High Rate Lithium-Ion Cell Testing

Stuart Santee, Seth Cohen, Joe DiCarlo, Frank Puglia, and Joe Wallace

Yardney Technical Products, Inc. / Lithion, Inc.
82 Mechanic St., Pawcatuck, CT, USA, 06379
ssantee@lithion.com

Abstract: Lithion, a Division of Yardney Technical Products, constructed lithium-ion cells to improve electrode coatings, separators, electrolytes and other aspects of cell design. The cells developed under this effort are capable of discharge pulses at 188 C and 25°C, continuous discharge at 112 C and 25°C and continuous discharge at 28 C and -20°C. Specifically, our 9 Ah cell was discharged with an initial peak specific pulse power of 11kW/kg followed by continuous discharge at 112 C and 25°C, delivering 82% of capacity to 2.5 V and 96% of capacity to 2.0 V.

Keywords: lithium-ion; high rate; pulse power.

Introduction

Lithium-ion batteries, with their exceptional energy density and cycle life performance, are replacing other rechargeable battery systems in many applications[1]. With the continued development of applications such as directed energy weapons, unmanned aerial vehicles and aircraft batteries, lithium-ion technology must continue to develop its high pulse power and high rate continuous discharge performance aspects. While developing a cell with these performance characteristics, all aspects of the lithium-ion system were evaluated: anode material, cathode material, current collectors, electrolyte composition and separator. For the primary screening method, coin cells were utilized due to their versatility. For this paper, the material development portion of the effort is proprietary and will not be discussed. Cycling performance and characteristics will be discussed for cells ranging in size from 2032 coin cells to the full-scale 9 Ah rated lithium-ion cell.

Experimental

The effort and components required to produce a complete coin cell are minimal, and the ability to produce both anode and cathode half cells (versus lithium) allows for component isolation. The relatively small capacities and specific areas allow one to easily perform high rate testing. Coin cells were constructed with single 0.196 in.^{2} circular (0.5 in. diameter) electrodes versus a 0.625 in. diameter, 0.010 in. thick lithium slug in a 2032 size coin cell (provided by the National Research Council of Canada). The 9 Ah cells are designated INCP 72/26/112 and weigh an average of 460 g. Cycling for these cells was performed on various Maccor Series 4000 Battery Testers. For the -20°C testing, a T-type thermocouple was affixed to the bottom of the cell case. A DC Power Supply (6 V, 1500 A, 9 kW) from Rapid Power Technologies attached to the cell in reverse order was used to perform the 1010 A discharge. Current, voltage and time were recorded using a Vision Data Acquisition System from Nicolet. Cell cycling conditions are presented in Table 1.

Table 1: Cycling Conditions

Figure	Charge	Discharge	Temp.
2	10 A to 4.15 V taper to 0.2 A	450 A to 2.0 V	25°C
3	4 A to 4.15 V taper to 0.2 A	250 A to 2.0 V	-20°C
4	10 A to 4.2 V taper to 0.4 A	1010 A to 2.0 V	25°C

Results and Discussion

Lithion's effort in recent years to improve specific power in the lithium-ion system has been successful (Figure 1).

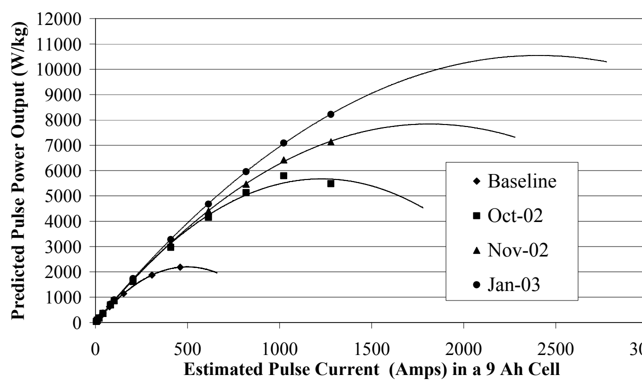

Figure 1: Coin cell data used to predict pulse power performance in 9 Ah cells.

Continued re-focusing of these efforts has allowed Lithion to achieve full-scale experimental data based on extrapolations from coin cell experiments. Once one component of cell design has been optimized with respect to all other components, a new component is explored.

Figure 2 illustrates continuous discharging of a 9 Ah cell at 50 C and 25°C. Important to note in Figure 2 is the absence of a local minimum for the first half of the discharge. The cell does not experience any voltage recovery at any point during the discharge. The cell has an initial drop in voltage below 3.6 V by the end of the first second of discharge. Most pulse applications are less than one second. The cell demonstrates low ionic and Ohmic resistances by maintaining a profile normally seen at nominal rates. The end of the discharge profile slopes steeply indicating capacity exhaustion. Only 6% of the discharge capacity is obtained between 2.5 V and 2.0 V.

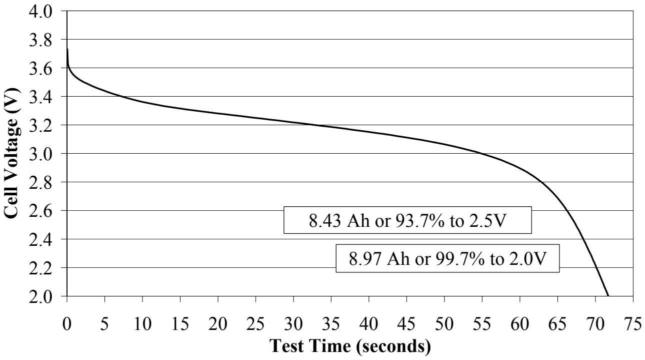

Figure 2: Discharge profile for a 9 Ah cell at 50 C and 25°C.

When the cell is tested at low temperatures, a more standard high rate discharge profile is obtained. Figure 3 illustrates high rate discharging of a 9 Ah cell at 28 C and -20°C.

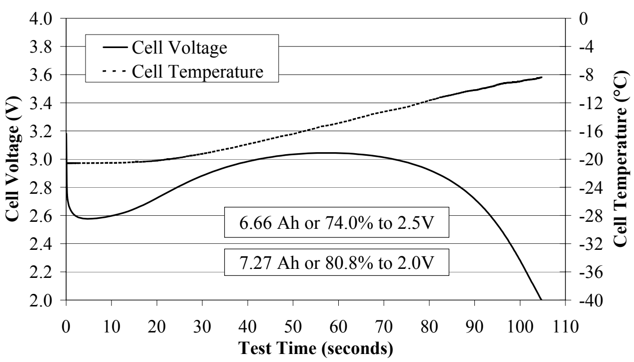

Figure 3: Discharge profile for a 9 Ah cell at 28 C and -20°C including cell case temperature.

Initial cell voltage continues to drop for the first five seconds of the test. At which point, the cell voltage begins to recover, and an increase in cell voltage is observed. Temperature data collected indicates that the rise in voltage is due to self heating. The skin temperature of the cell begins to noticeably increase around 20 seconds into the discharge. The cell voltage eventually reaches a mid-discharge peak at 57 seconds and 3.04 V. The cell capacity is lower than at 25°C, but 92% of the 7.27 Ah delivered were obtained above 2.5 V. Most important to note about the low temperature cycling is that all cells were discharged at C/5 to 3.0 V and held at -20°C for eight hours prior to charging.

The final 9 Ah cell testing was the 112 C discharge at 25°C represented in Figures 4 and 5. Figure 4 illustrates the entire discharge profile. The overall stability of the discharge profile leads to a high continuous power output of >2.7 kW. This converts to a specific power of >6 kW/kg.

The initial drop in voltage is attributed to a momentary overshoot of the target current by the test equipment. The first second of the discharge presented in Figure 5 has a peak discharge current of 1700 A. This represents a pulse of 188 C. The current and voltage of the cell for that moment represent an 11 kW/kg peak specific power pulse.

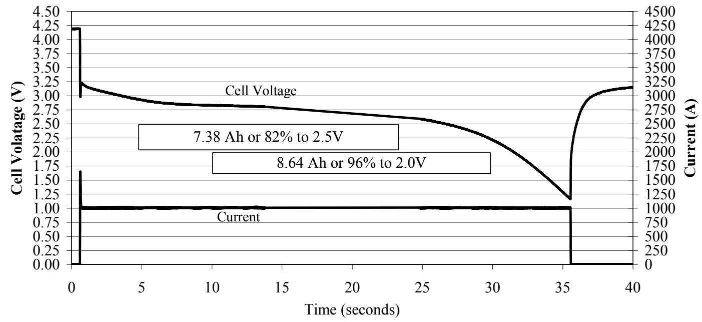

Figure 4: Discharge profile for a 9 Ah cell at 112 C and 25°C.

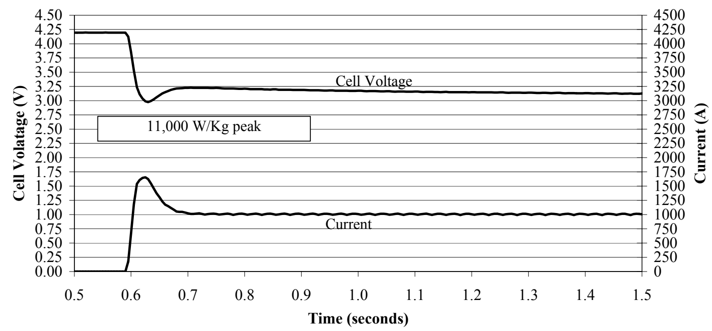

Figure 5: First second of discharge for a 9 Ah cell including 188 C pulse peak.

Conclusion

Coin cells can be used to effectively evaluate high rate lithium-ion cell materials. Materials developed and screened at Lithion, Inc. were used to produce 9 Ah cells that delivered an 11 kW/kg peak specific power pulse. This is close to the projection of 10.5 kW/kg based on coin cell results and validates the principles used in the screening experiments for the development of high rate lithium-ion cells. Furthermore, the 9 Ah cells discharged continuously at 28 C and -20°C to 80% of rated capacity and at 112 C and 25°C to 96% of rated capacity.

Acknowledgement

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References

1. *Handbook of Batteries*, 3rd ed., Linden, D., Reddy, T.B., Eds. McGraw-Hill: New York, 2002, pp 14.1.