, PHASE VB

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The overall objectives for the program are to develop sodium/sulfur batteries for powering electric vehicles and to develop technology for large stationary batteries for utility applications. This contract continues the effort first funded by the Energy Research and Development Administration in 1975 under its Contract No. EY-76-C-02-2556 with Ford Motor Company. The present contract is based on a tripartite agreement between Ford Aerospace and Communications Corporation, Ford Motor Company, and DOE, in which Ford Aerospace provides the technical direction for the entire program. Ceramatec Inc., is the developer and supplier of electrolytes.

The Phase VB work encompasses continuing cell development leading to improved performance, reproducibility, and life and also includes work on battery control systems design and analysis. 1982 objectives include the development of an electric vehicle cell for a battery that will be bench tested in 1983.

Fail-safe designs have been demonstrated for load-leveling and electric-vehicle cells, which yield acceptable performance: approximately 85 percent of theoretical capacity and greater than 75 percent energy efficiency when operated at approximately 100 mA/cm^2 of electrolyte surface. Some of the Mark-II load-leveling cells have operated acceptably for more than 1500 cycles. The electric vehicle cells have demonstrated excellent performance even at very high rates. At the 3-h rate for which the cell was designed, a specific energy of approximately 140 W h/kg was achieved. At the 1.6 C rate, the delivered specific energy was approximately 120 W h/kg.

A 512-cell, 100-kW h load-leveling battery has been operating for approximately 18 mo, providing data on interconnection strategies, control systems, and cell life. The lead–acid battery in a small utility vehicle was replaced by a 14.5-kW h sodium/sulfur battery. Although the sodium/sulfur battery, constructed from nonoptimized insulation and load-leveling cells, weighed 450 lb compared to 250 lb for the lead–acid battery, the driving time with the sodium/sulfur battery was 10 h compared with 2 h with the lead–acid battery.

Cell development in 1983 will emphasize an improved electric vehicle cell with potential for low cost and a high-energy cell for stationary energy storage applications with extended discharge periods. Plans include bench testing an electric vehicle battery and the construction and testing of an improved module for stationary energy storage. Components such as bus bars, interconnections, insulation, control systems, etc., are to be developed. Data from the electric vehicle experimental battery and from the stationary

energy storage module will serve to focus attention on areas of components and cells requiring additional development.

Recent publications

1 D. W. Bridges and R. W. Minck, Evaluation of small sodium–sulfur batteries for load leveling, *Sixteenth Intsoc. Energy Conversion Eng. Conf., Am. Soc. Mech. Eng., Paper No. 819392, August 1981.*

2 R. S. Gordon, Sodium–sulfur cells with beta″-alumina electrolyte, in *Battery Materials Technology Publication NMAB 390*, National Academy Press, Washington, DC, 1981.

3 R. S. Gordon and G. R. Miller, Status of beta″-alumina electrolyte development, *DOE Battery and Electrochemical Contractors' Conference, Washington, DC, June 2 - 4, 1981.*

4 R. S. Gordon, G. R. Miller, T. D. Hadnagy *et al.*, Ceramics in high performance batteries, in P. Vincenzini (ed.), *Energy and Ceramics*, Elsevier Scientific Publishing Co., 1980, pp. 925 - 949.

5 R. A. Harlow, M. L. McClanahan and R. W. Minck, Status of the DOE/Ford sodium–sulfur battery development program, *DOE Battery and Electrochemical Contractors' Conference, Washington, DC, June 2 - 4, 1981.*

6 H. J. Haskins and D. W. Bridges, Operation of a 100-kilowatt hour sodium–sulfur battery, *Seventeenth Intsoc. Energy Conversion Eng. Conf., Paper No. 829097, August 8 - 12, 1982.*

7 H. J. Haskins and A. G. Domaszewicz, Small sodium–sulfur battery applicable to solar and wind energy systems, *Sixteenth Intsoc. Energy Conversion Eng. Conf., Paper No. 819393, August 1981.*

8 M. L. McClanahan and R. W. Minck, Durability of beta″-alumina from a user's viewpoint, *One Hundred Sixty-First Meeting of the Electrochemical Society, Montreal, Quebec, Canada, May 9 - 14, 1982.*

9 B. J. McEntire, G. R. Miller and R. S. Gordon, Sintering of polycrystalline ionic conductors: β''-Al_2O_3 and Nasicon, in G. C. Kucynski (ed.), *Sintering Processes*, Plenum Press, NY, 1980, pp. 517 - 524.

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11 M. Mikkor, Current distribution within sulfur electrodes of cylindrical sodium–sulfur cells, *Seventeenth Intsoc. Energy Conversion Eng. Conf., Paper No. 829098, August 8 - 12, 1982.*

12 G. R. Miller, B. J. McEntire and R. S. Gordon, Production economics — The driving force behind the development of β''-alumina ceramic electrolytes, *Fall Meeting of the Basic Science Division of the American Ceramic Society, Louisville, KY, October 12 - 14, 1981.*

13 G. R. Miller and D. G. Paquette, Physical properties data compilations relevant to energy storage, in *Engineering Properties of Single and Polycrystalline Sodium Beta″-Alumina, NSRDS-NBS 61, Part III*, National Bureau of Standards Publication, 1979.

14 R. W. Minck and C. R. Halbach, Characteristics of sodium–sulfur cells for diverse applications, *Seventeenth Intsoc. Energy Conversion Eng. Conf., Paper No. 829096, August 8 - 12, 1982.*

15 J. R. Rasmussen, G. R. Miller and R. S. Gordon, Degradation and lifetime of β''-alumina electrolytes, *One Hundred Sixty-First Meeting of the Electrochemical Society, Montreal, Quebec, Canada, May 9 - 14, 1982.*

16 J. R. Rasmussen, G. R. Miller and R. S. Gordon, Factors influencing the lifetime of β''-alumina electrolyte tubing, *34th Pacific Coast Regional Meeting of the American Ceramic Society, Newport Beach, CA, October 25 - 28, 1981.*