Performance and stress tests on Carbon based Power Capacitors

1. **Scope of the tests**

Standard datasheets of battery and supercapacitor cells often provide data that is only applicable in well controlled standardised conditions. Example are that charging has to be done at 0.5C (half of the nominal current and at a standard temperature of 25 °C). In real systems such conditions would be very restrictive. In the following tests we wanted to have a better understanding of the properties of carbon based power capacitors that can operate at very different temperatures and can be charged and discharged at much higher currents. In addition, these tests have been set up as stress tests with e.g. applying maximum sustained current during the while tests and with relative short relaxation intervals.
These tests are not final but provide a base to start from for more elaborate tests. One conclusion that can already be drawn is that the power capacitors operate without any problem at higher currents and higher temperatures. However, the tests also showed the importance of relaxation periods. At high discharge rates not all available energy can be dumped into the load and relaxation allows to recover the residual energy. It is laos noted that the cells were 100% charged (stopped when current drops below 0,1 A rather than 0,02 A) to reduce the testing time.

1.1. Product Type

Toomen carbon based power capacitor Cell.
Further referred to as “power capacitor cell” or “cell”.

- 1.0Ah/2000F/3.2VDC (18500 cylindrical)
- 1.3Ah/3300F/2.7VDC (18650 cylindrical)

1.2. Test site and test equipment

Flanders Make , Lommel
PEC SBT 8050

1.3. Test sequence:

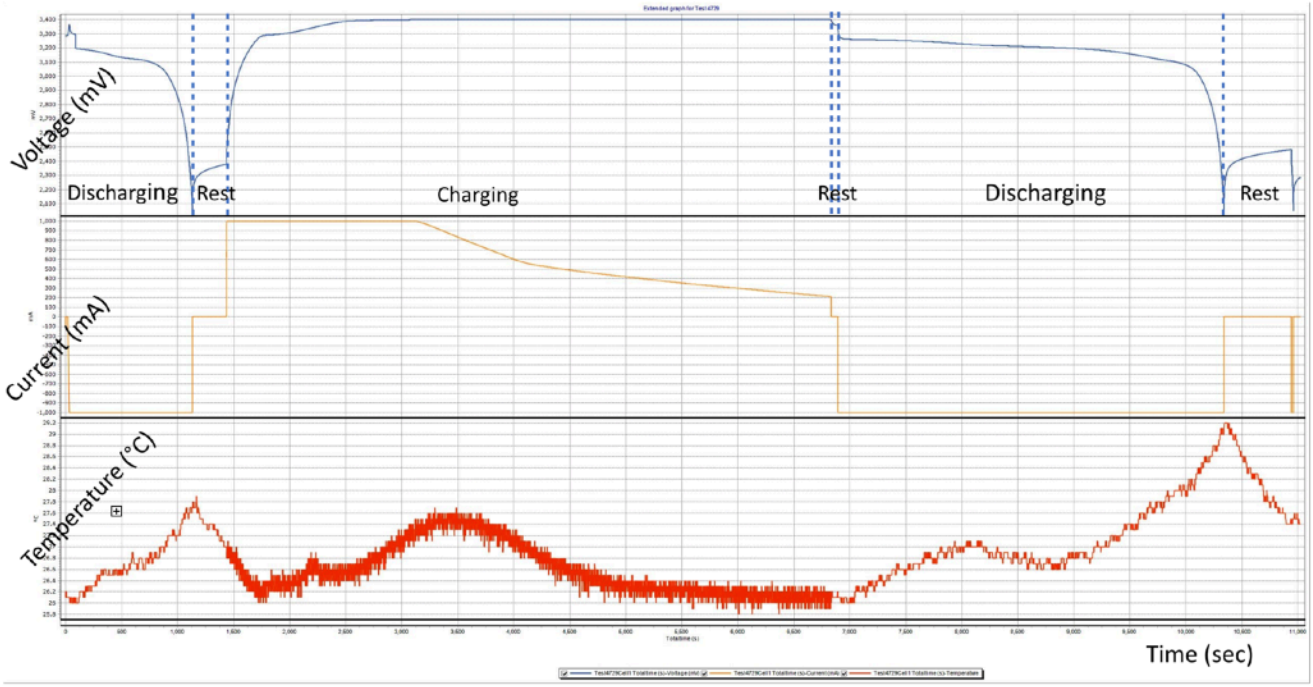
Cells are taken from stock. Typical sequence:

- Discharge till minimum voltage
- Relaxation (typically 60 seconds, no current)
- Charge with specified charging current and specified voltage till current < 0.1 A.
    - Fast charge phase: current is maximum till maximum voltage is reached
    - Slow charge phase: current slowly drops while voltage difference goes to zero.
- Relaxation (typically 60 seconds, no current)
- Discharge with specified current till voltage drops to minimal discharging voltage + 0,05 V
- Relaxation (typically 600 seconds, no current)
- Optional: discharge to estimate residual charge.

1.4 Data recorded:

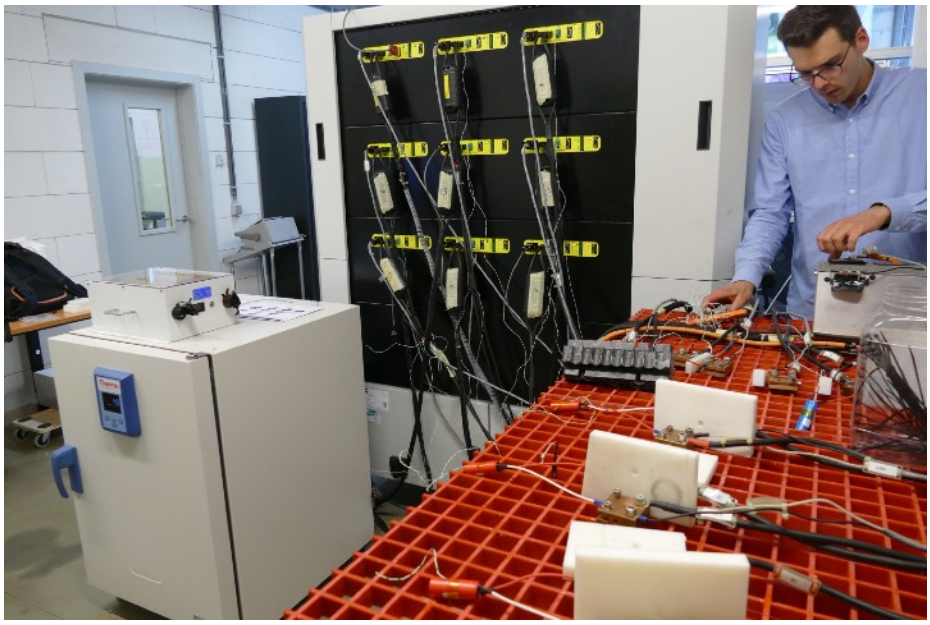
- Current (mA on graphs)
- Voltage (mV on graphs)

- Temperature on skin of cell (°C on graph)
- Time (seconds)
- Measurements with FLIR camera to validate temperature sensor
- No active cooling used (heat is dissipated to ambient air or to a heat absorbing material).



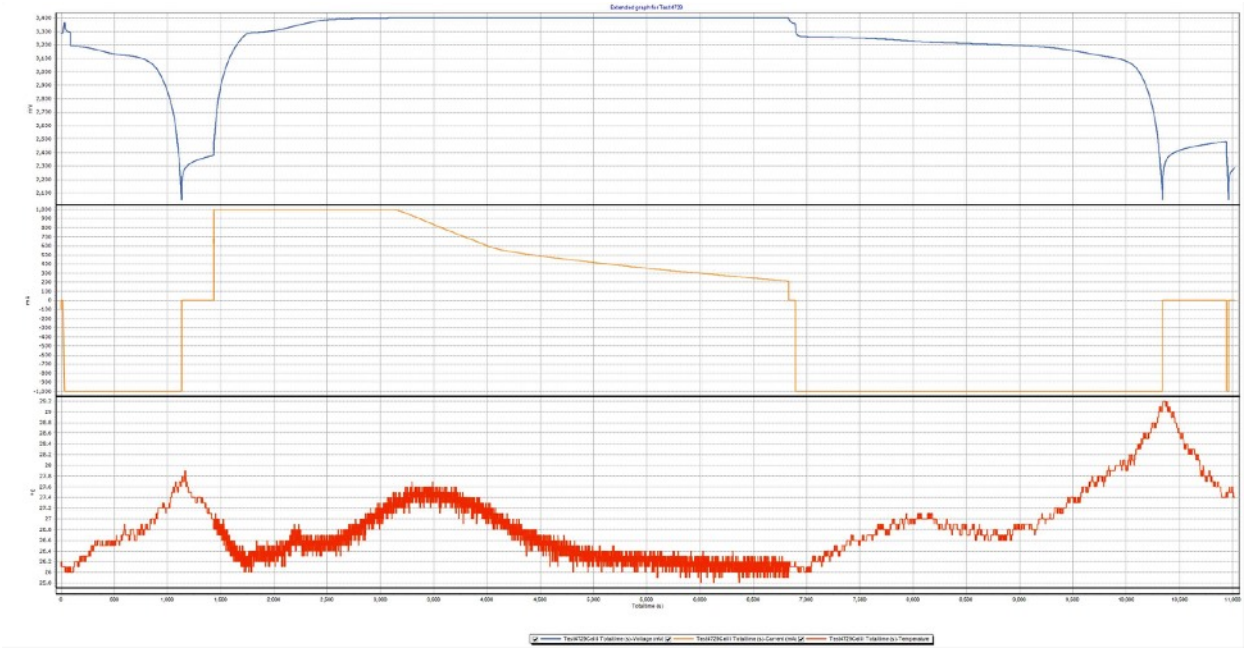
1.5 Types of tests

- Test at room temperature (maintained at 25°C +/- 2°C). Constant charge and discharge current
- Test in thermal oven at 45°C
- For some test the cells were placed in a heat absorbing material.
- Test at room temperature with pulsed discharging current.

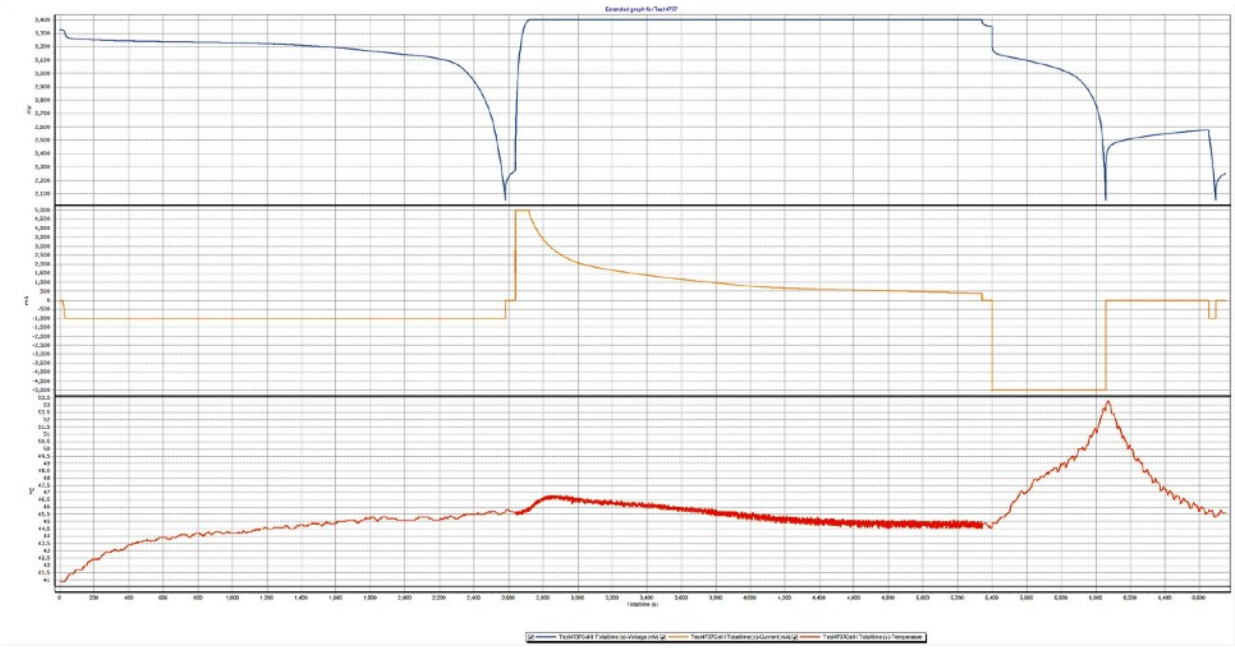


3. Test results

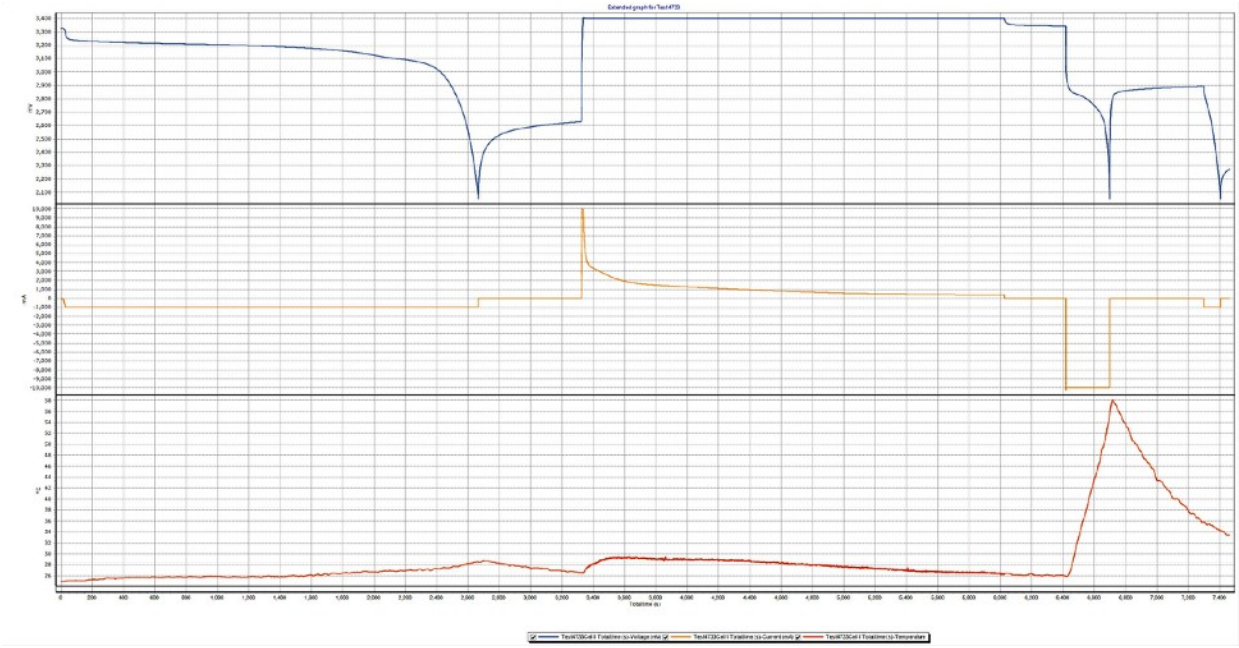
3.1 TMDD1.0/3.2/18500 - 1.0Ah/2000F/3.2VDC



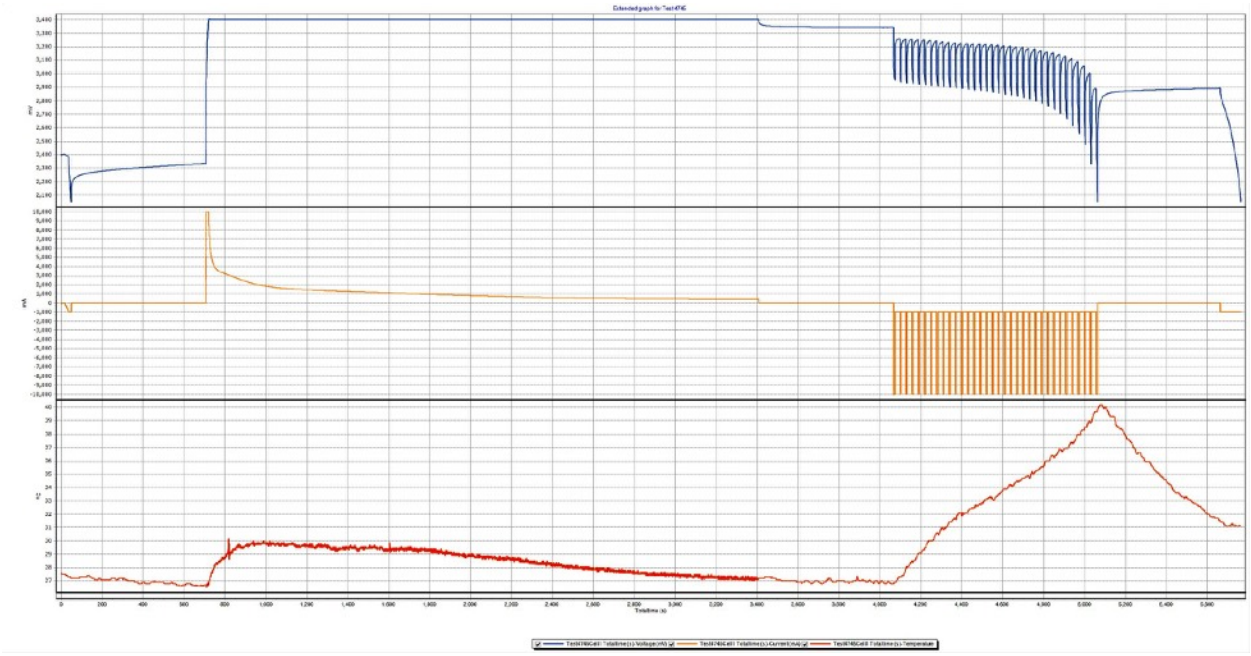
Test 4729 - 18500 cell - charge at 1C (1A) - discharge at 1C (1A) room at 25°C +/- 2 °C
Maximum temperature increase: +3.2 °C
Energy injected: 3,216 Wh in 3882 seconds
Energy released upon discharge: 3,05 Wh in 3688 seconds.
DOD (Depth Of Discharge): 102%



Test 4737 - 18500 cell - charge at 5C (5A) - discharge at 5C (5A) room at 45°C +/- 2 °C
Maximum temperature increase: +9.5°C
Energy injected: 3,09 Wh in 2626 seconds
Energy released upon discharge: 2,734 Wh in 656 seconds
DOD: 91%

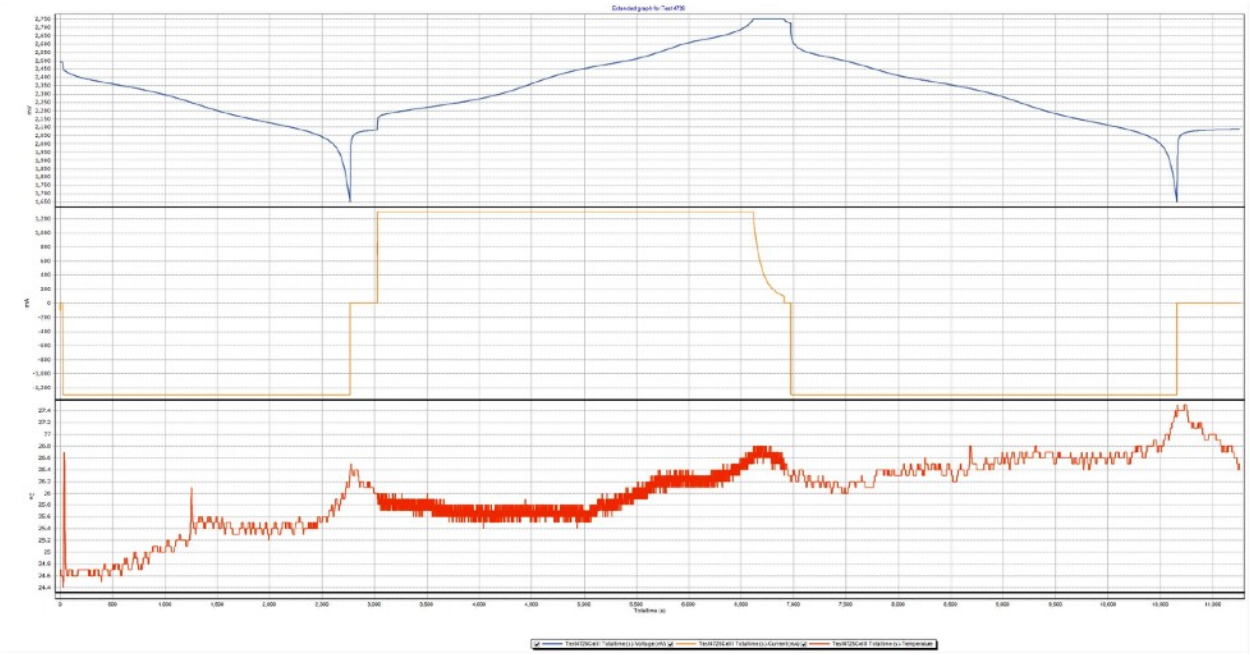


Test 4733 - 18500 cell - charge at 10C (10A) - discharge at 10C (10A) room at 25°C +/- 2 °C
Maximum temperature increase: +26°C
Energy injected: 2,70 Wh in 2989 seconds
Energy released upon discharge: 2.14 Wh in 281 seconds
DOD: 78%

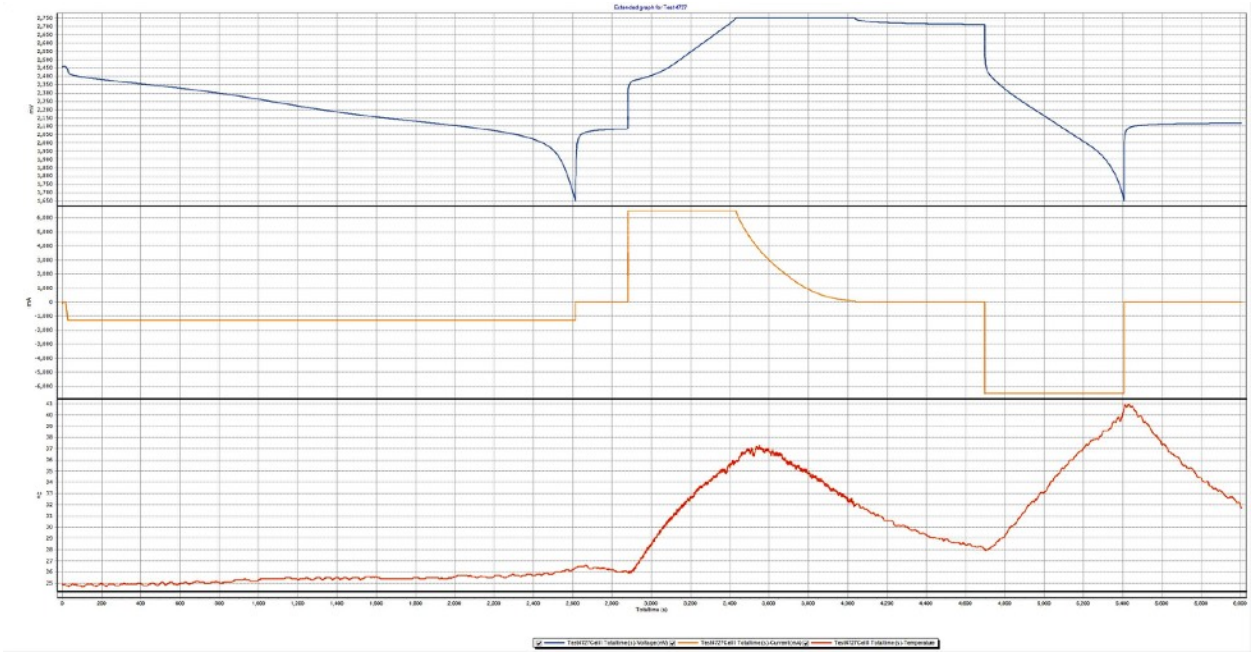


Test 4745 - 18500 cell - charge at 10C (10A) - discharge pulsed at 10C (10A) room at 25°C +/- 2 °C. Average discharge current 2,6A (2,6C). Pulse: discharge for 6 seconds at 10C (10A) then for 24 seconds at 1C (1A) and repeat until voltage drops to minimum.
Maximum temperature increase: +13°C
Energy injected:2,76 Wh in 3300 seconds
Energy released upon discharge: 2,37 Wh in 1000 seconds
DOD: 78%

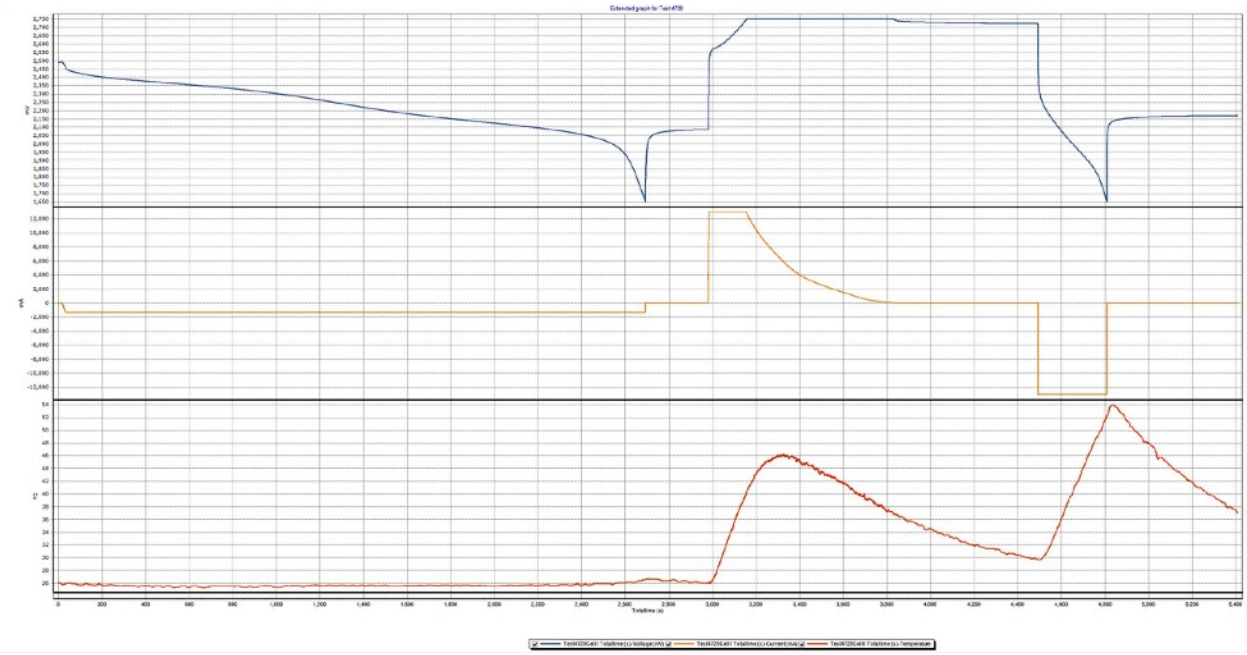
3.2 TMDD1.3/2.7/18650 - 1.3Ah/2000F/2.7VDC



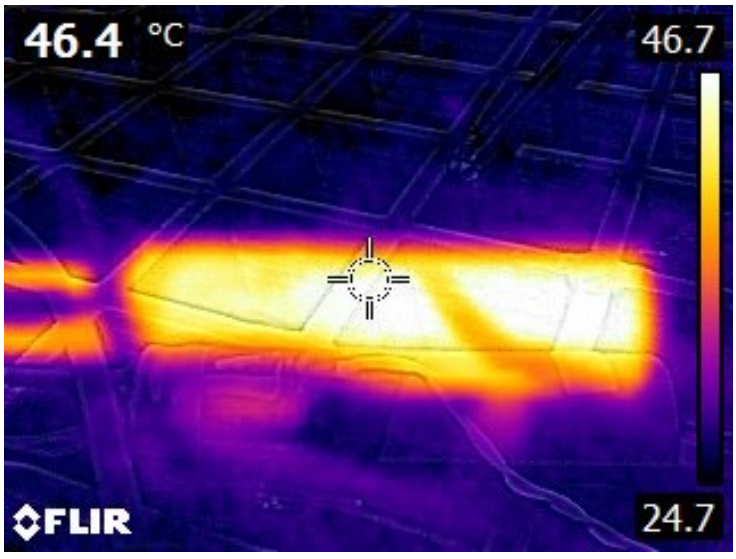
Test 4726 - 18650 cell - charge at 1C (1.3 A) - discharge at 1C (1.3A) room at 25°C +/- 2 °C
Maximum temperature increase: +2.0 °C
Energy injected: 3,216 Wh in 3880 seconds
Energy released upon discharge: 3,048 Wh in 3688 seconds
DOD: 102%

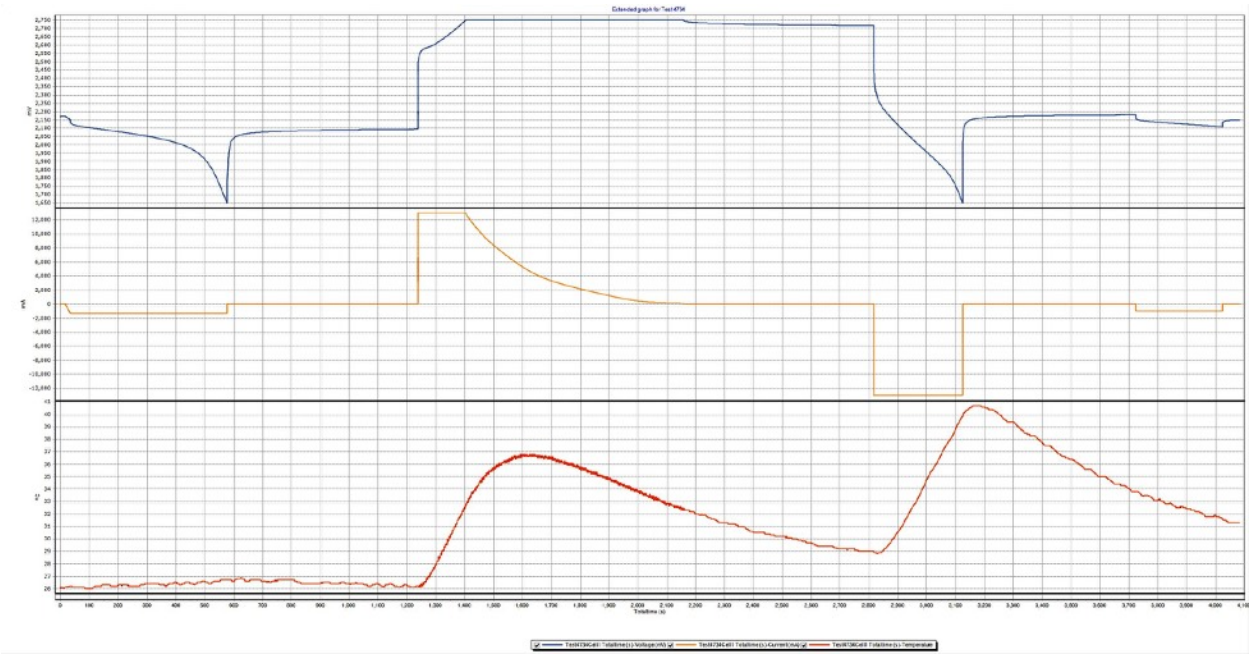


Test 4727 - 18650 cell - charge at 5C (6.5A) - discharge at 5C (6.5A) room at 25°C +/- 2 °C
Maximum temperature increase: +19.0 °C
Energy injected: 3.42 Wh in 1155 seconds
Energy released upon discharge: 2,7 Wh in 710 seconds
DOD:99%

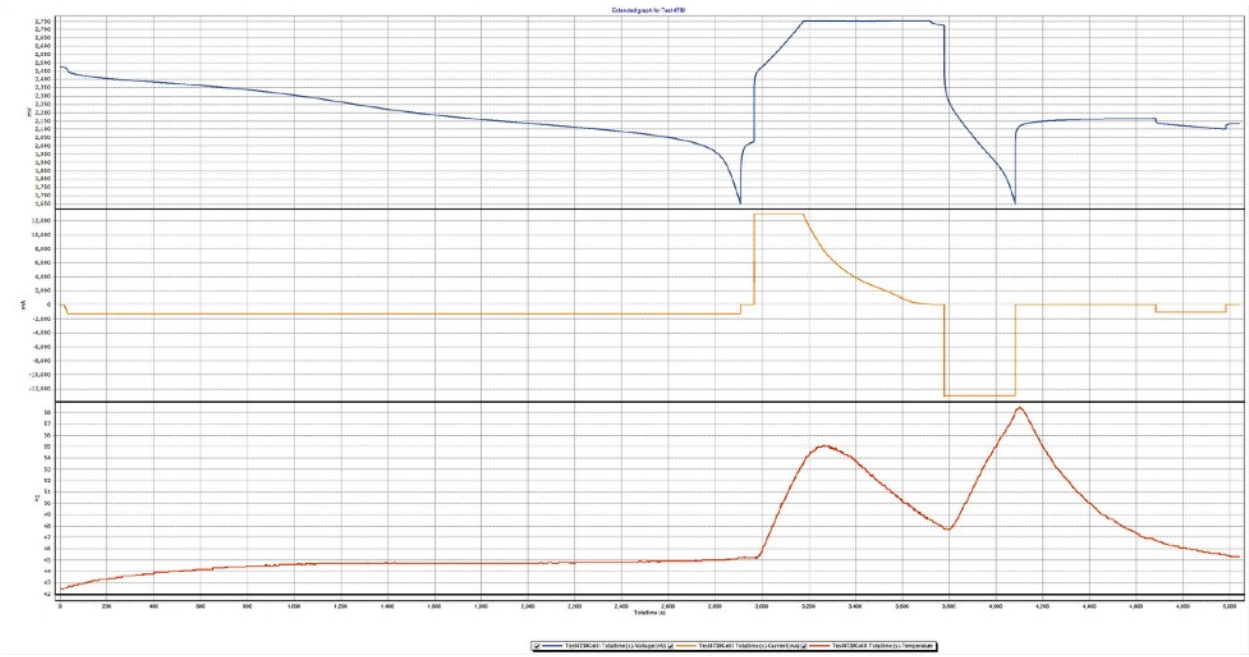


Test 4728 - 18650 cell - charge at 10C (13A) - discharge at 10C (13A) room at 25°C +/- 2 °C
Maximum temperature increase: +22 °C
Energy injected: 3,59 Wh in 850 seconds
Energy released upon discharge: 2,28 Wh in 315 seconds
DOD: 88%

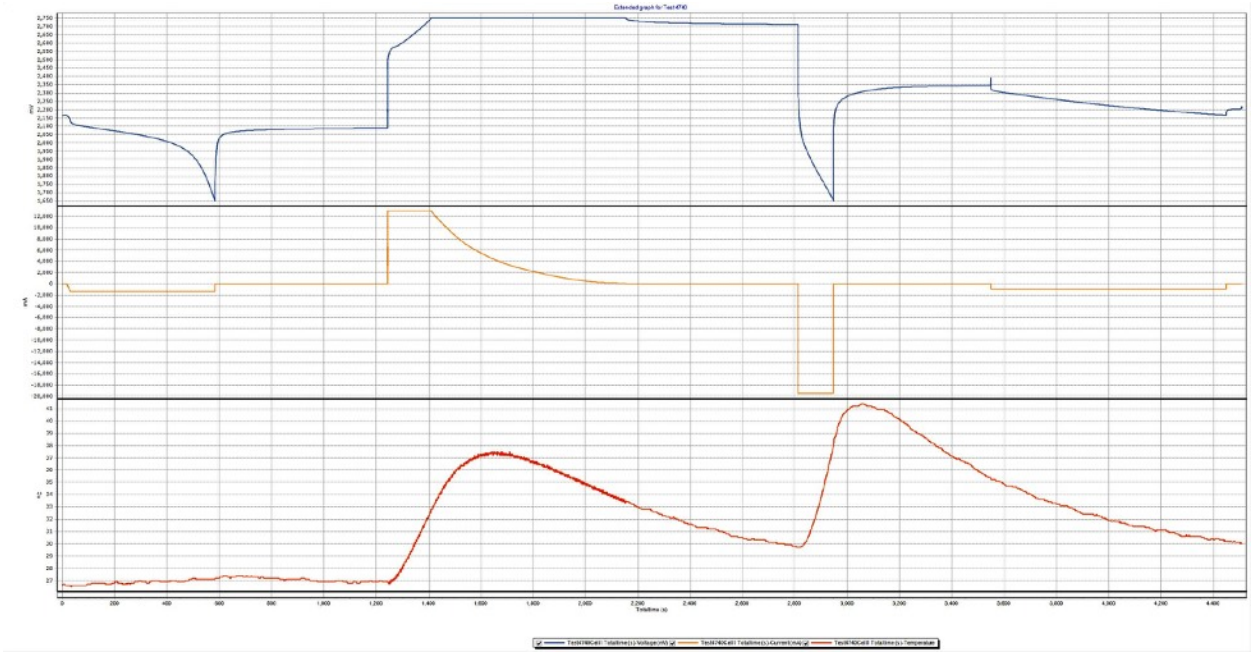




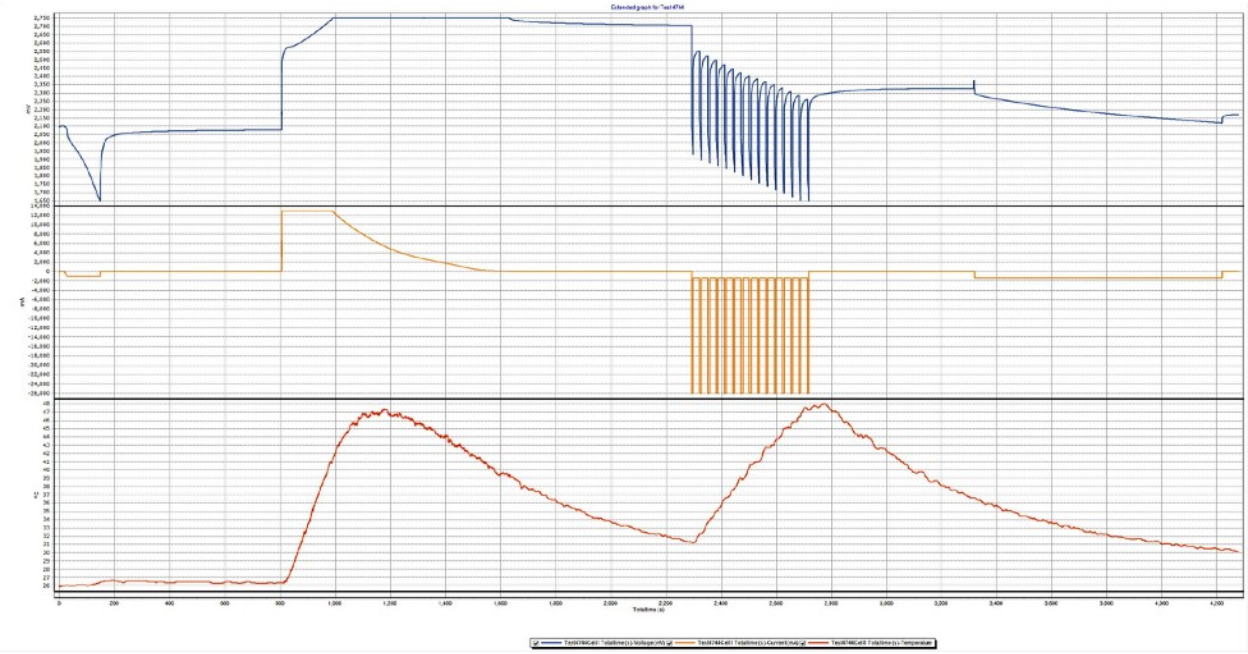
Test 4734 - 18650 cell - charge at 10C (13A) - discharge at 10C (13A) room at 25°C +/- 2 °C
Maximum temperature increase: +15 °C (use of heat absorbing material)
Energy injected: 3,61 Wh in 919 seconds
Energy released upon discharge: 2,21 Wh in 306 seconds.
DOD: 85%



Test 4739 - 18650 cell - charge at 10C (13A) - discharge at 10C (13A) room at 45°C +/- 2 °C
Maximum temperature increase: +13.5 °C
Energy injected: 3,60 Wh in 752 seconds
Energy released upon discharge 2,20 Wh in 319 seconds. Residual energy.
DOD: 89%



Test 4740 - 18650 cell - charge at 10C (13A) - discharge at 20C (26A) room at 25°C +/- 2 °C
Maximum temperature increase: +13.5 °C (use of heat absorbing material)
Energy injected: 3,61 Wh in 909 seconds
Energy released upon discharge: 1,36 Wh in 135 seconds.
DOD: 75%



Test 4744 - 18650 cell - charge at 10C (13A) - discharge pulsed at at 20C (26A) - room at 25°C +/- 2 °C. Average discharge current 6,24 A (4,8C) Pulse: discharge for 6 seconds at 20C (26A) then for 24 seconds at 1C (1.3A) and repeat until voltage drops to minimum.
Maximum temperature increase: +12.5 °C
Energy injected: 3,68 Wh in 825 seconds
Energy released upon discharge: 1,48 Wh in 425 seconds.
DOD: 57%

4. Extract of the datasheet of the tested cells.

			TMDD1.0/3.2/ 18500	**TMDD1.3/2.7/ 18650**
			1.0Ah/2000F/ 3.2VDC	**1.3Ah/3300F/ 2.7VDC**
	Item	**Unit**	**Value**	**Value**
1	Nominal capacity	Ah	1,0	1,3
		F	2000	3300
	Tolerance	%	5	5
2	Rated Voltage	V	3,2	2,7
2B	Rated Energy/cell	Wh	3,0	3,0
2C	Nominal Energy/ cell	Wh	3,2	3,5
3	Charge Mode		Constant potential	
4	Recommended charging voltage	V	3,4	2,75
4B	Limit charging voltage V-max	V	3,5	2,85
5	Final discharging voltage	V	2	1,6
6	Max. continuous charging current	A	10,0	19,5
7	Max. continuous discharging current	A	10,0	19,5
7A	Max. continuous power	W	30,0	54,0
7B	Allowable pulse discharge current (< 200 ms)	A	80,0	100,0
8	Max. Internal Resistance	mOhm	20	13
9	Weight	g	30	39
	Weight tolerance	%	1	1
10	Diameter	mm	18	18

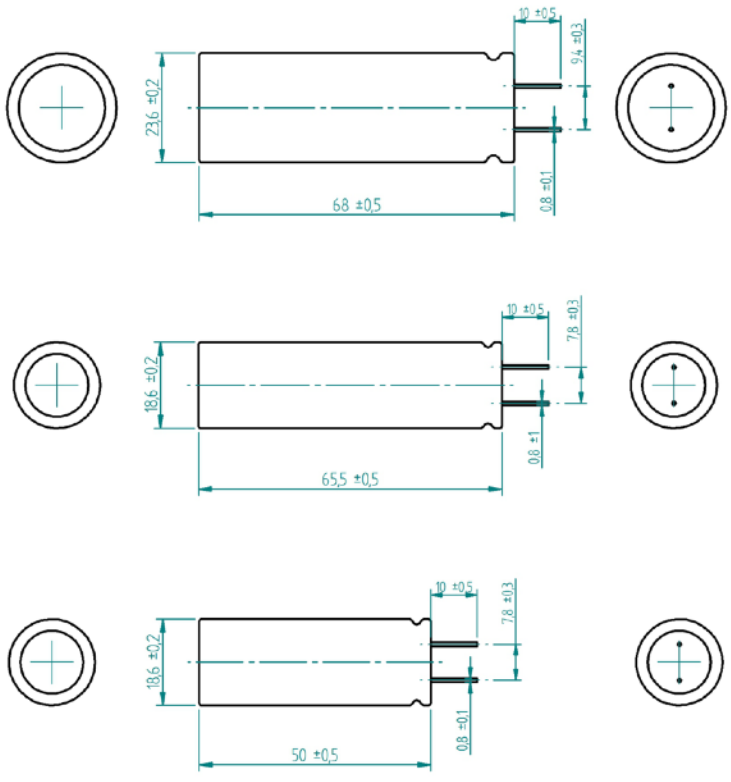
11	Height	mm	50	65
	Volume single cell	mm3	12723	16540
	Volume packed cell	mm3	16200	21060
12	Transportation Voltage +/- 0,1V	V	3,1	2,4
13	Storage Voltage +/- 0,1V	V	3,1	2,4
14	Min. Operation Temperature	°C	-20	-40
	Max. Operation Temperature	°C	70	80
15	Min storage Temperature	°C	-5	-5
	Max. Storage Temperature	°C	35	35
16	Max. storage humidity	RH %	85	85
18	Energy Density / Mass	Wh/kg	100	80
18B	Energy density / volume	Wh/dm3	235,8	181,4
19	Power density / Mass	W/kg	1500	1500
20	Instantaneous Power Density (200 ms)	W/kg	4000	4000
21	Residual energy after discharging @ XX A			
	XX = 15 (15C)	%	--	80
	XX = 20 (20C)	%	--	75
	XX = 18 (15C)	%	80	--
	XX = 25 (20C)	%	75	--
22	Lifetime charge/ discharge cycle till 75%		20000	50000

23	Energy holding after 28 days	%	95	95
24	Short circuit temperature	°C	150	150
25	Guarantee period	months	12	12
26	Fire Hazardous substances	N.A.		

Standard Charge Profile

Under the condition of ambient temperature (25 ±3)℃, charge the power capacitor cell with the maximum charging voltage under a 0.5C limited constant current until the charging current is less than or equal to 0.02A, then stop charging.
Notes: exceeding the maximum charging voltage or charging/discharging at a higher current rate can influence the lifetime, especially at higher temperatures.

Dimensions of the carbon based power capacitor Cells



11. Disclaimer

These tests doe not represent officlal data. Any ius of it is indicative and should be confirmed by additional tests.

The company shall not be liable for any problems arising from the use of the hybrid carbon-based power capacitor cell outside its specifications.

The company does not assume any responsibility for products beyond the quality guarantee period.
The company is not responsible for the damage caused by the customer's acceptance tests or during damage caused by any assembly process.

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