Advanced NiMH Power Battery for High Rate Applications

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Mark Kohler, PMP
Program Manager
mark.kohler@g4sinc.com
Who is
G4 Synergetics?
G4 Manufactures Ultra High Power, Rechargeable Advanced NiMH Batteries
Company Overview

- Long history of nickel battery development
  - General Electric
  - Energizer
  - Gates
- Team consists of battery veterans with over 150 years experience
- Based in United States (Alachua, FL)

Land: 103 acres
Facility: ~40,000 sq. ft.
Why did G4 select Ni-MH?
Proven battery technology for high power applications

- The HV battery, battery control module are covered for 8 years/100,000 miles.

Source (April 2014): www.toyota.com

Commercially Proven Chemistry for Safe and Long Cycle Life Performance
What is unique about the G4 design?
Stacked Configuration w/BMS

45Ah, 12V Module
What does this battery architecture actually achieve?
### Battery Competitive Analysis

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Lead Acid</th>
<th>Standard Lithium Ion</th>
<th>EDLC (Super-capacitor)</th>
<th>LTO Lithium Ion</th>
<th>NiMH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Electrode</td>
<td>PbO$_2$/PbSO$_4$</td>
<td>LCO, LMO, LFP, NMC</td>
<td>Activated Carbon</td>
<td>LCO, LMO, LFP, NMC</td>
<td>NiOOH</td>
</tr>
<tr>
<td>Negative Electrode</td>
<td>Pb/PbSO$_4$</td>
<td>Graphite</td>
<td>Activated Carbon</td>
<td>LTO</td>
<td>Metal hydride</td>
</tr>
</tbody>
</table>

#### Cost at system level
- **Lead Acid**: $200 - 1,000 per kWh
- **Standard Lithium Ion**: $500 - 1,000 per kWh
- **EDLC (Super-capacitor)**: $8,000 per kWh (competitive if chg/dch time is <90s)
- **LTO Lithium Ion**: $1,000 - 2,000 per kWh
- **NiMH**: $1,500 per kWh

#### Strengths:
- **Lead Acid**: Low cost solution, High volume production and decreasing system cost, Can be charged and discharged very quickly
- **Standard Lithium Ion**: High volume production and decreasing system cost, Can be charged and discharged very quickly
- **EDLC (Super-capacitor)**: Can be charged quickly, High power
- **LTO Lithium Ion**: High power, Long life
- **NiMH**: High power

#### Weaknesses:
- **Lead Acid**: Cannot be charged quickly, Low gravimetric energy density
- **Standard Lithium Ion**: If charged faster than C/2.5, lithium plating can occur and safety/cycle life is compromised, Low energy density and high cost
- **EDLC (Super-capacitor)**: Low energy density and high cost
- **LTO Lithium Ion**: LTO is expensive and energy density is lower, Liquid cooling normally required
- **NiMH**: Higher than standard lithium cost, Need to explain value proposition to customers

- **High energy**
- **Low cost**
- **Slow charge**
- **High power**
- **Moderate energy**
- **Reasonable cost**
Lithium Ion Battery:
- Uncontrollable thermal spikes due to exothermic “run-away” reaction
- Engineered solutions may not arrest thermal event once it is established

G4 NiMH Battery:
- No thermal spikes – intrinsically safe
- Thermal rise is easily detected and easily controlled by termination of charge

2-Cell Li-ion battery had a violent event after ~6 Hours, G4 architecture allowed continuous, safe venting
In this model, G4 delivers ~7 times more energy than competitive Lithium-Ion polymer batteries (LPB) at nearly the same discharge power.
D1301: High Rate, 6-Cell, 25Ah, Battery @ 400A, 30 Cycles Test (fans on)

2 min pulses at 400 Amps, 5 minute dwell period between pulses
D1251:12-cell G4 Battery: 400A, 2 Minute Test (Fans on) for 200 Cycles
~2 minutes dwell period v. 5 minutes in 25Ah design
Battery cooled to 45°C between discharge/charge
G4 Synergetics: 10 Cell 45Ah Battery: Discharge Rate Dependency at Room Temperature
G4 Synergetics: 10 Cell 45 AH Battery: Charge Rate Dependency at Room Temperature
How much current is 800A?

45Ah, 12V Module
40% DoD RT Cycle Life - Normalized Capacity

Normalized Capacity

Cycle No.

G4 25Ah

DLH
Cooling factored in
So What? You made us snooze with all this data!
The Real Question is: “What can the G4 battery do for the warfighter?”
Military Investigations:

1. Pulsed power weapons and applications - in evaluation stage at UTA
2. Rapid recharge capability at high rates could re-deploy assets in rapid fashion
3. For FOB/facilities, smoothing/firming of intermittent energy sources (PV, wind), power/voltage stability
4. Potential to circumvent stringent and costly testing criteria – DOT “friendly”
5. Strategic applications that G4 is not privy to
The University of Texas at Arlington’s Pulsed Power and Energy Laboratory - David Alan Wetz Jr., Ph.D
Contact Information:

Mark Kohler, PMP
Program Manager

mark.kohler@g4sinc.com