Lithium Iron Phosphate Batteries
An Ideal Technology for Ham Radio?

Bob Beatty, WB4SON
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A History of Battery Development

• 1791 – Luigi Galvani (“Animal Electricity” Frogs beware)
• 1800 – Alessandro Volta (Voltaic Cell)
• 1859 – Gaston Plante (Lead Acid Battery)
• 1899 – Waldmar Jungner (Nickel Cadmium)
• 1949 – Lew Urry (Alkaline-Manganese)
• 1970s – Group (Sealed Lead Acid)
• 1990s – Group (Nickel-metal-hydride)
• 1994 – Bellcore (Lithium-ion polymer)
• 1996 – U Texas (Lithium Iron Phosphate)
• 2002 – MIT (Nanotechnology applied to LiFePO4)
## Comparing Properties 1

<table>
<thead>
<tr>
<th></th>
<th>Lead Acid</th>
<th>NiCad</th>
<th>NiMH</th>
<th>LiPo</th>
<th>LiFePO4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cycle Life</strong></td>
<td>300+</td>
<td>2000+</td>
<td>300+</td>
<td>1000+</td>
<td>3000+</td>
</tr>
<tr>
<td><strong>Energy Density</strong></td>
<td>25 WH/Kg</td>
<td>50 WH/Kg</td>
<td>75 WH/Kg</td>
<td>175 WH/Kg</td>
<td>150 WH/KG</td>
</tr>
<tr>
<td><strong>Charge Efficiency</strong></td>
<td>50%</td>
<td>70%</td>
<td>66%</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Self-Discharge</strong></td>
<td>20%/M</td>
<td>10%/M</td>
<td>30% &amp; 2%</td>
<td>5%/M</td>
<td>3%/M</td>
</tr>
<tr>
<td><strong>Nominal Voltage</strong></td>
<td>2.1V</td>
<td>1.2V</td>
<td>1.2V</td>
<td>3.7V</td>
<td>3.3V</td>
</tr>
<tr>
<td><strong>Initial Cost</strong></td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Life Cycle Cost</strong></td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
### Comparing Properties 2

<table>
<thead>
<tr>
<th></th>
<th>Lead Acid</th>
<th>NiCad</th>
<th>NiMH</th>
<th>LiPo</th>
<th>LiFePO4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxic Materials</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Explosion Risk</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Flammable/Outgas</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Transportation Risk</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes*</td>
</tr>
<tr>
<td><strong>Memory Effect</strong></td>
<td>No</td>
<td>Yes</td>
<td>Less</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Charger Complexity</strong></td>
<td>High</td>
<td>Very High</td>
<td>Very High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Storage Complexity</strong></td>
<td>High</td>
<td>Low</td>
<td>Very High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

* Exemption being sought for LiFePO4. For now treated same as Li-Ion.
Comparing LiFePO4 and SLA

• 1/3 weight of a LA/SLA (20 lb vs 70 lb @ 60AH)
• 10x life of a SLA (2000 vs 200 cycles @ 100%)
  – LiFePO4 > 14K @ 30% depth of discharge vs SLA ~1K
  – LiFePO4 > 4K @ 50% depth of discharge vs SLA ~450
  – LiFePO4 > 2K @ 100% depth of discharge vs SLA ~200
• More usable power
  – SLA specified at C/20 rate vs LiFePO4 at C/1 rate (60%)
  – SLA limited to 50% for rated life
Comparing LiFePO4 and SLA

- Life cost about half
  - $400 vs >$1000 for 60 AH Usable Capacity
  - $80 vs >$100 for 7 AH Usable Capacity
- Higher voltage & flatter curve
- Low self-discharge (<3% LiFePO4 vs 20% SLA)
- Charge/Discharge efficient (99% vs 50%)
- No Hazmat, No out-gassing
7AH SLA Discharge Curve

Actual Capacity 5.25AH (New battery cycled 4 times)
Above 12.0 volts for only 50% of capacity (2.7AH)
Don’t discharge below 50% to meet life specifications!
4.2 AH LiFePO4 Discharge Curve

Actual capacity 4.3AH
Above 12.0 volts for 90% of capacity
Meets life specifications at 90-100% discharge
Temperature Impact on Capacity
(At C/1 Rate)

<table>
<thead>
<tr>
<th></th>
<th>-20°C</th>
<th>-10°C</th>
<th>0°C</th>
<th>23°C</th>
<th>55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiFePO4</td>
<td>50%</td>
<td>85%</td>
<td>98%</td>
<td>100%</td>
<td>92%</td>
</tr>
<tr>
<td>SLA</td>
<td>18%</td>
<td>30%</td>
<td>40%</td>
<td>60%</td>
<td>60%</td>
</tr>
</tbody>
</table>

NOTE: SLA capacity is 60% at room temperature because a higher C/1 discharge rate is being used. (Normal discharge rate is C/20. Ex: 3A for a 60AH battery). LiFePO4 is specified at C/1 rate. Ex: 60A for a 60AH battery.
Temperature Impact on Life

• Cycling at high discharge/charge rates at temperature extremes is not a good idea for most battery technologies.

• For SLA each 8°C above 23°C cuts life in half (life is pretty bad to begin with). At 55°C expect SLA life of 40 cycles. A LiFePO4 battery will have a life of about 1000 cycles at 55°C.

• Low temperature cycling is worse for a LiFePO4 battery. At -10°C, expect a life of about 500 cycles. The SLA life doesn’t degrade at lower temperature. At -20°C both SLA and LiFePO4 cells have about the same cycle life (300 cycles).

• Unlike SLA, Charging/Discharging a LiFePO4 does not heat battery.

NOTE: “Life” is defined at 80% of initial capacity for a LiFePO4 and 60% for a SLA.
Drawbacks of LiFePO4

- Higher up front cost
- Electronics needed to maximize life & protect
- Can’t discharge below 2.0 v /cell
- Avoid cycling below 0°C for maximum life
- Ground shipping only (no air)
Charging LiFePO4

• Current limited (<2C) Constant Voltage (14.6) if battery has PCM, balancing charger otherwise. (MUCH less complicated than SLA: Bulk Charge/Absorption/float/desulfinating)

• No special concerns based on depth of discharge (Must slow charge SLA if <50%)

• IDEAL for solar charging due to charge/discharge efficiency of almost 100%
LiFePO4 Field Day GOTA System

• System comprised of:
  – 100 watt rigid panel (about 2.5 x 3.5 ft)
  – 60 AH LiFePO4 battery with PCM
  – MPPT 10 Amp Charge Controller
• Panel produced ~7.5 amps/hr in 8 hrs of full sun (60AH)
• Panel produced ~1.5 amps/hr in 6 hrs of shade (9AH)
• Battery made up peak demand and shade/dark draw
• GOTA use averaged ~3 amps/hr over 19 hours
• Surplus of 12AH generated during contest
• Could have made 36 AH more if panel moved
• Run Stations need 9.5AH x 24Hr = 230 AH
Cost of FD GOTA Power System ~ $650

- Four 60 AH Prismatic Cells $360
- PCM Charge/Discharge Controller $40
- MPPT 10 Amp Charge Controller $115
- 100 Watt rigid solar panel $135
Can you do a FD “Run” Station? (260 AH Battery)

- Run Station needs 9.5 Amps/Hour for 24 hours or 230 AH
- Two 130 AH LiFePO4 batteries in parallel would meet demand and cost $1700
- Weighs 40 pounds/battery (80 lbs total)
- Batteries would need to be solar charged prior to contest.
- Almost ZERO risk
Can you do a FD “Run” Station? (130 AH battery 300 W Panel)

- Need minimum of 95 AH for dark period
- Three 100 watt panels will produce 9 amps in heavy overcast = 126 Amp-hours (40% rated)
- Total power need is 228 Amp-Hours
- Battery (130 AH) plus 125 AH = 255 AH
- Battery cost $650. Solar cost $750 = $1400
- Higher Risk if output lower or shaded too
Sources of LiFePO4 Batteries

- [http://www.batteryspace.com](http://www.batteryspace.com) (Competitive prices on LARGE Prismatic Cells, PCM boards, high output CV/CC chargers)
- [http://www.bioennopower.com](http://www.bioennopower.com) (Large choice of batteries/chargers)
- [http://www.tenergy.com/Site/12-8V-LiFe-Battery-Packs](http://www.tenergy.com/Site/12-8V-LiFe-Battery-Packs) (Good brand)
- [http://www.k2battery.com/battery-packs-12v.html](http://www.k2battery.com/battery-packs-12v.html) (Good brand)
- [http://www.powerwerx.com](http://www.powerwerx.com) (Power Monitors, PowerPole connectors, tools, adapters, accessories, bulk and custom cables)