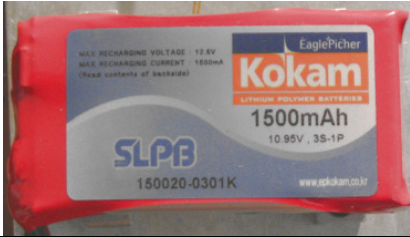


Technical Note		Cycle Life of LiPo Packs		N°: TN06004			
<b>Device under test</b>		Kokam 1500mAh 3S1P, SLPB 150020-301K		Weight 136g Dimension 77x38x25 mm			
							
<b>Test method</b> <b>Test conditions</b>		a) <b>Life test</b> according to PA06002e-v3; $I_{av} = 9A$ (6C), $I_P = 30A$ (20C), $V_{CUToff} = 8.7V$ (2.9V/cell). 170 cycles "short peaks", then 30 cycles "intensive" and finally 68 cycles "stop & go". No forced air cooling, $T_a = 17^\circ C$ .  b) <b>Intermediate measures:</b> Discharges with DC current 18A (12C), $V_{CUToff} = 8.7V$ (2.9V/cell)					
<b>Results</b>							
Initially a substantial mismatch (>170mV) of the cell voltages was found. The cells had to be balanced for the first 20 cycles. After this "forming" period balancing was practically not required any more.							
1) Cycle life test 268 cycles (Fig. 6, 7) The discharged capacity/energy remained almost constant during the whole test. For the first 200cycles the cell degradation was very small, during the last 68cycles a more distinct degeneration of $V_m$ and $R_i$ was observed. Extrapolated values: $V_m -100mV$ and $R_i + 2m\Omega$ per 100cycles (values for the whole battery) (Fig.7).							
2) DC discharge (Fig.1, 2)							
	12C capacity Ah		12C energy Wh		12C discharge voltage $V_m$		$\Delta T$ K
before life test	1.36	100%	13.72	100%	10.09	100%	44.3
after 25 cycles	1.42	104%	14.24	104%	10.03	99%	46.9
after 73 cycles	1.42	104%	14.23	104%	10.02	99%	46.9
after 104 cycles	1.43	105%	14.37	105%	10.05	100%	48.4
after 170 cycles	1.44	106%	14.42	105%	10.01	99%	48.8
after 200 cycles	1.44	106%	14.48	106%	10.06	100%	47.0
after 267 cycles	1.44	106%	14.45	105%	10.03	99%	49.3
After the "forming" period the capacity/energy remained constant, while $\Delta T$ increased by about 10%.							
3) Voltage symmetry during 12C discharge (Fig. 3, 4 and 5) Initially, under load cell #3 was significant weaker. After "forming", a good match of the cell performance was achieved (Fig. 4). At the end of the test cell #3 turned out to be the most robust!							
<b>Conclusions &amp; Comments</b>							
<ul style="list-style-type: none"> <li>▪ The need for a "forming" period seems to be typical for Kokam 20C cells and requires special attention.</li> <li>▪ These cells have excellent cycling capabilities, the life expectancy is beyond 250 cycles if the following rules are used:                             <ul style="list-style-type: none"> <li>- use a balancer at least for the first 20 cycles.</li> <li>- don't deep cycle the battery. By discharging the last few %Ah, a substantial part of the cycle life is sacrificed. In my test the no load cell voltage was not less than 3.4V/cell after discharge.</li> <li>- store the cells under proper conditions only (3.6 – 3.7V/cell).</li> </ul> </li> <li>▪ <math>R_i</math> is low but has a relative high temperature coefficient. Minimum <math>R_i</math> is around 12m<math>\Omega</math> per cell.</li> <li>▪ The discharge voltage is only moderate and averages 3.35V/cell under the tested conditions.</li> </ul>							
<b>Date</b> 2006-06-05		<b>Vis.</b> jb		© slowflyer.ch		<b>No. of pages</b> 6	

12C intermediate test results

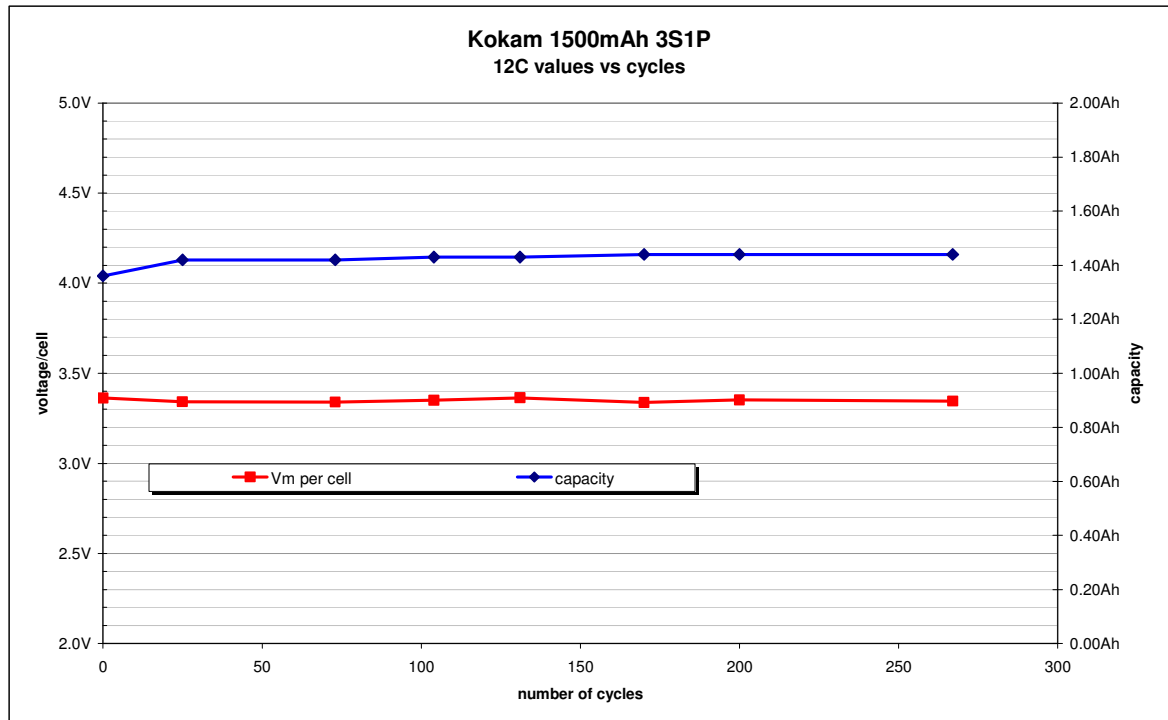


Fig. 1 developing of 12C-capacity and average discharge voltage vs the number of discharge cycles

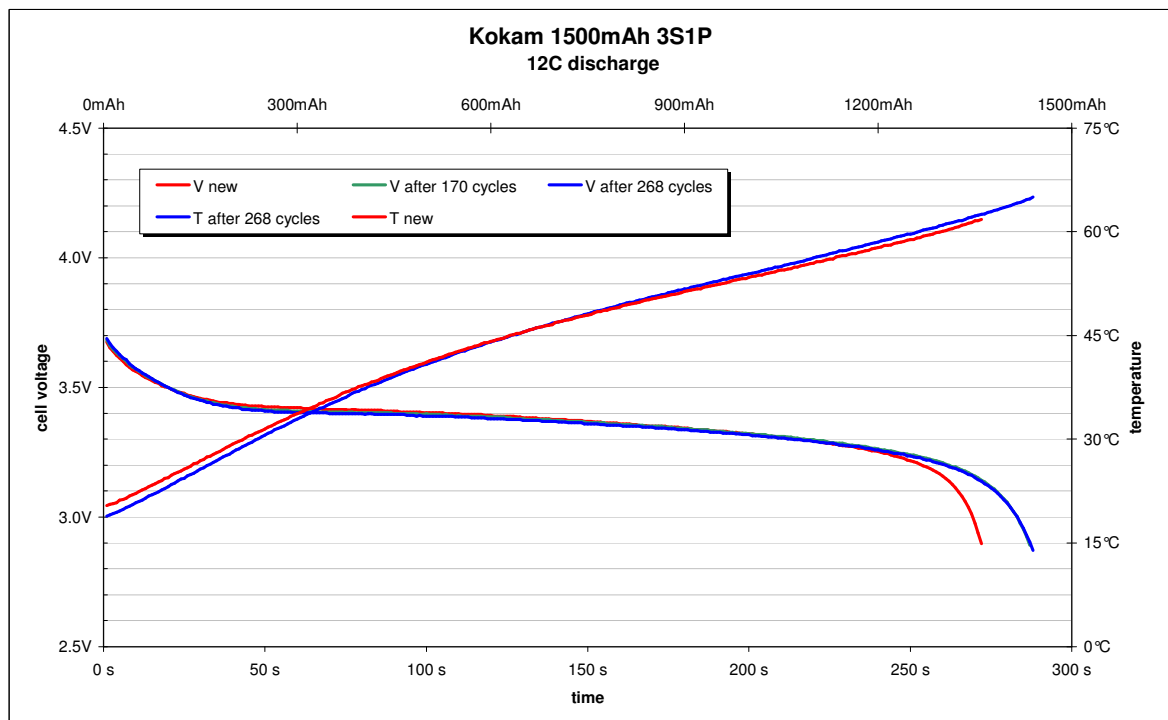


Fig 2. comparison of discharge curves @12C. The V-curves after 170 and 268 cycles are almost identical

Cell voltages

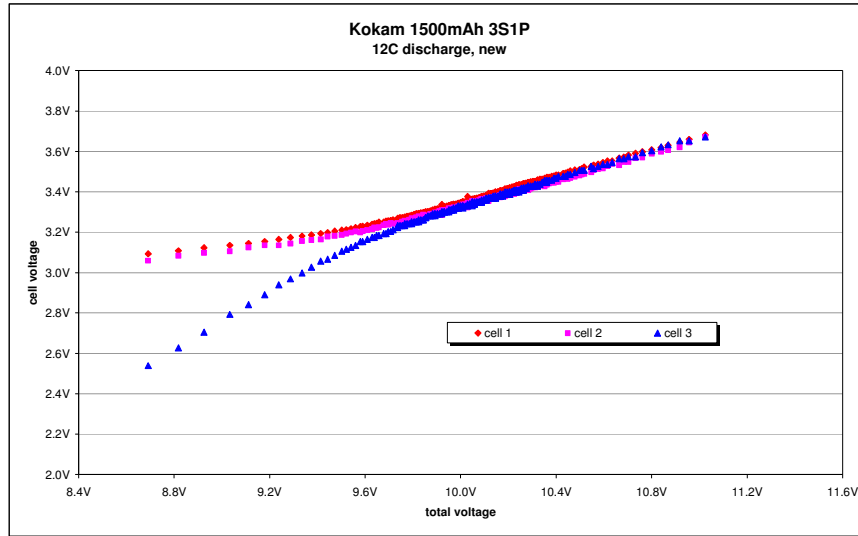


Fig. 3 Individual cell voltages during 12C discharge, initial state

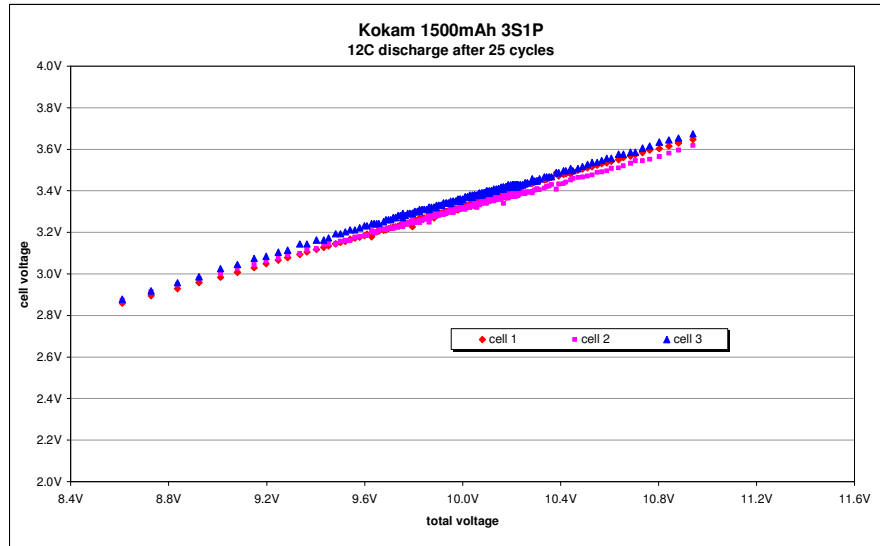


Fig. 4 Individual cell voltages after 25 cycles

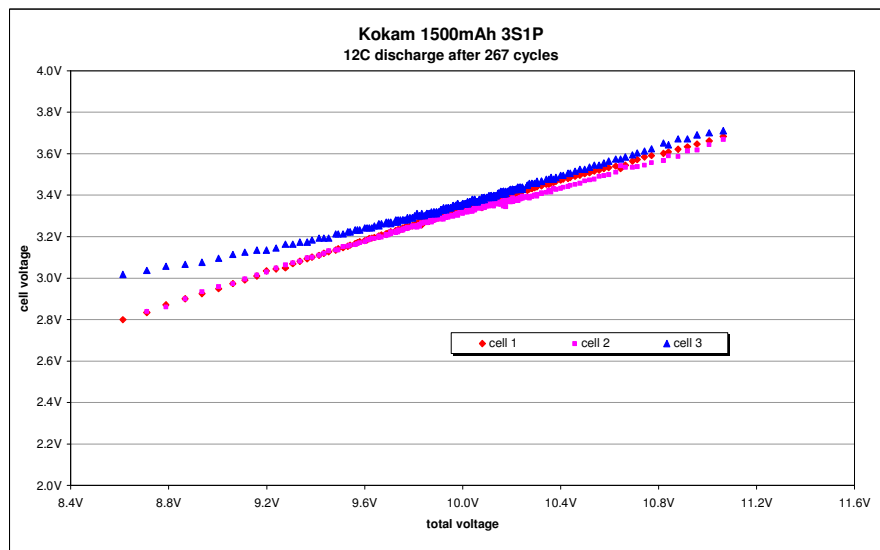


Fig. 5 Individual cell voltages during 12C discharge after life testing (268 cycles)

## Life test with different load profiles

The following load profiles were applied (refer to PA06002e-v3 for details):

Part1: 170 cycles "short peaks"

Part2: 30 cycles "intensive"

Part3: 68 cycles "stop & go"

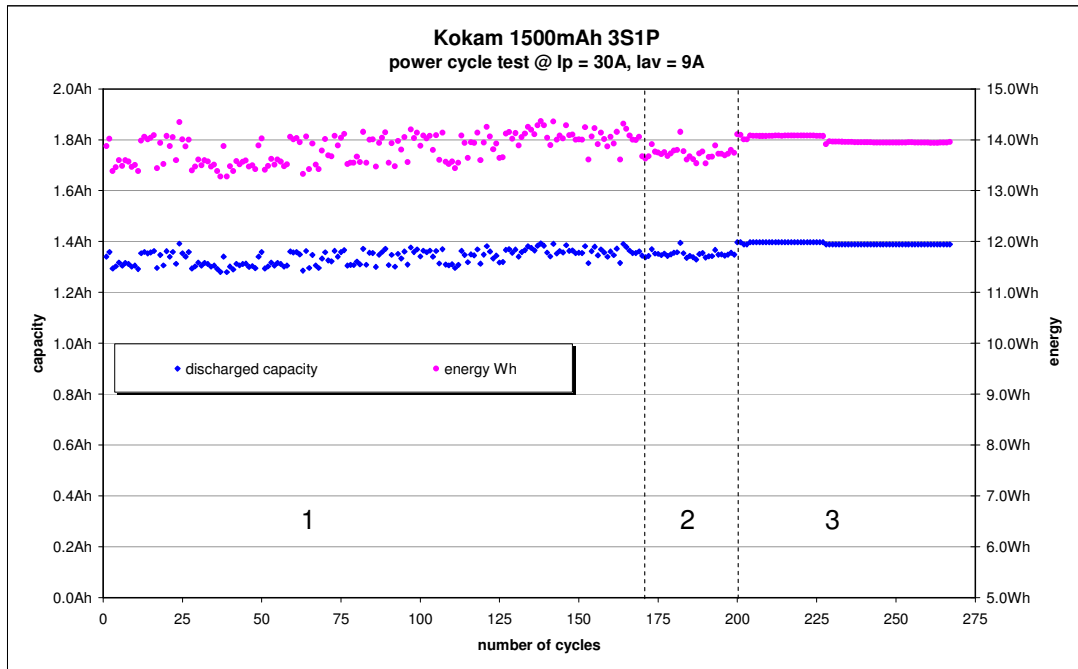


Fig. 6 developing of discharged capacity and energy during life testing  
Remark: The discharged capacity in the life test is not identical to the capacity of the battery.

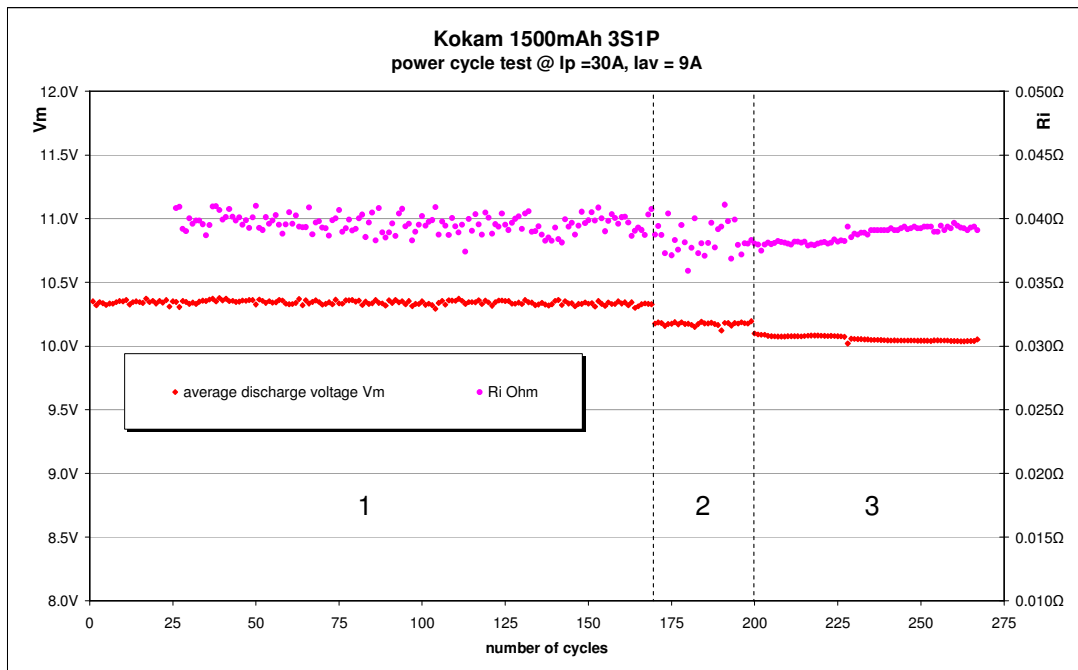


Fig. 7 developing of  $R_i$  and average discharge voltage during life testing.

While  $R_i$  remained stable during part1,  $V_m$  slightly decreased (50mV after 170cycles). During part3 a more distinct degeneration of  $V_m$  and  $R_i$  can be observed.

Internal Resistance

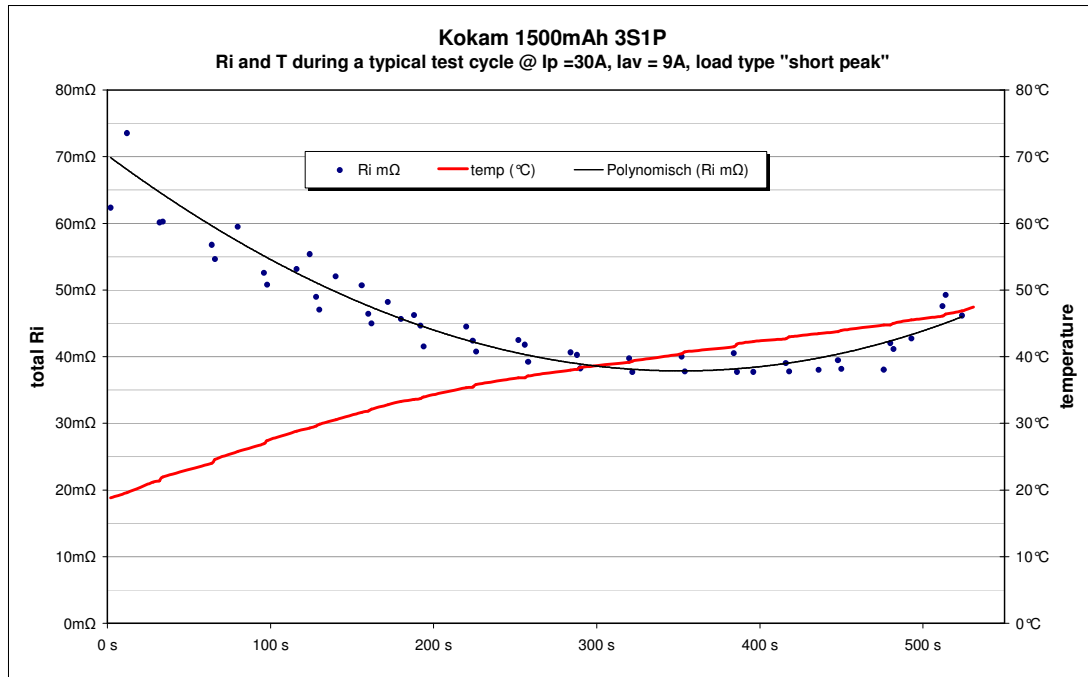


Fig. 8 temperature and Ri during a typical discharge cycle in life test (load profile "short peaks")

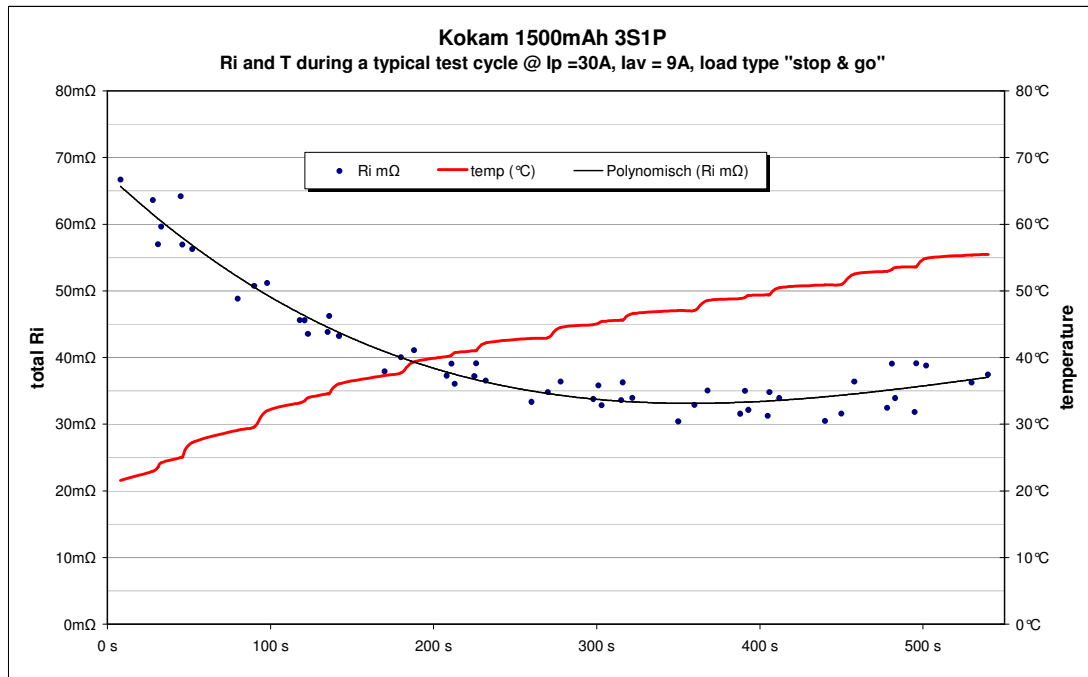


Fig. 9 the same as Fig. 7 but with another load profile (stop&go)

A complete charge/discharge cycle

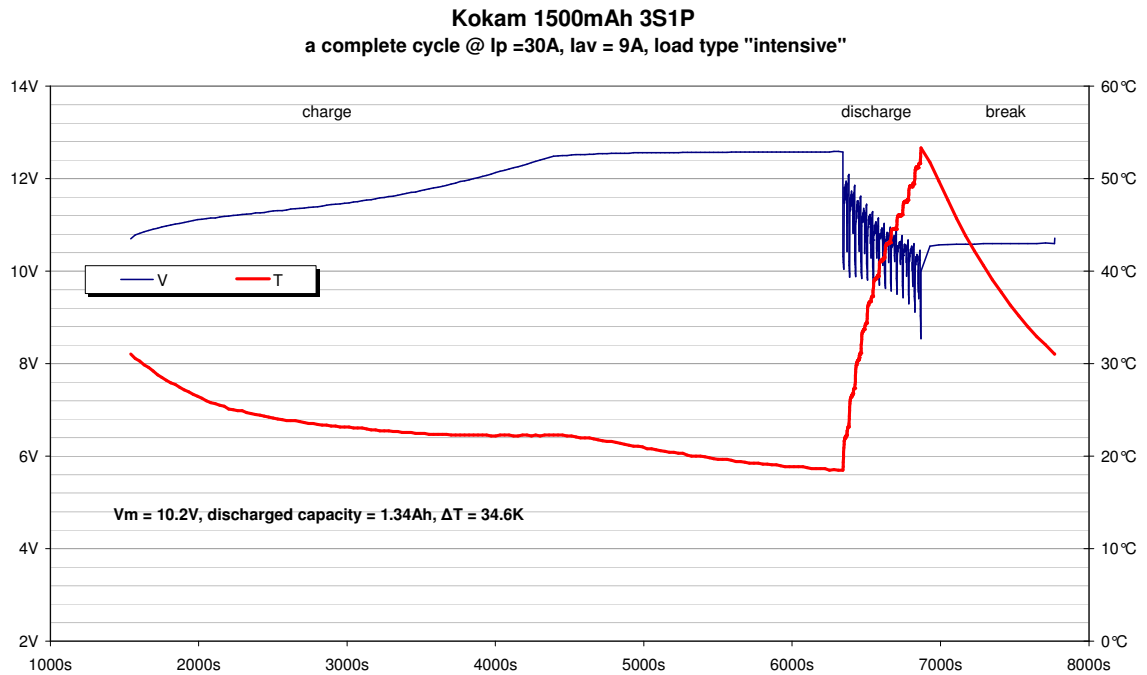


Fig. 10 a full cycle during life test

Just because I was curious, here a discharge cycle with 40A, done after life test.

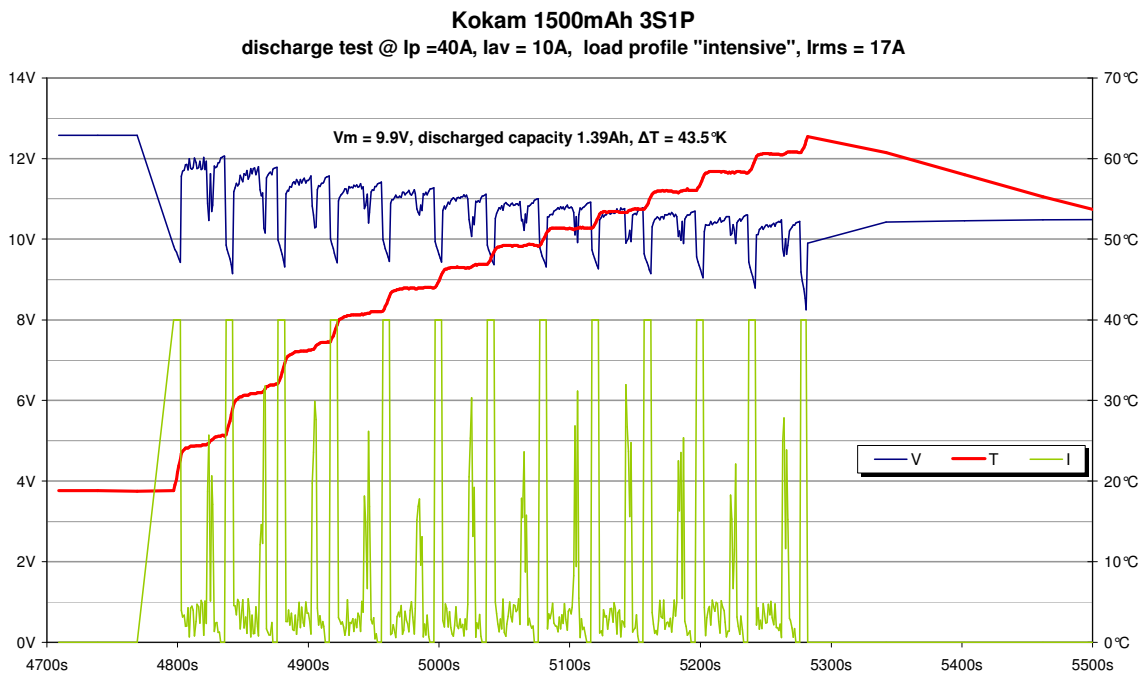


Fig. 11 a special discharge test with 40A peaks.  $V_{cutoff}$  was set to 8.4V