Advanced Battery Technology Programs

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The advanced battery technology programs include market research and testing of state-of-the-art, commercial off-the-shelf as well as custom-made cells for testing and inclusion in the existing NASA Johnson Space Center cell database. As in the past, this allows for the ease of selection and use of cells for quick turnaround projects requiring power for government-furnished equipment as well as payload hardware. Advanced cell technology studies were carried out under the Exploration Technology Development Program that was changed to Exploration Technology Development and Demonstration—the government-furnished equipment battery technology programs. The results from a few of the cell studies will be described in this publication.

As part of the Exploration Technology Development Program /Exploration Technology Development and Demonstration effort, commercial off-the-shelf cell studies included the Panasonic as well as AGM cell test programs. The Panasonic lithium-ion (Li-ion) cell of 2.9 ampere-hour (Ah) capacity had an energy density that was greater than 200 Watt-hours per kilogram (Wh/kg). The AGM 7.5 Ah cell had an innovative safety circuitry internal to the cell in the header area. Tests carried out included rate capability studies, performance under different temperatures, overcharge, over-discharge, external short, heat-to-vent, and simulated internal short tests.

Table 1. *Summary of the Rate Capability Studies Carried Out on the Panasonic 18650 Lithium-Ion Cell*

Charge Rate	Discharge Rate	Cycle Number	Capacity (Ah)	Energy Density (Wh/kg)	Change in Energy Density From 1 to 200 Cycles (Wh/kg)
C/5	C/10	1	2.917	241.91	
		200	2.792	231.28	10.63
C/5	C/5	1	2.899	239.06	
		200	2.676	219.69	19.37
C/5	C/2	1	2.827	228.25	
		200	2.622	210.50	17.75
C/5	C	1	2.817	221.75	
		200	2.493	194.51	27.24
C/10	C/10	1	2.914	242.34	
		200	2.781	230.88	11.46
C	C	1	2.812	222.15	
		200	1.195	88.97	133.19

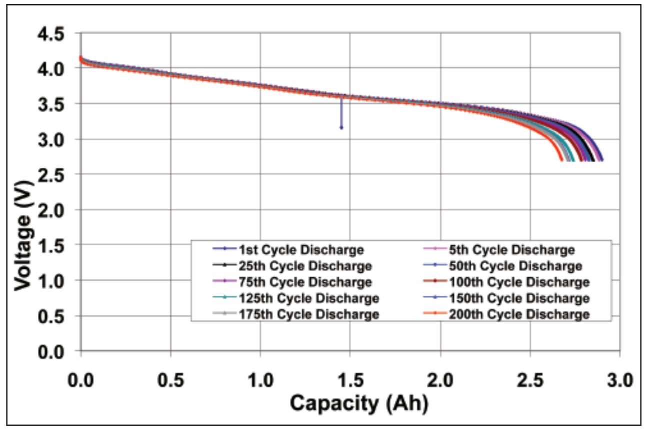

Fig. 1. *Panasonic 18650 lithium-ion cell rate capability at C/5 charge and discharge rates.*

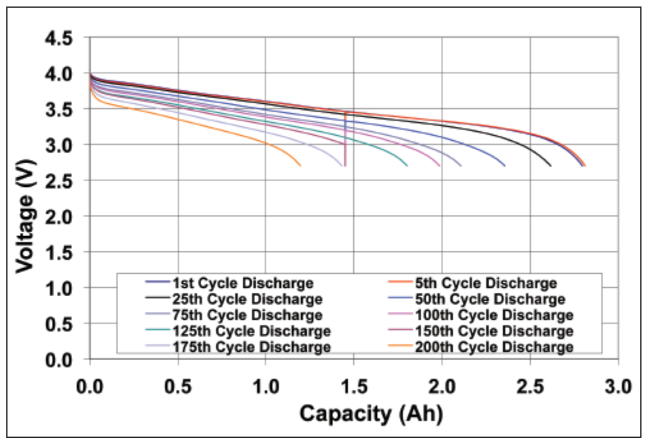

Fig. 2. *Panasonic 18650 lithium-ion cell rate capability at 1C-rate charge and discharge.*

Figures 1 and 2 show the trend for two different rate protocols. Table 1 provides a summary of the results obtained for the rate capability studies for the Panasonic 18650 Li-ion cell.

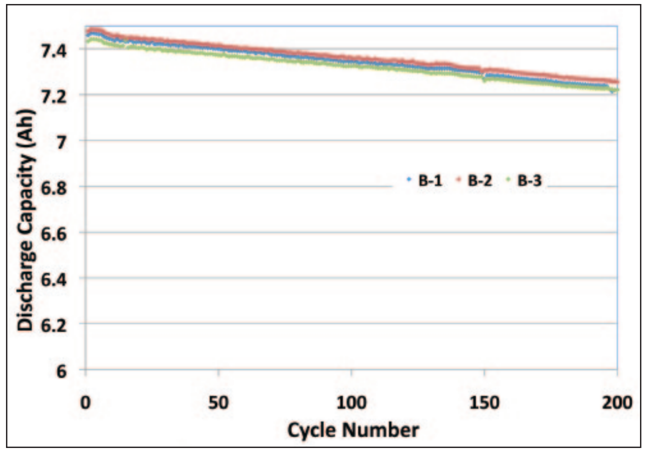

Fig. 3. *Rate capability test for the AGM 7.5 Ah lithium-ion cell at C/5 charge and discharge rates.*

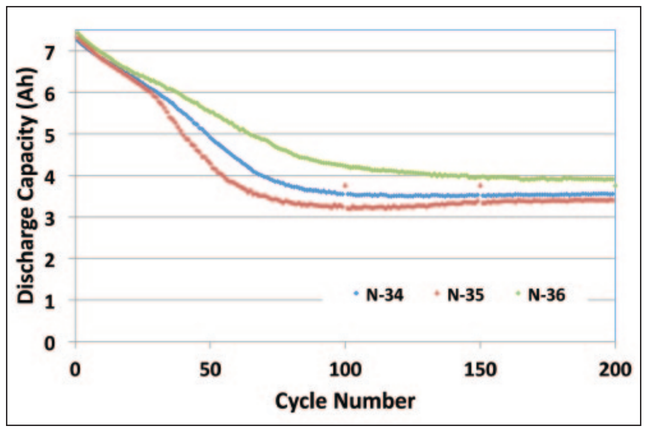

Fig. 4. *Rate capability test for the AGM 7.5 Ah lithium-ion cell at 1C-rate of charge and discharge.*

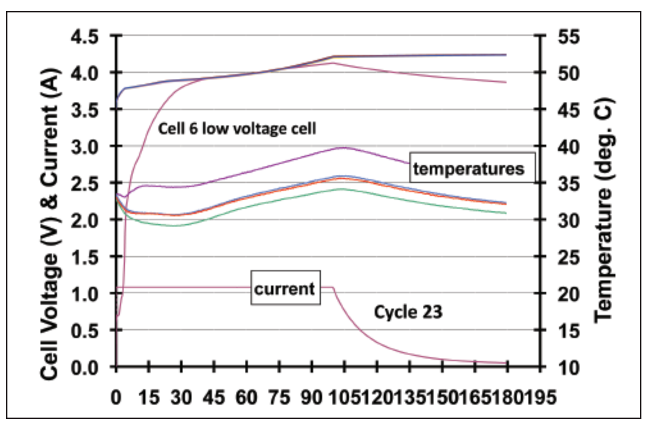

Fig. 5. *Charge profiles of cell string with an imbalanced cell that had 125 mAh capacity removed at the start of the test program.*

Figures 3 and 4 show the trend for two different sample rate protocols for the AGM Li-ion cells.

The AGM Li-ion cells showed variability in performance from cell to cell and did not have a high rate capability. They performed very well at low rates of charge and discharge. It was also observed, during the overcharge test, that the circuit board inside the cell cuts off cell performance making the cell safe.

Cell studies under the government-furnished equipment advanced technology program included the performance and safety testing of the Varta Li-ion polymer cells. The Varta Li-ion polymer cells were used to power a nano-satellite flown by the University of Texas at Austin in the space shuttle payload bay and later released on orbit for Global Positioning System studies. Another test program was also carried out to determine the effect of over-discharged cells in a cell string that had one imbalanced cell. The extent of capacity imbalance was varied and characterized to determine the voltage imbalance this would induce. The performance of the cell string was studied for a maximum of 75 cycles to determine the level of imbalance that was tolerated and safe. It was determined, under the conditions studied, that if the imbalance was approximately 20 millivolts (mV), no over-discharge into reversal was observed for the 75 cycles studied. But if the imbalance was greater than or equal to 70 mV, the unbalanced cell goes into reversal during the first discharge. With imbalances in between these values, the number of cycles obtained before cell reversal occurred varied linearly. For example, with 100 milliampere-hours (mAh) removed (imbalance of 50 mV), reversal starts occurring at about 56 cycles. For the case where 125 mAh were removed (imbalance of 60 mV), cell reversal starts at 22 cycles. Figure 5 shows the charge profile for the cell that had gone into reversal on the 22nd cycle.

Destructive physical and chemical analysis of cells at over-discharged or reversed states indicated excess hydrofluoric acid is present in over-discharged cells. This could be a huge impact on cells in over-discharged conditions as they could cause corrosion of the inner walls of the metal can with age.

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