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Nickel-Zinc Large Format Batteries for Military Ground Vehicles

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ABSTRACT

In this session, PowerGenix Director of Application Development Todd Tatar will describe the nickel-zinc (NiZn) technical solution, the properties and benefits of NiZn batteries, potential advantages of NiZn batteries in military ground vehicles, and a switching battery management solution to parallel batteries for extended power.

INTRODUCTION

Nickel-zinc (NiZn) is an extremely safe and environmentally friendly battery chemistry that outperforms lead-acid, nickel-metal hydride (NiMH), and nickel-cadmium (NiCd) batteries in a smaller and lighter form-factor and avoids the high cost and safety issues associated with lithium-ion (Li-ion) batteries. NiZn batteries are 30% lighter and 25% smaller than conventional NiMH batteries and NiCd. Compared to Li-ion batteries, NiZn can provide 40% greater usable power density at less than half the cost. NiZn batteries contain no lead, cadmium, mercury or other toxic heavy metals, are nontoxic and noncombustible, and are easily recyclable. These characteristics make NiZn batteries an ideal solution for applications that demand large amounts of power in a small, lightweight, and safe package.

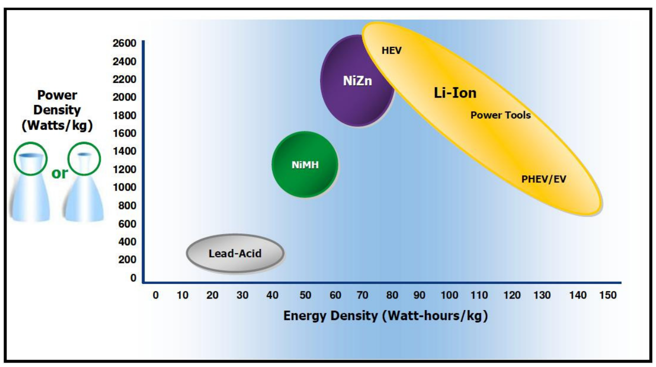

Figure 1: Energy Density Comparison

Until recently, technical problems with zinc instability prevented NiZn batteries from being a viable solution. PowerGenix has invested significant resources in the development of NiZn technology and solved the traditional technical problems associated with NiZn batteries. These innovations have been largely driven by advances in materials development and science. Utilizing a combination of patented materials and components (electrolytes, electrode compositions, and separator coatings), PowerGenix has minimized the issues of dendrite formation and shape change in the zinc electrode during cycling. In addition, PowerGenix has optimized the electrode electrical connects to the cell cover assembly and outer can to reduce internal resistance and increase power density.

Some of the specific material and design improvements developed by PowerGenix include:

- Proprietary electrolyte additives and formulations
  - Reduce zinc solubility and prevent dendrite formation
- Zinc electrode additives
  - Control electrode shape change
- Nickel electrode past formulations
  - Improve efficiency, power delivery, and charge acceptance
- Proprietary separator coatings
  - Inhibit dendrite formation
- Low resistance current collectors and electrode electrical connections
  - Improve power delivery and charge acceptance
- Positive and negative electrode compositions that do not contain any heavy metals
  - Designed for production on existing Ni-Cd and Ni-MH manufacturing equipment

The material and design improvements have been used to produce NiZn batteries with high power density and long life without compromising the inherent advantages of NiZn technology in energy density, cost, environmental profile, and safety.

The cost-effectiveness of the NiZn technology is illustrated in the chart below.

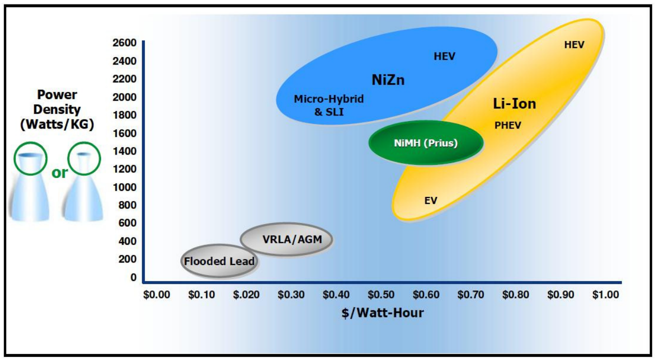

Figure 2: Ni-Zn Cost Effectiveness

COMMERCIAL APPLICATIONS

PowerGenix is already enjoying commercial success in the consumer rechargeable battery market, where the higher voltage of NiZn batteries (1.6V) provides the optimal user experience as in devices designed to operate on 1.5V alkaline disposable batteries. The higher voltage of the 1.6V NiZn battery relative to 1.2V NiMH and NiCd rechargeable batteries means that the first time, there is no performance penalty for substituting rechargeable batteries for disposable.

NiZn batteries are also an excellent replacement for NiCd and NiMH batteries in power tools and lawn and garden equipment. NiZn's higher energy density enables 30% smaller/lighter and less expensive power packs. NiZn is a non-toxic replacement for NiCd batteries. NiZn can also be an equal or higher power alternative for Li-ion batteries in these same devices, at half the cost and completely safe. PowerGenix is addressing these markets and has supply agreements with makers of power tools, lawn and garden equipment, electric scooters, and motorized bicycles.

PowerGenix NiZn batteries can also be a drop-in replacement for NiMH batteries in hybrid-electric vehicle (HEV) applications. In a Toyota Prius trial, PowerGenix NiZn batteries provided greater power in a pack that was two-thirds the size and 25% less expensive than the standard NiMH pack in the vehicle.

Parameter	PEVE Ni-MH	PGX NiZn
Form Factor	Prismatic	Cylindrical
Number of Cells	168	128
Nominal Voltage	201.6 V	204.8 V
Nominal Capacity	6.5 Ah	6.5 Ah
Pack Energy	1,338 Wh	1,357 Wh
Pack Peak Power	20 kW	**26 kW**
Gravimetric Energy Density	46 Wh/kg	**69 Wh/kg**
Bare Pack Weight	29.1 kg	**19.2 kg**

Figure 3: Comparison of Ni-MH and Ni-Zn Prius Battery

MILITARY APPLICATIONS

The cost, safety and performance advantages of NiZn batteries make them ideally suited for a variety of military applications. These include the power electronic equipment used by the modern soldier, such as mobile communication sets, robotic vehicles, field computers, laser devices, infrared sights, and other devices. In these applications, NiZn has the same advantages as it does in consumer products: high power, small size/weight, non-toxicity, safety, and low cost. These factors make NiZn an excellent battery chemistry to replace alkalines and NiMH/NiCd rechargeables as the military seeks to reduce and simplify supply logistics.

The versatility of the NiZn chemistry is demonstrated by the discharge curve of the sub-C at various rates, below.

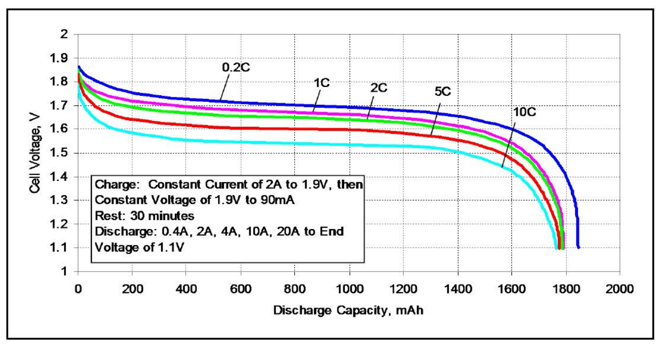

Figure 4: Sub C Discharge Characteristics

The NiZn technology delivers long cycle life comparable to conventional NiMH batteries, typically exceeding 500 cycles, during sustained 5C rate charge and discharge cycles as exhibited in the SubC 1C Charge and 5C Discharge Cycle graph.

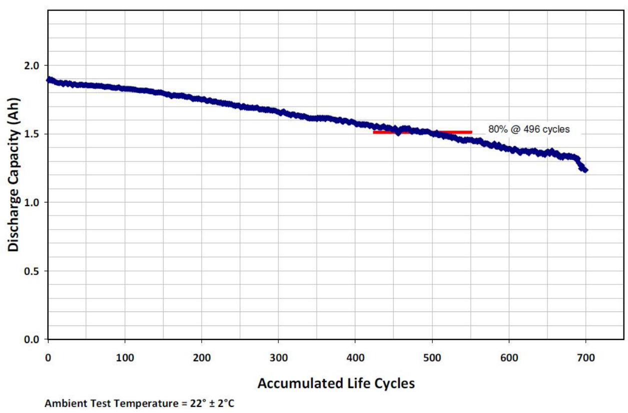

Figure 5: SubC 1C Charge and 5C Discharge Cycle Life

The high power density, light weight and wide operating temperature range make the technology attractive for use in military aircraft and land vehicles. The cost, safety and performance advantages of NiZn make it suited for a variety of applications in military vehicles, including starting, lighting and ignition (SLI); silent watch; equipment actuation; hybrid-electric propulsion systems; and micro-hybrid start-stop applications.

Hybrid vehicles are an especially important application because of NiZn's ability to save fuel and reduce fuel logistics risks in the most cost-effective manner. PowerGenix NiZn technology has great potential for applications in two types of hybrid vehicles. In micro-hybrid or "start/stop" hybrids, NiZn can be a higher performing, lower weight replacement for lead-acid batteries, which are limited in their charge/discharge speed and efficiency and performance life. This can result in 5-15% fuel savings at very low cost – $400-1000 for the entire system. PowerGenix has been testing its NiZn on the industry standard SBA-S0101 Micro-Hybrid Test. NiZn cells have passed the 30,000 test target and continue to cycle, with minimal fade, past 65,000 cycles, which represents the best performance of current lead-acid batteries.

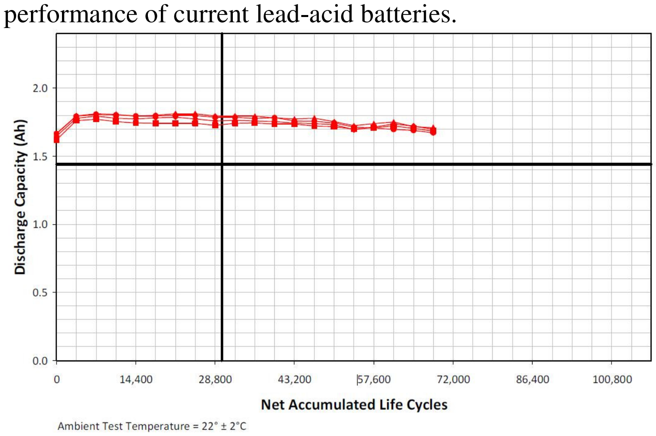

Figure 6: SBA-S-0101 Micro-Hybrid Test

PowerGenix NiZn technology can also increase performance in full HEVs – replacing NiMH with packs that are 1/3 lighter/smaller and about 25% less costly. PowerGenix is in the process of testing its NiZn chemistry against the PNGV benchmark 25Wh HEV test. These cells have reached halfway to the 300,000-cycle target with low fade and continue to cycle well.

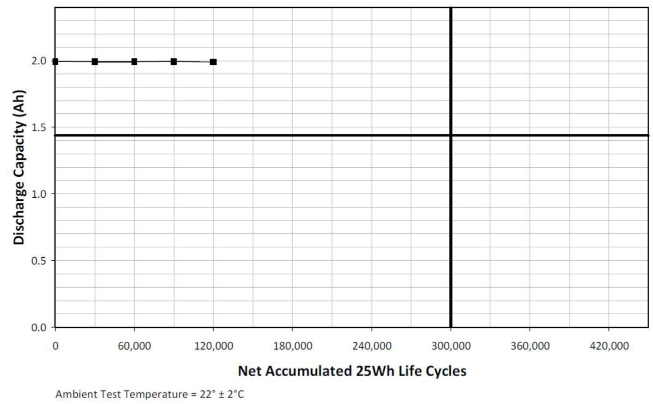

Figure 7: PNGV (Full HEV)

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) has purchased PowerGenix NiZn prismatic batteries for test as a possible replacement for the lead-acid "6T" batteries currently in use. The most widely deployed battery format, 6T, is used in 95 percent of U.S. military vehicles. In 2008, the military purchased roughly 700,000 6T batteries.

The advantages of the NiZn battery over the current lead-acid chemistry in the 6T are remarkable. The NiZn battery can deliver more than twice the energy (Specific energy ~70Wh/kg) in less than half the space (volumetric energy density ~ 150Wh/L). As the U.S. military develops more sophisticated technologies for use in high risk, demanding environments, outfitting these vehicles with lighter and more powerful batteries such as NiZn will increase performance and safety.

As seen in the Life Capacity Discharge Cycle graph conducted at 38°C in a subC format, the NiZn battery performance far exceeds TARDEC requirement of 360 life capacity discharge cycles. Cells accumulated over 600 cycles while still continuing to deliver the required performance with a large capacity margin, when testing was terminated.

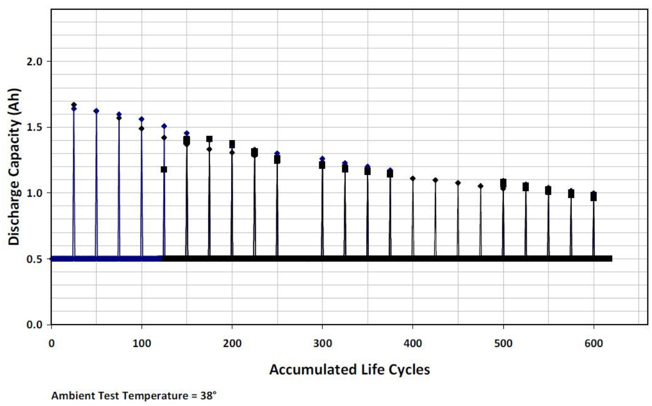

Figure 8: Life Capacity Discharge Cycle@38°C & 25%DoD

Extending the NiZn technology into other large scale formats is successfully underway. Powergenix's first prototype is designed to exceed the Tardec 6T specification with a starting capacity of 160Ahr. The final 6T format will be constructed with 16x80Ahr prismatic cells in a 2P8S configuration.

The first build prototypes have reached the designed amp-hour capacity requirements of 80Ahrs and are cycling pass 100 cycles at 0.5C.

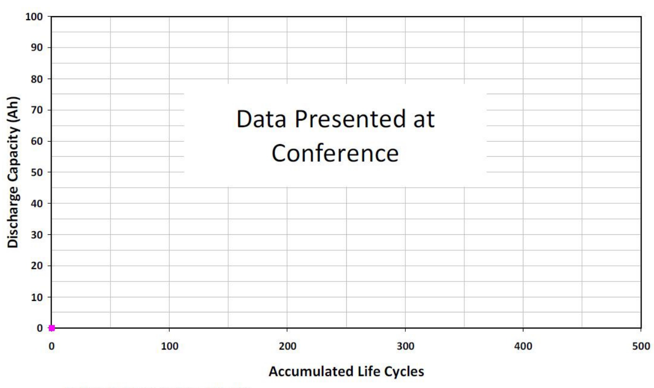

Figure 9: Prototype 80Ahr Prismatic Cells 0.5C Cycling

NiZn Target 6T Battery Specifications	
Configuration	16 cells / module, 2P X 8S
Voltage	12.8v
Capacity	160Ah, 2050Wh
Impedance	<1mohm
Dimensions	260mm x 208mm x 254mm
Size	Volume: 13.7L, Weight: 30kg
Specific Energy	69Wh/kg
Energy Density	150Wh/L

Figure 10: NiZn "6T" Format Battery

EXTENDING POWER IN APPLICATIONS

Recently Powergenix was challenge to create a solution in a small vehicular application that could not be solved by building a larger battery. As seen in the application graph below even though the 20Ahr PbA was reaching a 2 hour run-time, the application runtime was limited by half and speed reduced to due to weight constraints. Both weight and parallel battery interfaces were barriers to satisfying this application requirement. Using NiZn would solve the weight requirement due to its excellent high energy density but not the total capacity requirement for longer run-time. Managing multiple high energy batteries in parallel did not have a solution. This led to a switching BMS project that would properly manage multiple batteries under charge and discharge conditions.

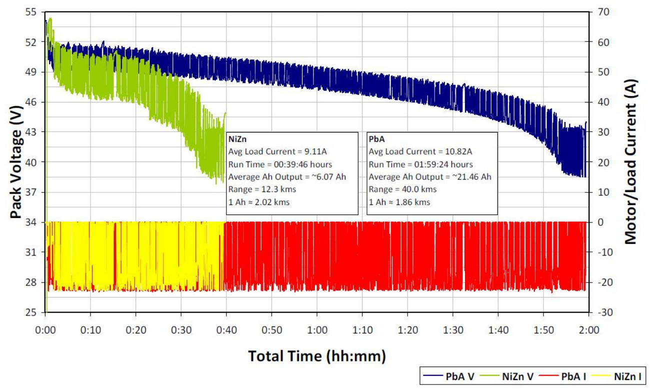

Figure 11: Discharge Capacity Gap 6.5Ahr NiZn vs 20Ahr PbA

The BMS solution was constructed using a microprocessor controlling electronic switches. Viewing the Block Diagram of Switching BMS indicates a strategy to keep the batteries in a series state at all times. The number of batteries interfaced to the BMS was limited by the number of microprocessor I/O's and realistic room for the interfaces. The application was successfully demonstrated using 3 batteries. The batteries could be charged or discharged through the BMS.

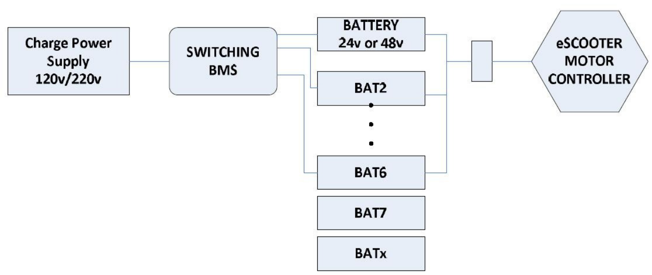

Figure 12: Block Diagram of Switching BMS

The BMS Switching graph shows a detailed drive cycle on a hilly terrain. The switching time between batteries had a 10millisec delay to prevent a back EMF. The delay was not evident to the application user. Batteries did not have to matched or have similar SOC. Worry of overcharge or over-discharge was managed by the BMS. At end of discharge a battery was removed from the discharge switching regime.

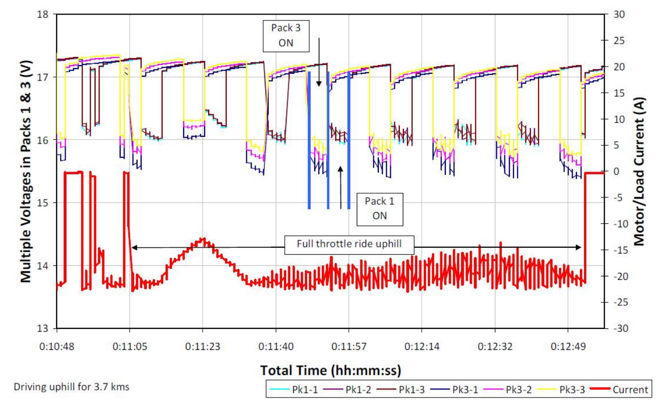

Figure 13: BMS Switching- 500W Electric Scooter

CONCLUSION

PowerGenix' technology solves the problems associated with NiZn rechargeable battery systems. The technology has large potential for military applications including portable, vehicular, and stationary storage. The NiZn technology is non hazardous and nonflammable. Up to 95% of constituent materials can be recycled. No other chemistry can deliver the Power/Price/Performance for demanding applications.

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