



Large Size Lithium Ion Cells Based on LiFePO_4 Cathode Material

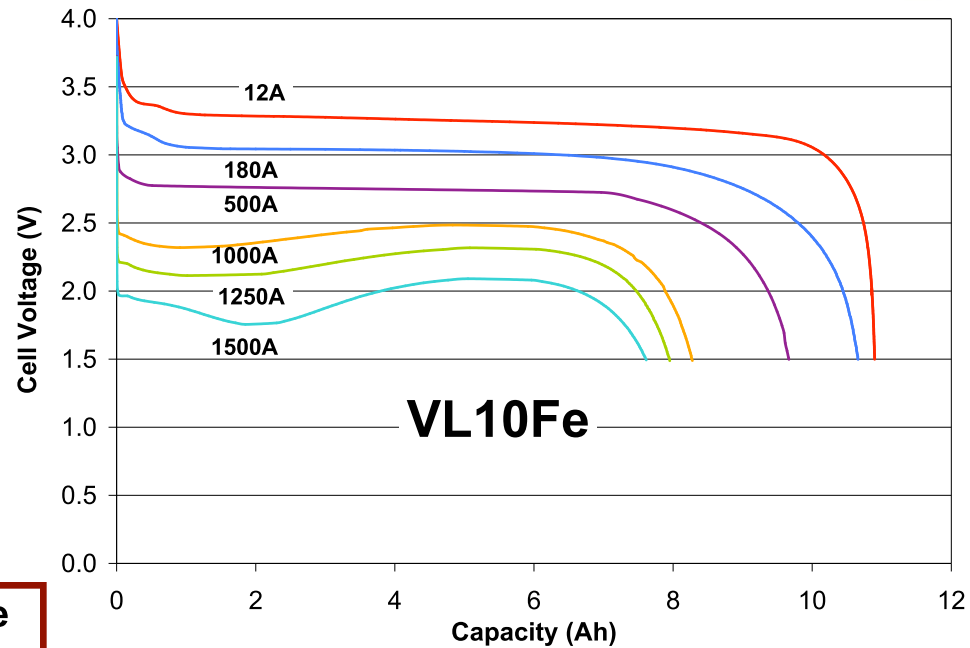
Bridget Deveney, Kamen Nechev, Teymur Guseynov
SAFT America Inc.

Richard Jow, Kang Xu
Army Research Laboratory

LiFePO₄ Development

- **Iron Phosphate is an emerging Cathode material for Li-ion. Advantages in abuse tolerance**
Cost in energy density and power
 - Phostech is currently the only licensed supplier of the UT technology.
- **In 2005 Cockeysville initiated working on LiFePO₄ under a developmental program with Army research laboratory**
 - Research provided guidance and cathode materials based on at least 2 years of prior exploration of the technology
 - Cockeysville based the development effort on its high power electrode design expertise
- **Currently Cockeysville is continuing the LiFePO₄ development under MANTECH (US Army) funded effort. Two cell sizes (VLV and VLP) have been built and are in testing.**
- **As requested by the customer a module containing Very High Power cell with the LiFePO₄ cathode was delivered in December 2006 and subjected to a bullet test.**

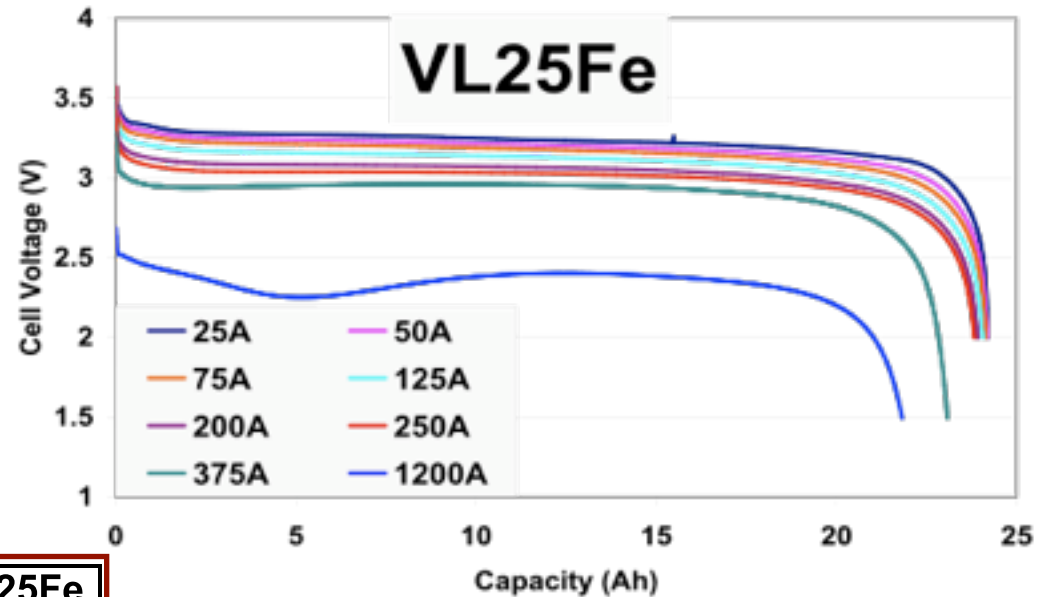
VL10Fe Cell Based On LiFePO_4 Cathode



- Cell optimized for Very High Power applications
- SAFT is using licensed supplier for the Iron Phosphate cathode material

Cell	VL10Fe
Cathode	LiFePO_4
Nominal Voltage (V)	3.3
Nominal Capacity at C rate (Ah)	10
Maximum Discharge Current at 25°C (A)	
Continuous	1500
2s Pulse	1700
200ms pulse	2200
Specific Energy (Wh/kg)	54
Energy Density (Wh/L)	128
Specific Power at 25°C 100% SOC (W/kg)	
Continuous	4375
2s Pulse	5000
200ms Pulse	6400

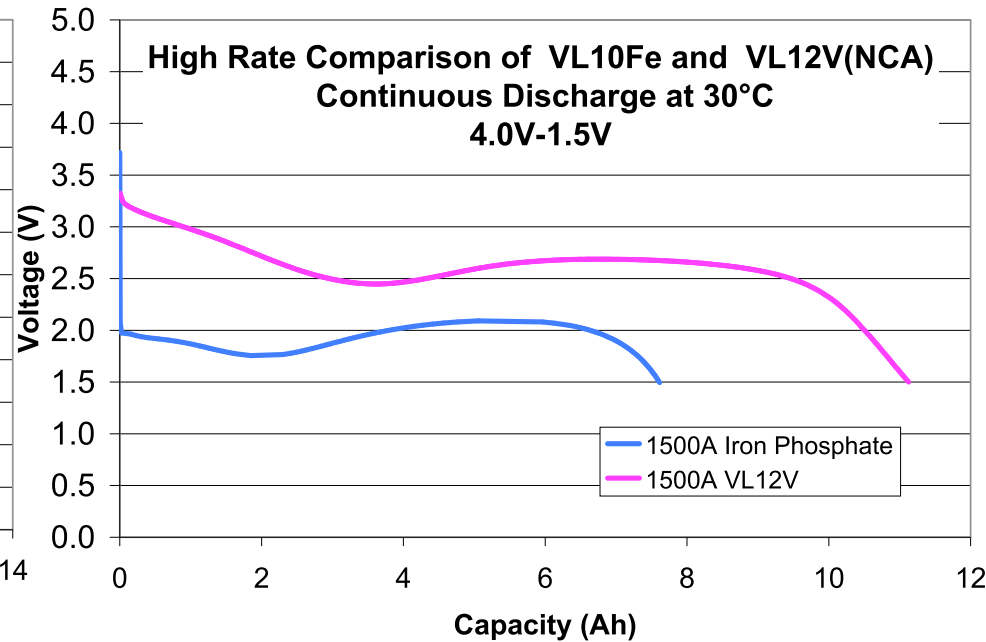
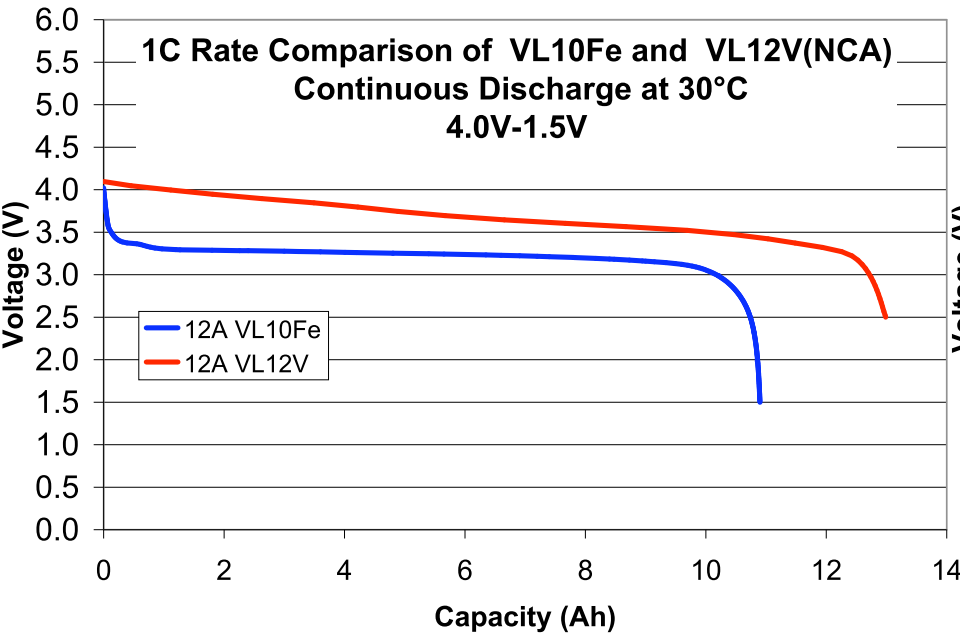
VL25Fe Cell Based On LiFePO_4 Cathode



Cell	VL25Fe
Cathode	LiFePO_4
Nominal Voltage (V)	3.3
Nominal Capacity at C rate (Ah)	25
Maximum Discharge Current at 25°C (A)	
Continuous	1200
2s Pulse	2200
200ms pulse	2300
Specific Energy (Wh/kg)	89
Energy Density (Wh/L)	189
Specific Power at 25°C 100% SOC (W/kg)	
Continuous	3150
2s Pulse	4400
200ms Pulse	4600

- Cell optimized for Medium Power/Medium Energy applications
- SAFT is using licensed supplier for the Iron Phosphate cathode material

LiFePO₄ Development: Capacity and Energy



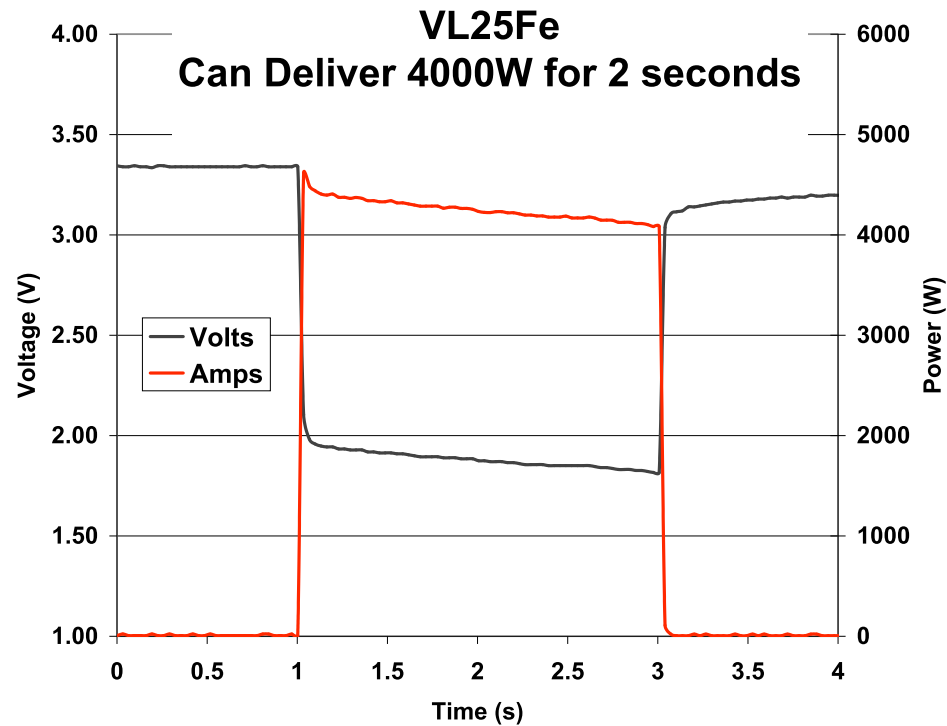
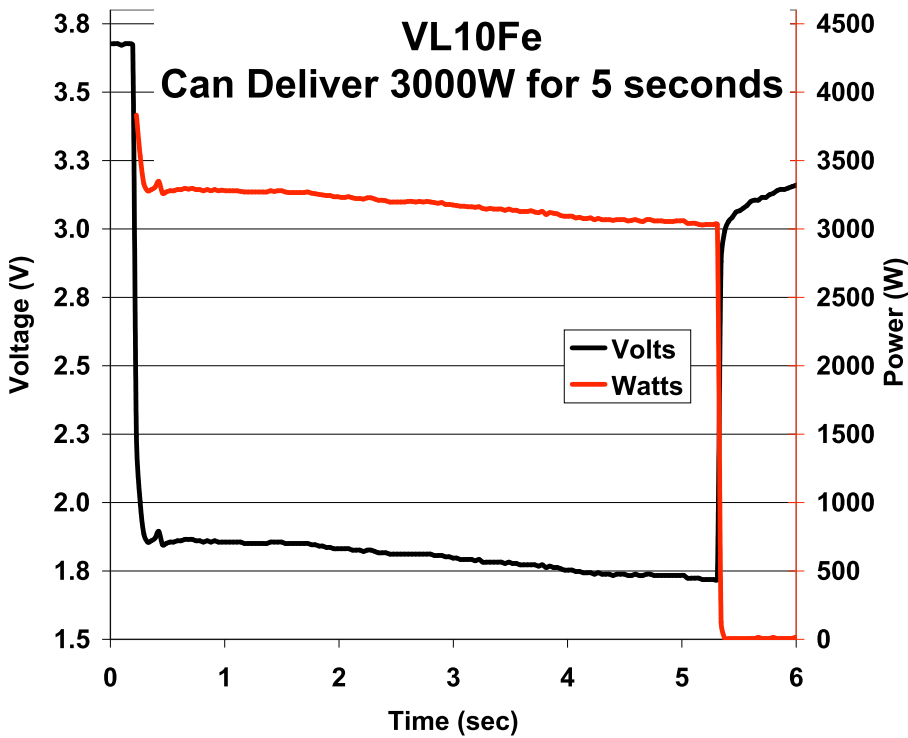
Total Energy Delivered Compared to a standard VL12V (NCA cathode):

● **75% of VL12V Energy at 12Amps**

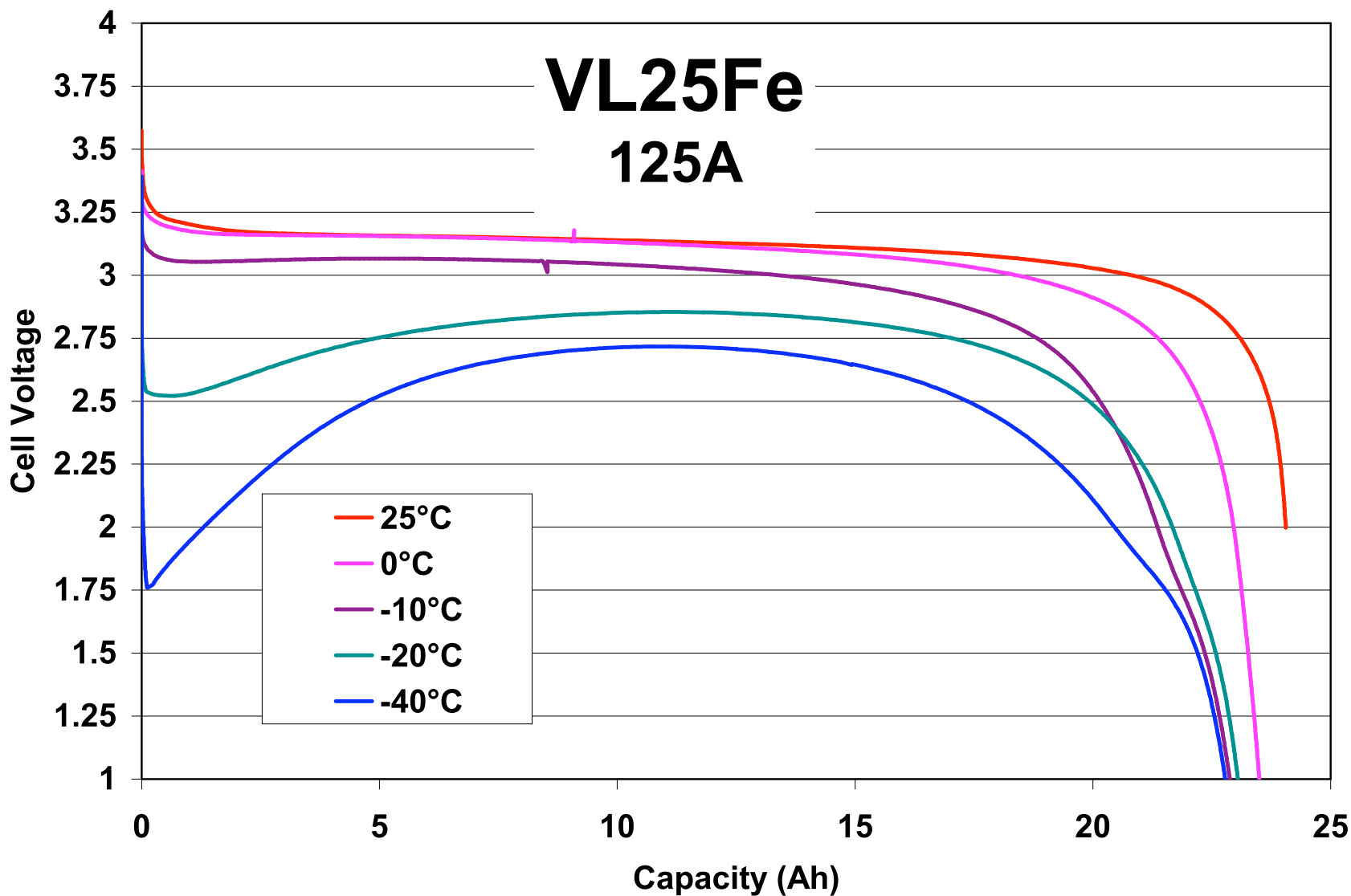
50% of the VL12V Energy at 1500Amps

LiFePO₄ Development: Power

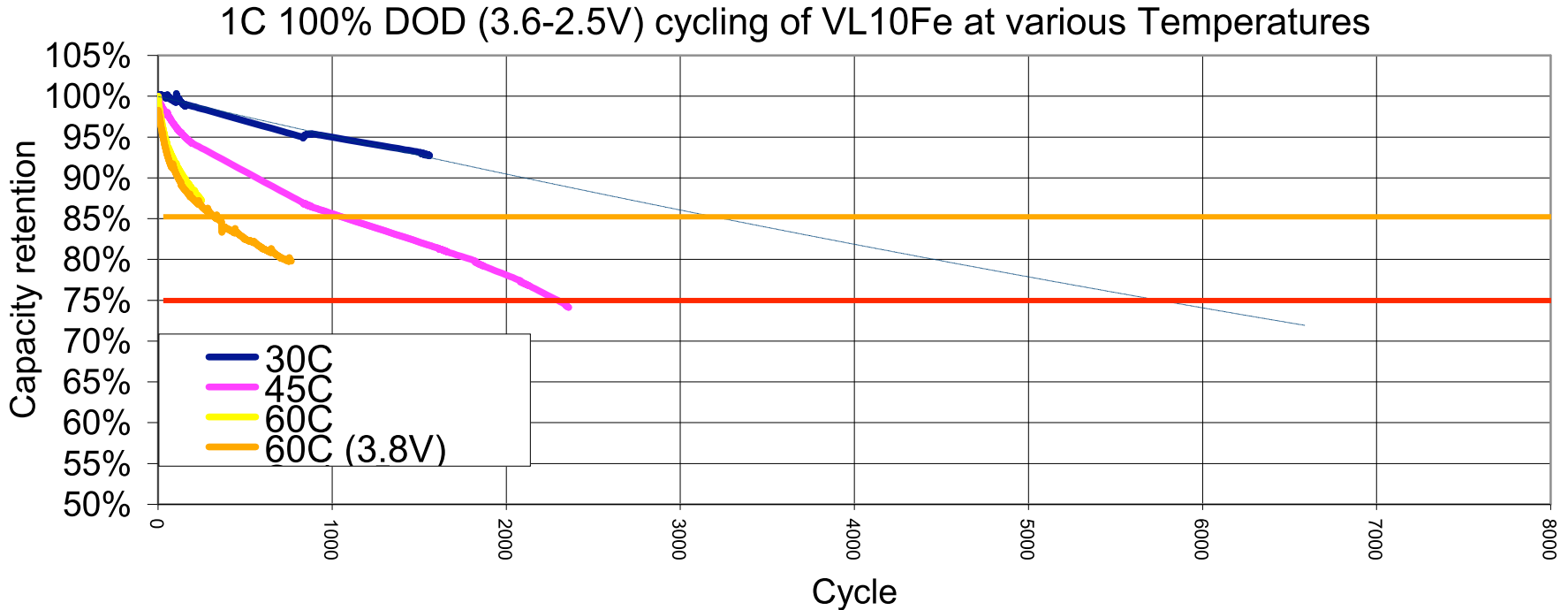
VL10Fe 5400W/kg ➡ **SECOND MOST POWERFUL CELL**
AFTER SAFT VL-V CHEMISTRY



LiFePO₄ Development: Low Temperature



LiFePO₄ Development: Life



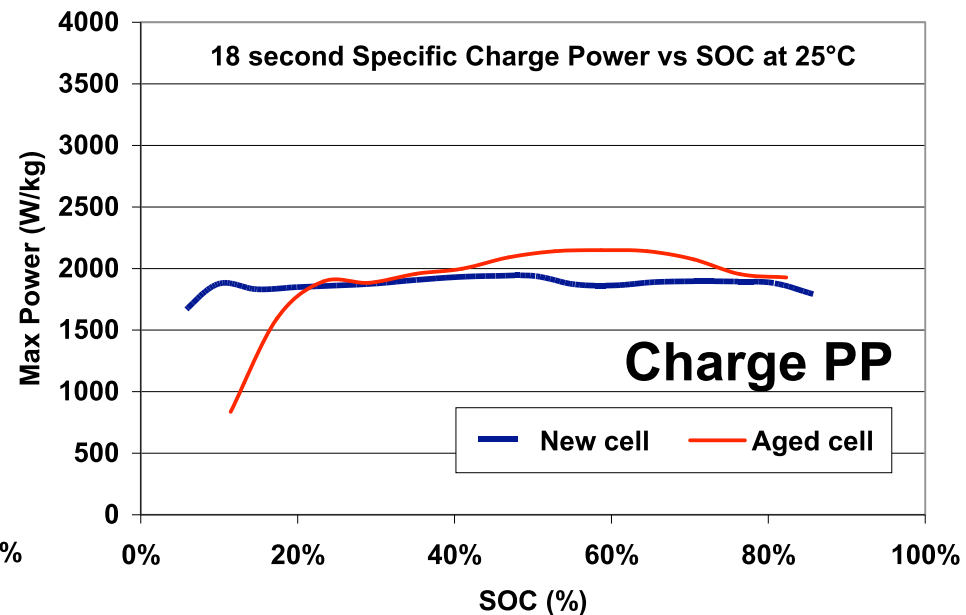
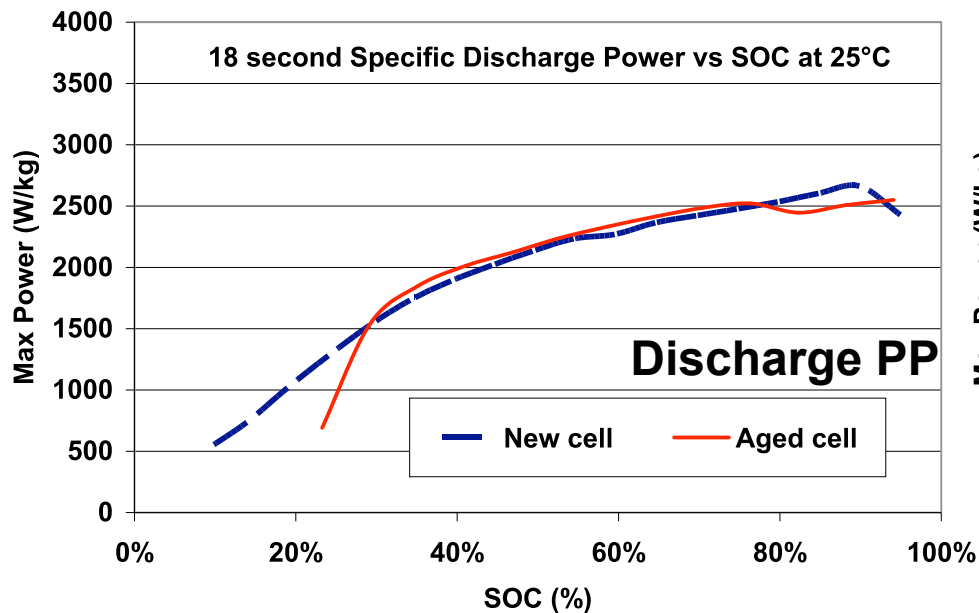
● Cycling of VL10Fe

- 30°C- projected 4400 cycles to 80% capacity, 5700 cycles to 75%
- 45°C-1800 cycles to 80% capacity, 2300 cycles to 75%
- 60°C- 700 cycles to 80% capacity, projected 1150 cycles to 75%

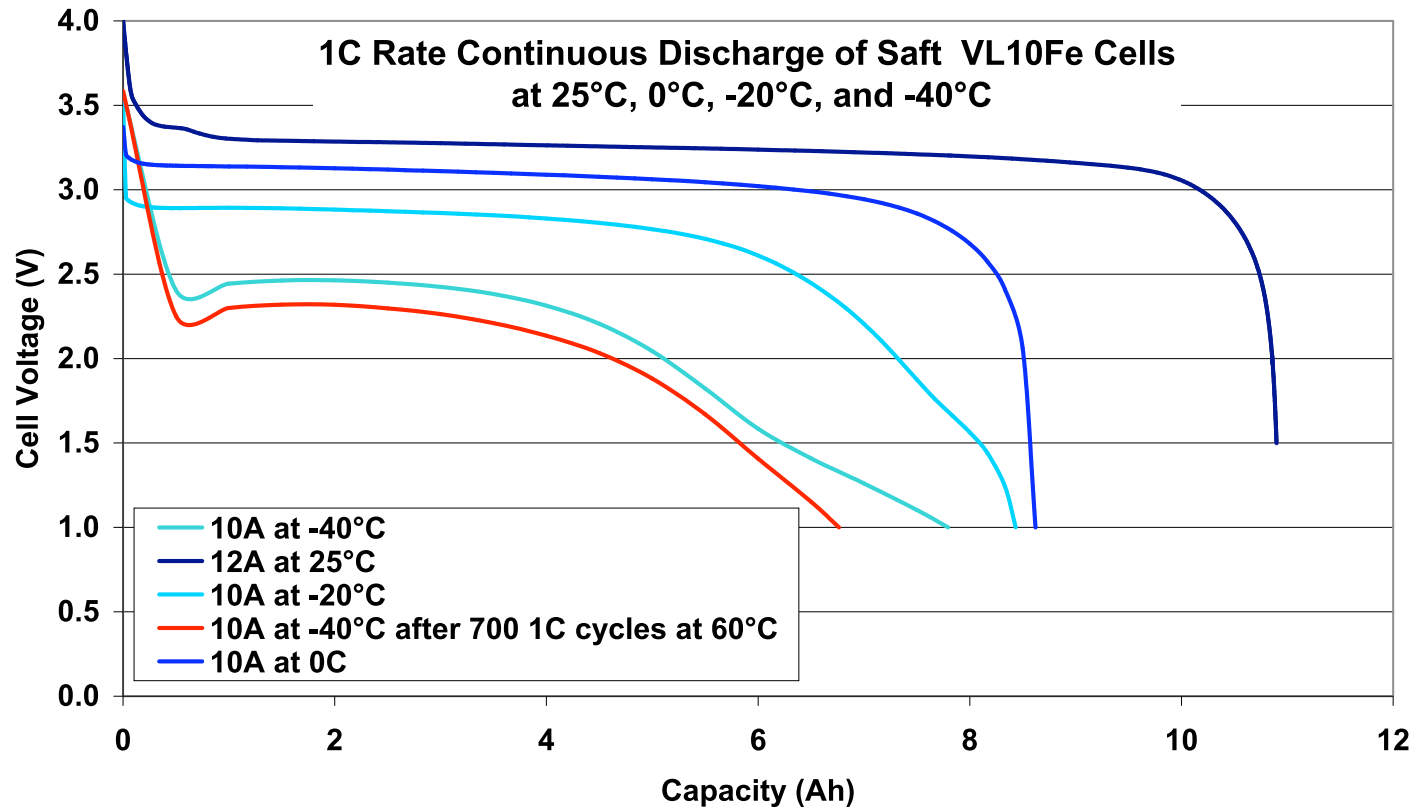
LiFePO₄ Development: Life

● Pulse Power retention with ageing

- 2500 W/kg 18sec Discharge PP @ (70-100)% SOC & 25°C
- 1900 W/kg 18sec Charge PP @ (20-80)% SOC & 25°C
- Nearly no power loss after 700 full cycles @ 1C rate & 60°C



LiFePO₄ Development: Life

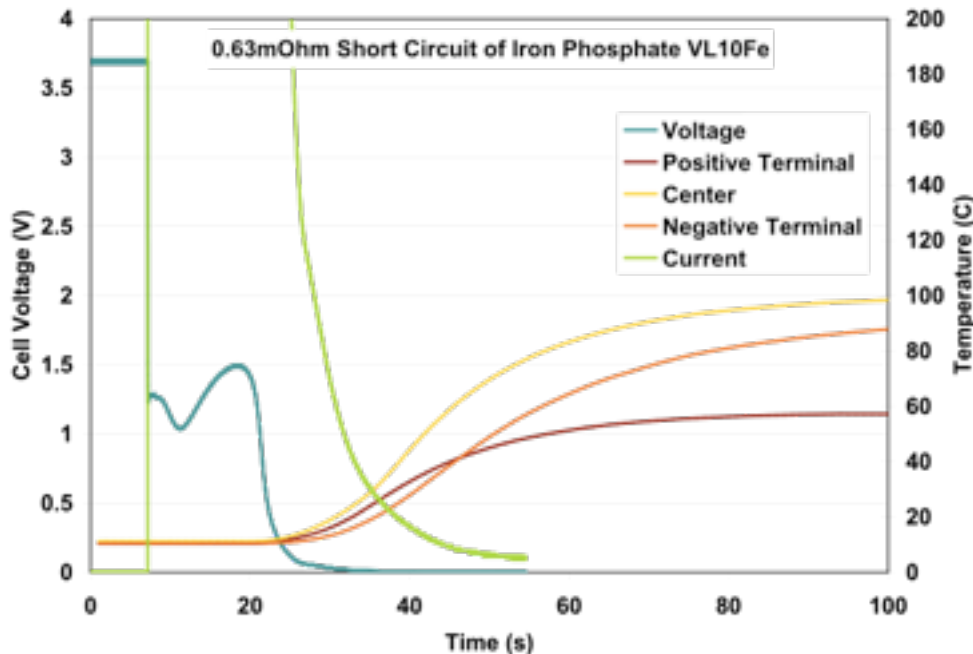


- Very little loss of low temperature power after cycling at high temperature

LiFePO₄ Development: Safety

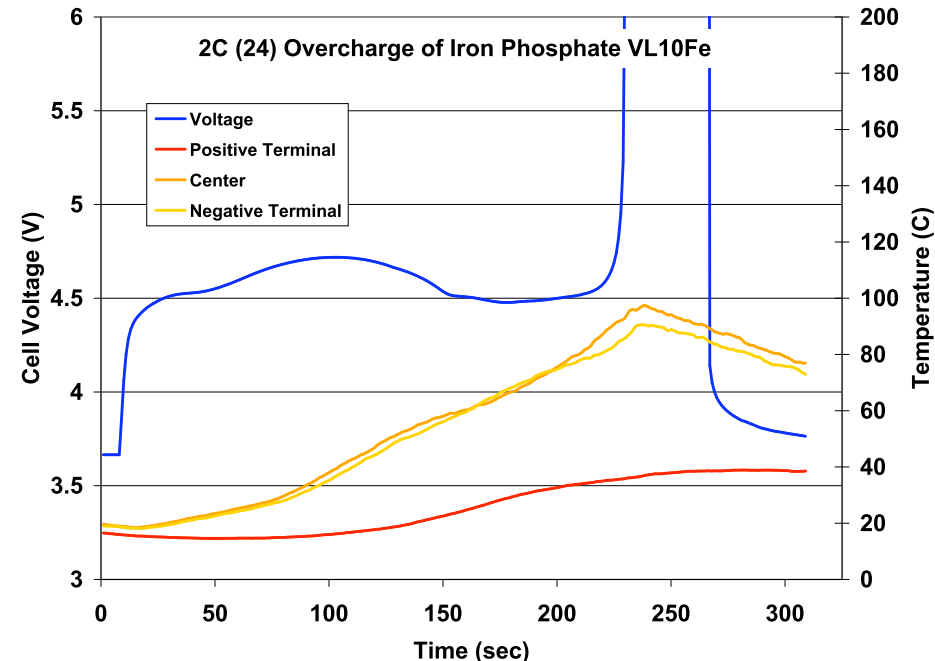
0.63 mOhm Short Circuit

- No event
- T < 100°C



2C (24A) Overcharge

- Vented with no smoke & no fire
- T < 100°C

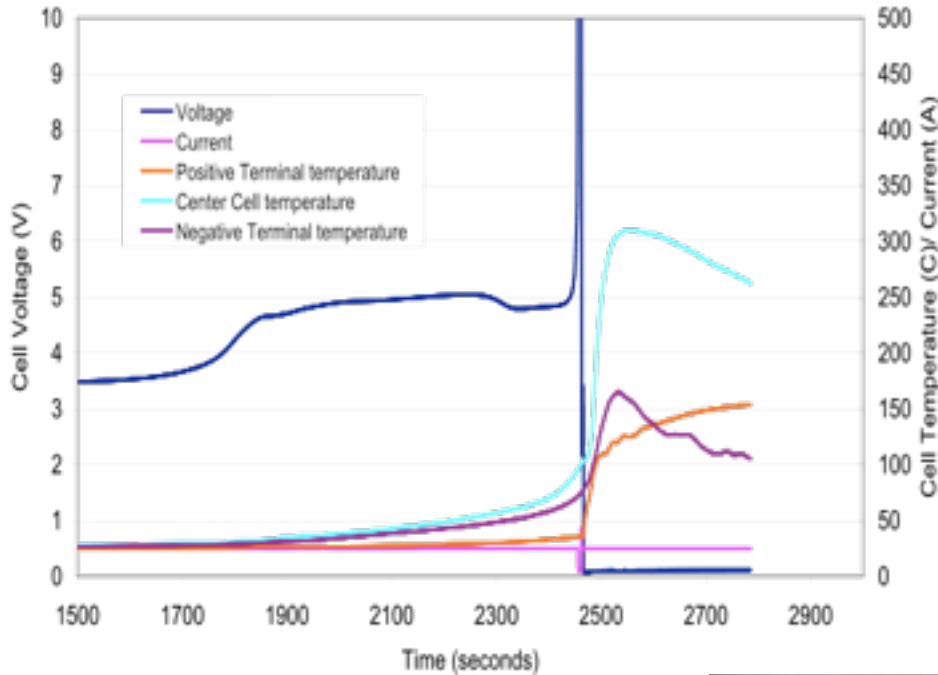


LiFePO₄ cathode: enhanced safety

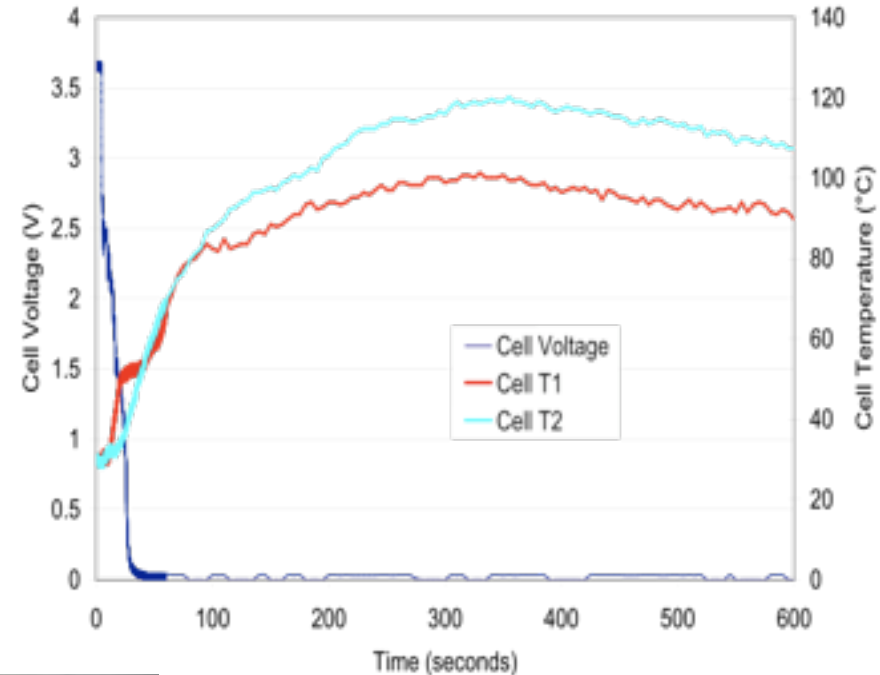
less lithium excess + reduced oxygen evolution → less heat generation
+ lower energy density → lower temperature rise

LiFePO₄ Development: Abuse Testing

1C (25A) Overcharge of VL34P Iron Phosphate Cell (constrained terminals)



Slow Nail of LiFePO₄ VL34P



- **25A/24V Overcharge**

- Smoke, No flame
- Max temp 310°C



- **Slow Nail at 100% SOC**

- Smoke, No Flame
- Max Temp 120°C

- **VL25Fe cells abuse testing: No fire with slow nail or overcharge**

LiFePO₄ Development : Conclusion

- **Saft cells are the highest power Iron Phosphate cells available today**
- **In all this work SAFT is using material from the only licensed by UT supplier of LiFePO₄ – Phostech/Süd-Chemie.**
- **Saft Iron Phosphate is suitable for power applications that require an added level of redundant safety**
- **The requirements of the application must be considered as there are tradeoffs in:**
 - Power & energy
 - Low temperature performance
 - Less robust at high temperature for storage
 - Weight and Volume
- **The overall requirements of the application must be taken into account to design the ideal total solution**

Acknowledgements

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- *Saft would also like to thank Dr. Richard Jow of ARL for his continued guidance and support and insight into new materials and performance improvements.*