significant, with the development of a model that accurately represents heat generation and rejection rates during actual battery operation. The result of this effort has been the redesign of cells/modules to maximize heat rejection.

In 1980 separator development effort will concentrate on optimization of electroporous-type systems. This will include optimization of polymer blend composition and continued scale-up in separator production. Recent improvements in zinc electrode performance observed in small cell tests will be extended to full-size cells. Evaluation of the effectiveness of promising electrode and electrolyte additives in extending cycle life will also be continued in scaled-up cells.

Recent publications

1 C. C. Chen and H. F. Gibbard, Thermal management of battery systems for electric vehicles and utility load-leveling, *Proc. 14th IECEC, Boston, August 5 - 10, 1979.*
2 G. D. Bucci, R. J. Fedor, R. P. Fedora and R. R. Steiner, The development of nickel/zinc batteries for commuter electric vehicles, *Abstracts of Papers, ACS/CSJ Chemical Congress, Honolulu, April 1 - 6, 1979, Abs. INDE-50.*

RESEARCH, DEVELOPMENT AND DEMONSTRATION OF A NICKEL–ZINC BATTERY FOR ELECTRIC VEHICLE PROPULSION

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The objective of this program was to accelerate the development of nickel–zinc batteries for use in electric vehicles. The early R&D portion of the program had the objective of eliminating the technical barriers which limited electrical performance, battery lifetime and the attainment of low cost. The ultimate goal of the program is the emergence of a practical Ni/Zn battery system that has the promise of meeting the performance, economic, and environmental requirements for electric vehicle application.

During the calendar year 1978 and the first five months of 1979 the emphasis was directed in four major areas:

(1) elucidating the Failure Modes of the nickel–zinc battery system;

(2) improving performance of the system;

(3) effecting a cost reduction program;

(4) building full-size (250 A h, 6.4 V) electric-vehicle modules for demonstration at the National Battery Test Laboratory.

(1) The Failure Modes Analysis Program established early that the negative electrode was responsible for capacity degradation during repetitive deep-discharge cycling and was thus the life-limiting component. This capacity degradation was found to result from loss of zinc from the negative compart-

ment and from zinc passivation. The selected use of additives and binders in the zinc electrode, improvements in the separator system, and a less abusive charging technique were employed to mitigate these problems and allowed for movement to the next performance plateau.

The main separator system then became the life limiting component. Combining the strengths of both diffusive and microporous type separator materials was investigated and this appears to offer the next improvement to cell life.

The charging technique is a key to the success of the system and abusive techniques can result in the failure of even the most rigorously designed cell.

(2) Performance has been improved by using the findings of the Failure Modes Analysis. Cells rated at 30 A h have delivered about 70 W h/kg and have been cycled using an 80% DOD at the 3 hour rate with a 16 hour recharge. In excess of 130 cycles have been achieved.

Investigations were conducted to obtain a maintenance-free cell. This task achieved significant success resulting in a fifty percent. improvement in life to that noted above.

(3) The cost reduction effort dealt with each component of the battery cell. The initial effort to reduce the cost of the positive electrode centered around development of a roll bonded electrode fabricated from chemically precipitated nickel oxide. In spite of the potential lower cost attractiveness of this electrode type, the poor performance in terms of energy density, expressed as watt-hours, per unit volume, and reduced capacity at high rates led to the abandonment of this approach in favor of the sintered electrode type. The cost reduction of a sintered positive electrode was based on the use of a thicker and more porous sinter as well as a streamlining of the manufacturing process. Collectively, these steps reduced the amount of nickel, labor, and process aids required, and thus lowered both unit cost and weight.

The use of alternatives to silver as the negative electrode grid was explored. A silver plated foil appears most attractive to date.

(4) The performance of full sized (250 A h, 6.4 V) four-cell modules cycled as batteries was disappointing. Although early designs exhibited excellent initial performance approaching program goals, life was severely limited. Altering the design at the expense of reducing the initial performance parameters to a "satisfactory" level improved life but not to the degree projected. It appears that the failure mechanisms operating (*i.e.*, zinc penetrations and imbalanced electrolyte distribution) are accelerated in these large cells. Further work is called for to investigate separator–electrolyte distribution relationships in these large cells if the life goals for the nickel–zinc couple are to be realized.

There is no further funding for this contract.

Recent publications

1 S. F. Schiffer, Development of the nickel–zinc battery for electric vehicle propulsion, *Proc. Fifth Int. Electric Vehicle Symp., Philadelphia, October 2 - 5, 1978.*

2 H. N. Seiger, A critique of the zinc electrode in alkaline secondary batteries, *154th Meeting Electrochem. Soc., Pittsburgh, 1978.*

HIGH CYCLE LIFE, HIGH RATE NICKEL–ZINC BATTERIES

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General purpose/goals

This project is being jointly funded by the Departments of Energy, Navy and the Army. The objectives of the project being conducted by ERADCOM are: (a) to develop and evaluate new separator systems for nickel/zinc cells which are resistant to zinc penetration shorts, (b) selection of successful mercury substitutes in the zinc anode which reduce the rate of shape change (corrosion and slumping) on cycling, and (c) the development of a semi-sealed nickel–zinc battery which operates on the oxygen cycle and is maintenance-free by means of pressure cutoff control on charge.

It is projected that the above concept will provide for a cost effective nickel–zinc battery which will exceed 300 deep cycles with a capacity retention of over 80% and have an energy density over 35 W h/lb, based on rated capacity.

(1) Nickel–zinc cells with separator wraps consisting of two 0.001 in. nickel-coated, microporous polypropylene layers sandwiched between two 0.001 in. layers of uncoated membranes were resistant to shorting during 53 deep C/5 rate cycles with overcharges of 250% per cycle. These cells delivered 90% of theoretical capacity (nickel limiting) during the 53 cycles. Cells with uncoated separator wraps shorted intermittently during the 53 cycles and delivered 66% of theoretical at cycle 53.

(2) Capacity retentions of 85 - 88% of initial values were obtained after 110 cycles at 80% depth of discharge (at the C/5 rates of charge and discharge) with 5.0 A h nickel–zinc cells having the following features:

(a) pressure cutoff on charge at 8 psig;

(b) c.p. charging at 1.89 V/cell;

(c) an anode composition of 95% ZnO, 2% CdO, 1% PbO, and 2% Teflon;

(d) electrolyte starved, using 34% KOH + 1% LiOH;

(e) a separator system consisting of thin cellulosic layers sandwiched between two protective layers of 0.001 in. microporous polypropylene;

(f) a safety venting at 10 psig ± 0.5 psig.

Work is presently being directed towards (a) immobilizing the nickel layer of the separator system within the cationic region, which is sandwiched between two non-degradable layers of microporous polypropylene (to prevent contamination of the zinc anodes), (b) evaluating mercury substitutes