SAFT's Pouch Product and Capability

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Abstract:
Saft has developed Li-ion technology for space, defense and commercial applications, offering high energy cells and high power cells based on customers' requirements. While a number of our standard products are in cylindrical format, Saft has also successfully integrated pouch cells into our product line. Over the past five years our pouch proficiencies have expanded in terms of custom size factor availability and performance. Saft can design, build, and deliver Li-ion pouch cells for a broad range of high power to high energy applications. The high power cells are used for Formula 1 car racing applications and are being considered for laser weapons applications, while the high energy cells are suitable for the Navy, E-type racing(i.e., fully electric cars)and more applications. In parallel, novel Li-ion chemistries have been developed to improve cell safety. For example, lithium titanium oxide (LTO) and lithium manganese iron phosphate (LMFP) have been extensively investigated in pouch cell format and tested under abuse conditions. Extremely safe cell chemistries, such as all solid-state batteries in pouch cell format, are under development. Saft's vision is to provide electrochemical solutions and custom-made pouch cell manufacturing capabilities to meet our customers' needs.

Keywords: Pouch Cell; High Power; High Energy; Safety, Saft

Introduction
Saft has been manufacturing Li-ion batteries for 30 years and is a world leader in providing Li-ion systems for demanding applications in commercial, defense and space markets. Our products have evolved to match the requirements of the market, focusing on high performance over a wide temperature range, long life, high quality and reliability, and rugged systems that can operate in uncontrolled and abusive environments. Saft continues to improve current Li-ion batteries and develop next-generation energy storage devices. Here we highlight Saft's developments in pouch cell design and manufacturing for both high power and high energy applications. Saft works with customers for low- and high-volume needs.

Diverse Form Factor Capability
Pouch cells weigh less and offer more flexibility in cell size and shape than cylindrical cells. Saft has been developing pouch cell designs for the last few years with the first prototype cell in 2012 and commercial cell in 2014. We have experience manufacturing pouch cells ranging from 2Ah all the way to 50Ah and in sizes from 13cm ×8cm to 21cm × 28cm. Cell length, width and thickness can be tailored to each customer's request and designed to best fit the application. In addition, the chemistry (active materials and electrolyte) and power/energy can be tailored to meet most needs. Figure 1 shows the range of power and energy cells available.

Type	Specific Energy		Specific Power	
High Energy	250 Wh/kg		2 kW/kg	
Power	120 Wh/kg		6 kW/kg	
Very High Power	80 Wh/kg		20 kW/kg	
Ultra High Power	52 Wh/kg		40 kW/kg	

Figure 1: Range of power/energy available from Saft cells.

High Power and High Temperature Pouch Cell
High power pouch cells are one of Saft's specialty products. These "power blocks" are optimized to power hybrid vehicles, directed-energy weapons, and specialty race cars. Saft continues to lead in high power cell applications through research & development and advanced manufacturing.

Our high temperature pouch cells can operate at 100°C and at extremely high rates (200C). Table 1 presents the specific energy and power performance capabilities of Saft's high power cells in cylindrical and pouch cell formats. Both cell formats have extremely high power-to-energy (P/E) ratios, over 500. Figure 2 shows capacity retention for Saft pouch cells discharged at different C-rates at room temperature (25°C). Figure 3 compares cell performance for several rate capabilities at three temperatures. The cell can discharge at a 50C rate and retain more than 85% capacity at 25°C. The cell capacity retention after 50C rate discharge increases to 91% at 45°C and to 96% at 60°C.

	Performance of Saft Cell	
	Saft 3.5Ah cylindrical cell	Saft 2Ah pouch cell
Wh/Kg	78	100
W/Kg	46,260	50,250

Table 1: Specific energy and power of high power cylindrical and pouch cells.

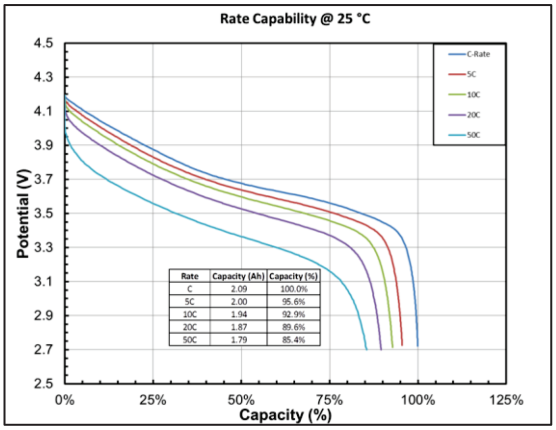

Figure 2: Rate capability of Saft pouch cell at room temperature, and cell size is roughly 100cm x 100cm x 2 mm.

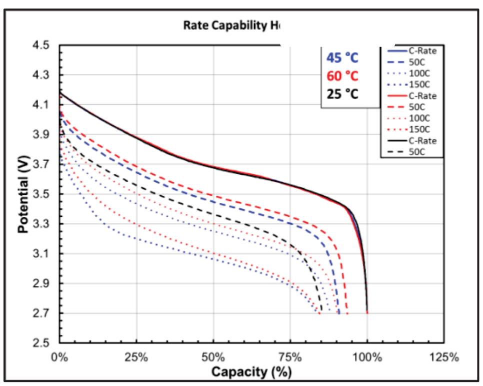

Figure 3: Rate capability of Saft pouch cell at 25°C, 45°C and 60°C. Cell size is roughly 100cm × 100cm × 2 mm.

In addition, Saft has been investigating LTO chemistry in a pouch format. Performance features such as high power, improved safety and fast charging capability are achievable with LTO chemistry leading to an attractive battery solution for directed energy weapon systems [1-3]. In parallel the pouch cell design improves packaging efficiency and reduces weight. LTO electrode was coupled with Nickel Manganese Cobalt (NMC) cathode material and the cells were tested using two different procedures, current ramping and constant current, as depicted in Figure 4. For the current ramping procedure, both charge and discharge pulses spike to 250A and ramp to 0A over 3 seconds, with 20 seconds of rest between each pulse. Pulses are 7% depth of discharge (DOD) with an average rate of 83C. For the constant current procedure, discharges are 150A for 10 seconds and charges are 50A for 30 seconds with no rest between pulses. Pulses are 28% DOD, 100C and 33.3C, respectively.

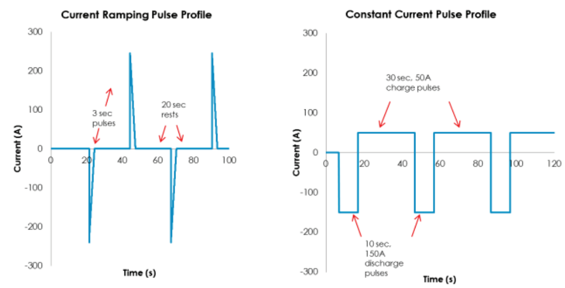

Figure 4: Current profiles over time during testing for direct energy weapons applications.

Preliminary results show that the current ramping test causes negligible capacity fading (<1%) and impedance growth (<3%) after 10,000 cycles. Constant current pulse testing, which utilizes four times higher DOD ranges, result in 14% capacity fading and 22% impedance growth after 5,000 cycles. The cell temperature stays below 30°C for both pulsing tests, which is 10°C-15°C lower than the results for Saft's VL5U cells (based on graphite anode).

High Energy Pouch Cell

Saft has developed very high energy pouch cells with excellent cycling performance. This work optimizes cell design in terms of electrode porosity, separator selection, and positive material screening. Compared to Panasonic's 3.4Ah 18650 Saft's pouch shows higher volumetric energy and significantly better cycling at 45°C, as shown in Figure 6.

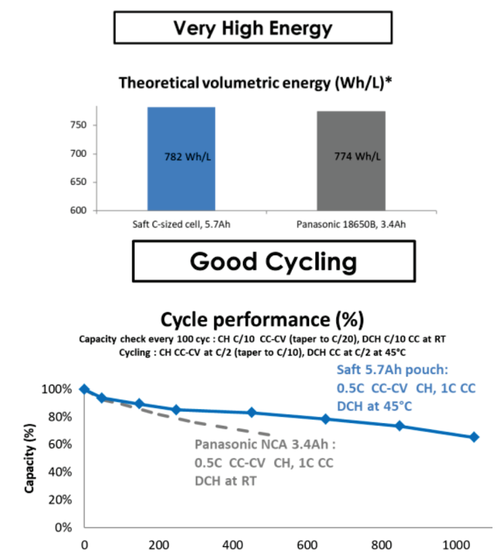

Figure 6: Saft's high energy pouch cell vs. Panasonic 18650B. The volumetric energy comparison excludes mechanical parts.

Furthermore Saft's high energy cells show high rate capability at room temperature, as depicted in Figure 7, with 68% capacity retention at a 2C rate. On top of having good charge / discharge performance the high energy pouch cells developed by Saft experience lower temperature increases during high rate discharges compared to an 18650 cell. This is possible because of the higher heat dissipation surface in the pouch cell format (Figure 8) [4].

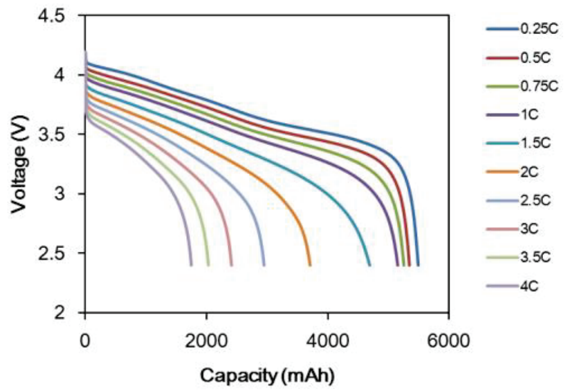

Figure 7: Rate capability testing at 25°C of Saft's high energy pouch cell.

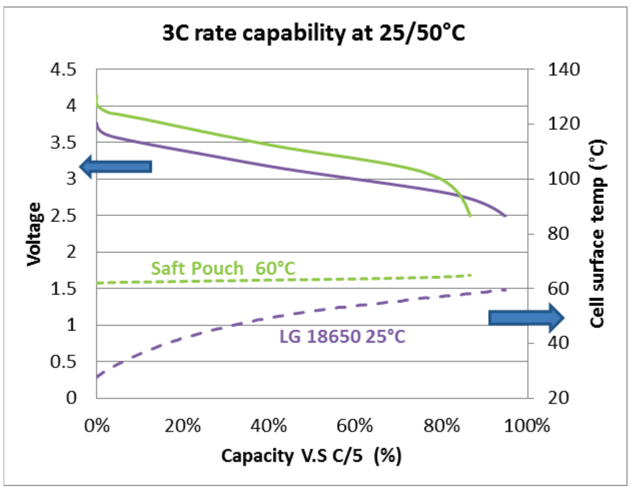

Figure 8: Temperature increase during rate capability testing.

Within the high energy market Saft developed a 4.9Ah (240Ah/kg) prototype high energy-high power pouch cell and compared the cell's performance to Sony's VTC6 18650 (240Ah/kg) commercially available cells. Based on hybrid pulse-power capability (HPPC) testing results, Saft's newly developed high energy-high power pouch cells deliver better power density at 25°C and 60°C compared to Sony's VTC6 18650 cell, as shown in Figure 9. HPPC consists of 10C discharge pulses for 10s at different states of charge (SOCs).

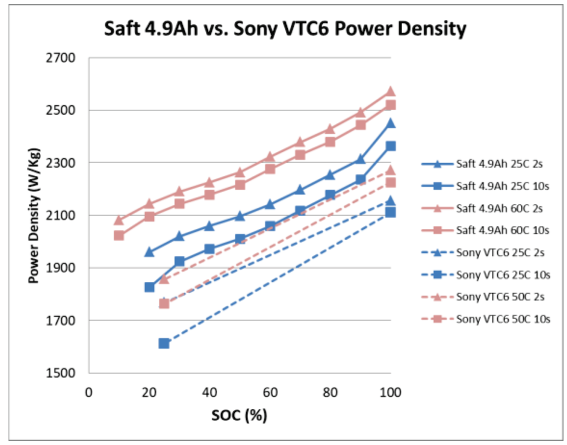

Figure 9: HPPC testing at 25°C (blue lines) and 60°C (pink lines) comparing Saft's 4.9Ah pouch cell (continuous lines) and Sony's 3Ah VTC6 18650 cell (dotted lines).

Compared to Samsung's 30Q 3Ah 18650 (240Ah/kg) cell, Saft's 4.9Ah cell shows better performance during electric race cycling tests. The Saft pouch does not heat up significantly (max. temp. 45°C vs. 67°C for the 30Q 18650 pouch) and shows much less impedance. See Figure 10.

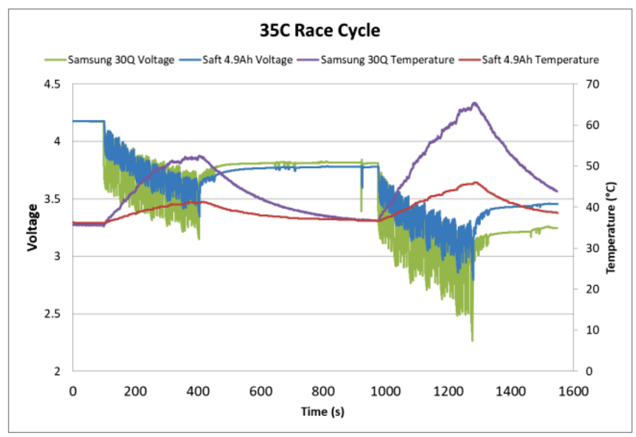

Figure 10: Results of Race Cycle testing that compare Saft's 4.9Ah (22-2) prototype pouch cell voltage and temperature performance to Sony's 3Ah 30Q pouch.

Pouch Cell Safety

Saft has also developed a high power Lithium Manganese Oxide (LMO)/LTO cell within the US Advanced Battery Consortium / US Department of Energy (USABC/DOE) funded 12V start-stop program. The chemistry was selected for its power capability and safety features. Saft built and tested 46Ah pouch cells using the LMO/LTO electrochemistry. These prototype cells showed extremely promising cold crank performance, passing three pulses at -30°C. One cell underwent nail penetration abuse testing. Some venting occurred from the nail penetration test, however no fire or disassembly took place, as shown in Figure 11.

Figure 11: Nail penetration test pictures of 46Ah LMO/LTO cell. Cell was charged to 2.7V @ 46A tapered to 2.3A and placed into Nail Penetration fixture.

The LTO pouch cell design is very safe and is ideal for applications that require fast charging, low weight, better packaging efficiency and safety. In order to offer safer pouch cells to the high energy and high power markets, Saft is also developing LMFP chemistry in pouch cell format. LMFP offers the same safety as Lithium Iron Phosphate (LFP) and the energy density of NMC because of its olivine crystal structure and high operating voltage, around 4V [5]. This chemistry can deliver more than 20% higher energy compared to Saft's current Super Lithium Iron Phosphate (SLFP) technology. Previous overcharge and nail penetration tests with hard case prismatic and cylindrical cell format cells did not show thermal runaway. Abuse testing is planned for the pouch cell configuration.

Solid-State Batteries for Ultra High Energy

"All solid-state" batteries could revolutionize energy storage systems in terms of safety, energy density, and bipolar design. Saft is actively investigating and determining how and when to implement the technology. We have identified the most promising technology and are partnering, through joint development and strategic investments, to develop prototypes for performance and safety testing. We expect to have a prototype cell based on all solid-state batteries in 2018. Saft's knowledge in pouch cell manufacturing and our full-service cell / battery production facilities are assets that lower startup costs and risks associated with solid-state battery prototyping and evaluation of solid-state technology scale up prospects.

Conclusions

Saft has been developing lithium ion pouch cells since early 2012. Pouch cell manufacturing capability offers a range of different form size factors, tailored to meet each customers' program-specific needs. Saft's pouch cells are competitive in the high power markets, with graphite chemistry delivering 200C rates at 100°C and LTO delivering 83C at room temperature. Within the high energy domain, Saft's pouch cells offer better cycling capability than Panasonic's 18650 with better heat dissipation. Beyond Lithium-ion batteries, Saft is investigating all solid-state cell technology. Given the extent of Saft's knowledge in processing pouch cells and our capability to transform concepts into prototypes, and then test performance and safety in house, we are a cost-effective source for evaluating solid-state technology efficacy and product scale up manufacturability.

References

1. Colbow, K. M., Dahn, J. R., and Haering, R. R., "Structure and Electrochemistry of the Spinel Oxides LiTi2O4 and Li4/3Ti5/3O4," *J. Power Sources*, vol. 26, pp. 397–402, 1989.
2. Ferg, E., Gummow, R. J., Kock, A. de, and Thackeray, M. M., "Spinel Anodes for Lithium-Ion Batteries," *J. Electrochem. Soc.* vol. 141(11), pp. L147, 1994.
3. Amine, K., Belharouak, I., Chen, Z., Tran, T., Yumoto, H., Ota, N., Myung, S. T., and Sun, Y. K., "Nanostructured Anode Material for High-Power Battery System in Electric Vehicles," *Adv. Mater.*, vol. 22 (28), pp. 3052–3057, 2010.
4. Kim Yeow, Ho Teng, Marina Thelliez, Eugene Tan, "3D Thermal Analysis of Li-ion Battery Cells with various Geometries and Cooling Conditions using abaqus", AVL Powertrain Engineering
5. Martha, S.K., Grinblat, J., Haik, O., Zinigrad, E., Drezen, T., Miners, J.H., Exnar, I., Kay, A., Markovsky, B., and Aurbach, D., "LiMn0.8Fe0.2PO4: An Advanced Cathode Material for Rechargeable Lithium Batteries," *Angew. Chem. Int. Ed.*, vol. 48, pp. 8559-8563, 2009.