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Effects of Low Temperature Discharge on Performance of Lithium Oxyhalide Primary Cells

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    - Constant current versus constant power
    - Constant current versus pulsed discharge
    - Mixed temperature discharge
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Electrochem

Electrochem, based in Raynham, MA, manufactures primary lithium oxyhalide cells with very high energy density for extreme conditions – e.g., high or low temperature, high shock and vibration, long endurance.

Electrochem makes three lithium oxyhalide primary chemistries:

• Thionyl chloride ($SOCl_2$)	OCV = 3.65 V
• Sulfuryl chloride (SO_2Cl_2)	OCV = 3.93 V
• BCX ($SOCl_2$ + BrCl)	OCV = 3.9 V

Electrochem also builds primary and secondary battery packs for a range of markets and critical applications where **failure is not an option**. Below are examples of some of the markets and applications we serve.

Energy
- Downhole Drilling
- Pipeline Inspection
- Seismic Surveying

Military
- Communications
- Detection
- Avionics

Environmental
- Oceanographic Systems
- Detection & Monitoring
- Industrial/Utility

Cell Performance

The testing described here covers a range from very low to moderate temperatures typical of those found in military and aerospace, as well as oceanographic applications and pipeline inspection.

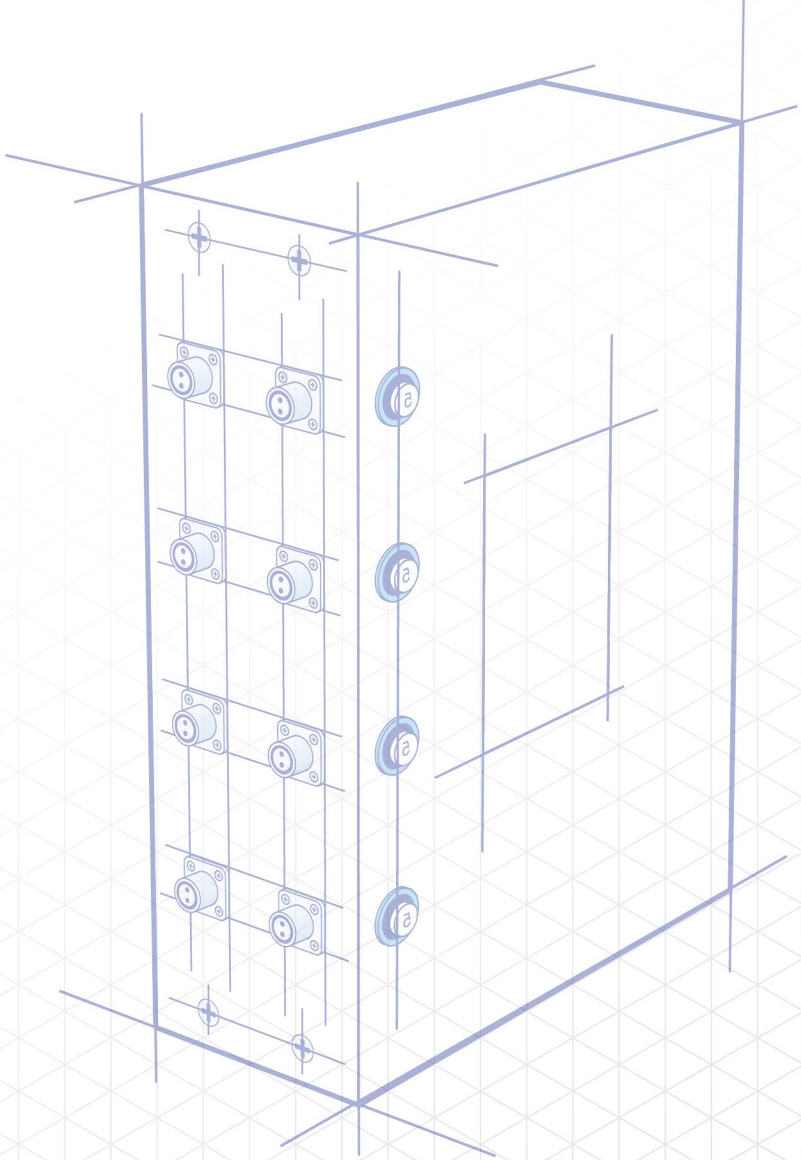
In many cases, batteries may be stored or used to power up a device at one temperature, but then be required to operate the device at a very different temperature.

Cell Performance Considerations

- For real applications, run-time is what matters.
- Most cell data-sheets show capacity (Ah) data obtained from discharge under constant current conditions. When the discharge voltage curve is very flat, constant current behaves the same as constant power, and estimating run-time from capacity is straightforward.
- If the discharge curve is not flat, then constant current and constant power behavior can be quite different, and calculating run-time is more complicated.
- Both capacity and run-time can be very sensitive to the cut-off voltage. Small differences in cut-off voltage can lead to big differences in the capacity and run-time that can be achieved. This is especially true at low temperatures, where running voltages are decreased.

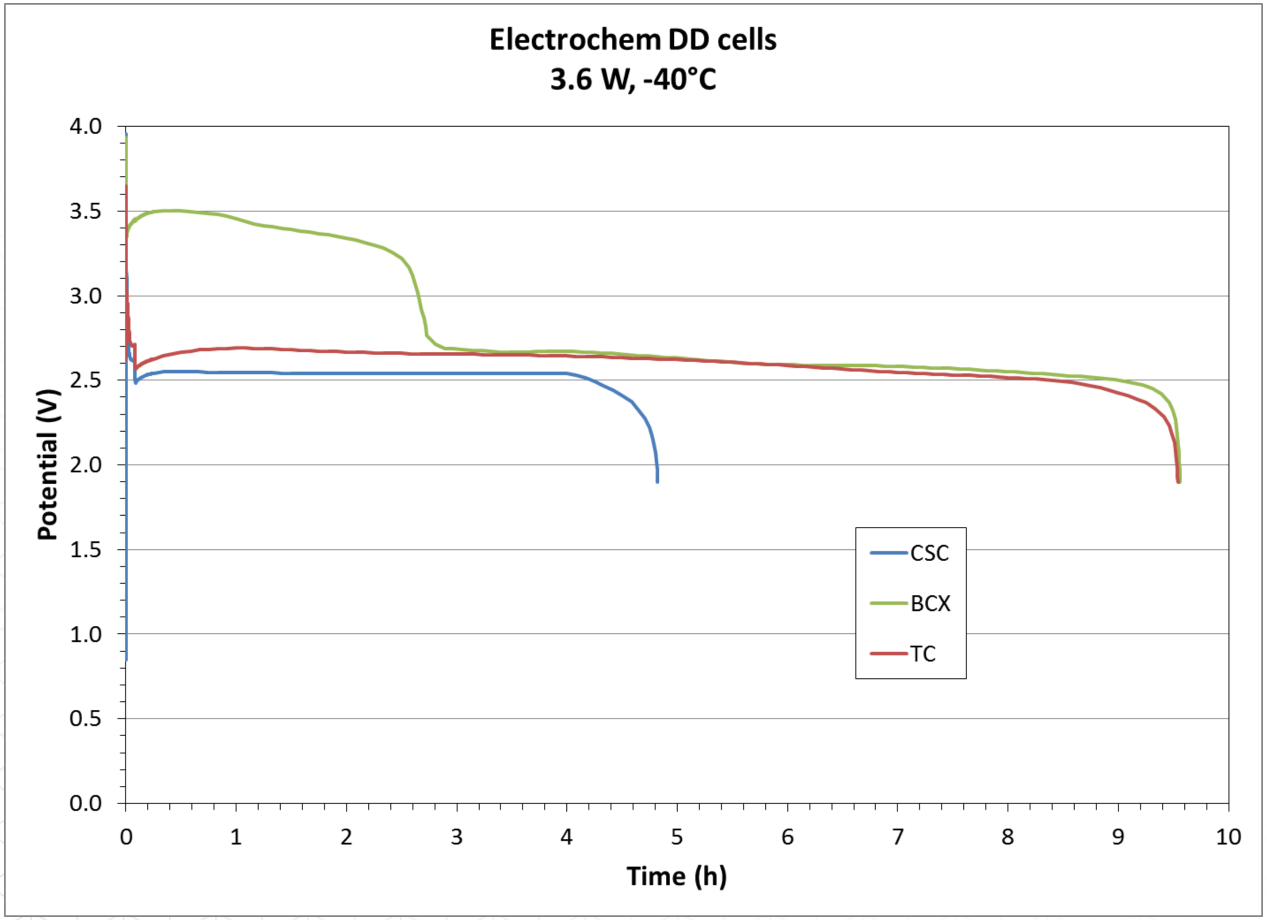
Testing Layout

- **Cells**: DD-sized (33.5 mm diameter, 120 mm length), high-rate design
- **Electrolytes**: thionyl chloride (TC), sulfuryl chloride (CSC), BCX
- **Temperatures**: -55°C, -40°C, -20°C, 0°C, RT (+23°C), +50°C
- **Discharge rates**: 500 mA, 1.25 A, 3.6 W
- **Pulsed discharge**: 2 A for 1 second, 0.5 A for 59 seconds (average 525 mA)
- **Mixed-temperature conditions**:
  - 3.6 W discharge; -40°C for 6 hours, 2 hour ramp to RT, discharge to end-of-life at RT
  - 3.6 W discharge; -40°C for 2 hours, 2 hour ramp to 0°C, discharge to end-of-life at 0°C
- **Sample**: Five cells per test condition.

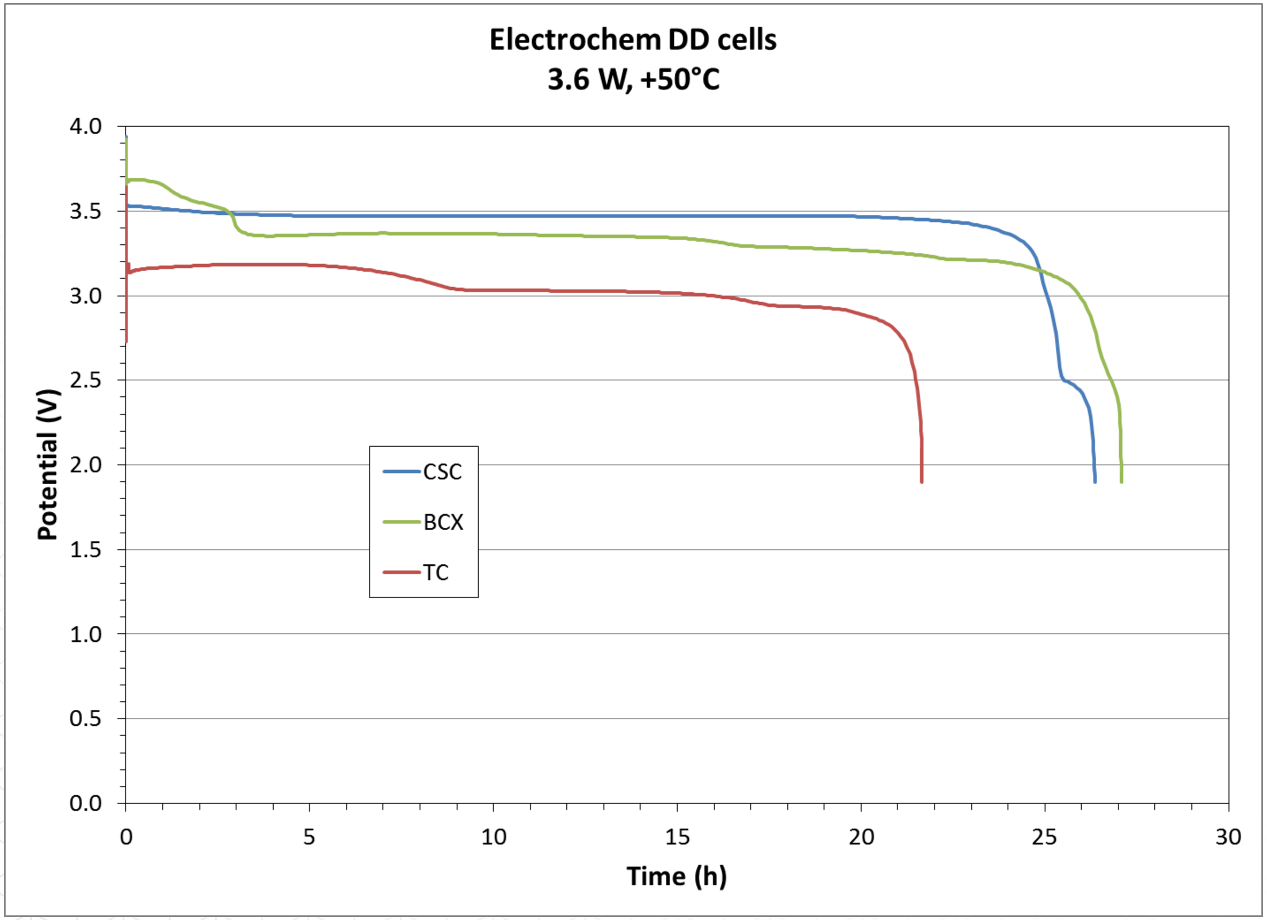


-40°C vs. +50°C

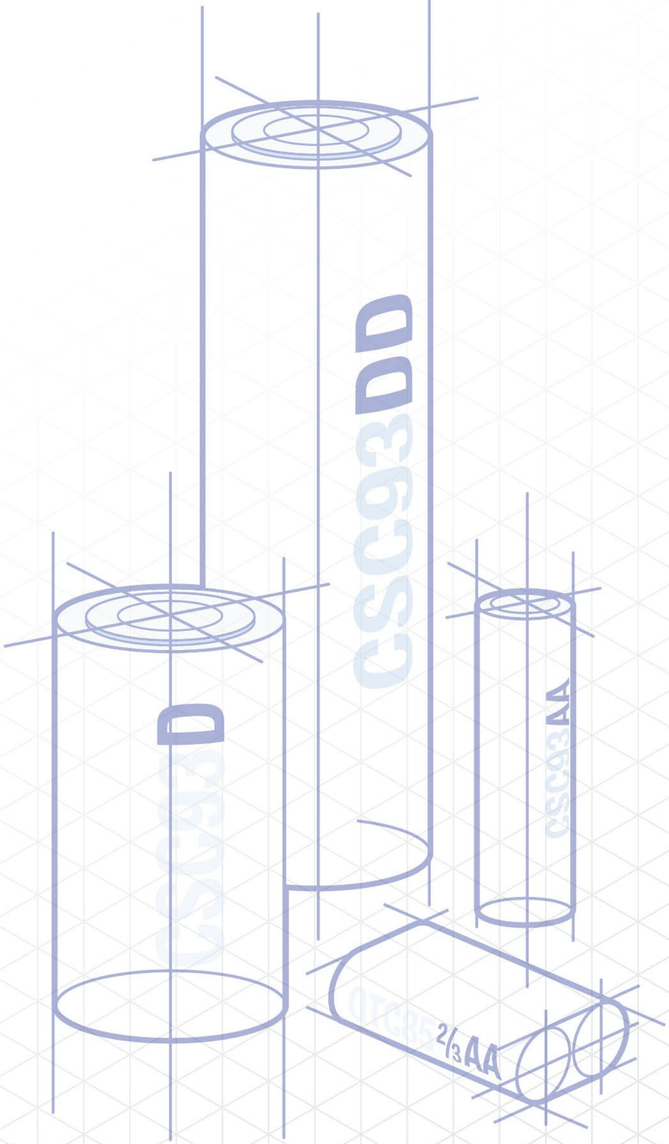
Test Results: Very Low Temperature (-40°C)



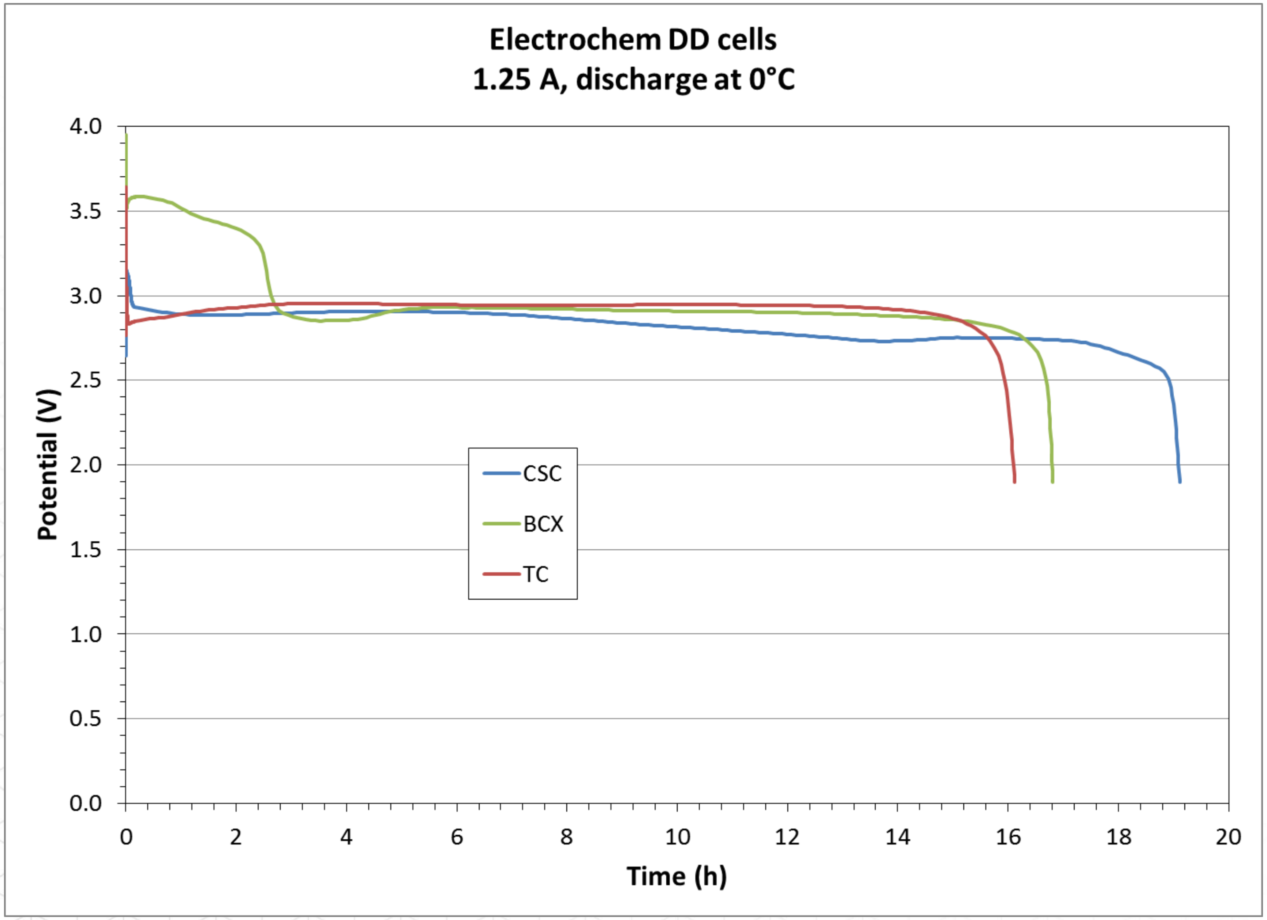
Test Results: Moderate/High Temperature (+50°C)



Constant Current
vs. Constant Power



Test Results: 0°C, Constant Current (1.25 A)



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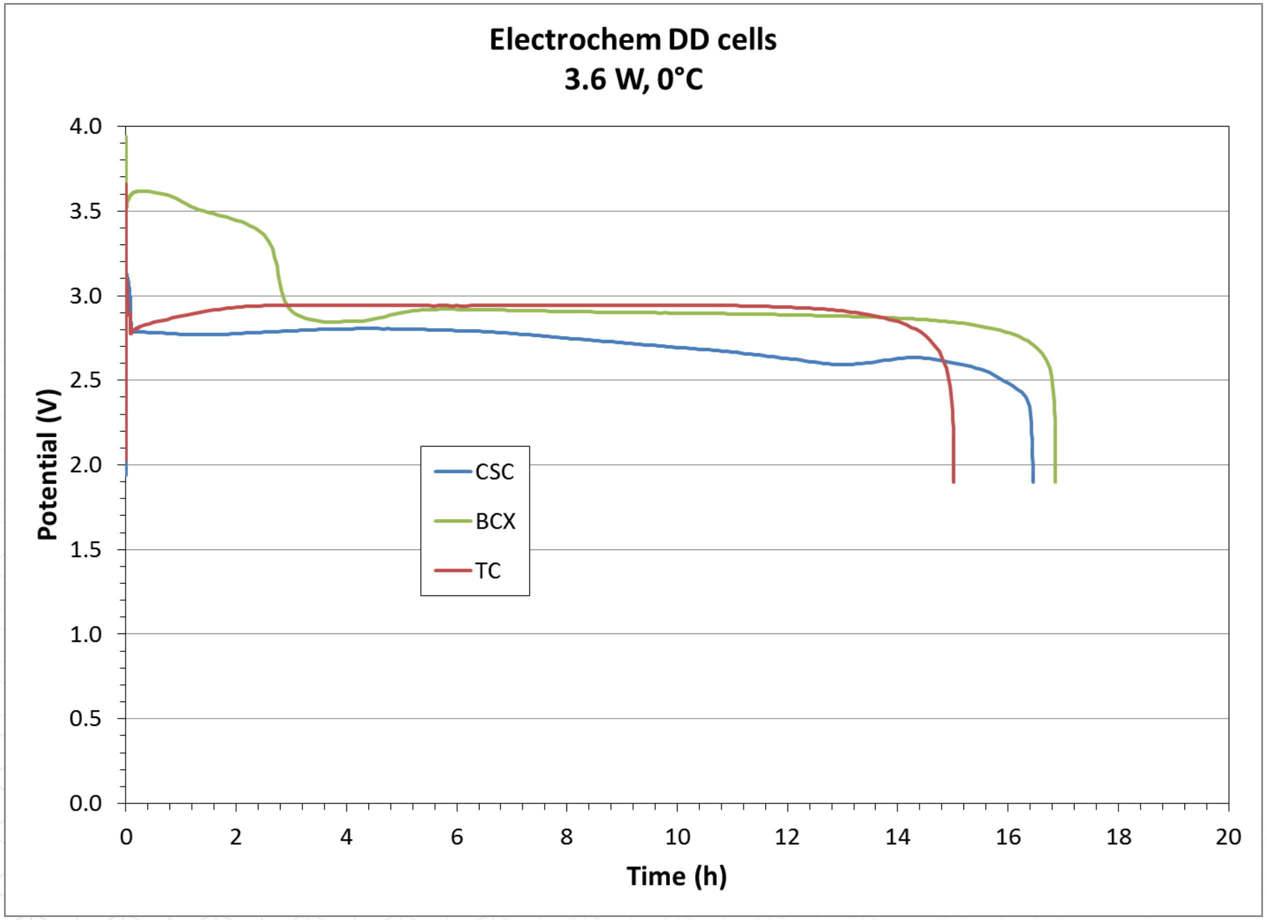
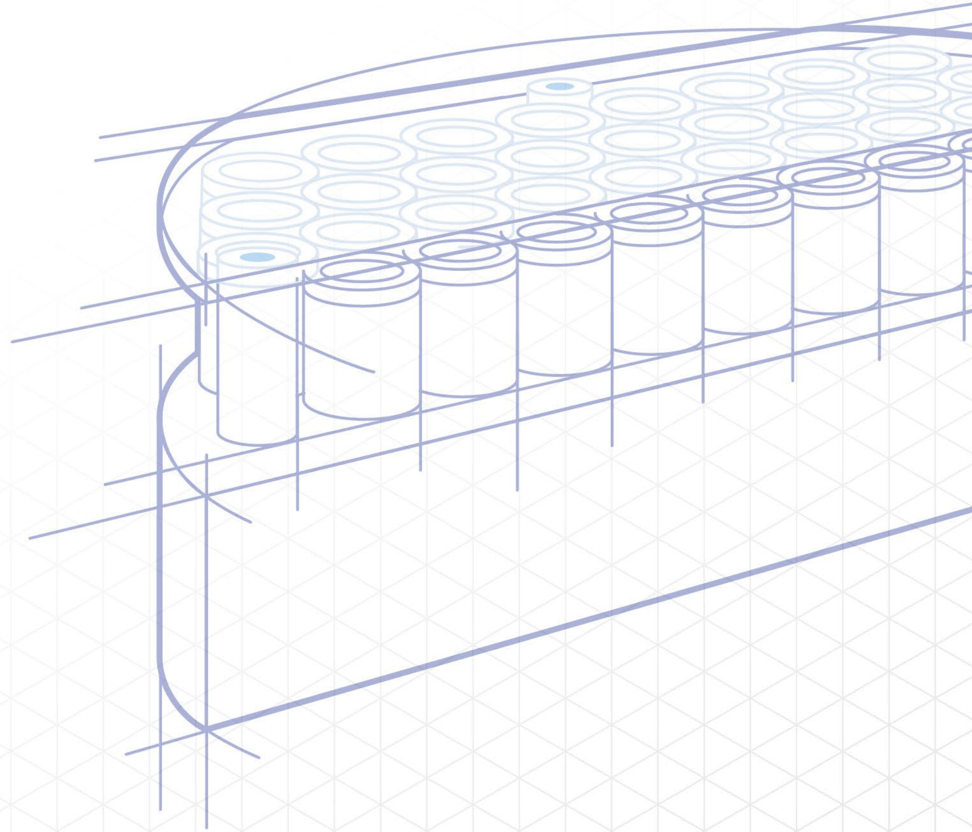
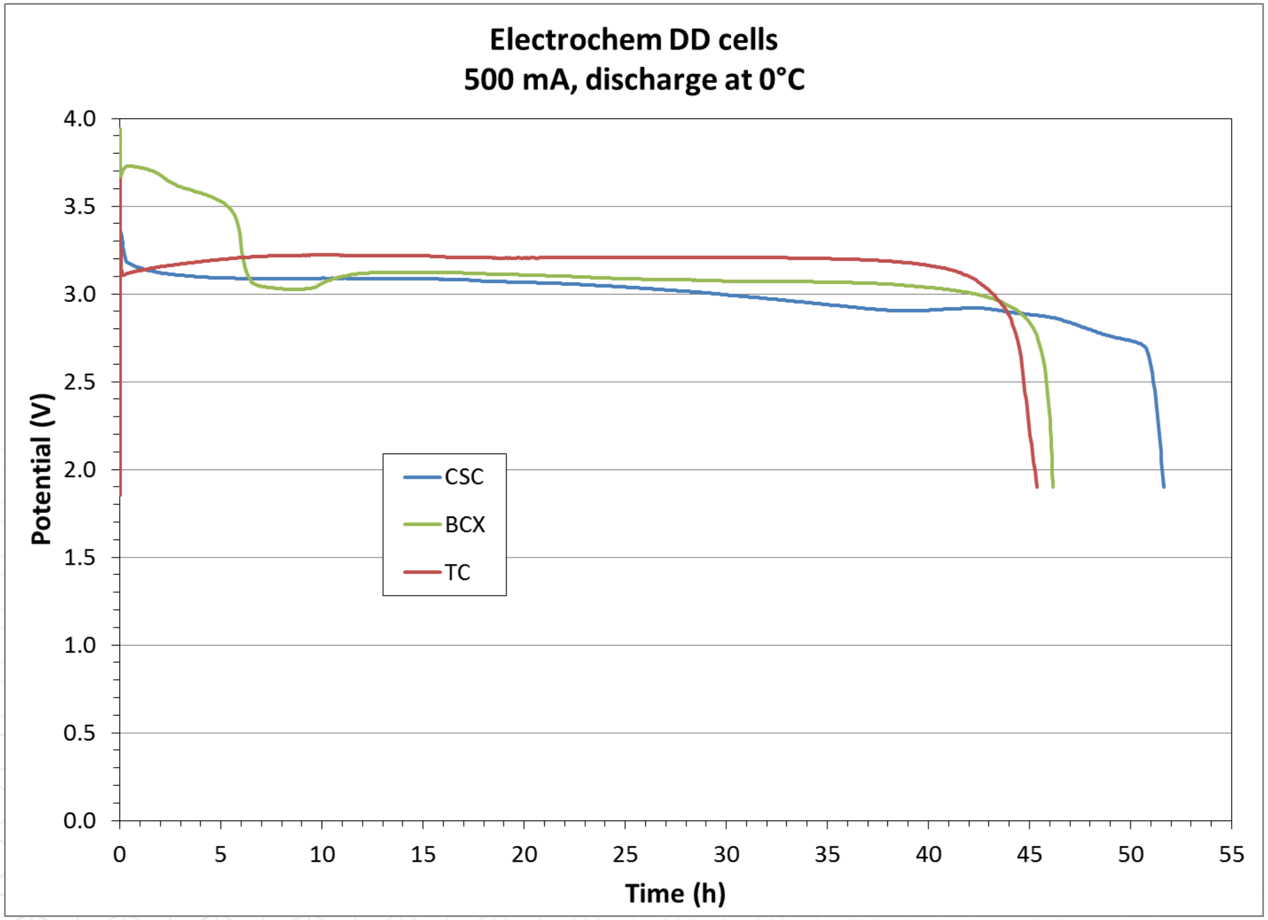
Test Results: 0°C, Constant Power (3.6 W)



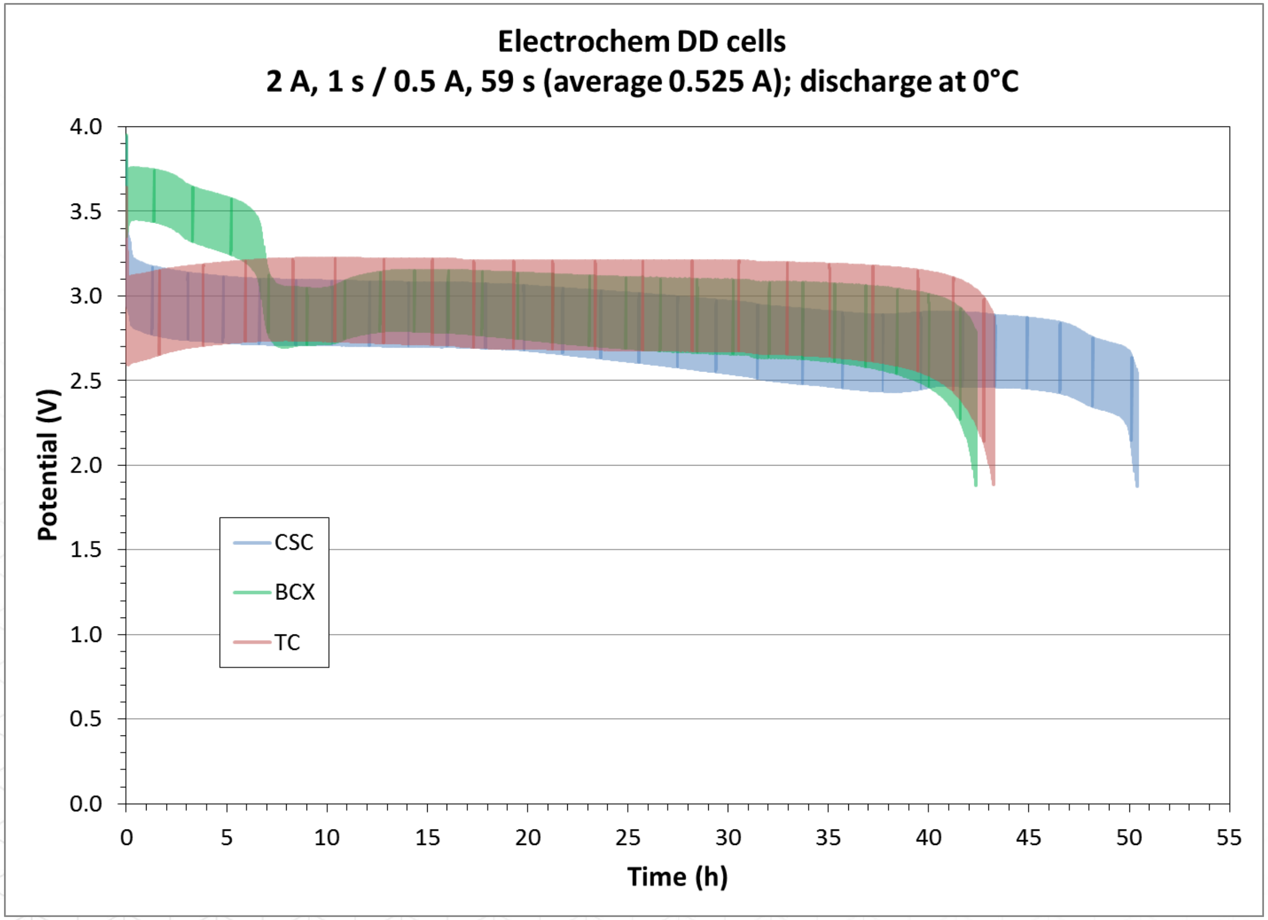


Constant Current vs. Pulsed Discharge

Test Results: 0°C, Constant Current (500 mA)



Test Results: 0°C, Pulsed Discharge (Average 525 mA)



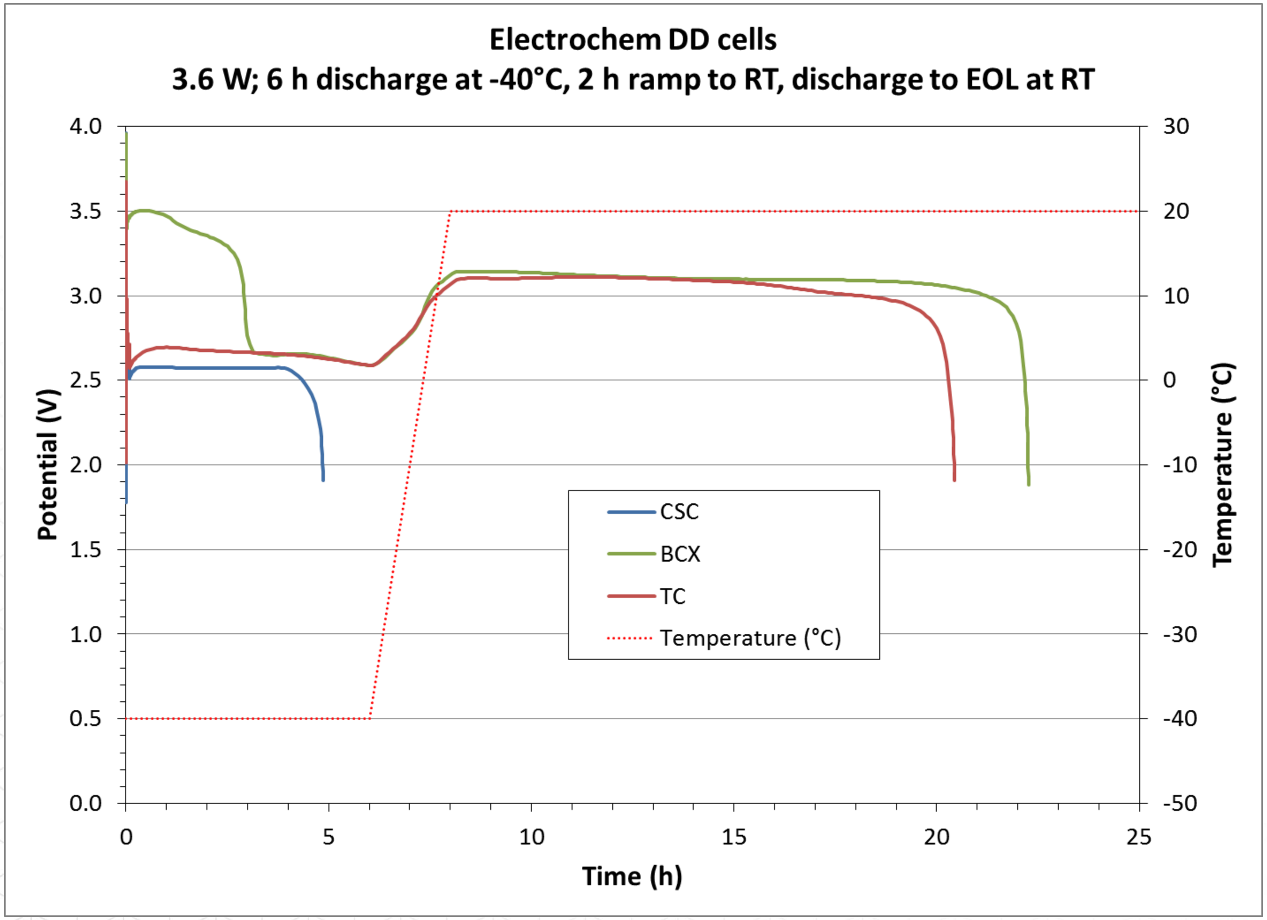
A Summary

Some summary points:

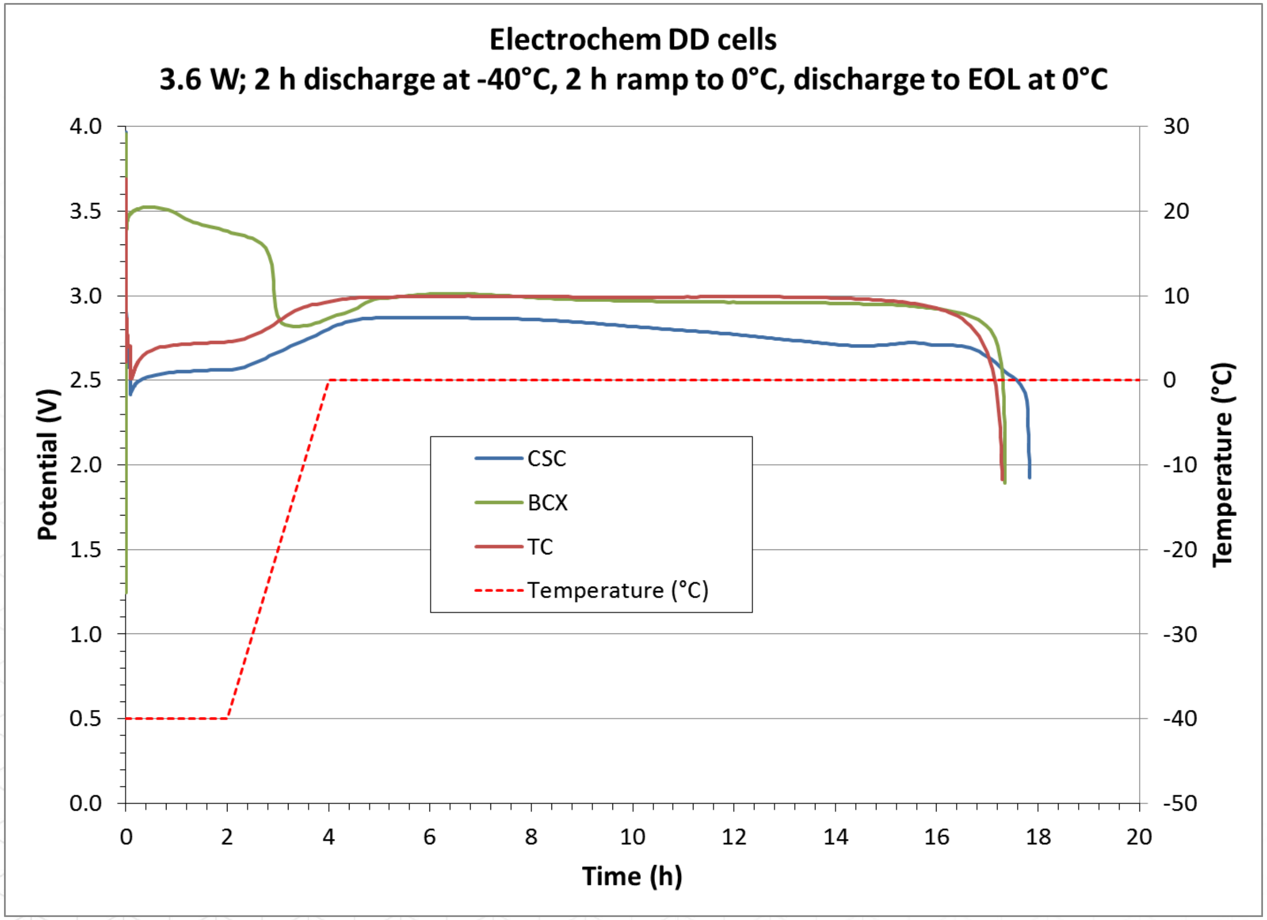
- BCX is superior to CSC at very low temperatures (-40°C).
- Higher capacity does not necessarily lead to longer run-time under constant power conditions.
- Both run-time and capacity depend strongly on the cut-off voltage. Pulse voltages can drop below the cut-off even though much cell capacity is still left.

What happens if the temperature changes during the discharge?

Test Results: Colder, then warmer (6 hours at -40°C)



Test Results: Colder, then warmer (2 hours at -40°C)

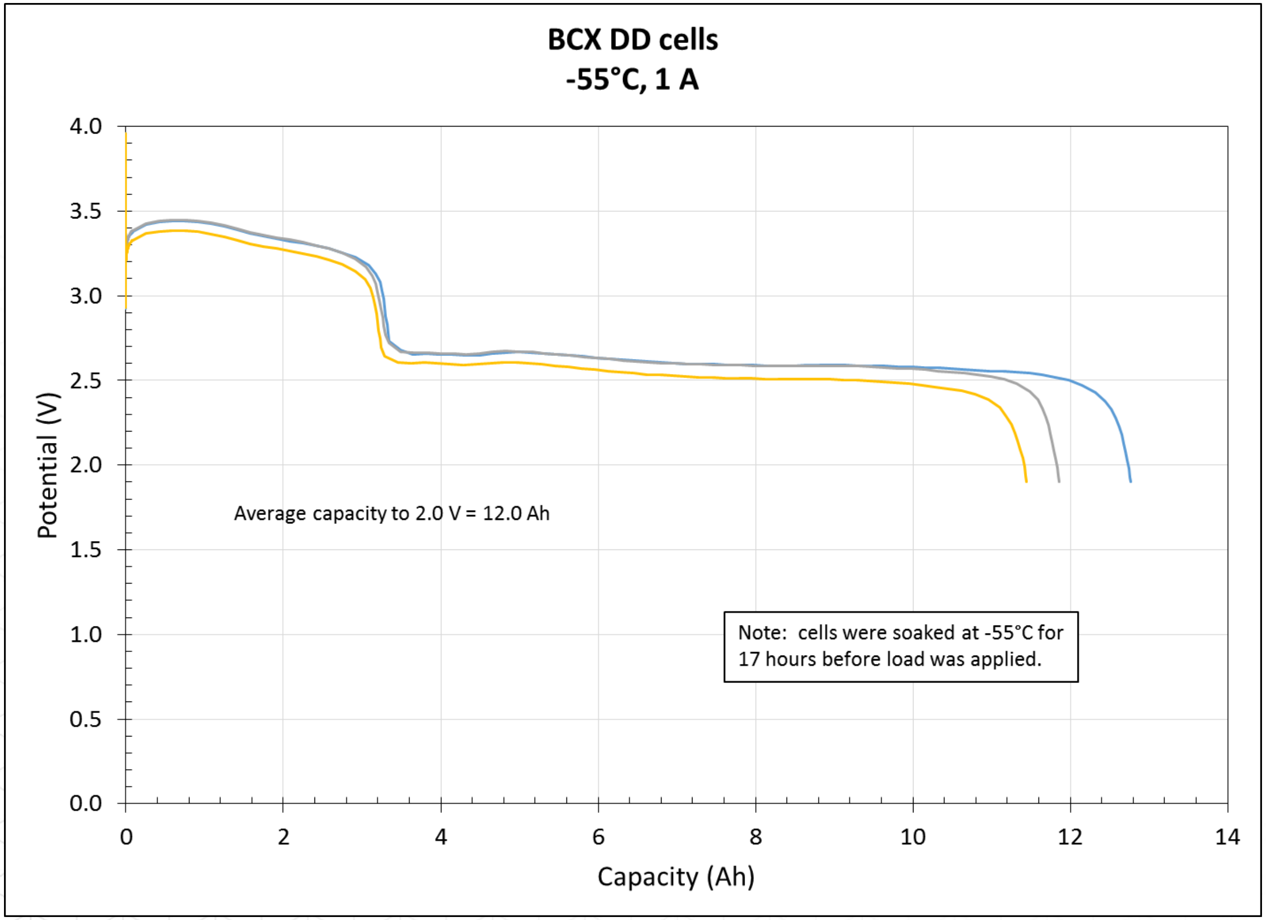


Comment About Multi-Temperature Operation

All of these cells can operate at very low temperature, for a time.

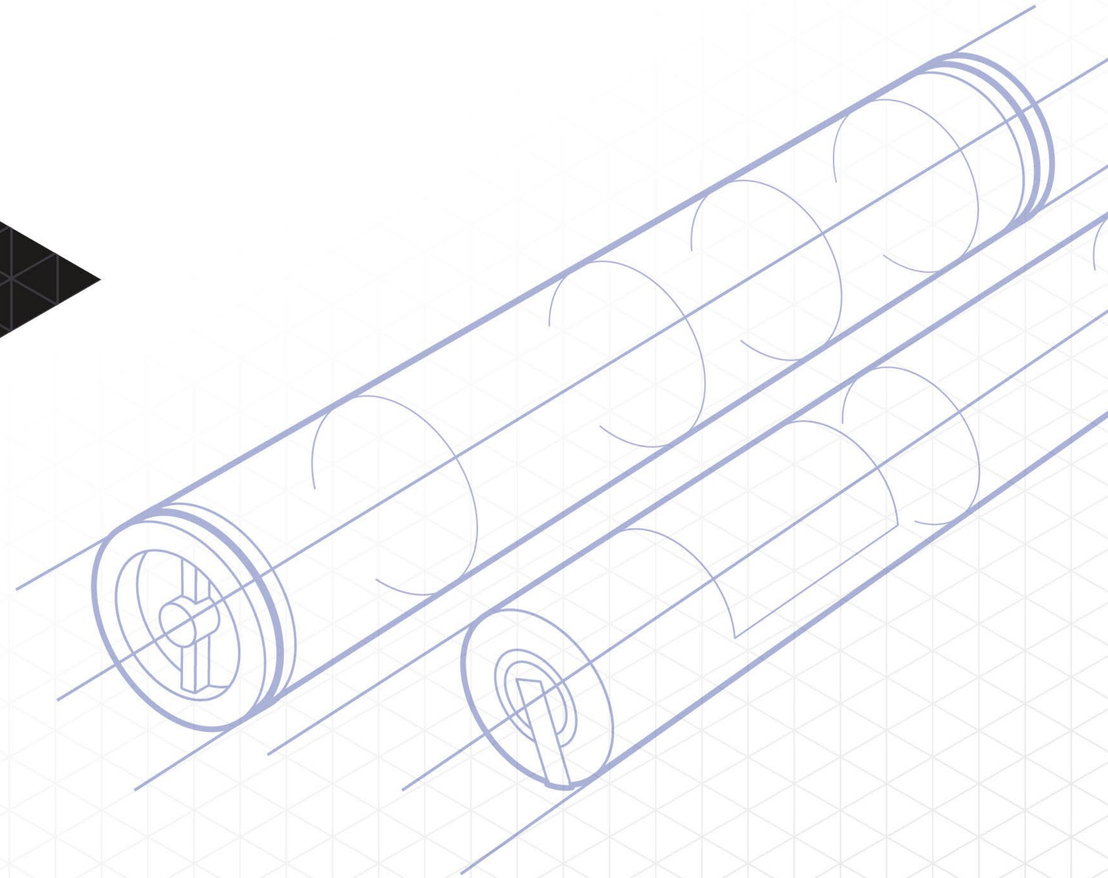
However, if the cells are discharged to 2.0 V at the low temperature, they may not recover fully when brought up to a higher temperature.

Very low temperature: discharge at -55°C



Thank you to Keith Anderson of Electrochem for his help in preparing this presentation.

Acknowledgments



Thank you for your attention!