

Donut Lab Solid-State Battery V1 High Temperature Performance Test

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Summary <p>The aim of the project was to conduct independent high-temperature discharge performance tests on the energy storage device supplied by the customer, which the customer identified as a solid-state battery cell.</p> <p>Based on the results of the initial capacity test within the recommended voltage range, the capacity of the tested cell was determined to be 24.9 Ah. Following the capacity measurement, the cell's discharge performance under high-temperature conditions was evaluated. The first discharge test was performed at +80 °C using a discharge current of 24 A. The second discharge test was conducted at +100 °C using a discharge current of 12 A. Charging was consistently performed at +20 °C.</p>	
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1. Description and objectives

The aim of the project was to conduct independent high-temperature discharge performance tests on the energy storage device supplied by the customer, which the customer identified as a solid-state battery cell. Three visually identical cells were provided for testing and labeled DL1, DL2, and DL3. Each cell was subjected to different tests conducted in parallel, all of which began with an initial capacity test. This report presents the results of the high-temperature discharge tests performed on cell DL2.

The specification of the device under test is presented in Table 1. All tests described in this report were carried out on the same cell, in accordance with the customer's test plan. The tests were performed using a PEC ACT0550 cell tester, with the cell placed inside a climate test chamber. 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 μ V
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 μ A

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	\pm 0.2 K to \pm 0.5 K
Temperature homogeneity	\pm 0.5 K to \pm 1.5 K

The current cables were attached to the tabs using aluminium bars secured with bolts and nuts. Voltage sense wires were attached using insulated alligator clips. The cell-surface temperature sensor was positioned under the folded seam on the side of the cell. The cell was placed on top of a heat sink on a shelf in the climate test chamber, and a steel plate was placed on top of the cell to provide pressure, as shown in Figure 1.



Figure 1: The cell placed on top of a heat sink on a shelf in the climate test chamber. A steel plate was placed on top of the cell to provide pressure.

Tests conducted for the cell:

1. Capacity test at +20 °C using a discharge current of 24 A and 12 A (#1)
2. Discharge test at +80 °C using a discharge current of 24 A (#2)
3. Discharge test at +100 °C using a discharge current of 12 A (#3)

2. Methods

2.1 Capacity test at +20 °C (#1) and discharge test at +80 °C (#2)

The cell was placed on a shelf inside a climate test chamber on top of a heatsink, similar to that used in the charge performance tests. A steel plate (2.4 kg) was positioned on top of the cell to provide mechanical pressure.

Start: The temperature setpoint of the climate test chamber was set to +20 °C. After a one-hour idle period, the cell was charged at a constant current of 24 A 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 1.2 A, that is 0.05C, corresponding to the standard charge procedure.

Cycle 1 (capacity test at +20 °C): After a one-hour idle period, the cell was discharged at a constant current of 24 A until the voltage reached 2.7 V (standard discharge procedure), followed by a one-hour idle period. The cell was then recharged using the standard charge procedure.

Cycle 2 (discharge test at +80 °C): The climate test chamber temperature was increased to +80 °C, and the cell was allowed to stabilize for two hours. The cell was then discharged at 24 A until the voltage reached 2.7 V (standard discharge procedure), followed by a one-minute idle period. The chamber temperature was subsequently reduced to +20 °C, and the cell was allowed to stabilize for one hour. The cell was then recharged using the standard charge procedure.

Cycle 3 (reference test at +20 °C): After a one-hour idle period, the cell was discharged at 12 A until the voltage reached 2.7 V, followed by a one-hour idle period. The cell was then recharged using the standard charge procedure.

The measured voltage, current, cell surface temperature, climate test chamber temperature, charge capacity and discharge capacity are presented in Figure 2.

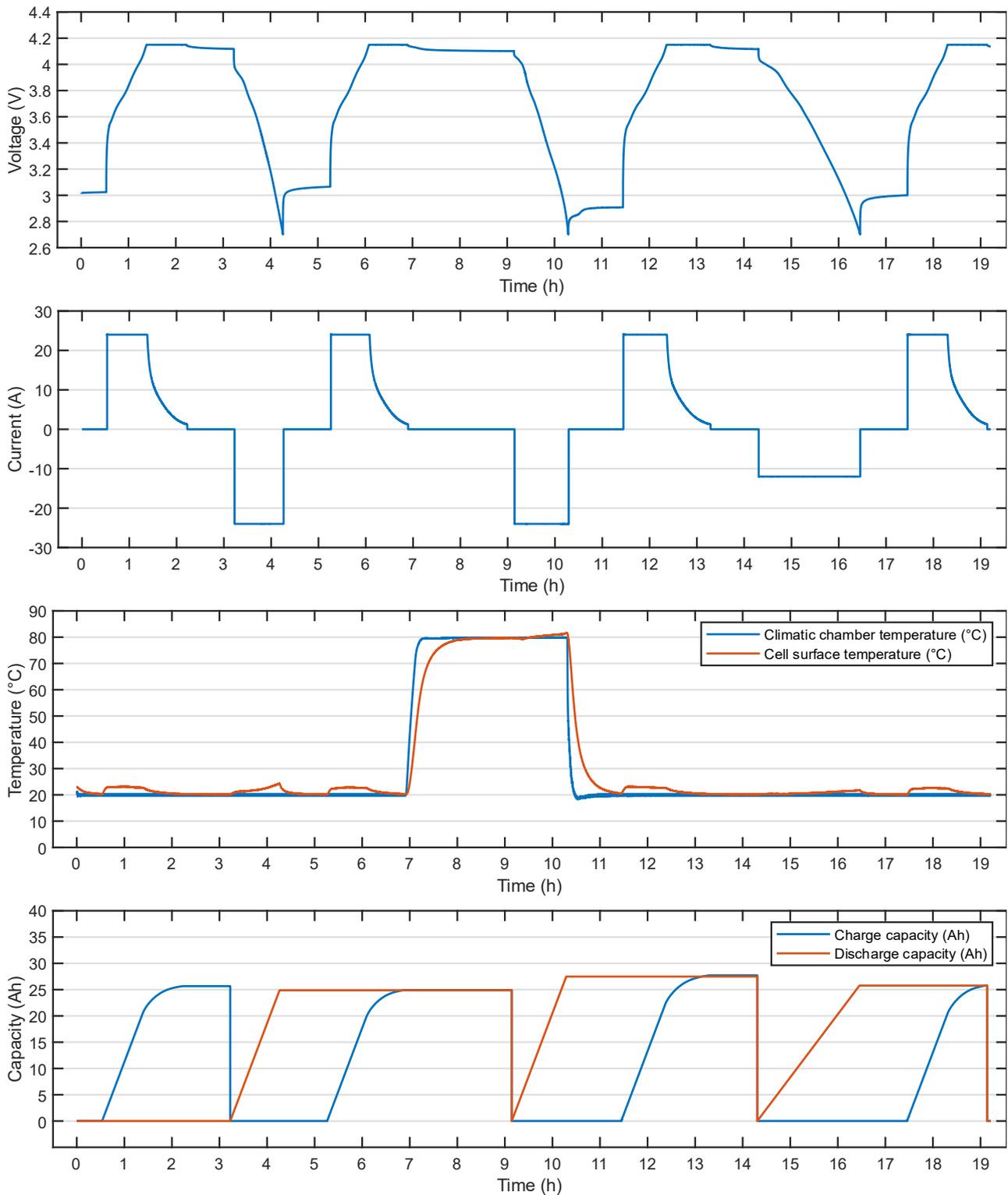


Figure 2: Voltage, current, temperature, and capacity during the capacity test at +20 °C, the discharge test at +80 °C, and the 12 A reference test.

2.2 Discharge test at +100 °C (#3)

The cell was placed on a shelf inside a climate test chamber on top of a heatsink, and a steel plate (2.4 kg) was positioned on top of the cell to provide mechanical pressure.

Start: The cell was initially in a fully charged state. The climate test chamber temperature was then set to +100 °C, after which the cell was allowed to stabilize for two hours.

Cycle 1: The cell was discharged at 12 A until the voltage reached 2.7 V, followed by a one-minute idle period. The chamber temperature was then reduced to +20 °C, and the cell was allowed to stabilize for one hour. The cell was subsequently recharged using the standard charge procedure. At the end of the test, the cell was discharged to about 50 % state of charge at +20 °C before it was disconnected.

The measured voltage, current, cell surface temperature, climate test chamber temperature, charge capacity and discharge capacity are presented in Figure 3.

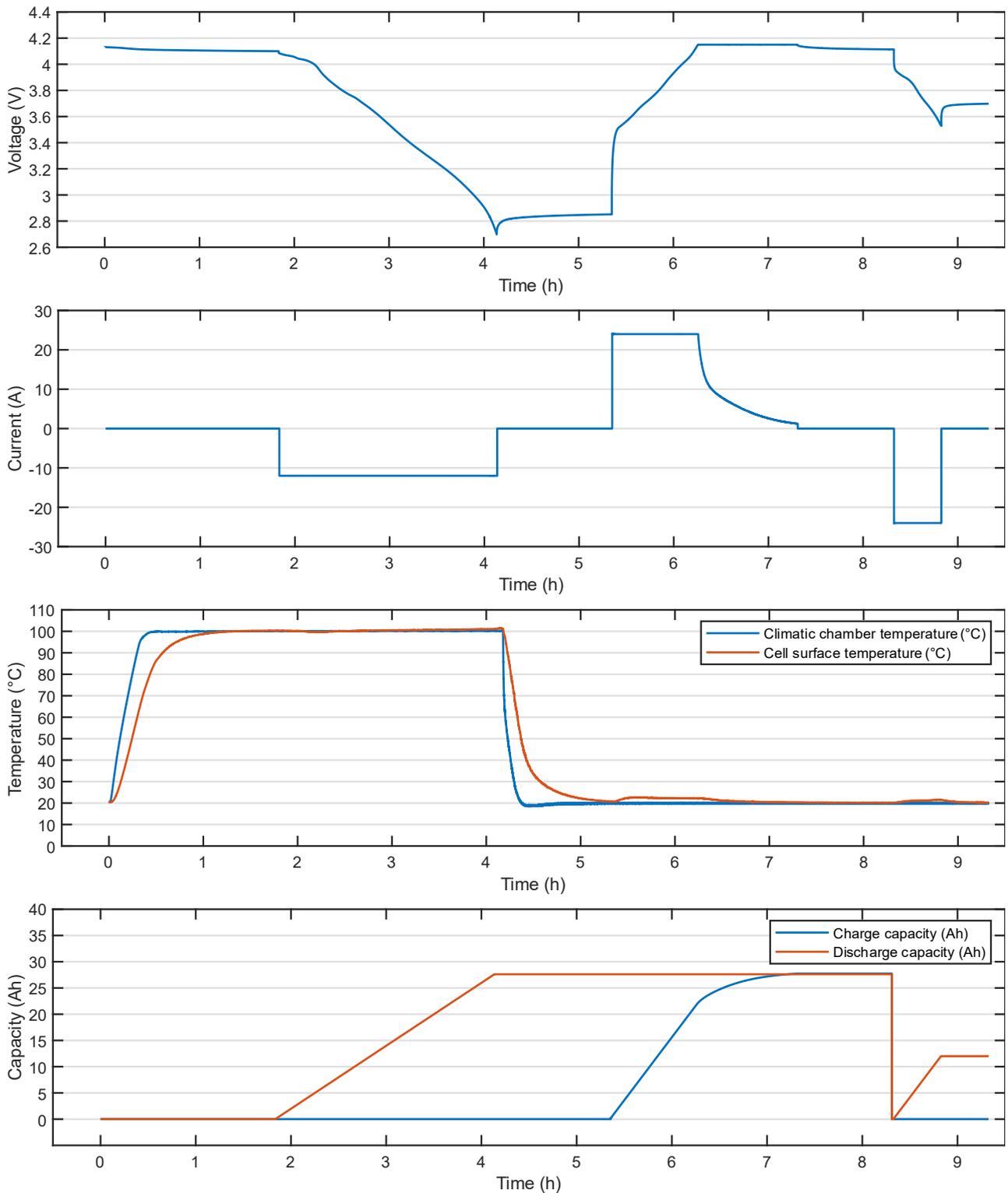


Figure 3: Voltage, current, temperature, and capacity during the discharge test at +100 °C.

3. Results

3.1 Capacity test at +20 °C (#1) and discharge test at +80 °C (#2)

The measured capacity during Test #1 and Test #2 for each cycle is presented Table 4. The discharge in Cycle 2 was conducted at +80 °C, whereas charging in Cycle 2 was performed at +20 °C. Cycles 1 and 3 were conducted at +20 °C as reference measurements at discharge currents of 24 A and 12 A, respectively. No visible changes to the cell were observed during Cycles 1–3.

Table 4. Measured capacity and energy during the capacity test at +20 °C and the discharge test at +80 °C.

	Discharge capacity	Charge capacity	Discharge energy	Charge energy
Cycle 1	24.872 Ah	24.918 Ah	86.499 Wh	96.763 Wh
Cycle 2	27.481 Ah	27.708 Ah	96.732 Wh	106.920 Wh
Cycle 3	25.770 Ah	25.801 Ah	90.365 Wh	99.977 Wh

3.2 Discharge test at +100 °C (#3)

The measured capacity during Test #3 for Cycle 1 is presented in Table 5. In Cycle 1, the discharge was conducted at +100 °C, while charging was performed at +20 °C.

Table 5. Measured capacity and energy during the discharge test at +100 °C.

	Discharge capacity	Charge capacity	Discharge energy	Charge energy
Cycle 1	27.610 Ah	27.746 Ah	97.340 Wh	107.050 Wh

After Cycle 1, the cell pouch was observed to have lost its vacuum (Figure 4). Nevertheless, the cell was able to charge normally after the discharge at 100 °C.

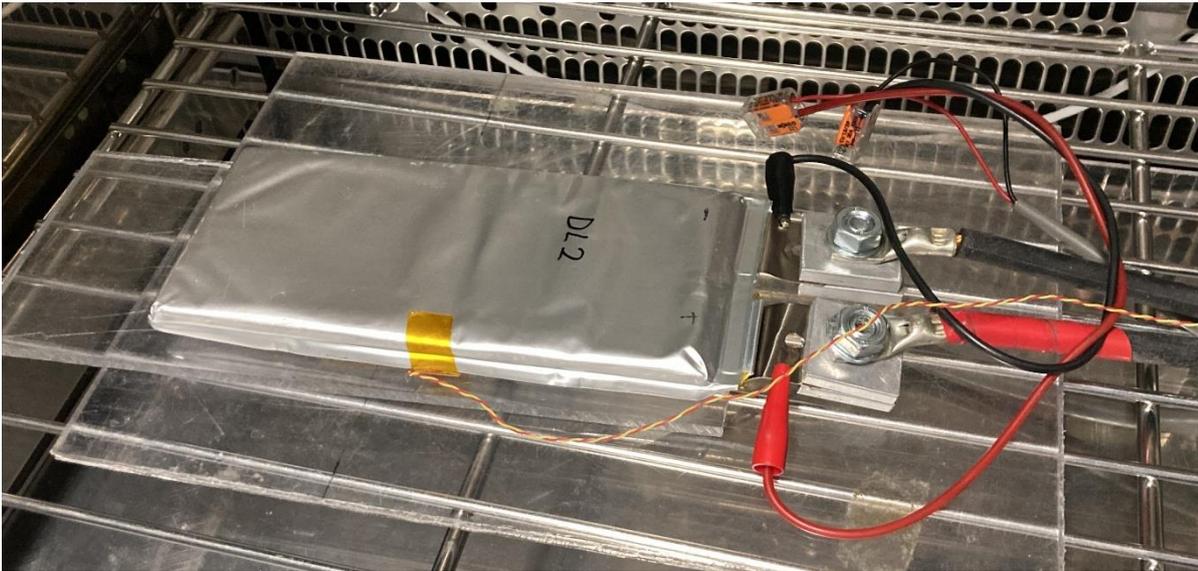


Figure 4: The cell placed on a shelf inside the climate test chamber. After the test, the cell pouch had lost its vacuum. The heat sink and steel plate were removed after testing.

4. Conclusions and summary

This project included an independent high-temperature discharge performance test on an energy storage device supplied by the customer, which the customer identified as a solid-state battery cell. Based on the initial capacity test, the capacity of the cell was determined to be 24.9 Ah. The cell was discharged at +80 °C and +100 °C in accordance with the customer's test plan, and capacity, energy and cell temperature were recorded.

Under the specified conditions, the cell was successfully discharged at +80 °C using a current of 24 A, achieving a discharge capacity corresponding to 110.5 % of the initial discharge capacity at +20 °C with the same current. After the discharge, the cell was able to be charged normally, and no observable changes were detected.

The cell was also discharged at +100 °C using a current of 12 A, achieving 107.1 % of the reference discharge capacity measured at +20 °C using the same current. After the discharge, the cell was able to be charged normally; however, the cell pouch was observed to have lost its vacuum.