00PSC-123

Bipolar Metal Hydride Batteries for High Power and Aircraft Applications

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ABSTRACT

Electro Energy, Inc. is developing high power long life bipolar nickel metal hydride batteries for Aircraft and other High Power Applications. The sealed wafer cell is the building block of the high power and voltage batteries making the assembly easy and cost effective. High power bipolar battery designs are ideal in applications where conventional battery use would require excessive capacity decreasing payload weight and volume. The bipolar nickel metal hydride design allows for high voltage designs with a 25% reduction in both weight and volume. Utilizing a sealed wafer cell design Electro Energy has demonstrated 1.2 KW/Kg and 1.9 KW/l.

INTRODUCTION

The nickel-metal hydride battery system has received considerable interest for portable electronics since approximately 1990. The system offers improved energy density over Nickel Hydrogen and Nickel-Cadmium batteries. It utilizes materials that are more ecologically friendly and are designed for sealed, maintenance free operation. Based upon these desirable characteristics Nickel-Metal Hydride cells constructed in a cylindrical configuration are currently in high volume production for small portable applications, cell phones, camcorders, computers, etc.

Development activities are under way to further develop this system in conventional electrode packaging for consumer, electric and hybrid vehicles and other motive power applications. As a departure from these conventional packaging approaches, EEI is developing a bipolar configuration. Under several development programs EEI has focused this technology on several high power and aircraft applications.

The advantages of a Bipolar design are the elimination of the need for separate terminals, tabs, electrode grids, plaques or foams and cell containers for the individual cells resulting in a reduction in weight, volume and cost of the finished batteries. Further, since the current is conducted perpendicular to the cell stack across the entire plane of the electrodes high power density can be achieved from this type of construction. Bipolar battery designs have generally been recognized as a desirable approach for these advantages. Electro Energy, Inc. has found that the bipolar design provides comparable volumetric energy as a lithium ion or polymer battery for 28-volt systems with significantly better power.

However, historically problems have always been encountered with leakage of the insulating edge seal resulting in failure of a bipolar battery design. The novel aspect of the EEI approach is to overcome the leakage problems, by constructing individual wafer cells which enable the fabrication of the seal on the perimeter of each cell, testing of each cell for leakage prior to battery assembly and the possibility to repair or replace bad cells if necessary. This concept requires an extra foil layer between cells but increases the seal reliability significantly.

The Nickel-Metal Hydride battery chemistry is shown in the following equations:

$$Ni(OH)_2 + OH^- \rightarrow NiOOH + H_2O$$

$M + H_2O \rightarrow MH + OH^-$

$Ni(OH)_2 + M \leftrightarrow NiOOH + MH$

The nickel electrode goes through two oxidation states, which is the same reaction that occurs in Nickel-Cadmium and Nickel-Hydrogen batteries. The metal hydride electrode serves to store hydrogen during the charging of the battery and then deliver the hydrogen for electrochemical reaction during discharge. EEI has concentrated on the use of AB_5 type alloy materials of the generic type $LaNi_5$ for the hydride electrode. Actual alloys are typically made up of mixes of rare earth metals as the A component and a combination of nickel, cobalt, manganese and aluminum as the B component. These formulations have proved to be quite stable in battery operation and are used commercially in a broad range of consumer products. Early formulations were rate and low temperature limited but recent formulations are comparable to cadmium electrode performance.

The bipolar Nickel Metal Hydride Battery offers the customer increased power and high volumetric and gravimetric energy density. The bipolar design as shown in Figure 1, permits the current to be conducted in the Z direction through the electrodes vs. in the X-Y plane as in conventional designs. This difference offers significant advantages in obtaining power, active material utilization and energy.

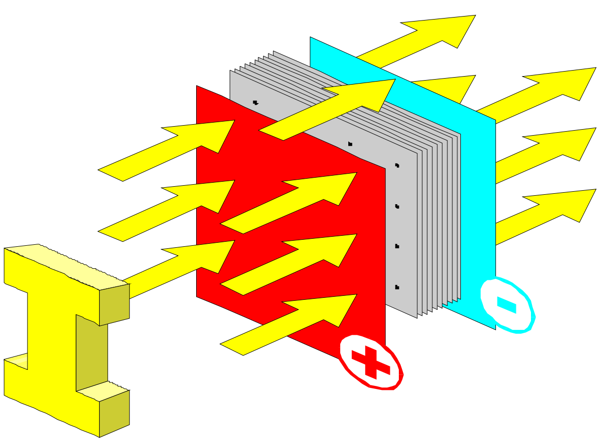

Figure 1. Diagram of Bipolar Current Path

Power is improved due to the inherent low resistance current path resulting in a low voltage drop. The current path is also much more uniformly distributed along the electrode face allowing the active material to be evenly charged and discharged providing a cooler operating battery and intrinsically longer life. Due to the elimination of nickel foam and/or grids to support the active material and the use of a plastic bonded electrode a high capacity electrode is produced for a given weight.

EEI has developed a true sealed cell configuration that has eliminated leakage and cell imbalance that has proven itself very tolerant to abuse. By eliminating the reliability problems associated with conventional relief valves or mushroom type relief valves, EEI has found that overall cell and full size battery performance has improved compared to commercially available battery systems as shown in Figure 2.

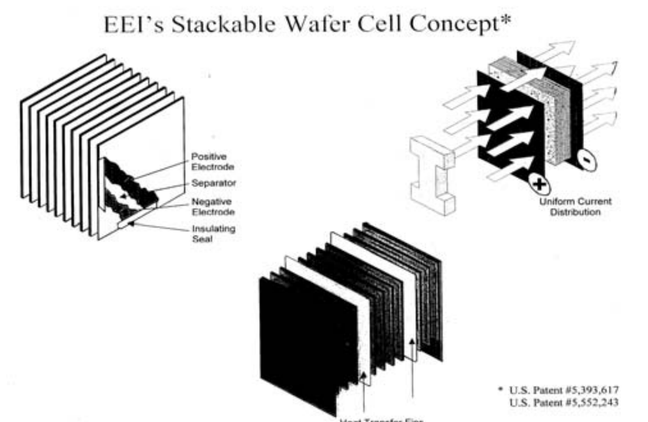

Figure 2. EEI New Generation High-Rate Wafer Cell Design

Each cell is individually sealed and stacked to obtain the desired system voltage. Thermal management has been incorporated into each wafer cell so that each cell has the same thermal map as the one next to it. This is very important and beneficial in improving cycle life and obtaining high rate capability in a battery system. The cell stack is placed into a container that has honeycomb end-walls to maintain stack compression as shown in Figure 3.

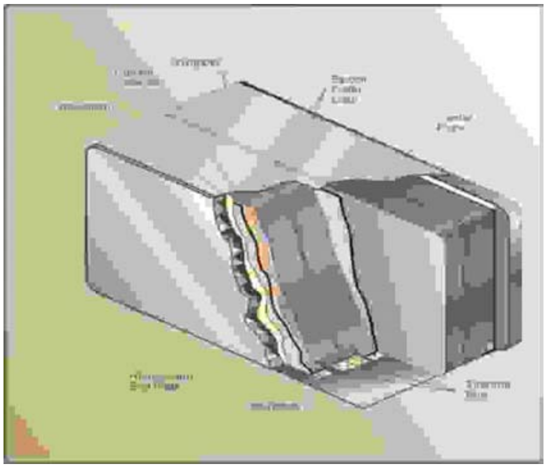

Figure 3. Assembled 24 cell 28 volt battery with 2 parallel stacks

Wafer cells have fabrication flexibility. Additionally, because of the bipolar configuration, non-conforming shapes are possible making the battery form fitting.

Aircraft/Aerospace Applications

Advanced batteries are a critical component of future aircraft missions. They must be capable of high power density, high energy density, and long cycle life, meet cost objectives and be safe and mission acceptable. In addition, a large number of existing airframes need higher performance battery systems without the ability to increase weight or additional volume due to upgrades in electronics. EEI has focused on the development of a battery that will meet tight volume requirements and substantially decrease the weight compared to the presently available nickel based batteries. The EEI design approaches the volumetric performance of lithium ion, making it a reasonable solution to the problems associated to increasing the capacity and power available on existing aircraft.

EEI is presently engaged in a program to develop a battery for the F 16 aircraft that uses a 7.5 Ah Lead-Acid battery case measuring 8.7 in x 6.7in x 5.7 in, with a maximum weight of 11.8 kg. Figure 4 shows a picture of the existing unit.

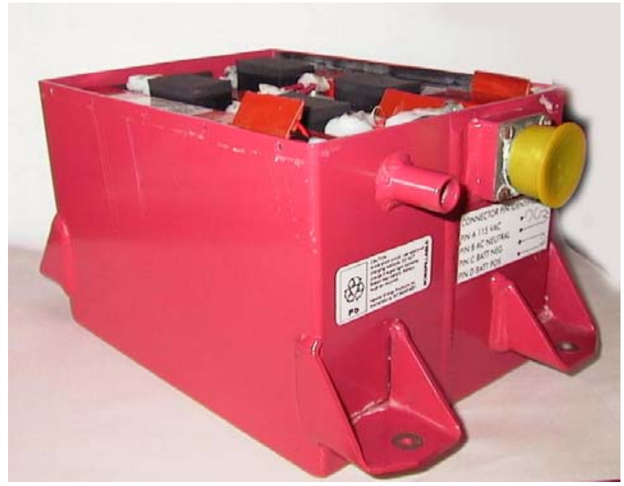

Figure 4 Existing Lead Acid Battery for the F-16

The design that EEI chose to replace this design consists of 20 cells of 7.7 in x 6.4 in. To ensure the power requirements, the baseline design uses 4 parallel stacks enclosed in a single box. The individual cells are rated at 5.5 Ah, with the 4 parallel stacks delivering 22 Ah. Figure 5 shows the cell layout in the battery box.

Figure 5. EEI Electrode Layout for the F-16 Battery

A weight breakdown of the baseline design at the cell level and battery level is shown in Table 1. This design is directed at a combination of power and energy. The cell thickness is 0.050 vs. a high power design where overall cell thickness are 0.030” or less. Generally an EEI energy battery is capable of constant cycling at the 2C rate. A high power EEI battery is capable of cycling at 15C rates. Recently, more attention is being directed at improving the cold temperature performance from -

25°C to -40°C to expand the operating capabilities of the EEI technology. Under a High Power program EEI is investigating reducing electrode thickness and cell thickness and weight to achieve a 2000 W/kg goal.

Table 1. EEI Cell and Battery Breakdown Analysis

Battery Housing Size (Maximum)	222 mm x 170 mm x 152 mm (H) 8.74in x 6.7 in x 5.7 in
Cell Size	7.65in x 6.45 in
Electrode Size	7.44 in x 6.45 in
Electrode Area	46 in^2
Number of cells/stack	20
Number of stacks	4
Current Density at 65 Amps	55 mA/cm^2
Cell Design:	
Nickel Electrode 5.5 Ah (5.5 g/Ah)	30 g
Nickel Electrode Thickness	0.017”
Hydride Electrode (5.5. Ah)(1.25)(4g/Ah)/0.9	31 g
Hydride Electrode thickness	0.011”
Separator Thickness	0.012”
Foil Thickness 0.001” x 2	0.004
Cell Thickness	0.050”
Electrolyte	19 g
Foil weight (2)	27 g
Misc.	10 g
Cell Weight	117 g
Battery Weight:	
Cells 80 x 117	9.4 Kg
Housing Weight (est.)	2.4 Kg
Total	11.8 Kg
Battery Height	
Cells 80 x 0.050”	4.0”
End Plates	1.0”
Misc.	0.7”
Total	5.7”

Conclusions

The EEI wafer design for the nickel metal hydride system has enabled packaging high energy and power density batteries for aircraft and aerospace applications. Depending upon the mission requirements the design can be directed to over 80 Wh/kg, or up to 2000 Watts/Kg for high power density. Typical batteries for aircraft range within these limits. The bipolar wafer cell design is adaptable to high voltage applications where a 270 plus voltage system is relatively easily constructed. EEI is expanding its capabilities in development and manufacturing.

Acknowledgements

We would like to acknowledge the following agencies for support for portions of the work presented here. These are the United States Navy and Air Force and the National Aeronautics and Space Administration, Glenn Research Center.