$LiFePO_4$ Testing

$LiFePO_4$ Batteries vs Lead Acid Batteries

- Charging cycles
- **Weight and Volume**
- Charging efficiency
- Charging complexity
- **Cost**
- **Cold temperature performance**

The PASSCAL Engineering group and Genasun have characterized the cold temperature performance of the $LiFePO_4$ batteries sold by Genasun:

- In-house cold temperature discharge testing
- Third part cold charging investigation

$LiFePO_4$ Testing

Cold Discharge Testing:

- **Test Phase 1** – High current discharge tests to verify batteries' ability to operate at cold temperatures
- **Test Phase 2** – Constant current to constant voltage (CC/CV) discharge tests to characterize low discharge rate performance
- **Test Phase 3** – Long term low current discharge test

Third-party cell characterization:

- Effect of cold charging on $LiFePO_4$ cells, charging efficiency at low temperatures

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$LiFePO_4$ Test Phase 1

Temp	5A	2A	1A
25C	103Ah	103Ah	104Ah
-20°C	57Ah	69Ah	85Ah
Capacity at -20°C	55%	67%	82%

- Clear loss of capacity at lower temperature
- Capacity loss lessens as discharge rate decreases (beneficial for Polar use)

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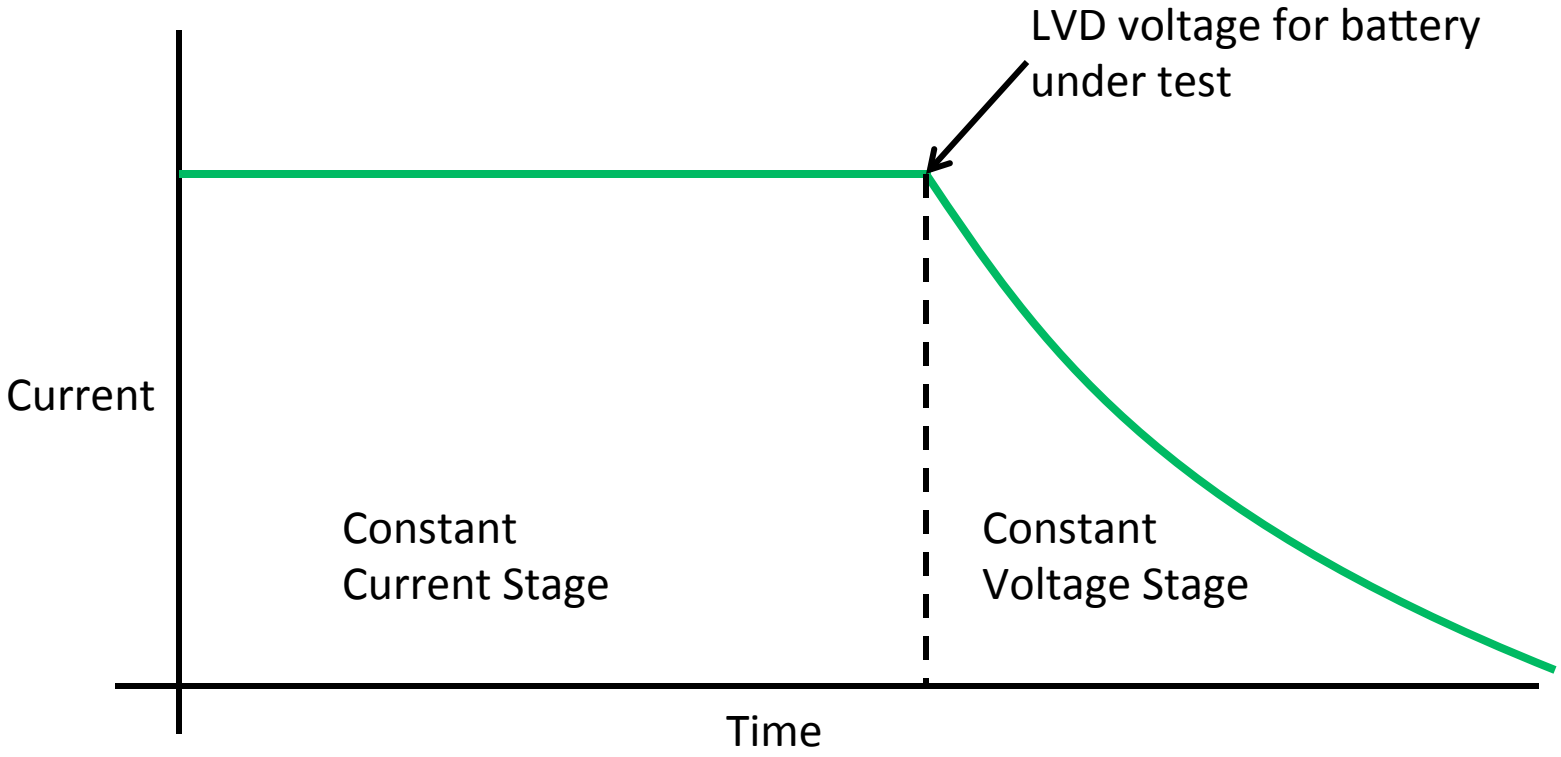
$LiFePO_4$ Test Phase 2

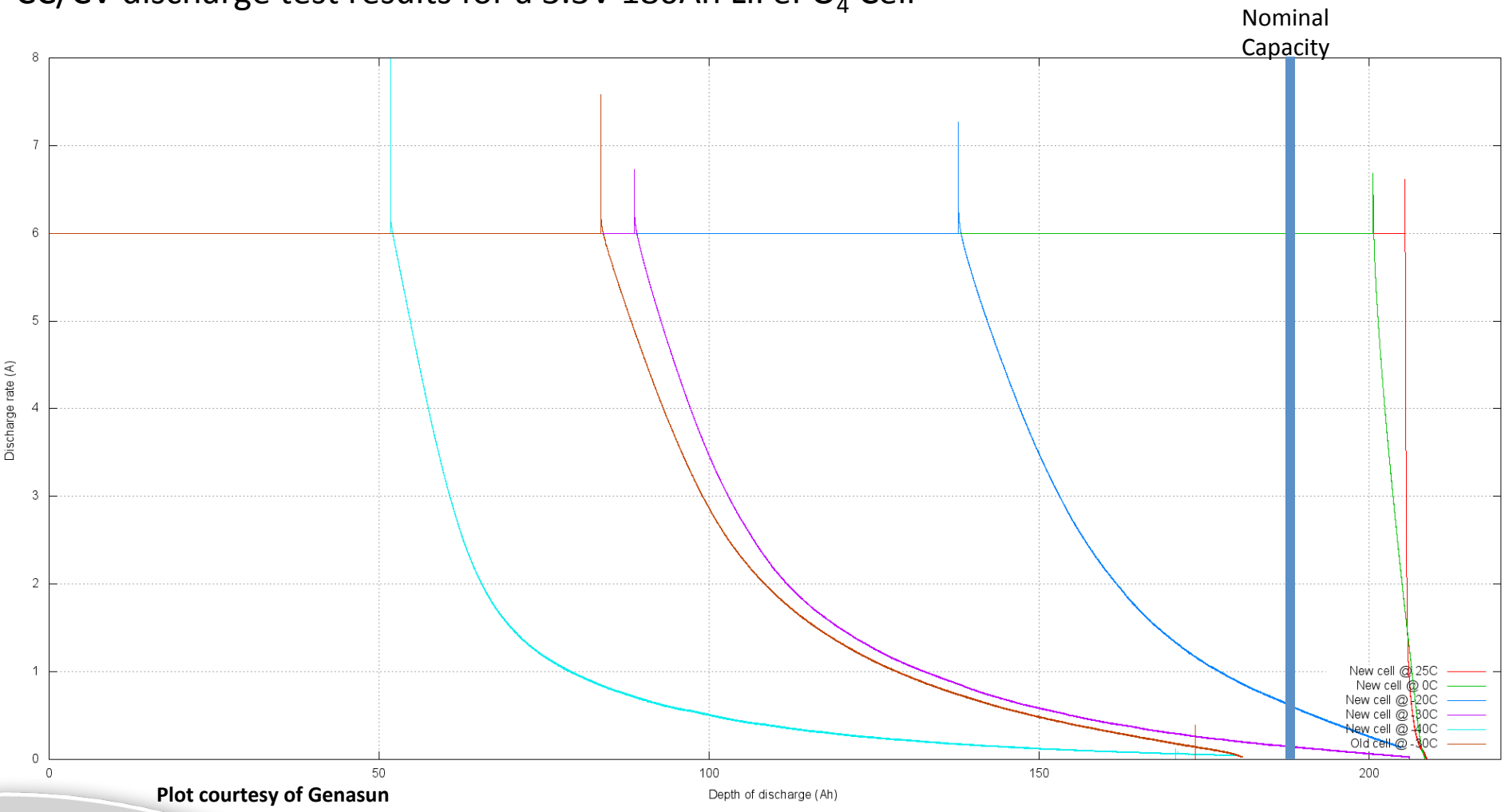
Genasun ran CC/CV discharge tests to rapidly characterize performance at low discharge rates



- Rapidly remove a significant portion of the battery's capacity
- Can obtain a complete capacity vs. discharge rate curve after running a single test
- Run this test at different temperatures to obtain capacity vs temperature relationship

$LiFePO_4$ Test Phase 2

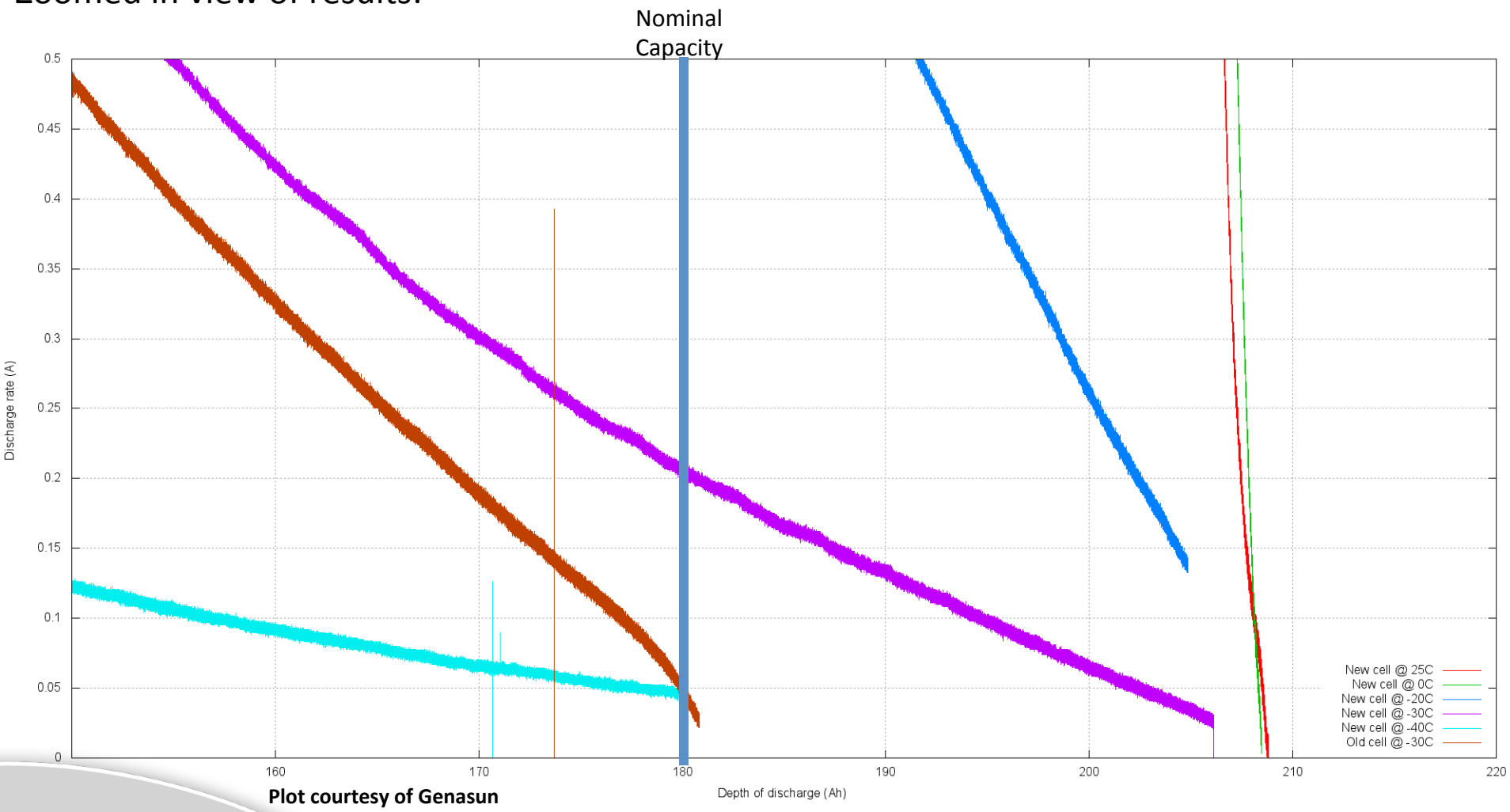
CC/CV discharge test results for a 3.3V 180Ah $LiFePO_4$ Cell



Plot courtesy of Genasun

$LiFePO_4$ Test Phase 2

Zoomed in view of results:



Plot courtesy of Genasun

$LiFePO_4$ Test Phase 2

Comparison of constant discharge rate and temperature affects on the 180Ah $LiFePO_4$ Cell:

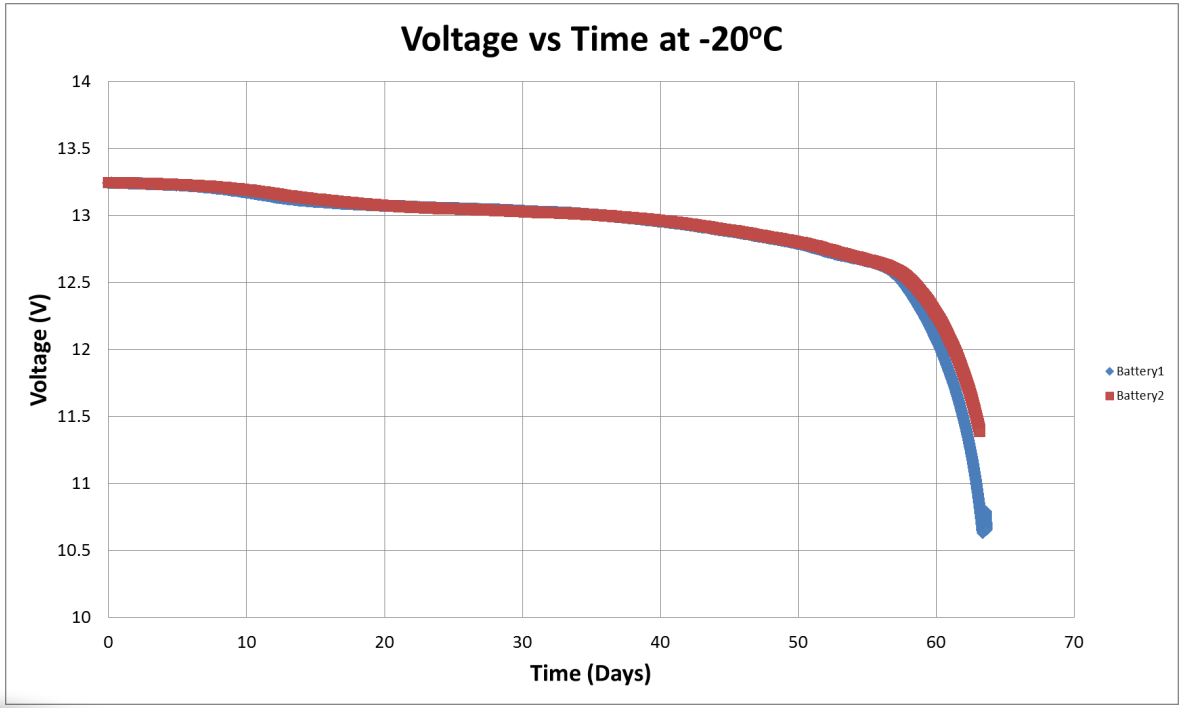
Discharge Rate	-40°C	-30°C	-20°C	0°C
1A	79Ah	132Ah	177Ah	206Ah
0.5A	100Ah	155Ah	192Ah	207Ah
0.25A	125Ah	175Ah	200Ah	207.75Ah
0.1A	157Ah	195Ah	205Ah	208.1Ah
0.05A	180Ah	203Ah	ND	208.3Ah

Low discharge rate allows the battery to deliver nameplate capacity even at very cold temperatures

$LiFePO_4$ Test Phase 3

Two month discharge test to validate cold temperature performance

- Two identical 100Ah $LiFePO_4$ batteries were discharged at -20°C with a load sized to drain the batteries in two months (≈65mA current draw).



Capacity Delivered:

Batt 1 = 97.7Ah

Batt 2 = 97.5Ah

Essentially no de-rate from nameplate capacity!

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$LiFePO_4$ Testing – Third Party

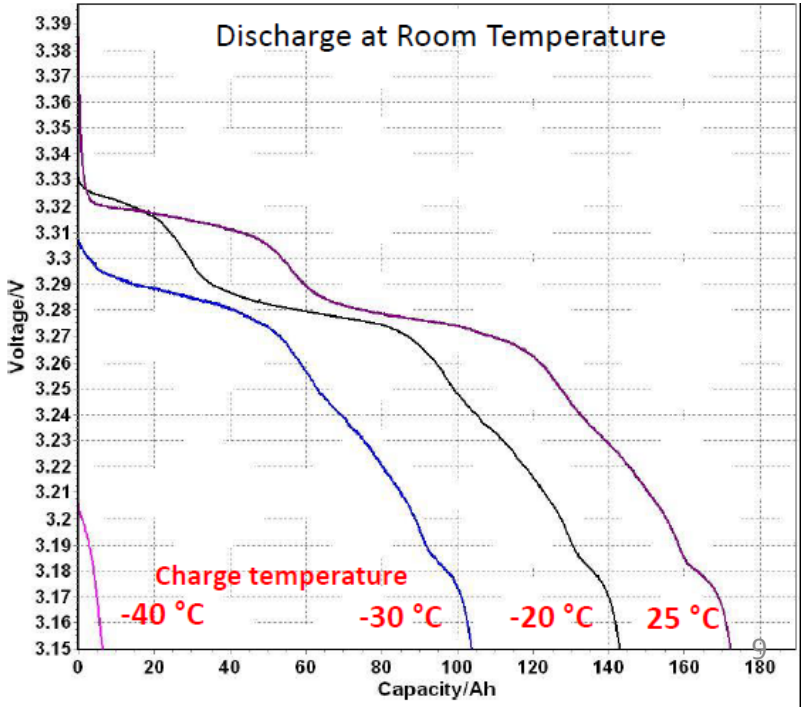
Third party – Exponent Engineering and Scientific Consulting contracted by Genasun

Key Points

- At low temperatures, cell resistance increases significantly which limits charge/discharge capacity
- No evidence of lithium plating in the cells when charged at low temperatures
  - i.e. cells are NOT damaged by cold temperature charging (within bounds)
    - Exponent charged cells with 39.5A at -10°C, -20°C, -30°C and -40°C
- Electrolyte NOT frozen at -40°C, but it is partially frozen at -60°C.

Temperature (°C)	Charge Capacity (Ah)
25	187.7
-20	159.8
-30	104.0
-40	19.0

Plot, table courtesy of Genasun



Battery Testing

1. Long Term AGM Testing:

- 108Ah SunExtender Battery discharged at -20°C and -30°C
- Resistive load discharged battery at C/5840 rate
  - Same rate batteries deployed at year round AGM station in Antarctica experience
- -20°C: 64% of nameplate capacity
- -30°C: 56.5% of nameplate capacity

2. Long Term LTC Testing:

- Test is currently running and should complete in two months
- -30°C test to verify battery performance for two year deployment station design and verify manufacturer's data.

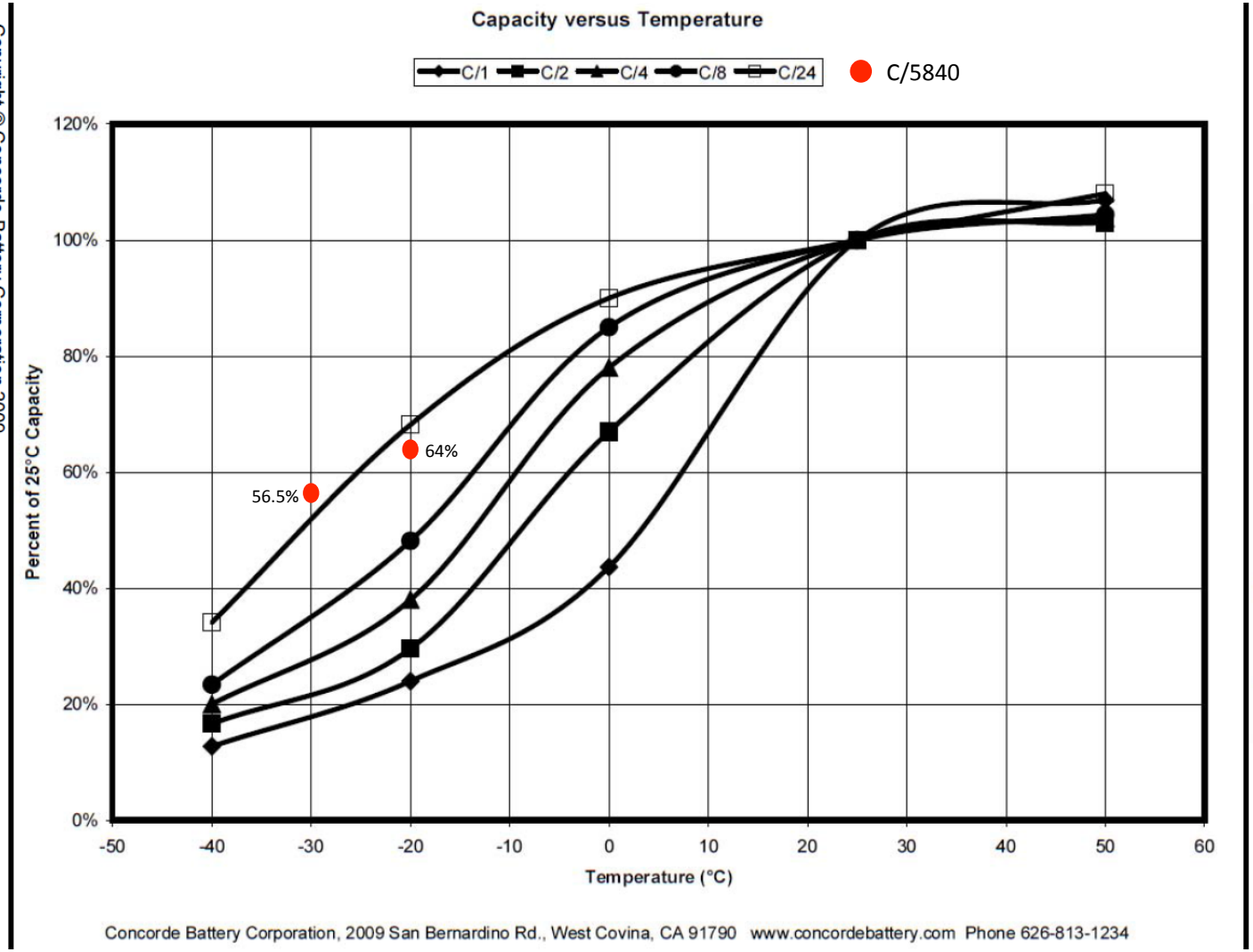
3. Air cell cold testing

- Planned test to characterize the performance of air cell batteries at cold temperatures (0°C to -30°C).
- Materials are purchased and test is scheduled to begin immediately

4. Rechargeable LiFePO4 battery testing

- No testing updates from last PTC. A written report of results is available, e-mail polar@passcal.nmt.edu for a copy
- Results of in field testing from the TA-Alaska project are expected soon

Battery Testing



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