CUSTOMER REPORT

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Donut Lab Solid-State Battery V1 5C Cycling Test of a Damaged Cell

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beyond the obvious

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Summary

The aim of the project was to conduct independent performance tests on the energy storage devices supplied by the customer, which the customer identified as solid-state battery cells. Three visually identical cells were provided for testing and labeled DL1, DL2, and DL3. In the tests reported herein, cell DL2 was subjected to continuous cycling for 50 cycles at a rate of 5C between 0–90 % state of charge (SOC), using the maximum voltage range specified for the cell (2.7–4.3 V). The tested cell had been subjected to separately reported performance tests prior to this test. In a previous test, the cell had lost its vacuum during the discharge test conducted at 100 °C. The aim of the present 5C cycling test was to assess whether the damaged cell remained functional when subjected to high charge and discharge currents following the loss of vacuum.

The initial reference performance test yielded an average 1C discharge capacity of 24.689 Ah, based on five consecutive 1C cycles. After six cycles at 5C, the discharge capacity began to decrease rapidly and continued to do so for approximately 15 cycles, after which the rate of capacity degradation slowed and the capacity stabilized. The average 1C discharge capacity measured during the reference performance test after 50 cycles at 5C was 11.194 Ah, corresponding to a 54.66 % reduction compared to the initial capacity. The average energy efficiency during the 1C cycles, calculated from the reference performance test data, decreased from an initial value of 89.6 % to 83.0 %. After completion of the test, the cell thickness had increased by 17 %, and the cell pouch was firm.

Espoo 13.3.2026

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1. Description and objectives

The aim of the project was to conduct independent performance tests on the energy storage devices supplied by the customer, which the customer identified as solid-state battery cells. Three visually identical cells were provided for testing and labelled DL1, DL2, and DL3. In the tests reported herein, cell DL2 was subjected to continuous cycling for 50 cycles at a rate of 5C between 0–90 % state of charge (SOC), using the maximum voltage range specified for the cell (2.7–4.3 V), as shown in Table 1 and described in Section 2. The tested cell had been subjected to separately reported performance tests prior to this test. The cell remained under VTT's control throughout the testing campaign. In a previous test, the cell had lost its vacuum during the discharge test conducted at 100 °C. The aim of the present 5C cycling test was to assess whether the damaged cell remained functional when subjected to high charge and discharge currents following the loss of vacuum.

The specification of the device under test is presented in Table 1. All tests described in this report were carried out in accordance with the customer's test plan. The tests were performed using a PEC ACT0550 cell tester, with the cell placed between two heatsinks inside a climate test chamber as shown in Figure 1. The specifications of the battery tester and the climate test chamber are presented in Table 2 and Table 3, respectively.

Table 1. Preliminary specification of the device under test, as provided by the customer.

Type of cell	Donut Solid State Battery V1
Nominal capacity	26 Ah at 1C (standard discharge)
Nominal voltage	3.6 V
Nominal energy	94 Wh
Recommended voltage	2.7–4.15 V
Standard charging method	CC–CV @ 1C, 4.15 V, CV cut-off 0.05C
Maximum charging voltage	4.3 V

Table 2. Specification of the battery tester.

Product	PEC ACT0550 cell tester, 80 channels
Output voltage	0–5 VDC
Voltage measurement accuracy	0.005% fsd
Voltage measurement resolution	1.9 µV
Automatically switched current ranges	0–50 mA, 50–500 mA, 0.5–5 A, 5–50 A
Current measurement accuracy	0.03% fsd (each current range)
Current measurement resolution	8 µA

Table 3. Specification of the climate test chamber.

Product	Weiss LabEvent T/110/40/3
Test space volume nominal	110 litres
Test space dimensions H x W x D	630x560x350 mm
Temperature range	-40 °C to +180 °C
Average temperature rate	3.5 K/min
Temperature deviation in time	±0.2 K to ±0.5 K
Temperature homogeneity	±0.5 K to ±1.5 K

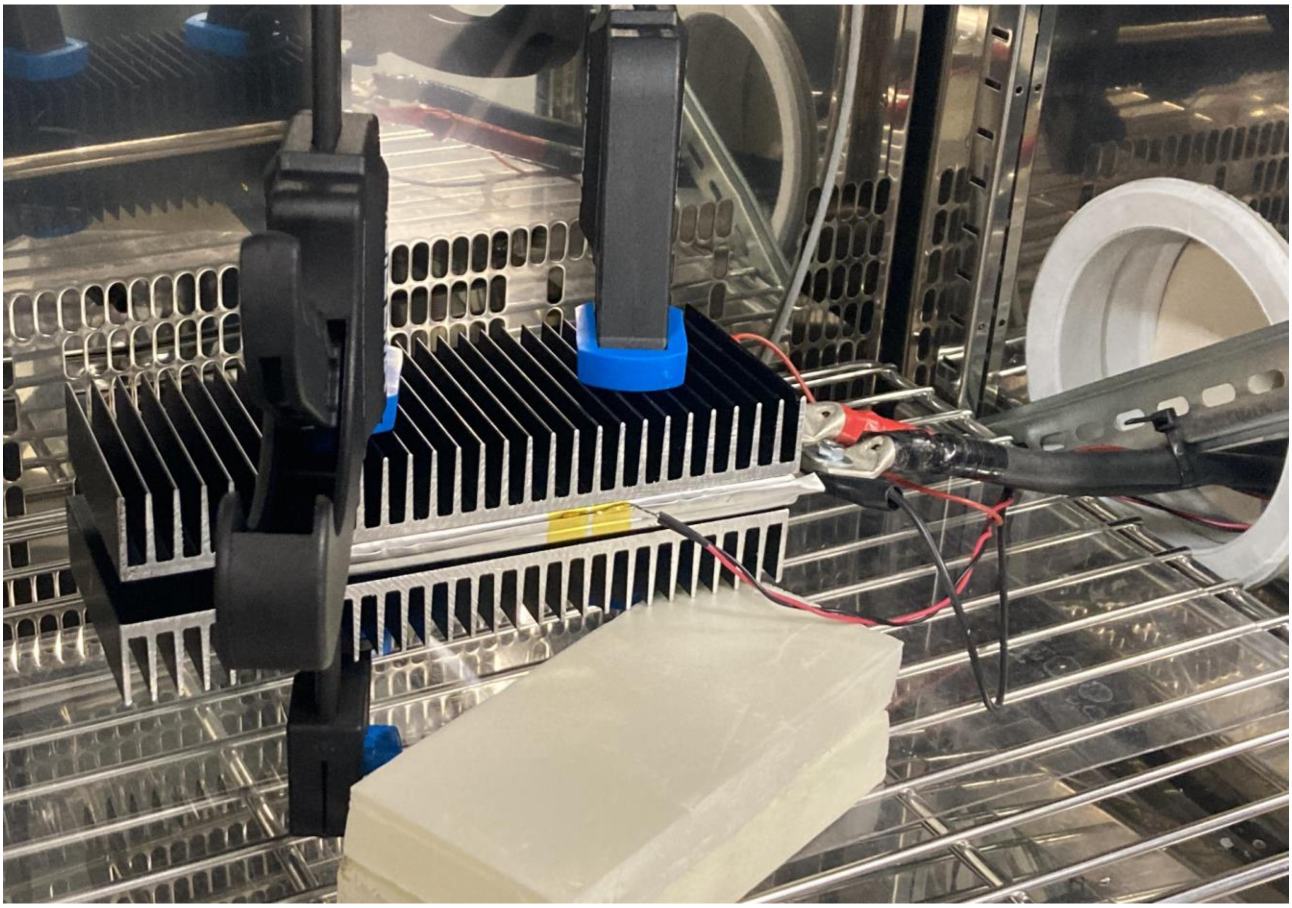

Figure 1. The cell positioned between heat sinks, with a temperature sensor attached under the folded seam on the side of the cell.

2. Methods

2.1 5C cycling test at +25 °C

The cell was placed between heat sinks inside a climate test chamber. Current cables were attached to the cell tabs by securing cable lugs with bolts passing through the tab holes.

Start: The climate test chamber temperature setpoint was set to +25 °C. After a one-hour idle period, the cell was charged at a constant current of 26 A (1C) until the highest recommended voltage of 4.15 V was reached, followed by constant-voltage charging at 4.15 V until the current decreased to 1.3 A (0.05C), corresponding to the standard charge procedure.

Cycles 1–5 (Reference Performance Test using 1C standard cycles): After a one-hour idle period, the cell was discharged at a constant current of 26 A (1C) until the voltage reached 2.7 V (standard discharge procedure). After a one-hour idle period the cell was charged using standard charge procedure. This standard cycle was repeated five times in total as a reference performance test (RPT).

Cycle 6 (Reference Cycle using 5C current): After a one-hour idle period, the cell was discharged at a constant current of 130 A (5C) until the voltage reached 2.7 V, followed by constant-voltage discharging at 2.7 V until the current decreased to 26 A (1C), corresponding to 0 % SOC. In the subsequent 5C cycle life testing, 90 % of the discharge capacity measured in this reference cycle was used as the charge limit. After a five-minute idle period, the cell was charged at a constant current of 130 A (5C) until the maximum voltage of 4.3 V was reached, followed by constant-voltage charging at 4.3 V until either 90 % of the reference-cycle capacity was reached or the current decreased to 26 A (1C). This was followed by a five-minute idle period.

Cycles 7–55 (5C Cycling Test): The cell was discharged using same procedure as in Reference Cycle (Cycle 6), at a constant current of 130 A (5C) until the voltage reached 2.7 V, followed by constant-voltage discharging at 2.7 V until the current decreased to 26 A (1C). After a five-minute idle period, the cell was charged at a constant current of 130 A (5C) until the voltage reached 4.3 V, followed by constant-voltage charging at 4.3 V until either 90 % of the Reference Cycle (Cycle 6) capacity was reached or the current decreased to 26 A (1C), followed by a five-minute idle period. This cycle was repeated 49 times in total.

Cycles 56–60 (Reference Performance Test): Five 1C standard cycles were performed as a reference performance test. The discharge capacity in Ah, discharge energy in Wh, charge capacity in Ah and charge energy in Wh were recorded for each cycle, and changes in these numbers were used to evaluate performance degradation during the 5C Cycling Test.

The voltage, current, cell surface temperature, ambient temperature, charge capacity and discharge capacity during the initial RPT cycles (Cycles 1–5), a full cycle from the 5C Cycling Test (Cycle 8), all 5C Cycling Test cycles (Cycles 6–55), and the RPT cycles at 1C (Cycles 56–60) are presented in Figure 2, Figure 3, Figure 4, and Figure 5, respectively.

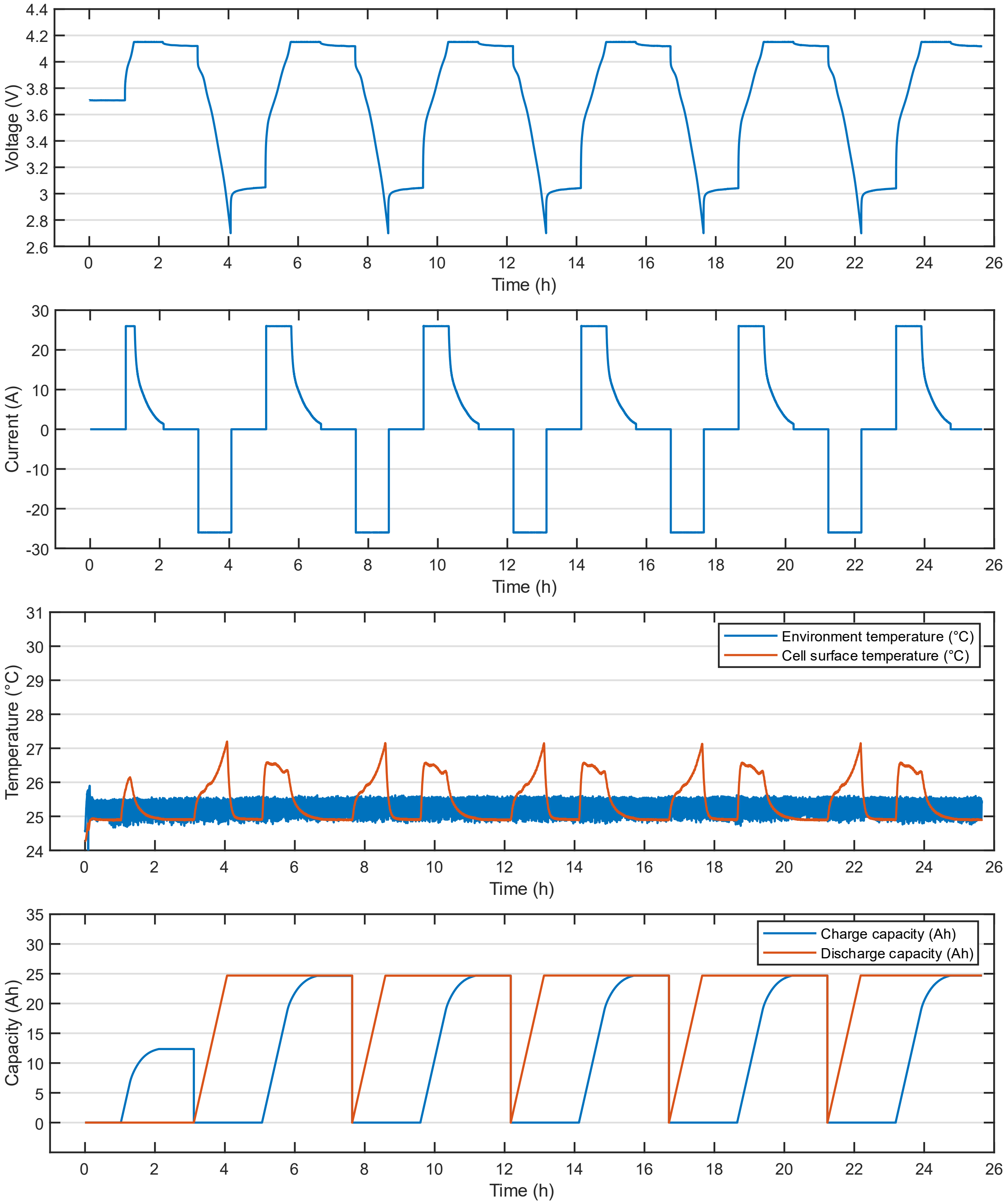

Figure 2. Voltage, current, cell surface temperature, ambient temperature, charge capacity and discharge capacity during the initial RPT using 1C standard cycles (Cycles 1–5).

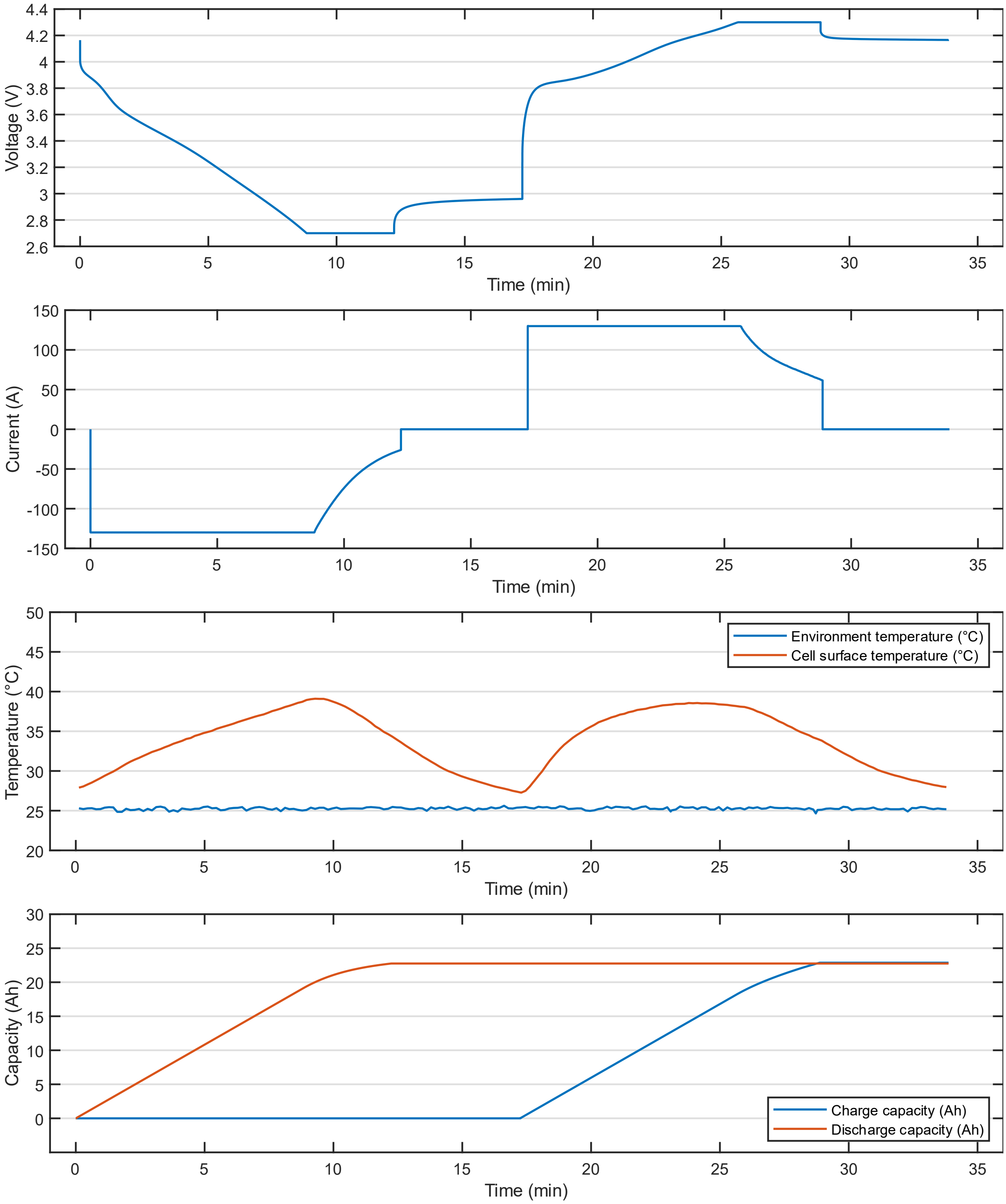

Figure 3. Voltage, current, cell surface temperature, ambient temperature, charge capacity and discharge capacity during one full cycle from the 5C Cycling Test (Cycle 8).

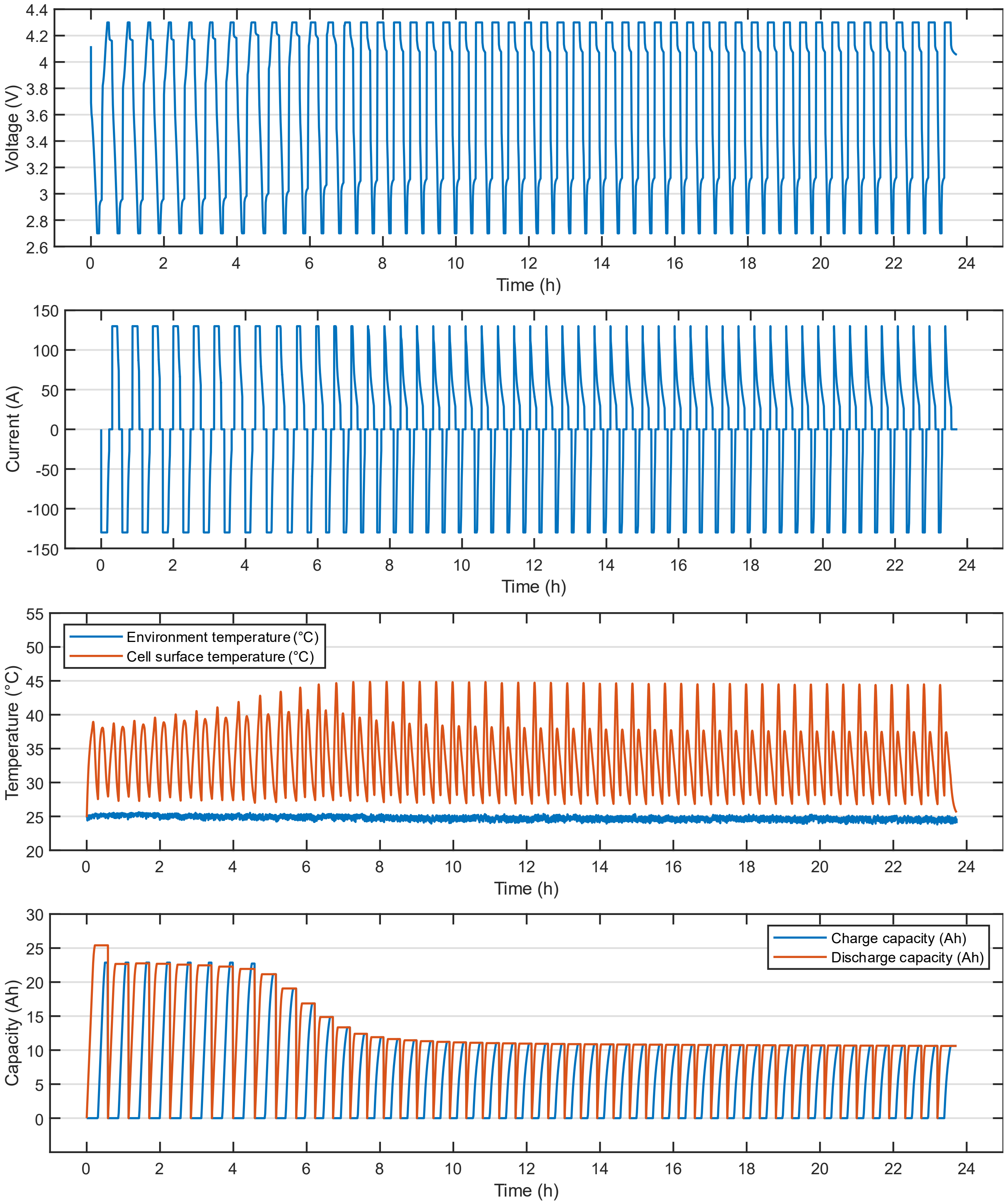

Figure 4. Voltage, current, cell surface temperature, ambient temperature, charge capacity and discharge capacity during 5C cycling test (Cycles 6–55).

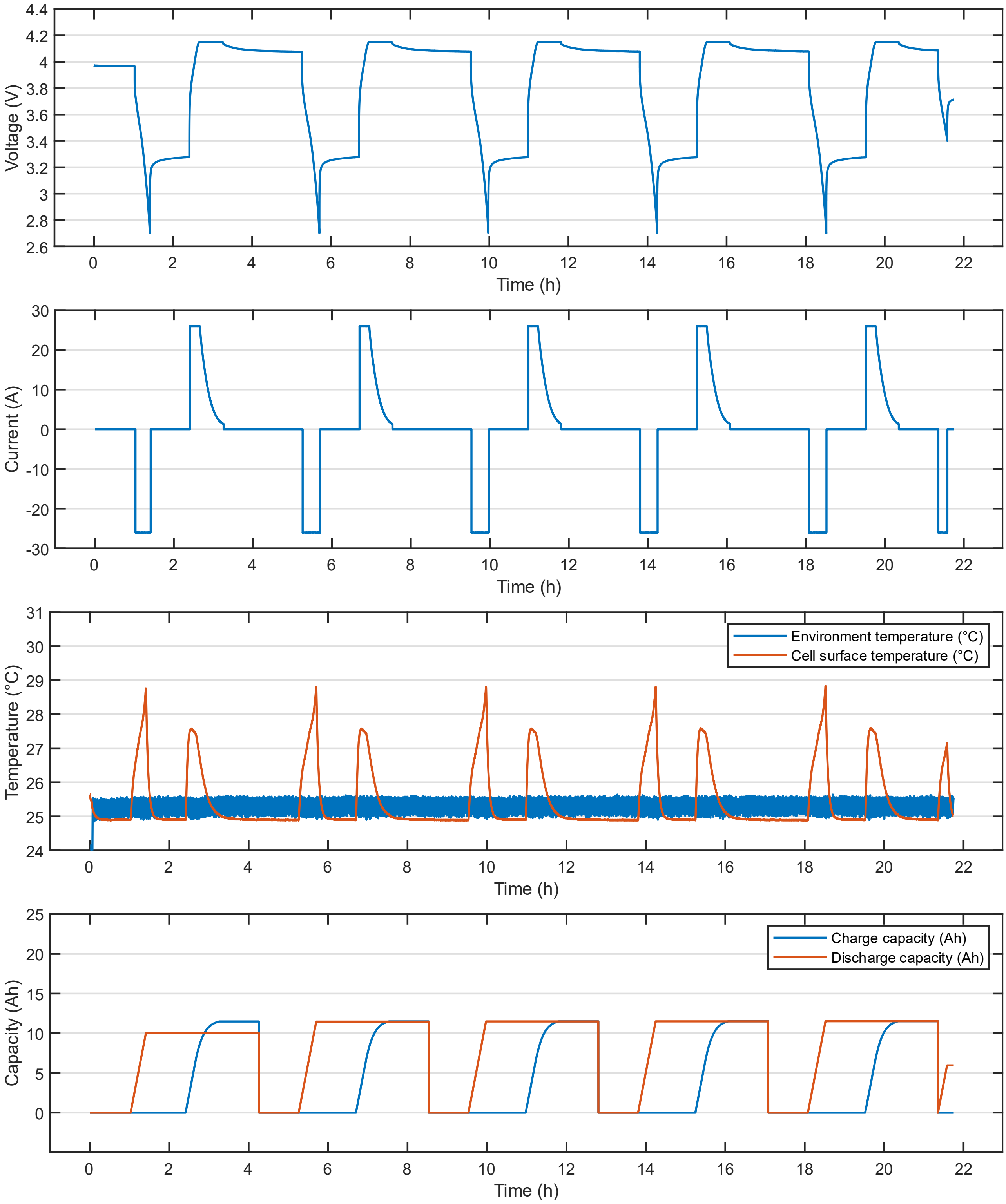

Figure 5. Voltage, current, cell surface temperature, ambient temperature, charge capacity and discharge capacity during the RPT 1C cycles after the 5C Cycling Test (Cycles 56–60).

3. Results

3.1 1C discharge capacity

The average discharge capacity during the five 1C cycles was initially 24.689 Ah. After 50 cycles at 5C, the average discharge capacity was 11.194 Ah. The results for each cycle are presented in Table 4 and Figure 6.

Table 4. Reference performance test cycle data.

	Disch. Capacity (Ah)	Disch. Energy (Wh)	Ch. Capacity (Ah)	Ch. Energy (Wh)
Initial	24.692	85.640	24.638	95.612
	24.673	85.676	24.673	95.699
	24.696	85.769	24.676	95.671
	24.684	85.734	24.689	95.701
	24.701	85.807	24.681	95.641
After 50 cycles	10.010	33.322	11.484	46.447
	11.468	38.529	11.492	46.466
	11.488	38.597	11.497	46.482
	11.496	38.627	11.510	46.532
	11.511	38.679	11.514	46.546

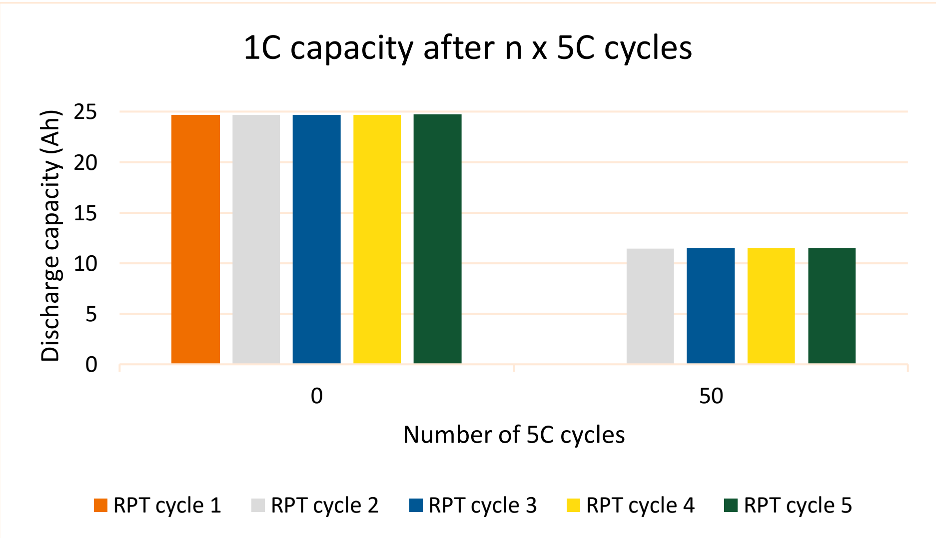

Figure 6. 1C capacity measured during the reference performance tests.

3.2 1C energy efficiency

The average energy efficiency during five 1C cycles was initially 89.6 %. After 50 cycles at 5C, the efficiency had decreased to 83.0 %. The results for each individual cycle are presented in Figure 7.

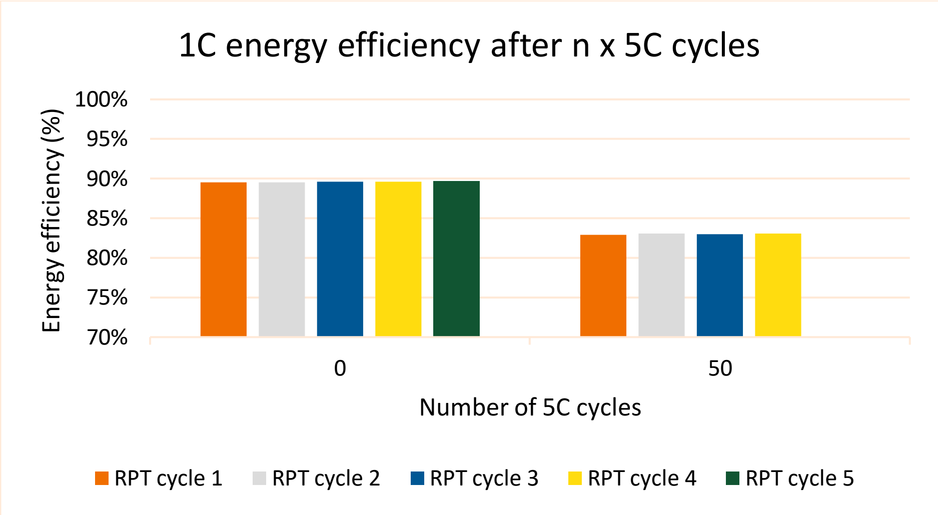

Figure 7. Energy efficiency measured during the reference performance tests.

3.3 Discharge and charge capacity during 5C cycles

The first full 5C discharge capacity (Cycle 6) was 25.405 Ah. Based on this value, the maximum charge capacity limit during the 5C Cycling Test was fixed at 22.866 Ah for Cycles 7–55. However, after six 5C cycles, the cell capacity had decreased to the extent that the 1C termination current during constant-voltage charging was reached in all subsequent cycles.

The measured discharge capacity during 5C cycling was initially 22.671 Ah (Cycle 7). During Cycles 12–26, the discharge capacity dropped rapidly from 22.280 Ah to 11.082 Ah, after which the capacity degradation rate slowed and the capacity stabilized. By Cycle 55, the discharge capacity had further decreased to 10.6626 Ah. The ratio of discharged capacity to charged capacity is presented in Figure 8.

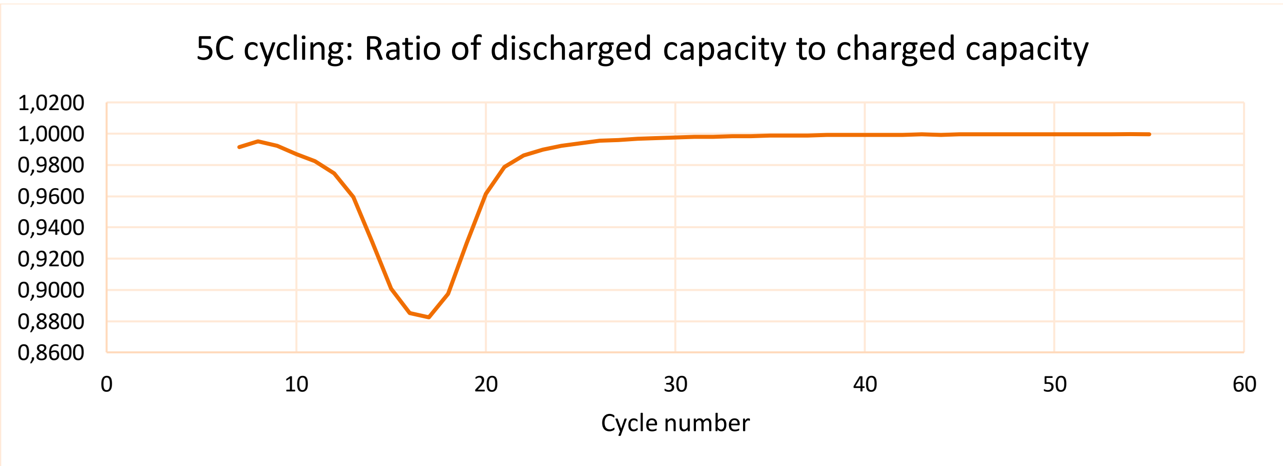

Figure 8. Ratio of discharge capacity to charge capacity during 5C cycling.

3.4 Energy efficiency during 5C cycles

The energy efficiency during the 5C cycles, defined as the ratio of discharged energy to charged energy, is presented in Figure 9.

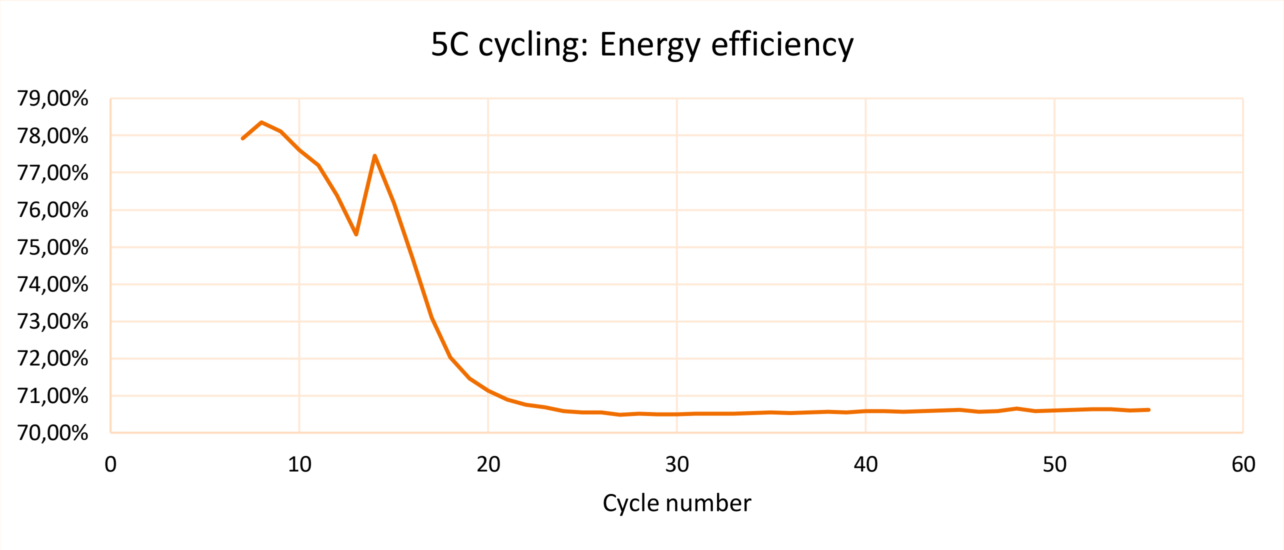

Figure 9. Energy efficiency during 5C cycling.

3.5 Cell physical condition

Images of the cell before and after the test are shown in Figure 10 and Figure 11, respectively. Prior to the test, the cell pouch had lost it vacuum during the previous high-temperature test conducted at 100 °C, and the pouch was loose and wrinkled. After the test, the cell thickness had increased by 17 %, and the cell pouch was firm.

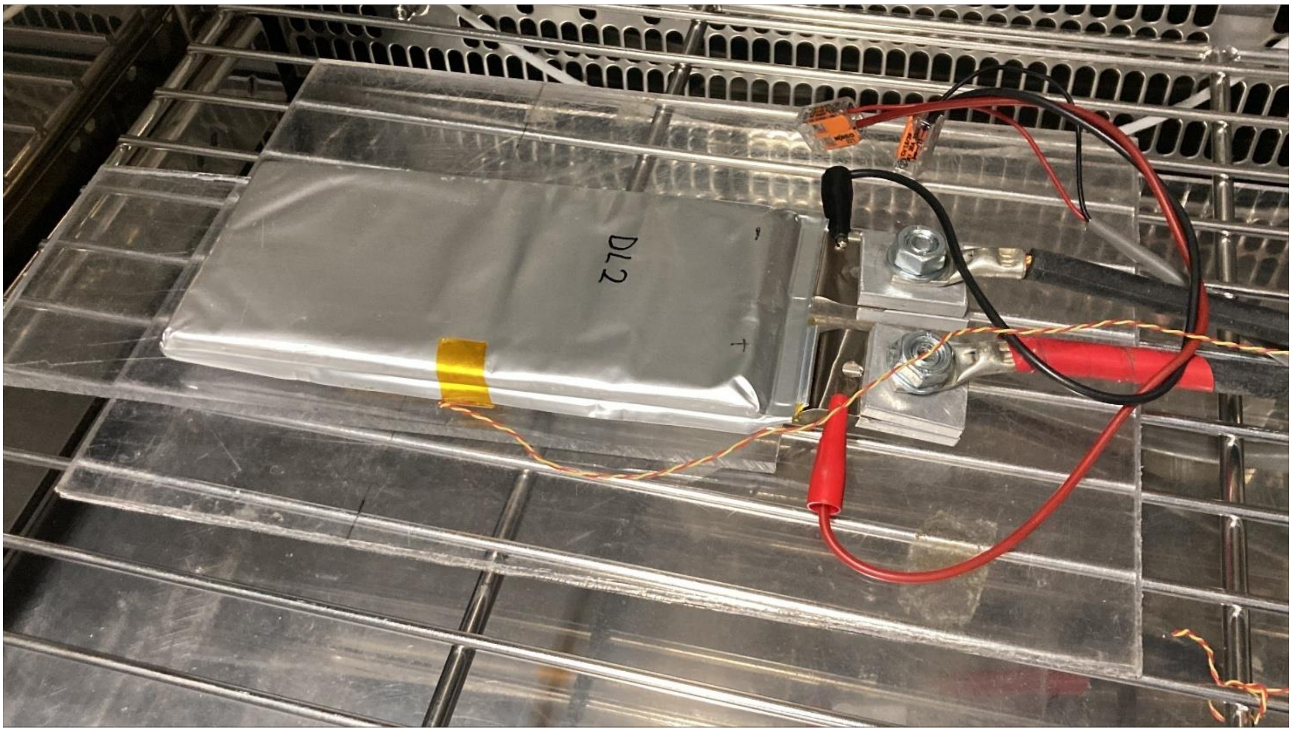

Figure 10. Condition of the cell after a previous high-temperature discharge test conducted at 100 °C.

Figure 11. Condition of the cell after the 5C cycling test.

4. Conclusions and summary

This project included independent cycling testing of an energy storage device supplied by the customer, which the customer identified as a solid-state battery cell. The test was conducted for cell DL2 that had lost its vacuum during a previous high-temperature test conducted at 100 °C. The cell was subjected to a 5C cycling test consisting of 50 cycles between 0–90 % state of charge (SOC), using the maximum voltage range specified for the cell (2.7–4.3 V). A reference performance test consisting of five cycles at 1C using the recommended voltage range (2.7–4.15 V) was conducted before and after the 5C cycling test.

The initial reference performance test yielded an average 1C discharge capacity of 24.689 Ah, based on five consecutive 1C cycles. After six cycles at 5C, the discharge capacity began to decrease rapidly and continued to do so for approximately 15 cycles, after which the rate of capacity degradation slowed and the capacity stabilized. The average 1C discharge capacity measured during the reference performance test after 50 cycles at 5C was 11.194 Ah, corresponding to a 54.66 % reduction compared to the initial capacity. The average energy efficiency during the 1C cycles, calculated from the reference performance test data, decreased from an initial value of 89.6 % to 83.0 %. After completion of the test, the cell thickness had increased by 17 %, and the cell pouch was firm.