Zinc-Air Batteries for the Dismounted Warfighter

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Abstract

The US Army and Marine Corps are evaluating primary zinc-air batteries, being developed under CECOM contracts, as battlefield power sources, along with the electrical interfaces required for connecting to their equipment. Field tests to date have demonstrated 6-9 days of continuous power for the AN/PRC-119 B and F radiotelephones (SINCGARS and ASIP), depending on traffic, and four days in the AN/PSC-5 satcom radiotelephone. Bullet penetration tests showed there to be no fire or explosion hazards under those conditions, and that the batteries continue to operate after taking several rounds.

Introduction

Third-generation zinc-air batteries are being developed as a lightweight, low-cost, and safe battlefield power source for the dismounted warfighter. First generation zinc-air was the relatively heavy and low-rate batteries sold into the remote signaling markets (buoys, railroads), second generation the button-cell batteries for hearing aids. The third generation embodies prismatic cells with thin-walled molded plastic housings in molded plastic battery cases.

Zinc-air cells and batteries operate via the electrochemical oxidation of metallic zinc with atmospheric oxygen. Their favorable attributes of light weight, low cost, and safety eventuate from the absence of the metal-oxide oxidants (positive electrodes) in most other battery systems. This absence, generally speaking, also limits their sustained specific power. Zinc-air batteries designed for high specific energy have demonstrated in excess of 300 Wh/kg at up to 20 W/kg, those designed for higher power up to 50 W/kg, at lower specific energies.

Successful laboratory development and testing of the present technology from 1998 through the first half of 2000 led to field trials by the US Army and Marine Corps thereafter, the results of which are discussed herein.

Cell and Battery Designs

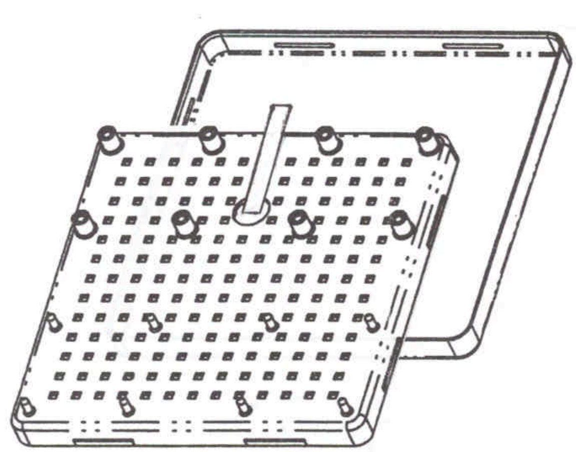

Figure 1: 30 Ah Cell Exploded View

The 30 Ah cell of the present design (Figure 1) measures 76 mm x 76 mm x 8 mm and weighs 92 g. Twelve of these are connected in series, in three 4-cell stacks, to form a nominal 12 V string (Figure 2).

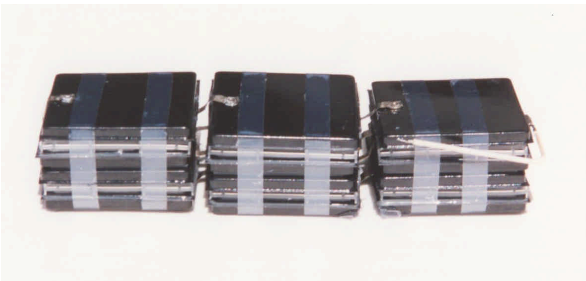

Figure 2: 12 Cell String

Two of these strings are placed side-by-side in a battery case (Figure 3), which has air inlet and outlet holes that are covered with a waterproof non-woven, and an internal fan for air circulation.

Figure 3: 12/24 V Model FCX Battery

Power outlet is via a cord connected to a COTS five-socket circular plastic connector, with two sockets per string and a fifth socket which energizes the fan when the mating connector from the electrical interface (discussed below) is attached. The battery is fully submersible, although sustained power output requires air access. The battery, which weighs 2.5 kg and measures 32 cm x 19 cm x 6 cm, has a capacity of 30 Ah at 24 V or 60 Ah at 12 V.

Electrical Interface

Since the battery does not look like a BA-5590, an electrical interface is required between it and the equipment it powers. Four different interfaces have been developed for the missions encountered to date, two of which are discussed herein. The first is the direct-power electrical interface, for general use (Figure 4).

Figure 4: Direct Power Electrical Interface

It is the same size, with the same design of electrical connector, as the BA-5590, except that it has a retractile cord extending from it with a five-pin circular plastic connector that connects to the battery.

The second, the satcom electrical interface, contains two 12V, 2 Ah COTS lead-acid batteries in an AN/PRC-117 battery box that also fits the AN/PSC-5, AN/PRC-113, and AN/PRC-138 radiotelephones (Figure 5).

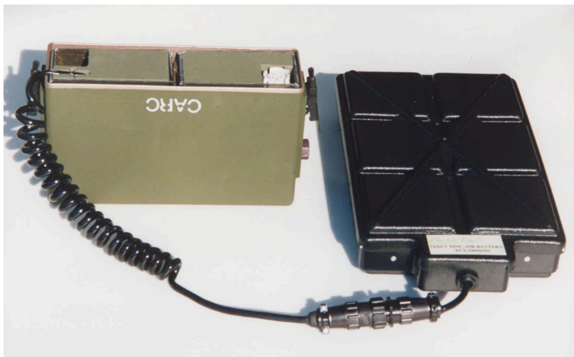

Figure 5: Satcom Electrical Interface

These, as a group, have high transmit power (50-100 W from the battery), most of which comes from the lead-acid batteries, which are electrically in parallel with the zinc-air battery via the retractile cord between the two. During standby/receive, the zinc-air battery powers the radio and recharges the lead-acid batteries. Performance of this zinc-air / lead-acid hybrid, which was pioneered by CECOM, is discussed below.

Field Experience

As of January 2002 over 200 batteries have been field tested by the US Army and the Marine Corps, at Fort Bragg, Camp Pendleton, Fort Irwin, 29 Palms, and Bridgeport (CA). They have powered AN/PRC-119 B and F radiotelephones, operating continuously, in rucksacks and at command posts and remote re-transmission sites. Battery life on these has been 6-9 days, depending on radio traffic. The zinc-air / lead-acid hybrid systems powered the AN/PSC-5 satcom radiotelephones, with transmit power requirement of 100 W, for four days during continuous use. Fortuitously the voltage matchup between zinc-air and lead-acid, in a 2:1 ratio, permits efficient operation at all states-of-charge, with very little, ostensibly, lost in overcharge. These batteries were direct-connected to each other, with no electronic controls between them.

Safety

One of the key safety concerns for battlefield equipment being bullet penetration, two of the batteries were taken to the sniper range at Marine Corps Base Quantico. Each was connected to a SINCGARS radio in transmit mode during its test. The first took five rounds of 5.56 from an M-16, during and after which the radio continued to transmit. The second took one round of 7.62 from a Marine Corps sniper rifle, with the same result. A second round of 7.62 in each blew the upper part of the batteries off, at which time the radio ceased operation. Both batteries got warm, less than 50 C above ambient, but neither exploded or caught fire.

Cost

The present, pre-pilot plant cost of the battery is $300, which is about 36 cents per watt-hour. In production we expect the cost to drop to about $150, or about 18 cents per watt-hour.

Acknowledgment

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