Journal of Power Sources 97–98 (2001) 22–24
www.elsevier.com/locate/jpowsour

US Army portable power programs

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Received 20 June 2000; accepted 30 December 2000

Abstract

This paper describes the recent US Army battery and charger programs aimed at providing lighter, large-size communications-type primary and rechargeable batteries that operate over a wide temperature range. It also discusses recent programs aimed at providing for forward charging of batteries, both in vehicles and with systems suitable for a foot soldier. Published by Elsevier Science B.V.

Keywords: US Army; Portable power programs; Land Warrior

1. Introduction

The US Army Communications–Electronics Command has had a significant program over the past several years aimed at providing for lighter primary and rechargeable batteries, as well as providing for more convenient charging in the field. This work is being conducted in conjunction with both battery developers and charger manufacturers. Improved primary batteries are being developed for special man-portable uses such as the Land Warrior, where the amount of electronic equipment is increasing and longer missions are required. There are no commercial primary batteries available that exhibit the required high capacities at the high energy and power densities desired. The emphasis on rechargeable batteries started about 5 years ago in response to the increasing cost of the primary lithium–sulfur dioxide batteries, especially during training. This has led to the fielding of relatively large lithium and nickel–metal hydride batteries, and to the need for versatile charging equipment which can be employed both in the front lines and rear support areas.

The main user concerns are energy content, power, weight, safety and ease of recharging, while those of the logistics and support personnel are cost, disposal requirements, unused capacity and proliferation of battery types. These impose additional limitations on the types of systems that can be considered.

2. Primary batteries

In the area of primary, or non-rechargeable batteries, there has been a major effort over the past few years to provide an improved battery to replace the very good lithium–sulfur dioxide battery that has been the workhorse for Army high-performance portable equipment for the past 15–20 years. We are now providing new prototype batteries to the Land Warrior program that have 50–80% more capacity, and in addition are safer. They are based on lithium and manganese dioxide, and are packaged in foil pouches rather than metal cans. If the initial successes continue these types will replace the current batteries. However, the lithium–sulfur dioxide batteries have two outstanding characteristics that will be difficult to match. They operate very well at low temperatures (−40°C) and have long storage lives. Studies show that they can be expected to lose only about 10% of their capacity after 10 years of random storage.

Prototype lithium–manganese dioxide pouch batteries have been tested in various sizes and applications with positive results. For example, the experimental BA-3847 primary pouch battery has a capacity of 14 Ah at 6–8 V, as compared to 7 Ah for the older BA-5847 sulfur dioxide primary and 3.8 Ah for the rechargeable lithium-ion version of this battery. Fig. 1 shows the estimated number of hours that an experimental new lithium–manganese dioxide 5590-size primary battery will operate a SINCGARS SIP radio as compared with a conventional BA5590 lithium–sulfur dioxide primary battery. The results show that this new type has the potential to extend the operating life from 30 to about 50 h. This technology is now being developed by both

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0378-7753/01/$ – see front matter. Published by Elsevier Science B.V.
PII: S0378-7753(01)00582-1

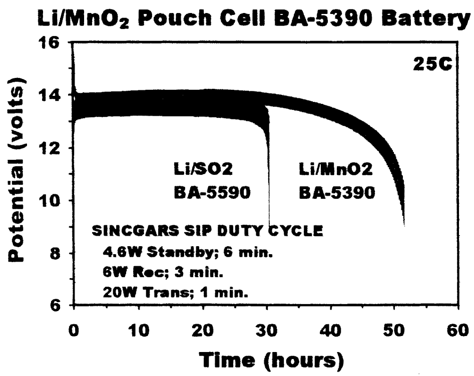

Fig. 1. Comparison of Li–SO_2 and pouch batteries.

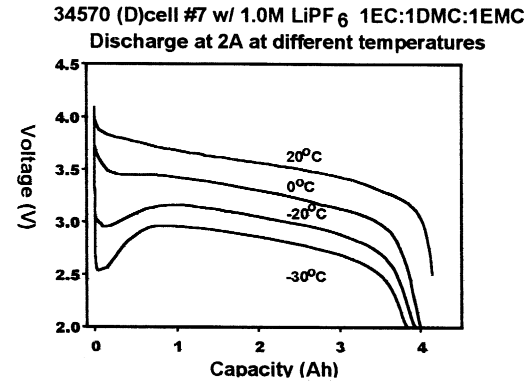

Fig. 2. Low temperature electrolyte.

Ultralife and Bluestar to provide prototype batteries for the Land Warrior program. They also operate with about the same advantage at 55°C, but drop off to about 20 h of operation at −30°C, about the same as for the lithium–sulfur dioxide battery.

In addition, we are developing very high energy density zinc–air batteries which, though limited in low temperature and high rate performance, can serve at silent portable battery chargers and as power sources for remote sensors and similar devices. In spite of the disadvantages of having a relatively low rate capability, limited performance at low temperatures, and limited life after activation, these batteries have an energy density in the 300–400 Wh/kg range and contain no flammable or potentially hazardous components. This would provide the capability for a zinc–air battery weighing less than 2 kg to recharge a standard BB-390 nickel–metal hydride communications battery (120 Wh) at least five times.

3. Rechargeable batteries and chargers

CECOM has introduced the lithium-ion and nickel–metal hydride batteries to replace the older nickel–cadmium batteries over the past few years. These have 1.5–3 times the capacities of the nickel–cadmium batteries that they replaced. Wherever possible, these are based on commercial cells. Since cells used in commercial batteries are generally smaller than those used by the military, this has required the use of larger numbers of cells in a single package, and therefore, more complex safety and charge control circuitry.

Programs are under way with contractors, as well as with the Air Force and NASA, to provide enhanced military capabilities for large lithium-ion batteries, particularly in the area of low-temperature performance and of maximizing energy content. A portion of this work is being carried out in CECOMs laboratories, and we have developed one of the promising low temperature electrolytes. This electrolyte consists of a 1:1:1 mixture of ethyl carbonate, dimethyl carbonate, and ethylmethyl carbonate, containing 1.0 M lithium hexafluorophosphate. Fig. 2 shows the performance over a range of temperatures of a D-size cell with this electrolyte, as compared in Fig. 3 with a cell using a standard commercial electrolyte consisting of a 2:2:1 mixture of ethyl carbonate, dimethyl carbonate, and diethyl carbonate containing 1.0 M lithium hexafluorophosphate. The freezing point of this new electrolyte is about −50°C, not as low as that of a mixture of 1:3 ethyl carbonate and ethylmethyl carbonate, −60°C. However, the conductivity of this new electrolyte is about the same at 25°C as that of the conventional electrolyte, so that the performance at room temperature is not reduced, as would be the case for the electrolyte with the lower freezing point. The data shows that the performance of a cell with the new electrolyte is about the same at −30°C as that of a cell using the conventional electrolyte at −20°C.

Storage life studies were conducted by storing fully charged cells at 50°C for 7 days. It was found during subsequent cycling at 20°C that the permanent capacity loss was about 5% and the temporary loss was about 6% for both cases. It has also been found with the new electrolyte that a cell can be cycled at 90°C without safety problems when discharged at the C/2 rate and recharged at constant potential at the C rate. Under these conditions the capacity drops to about 50% of its initial capacity in 75 cycles. When cycled at 70°C, the drop-off to 50% of initial capacity occurs at about 120 cycles.

We are working closely with potential users to develop and field a range of new battery chargers, from on-the-move

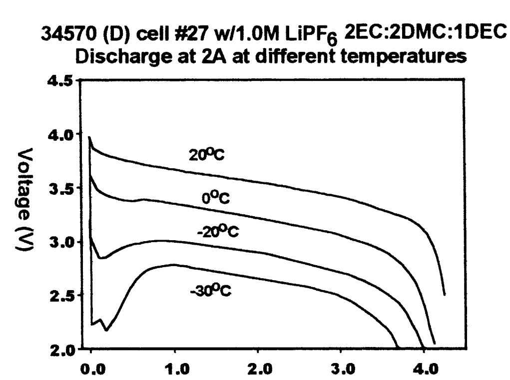

Fig. 3. Conventional electrolyte.

vehicle chargers to smart cables that can be carried by an individual warfighter. The first of these is a charger that can be bolted into the back of a vehicle. It will accept the military standard batteries, and each of these fits into the charger in a manner that provides contact with circuitry that provides the appropriate charging regimen. A total of 150 initial chargers have been fabricated and are now seeing service in a number of locations. The smart cable is a lightweight portable charger designed to operate off of any field DC source, such as vehicle power, solar power, and zinc–air batteries. These chargers will give the soldier enhanced mobility and can extend his mission time, along with lightening his load.

4. Summary

It is anticipated that in the future the current lithium–sulfur dioxide batteries will be replaced, at least in some applications, with pouch-type lithium–manganese dioxide batteries having 50–100% more capacity in a given volume. Large size zinc–air batteries will also likely be introduced in special applications and as field recharging units for rechargeable batteries. The low temperature performance of lithium-ion batteries is being improved so that they can operate at least down to $-30^{\circ}C$. It has also been found that cells using a low-temperature electrolyte can be cycled safely at $90^{\circ}C$.

Acknowledgements

We would like to acknowledge the cooperation of the following organizations in the work described above: DARPA (TRP Program), SAFT-America, Ultralife, Bluestar, NASA Mars Exploration Program, JPL, the Army Research Laboratory, and the Air Force Research Laboratory at WPAFB.