CUSTOMER REPORT

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Donut Lab Battery V1 swelling test

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Report's title Donut Lab battery pouch cell dilatometry	
Customer, contact person, address Donut Lab, Ville Piippo, Tallberginkatu 2 A 13, 00180 Helsinki	**Order reference**
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Summary

The aim of the project was to measure swelling behaviour of the battery cell provided by the customer during the charge and discharge cycling. This behaviour is important to be tested and evaluated as cycle life and safety of batteries rely on that. The results showed a decent extent of swelling behaviour around 4.4 % at different charge and discharge current densities.

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1. Description and objectives

The aim of this project was to evaluate the swelling and contraction behavior of the battery cell provided by the customer (hereafter referred to as “the cell”) during charge–discharge cycling at varying C-rates.

The specifications of the cell under test are presented in Table 1. The electrochemical tests described in this report were carried out in accordance with the cell specifications. All measurements were performed using a Digatron battery tester, with the cell placed inside a fume hood. The specifications of the test equipment are provided in Table 2.

Table 1. Preliminary specification of the cell under test, given by customer.

Type of cell	Donut Lab 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 0.02C
Maximum charging voltage	4.3 V

Table 2. Specification of the battery tester.

Equipment	Digatron MCT 250-06-3 RE
Output voltage	0-6 V
Voltage measurement accuracy	± 0.05 % of full scale
Voltage measurement resolution	1 mV
Output current	± 250 A (continuous) ± 300 A (10 s peak)
Current measurement accuracy	± 0.1 % of full scale
Current measurement resolution	1 mA

The cell was tested using the ComprePouch device. The ComprePouch device accommodates pouch cells with dimensions up to approximately 120 × 110 × 20 mm. It is capable of applying a maximum force of up to 25 kN. The system allows operation under both pseudo-constant pressure and pseudo-constant volume conditions and supports simultaneous measurement of applied force and cell thickness during cycling. In this report, the cell was kept under pseudo-constant pressure, and the thickness changes of the cell was monitored during cycling.

2. Methods

2.1 Capacity measurement

The cell has been subjected to separately reported tests before the swelling test. The cell capacity was also measured at rates of 0.2C, 0.5C and 1C at 25 °C temperature with three consecutive cycles at each rate prior to starting the swelling test. The cell was charged at a constant current until the 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) and discharged at a constant current until the voltage reached 2.7 V.

2.2 Handling the Battery in the swelling test device

The cell was positioned between two 3 mm thick aluminum plates to ensure uniform surface coverage during the swelling measurements (Figure 1).

Figure 1 The cell positioned in between two aluminium plates with 3 mm thickness.

Subsequently, the cell, together with the aluminum plates, was placed inside the ComprePouch device. After securing the cell within the device, the spindle nuts were gently tightened to stabilize the assembly and prevent any displacement during measurements. The tightening was guided by the built-in spirit level to ensure uniform and level pressure distribution across the cell.
Following these adjustments, an approximate force of 110 N was applied. The majority of this load originated from the weight of the ComprePouch metal plates, the top aluminum plate, and the lightly tightened spindle nuts. Based on the effective area of the cell, this corresponds to an applied pressure of approximately 86 mbar. Figure 2 shows the configuration of the ComprePouch device used in this test.

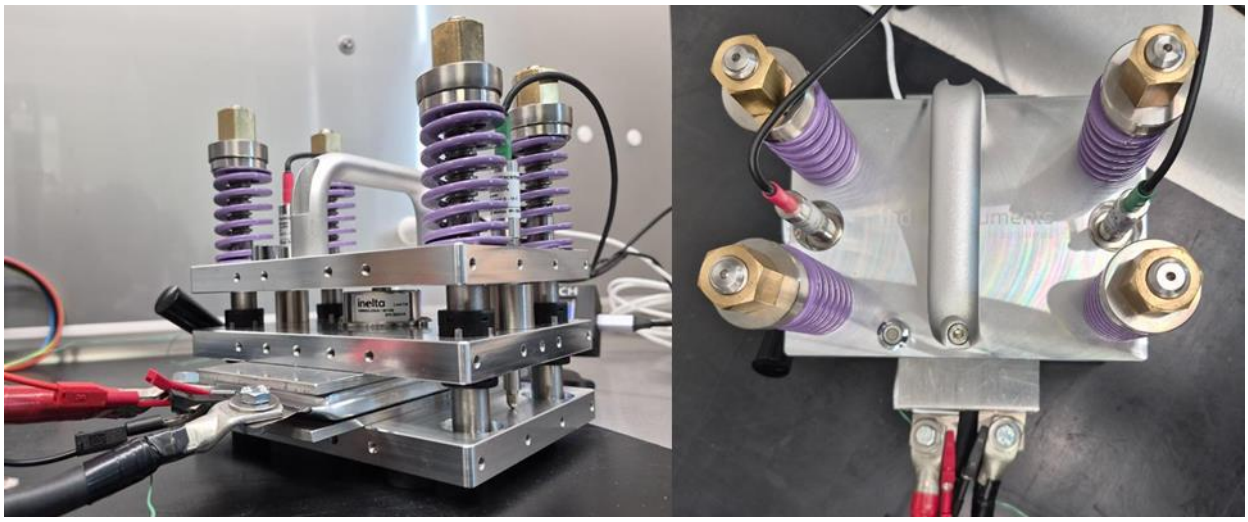

Figure 2 Side and top view of the ComprePouch device with the cell stack positioned inside.

2.3 Operando charge and discharge cycling

After securing the cell within the ComprePouch device and connecting the cycler cables, a series of current densities were applied, and the cell's dimensional changes ("breathing") were monitored in operando. The test protocol consisted of 4 cycles at 0.5C, followed by 4 cycles at 1.0C, 20 cycles at 2.0C, and a final set of 4 cycles at 0.5C to assess the reproducibility and rate dependency of the swelling behavior. A voltage window of 2.70 V – 4.15 V was used, as in the capacity measurement. Detailed electrochemical experimental procedure during the swelling test is presented in Table 3.

Table 3. Electrochemical experimental procedure during the swelling test.

Number of Cycles	Charging Method	Rest after Charging	Discharge Method	Rest after Discharge
4	0.5C CCCV, 0.03 C cutoff	30 min	0.5C CC	30 min
4	1.0C CCCV, 0.03 C cutoff	30 min	1.0C CC	30 min
20	2.0C CCCV, 0.05 C cutoff	15 min	2.0C CC	15 min
4	0.5C CCCV, 0.03 C cutoff	30 min	0.5C CC	30 min

The instrument measures the operando thickness of the cell. In the analysis, the lowest cell thickness of the dataset was used as the zero point. The data set was then normalized to the thickness of the cell measured with a micrometer screw before placing the cell in the ComprePouch device and presented in percents of dilation. The test was performed in ambient room temperature which was 23 ± 0.5 °C. During the test, the maximum temperature of the cell was 37.6 °C. The swelling of the aluminium plates due to thermal expansion is expected to be effectively very low (<0.1% of the cell thickness) and has not been taken into account in the analysis.

3. Results

3.1 Capacity measurement

The average measured capacity of the cell at each rate prior to swelling test is presented in Table 4. Test was conducted at 25 °C temperature.

Table 4. Measured capacity and energy during the capacity test.

	Discharge capacity	Charge capacity	Discharge energy	Charge energy
0.2 C	23.79 Ah	23.80 Ah	84.65 Wh	89.56 Wh
0.5 C	23.34 Ah	23.34 Ah	82.34 Wh	88.85 Wh
1 C	22.70 Ah	22.71 Ah	79.11 Wh	87.71 Wh

3.2 Swelling test measurements

The dilation of the cell and force applied to the cell by the springs during the whole swelling test is presented in Figures 3 and 4. The cell expands while charging and contracts while discharging. The cell experiences a dilation amplitude of approximately 4.4% and expands approximately 0.8% during the whole test.

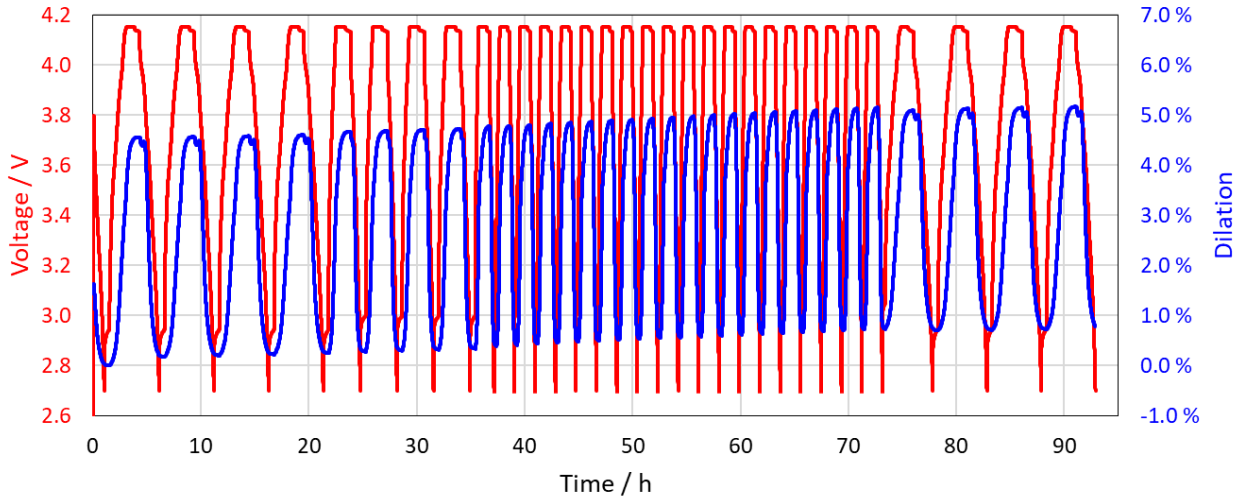

Figure 3. Voltage and cell dilation in percents during the whole swelling test experiment.

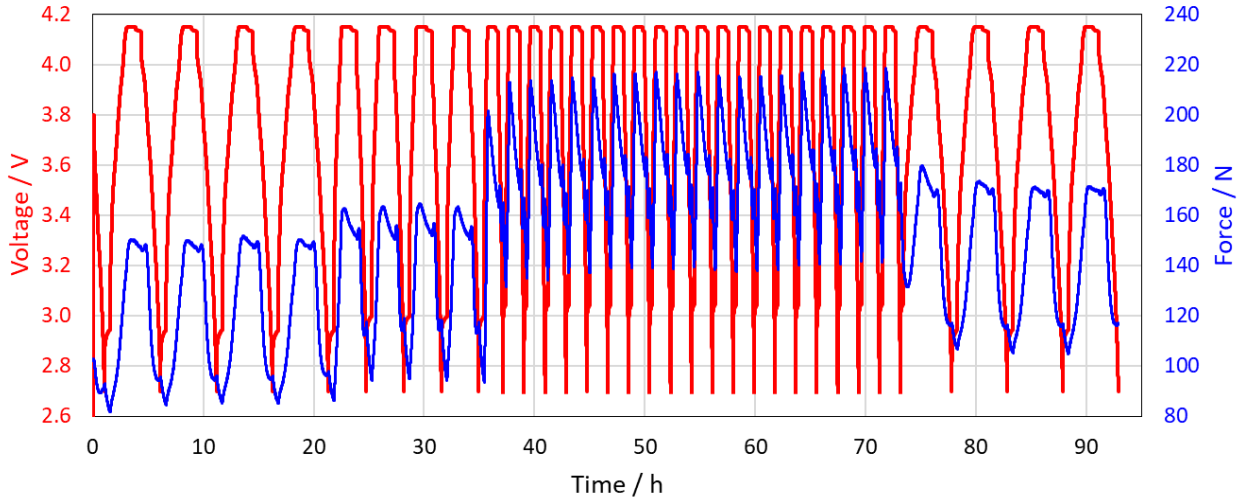

Figure 4. Voltage and force applied on the battery during the whole swelling test experiment.

The dilation amplitude of each charge/discharge cycle was analyzed by calculating the difference between maximum dilation and minimum dilation. This data together with discharge capacity is presented in Figure 5. The dilation amplitude is nearly independent of the charging rate but during consecutive cycling increases slightly (4.39% → 4.44% during 20 cycles at 2C/2C). Since the dilation is normalized here to the initial thickness of the cell, the amplitude remains practically unchanged if considering the cell expansion during the test.

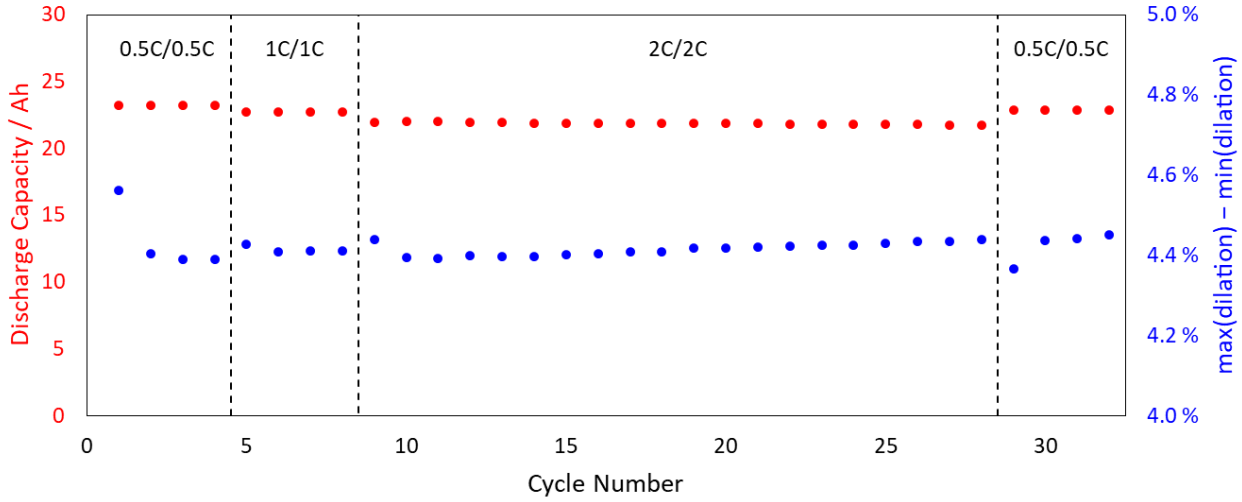

Figure 5. Discharged capacity and maximum difference of dilation in percents during each cycle of the swelling test experiment.

The dilation profiles during the charging and discharging of the battery at different rates are presented in Figure 6. The fourth cycle at each rate is always presented. The cell expands more at high state of charge (SoC) and there is a feature at ~70% SoC distinguishable while both charging and discharging.

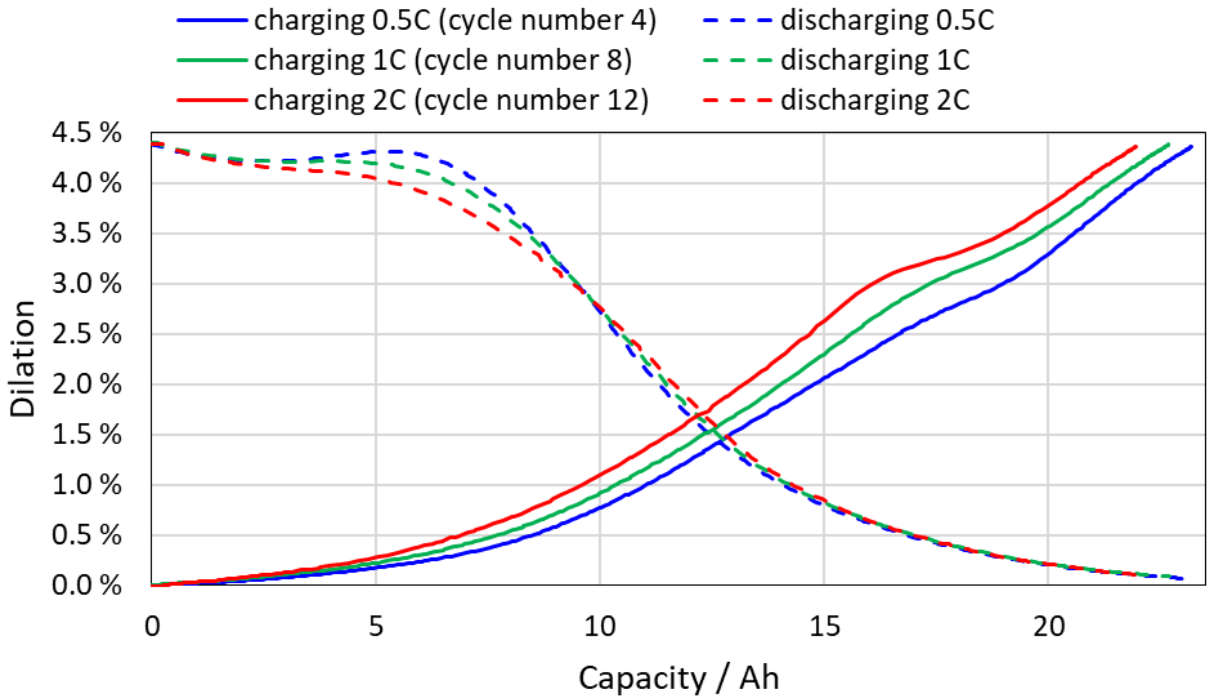

Figure 6. Dilation charge-discharge profile on the 4th cycle recorded of each charge/discharge rate. During charging (solid lines) the cell expands and during discharging (dashed lines) the cell contracts.

4. Conclusions and summary

The dilatometry measurements indicated an average breathing amplitude of approximately 4.4% during cycling. Approximately 0.8% of cell swelling was also detected during the test. The results further demonstrated that the breathing intensity is independent of the applied C-rate.