Technical Note *Cycle Life of LiPo Packs* N°: **TN06005-1**

Device under test	**EVO20 3300mAh 3S1P "new formulation"**  Weight 288g Dimension 150x48x20 mm
Test method ***Test conditions***	a) **Life test** according to PA06002e-v3 section 3.2; I_{av} = 19.8A (6C), I_P = 66A (20C). First 36 cycles with V_{CUToff} = 2.9V/cell, then V_{CUToff} = 3.1V/cell No forced air cooling, Ta = 17°C. b) **Intermediate measures:** Discharge with DC current 39.6A (12C), initially V_{Cutoff} was set to 2.9V/cell, after 36 cycles increased to 3.1V/cell

Results

1) Cycle life test 154 cycles (Fig. 6, 7)

	useful capacity [Ah]	Vm [V/cell]	used energy [Wh]	Ri [mΩ/cell]	temperature rise ΔT [K]
New *)	3.18	3.57	34.0	4.2	41.6
50 cycles	2.97	3.57	31.77	4.3	42.1
100 cycles	2.95	3.57	31.59	4.5	42.9
150 cycles	2.85	3.55	30.33	4.7	44.0

*) With the initial setting for Vcutoff (2.9V/cell) 96% of the rated capacity was discharged but this was too severe. The useful capacity decreased almost 7% during the first 36 cycles. With Vcutoff = 3.1V/cell there was almost no degradation observed for the next 50 cycles.
Practical energy density: 113Wh/kg (initial value).

2) DC discharge (Fig.1, 2)

	12C capacity Ah		12C discharge voltage Vm/cell		Vcutoff/cell	ΔT K
before life test	3.21	100%	3.53	100%	2.9	53.8
after 20 cycles	3.05	95%	3.51	99%	2.9	53.4
after 36 cycles	2.98	93%	3.51	99%	2.9	53.4
after 37 cycles	2.92	91%	3.51	99%	3.1	52.7
after 60 cycles	2.93	91%	3.52	100%	3.1	52.9
after 86 cycles	2.92	91%	3.52	100%	3.1	53.1
after 130 cycles	2.82	88%	3.52	100%	3.1	53.4
after 154 cycles	2.72	85%	3.50	99%	3.1	53.6

3) Cell matching (Fig.3, 4, 5 & 10, 11, 12)
The cell voltages remained within a 30mV band during charging although no balancer was used for the whole test. In the beginning a capacity mismatch of 1.7% was observed which increased to 7% at the end of the test.

Conclusions & Comments

- With the high discharge voltage (3.57V/cell) in life test and the low Ri these cells are well suited for high peak load applications.
- Ri has a moderate temperature coefficient and the minimum is rather low with 4 to 4.5mΩ per cell.
- The discharge characteristics (voltage & temperature rise) are clearly better than those of the EVO 20 standard packs.
- A cycle life of more than 150 cycles can be expected if the discharge depth is ≤ 90% e.g. by setting Vcutoff properly (≥3.1V/cell). If in doubt, the open-circuit cell voltages should be measured right after the flight (within 3 minutes). The cell voltages need not to be completely equal but they should be at least 3.3V-3.4V or higher.
- The cell matching is acceptable but does not (yet) reach the high level of the EVO 20 standard packs (refer to Fig. 3 & 4 of TN6002 for comparison).
- For the sake of cycle life a voltage balancer is not necessarily required. However, there are other good reasons for its use.

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12C intermediate test results

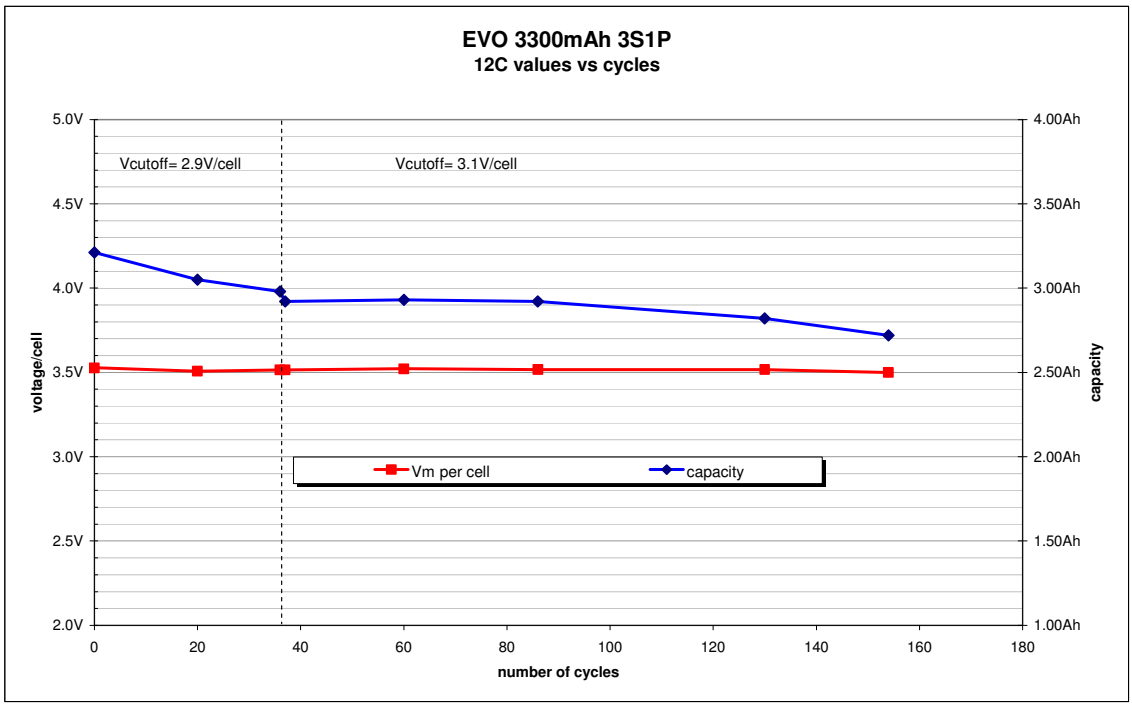

Fig. 1 developing of 12C-capacity and average discharge voltage vs the number of discharge cycles

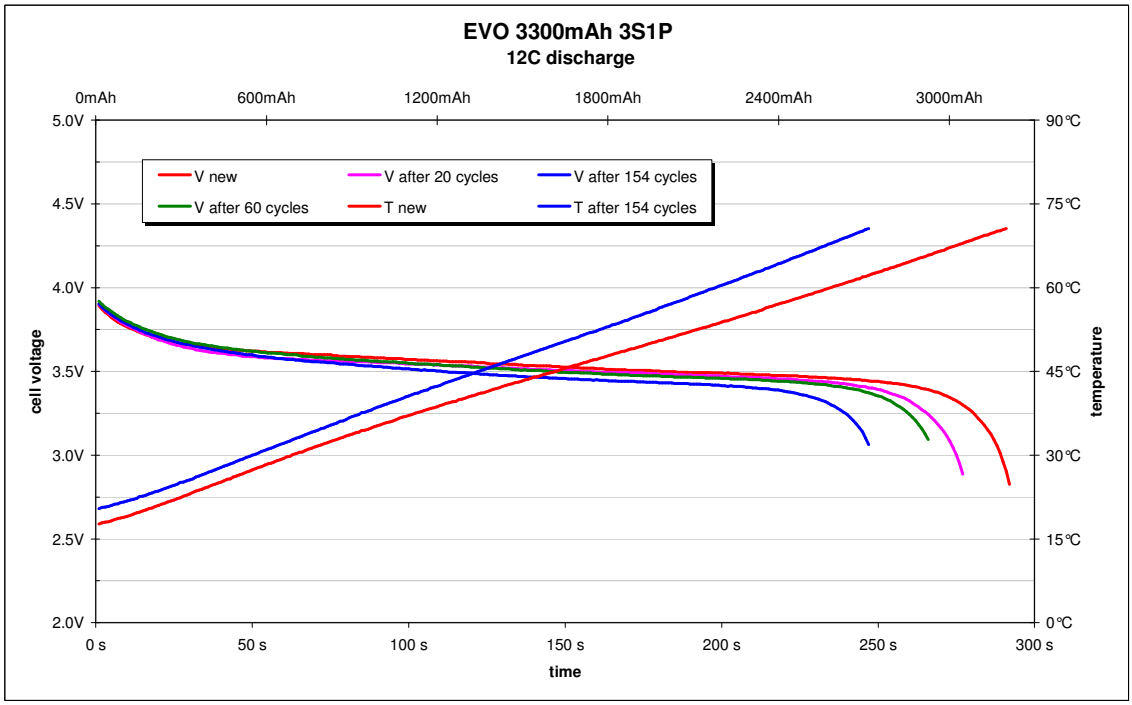

Fig 2. comparison of discharge curves @12C.

Cell voltages

Initially cell #2 had 1.7% less capacity than cell #1 and seemed to be the weakest. After 20 cycles the situation changed a bit but towards the end of the test cell #2 turned out to be clearly the weakest. The measured capacity mismatch was about 7% after the test.

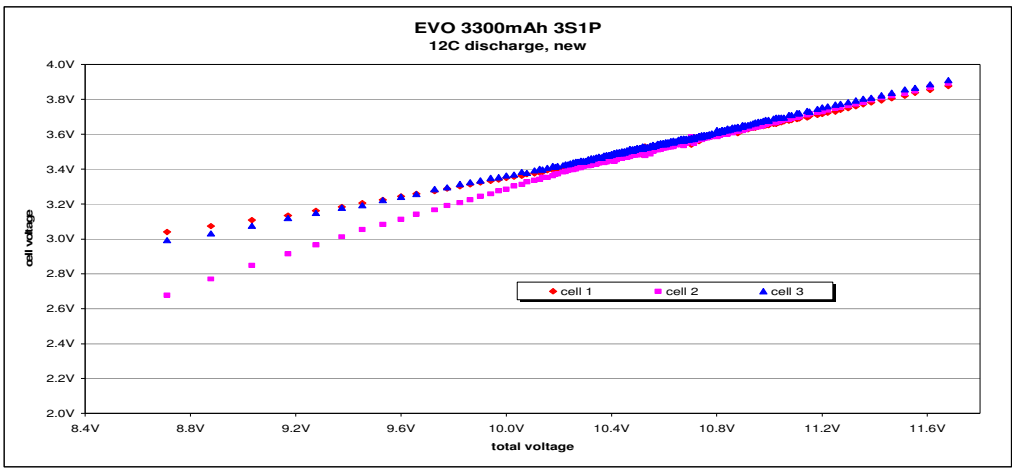

Fig. 3 Individual cell voltages during 12C discharge, initial state

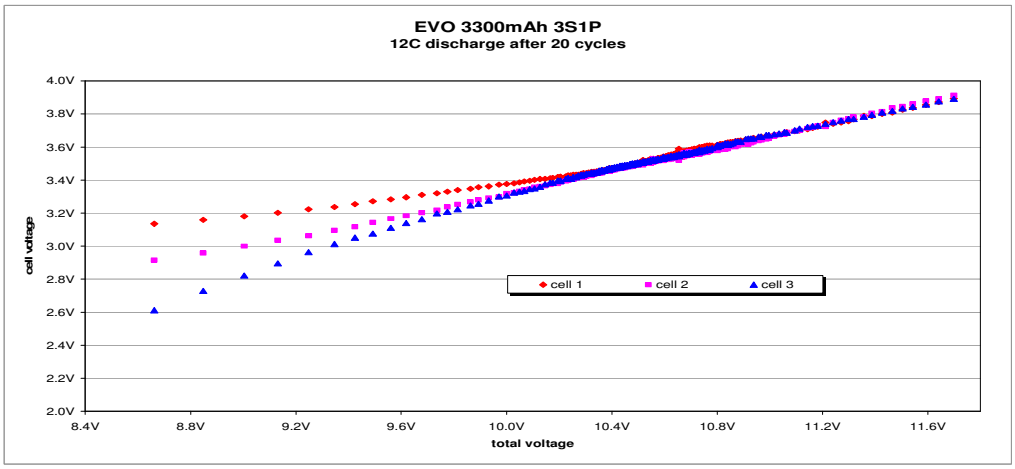

Fig. 4 cell voltages after 20 cycles of life test

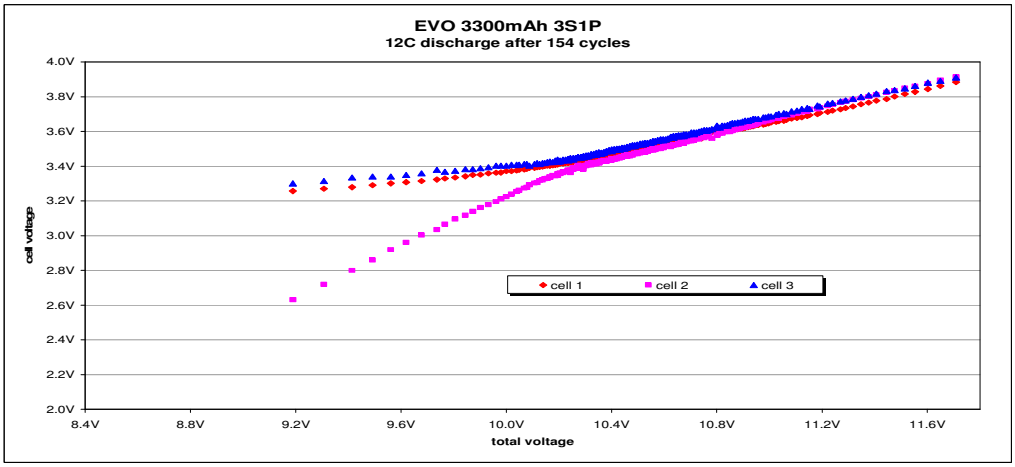

Fig. 5 Individual cell voltages after life test (154 cycles)

Life test with different Vcutoff settings

The load profile was the same over the whole life test (refer to PA06002e-v3 section 3.2 for details) just the cut-off voltage was changed after 36 cycles.

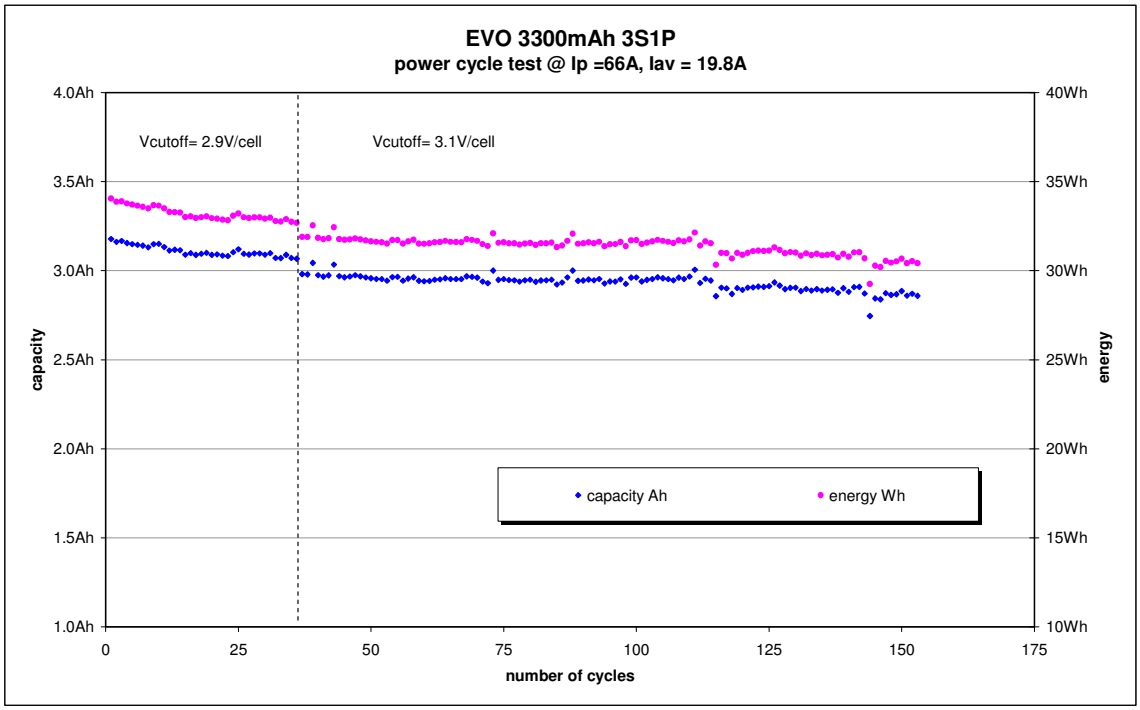

Fig. 6 developing of discharged capacity and energy during life testing
Remark: The discharged capacity in the life test is not identical to the capacity of the battery.

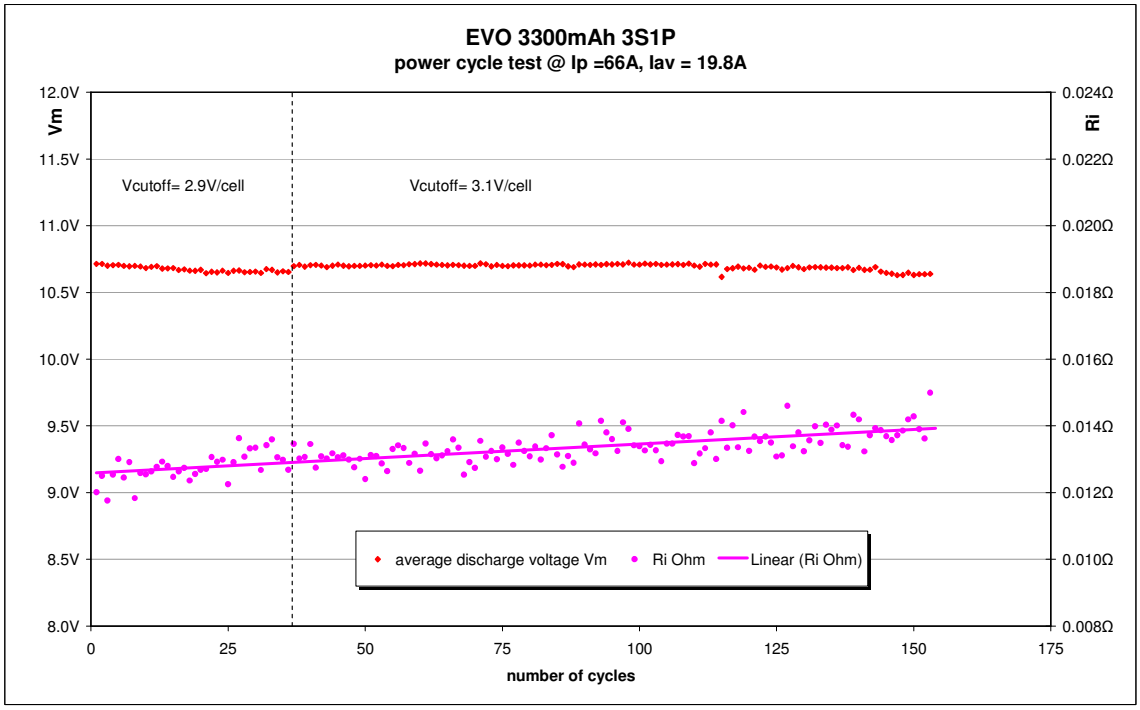

Fig. 7 developing of Ri and average discharge voltage during life testing.

Ri increased with a constant rate from 4.2mΩ/cell to 4.7mΩ/cell.

Internal Resistance during a discharge cycle

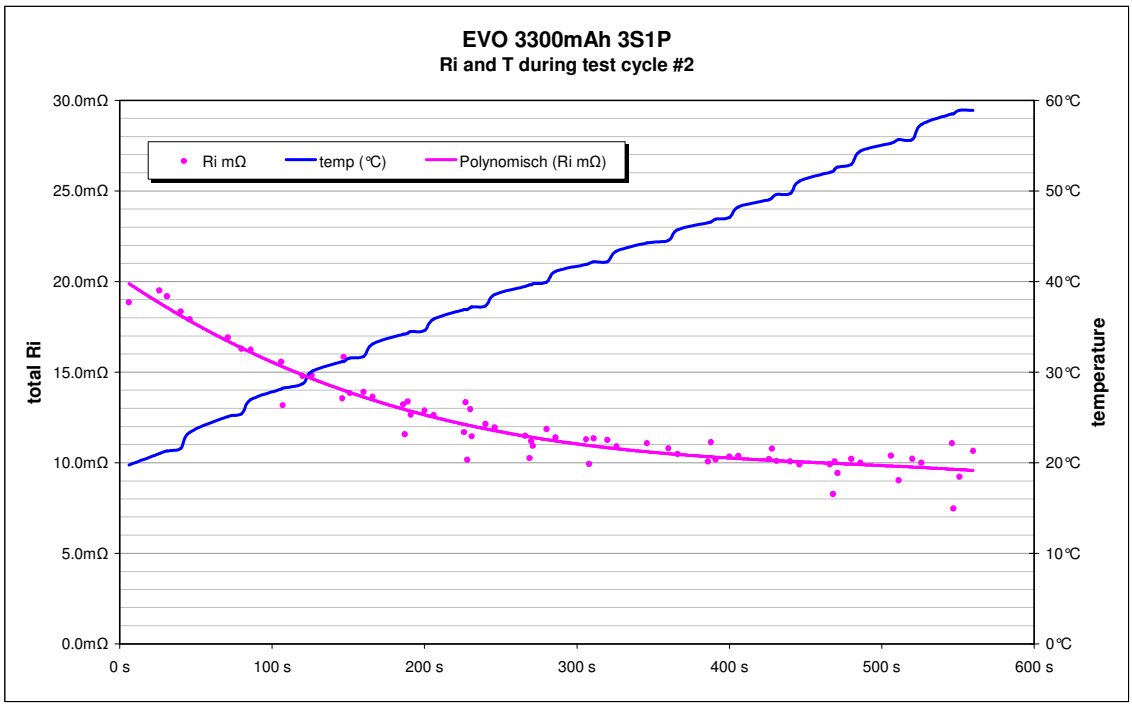

Fig. 8 temperature and Ri at the beginning of the life test

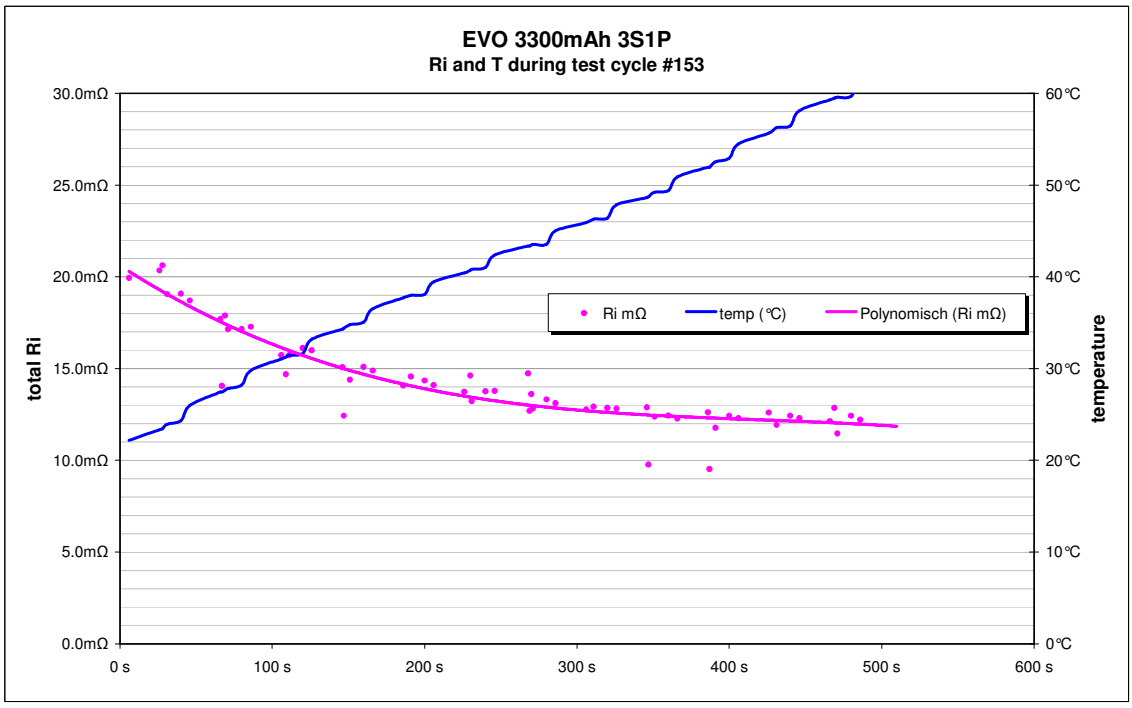

Fig. 9 the same at the end of the life test

It is characteristic for these cells that Ri decreases until the end of discharge.

Discharge voltage in life test

From the 12C test cell#2 was identified as the one with the lowest capacity although in life test cell #3 is discharged first with a voltage drop down to 2.5V (Fig. 10).
After 40 cycles the capacity difference of the 3 cells seemed to be smaller than in the beginning. In course of the test cell #2 degraded most with the effect that at the end of the test (Fig. 12) cell #2 had clearly less capacity than the other 2.

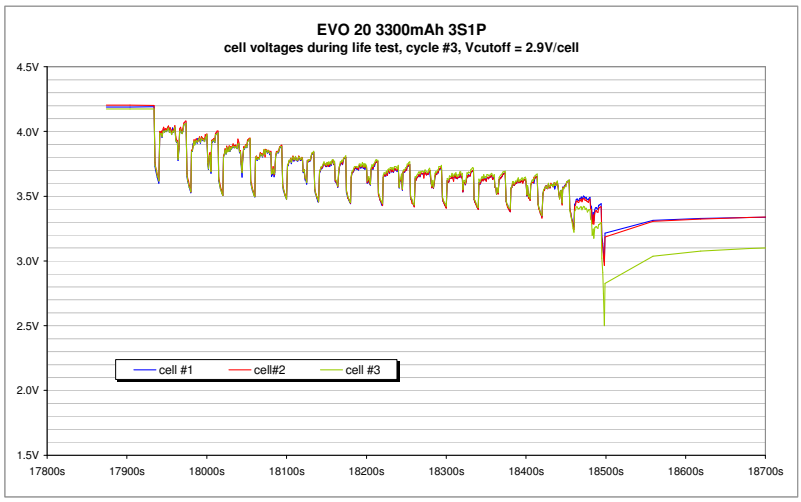

Fig. 10 individual cell voltages at the beginning of life test

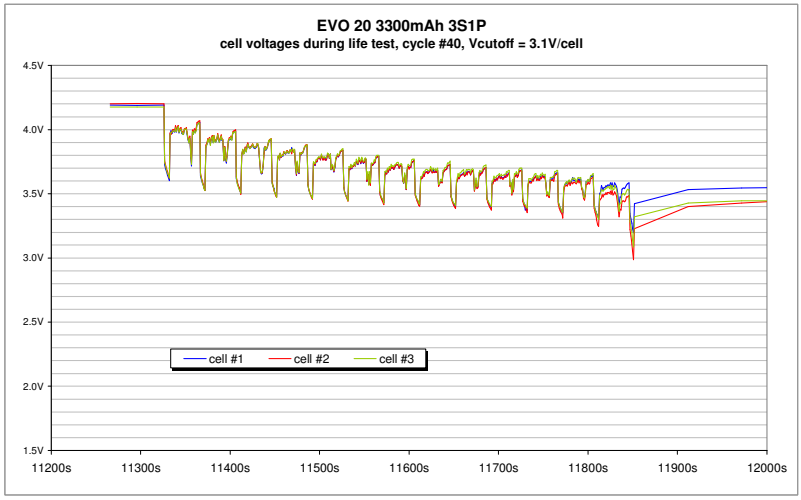

Fig. 11 cell voltages after 40 cycles

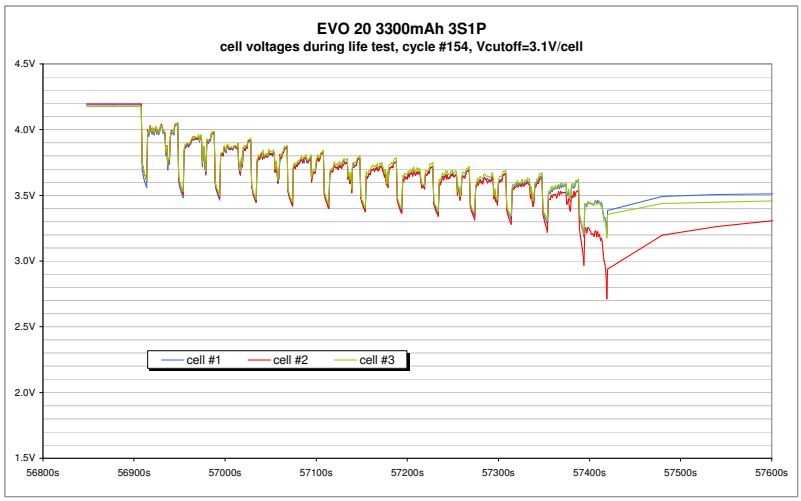

Fig. 12 the last cycle in the test (154)