Wearable Lithium-Ion Polymer Batteries for Military Applications

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ABSTRACT

This paper describes activities being performed at Alliant Techsystems with CECOM related to the evaluation of wearable batteries. Study focuses on novel packaging techniques achievable with plastic Li-ion battery technology and its integration into the ensemble worn by a soldier.

Introduction

There has been a steady increase in the technology worn and carried by the individual soldier. Today's soldier carries a wide array of electronic devices such as computers, communications equipment, enhanced sensory devices, weapon systems, etc., all requiring portable power. The increasing demand for power required by these electronic devices, coupled with a requirement to function as a distinct military system, has significantly increased the weight of the load carried by the individual soldier.

The Army is aware of the situation and has identified problem areas of battery weight, space and power density for the current rechargeable power sources carried by the soldier. One area identified for further study is the potential benefits that rechargeable lithium-ion polymer batteries can achieve in both increased energy density and ergonomic packaging.

The objective of this study is to evaluate and demonstrate novel approaches to packaging a rechargeable battery in a man wearable configuration for integration into specific military applications.

Li-ion Battery Technology

The plastic battery technology selected for evaluation in this effort will be provided by Valence Technology and is based on a lithium ion electrochemistry licensed from Bellcore.

Valence Technology has significantly matured and enhanced the technology into batteries which are ready for high volume commercial manufacturing. The Li-ion polymer battery technology can deliver the same energy at one-third the weight of nickel cadmium batteries (NiCd) and one-half the weight of nickel metal hydride (NiMH) batteries. Storage losses are less than 10% per month compared to 20% for NiCd and 60% for NiMH. In addition, this Li-ion polymer battery technology experiences no memory effect, an undesirable characteristic of NiCd batteries.

Figures 1 and 2 illustrate the operational characteristics of the battery technology and are but a sample of the extensive characterization which has been collected for this battery technology. Table 1 summarizes the key performance characteristics of this Li-ion plastic battery technology.

Flexible Manufacturing/Rapid Prototyping

A commercially viable manufacturing process is being established for Bellcore's Li-ion plastic battery technology by a number of licensees of the technology. The manufacturing plans for these companies are directed towards high volume production in support of products targeted for consumer applications such as cellular phones and portable computers. The production lines being developed and installed for these commercial applications use dedicated and special purpose tooling.

Alliant's pilot production line implements the commercial manufacturing process except instead of using dedicated and special purpose tooling, the pilot line uses easily reconfigured tooling and manual assembly processes. The result is a flexible manufacturing line which can cost-effectively produce prototype batteries for evaluation with a relatively short turnaround.

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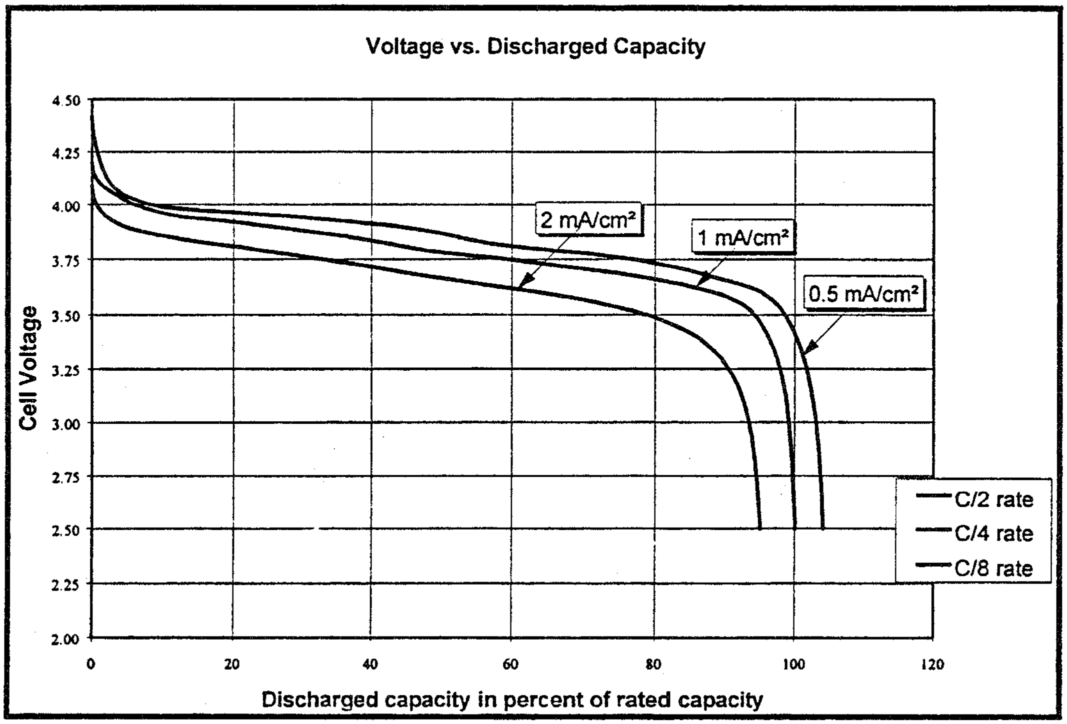

Figure 1. Typical discharge performance for a range of current densities.

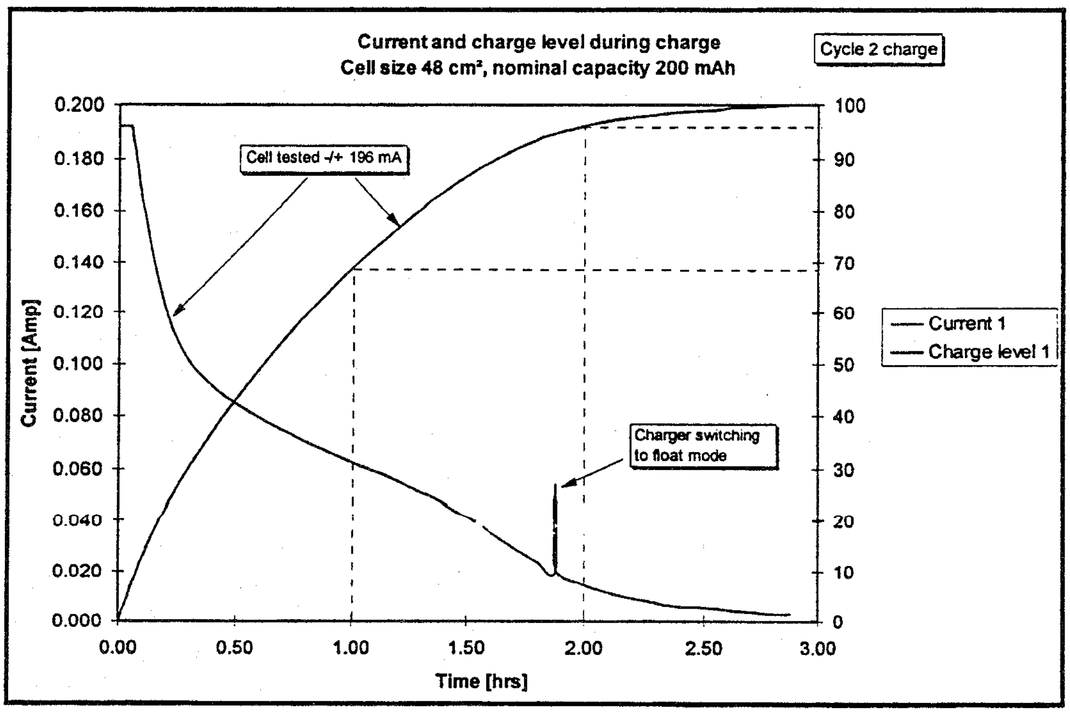

Figure 2. Current and Charge Level Characteristics During Recharge

Table 1
Summary of Li-Ion Plastic Battery Performance

Operating Voltage (nom.):	3.8 volts	Cycle Life:	>300 demonstrated
Specific Energy:	130 Wh/kg	Self-Discharge:	<10%/month
Energy Density:	246 Wh/L	Operating Temp:	-20°C to +55°C
Cost (cell level):	\$2.5 to \$3.5/Wh	Charge Rate:	80% capacity in 1 hr 100% in 3 hrs
Environmental Concerns:	non toxic		
Safety:	Especially designed to pass abuse tests including nail penetration and crush tests		

Alliant's innovative prototype manufacturing approach addresses not only near term Army requirements for rechargeable batteries such as the BB-2847 shown in figure 3 and the BB-X590 battery depicted in figure 4, but virtually any battery form factor the DoD may require can be produced on this prototype line.

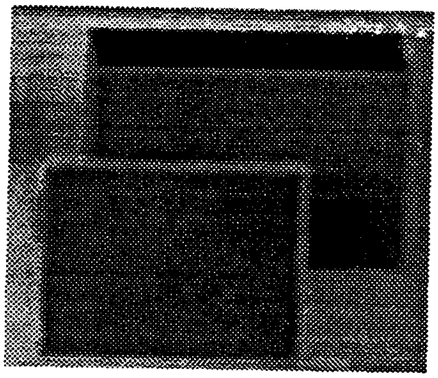

Figure 3. BB-2847 Battery

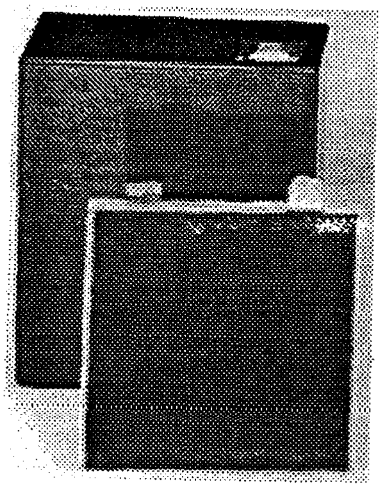

Figure 4. BB-X90 Battery

Study Objective

Alliant Techsystems study will demonstrate a modular power source technology concept which can be readily molded or shaped into ergonomic configurations that can be integrated into the soldier's ensemble. The inherent performance and packaging features of the rechargeable lithium-ion plastic battery technology are synergistic with the power source requirements of the individual soldier. The Li-ion plastic battery technology selected for demonstration in this concept study will be focused on illustrating the significant weight reduction and advanced rechargeable technology can achieve compared with the NiCd and NiMh batteries currently carried by the soldier as the alternative to primary batteries.

Why Plastic Li-ion Batteries?

The innovative packaging potential offered by the Li-ion plastic battery technology permits us to consider battery configurations consistent with requirements of the soldier system. The energy density of the selected Li-ion plastic battery technology is 130 Wh/kg, which is approximately three (3) times that of nickel cadmium batteries currently used in the rechargeable BB-590. The inherent packaging flexibility of this battery material permits the shaping of power sources into configurations not possible with conventional batteries. The shape flexibility of this material coupled with its higher energy density can result in a significant reduction in the overall weight of the portable rechargeable power carried by an individual soldier.

Planned Activities

In this study Alliant Techsystems plans to build six (6) functional systems for evaluation. The prototype systems will be a wearable configuration such as a flexible vest with a distributed and modular architecture. The prototype systems will include the associated support sub-systems for energy storage control, management and interface to the application (electronic system). One possible configuration for demonstration of this concept is depicted in figure 5.

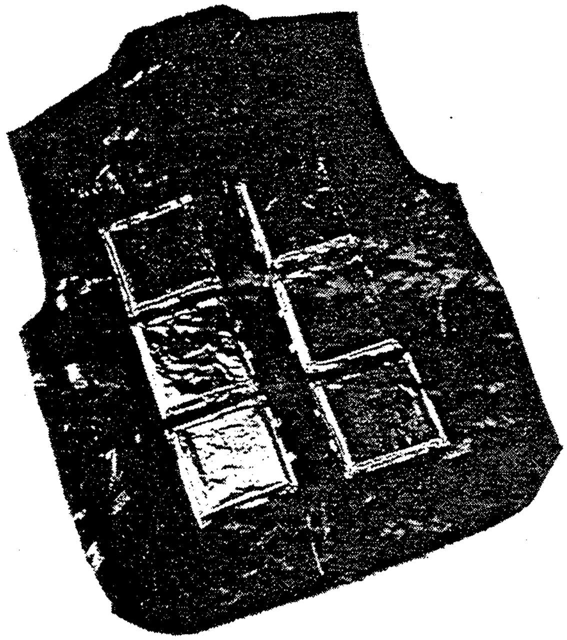

Figure 5. Man Wearable Energy Systems Concepts

Based upon the information completed in the review of portable power requirements, a number of concept battery configurations will be analyzed. These concept configurations will consider the full range of possible shapes and geometries intended to be worn or carried by the soldier in non-traditional ways. The emphasis of this activity will be to create a full range of possible batteries configurations supporting the concept evaluation of an integrated and distributed power systems which is wearable by a soldier.

Battery specific electronics will implement functions such as over and under voltage protection, over current limit, and a fuel gauge to estimated remaining battery capacity. In addition to the battery specific electronics, a dedicated effort will focus on the requirements for recharging individual batteries as well as an integrated power system containing an array of wearable batteries. As part of the charger requirements definition effort, a variety of potential sources of energy for recharging the batteries will be considered. A preliminary list of potential energy sources for renewal of the soldier's power system are field generators, mobile DC power from vehicles, solar collectors, and primary batteries.

An important aspect of the effort is associated with evaluating the interaction of the soldier with the power system. Specific attention will be paid to how the batteries would be worm or carried by the soldier. This portion of the program will also investigate the electrical and physical connection of the batteries to the soldier's clothing and electronic equipment. The objective is to evaluate the requirements for acceptance of an integrated power source form the perspective of the soldier.

CONCLUSIONS

Under this effort the flexible pilot line established to support the design and prototyping of rechargeable Li-ion plastic batteries will be used to manufacture all of the batteries evaluated. The study's efforts are directed towards exploiting the unique packaging capabilities this battery technology offers. Special attention will be paid to the ergonomic aspects of designing a battery that is purpose specific and incorporated as a integrated component into a system worn by a solider.

This effort also serves as a test bed to identify and develop a concept for an integrated man-wearable distributed rechargeable energy system.

ACKNOWLEDGMENTS

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