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Thermal Stability Evaluation of Lithium-ion Cells Using Accelerating Rate Calorimetry

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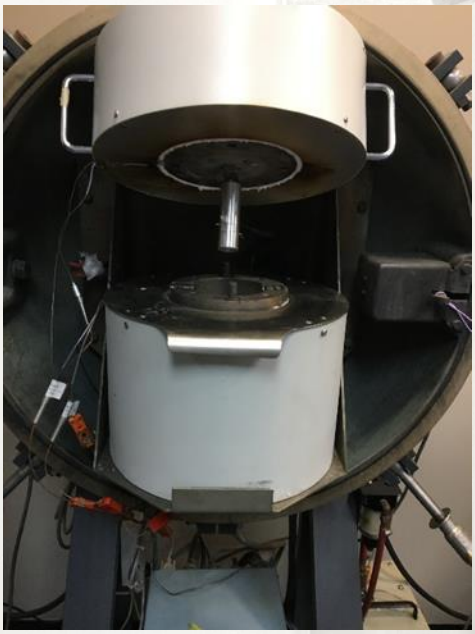

Accelerating Rate Calorimeter (ARC®)

Belmont Scientific, Inc
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Introduction:

Lithium-ion batteries are one of the fastest growing and most widely adapted technologies. Lithium-ion batteries are used in a wide range of applications, from powering cell phones and laptop computers, to powering the next generation of pickup trucks. The versatility and energy density of modern Lithium-ion batteries makes them more favorable over other energy storage systems. However, high energy density means highly reactive chemical composition. This can lead to cell failure, should the cell be exposed to extreme conditions. Cell failures can cause harm if safety measures are not taken. Belmont Scientific, Inc. has devised a method for testing of Lithium-ion pouch and cylindrical cells.

Lithium-ion pouch cells are most commonly used in cell phones, tablets, and some laptop computers due to their sleek profile. Cylindrical cells are most commonly used in automotive and power bank applications because of their higher capacity. Lithium-ion cells can experience a phenomenon known as a thermal (Exothermic) runaway reaction when exposed to high temperatures or stress. This type of reaction occurs when a Lithium-ion cell generates heat due to a chemical reaction inside the cell. The heat released due to the reaction then in turn heats the cell which increases the reaction rate, which increases the heat generation. This cycle will continue until the cell explodes and/or catches fire, potential harming the user or destroying property. To understand the thermal runaway of Lithium-ion cells, Belmont Scientific has developed an Accelerating Rate Calorimeter (ARC®) experiment to identify the following parameters; exothermic onset temperature, cell leak temperature, separator shutdown temperature, heat of reaction, pressure/gas generation, and maximum temperature achieved.

Experimental Method:

Belmont Scientific has developed a methodology for the testing of both pouch and cylindrical Lithium-ion cells. The ARC, by design, will maintain an adiabatic condition. The ARC detects when the cell is heating itself at a pre-determined rate. This is the exothermic onset temperature, or the beginning of a thermal runaway reaction. As the cell continues to through thermal runaway, the ARC will maintain an adiabatic condition by matching the heating rate of the cell until the reaction is complete. Through this method, the heat of reaction of the thermal runaway can be calculated, along with other thermodynamic properties. Pressure/gas generation can also be determined for cylindrical cells and for pouch cells. The composition of the generated gas can also be analyzed. Cell leak/vent temperature in cylindrical and pouch cells can also be determined. For cell leak, pressure, and gas generation measurements , a specialty closed holder is used during the ARC test. Another method to determine some thermodynamic properties is an oven test. For more information on oven tests, see the paper, *Determination of Cell*

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Rupture and Separator Shutdown of a Pouch Cell Using an Oven Test. Thermal data parameters are easily determined in a conventional ARC® test. Separator shutdown temperature can be harder to determine because it requires both temperature and voltage measurement.

Lithium-ion cells contain a polymer separator which prevents direct contact between the anode and cathode. Separator shutdown of a Lithium-ion cell is the temperature where the perforated plastic separator inside the cell melts. The separator melting prevents charged particles from passing from one electrode to the other. This means the cell is incapable of doing work. In order to find the separator shutdown temperature, a voltage measurement must be taken as the cell is put through the ARC® test. Once the data is collected, the separator shutdown temperature can be determined by comparing the ARC (Thermal and pressure data) with the voltage data.

Results:

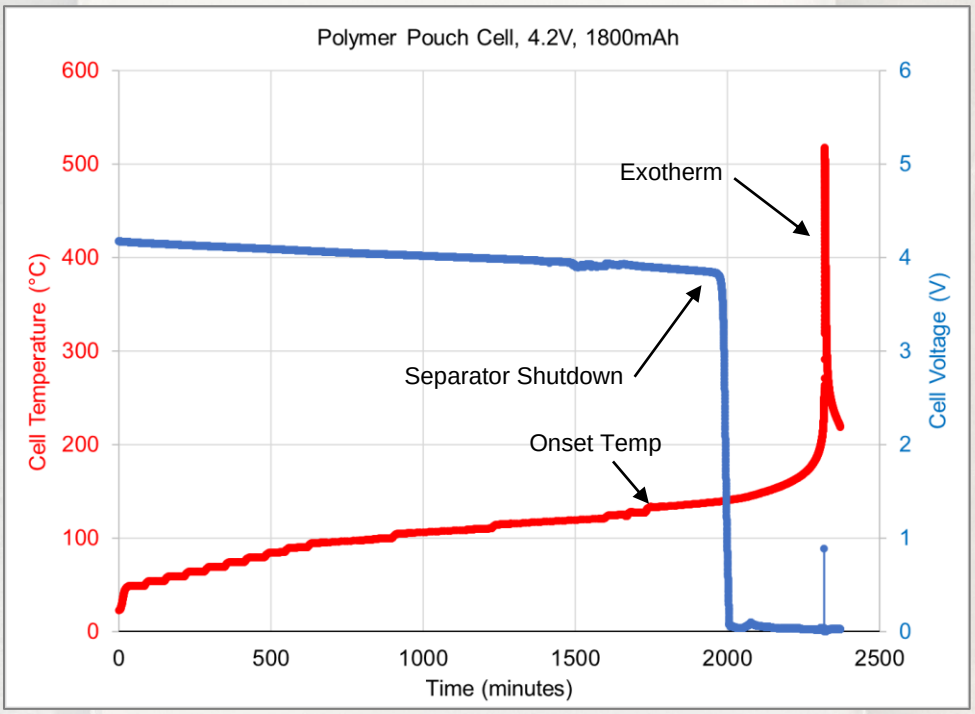

FIGURE 1. TEMPERATURE AND VOLTAGE VS. TIME OF A POUCH CELL.

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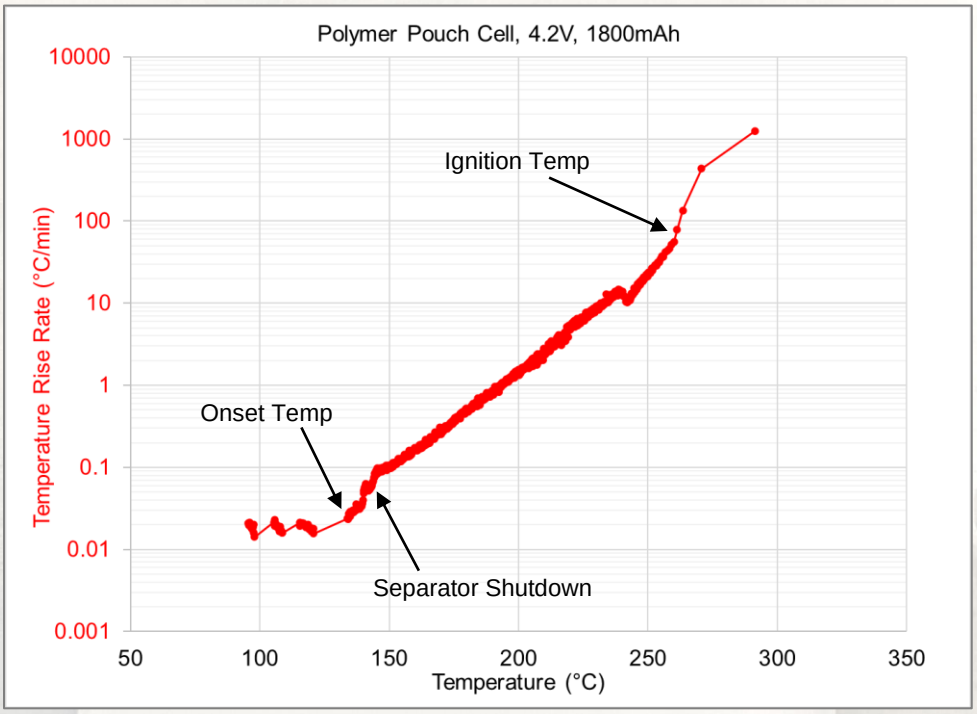

FIGURE 2. TEMPERATURE RISE RATE VS. TEMPERATURE OF A POUCH CELL.

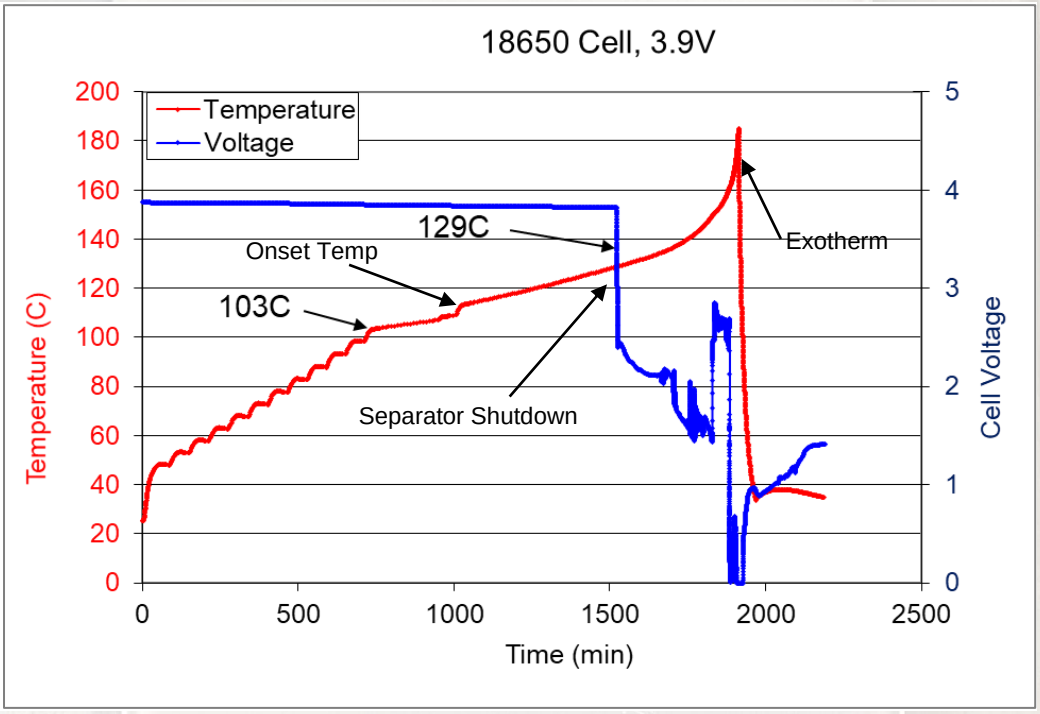

FIGURE 3. TEMPERATURE AND VOLTAGE VS. TIME OF A CYLINDRICAL CELL.

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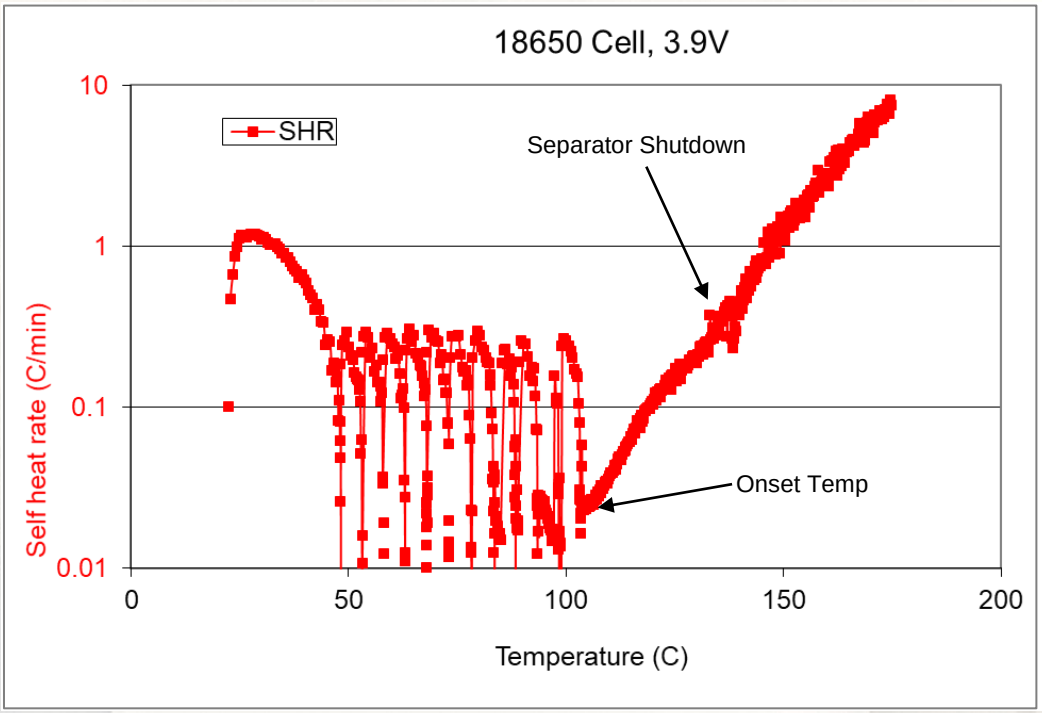

Figure 4. Temperature Rise Rate vs. Temperature of a Cylindrical Cell.

Parameter	Result	
Cell Type	Cylindrical Cell	Pouch Cell
Onset Temperature	✓	✓
Max Measured Temperature	✓	✓
Adiabatic Temperature Rise	✓	✓
Heat of Reaction (ΔHr)	✓	✓
Weight Loss	✓	✓
Separator Shutdown Temperature	✓	✓
Cell Leak/Vent Temperature	✓	✓
Pressure/Gas Generation	✓	✓
Ignition Temperature	✓	✓
Analysis of Generated Gas	✓	✓

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