Low Temperature Performance of Space Qualified COTS Li-ion Cells

NASA Battery Workshop 2026
Energy Storage II – Cell Level Developments for Energy Storage

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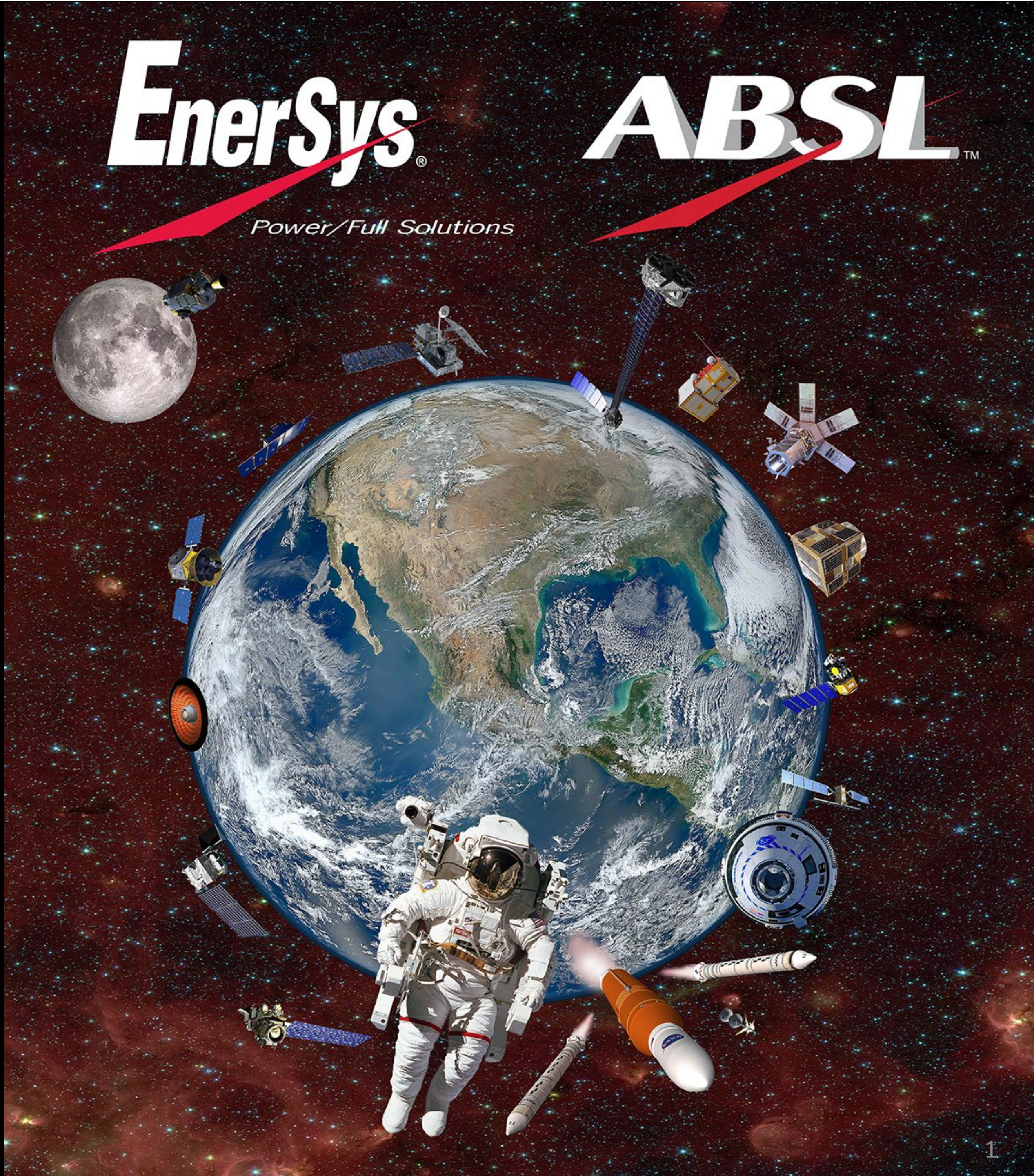

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The Power of EnerSys

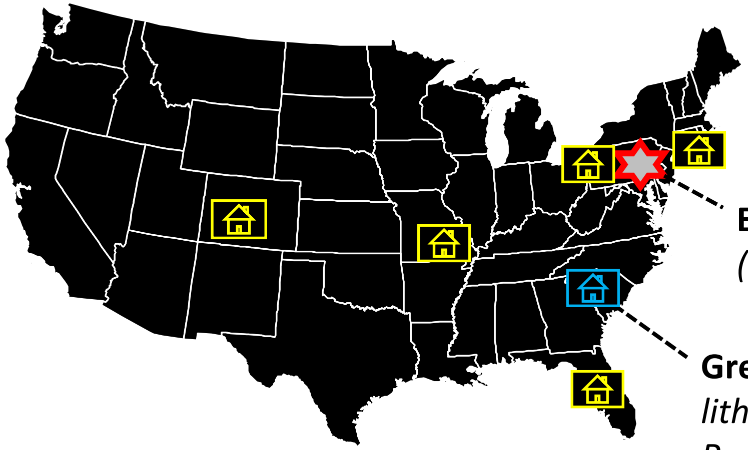
- World's Largest Industrial Battery company ~ $3.6B annual sales (FY2025)
- Leading brands in wide range of end-user markets
- US-owned / Publicly Traded
- Global – Over 10,000 employees with more than 30 locations, serving customer across 100 countries

ABSL Longmont, CO

- Motive Power
  - Forklifts
- Energy Systems
  - Telecom
  - UPS/Utility/ESS
- Specialty
  - Transportation
  - Aerospace & Defense

EnerSys Aerospace & Defense

Locations



EnerSys Headquarters: Reading, PA
(US Owned Company)

Greenville, SC
lithium-ion cell gigafactory
Production Start Date: TBD

Nine Engineering & Manufacturing Locations Serving Multiple Markets

Business Line	Brands	Technology	Location
Gigafactory	All EnerSys Li-Ion Brands	Lithium-Ion Materials, Cells, & Batteries	Greenville, SC
Space	ABSL	Lithium-Ion Cells, & Batteries	Longmont, CO & Culham, UK
Aviation	Hawker	Lead Acid & Li-Ion	Warrensburg, MO & Newport UK
Medical & Space	Quallion	Lithium-Ion Materials, Cells & Batteries	Horsham, PA
Munitions	EAS	Lithium Primary, Liquid Reserve & Thermal Batteries	Horsham, PA & Tampa, FL
Land & Sea	Armasafe / Hawker	Lead Acid	Warrensburg, MO
Ground Forces	Bren-Tronics / Rebel Systems	Li-Ion Batteries, Chargers, Tactical Power Electronics & Coms	Commack, NY & St. Petersburg, FL

ABSL Facilities Overview

Longmont, CO

- ABSL opened its original US facility in 2008 in Longmont CO, & joined the EnerSys family in 2011
- Growth over time has required multiple facility expansions
- Moved to current location in 2013 & took over neighboring suite in 2019
- Current facility covers 41,000 sqft of assembly, test, inspection, office, and meeting spaces
- 90+ passionate staff members
- Conveniently located in Northern Colorado. ~45 min drives to Rocky Mountain National Park, Denver International Airport (DEN) & Downtown Denver

- Wide range of engineering capabilities paired with ABSL's proprietary cell screening & processing
- Contamination-controlled manufacturing rooms
- In house destructive and environmental test laboratories
- Dedicated product development space
- Secured inventory stores
- In house CT Scanner
- 3rd party environmental testing lab is across the street

Motivation

- Batteries play a critical role in lunar missions, but lunar night survival (and performance) is very challenge
- Lunar night temperatures of -180°C for 14 days
- Thermal management systems are expensive (Mass, Power)
- Key Question: How much current can lithium-ion cells deliver at low temperatures?

Lunar Sunset from NASA cameras on Firefly's Blue Ghost Lander

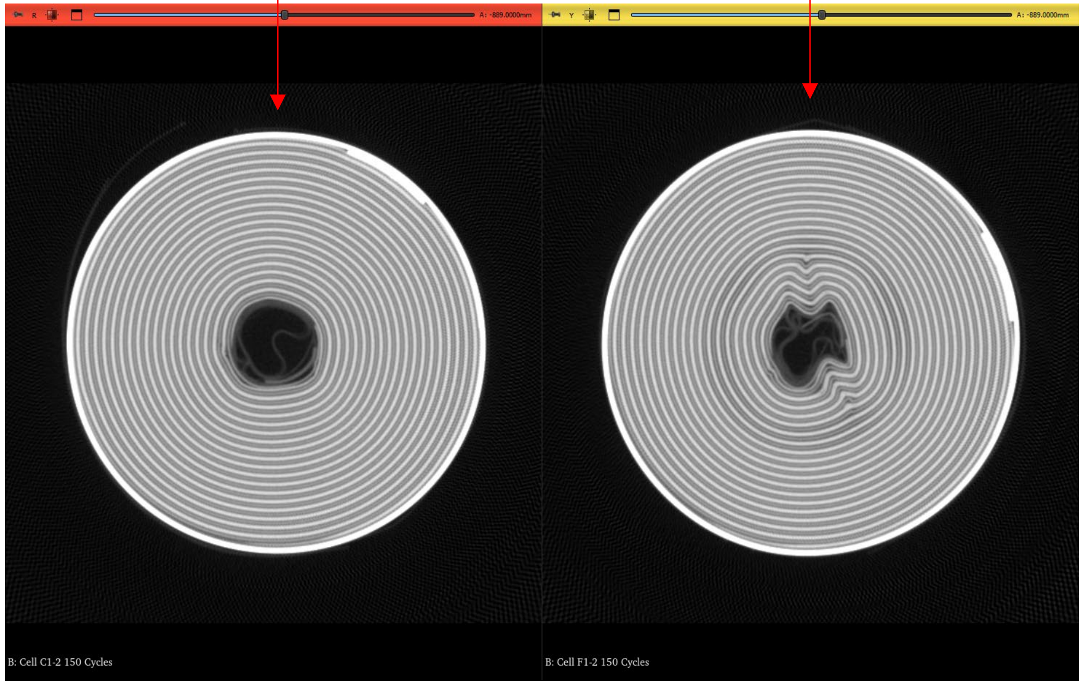
Previous ABSL COTS Cell Research on Low Temperature Effects

EnerSys Power/Full Solutions   ABSL

- No long-term capacity impact on 1–28-day cold storage at -60°C
- After a single freeze-thaw cycle to -160°C, cylindrical COTS Li-ion cells show little to no immediate capacity loss, but long-term performance is negatively impacted[1,2]
- COTS cells with freeze-thaw plus subsequent electrical cycles show electrode delamination and accelerated core collapse vs. control[2]

150 Cycles

Freeze/Thaw + 150 Cycles



[1] Pritchard, Ryan et al, "*Investigation of COTS Li Ion Cell Performance at Low Temperature*", Space Power Workshop 2024
[2] Rauchwarg, Justin et al, "*Effects of Low Temperature Freeze Cycles on COTS Li-ion Cells"*, Space Power Workshop 2025

Test Overview

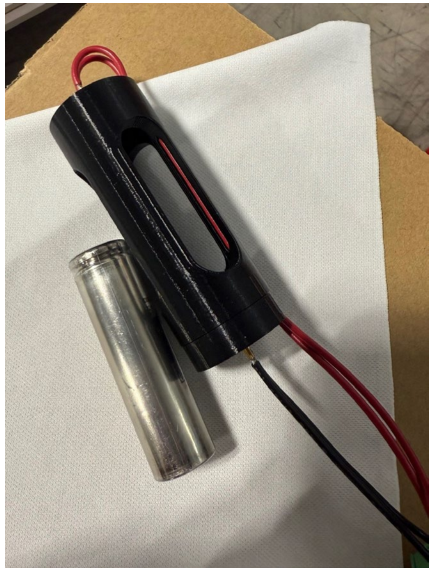
Test Overview

20°C Discharge Baseline
From 100% SOC
→ 10°C 4-hour soak
→ 10°C Taper Charge
→ Temp X°C 4-hour soak
→ Discharge
From 100% SOC

0°C	2C
-10°C	1C
-20°C	C/2
-40°C	C/5
-50°C	C/10
-60°C	

(Loop back from Discharge to 10°C 4-hour soak)

- **3 Different Cells:**
- **Cell A** – Energy focused commercial 1865
- **Cell B** – Power focused commercial 1865
- **Cell C** – Power focused commercial 2170



Test Overview - Details

20°C Characterization

10°C Taper Charge

Cold Temp Discharge

20C Characterization

- C/5 discharge to 2.5 V
- C/2 charge with C/100 taper to 4.2 V
- C/5 discharge to 2.5 V

10C Taper Charge

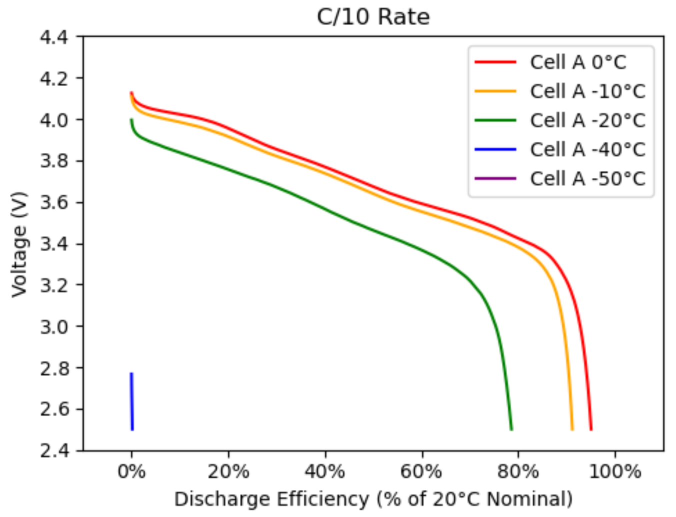
- C/5 discharge to 2.5 V
- C/2 charge with C/100 taper to 4.2 V

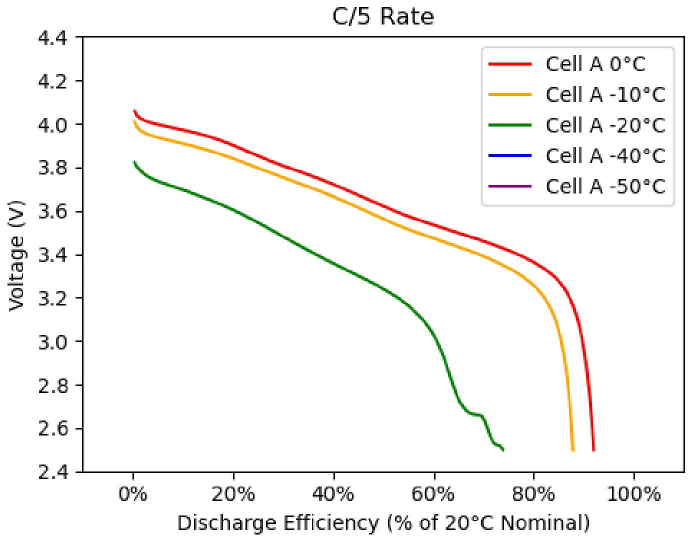
Cold Temperature Discharge

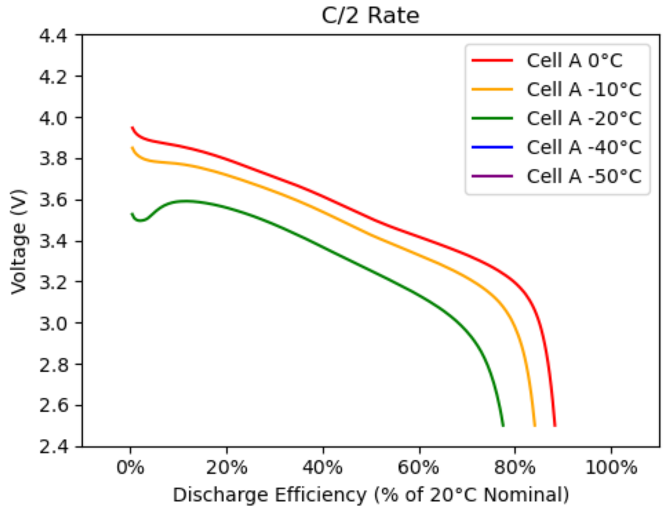
- 4+ hour soak at temperatures: 0°C, -10°C, -20°C, -40°C, -50°C, -60°C
- Discharge at: 2C, 1C, C/2, C/5, C/10 to 2.5 V or 2.0 V

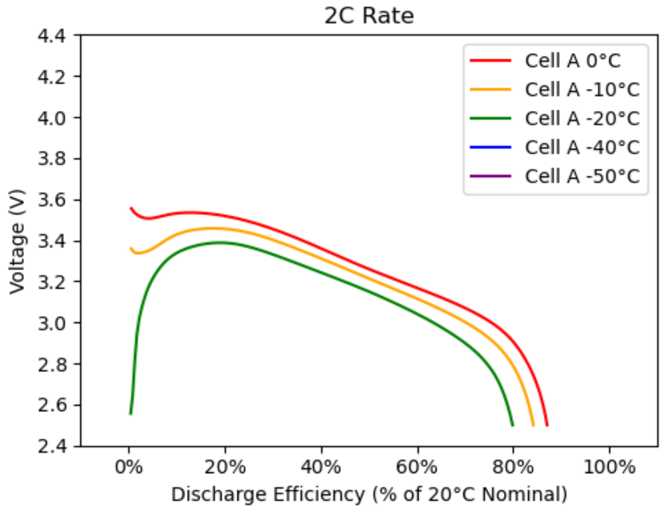
Results

Cell A at various C-rates



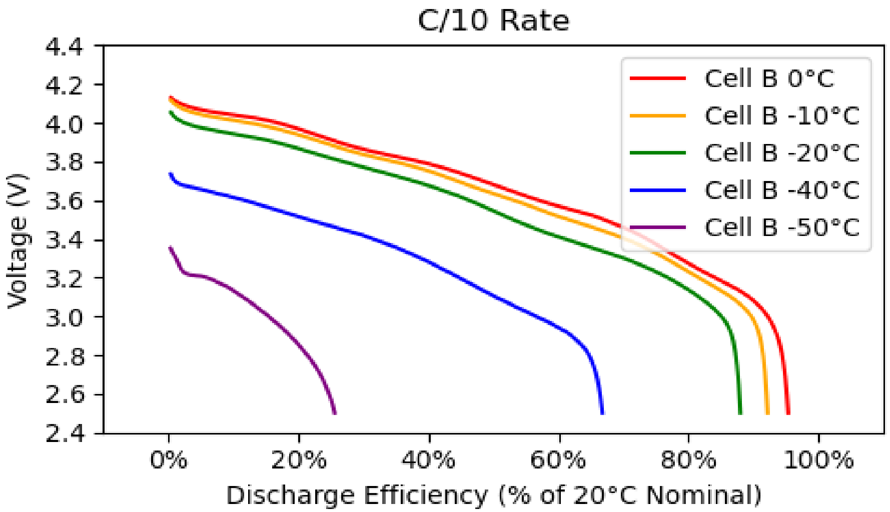


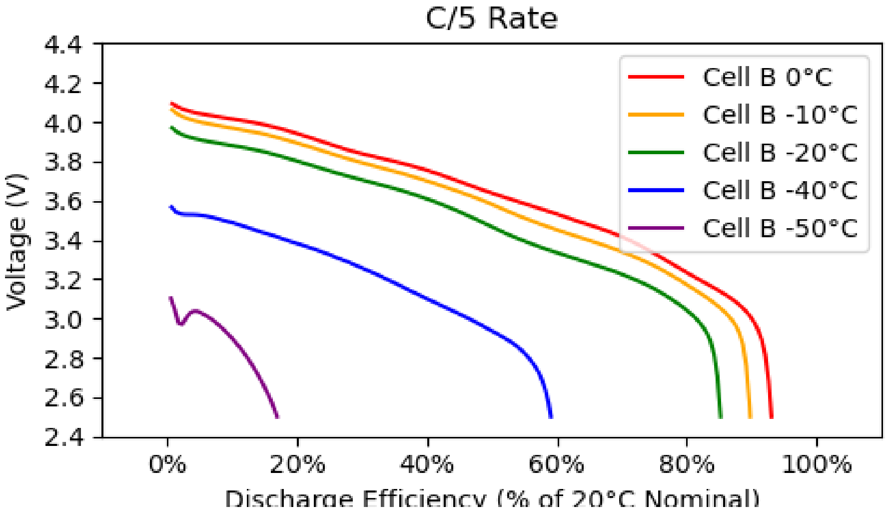


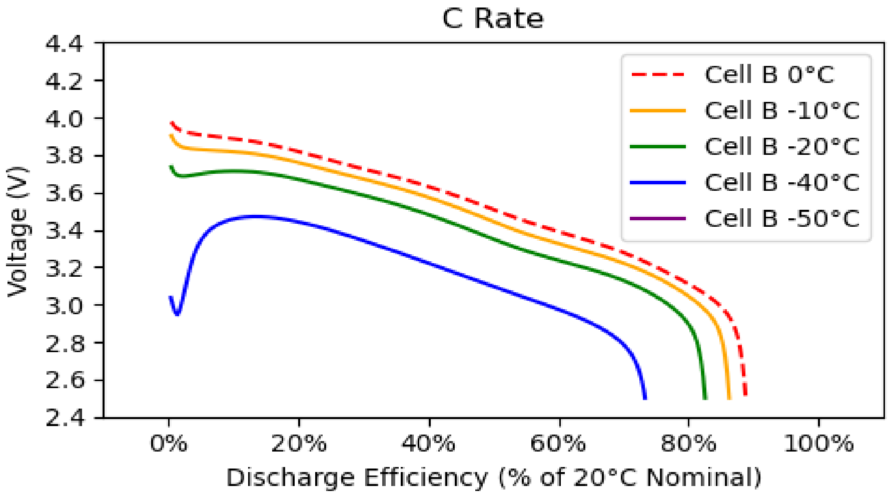


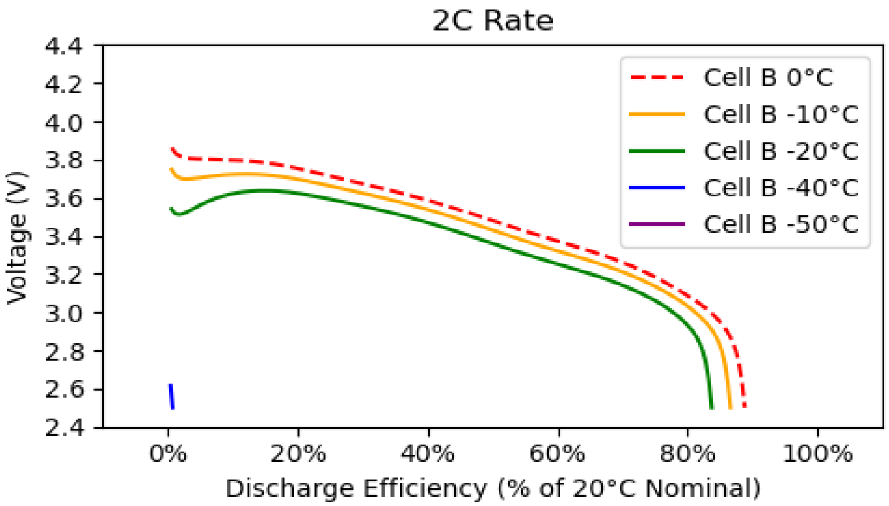
- Energy 1865 Cell
- X-axis is Discharge Efficiency
- Between -20°C and -40°C is cutoff for discharge capacity

Cell B at various C-rates



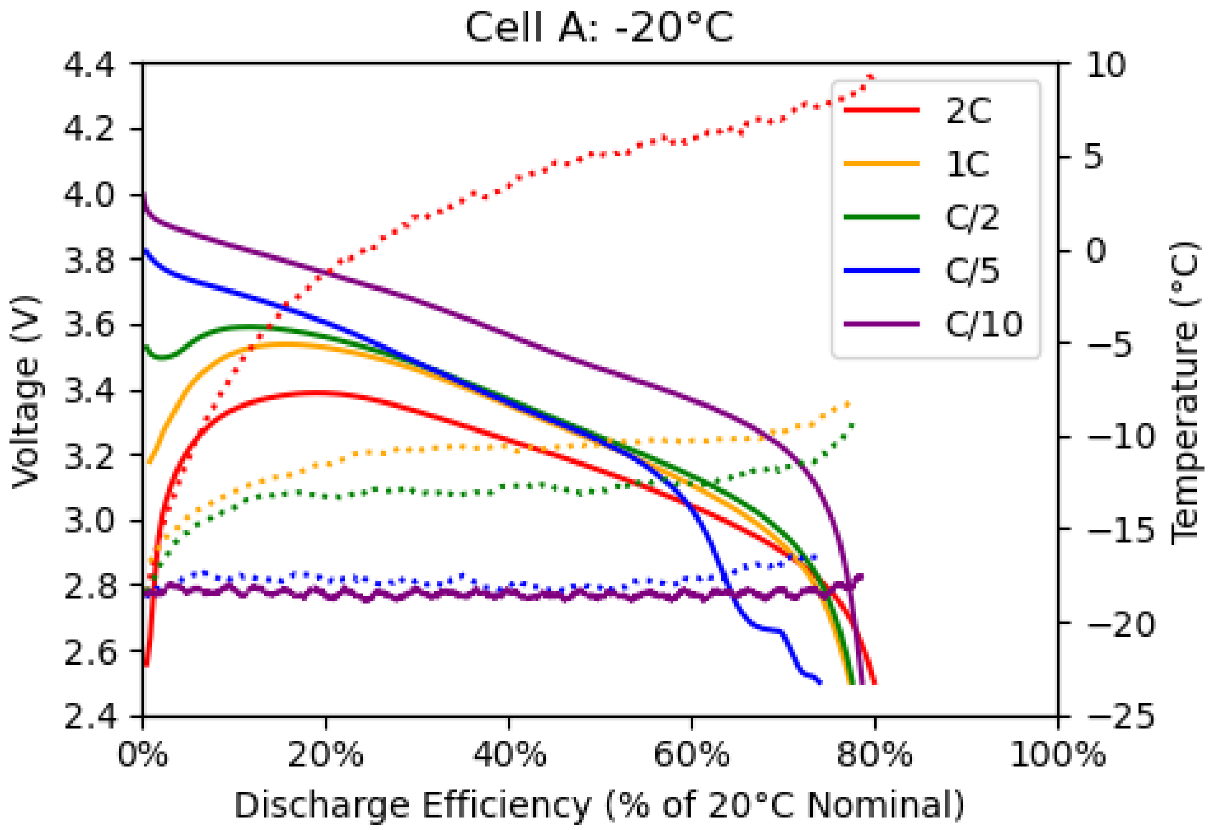


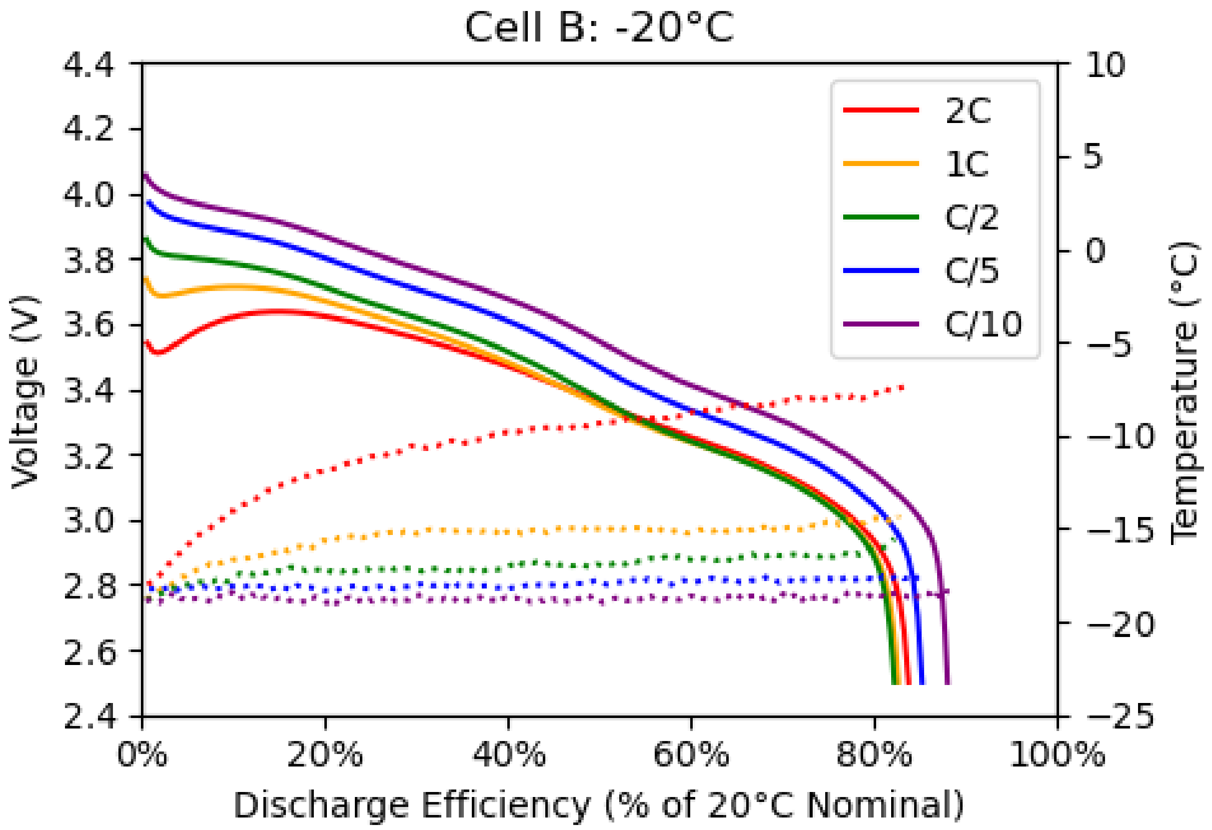




- 1865 Power Cell
- X-axis is Discharge Efficiency
- Between -40°C and -50°C is cutoff for discharge capacity
- C/10 shows better performance than 2C

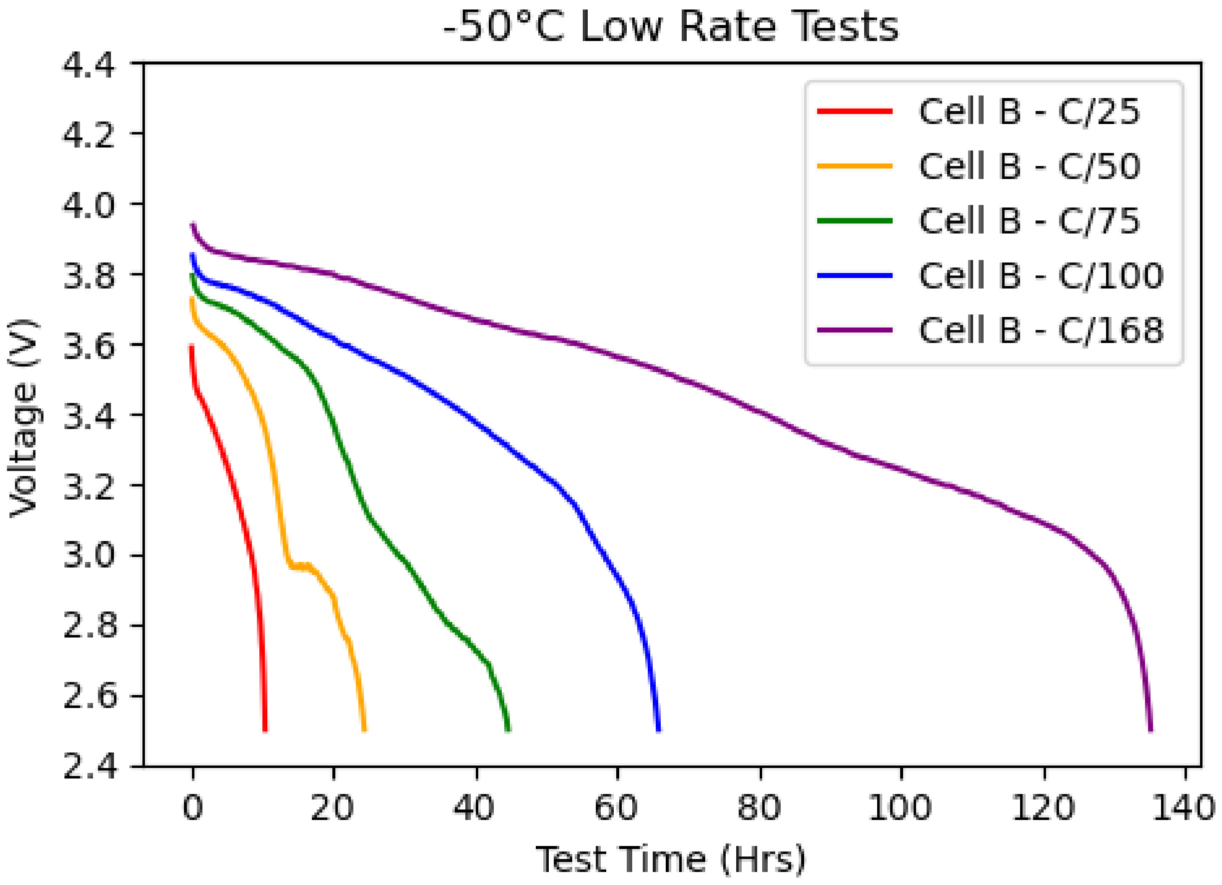
Cell A and B @ -20°C

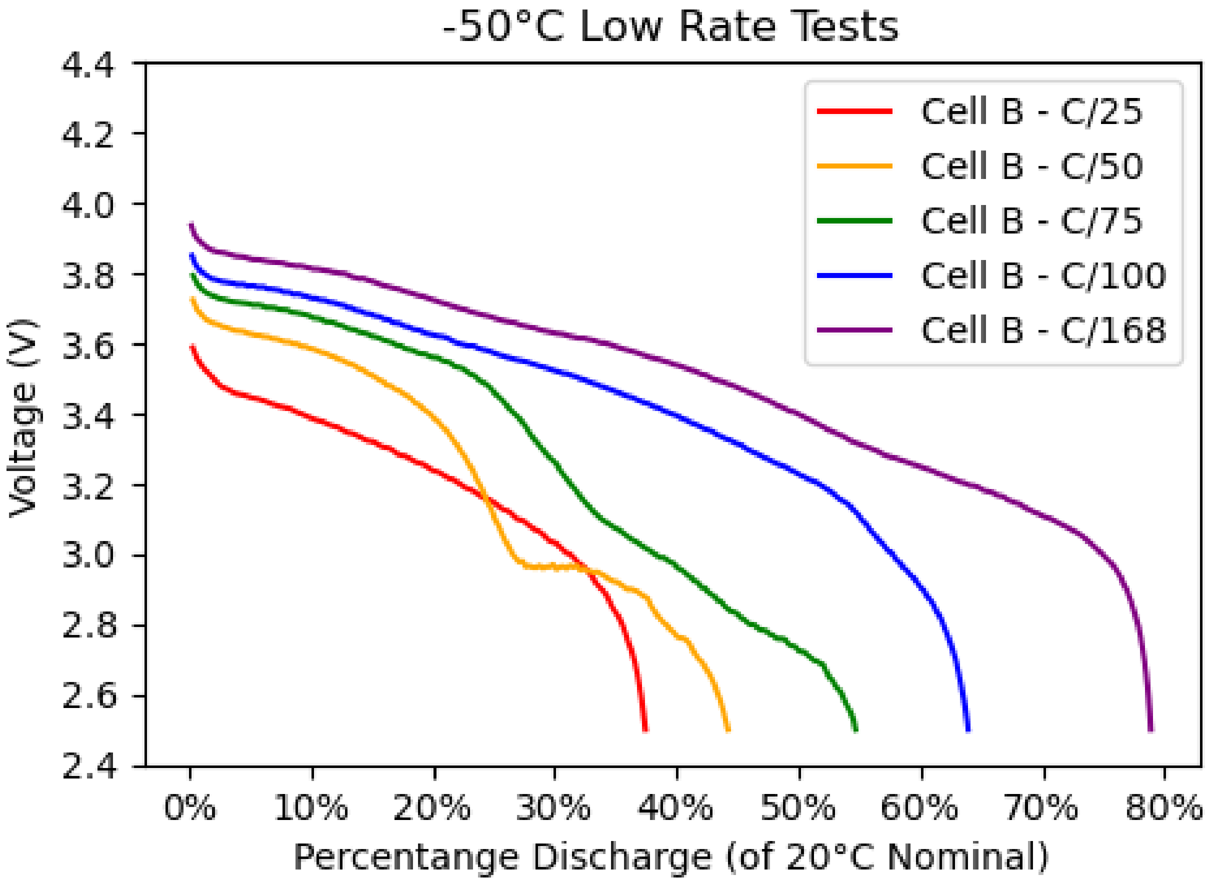




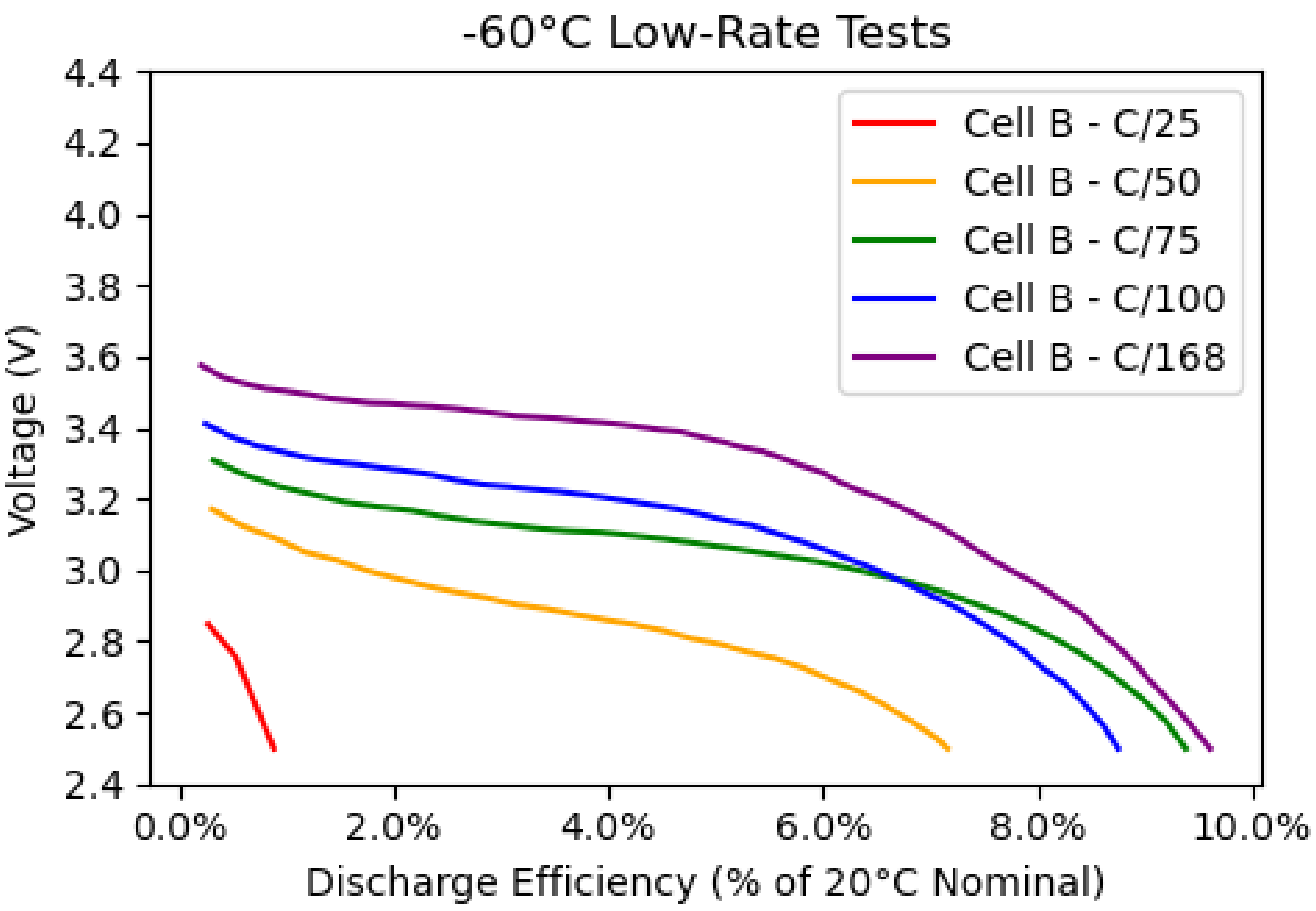
Low Low Rate Testing for Cell B

Cell B at **-50°C** – Low C Rates



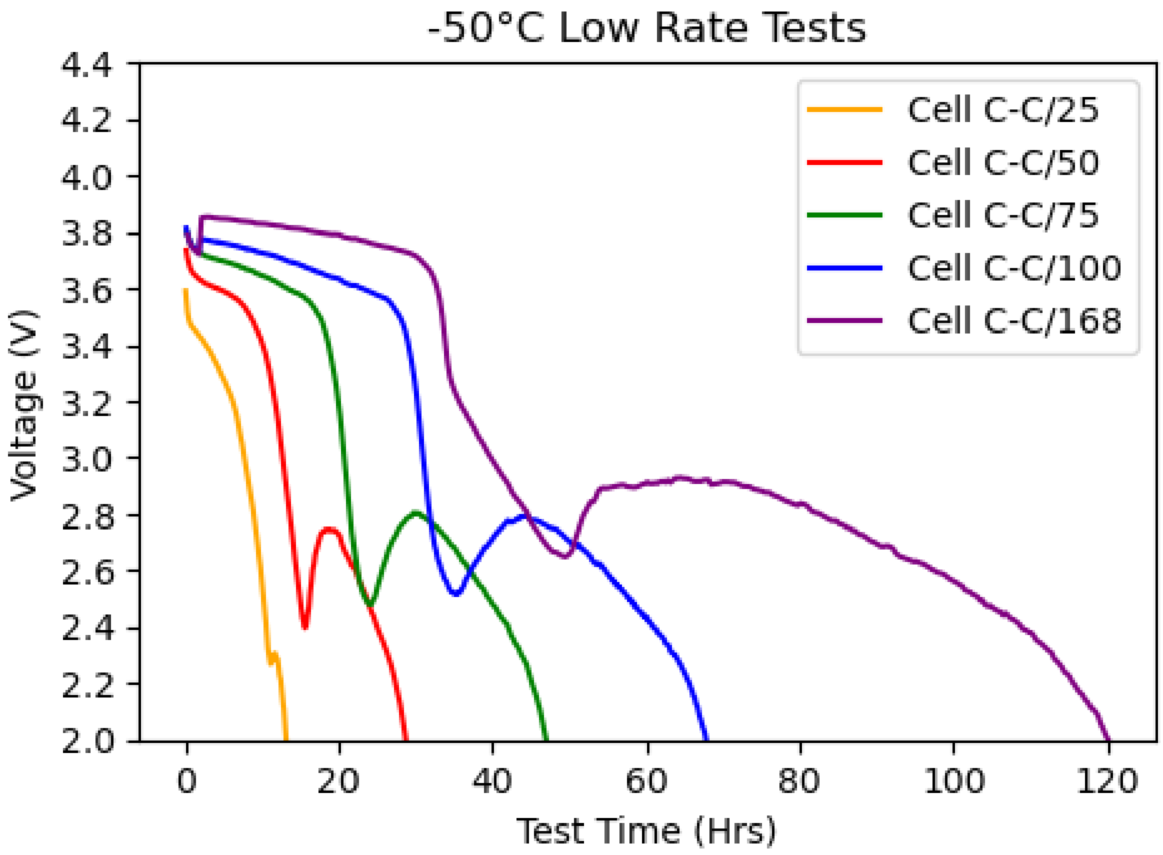


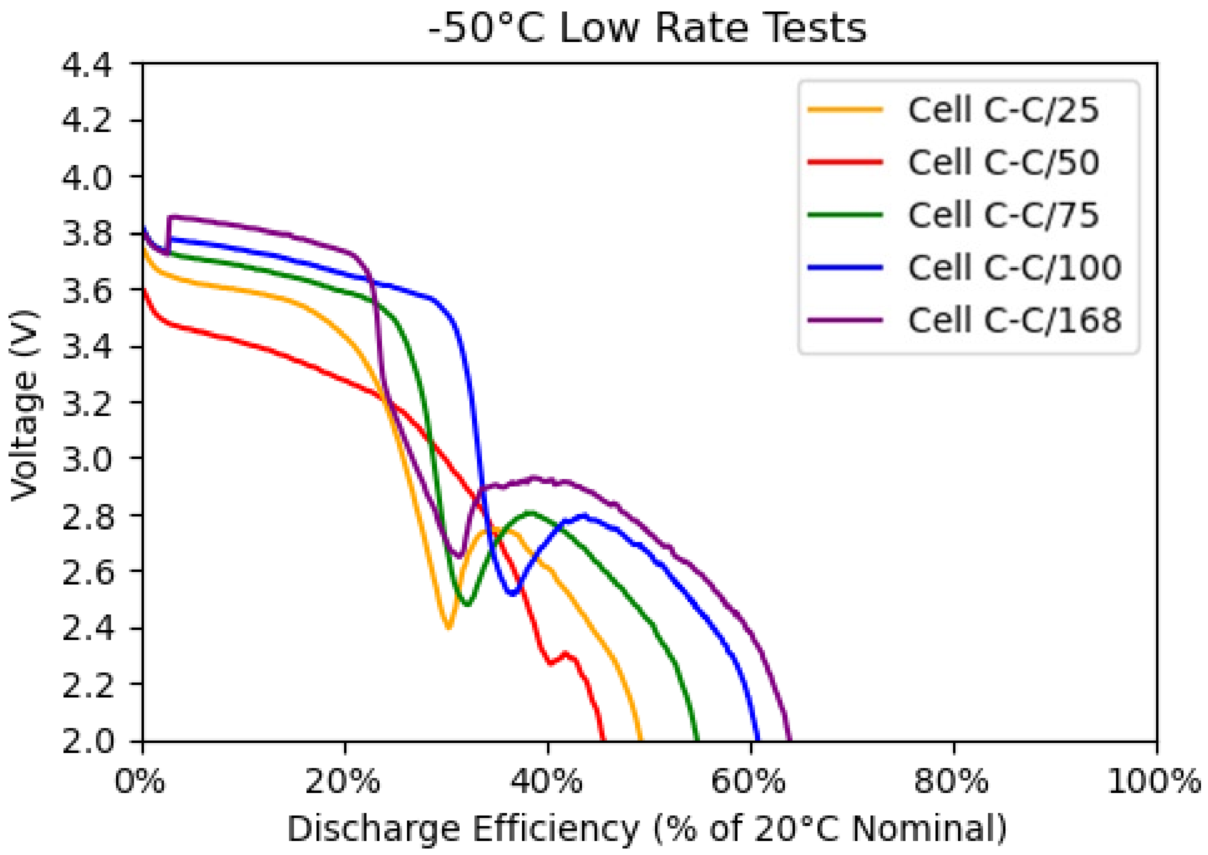
Cell B at **-60°C** – Low C Rates



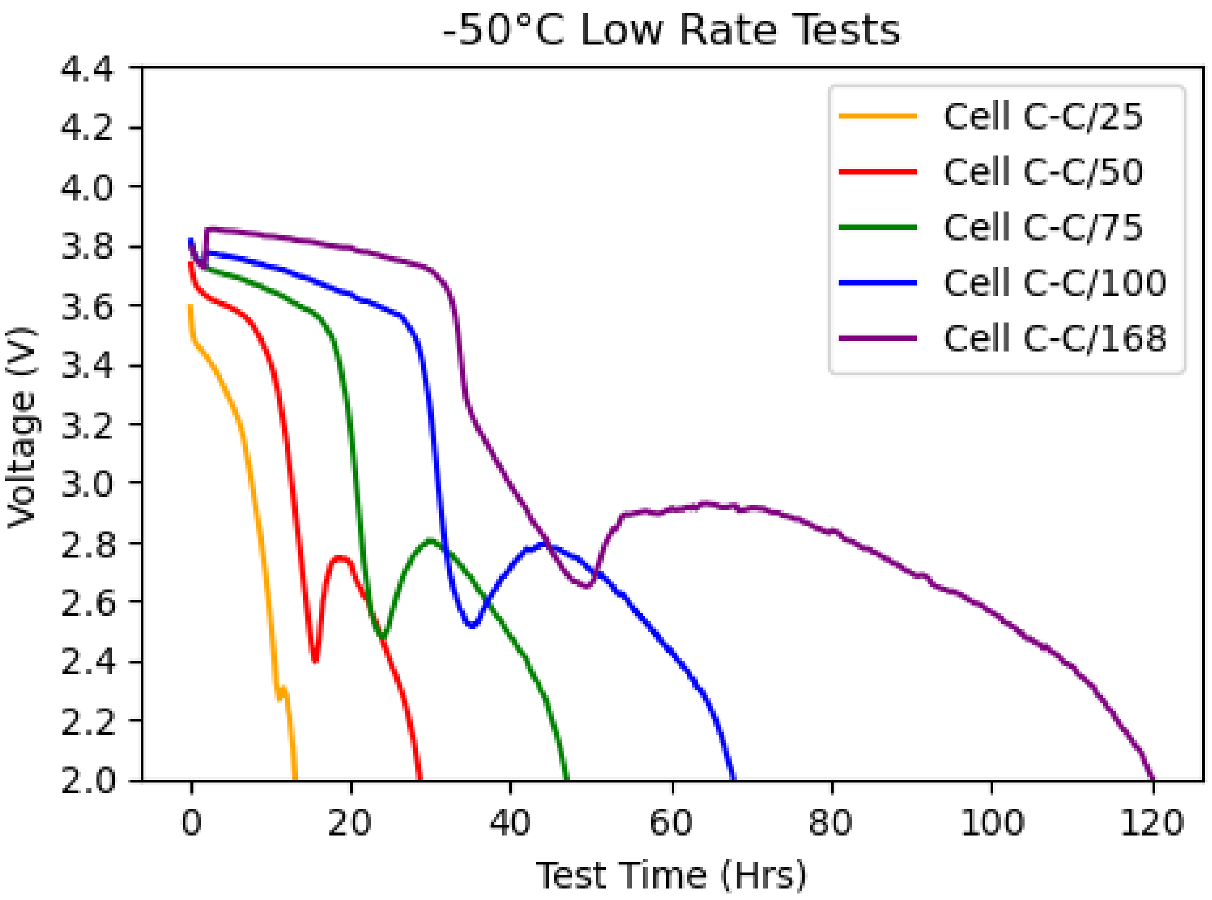
Cell C

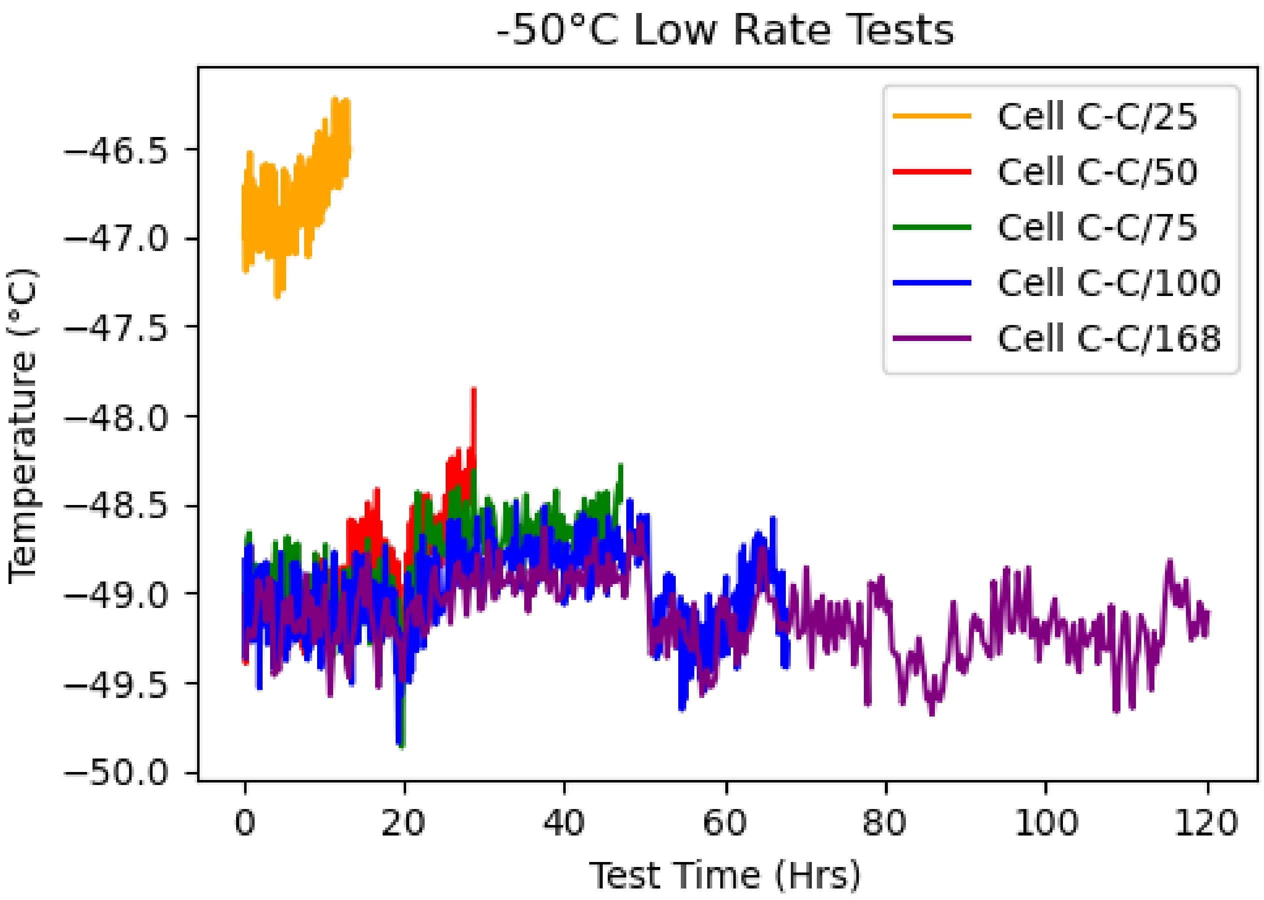
Cell C at **-50°C** with 2.0 V cutoff





Cell C at **-50°C** with 2.0 V cutoff





*1.5 A charge to 4.2 V with 100 mA taper and 4 A discharge to 2.5 V used for cycling

Cell C

Cell C – 2170 Power Cell

- Roughly 12% higher energy density than 1865 cell
- Likely thicker electrode → higher Li-ion concentration gradient

- At low temperatures, transportation of lithium through electrolyte is very very slow.
- At start of discharge, Li ions become concentrated at cathode electrode and depleted at anode graphite surface
- This large gradient causes overpotential and thus reduces cell voltage
- At some point, Li ion concentration lessens and distributes into cathode surface, causing voltage relaxation

Conclusion

Conclusion

Cell A & B – 1865 COTS Energy and Power Cell

- Temperature, not discharge rate, has a stronger factor on delivering discharge energy at low temperatures
- Discharge energy drops rapidly below minimum operating temperature at -20°C to -50°C. However, energy can be significant if discharge rate is low enough.

Cell C – 2170 COTS Power Cell

- Minimum operating temperature can be lower than spec sheet minimum: -40°C

Next Steps

- Test new/additional cells as they arrive
- Try even lower c-rates
  - Possibly even lower temperatures
- Gauge interest on cycle life capacity at these temperatures and c-rates
- How cold can this cell operate at low c-rates?

Acknowledgements

Ryan Pritchard – Cold Temp Testing Last Year

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Thank you!

Questions?