THERMAL MONITORING OF BATTERIES USING CALORIMETRY & POTENTIOSTAT

INTRODUCTION

Batteries play a critical role in electric mobility, stationary energy storage, portable electronics, and numerous industrial applications. Their high energy density, compact design, and long cycle life make them indispensable to the global energy transition.
Yet, battery operation is inherently coupled with thermal effects. During each charge and discharge cycle, heat is generated through mechanisms such as resistive losses, electrochemical reactions, and—under certain conditions—parasitic side reactions. If unmanaged, this heat can compromise performance, accelerate aging, or in severe cases, trigger thermal runaway.
Thermal monitoring, which involves tracking the evolution of battery temperature during operation, is therefore essential. Such data not only ensures safe operation but also provides valuable insights into internal processes, enabling optimization of operating conditions and refinement of predictive models.

In this application note, the thermal behavior of a battery under charge/discharge cycling is examined using a setup that integrates a calorimeter with a potentiostat. The results demonstrate how heat generation depends on the selected state-of-charge (SOC) window, highlighting the influence of electrochemical conditions on thermal output.

EXPERIMENT

1. Instruments & accessories

Connection between the tested battery (a standard, AAA format, NiMH secondary battery) and the Origalys OrigaFlex OGF+01A potentiostat was achieved using 4 wires in order to compensate for any small potential bias dues to the wires' electrical resistance.
The battery was then paced in a calorimetry cell and inserted in a Calvet calorimeter, initially equilibrated at 30°C.

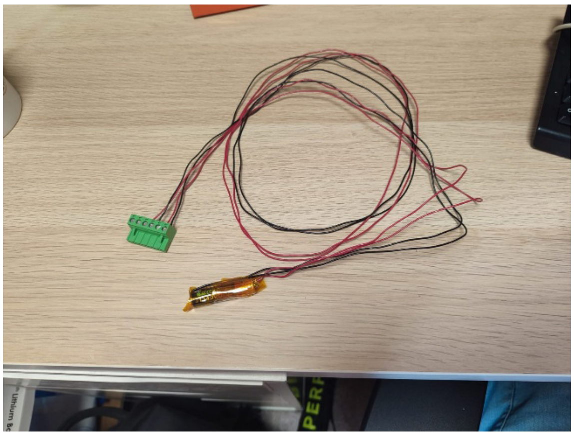

Figure 1: Duracell AAA NiMH 900 mAh

Summary of the setup	
Battery	Duracell AAA NiMH 900 mAh
Electrode system	4 electrodes configuration
Instrument	Potentiostat : OrigaFlex OGF+01A Calorimeter : Calvet
Software	Potentiostat : OrigaMaster 5 Calorimeter : Calisto

Figure 2: OrigaFlex OGF+01A coupled to a Calvet calorimeter

About Origalys

OrigaLys is a French company specializing in electrochemical analysis instruments, founded in 2010 by former Radiometer engineers.

Building on over 75 years of expertise, it designs and manufactures innovative tools like potentiostats, pH meters, and corrosion analyzers, with a strong focus on education, research, and industrial applications.

2. Settings

Monitoring of the potential via potentiostat was performed with the OrigaMaster 5 software. Figure 3 presents the experimental flowchart. Before the charge/discharge cycles, an Open Circuit Potential measurement was performed to ensure that the battery showed no obvious signs of damage or abnormal behaviour.

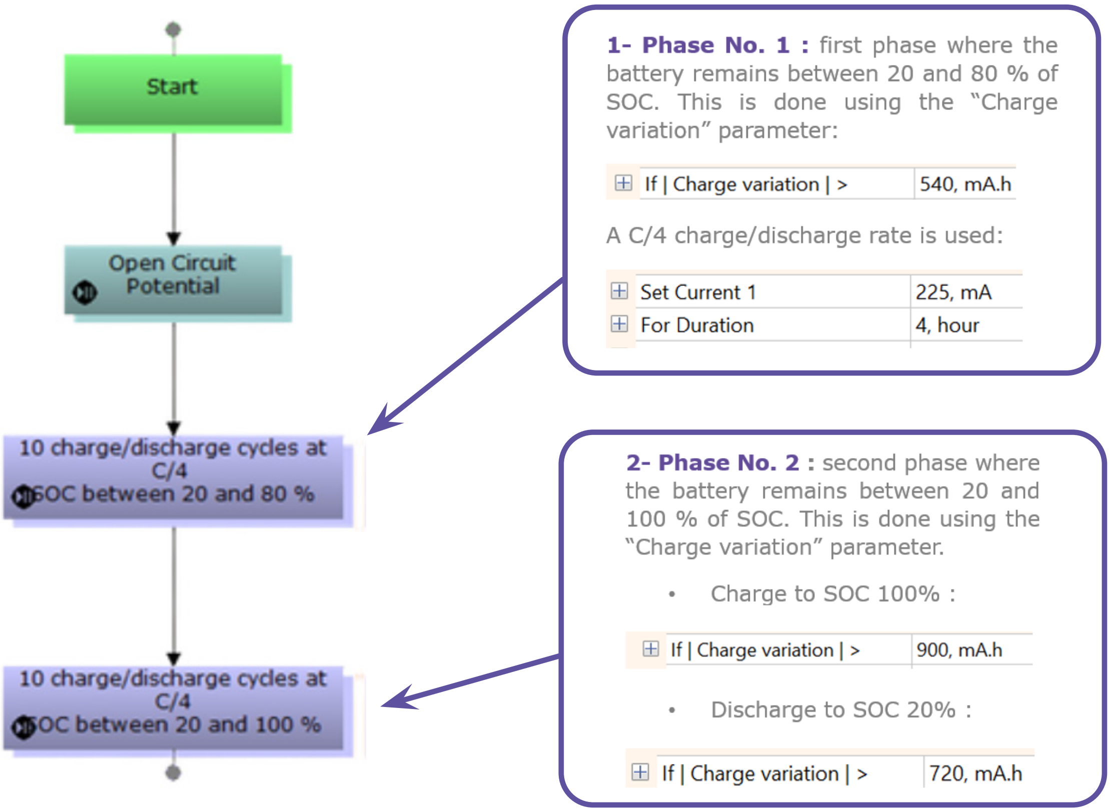

Figure 3 : Flowchart of the experiment

Note: Prior to starting the experiment, the battery was initialized at a 20% SOC. For more details on SOC and how it is determined, please refer to Origalys application note "Battery Aging Indicators AP-B0X: State of Charge, State of Health".

The battery was introduced inside the sample cell and the reference cell remained empty. Before starting the test, the calorimeter was set at 30 °C and the experiment was started only after the heatflow signal had returned to the baseline after the cell introduction.

Monitoring of the heatflow was performed on the Calisto Acquisition software. Figure 4 presents the experimental parameters of one of the zones. The experiment was composed of five identical zones. The acquisition period was set automatically at 5.8 s.

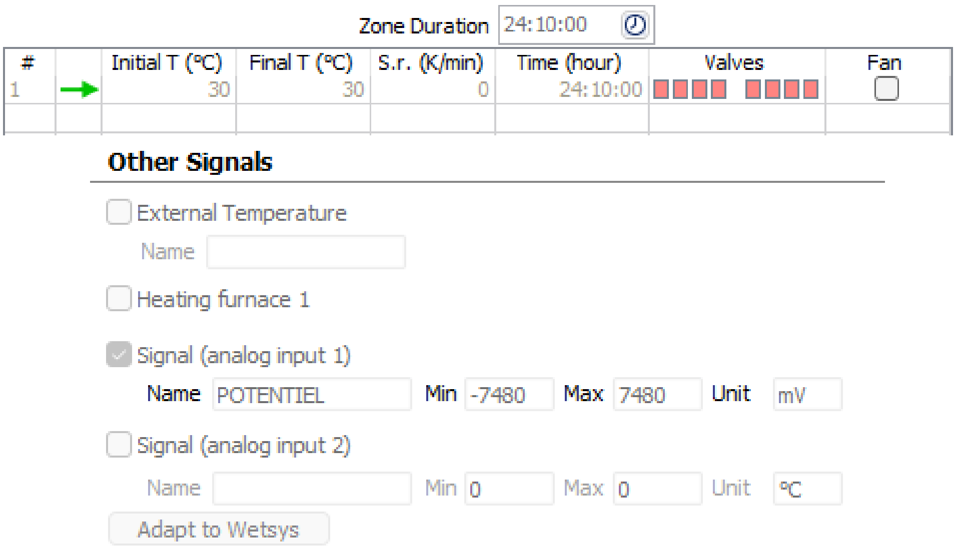

Figure 4: Experimental parameters (the zone thermal profile and the programming of the potential signal)

<u>Connection:</u> The potentiostat was connected to the calorimeter using the available ANALOG IN/OUT plugs in order to plot potential signal (expressed in mV) in real time on Calisto.

RESULT

The evolution of potential over time during the 20 cycles is plotted in Figure 5.

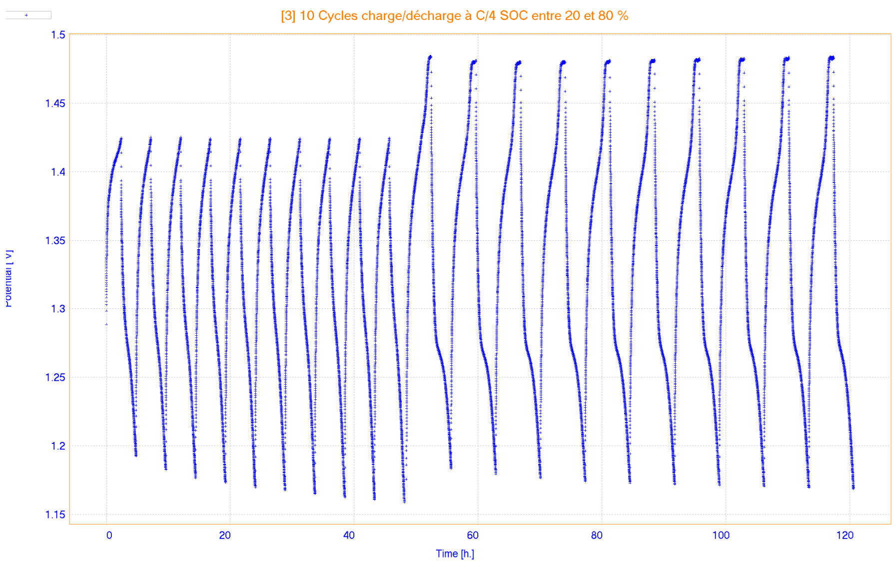

Figure 5: 10 charge/discharge cycles

The full experiment took 120 hours :

- During the first 48 hours, the battery is cycled between 20% and 80% State of Charge (SOC). Over this period, a 35 mV decrease in the discharge voltage is observed, indicating the early signs of performance degradation.

In the following 72 hours, the SOC range is extended from 20% to 100%, subjecting the battery to deeper charge cycles.
Figure 6 shows the SOC and heat flow plotted against time.

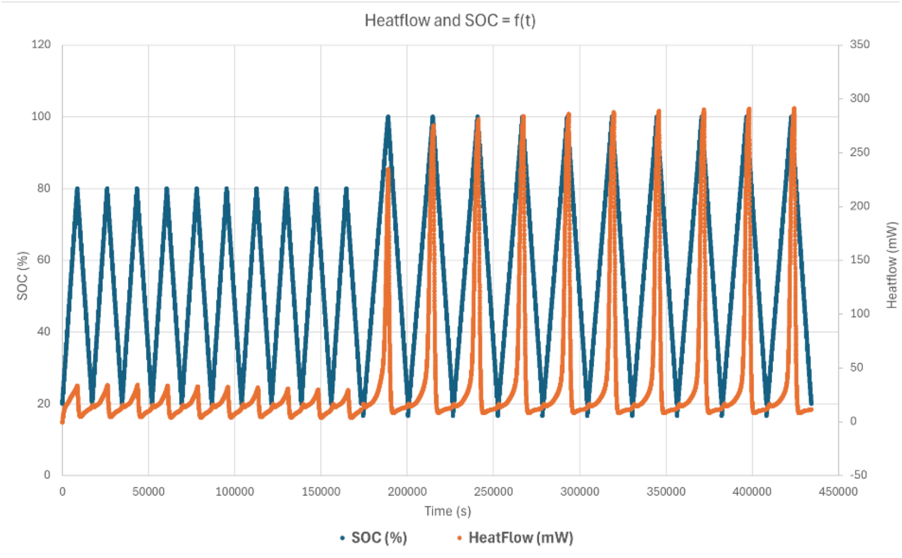

Figure 6: Variation of SOC and Heatflow over time

When the SOC is maintained between 20% and 80%, the heat flow generated by the battery shows a slight decrease, from 34 mW to 29 mW, indicating that the temperature remains relatively stable during this cycling phase.

However, immediately after the first full charge cycle (up to 100% SOC), the heat flow rises sharply to 234 mW, over eight times higher than in the previous phase. It then stabilizes around 290 mW.
This significant increase suggests that charging the battery to full capacity induces much greater thermal activity, likely due to higher overpotentials, side reactions, or increased internal resistance, compared to limiting the charge to 80% SOC.

CONCLUSION

These results clearly demonstrate that charging the battery up to 100% SOC significantly increases the heat flow generated, compared to cycling within a reduced SOC window (20%–80%). While partial charging results in relatively stable thermal behavior, full charging leads to a sharp rise in heat production, indicating greater thermal stress.

This suggests that full charging can have a strong impact on the battery's temperature, which may accelerate aging processes and affect long-term performance and safety.

ADDITIONAL INFORMATION

Before testing a battery through the charge-discharge method, it is crucial that the user knows about the parameters of the battery. The most important parameters are:

- **Capacity:** A battery's capacity is the amount of electric charge it can deliver. The unit is mAh (mA.hour).
- **Nominal Voltage:** It describes the voltage of a battery in the middle of its discharge cycle. This is also where the voltage stays for the longest period during the discharge. For example, most lithium-ion batteries have a nominal voltage of 3.6 volts. When fully charged, it's 4.2 volts.
- **Maximum current for discharge:** The maximum current that can be applied on the battery during discharge phase.
- **Maximum current for charge:** The maximum current that can be applied on the battery during charge phase.
- **Maximum voltage of charge:** The maximum limit of potential that the battery can have during the charge.
- **Minimum voltage of discharge:** The minimum amount of potential that the battery can have during the discharge.

For industrial batteries all these parameters are available in the datasheet or website of the manufacturer.
For homemade batteries, the user must know all these parameters to run the test correctly and safely.

INSTRUMENT

CALVET

Ambient to 300°C

HIGHEST HEAT MEASUREMENT ACCURACY
3D sensor based on thermocouples with Joule effect calibration.

ISOTHERMAL OR TEMPERATURE SCANNING MODES
for increased flexibility and replication of real life conditions.

CONVENIENT INTERCHANGEABLE CRUCICLES AND CELLS
to perform event the most demanding experiments:
- high pressure (1000bar) and high vacuum
- pressure measurement and control
- mixing/stirring experiements.

EXTERNAL COUPLING CAPABILITY
designed to increase your research options in manometry, BET instrumentation, gas analyzers, humidity controllers and gas panels