CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Electrical Engineering
Department of Electrotechnology
Technická 2, 166 27 Praha 6

Report on Tests of A123 26260 Type Cells

Client:

Olife Corporation a.s

Company ID (IČO): 29291780
Registered office: Lazarská 11/6, 1200 Praha 2

Contract No.: **2014-03-19-01**

DHČ No: **13113 830 8301401C066**

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Author:

Prague, 12 June 2014

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Date: March to June 2014.

The tests were performed in the laboratories of the Department of Electrotechnology of the Czech Technical University (ČVUT) in Prague under economic contract No. 830 830 1401 C066.

The report is divided into chapters according to the sequence of the tests performed. As opposed to the original schedule of tests, according to an agreement with the client the number of tests has been increased by tests at above-the –limit ambient temperatures and measurements of the temperature profile of temperature increase on a chain of 4 cells in order to determine the increase of temperature of the cells when charging with large current (according to the data sheet, the value is 4C). Measurement of the temperature conditions on a complete set of 28 Ah, 12 V cells was omitted due to the unavailability of a sample of a battery set due to the unsuitable technology of welding of cells in an assembly. If the problem of connection of the cells can be resolved this measurement can be covered by another economic contract between the parties.

1. Checking the condition of the cells supplied.

According to the client's information, cells from two supplies quite different in terms of time in a condition as supplied by the manufacturer were delivered, and therefore basic measurements of the condition of the cells were performed.

1.1 Measurement of differential resistance

Protocol of measurement of differential resistance LiFePO4 of A123 cells, type AIMR26650

Date of measurement	17/03/2014	
Temperature	19.9 to 20.0 °C	
Voltcraft ALC8500		Size current 2.5A, real 2.9A

The measurement was performed on the cells stored (set A 2 years without recharging; set B new 092013, without recharging

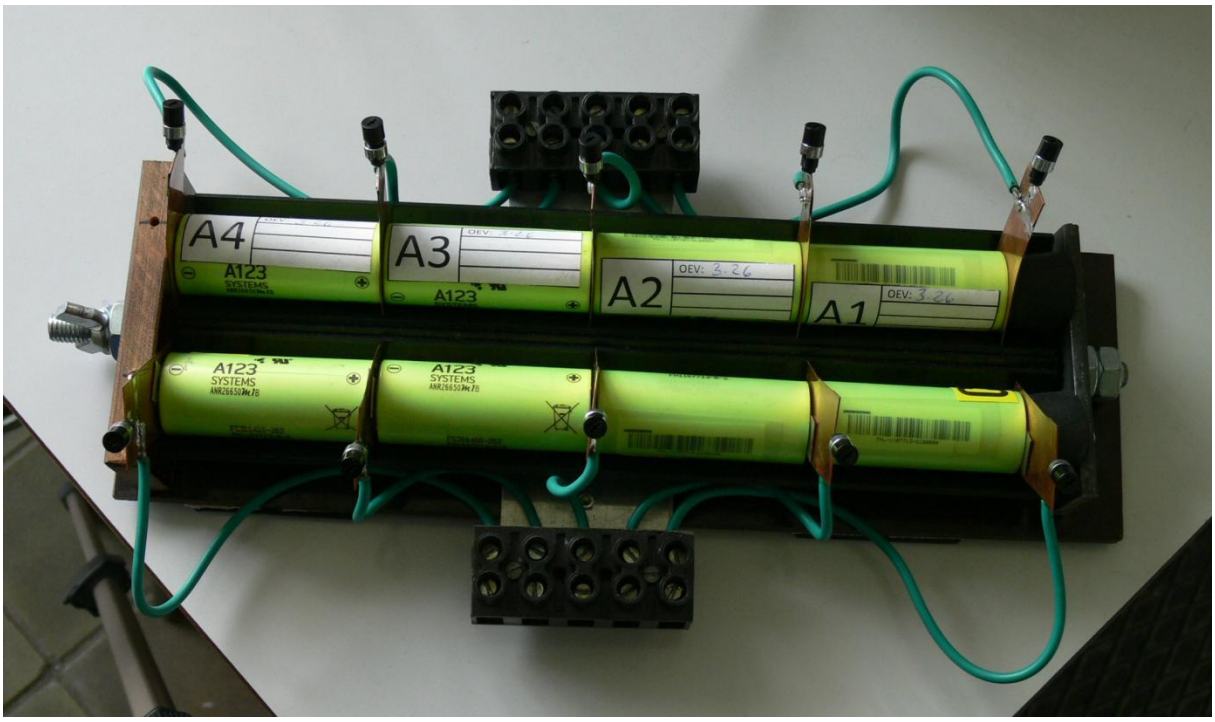
Four-point method of measurement of the resistance; measured on separate cells

Sample	Resistance (mΩ)						
A1	10.2	9.5	9.5	9.2	9.2	9.2	**9.2**
A2	9.5	9.5	9.5	9.2	9.5	9.5	**9.5**
A3	10.2	9.9	9.5	9.5	9.5	9.5	**9.5**
A4	10.2	10.2	9.9	9.9	9.9	9.5	**9.9**
B1	10.2	10.2	10.2	10.6	9.9	10.6	**10.2**
B2	10.6	10.2	10.2	10.2	9.9	10.2	**10.2**
B3	9.9	9.5	9.2	9.9	9.5	9.5	**9.5**
B4	10.9	10.6	9.9	10.2	10.2	**10.2**	9.9

Measurement on a pack with Cu intermediate contact metal sheets					
Al,2,3,4	44.8	43.8	43.4	43.4	**43.4**
Bl,2,3,4	47.6	45.8	45.8	45.8	**45.8**

1.2 Measurement of the condition of cells before the first charging - test of condition when supplied

Measurement fixture for the clamping of the cells

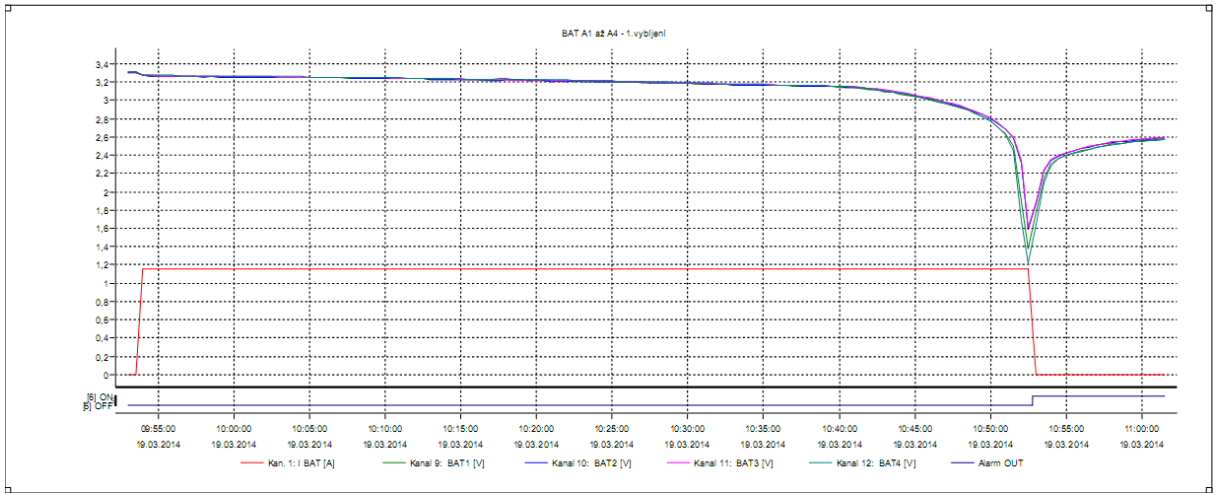


The supplied cells were labeled as set A1, 2, 3, 4 and B1, 2, 3, 4. The fixture for measurement enables access to the contacts of all cells, mechanical tightening of the structure and measurement of temperature on the pack of cells as well as on individual cells.

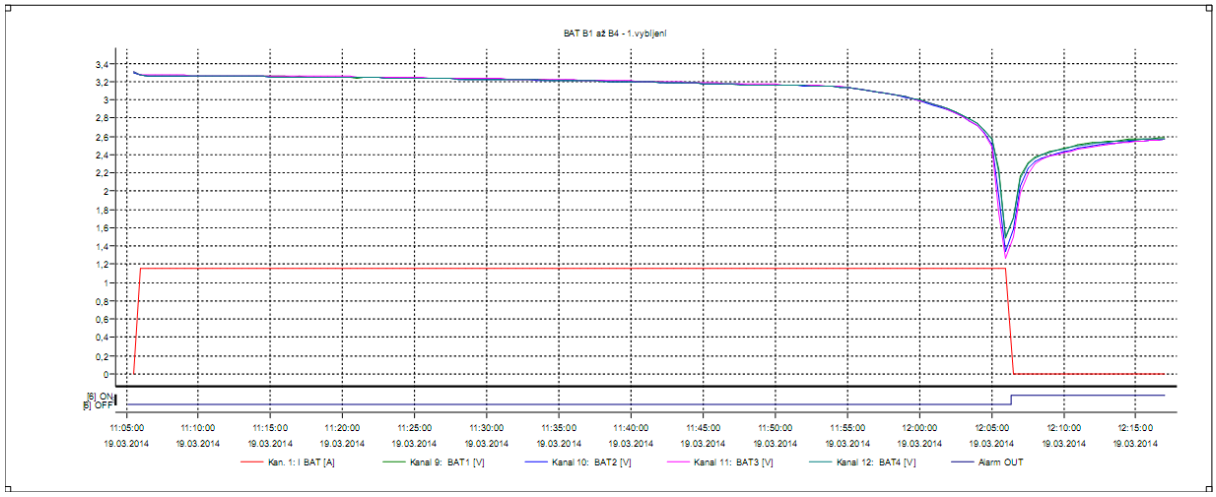
Test of the cell condition when supplied

With respect to the fact that the cells from set A were stored for a relatively long time and cells from set B were stored only for several months a test of the charging status was performed by means of a capacity test without prior recharging. According to the assumptions, it was confirmed that the cells were supplied from the manufacturer with a charge at 50% of the nominal capacity, and the storage time of set A and B did not have a great impact on the magnitude of the charge. The results of the capacity test are attached.

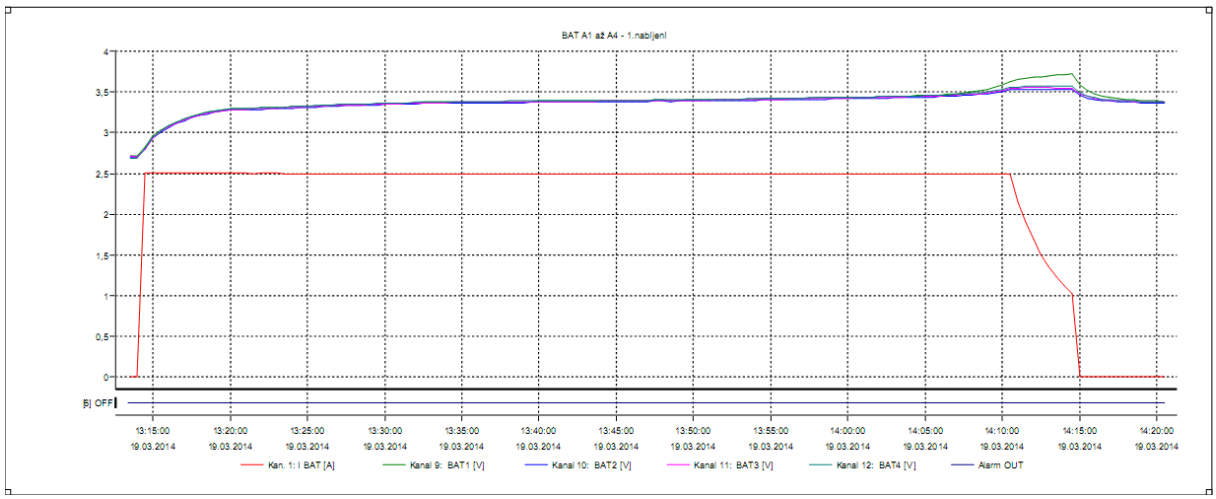
Subsequently the cells were recharged to the final capacity, and capacity tests were performed again to check the actual capacity for comparison with the nominal value.



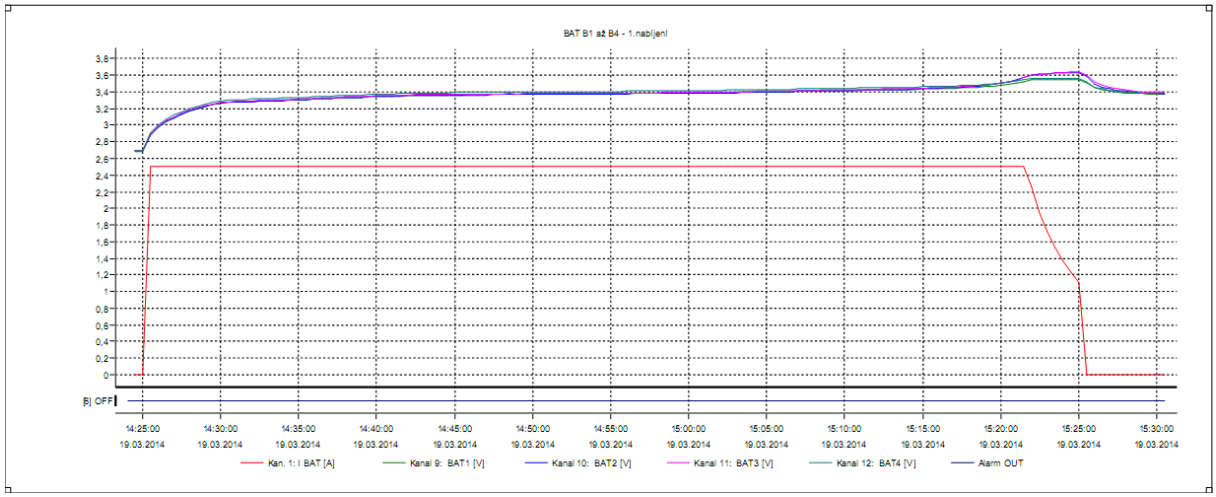
Capacity test after delivery - set A



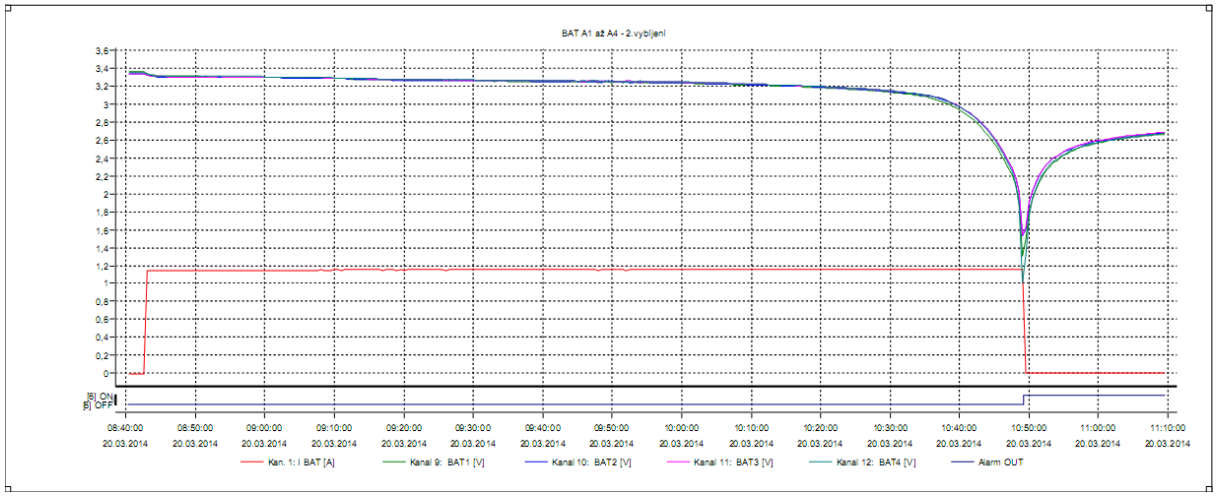
Capacity test after delivery - set **B**



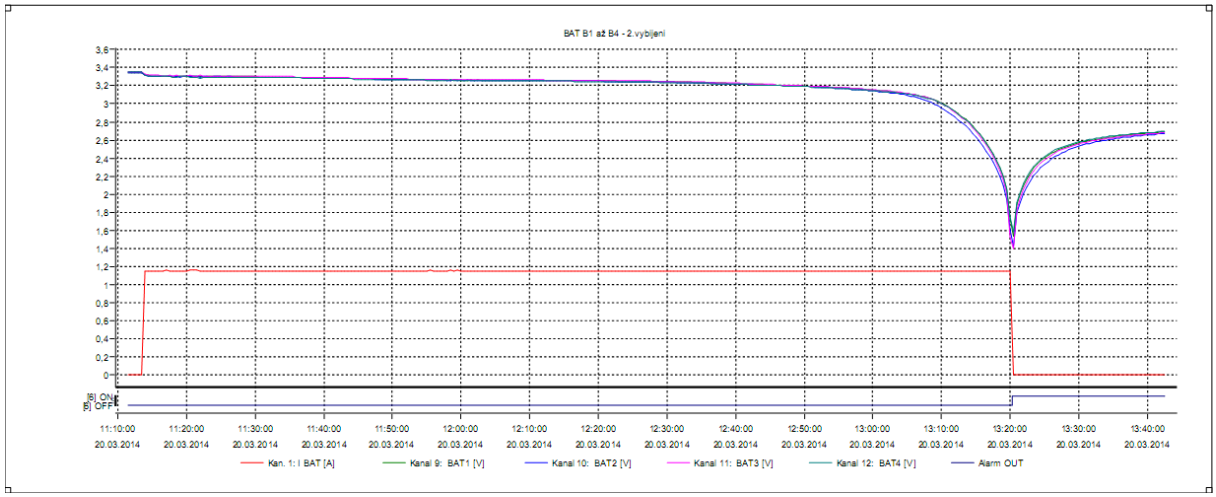
1st charging - set A



1st charging - set B



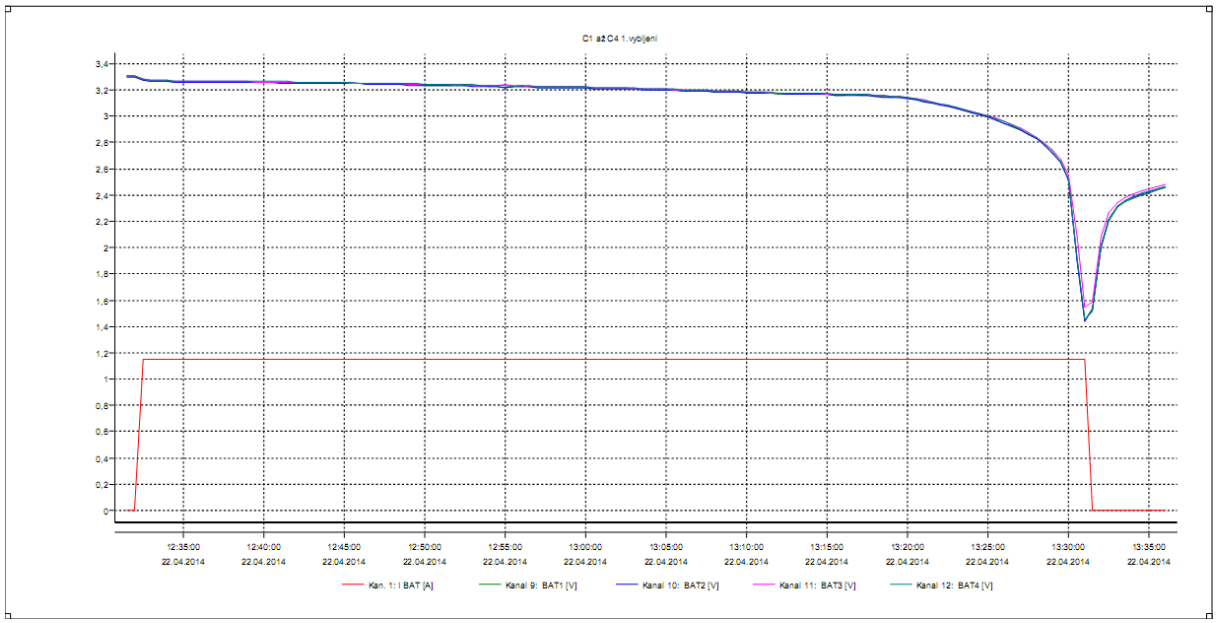
Capacity test after full charging - set A



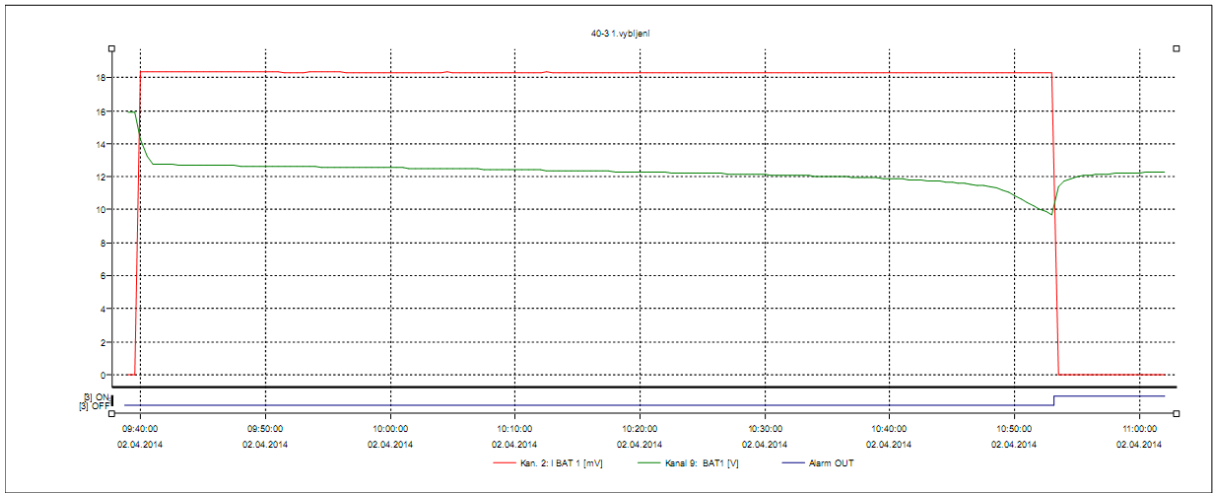
Capacity test after full charging - set B

Subsequently, cycles of the 2nd charging of set A, B followed. The characteristics corresponded with the 1st charging; therefore the report does not show the charts.

Subsequently, cells for set C were supplied. Below the report shows charts of the initial discharging process to check whether the supplied cells have identical properties as those in sets A and B.



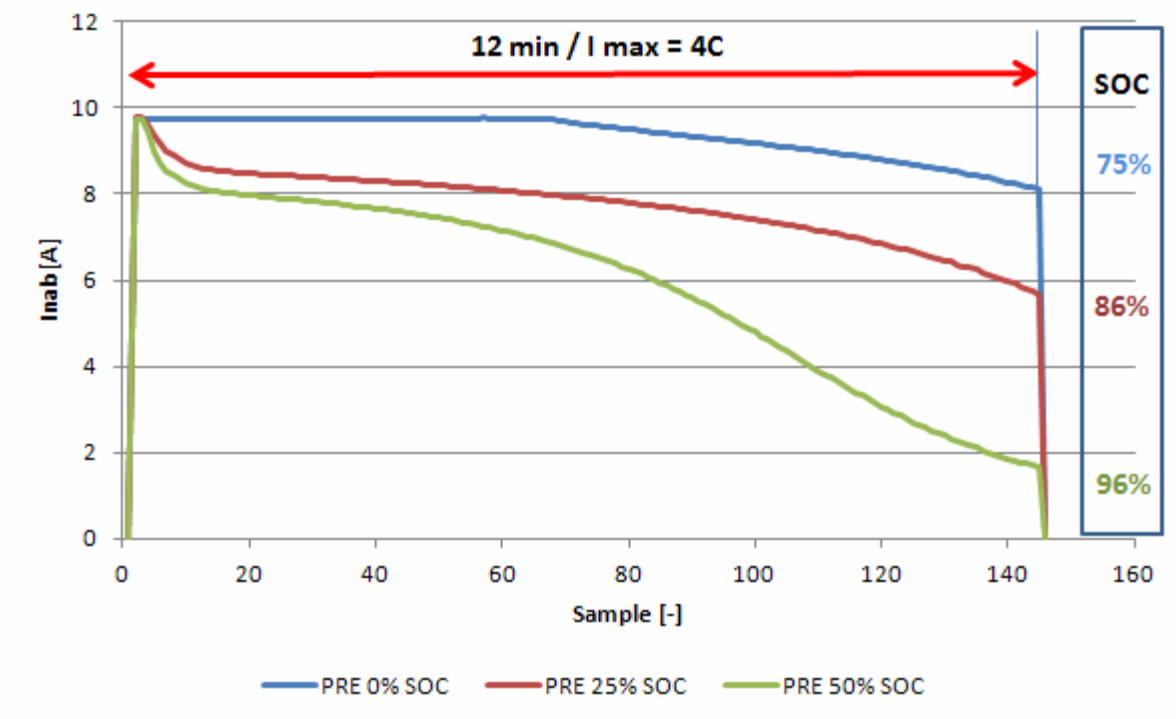
Capacity test – set C1 to C4. Cells C5 to C7 were checked identically. Subsequently all cells in set C were fully charged, and a capacity test of the 12V battery was performed (set C1 to C4).



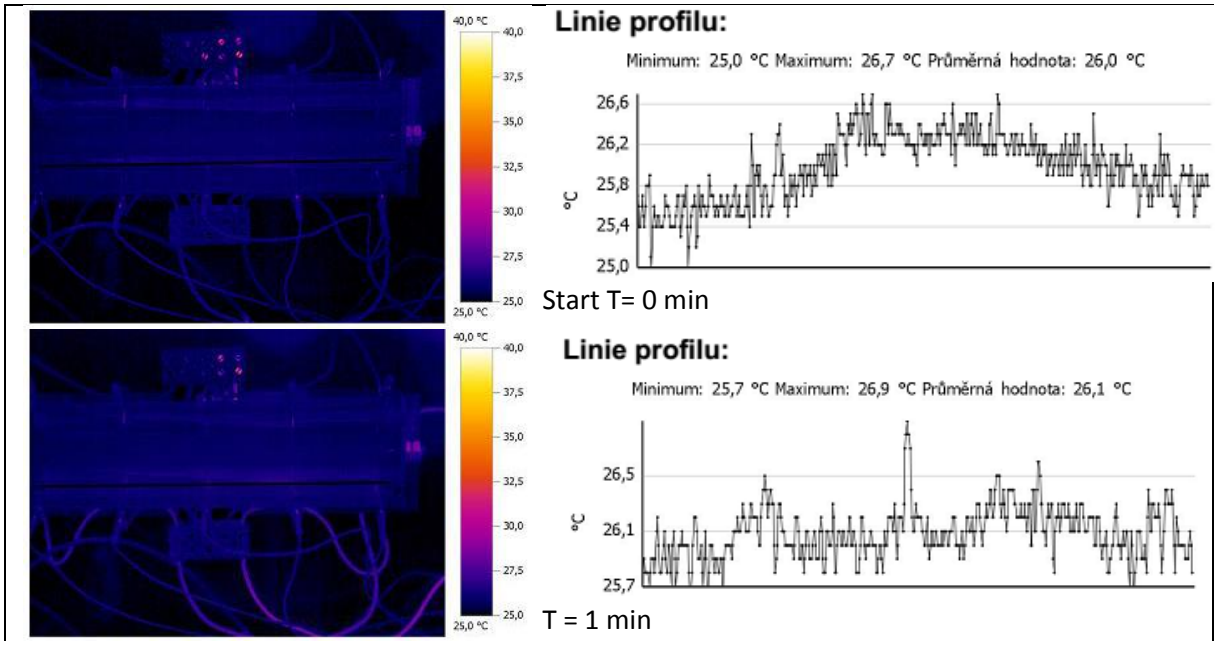
Capacity test of a 12V battery

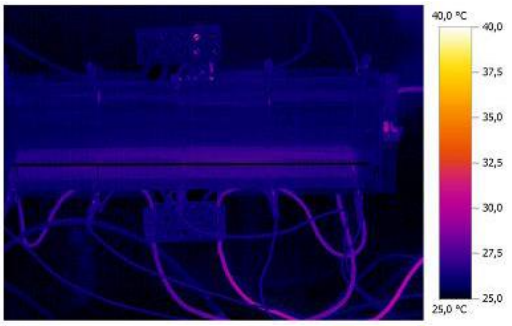
In the next section, tests were performed of the charging processes of the cells which were partially discharged prior to the charging. The summary results are shown in a well-organized chart.

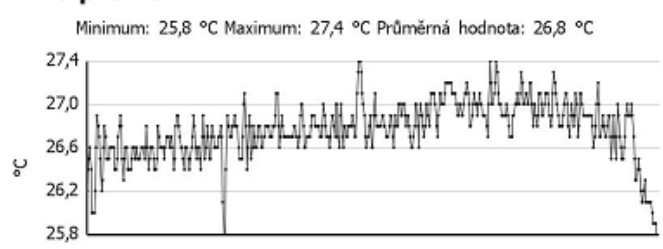
2.1 Charging characteristics of partially discharged cells A123 26650 (25 °C)



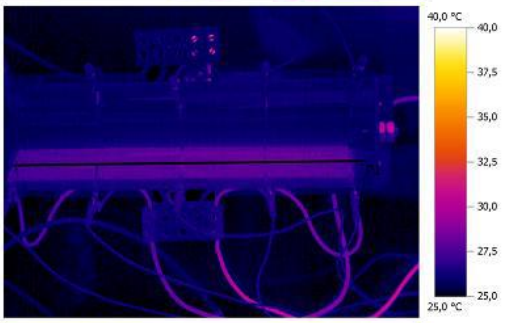
2.2 Temperature profile of the cells in a block of 12V; charging with current 4C.

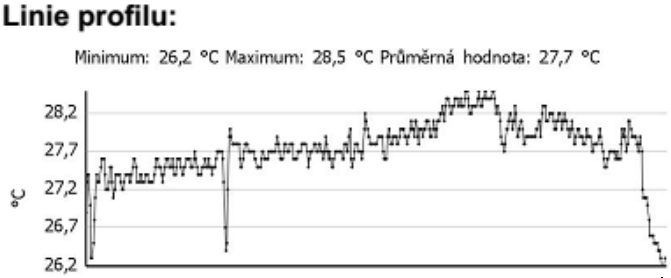




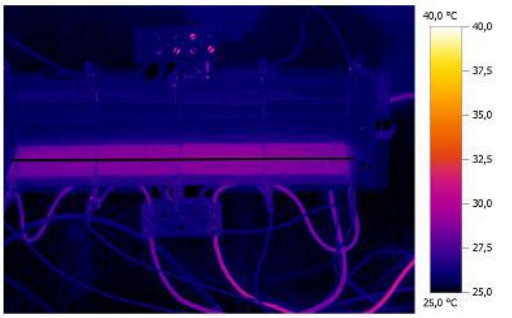


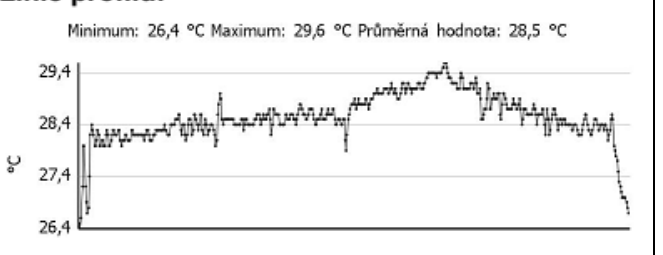
T = 2 min



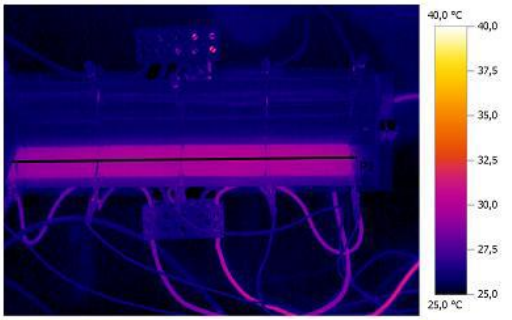


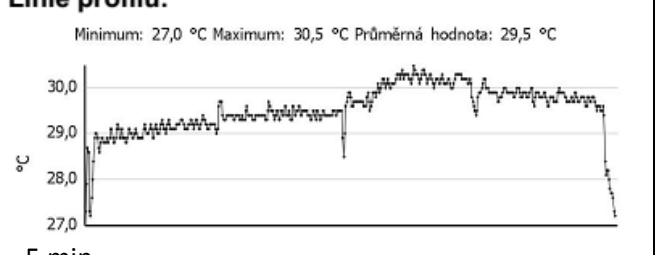
T = 3 min



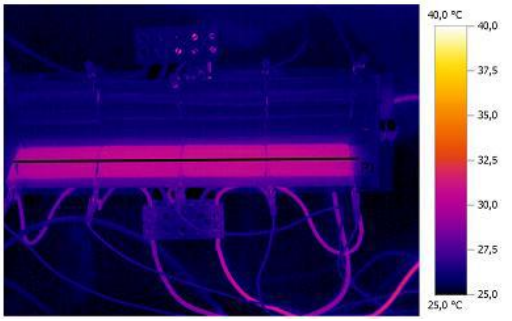


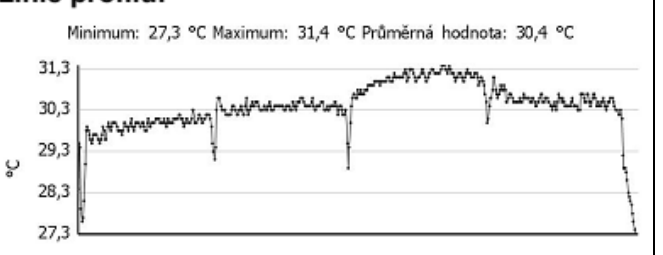
T = 4 min



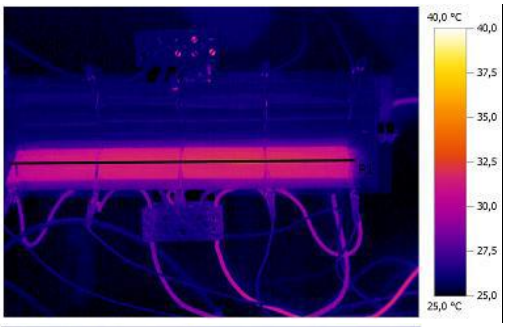


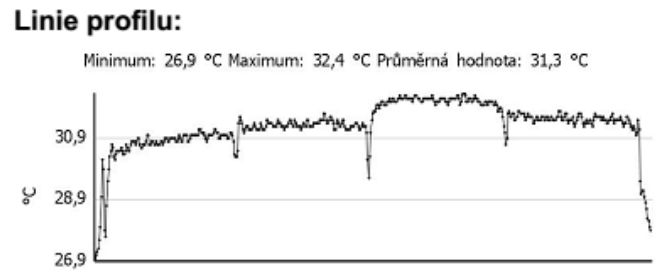
T = 5 min



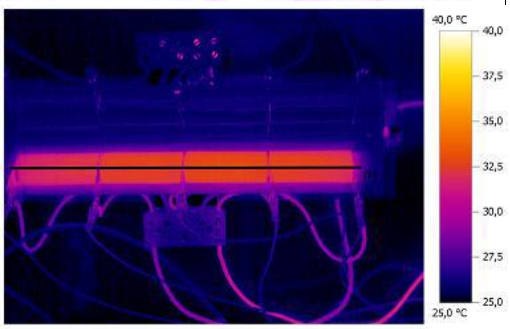


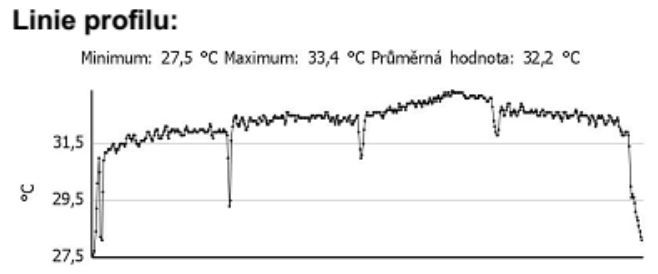
T = 6 min



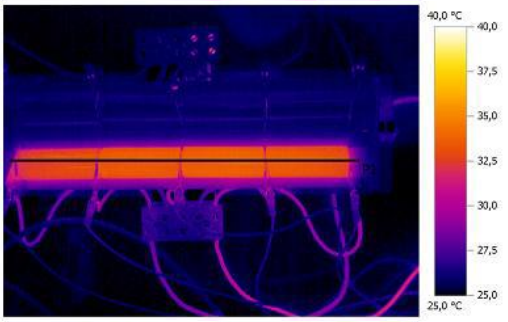


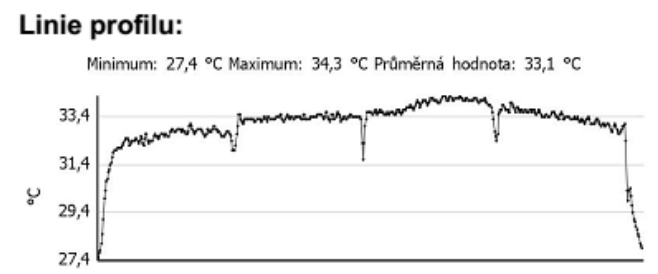
T = 7 min



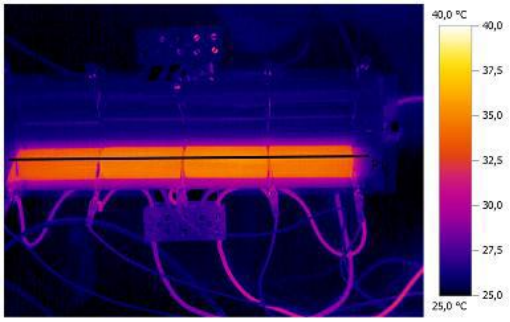


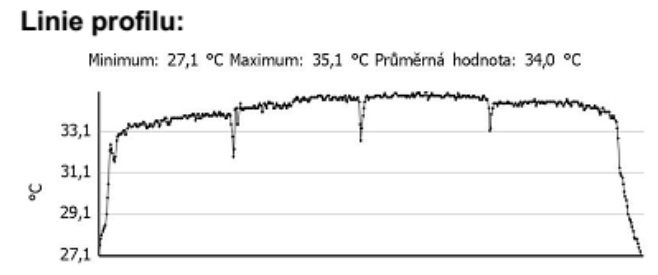
T = 8 min



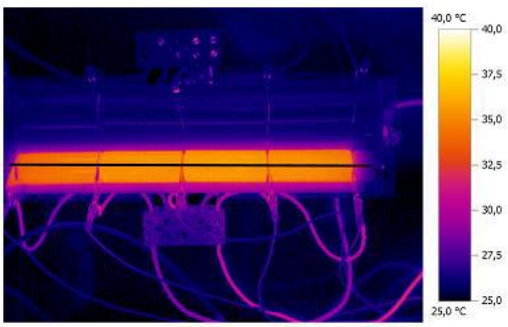


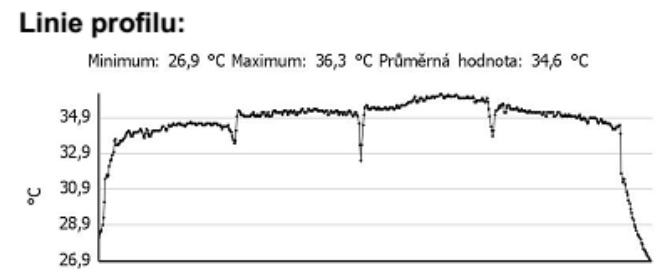
T = 9 min



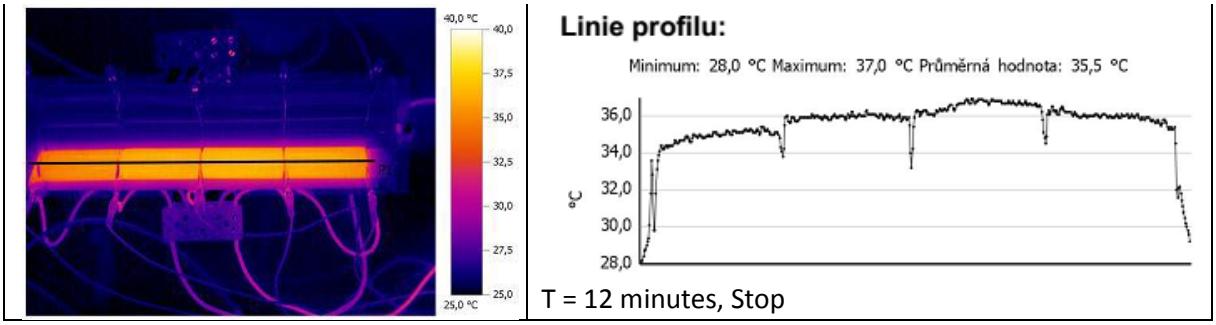


T = 10 min





T = 11 min



Czech original	English translation
Linie profilu	Profile line
Minimum	Minimum
Maximum	Maximum
Průměrná hodnota	Average value

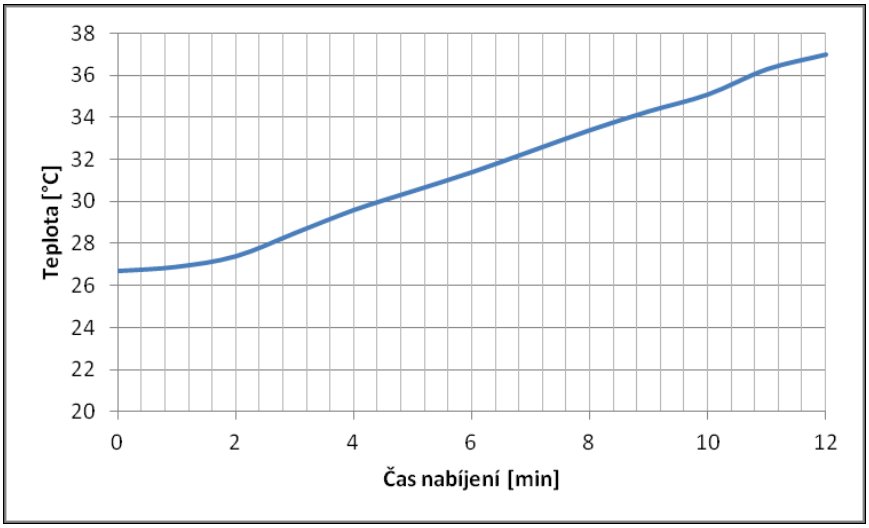


Figure 1: Curve of the maximum temperature of the cell dependent on time during charging.

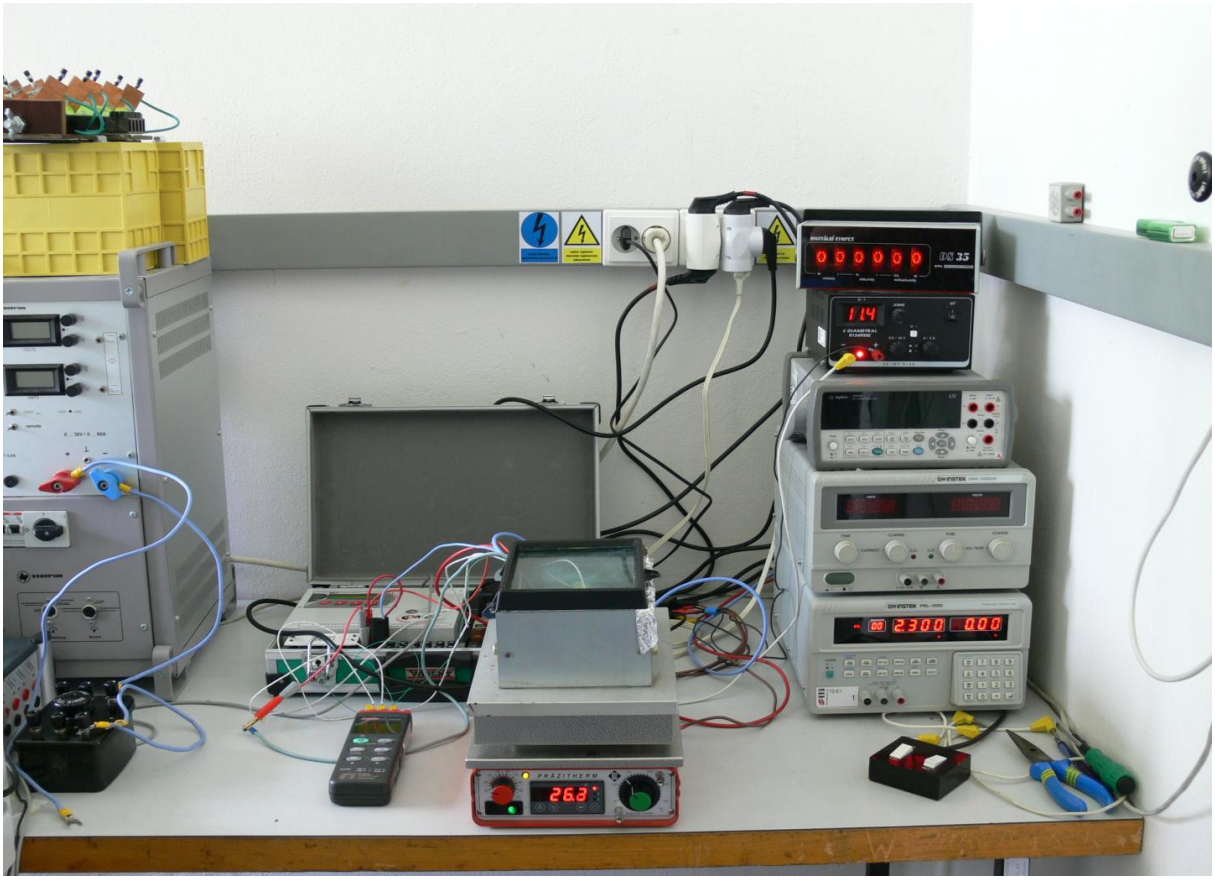
Czech original	English translation
Teplota	Temperature
Čas nabíjení	Charging time

3. Measurement of the heating of cells when charging in the area of temperatures above limit

Workplace:

Heating plate (maximum temperature 250 °C)
Fixture for placement of the cells subject to measurement in the air 20 mm above the plate
Thermistors for the measurement of temperature Ta in the central area of the cells, vertically and longitudinally
Thermistors for the measurement of the cells by contact on the upper surface of the cell beneath the cardboard cover
Four-channel digital thermometer Voltcraft
Statron charger
Digital control panel Comet
Active load Voltcraft
Digital recorder HP

The workplace is pictured below:



Samples for measurement:

Cell A123 26650, sample identification T6, T7. 2 cells were connected serially for the measurement.

Measurement procedure:

Before the measurement at the given ambient temperature (initial temperature of the cells) the cells were discharged with current 1C (DOD 100%) to the final voltage 2V. After the stabilization period of 10 minutes or more at the temperature set for the start of the measurement, the cells were charged from a source of constant current / constant voltage. The charging current was 4C, voltage 2 x 3.6V, i.e., 7.2V. The charging was terminated after signs of full charging have been observed, i.e., very shortly after 15 minutes of charging. A pause of 5 minutes or more followed. Before the next charging cycle, the cells were again discharged using the current 1C, followed by a pause of 10 minutes or more.

The temperature during the measurement was maintained in order to achieve the required initial temperature T6, T7 at time 0 by controlling the ambient temperature Ta by the temperature of the hating plate. Due to the different thermal constants of the system components the values of temperature Ta and the initial temperatures T6, T7 were not exactly identical; preference was given to the temperatures of the cells.

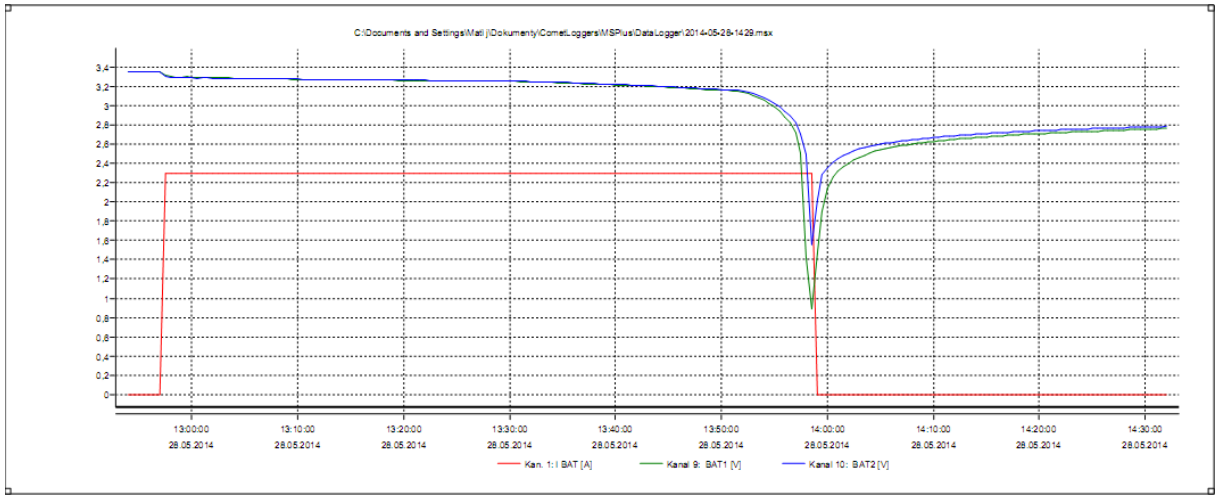
According to the client's requirement, the measurement was performed in the area above the catalog value of the maximum permissible voltage Ta (55 °C) for Ta = 60, 65, 70, 75 °C. With respect to the fact that at Ta = 75 °C the temperature achieved on the cells was over 80 °C, for safety reasons measurement at even higher temperature was not performed in order to prevent contamination of the laboratory environment in the event of a failure, if any, of the leak tightness of the cells.

The attached table clearly implies that when charging with the maximum permissible current 4C the temperature increase (heating) of the cells ranges between 6.0 and 6.8V and is little dependent on the ambient temperature.

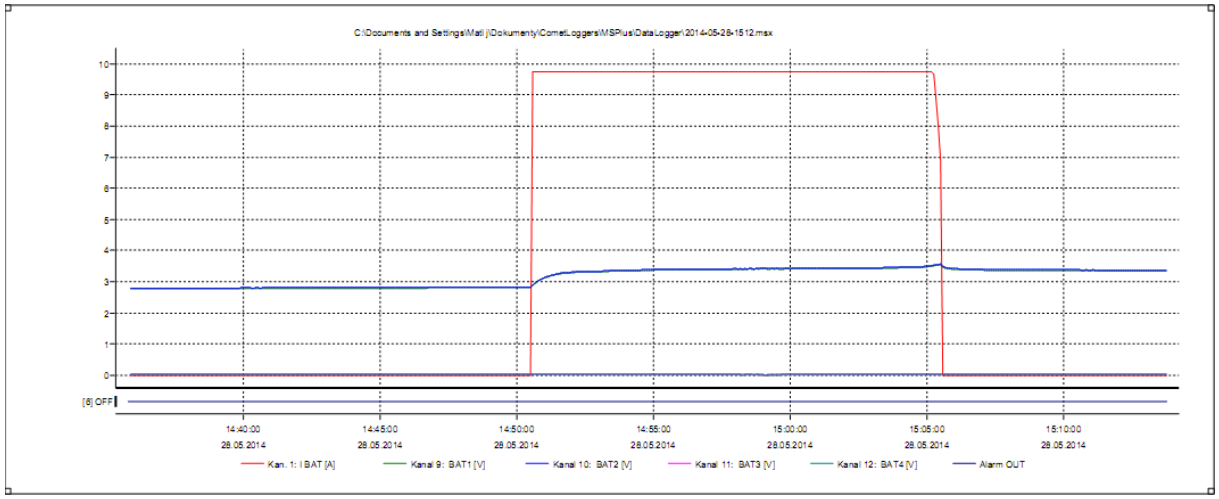
During the discharging mode the achieved capacities of the cells did not charge almost at all depending on the temperature; the voltage synchronism on the cells was manifested somewhat, but not significantly, by differences in the voltage in the final stage of the discharging.

A similar situation occurred also in the end of the charging process. Below we also provide the charging and discharging characteristics for each temperature.

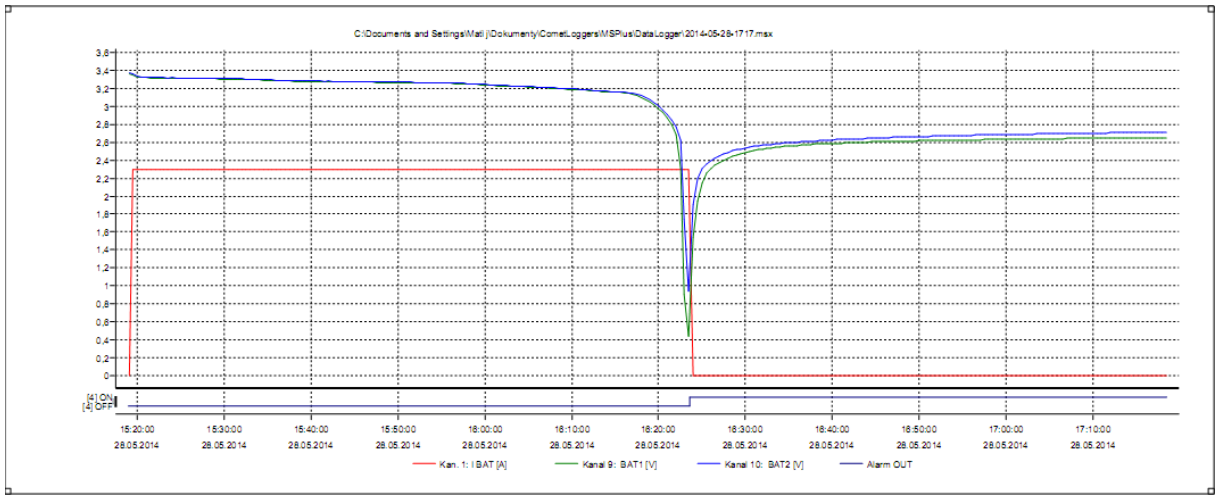
Date	time	Ta	T7	T6		ΔT7	ΔT6
	min	°C	°C	°C		°C	°C
28052014	0	64.9	60.2	59.9			
	5	61.5	62.2	61.6			
	9	62.4	64.3	63.7			
	12	61.5	65.8	65.1			
	15	62.5	66.8	66.0		6.8	6.0
29052014	0	65.7	64.6	65.0			
	8	64.0	67.1	67.2			
	12	65.0	69.6	69.5			
	15	65.0	70.6	70.4		6.0	5.4
29052014	0	71.0	70.0	70.0			
	7	72.0	72.6	72.5			
	12	70.0	75.5	75.2			
	15	70.7	76.6	76.3		6.5	6.3
29052014	0	76.4	75.1	75.1			
	7	75.5	77.6	77.6			
	12	75.9	80.2	80.1			
	15	76.5	81.2	81.1		6.1	6.0



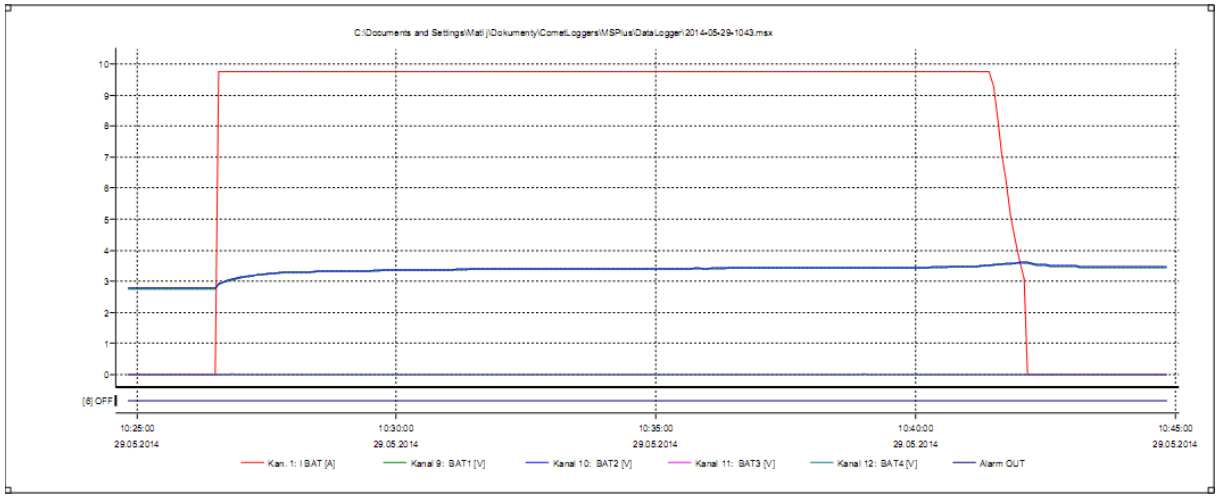
Discharging prior to charging at 60 °C



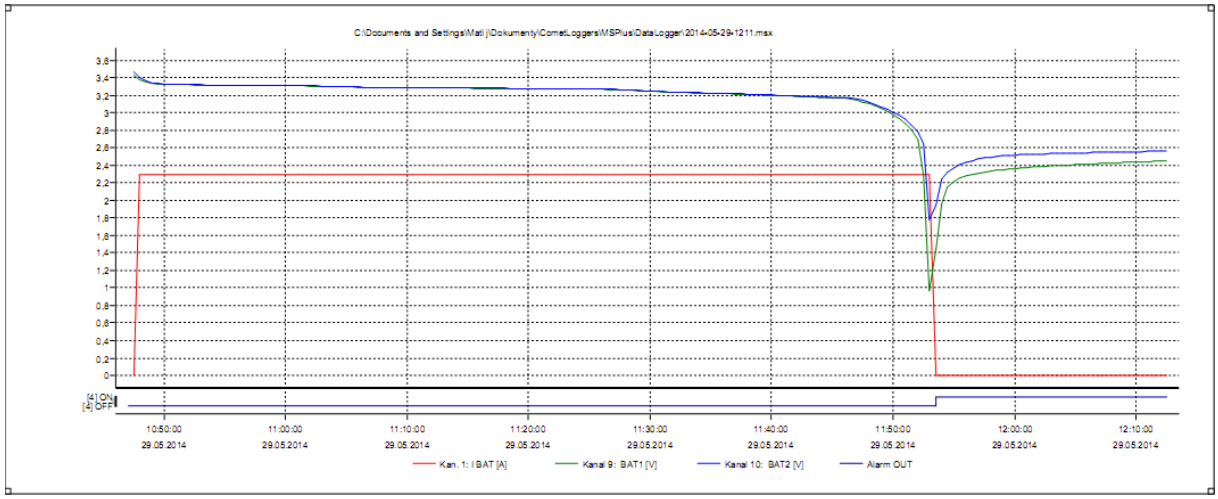
Charging at 60 °C



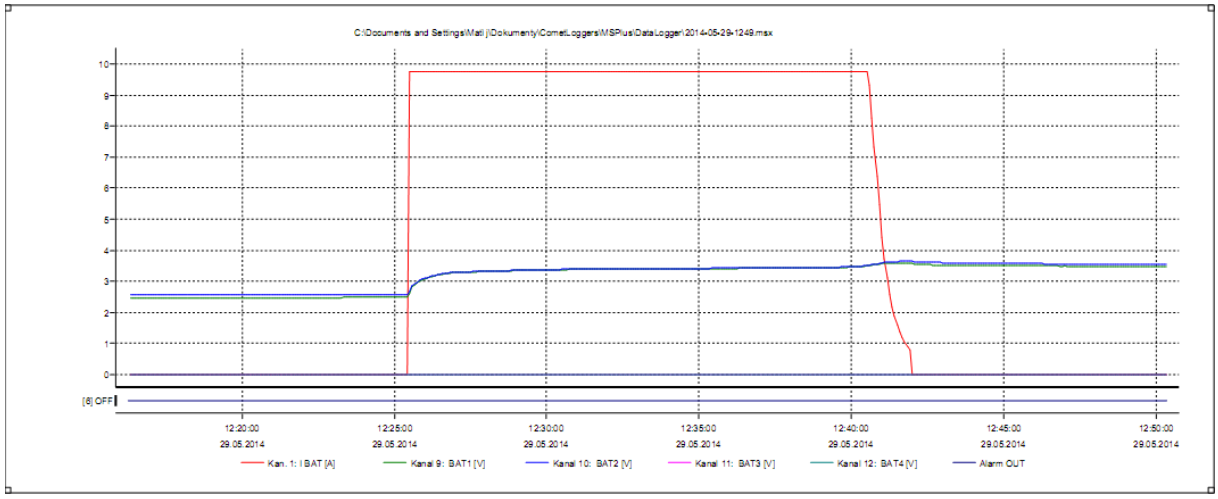
Discharging after charging at 60 °C



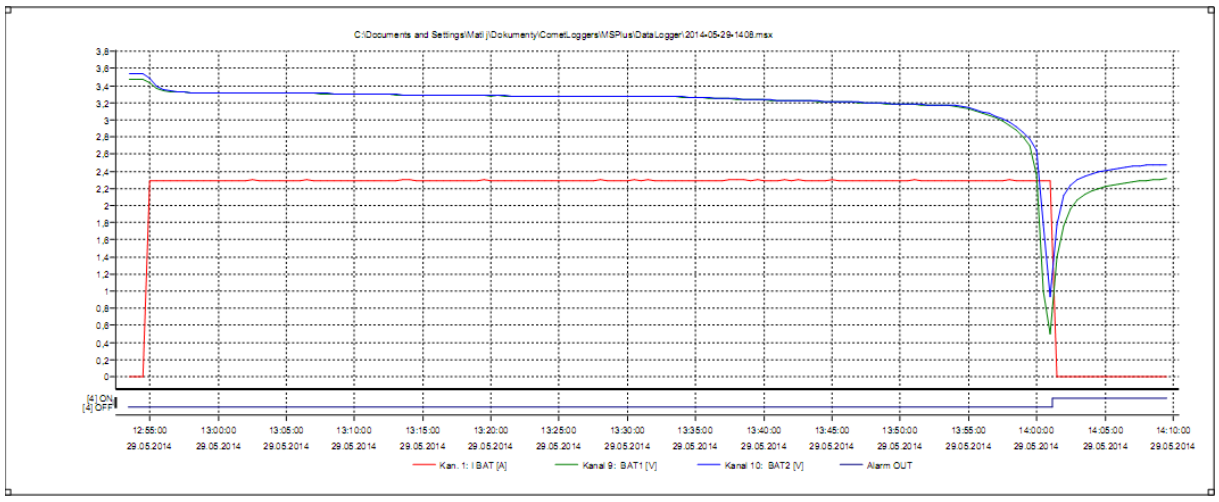
Charging at 65 °C



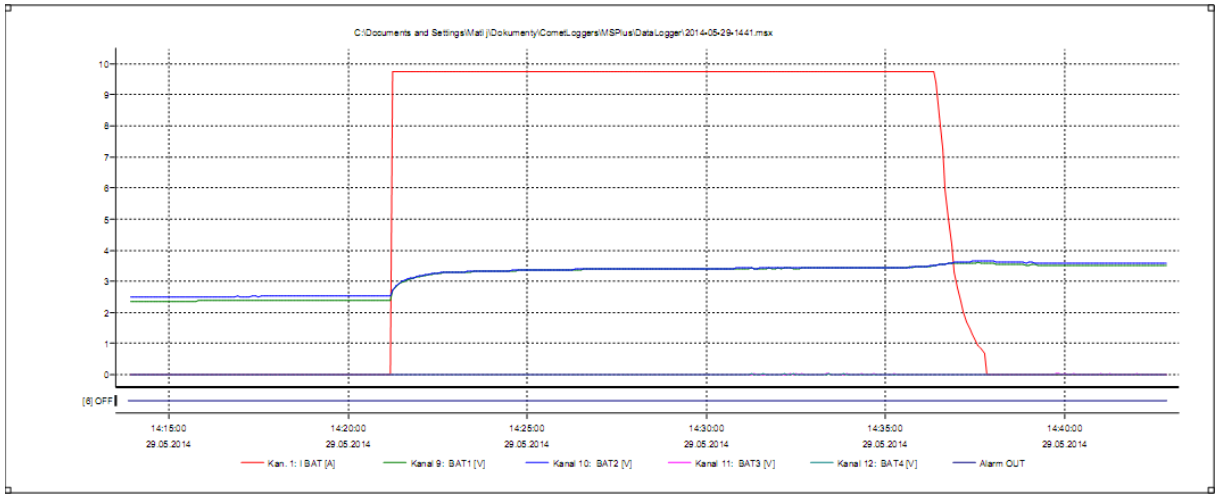
Discharging after charging at 65 °C



Charging at 70 °C



Discharging after charging at 70 °C



Charging at 75 °C

4. Conclusions

The following conclusions have been drawn from the measurements performed:

- The supplied cells are charged at half capacity
- The measured values of the differential resistance of the cells were determined only indicatively; they are close to the catalog values but are not entirely identical for the individual cells
- The actual capacity of the cells corresponds with the data provided in the datasheet
- The achievable capacity is basically independent of the degree of discharging or the size of the charging current
- When charging with the maximum permissible current (4C) almost the entire

charging process occurs in the constant current mode

- The charging voltage on all cells is basically identical during the charging process; the final voltage is somewhat different, but not significantly; it can therefore be assumed that the operation of the battery with 4 cells connected serially will not require balancers
- The temperature increase (heating) of the cell under quick charging is little dependent on the temperature of the cell during the charging process and is approximately 6 °C.
- When charging at ambient temperature 75 °C and final temperature 82 °C the case of the cell was not deformed and no gas blow-off occurred

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