Advanced Zinc-Air Primary Batteries

Ron Putt, Dr. Neal Naimer, Binyamin Koretz; Electric Fuel Corporation
1750-E Opelika Road, Auburn, AL 36830

and

Dr. Terrill Atwater, US Army CECOM RDEC
AMSEL-RD-C2-PS-B, Fort Monmouth, NJ 07703

Abstract
Lightweight, low cost, safe and reliable power sources are needed to provide battlefield power for today's foot soldier, owing to the proliferation of electronic gear that he carries. Primary zinc-air batteries that employ state-of-the art materials and manufacturing technology are an excellent candidate. Specific energies of over 400 Wh/kg have been demonstrated at the cell level, with projected high-volume manufacturing costs rivaling those of alkaline manganese.

Introduction
Zinc-air cells and batteries provide electrical energy through the electrochemical reaction between metallic zinc and atmospheric oxygen in an alkaline electrolyte. They are available today in low-rate (1-3 year), remote-signaling batteries (buoys, railroads), low capacity (< 1 Ah) button cells for hearing aids and other miniature devices, and recently (as of 1999) small (3-5 Ah) prismatics for cellular telephones (Electric Fuel Corporation). None of these meets the typical US Army mission requirement of several hundred watt-hours capacity with specific energies exceeding 300 Wh/kg.

Electric Fuel, under contract to the US Army CECOM RDEC, has developed a variety of 12 and 24 V primary batteries based on an advanced zinc-air cell design concept, discussed herein.

Cell and Battery Design
The common building block for all of the CECOM batteries is a 767606 cell, measuring 76 x 76 x 6 mm (Figures 1 and 2).

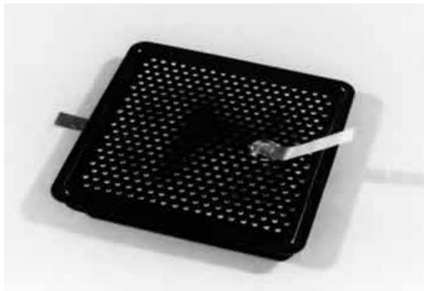

Figure 1: Photograph of 767606 cell

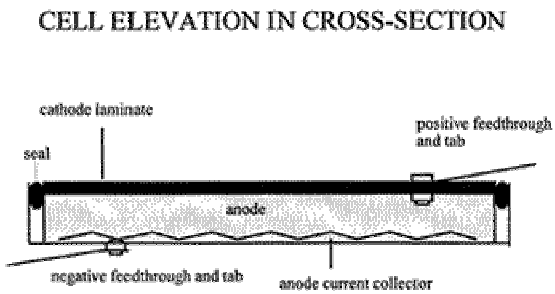

Figure 2: Cutaway Elevation of 767606 cell

The anode, similar to that found in alkaline manganese cells, comprises battery grade zinc powder (no added mercury or lead) and gelled potassium hydroxide electrolyte. The cathode laminate consists of a central active layer comprising a PTFE-bonded carbon/catalyst porous structure with a nickel screen for current collection, a PTFE barrier layer, and a microporous separator. These components are contained in thin-walled plastic covers which are joined and sealed with adhesive. Feedthroughs provide current conduction from the electrodes' current collectors to the external interconnect tabs.

Four cells (or two, depending on the battery size) are interconnected in a series stack (Figure 3), in which pairs of cells face each other cathode-to-cathode, separated by a spacer to allow air access.

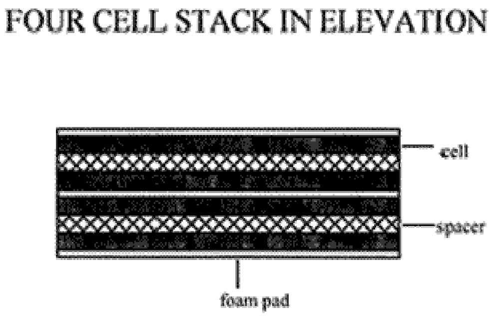

Figure 3: Elevation View of Four-Cell Stack

Multiple stacks are contained side-by-side in a plastic battery case. A d.c. fan, powered by the battery, is contained in a separate box plugged into the battery. This fan provides air flow through the cell stacks (exit ports are in three vertical walls of the battery case), and is reusable for multiple batteries, thereby minimizing the cost of the battery itself.

Figure 4: Photograph of 24 V BRICK with Fan Box

Cell and Battery Performance

A typical cell discharge curve is shown in Figure 5. Delivered capacity at 1.5 A is 30 Ah; average voltage is 1.14 V.

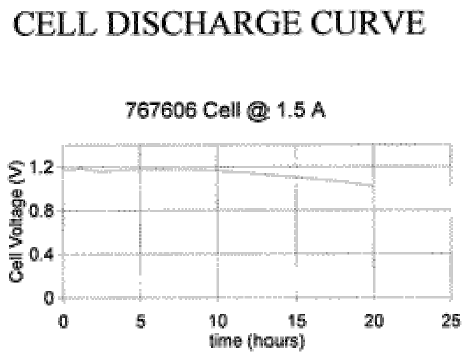

Figure 5: Cell Discharge Curve

These translate to a specific energy of 400 Wh/kg and a specific power of 20 W for the cell. Specific energy and specific power, at the cell level, relate as shown in the Ragone plot of Figure 6. At low specific power the specific energy approaches 500 Wh/kg; specific energy begins to fall off abruptly above 25 W/kg for this cell design.

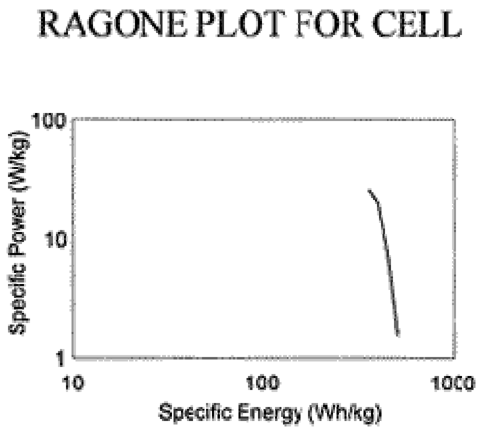

Figure 6: Ragone Plot for the Cell

The discharge curve for a 24 V BRICK is shown in Figure 7. This discharge was conducted at 40 W, which is the nominal power requirement for the forward field charging mission.

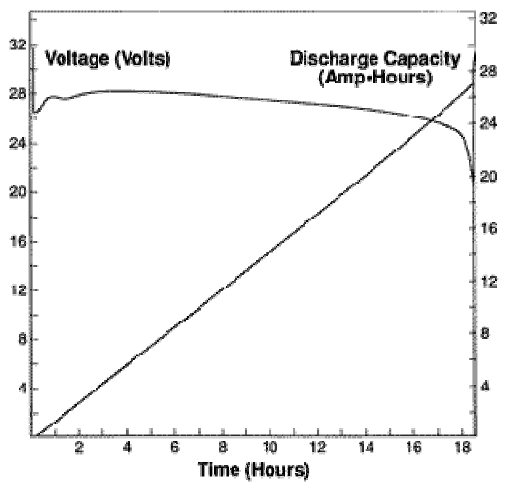

Figure 7: 24 V BRICK Discharge Curve @ 40 W (CECOM data)

Cost
One of the major goals of the CECOM program has been to halve the Army's cost, per watt-hour, of the lithium-sulfur dioxide BA-5590 batteries now in use, for which the Army currently pays about 35 cents per watt-hour. Based on the low materials and process costs for our cell and battery designs, we believe that about 17 cents per watt-hour is realistic, once cell assembly is automated.

Safety

An experimental safety assessment was performed as part of the development program. Cells were subjected to various abuse conditions, during and after which their internal temperatures were monitored and recorded. Figure 8 shows typical temperature transient data. Direct shorting and drill bit penetration produced the highest temperature excursions, both to less than 80 C. There were no fires or explosions in any of the tests performed.

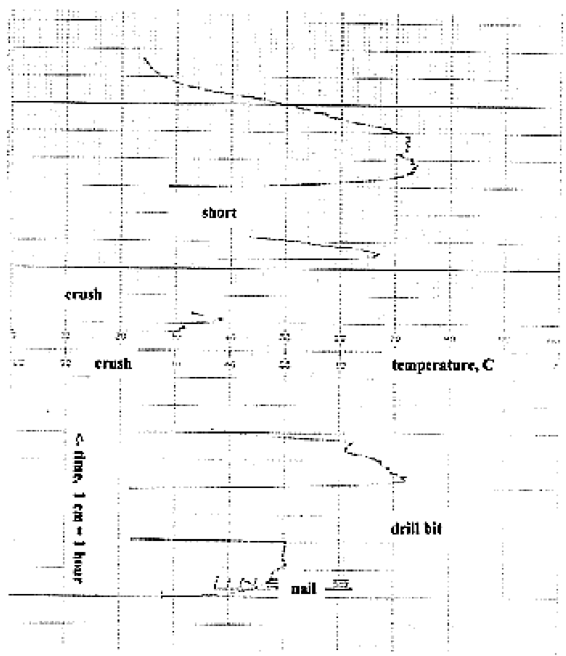

Figure 8: Temperature Transients During Abuse Testing.

Conclusion

The development work and testing performed on primary, prismatic zinc-air cells and batteries during this program has shown that this technology is an excellent candidate for primary, portable power on the battlefield. We have demonstrated high specific energy for cells and multi-cell batteries, whose designs use low-cost materials and which are amenable to automated manufacturing. And testing has shown the absence of explosion and fire hazards under severe abuse conditions. The next step would be to conduct shakedown trials in the field to ruggedize the design, to be followed by a manufacturing technology program towards procurement.

Acknowledgment

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