# Lead Acid Battery Report - Issue 2 by Robert Weekley, August 17, 2011

Some Lead Acid Batteries are chosen for use in Electric Vehicles because of their High Power Output capabilities, flexible orientation options, and available single-cell selections for flexible pack design options.

There are some excellent products that fit this description produced by Enersys, under the Hawker Brand, and Cyclon name, and in this report we will be looking at them in comparison to similar sized or rated cells of the Lithium Iron Phosphate chemistry as produced in similar cylindrical packaging by Headway.

These are offered at some of the best prices found online for Headway Cells at www.evassemble.com. The Cyclon cells can be found at a number of online stores, I will be looking at them for sale at just two: www.atbatt.com, and www.batteriesplus.com. The Headway Cells are 3.2V Nominal, but 3V is often used as a value for pack building with them. The Cyclon Cells are just considered as 2V per cell.

**Is 8 Amp Hour of Capacity really 8 Amp Hour of Capacity after all?**

Taking Data from the Cyclon Selection Guide: http://www.atbatt.com/sku_pdf/cyclon_selection_guide.pdf and Cyclon Application Manual: http://www.atbatt.com/sku_pdf/cyclon_application_manual.pdf, – as provided from Enersys by atbatt, this report will look at the 8Ah 'E' Cell, first, with the possibility of additional comparisons with the 12 Ah 'J' Cell. These will be compared directly with the Headway model 38120S, 8 Ah cell, and model 38140S, 12 Ah Cells.

The Basic Specs for the Cyclon 8 Ah 'E' Cell are: 2V; 8Ah (20 Hour Rating); 16 Wh. (Watt Hour); 1.1 Lb / 0.50 Kg; 3.94" Long x 1.75" Diameter (100.1 mm Long x 44.5 mm Diameter); Design Life of 15 years at 20°C (68°F). Using the Selection Guide, we see the actual weight listed as 489.9 grams, and looking to page 14, we see the constant current discharge for the 8 Ah 'E' Cell under loads that can run from as long as 20 hours, down to as short as 5 minutes, to a discharged voltage end of 1.67 Volts (Per Cell) at 25°C. It is apparent that the Cyclon Cells use a 10 Hour rating (1 hours x .81Amps = 8 Amp Hour (actually – 8.1Ah). We will focus on the 60 minute, or 1 hour rating (or capacity) levels.

From the selection guide:
**Constant current discharge/amps to 1.67 VPC @ 25°C (VPC = Volts Per Cell)**

| Product | 5 min. | 10 min. | 1 5 min | 30 min. | **60 min.** | 90 min. | 5 hr. | 8 hr. | 10 hr. | 20 hr |
|---|---|---|---|---|---|---|---|---|---|---|
| E cell (8.0Ah) | 41.7 A | 26.4 A | 19.0 A | 11.0 A | **6.2 A** | 4.4 A | 1.6 A | 1.0 A | 0.81 A | 0.42 A |

For the 8 Ah Cell, at the 1 hour run time, it can deliver a 100% Depth of Discharge capacity of 6.2 Ah, or in other words, for a load of 6.2 Amps, it will deliver 100% of it's available energy in one hour, before reaching the cut-off voltage of 1.67 Volts if tested at 25°C. This means the 1 hour rating is actually '0.775C' or 0.775 x the 8 Ah Rating, just a little bit over ¾ 'C' meaning 75% of the rated energy. This is for a discharge of 100% Depth of Discharge (100% DOD). Generally, this is less in colder weather, and most cells are rated at 25 °C.

The Cyclon cells are rated for use in discharge at -65°C to +80°C, and for charge at -40°C to +80°C.

Notice the 5 minute rating of 41.7 Amps, for 5 minutes, this means the current that can be applied for 5 minutes, before the battery (cell) is depleted to the cut-off voltage of 1.67 Volts = 5.2125 x the rated 8 Ah capacity, or simply just over 5C. We will be discussing available power in this fashion, in 'C' ratings. This is also for a discharge of 100% Depth of Discharge (100% DOD)

If we only wanted to discharge down to 80% Depth of Discharge (80% DOD), that means we would have 80% x 6.2 Ah = 4.96 Ah available, or – we could just use 4.96 Amps for 1 hour to deplete the cell by 80% of its

available energy. In a typical electric Vehicle we would use a lot more current than this, but such cells can also be built into a pack, with connection in both parallel for more energy and higher current capability, and series for more voltage.

Let us now look at the Headway 38120S Lithium Iron Phosphate Cell as provided by EV Assemble here: http://tiny.cc/38120S-8ah - and some of its Specifications found there: (This cell is a high C-rate version good for high C-Rate Demand (Just what Electric Vehicles are!).

Nominal Capacity = 8 Ah; Charging Voltage = 3.65V; Nominal voltage = 3.2V; Cut-off Discharge Voltage = 2.0V; Maximum allowable continuous discharge Current = 160 Amps; Maximum Charge Current = 80 Amps; Cycle Life Available: 1500 cycles at 1C (8 Amps Load) at 100% DOD, or 2000 cycles at 1C at 80% DOD; Working Temperature: Charge -10°C to 45°C, Discharge -20°C to 65°C; Initial internal Impedance = <4mΩ (Milliohms); Diameter = 38 mm; Length = 120 mm; Weight = 330 gms.

Looking at these side by side in this chart, we can get a better comparison:

| Product Name>: | **Hawker Cyclon 'E' Cell 8.0 Ah** | **Headway 38120S Cell 8 Ah** |
|---|---|---|
| Price: | $19.99 - $20.69 | $15.00 |
| Rated Capacity | 8 Ah (10 Hours) | 8 Ah (1 Hour) |
| 1 Hour Capacity | 6.2 Ah | 8 Ah |
| Standard 80% DOD Ah/Wh | 4.96 Ah / 9.9696 Wh | 6.4 Ah / 18.08 Wh |
| Max Current Continuous Rating | 5.2125C (41.7 Amps, 5 Minutes) | 20C (160 Amps, 3 minutes) |
| Cycle Life Specs | 300 cycles (100% DOD, C/5). | 1500 cycles at 1C at 100% DOD, |
| Cell Height | 100.1 mm | 120 mm |
| Cell Diameter | 44.5 mm | 38 mm |
| Cell Weight | 489.9 grams | 330 grams |
| Discharge Temperature | -65°C to +80°C | -20°C to 65°C |
| Charge Temperature | -40°C to +80°C | -10°C to 45°C |

The Batteries plus Pricing and information page: http://tiny.cc/batteriesplus-E-Cell-8Ah
The atbatt Pricing and information page: http://tiny.cc/atbattery-E-Cell-8Ah
The EV Assemble Pricing and information page: http://tiny.cc/38120S-8ah

A Quick glance at the above chart shows the Cyclon rated for higher temperature extremes, yet delivers less energy (9.97 Wh vs. 18.08 Wh), Costs more ($19.99 vs. $15.00), weighs more (489.9 grams vs. 330 grams), last shorter in cyclical applications (300 Cycles vs. 1500 cycles), is rated for lower energy discharge cycles (C/5 vs. 1C), offers a lower voltage (2.0V vs. 3.2V) requiring more Cells to build a given pack voltage (i.e. 6 cells for 12V vs. 4 for 12.8V), and while it is shorter (100.1 mm vs. 120 mm) it is fatter (44.5 mm vs. 38 mm) than the Headway 8 Ah Cell.

**A 12V assembly of the Cyclon vs. the Headway Cells:**

| | **Hawker Cyclon 'E' Cell 8.0 Ah** | **Headway 38120S Cell 8 Ah** |
|---|---|---|
| # of Cells wide x # of Cells Long | 2 x 3 | 1 x 4 |
| Total # of Cells & Cost | 6; $119.94 | 4; $60.00 |
| Pack Width, Length | 89 mm x 133.5 mm (Cells Tight) | 40 mm x 160 mm (With Spacers) |
| Pack Weight (Cells) | 2,939.4 gms / 2.94 Kg / 6.468 Lbs | 1,320 gms / 1.32 Kg / 2.904 Lbs |
| Cell Lifetime Cost for 1500 Cycles | $599.70 | $60.00 |

**Cyclon 'E' Cell set: 59.82 Watt Hours/Cycle, Headway 38120S Cell set: 72.32 Watt Hours/Cycle. 80% DOD**

These figures show that the Hawker Cyclon 'E' Cell 8 Ah product, being (for this capacity) one of the very best Lead Acid type Cells (Sealed, High Venting Pressure, good for (relatively) High Currents, etc. is no match for the specs of the 8 Ah Headway LiFePO4 Cell in Cost, Power, or Energy, and is 10X more Expensive in a given equal cycle run time, while still delivering less energy!

We can proceed to compare the Cyclon 12 Ah Cell with the Headway 12 Ah Cell below.
The Cyclon 12 Ah 'J' Cell is very interesting in that, for some reason, on both the chosen websites, lists for a higher price than their 25 Ah 'BC' Cell, so we will compare the Cyclon 12 Ah and the Cyclon 25 Ah Cells with the Headway 12 Ah Cell, in a two-on-one comparison.

AtBatt BC Cell Page: http://tiny.cc/atbattery-BC-Cell-25Ah ABBC
AtBatt J Cell Page: http://tiny.cc/atbattery-J-Cell-12Ah ABJ
Batteries Plus BC Cell Page: http://tiny.cc/batt-plus-BC-Cell-25Ah B+BC
Batteries Plus J Cell Page: http://tiny.cc/batt-plus-J-Cell-12Ah B+J
EV Assemble 38140S 12 Ah Cell Page: http://tiny.cc/38140S-12ah EVA140

**Cyclon 12 Ah Vs. Cyclon 25 Ah Vs. Headway 12 Ah Cells.**

| Product Name>: | **Cyclon 12 Ah 'J' Cell** | **Cyclon 25 Ah 'BC' Cell** | **Headway 12 Ah Cell** |
|---|---|---|---|
| Price: | B+: $70.99; AB: $71.99 | B+: $44.99; AB: $53.99 | EVA: $18.39 |
| Rated Capacity | 12 Ah (10 Hour) | 25 Ah (10 Hour) | 12 Ah (1 Hour) |
| 1 Hour Capacity | 9.2 Ah (100% DOD) | 19.3 Ah (100% DOD) | 12 Ah (100% DOD) |
| 1 Hour 80% DOD Ah | 7.36 Ah (80% DOD) | 15.44 Ah (80% DOD) | 9.6 Ah (80% DOD) |
| Max Continuous Current | 51.7 Amps (5 Min) | 118.3 Amps (5 Min) | 120 Amps (10C, 6 Min) |
| Max Pulse Current | 800A (Short Circuit) | 1,335A (Short Circuit) | 180 Amps (15C, 10 Sec.) |
| Maximum Charge Amps | 38 Amps (Estimated from 10 Min Discharge Rate) | 73 Amps (Estimated from 10 Min Discharge Rate) | 60 Amps |
| Cycle Life Specs (1) | 200 @ 0.1C, 100% DOD | 200 @ 0.1C, 100% DOD | 1500 @ 1C, 100% DOD |
| Cycle Life Energy (1) | 4,800 Wh | 10,200Wh | 54,000 Wh |
| Cycle Life Specs (2) | 1000 @ 0.1C, 28% DOD | 1000 @ 0.1C, 28% DOD | 2000 @ 1C, 80% DOD |
| Cycle Life Energy (2) | 6,720 Wh. | 14,280 Wh | 57,600 Wh |
| 300 cycles (100%, C/5). | 6,900 Wh | 14,550 Wh | |
| Cell Height | 4.85" / 123.2 mm | 6.25" / 158.8 mm | 140 mm (155 with tab) |
| Cell Diameter | 2.04" / 51.8 mm | 2.57" / 65.3 mm | 38 mm |
| Cell Weight | 29.60 oz. / 839.2 gm | 58.88 oz. / 1669.2 gm | 386 gm |
| Discharge Temperature | -65°C to +80°C | -65°C to +80°C | -20°C to 65°C |
| Charge Temperature | -40°C to +80°C | -40°C to +80°C | -10°C to 45°C |
| Internal Resistance mΩ | 2.5 mΩ | 1.5 mΩ | <6 mΩ |
| 1 Hr. Cycle Cost | $0.2366 - $0.2399 | $0.1499 - $0.1799 | $0.01226 |

Noted points, explained:
(1) Cyclon – J: 12Ah (1.2A x 10 Hr = .1C, 100% DOD) x 200 cycles x 2V Nominal = 4,800 Wh.
(1) Cyclon – BC: 25.5 Ah (2.55A x 10 Hr = .1C, 100% DOD) x 200 cycles x 2V Nominal = 10,200 Wh.
(1) Headway – 12Ah (12A x 1 Hr = 1C, 100% DOD) x 1500 cycles x 3V Nominal = 54,000 Wh.

(2) Cyclon – J: 3.36Ah (1.2A x 2.8 Hr = 0.1C, 28% DOD) x 1000 cycles x 2V Nominal = 6,720 Wh.
(2) Cyclon – BC: 7.14Ah (2.55A x 2.8 Hr = 0.1C, 28% DOD) x 1000 cycles x 2V Nominal = 14,280 Wh.
(2) Headway – 9.6 Ah (12A x 1 Hr = 1C, 80% DOD) x 2000 cycles x 3V Nominal = 57,600Wh.

1 Hr. Cycle Cost = Purchase Cost / cycle life expectancy.
(300 C/5 Cycles for Cyclon, 1500 1C Cycles for Headway.)

First, it can be seen from the last line of the table above, that the cost per discharge/charge cycle of the Headway 12Ah cell is 5% of the 12Ah Cyclon Cell, and is just 8% of the 25Ah Cyclon Cell, or in other words, the Cyclon Cell, per Cycle costs from 12.5x as much to as high as 20x as much over their life, when compared to the Headway Cell.

On a Dollar per Amp Hour (80% DOD) Purchase Cost (A common view of reference, even if incomplete, since a $ per Watt Hour basis would be better) shows the 12Ah Cyclon costs $9.64 per Ah, the 25 Ah Cyclon costs just $2.91 per Ah, while the Headway 12Ah Cell cost even less at $1.92 per Ah.

Using $ per Purchased Wh then, the figures are – 12Ah Cyclon: $4.83 / Wh; 25 Ah Cyclon: $1.46 / Wh; and the Headway Cell: $0.64 per Wh.

While the 25 Ah Cyclon appears to have the highest Charging Current capability – this is estimated based on the information that these cells can take high inrush currents at low states of charge while the bulk charging is accomplished, this cell's Maximum Continuous Discharge Current based on it's five minute rating is just 118.3 Amps, and the Headway 12 Ah Cell is 120 Amps for 6 minutes (10C).

This is for a cell of under half the rated Ah, and ¼ of the weight, but when push becomes shove can deliver similar power for 20% longer (1 minute longer than 5 minutes = +20%), plus it is delivering a higher wattage level per cell since the Cyclon Cells are 2V and the Headway Cell is 3V. this means that the 25Ah Cyclon is delivering 236.6 Watts for 5 minutes = 1,183 Watt Minutes to a 100% DOD, while the Headway Cell is delivering 360 Watts for 6 minutes = 2,160 Watt Minutes to a 100% DOD, or twice as much energy for as low as 41% of the cost of the Cyclon, and just 23.1% of the Weight per Cell.

When configuring a 12V Pack, six of the Cyclon Cells are needed since they are 2V Cells, whereas just four of the Headway Cells are need, since they are 3V Cells. Let's do a simple demonstration comparing the 25Ah Cyclon Cells in a pack vs. the 12Ah Headway Cells:

**Cyclon 12V Pack; 19.3Ah; $269.94 (6 x $44.99); 10.015 Kg (6 x 1669.2 gm)**

| | | |
|---|---|---|
| 2V, 19.3 Ah (1 Hour), $44.99 | 2V, 19.3 Ah (1 Hour), $44.99 | 2V, 19.3 Ah (1 Hour), $44.99 |
| 2V, 19.3 Ah (1 Hour), $44.99 | 2V, 19.3 Ah (1 Hour), $44.99 | 2V, 19.3 Ah (1 Hour), $44.99 |

195.9mm long x 130.6mm wide, if cells are touching, 3x2 layout as above.

**Headway 12V Pack; 12Ah; $73.56 (4 x $18.39); 1.544 Kg (4 x 386 gm)**

| | | | |
|---|---|---|---|
| 3.2V, 12Ah(1 Hr), $18.39 | 3.2V, 12Ah(1 Hr), $18.39 | 3.2V, 12Ah(1 Hr), $18.39 | 3.2V, 12Ah(1 Hr), $18.39 |

152.0mm long x 38mm wide if cells are touching, 1x4 layout as above.

So – Two Headway Packs would cost just $147.12, deliver 24Ah (If wired in parallel), and weigh just 3.088 Kg, or just 30% of the weight of the 1.84x more expensive Cyclon pack above, and deliver 24.35% more power at 100% DOD, and if wired in parallel could deliver peak continuous currents up to 240 Amps, with pulses up to 360 Amps! Also – set side-by-side, could take up just 152mm x 76mm, still smaller than the 6 25Ah Cyclon Cells.

Building a 12V Pack with the Headway Cells using weight as a target, compared to the 25Ah Cyclon Cell Set (Chosen for their lower cost per cell, and greater available energy than the 12Ah Cyclon Cells), we can see that more than six (6) sets of 4 Headway Cells (actually – 6.48 Sets) could be built in the same weight as the Cyclon Cells, and if wired in parallel, would equal 6x12 = 72Ah at 100% DOD, but would cost $441.36. So that would cost more in the given weight, it is true then – Lithium Iron Phosphate Cells cost more by weight! Such a set of 6x4 cells also would be larger, at 228mm x 152mm, than the original 3x2 set of 25Ah Cyclon Cells. However – the Cell Lifetime Cost for 1500 Cycles of the Headway Cells at a 1C Discharge to 100% DOD = the initial cost of $73.56, while the Cyclon Cells at a Cycle life rating of 300 cycles, will need 5 sets for a total 1500 cycle cost of $1,349.7, or 18x as much! (And this is just comparing a 12V Set, not an EV Pack, future reports will take cells/batteries compared at a sample EV Pack Level.)

Therefore - I believe it is quite easy to see that you are getting better value for the money, better value for your space, more energy, more power, and actually spending less money to deliver a given energy value by using Headway Lithium Iron Phosphate Cells over the Cyclon SLA (Sealed Lead Acid) Cells.