ALUMINUM–AIR ELECTRIC VEHICLE PROJECT

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The goal of the aluminum–air electric vehicle program is to develop to the point of commercial feasibility a general-purpose vehicle with the range, acceleration, and rapid-refueling capability of today's automobile. The motivation for this goal is the prospect of a significant decrease in petroleum consumption through the use of electric vehicles capable of broad-based and extensive penetration of the automotive market. Benchmark goals for the total cost of vehicle operation and for total energy use are to achieve equivalence with internal combustion engine vehicles using synthetic liquid fuels derived from coal.

Our approach to these goals involves parallel developments of (1) full-scale automotive batteries using anodes and air-cathodes adapted from existing technologies and practices; (2) cost-effective anode and cathode materials and structures; (3) electric propulsion systems optimized for Al–air battery characteristics and low cost. Program emphasis through 1980 rests with the first development task.

Subscale aluminum–air cells (25 cm^2) have been demonstrated at LLL under operating conditions anticipated for automotive applications: 40 - 70 °C; current density, 0 - 10 kA/m^2; 6M NaOH + 0 - 3M $Al(OH)_3$ (dissolved), Reynolds numbers, 200 - 3400. Peak net energy and power yields were 4.0 kW h/kg Al (at 1.3 kA/m^2) and 0.47 W/cm^2 for Reynolds RX808 anode alloy and an air cathode supplied by Prototech, Inc; the temperature and electrode separation were 60 °C and 3.2 mm, respectively.

An aluminum–air battery system has been designed using computer modeling of heat and mass balances and transfers. Industrial data on kinetics of aluminum trihydroxide crystal growth have been used to design an on-vehicle system for conversion of the dissolved sodium aluminate intermediate product to a granular product identical with a feed-stock of the aluminum industry. The estimated weight and volume of a 70 kW h, 40 kW (peak) battery are 220 kg and 375 dm^3 when the battery includes sufficient aluminum for 1600 km of vehicle travel.

A number of anode alloy and air cathodes have been tested in half-cells under conditions anticipated for automotive applications. Anodes constructed from 5A-base aluminum (with 700 ppm Fe and 500 ppm Ga) yielded about 80% of the energy of RX808, but at a lower temperature (40 °C). Air cathodes were operated in flowing caustic–aluminate electrolyte at 60 °C with acceptable polarizations (100 - 200 mV *vs.* Hg/H_2O at 1 kA/m^2).

Preliminary studies of vehicle economics, energy use and efficiency, and industrial impact have been completed with indications of potential competitiveness with synthetic liquid fuels derived from coal.

In 1980 a full-scale single cell, having an anode area of 1000 cm^2 and interelectrode spacing of 1 - 3 mm, will be constructed and demonstrated.

The cell will be tested in conjunction with an aluminum trihydroxide crystallizer with design specifications derived in 1979. A full scale cell with provisions for rapid anode addition will also be designed. Fundamental studies are planned concerning the effects of minor alloying agents on anode behavior. Subcontracts have been signed or are being planned for (1) development of full-scale single-cell hardware, (2) development of cost effective anode alloys, (3) development of air cathodes for use in aluminum–air cell development, (4) development of processes and components for on-board vehicle production of industrial grade aluminum trihydroxide, (5) economic and energy use studies, and (6) safety and environmental impact analysis.

Four major technical issues are: (1) development of a cost-effective air cathode capable of operating in an automotive environment; (2) development of a cost-effective anode capable of being produced in a single-step reduction process, using calcined battery reaction product as the feedstock; (3) development of a cell capable of rapid anode addition; (4) demonstration of on-board processes and components for production of industrial-grade aluminum trihydroxide.

Recent publications

1 J. F. Cooper and E. L. Littauer, Mechanically-rechargeable, metal–air batteries for automotive propulsion, *Proc. 13th Intersoc. Energy Conversion Engineering Conf., SAE, San Diego, CA, August 22, 1978. (Lawrence Livermore Lab. Rep. UCRL-81178.)*

2 J. F. Cooper and E. Behrin, General purpose aluminum–air/flywheel electric vehicles, *Univ. California, Lawrence Livermore Lab. Rep. UCRL-82003, November 1978.*

3 Aluminum–air battery for electric vehicles, *Energy and Technology Review*, Lawrence Livermore Laboratory, November 1978.

4 R. V. Homsy, Aluminum–air power-cell system design, *Univ. California, Lawrence Livermore Lab. Rep. UCRL-82497, August, 1979.*

5 J. F. Cooper, Control of battery electrolyte composition through precipitation of aluminum trihydroxide: feasibility study, *Univ. California, Lawrence Livermore Lab. Rep. August 1979.*

ASSESSMENT OF AIR CATHODES FOR METAL/AIR BATTERIES

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Emphasis to date has focused on zinc/air batteries using alkaline electrolytes; the major obstacles to this system's successful development have been: low cycle life at high depths of discharge, carbonate buildup in the electrolyte, zinc electrode cost, and greater tendency of Teflon-bonded electrodes to flood in alkaline than in acid electrolytes. Most of these problems can be eliminated if the battery is modified to an acid electrolyte system. Zinc electrodes are well-developed for acid electrolyte cells because of the development of metal/halogen batteries. As a result, the air electrode is the major