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Technical report on battery testing

About our company.

BATTERY RENOVATION is a company that specializes in professionally testing and refurbishing rechargeable batteries for electric bicycles, scooters, and other devices based on Li-Ion cells.
Additionally, we develop and manufacture specialized, high-precision equipment for diagnosing Li-Ion elements and batteries, as well as assembling new Li-Ion battery packs for various purposes.
We also sell tested Li-Ion cells with a "battery element passport" issued based on test results.

What sets us apart? It's our responsible approach, high expertise, the use of innovative scientific methods, and the availability of unique specialized equipment that allows us to quickly and accurately analyze the parameters of battery packs and Li-Ion cells, ensuring a high standard of diagnostic quality and refurbishment work.

Every rechargeable battery and individual Li-Ion cell we install in a battery pack or sell undergoes rigorous testing, with detailed test results presented in both tabular and graphical formats.

Thanks to our thorough and responsible approach, all our customers not only have the right but also the opportunity to know precisely what they are acquiring. They can not only refurbish their rechargeable batteries or purchase new Li-Ion cells but also acquire a completely accurate and well-documented amount of Watt*Hours of energy.

1. Introduction:

This technical report provides detailed information about the testing of the battery, both before and after renovation (if applicable). The results of each of the two tests are compiled into a final table, and the testing process is visually represented in graphical form.

In the event of battery renovation with the replacement of Li-Ion cells, the test results for each cell installed in the battery are presented in a separate Technical report (in PDF format) in a detailed and visually graphic manner. Before installation in the battery, all Li-Ion cells undergo thorough testing and are individually selected based on their characteristics determined during the testing process.

2. Key features of measurement equipment:

Voltage measurement resolution (volts)	0,0025
Current measurement resolution (amps)	0,001
Time measurement resolution (seconds)	0,0001
Total relative measurement equipment error (not exceeding) (%)	0,25

3. Battery testing stages:

1. **Visual inspection of battery condition with a check of overall functionality**:
   We examine the battery's exterior and check if it's working properly.

2. **Assessment of the battery's internal components** (possible only when the battery casing is opened):
   External evaluation of the Battery Management System (BMS). *The BMS is an electronic board inside the battery responsible for ensuring the battery operates safely and correctly during the charging and discharging processes*. Additionally, the voltage of each individual cell is measured **Voltage of battery cell (Volt)**.

3. **Charging test**:
   If a standard charging device is provided with the battery, we assess its functionality when interacting with the battery. Additionally, an essential safety parameter is recorded—the voltage at which the BMS protection activates to prevent overcharging, known as the **BMS cutoff voltage at the end of charging (Volt)**.

4. **Load test**:
   The battery undergoes brief, intermittent discharges with varying loads and power levels over several seconds. During this test, we determine the **Voltage drop percentage (%)** and calculate the battery's **Battery internal total resistance (effective) (Ohm)** measured during a constant current discharge.

5. **Discharge test of the battery**:
   During the discharge test, fully charged Li-Ion cells within the battery are discharged from a voltage corresponding to full charge (4.2 volts) to a voltage corresponding to full discharge (2.6 volts). The voltage drop scale is divided into segments, each 0.01 volt apart. After each segment (i.e., for every 0.01-volt decrease in cell voltage during discharge), precise measurements of voltage, discharge current, and time are automatically recorded. Based on these measurements, various other parameters, including battery capacity, are calculated.

   Battery capacity **Battery capacity (Watt * hour)** is the sum of the capacities of all battery elements and represents the energy released by the battery over the entire discharge duration.

   At the end of the discharge, another crucial parameter is also recorded to ensure the battery's longevity—the voltage at which the BMS protection activates to prevent over-discharge, known as the **BMS cutoff voltage at the end of discharging (Volt)**.

4. The terminology used in the final battery test results table:

Battery capacity (Watt * hour): The total capacity of the entire battery, equivalent to the energy released from fully charged to fully discharged. It is the sum of the capacities of all the Li-Ion elements within the battery.

Voltage of battery cell (Volt): The voltage at each of the battery cells (measurement possible only when the battery casing is opened).

Voltage drop percentage (%): The decrease in voltage of the battery measured during a load test when the battery discharges for a short duration with a specified power level.

Battery internal total resistance (effective) (Ohm): The calculated overall internal electrical resistance of the battery, which is influenced by various factors. It is measured during a constant current discharge in the load test.

Whole battery power (Watt): The discharge power of the battery during the brief load test.

Average discharge power (Watt): An average value equivalent to the average discharge power of the entire battery (or a single Li-Ion element).

BMS cutoff voltage at the end of charging (Volt): The voltage is measured twice during the charging cycle. First, a few seconds before the BMS protection activates to prevent overcharging. Second, a few seconds after it. The first measurement records the voltage supplied by the charger to the battery before the BMS protection activates, while the second measurement records the voltage of the battery itself after the charger is disconnected.

BMS cutoff voltage at the end of discharging (Volt): The voltage during the discharge cycle that triggers the BMS protection, preventing harmful over-discharge of Li-Ion elements. Voltage is measured twice: first, with the load connected a few seconds before the BMS protection activates, and second, a few seconds after it.

5. The terminology used in the graphic representation of battery testing during discharge:

Voltage (Volt): The battery voltage recorded during the current segment, equivalent to the step in a voltage drop of one Li-Ion element by 0.01 volt.

Discharge time (Second): The total time elapsed from the start of discharge until the parameters are recorded in the current segment.

Current (Amper): The discharge current of the battery recorded during the current segment.

Segment capacity (mWatt * h): The energy released by the battery when the battery voltage drops by 0.01 volts on a single Li-Ion cell during the current segment.

Capacity (Watt * h): The energy released by the battery from the beginning of the discharge, including the segment capacity of the current segment.

Power (Watt): The power of the battery discharge during the current segment.

6. Technical report on battery testing before renovation

6.1 Summary table of battery test results

TEST DATE	17/06/2023
ORDER NUMBER	2306171458
BATTERY BREND	Bosch 400

PRODUSER'S BATTERY CHARACTERISTICS:	
Maximum battery capacity (Watt*hour)	**400**
Maximum battery voltage (Volt)	**42.00**
Minimum battery voltage (Volt)	**25.00**
Amount serial connected Li-Ion elements in battery	**10**
Amount parallel connected Li-Ion elements in battery	**4**
Amount all Li-Ion elements in battery	**40**

Most important battery condition parameters measured during tests	**Data taken from the whole battery**		**Data converted to one Li-Ion element**	
	Test parameter value	**Normal parameter range**	**Test parameter value**	**Normal parameter range**
DISCHARGE TEST (refer to charts below)				
Battery capacity (Watt * hour) (measured with awerage discharge power 159.85 Watt) (equivalent Li-Ion element discharge power 4 Watt)	**158.07**	**-**	**3.95**	> 10
LOAD TESTS (duration 3 secunds)				
Load test 1 (whole battery power 201.231 Watt)				
Voltage drop percentage (%)	**7.29**	< 5	**7.29**	< 5
Battery internal total resistance (effective) (Ohm)	**0.580**	-	**0.232**	0.15
Load test 2 (whole battery power 411.42 Watt)				
Voltage drop percentage (%)	**15.98**	< 10	**15.98**	< 10
Battery internal total resistance (effective) (Ohm)	**0.559**	-	**0.224**	0.15
Load test 3 (whole battery power 568.177 Watt)				
Voltage drop percentage (%)	**25.00**	< 15	**25.00**	< 15
Battery internal total resistance (effective) (Ohm)	**0.562**	-	**0.225**	0.15
Battery Managment Sistem HEALTH TESTS				
BMS cutoff voltage at the end of charging (Volt) **before / after** BMS overcharge protection triggered	**42.32** **42.32**	**-**	-	4.25
BMS cutoff voltage at the end of discharging (Volt) **before / after** BMS overdischarge protection triggered	**25.85** **25.83**	**-**	-	2.5

Conclusion based on diagnostic results: Replacement of Li-ion elements is required.

Voltage of battery cell (Volt)	
Cell number	**Voltage (Volt)**
1	4.03
2	4.02
3	3.92
3	4.03
5	4.02
6	4.03
7	4.03
8	4.02
9	4.02
10	4.03
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6.2 Graphic representation of parameters during discharge testing relative to discharge time (Charts 1 - 4) before renovation

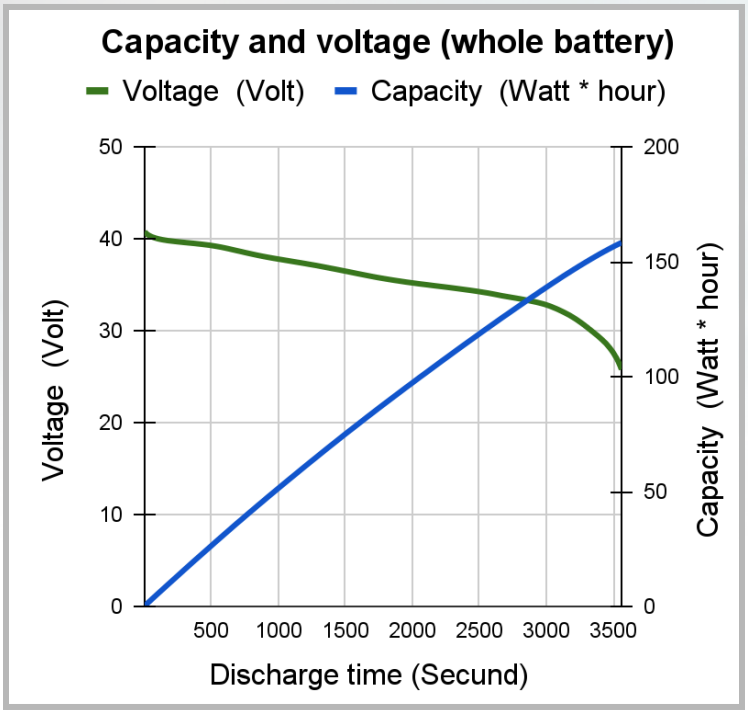

Chart 1

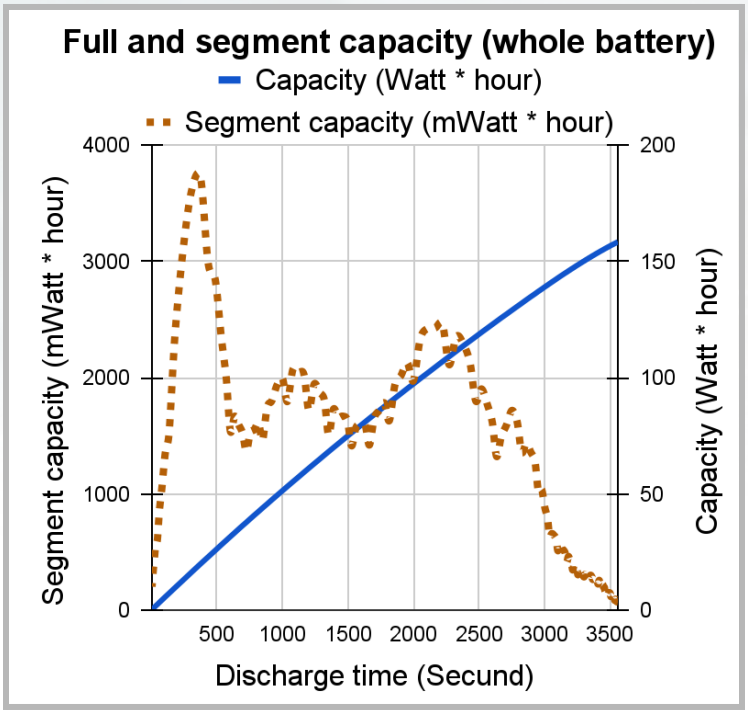

Chart 2

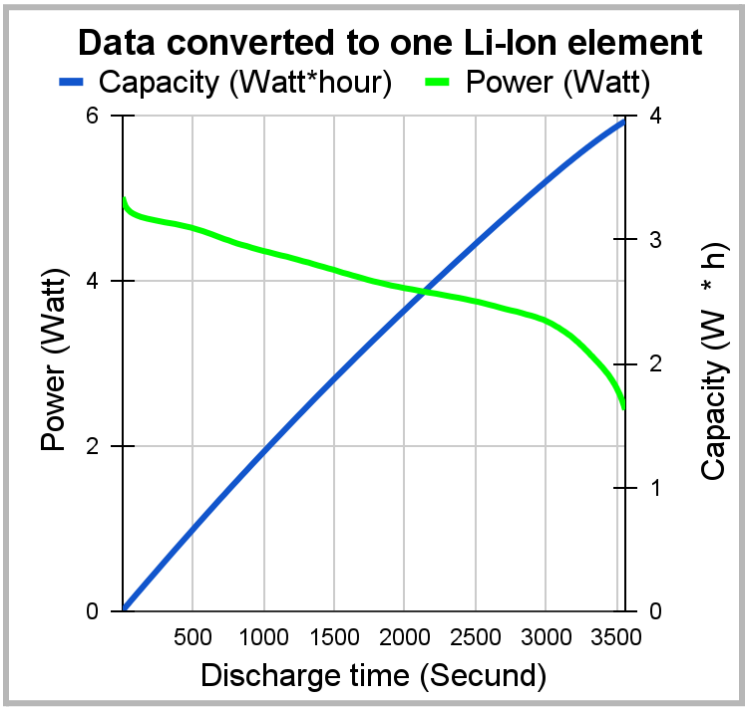

Chart 3

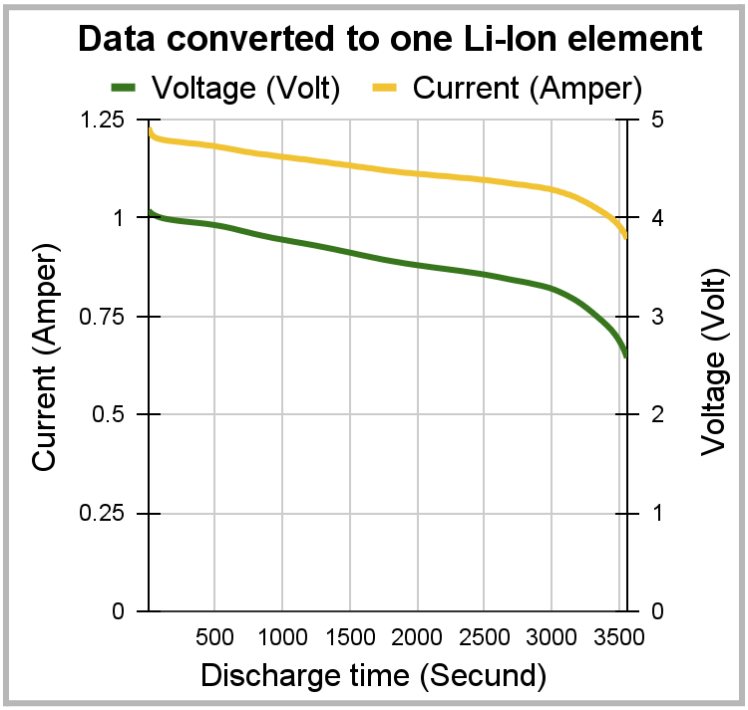

Chart 4

6.3 Graphic representation of parameters during discharge testing relative to battery voltage (Charts 5, 6) and relative to a single Li-Ion cell voltage (Charts 7, 8) before renovation

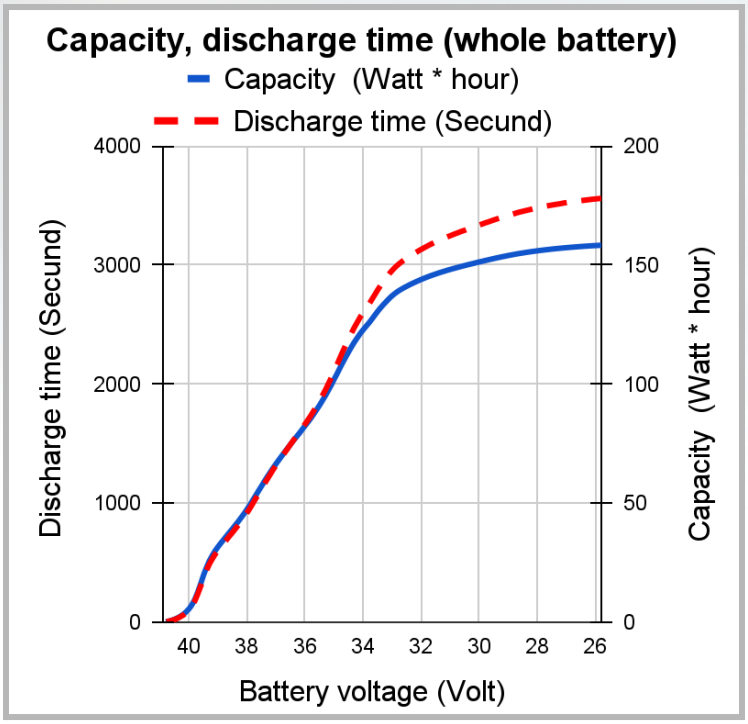

Chart 5

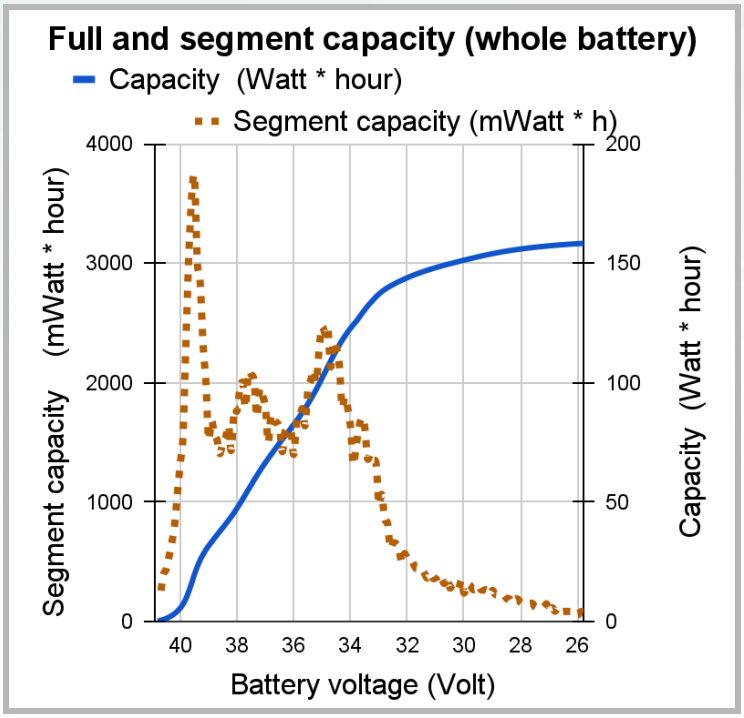

Chart 6

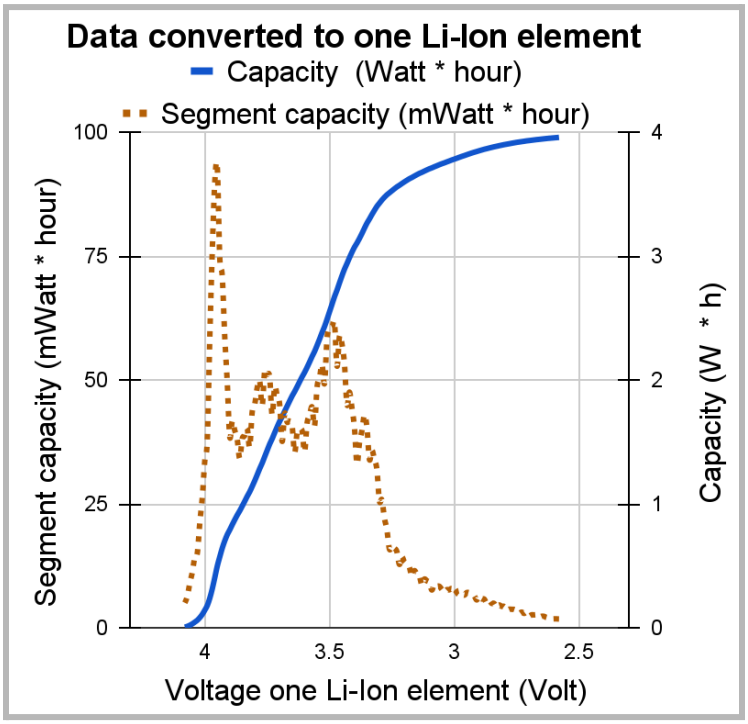

Chart 7

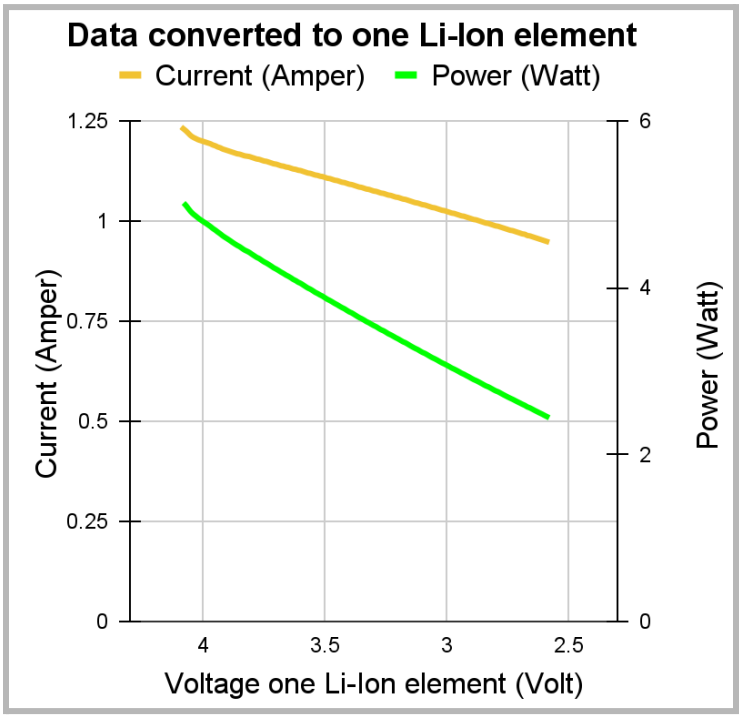

Chart 8

7. Technical report on battery testing after renovation

7.1 Summary table of battery test results

TEST DATE	18/06/2023
ORDER NUMBER	2306171458
BATTERY BREND	Bosch 400

PRODUSER'S BATTERY CHARACTERISTICS:	
Maximum battery capacity (Watt*hour)	**400**
Maximum battery voltage (Volt)	**42.00**
Minimum battery voltage (Volt)	**25.00**
Amount serial connected Li-Ion elements in battery	**10**
Amount parallel connected Li-Ion elements in battery	**4**
Amount all Li-Ion elements in battery	**40**

Most important battery condition parameters measured during tests	**Data taken from the whole battery**		**Data converted to one Li-Ion element**	
	Test parameter value	**Normal parameter range**	**Test parameter value**	**Normal parameter range**
DISCHARGE TEST (refer to charts below)				
Battery capacity (Watt * hour) (measured with awerage discharge power 157.66 Watt) (equivalent Li-Ion element discharge power 3.94 Watt)	**482.12**	-	**12.053**	> 10
LOAD TESTS (duration 3 secunds)				
Load test 1 (whole battery power 204.54808 Watt)				
Voltage drop percentage (%)	**2.93**	< 5	**2.93**	< 5
Battery internal total resistance (effective) (Ohm)	**0.226**	-	**0.091**	0.15
Load test 2 (whole battery power 462.39456 Watt)				
Voltage drop percentage (%)	**6.78**	< 10	**6.78**	< 10
Battery internal total resistance (effective) (Ohm)	**0.222**	-	**0.089**	0.15
Load test 3 (whole battery power 685.6906 Watt)				
Voltage drop percentage (%)	**10.44**	< 15	**10.44**	< 15
Battery internal total resistance (effective) (Ohm)	**0.220**	-	**0.088**	0.15
Battery Managment Sistem HEALTH TESTS				
BMS cutoff voltage at the end of charging (Volt) **before / after** BMS overcharge protection triggered	**42.31** **42.31**	-	-	4.25
BMS cutoff voltage at the end of discharging (Volt) **before / after** BMS overdischarge protection triggered	**25.85** **25.85**	-	-	2.5

Conclusion based on diagnostic results: The battery is in good condition and ready to use.

Voltage of battery cell (Volt)	
Cell number	**Voltage (Volt)**
1	3.681
2	3.681
3	3.682
3	3.681
5	3.682
6	3.681
7	3.682
8	3.682
9	3.681
10	3.681
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7.2 Graphic representation of parameters during discharge testing relative to discharge time (Charts 9 - 12) after renovation

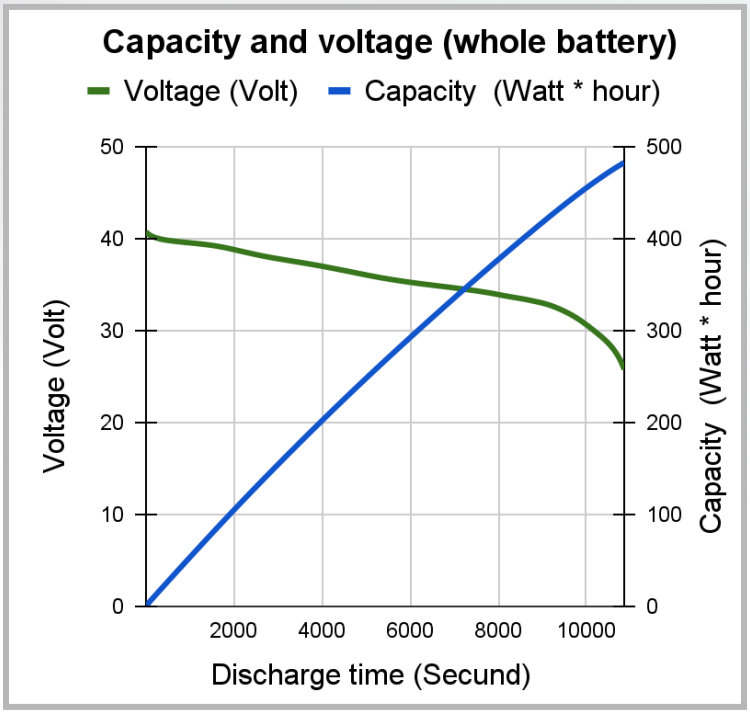

Chart 9

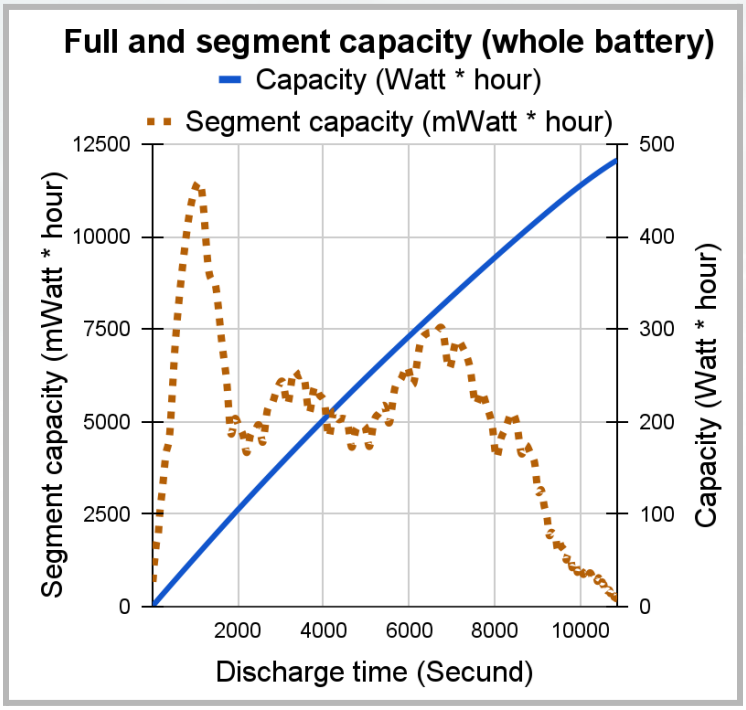

Chart 10

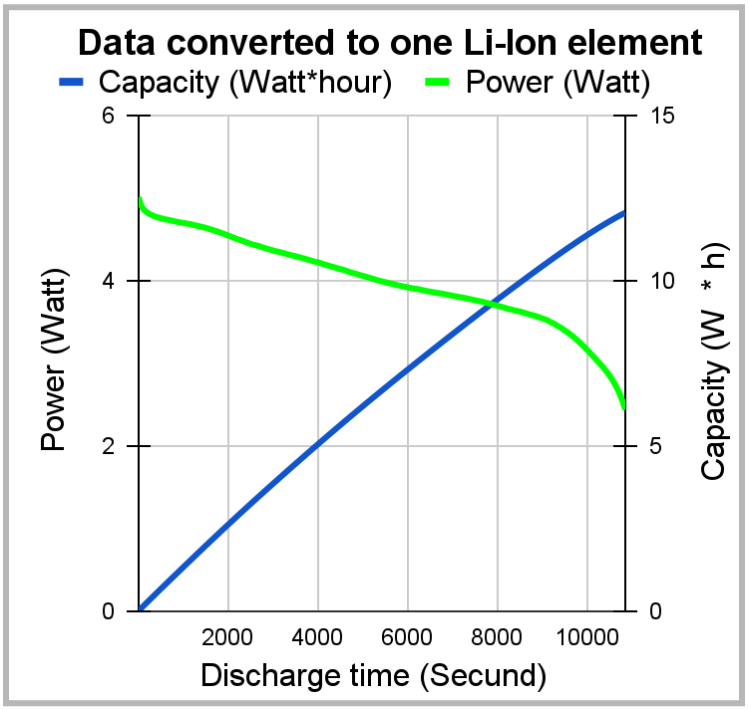

Chart 11

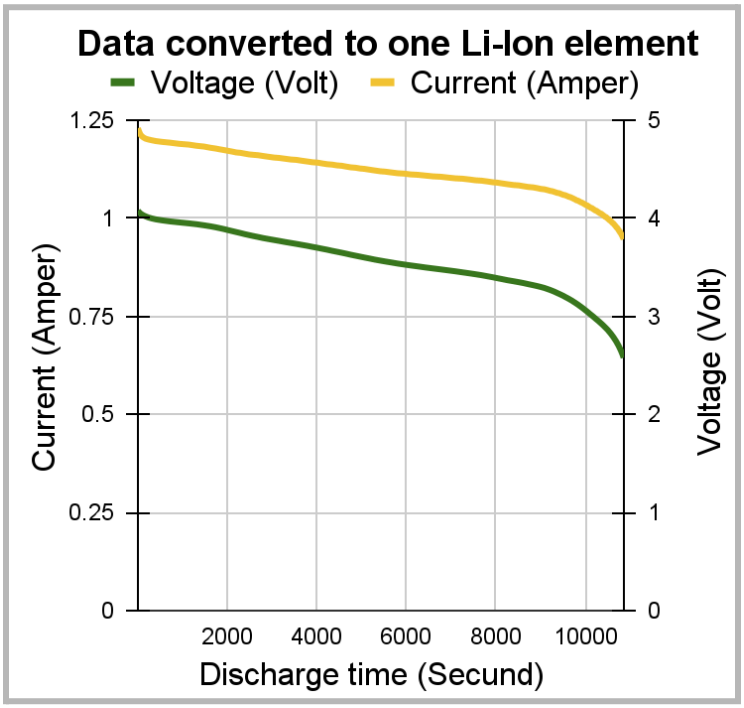

Chart 12

7.3 Graphic representation of parameters during discharge testing relative to battery voltage (Charts 13, 14) and relative to a single Li-Ion cell voltage (Charts 15, 16) after renovation

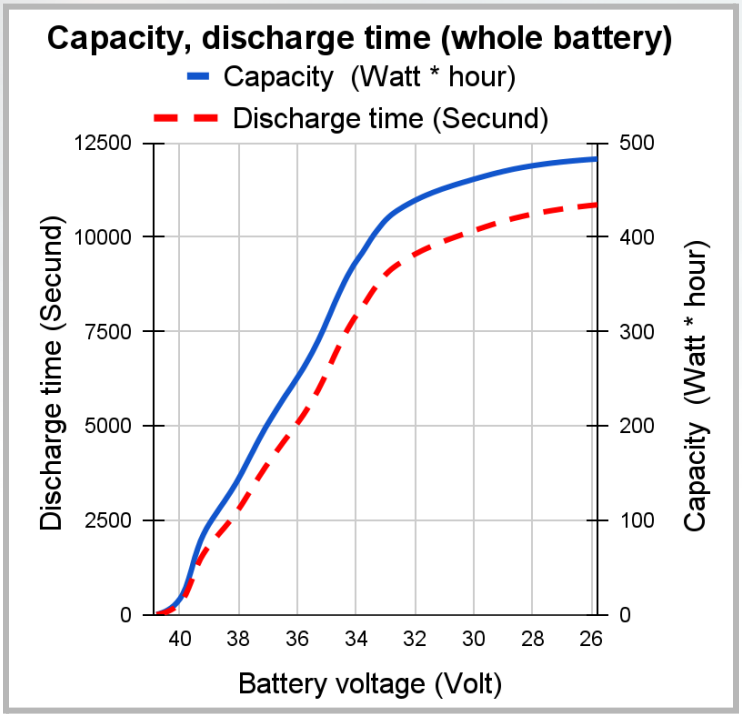

Chart 13

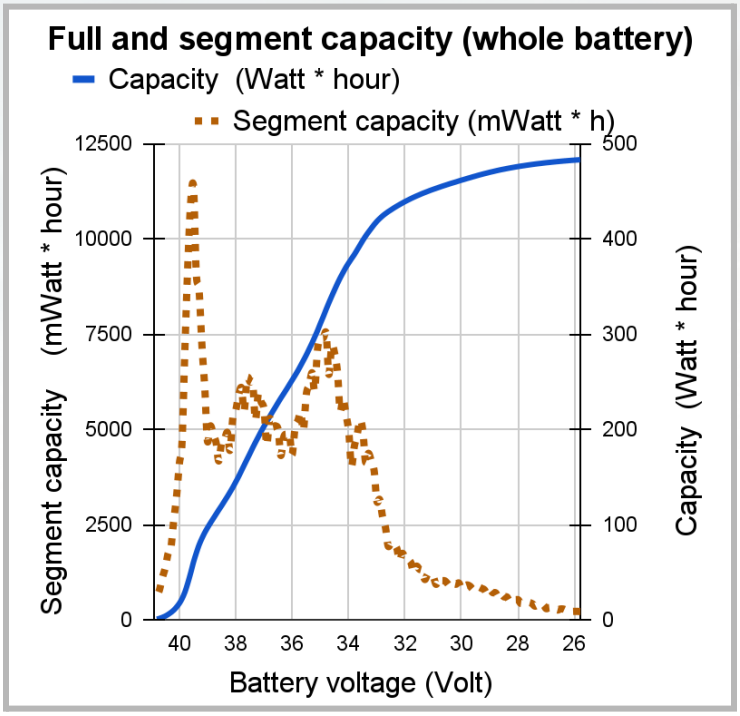

Chart 14

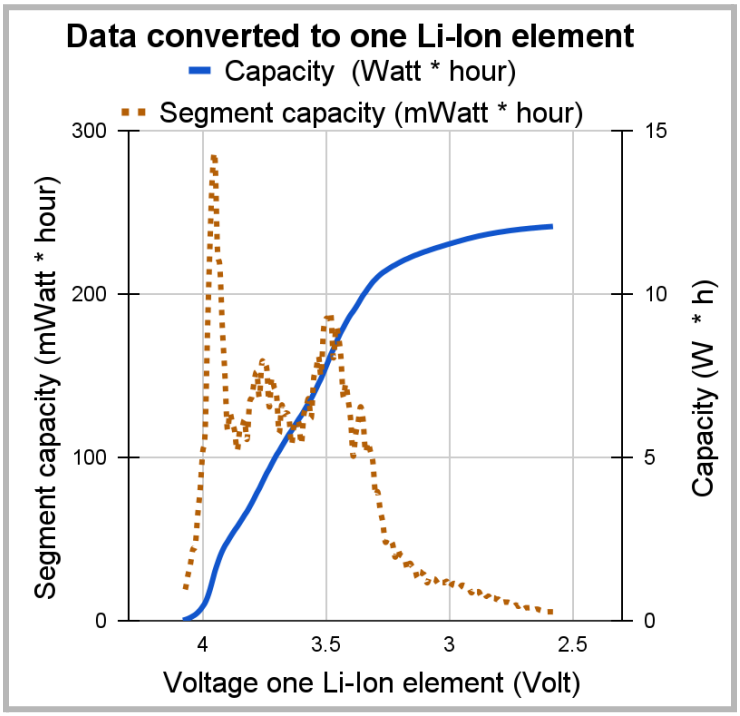

Chart 15

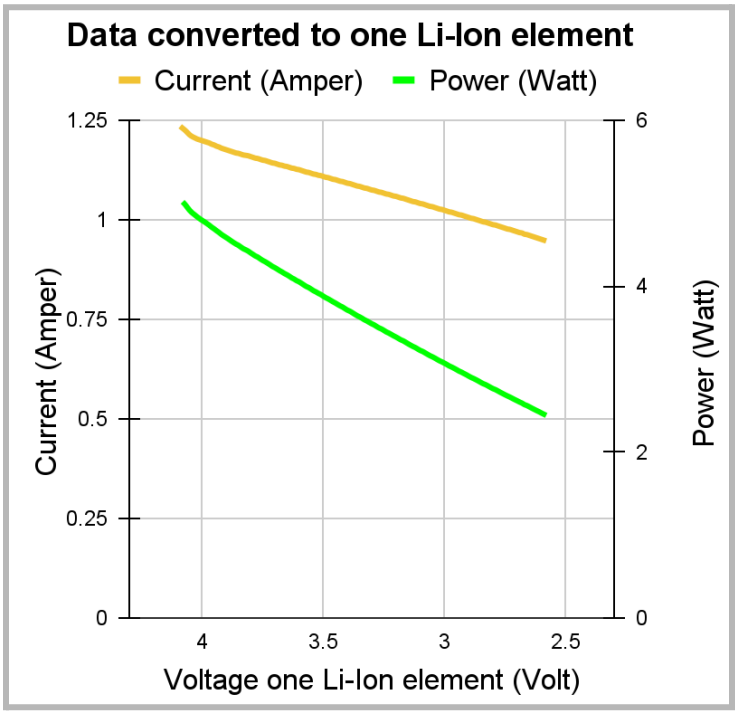

Chart 16