Ultra High Power Lithium-ion Batteries

J.L. Allen*, J. Wolfenstine, K. Xu, D. Porschet, T. Salem, W. Tipton, W. Behl, J. Read, T.R. Jow
US Army Research Laboratory, Adelphi, MD

S. Gargies,
US Army Tank-Automotive Research, Development and Engineering Center, Warren, MI

*Contact: jan.allen@us.army.mil; Tel: 301-394-0291

Objective and Approach

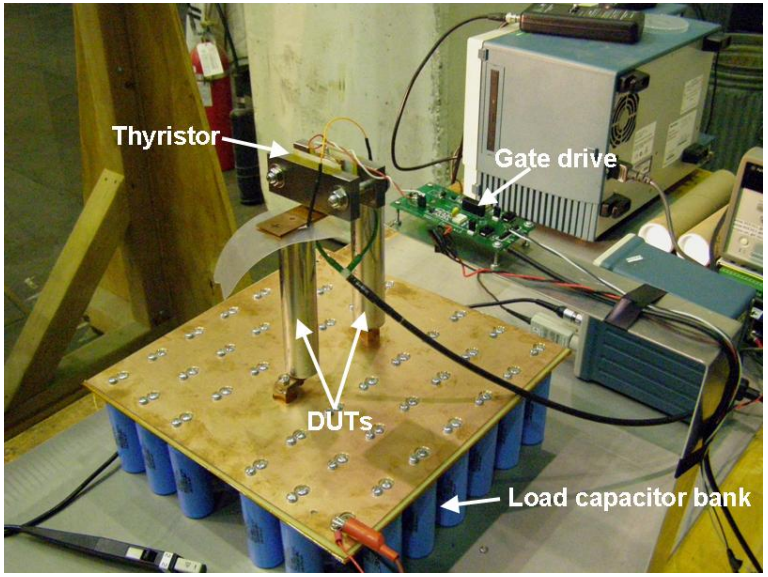
Objective

The objective of this work was to evaluate the performance of SAFT Ultra High Power (VL5U) cells and to determine applicability for Army applications.

Approach

SAFT UHP cells were subjected to high rate discharge testing testing at currents up to 1000 A (200C) and pulse discharge testing.

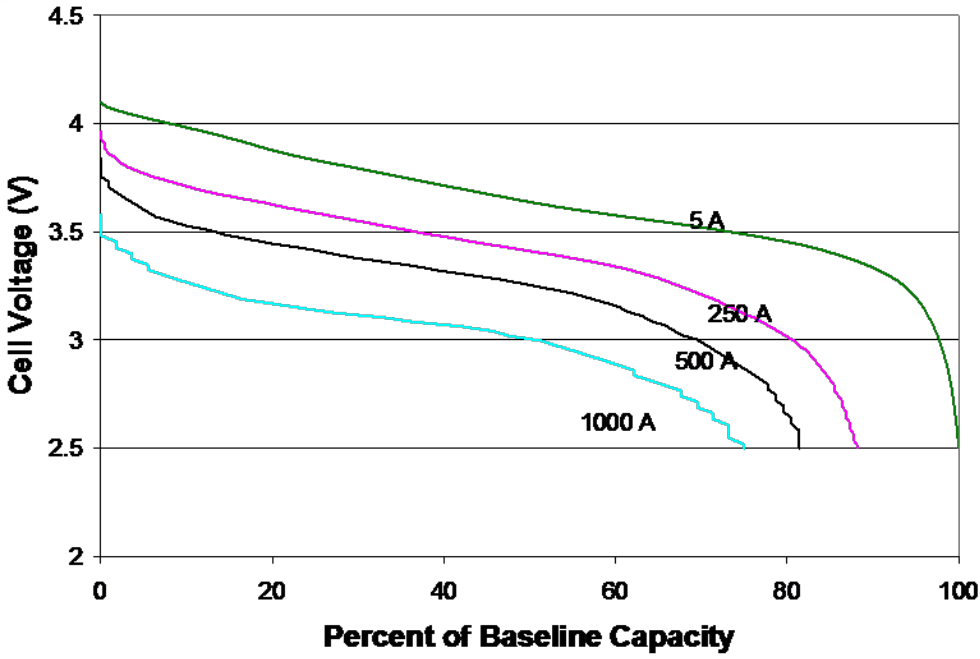
Configuration of SAFT UHP cell during constant current discharge. The cell was discharged inside an environmental chamber. The exterior temperature of the cell was monitored by a thermocouple.



Pulsed-current battery evaluation stand.

Power & Energy as Function of Rate (Room Temperature)

Rate	Energy		Power	
Amps	Wh/kg	Wh/L	kW/kg	kW/L
5	57	146	0.052	0.13
250	47	121	0.58	1.5
500	42	108	4.7	12
1000	36	93	8.7	22
2000*	27	69	14	36



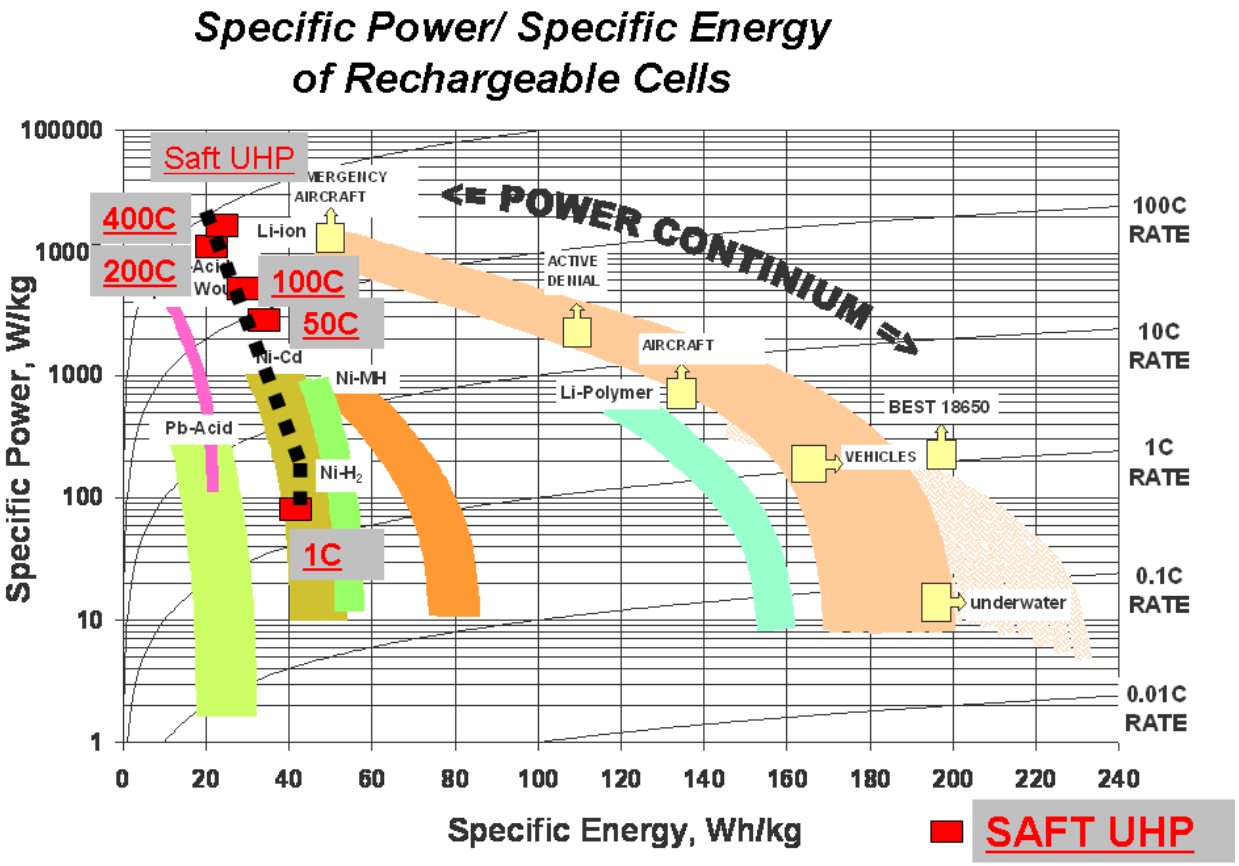
Room temperature energy and power of Saft VL5U cell as a function of rate of discharge.

Voltage and discharge capacity as a function of rate of discharge at 20° C. Baseline capacity is ~ 5Ah at room temperature.

Discussion: Cell is optimized for power with impressive performance at currents up to 2000 Amps. From pulse discharge testing minimum cell resistances are calculated to be 0.21 mΩ. Thus at an ouput of 2 V a maximum current of 8750 A may be achieved.

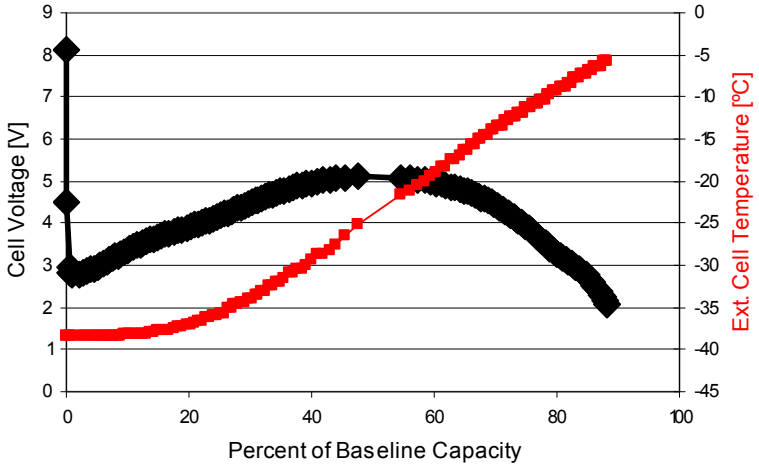
* Data point at 2000 A from IAT (Univ. of Texas)

Ragone Plot

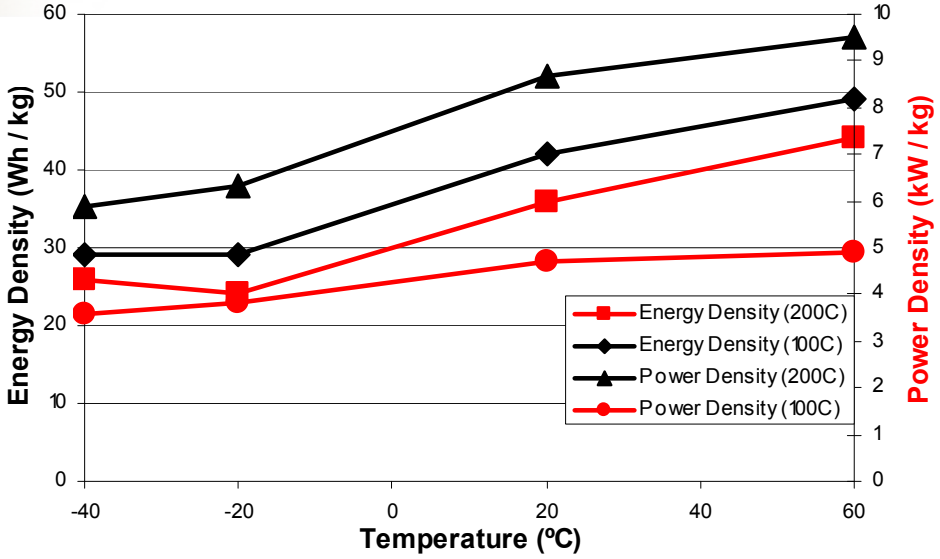


Room temperature performance plotted as a specific energy versus specific power chart (Ragone plot). Data points are shown in red. A trend line is shown as a dotted black line. Data point at 400 C from IAT (University of Texas) data. Baseline chart courtesy of SAFT.

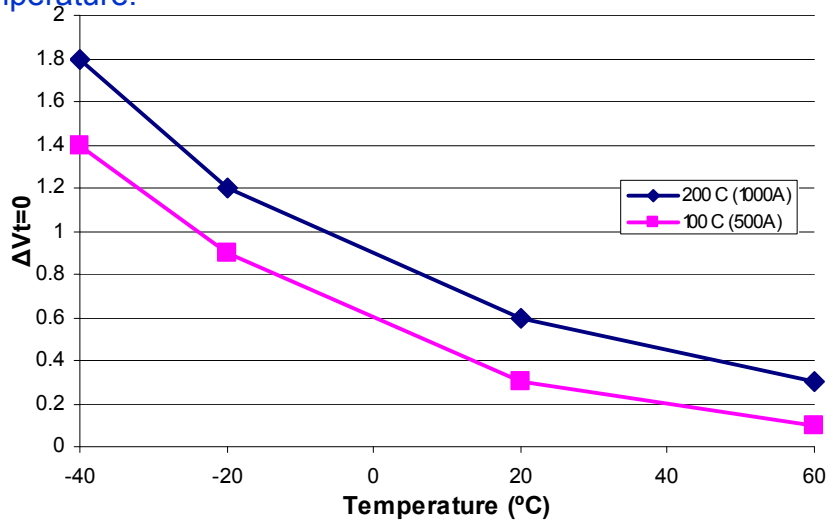
Low Temperature Behavior



Discharge curve of two cells in series at -40 ºC and 1000 A. Black curve is voltage and red curve is exterior cell temperature.



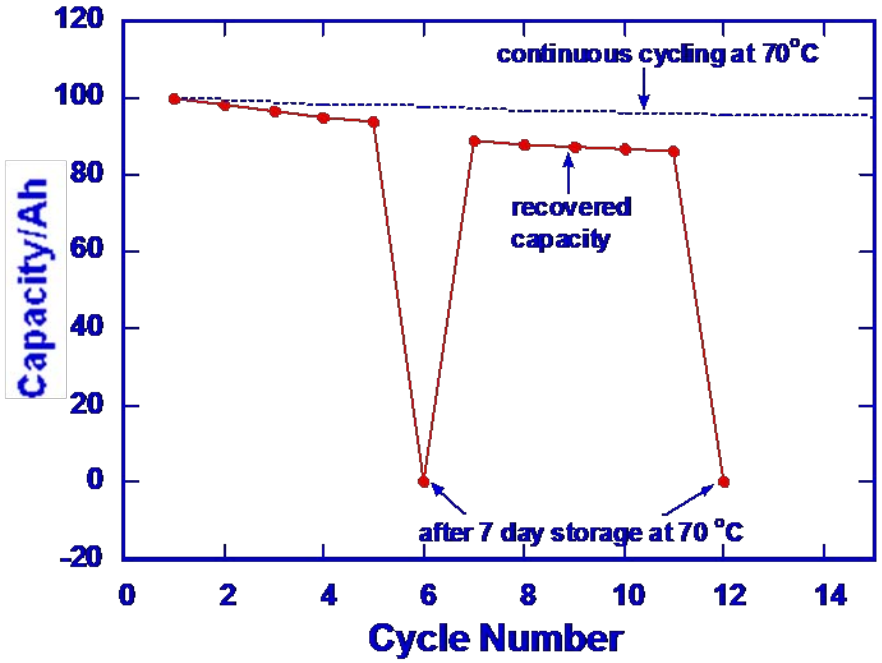
Specific energy and power density at 100C and 200C rates as a function of temperature.



Initial voltage drop at 100C and 200C as a function of temperature.

Discussion: Typical discharge curve shown, upper left. There is a large voltage drop at low temperature (plotted at left). The drop in energy and power density as a function of temperature is shown above.

Storage Life and high temperature cycling

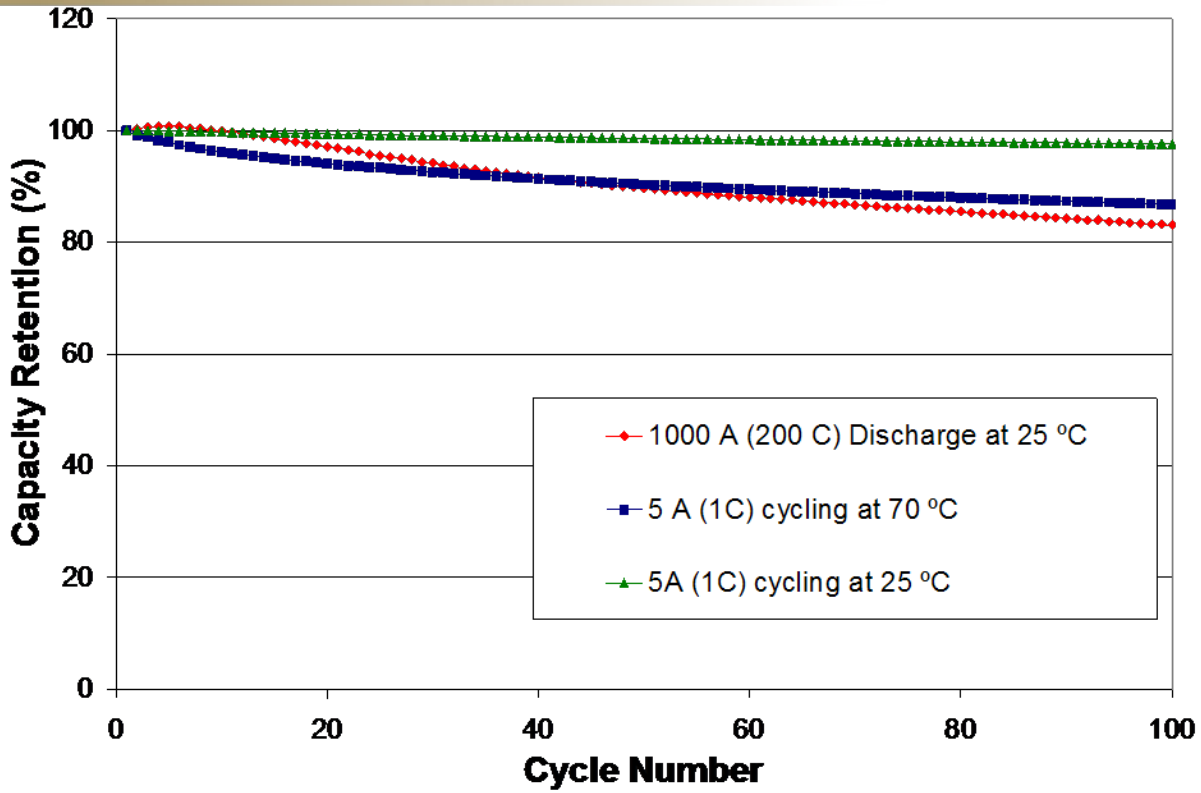


The temporary and permanent capacity loss of SAFT UHP cells after periods of 7 day storage at 70 ºC. Test is incomplete and on-going. 70ºC cycling data are also plotted for comparison.

Discussion:

The storage life of the cells at 70 ºC was evaluated. The results are shown in figure above. It seems the cell has high self-discharge rate. The capacity will be almost entirely lost after 7 days storage. Although about 80% of nominal capacity can be recovered by recharging, the fade rate is even higher than 70 ºC cycling. More data from different cell are needed for confirmation. This cell is a prototype and storage life will undoubtedly improve in a production cell.

Capacity retention under different cycling conditions



The capacity retention of SAFT UHP cells under different conditions.

Discussion: The capacity retention of the cells was evaluated under different cycling conditions.. The results suggest that high discharge rate degrades the cell capacity faster than does high temperature cycling. The reason might be the build-up of interfacial resistance caused by electrolyte decomposition. The core temperature of the cell during the 1000A discharge must be higher than 70 ºC.

Summary

- The SAFT UHP cells were shown to have high rate capability with about 80% of baseline capacity (5A, 1 C rate, room temperature) accessed at 1000 A (200C) rate of discharge.
- At low temperatures, -20 and -40 ºC, about 80% of the baseline capacity was obtained at a 500 A (100C) rate, however, the voltage was depressed with the voltage remaining below 3 V during the entire discharge.
- At -20 ºC, the voltage was depressed by up to 1 V relative to the room temperature discharge during the initial time of discharge and at -40º C, the voltage was depressed by up to 1.7 V during the initial time of discharge.
- Storage life testing at 70 ºC suggests a high rate of self-discharge for this *prototype* cell. A *production* cell will most likely have a good storage life.
- Cycling at different conditions suggests that high rate cycling degrades the cell faster than high temperature cycling. This suggests significant self-heating occurs at the high rates of discharge.
- Pulse discharge testing using a capacitive load showed that at an output voltage of 2 V a pulsed current of 8750 A may be achieved.