September 12, 2025

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THE CHANGE CATALYST®

AN APPROACH TO INCREASE NEGATIVE CHARGE ACCEPTANCE AND REDUCE WATER LOSS AT THE SAME TIME

The Issue

To maximize the performance of lead-acid batteries, particularly in EFB, AGM start-stop, deep-cycle, and energy storage applications, enhancing the negative plate's charge acceptance—especially under partial state-of-charge conditions—and mitigating side reactions such as hydrogen evolution reaction (HER) are critical.

Previous Approaches

Various approaches have previously been proposed to improve charge acceptance, including the use of high-conductivity carbon, increasing carbon loading, employing high-surface-area carbon, and carefully selecting surface functional groups. While these methods have achieved notable success, they have also significantly increased water loss, thus compromising the benefits of enhanced charge acceptance.

Water Loss

Water loss can be caused by harmful impurities like Ni, Cu, Sb, etc., which can be reduced by using low-impurity raw material and better control of the production process. However, water loss caused by active sites on the surface of carbon is difficult to alleviate. Higher surface area carbons have more active sites in catalyzing HER.

New Solution

In our research on carbon lignin interaction, Hammond developed a composite lignin that can selectively cover the active sites of carbon, thus drastically suppressing HER. It also provides similar performance to the typical industry-used lignin. This allows Hammond to provide expanders with improved charge acceptance and lower water loss at the same time.

Test Plan

- Test Expander: EFB formulation
- Hammond classical SLI expander as control. Control Expander: SLI formulation
- 4 types of carbon were compared in the project:
  1. Expanded graphite, low surface area, very good conductivity.
  2. Multi-purpose carbon black, medium-high surface area, medium-high structure.
  3. Acetylene black, hydrophobic surface, medium surface area, very high structure, good conductivity.
  4. Furnace black, medium surface area and medium structure.

Test Plan

- Two types of lignin were used in the project:

  1. Vanisperse A from Borregaard Lignotech (EFB A, EFB B, EFB C, and SLI expanders)
  2. HGI Composite Lignin (EFB D expander)

Total lignin loading is the same for all 4 EFB expanders.

To compensate for the lignin absorbed by carbon,

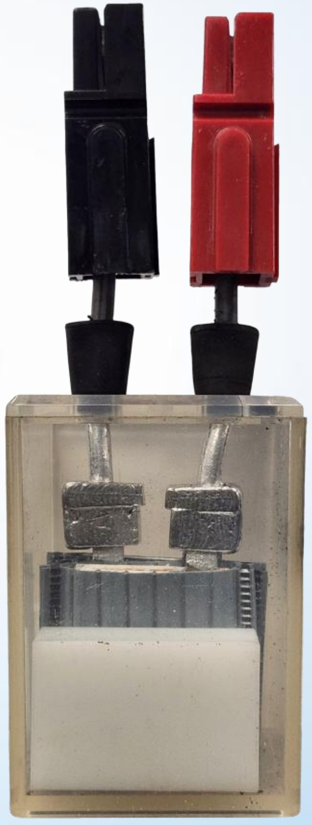
lignin used in the EFB expanders was slightly higher than SLI.

Cell Test

Cell Structure: 3P2N cells

Test Procedures

1. Formation
2. C20
3. CCA-1
4. Reserve Capacity-1
5. CCA-2
6. Reserve Capacity-2
7. Gassing
8. Peukert
9. 17.5% DoD (2 cells) / 50% DoD Cycling (2 cells)



Test Results – Cured vs. Formed NAM BET

All cells were formed with the same formation profile.

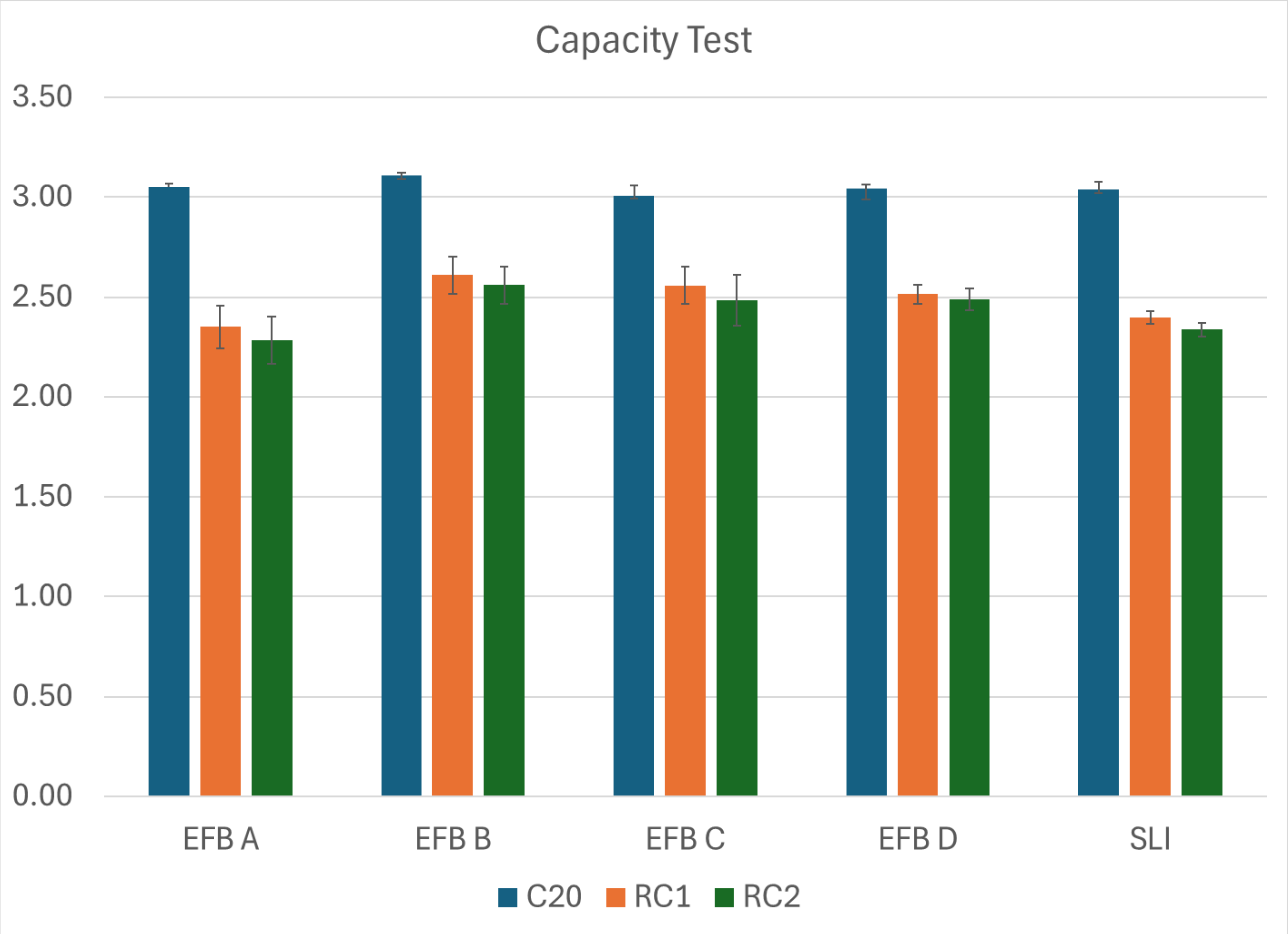
BET (m^2/g)	Carbon contribution*	Cured NAM	Formed NAM	FNAM/CNAM**
EFB A	0.32	1.97	1.21	0.61
EEB B	0.86	2.13	1.33	0.62
EFB C	0.55	2.06	1.30	0.63
EFB D	0.48	1.85	1.16	0.63
SLI	0.09	1.68	0.70	0.42

* Carbon contribution is the calculated BET contribution from the carbon in the paste.

** FNAM/CNAM is the ratio of Formed NAM BET vs. Cured NAM BET

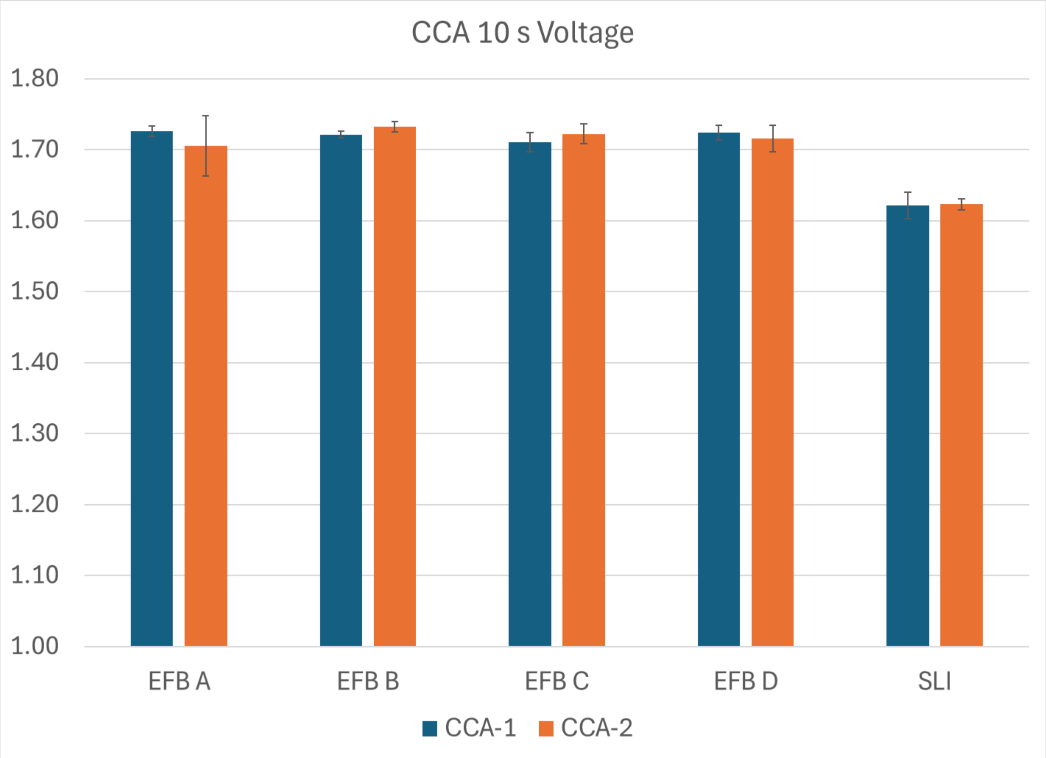
- Carbon can increase the cured and formed negative material BET.
- Same loading of lignin in the paste, the BET ratio between the formed and cured paste is very close.

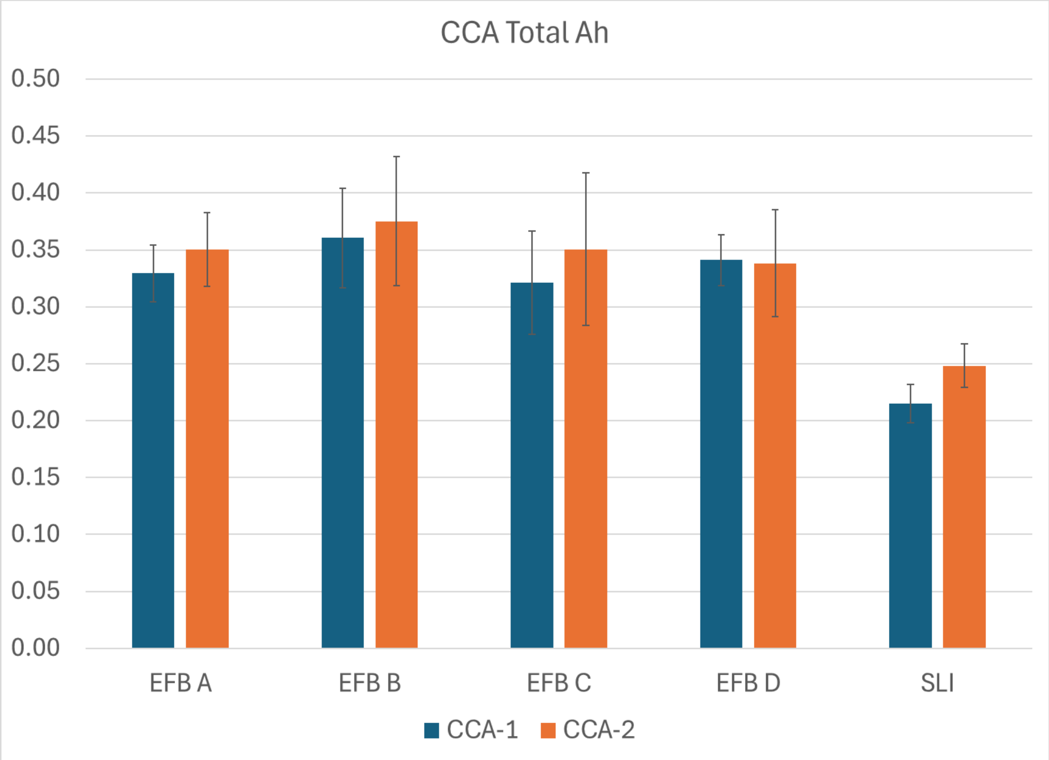
Cell Test – Capacities



- All expanders showed very close capacities.

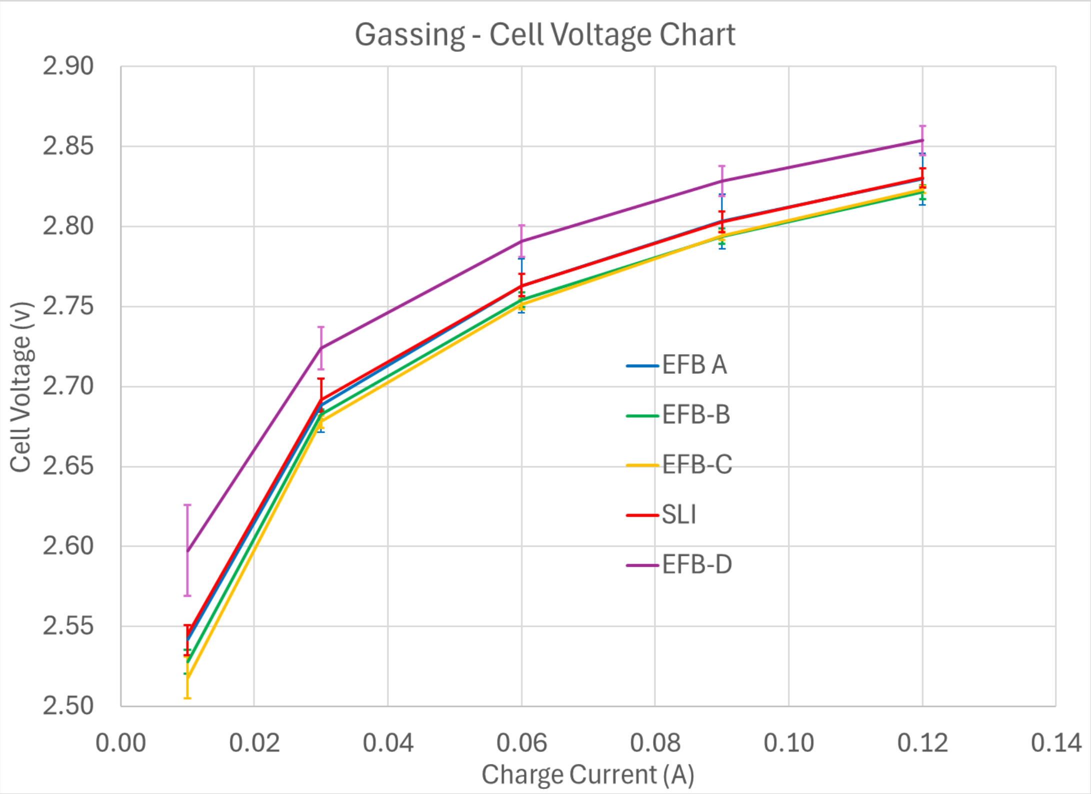
Cell Test – CCA test

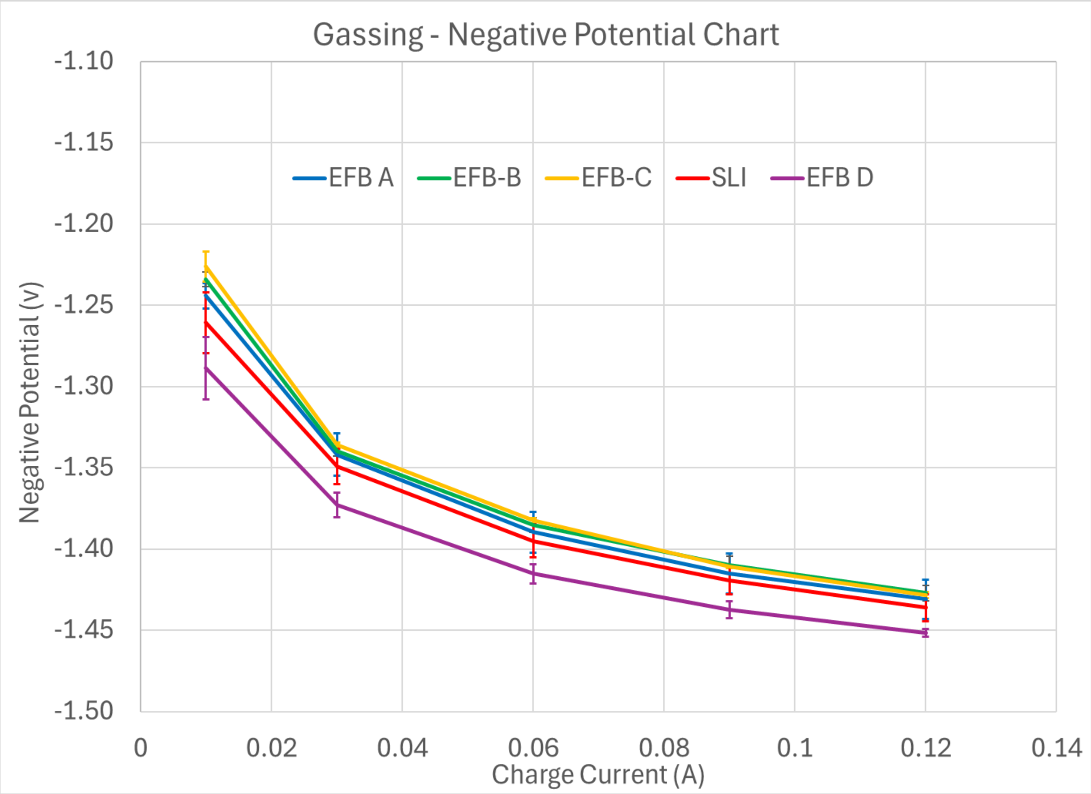




- All EFB expanders showed very close CCA 10 second voltage and CCA Total Ah (corresponding to total discharge time to 1 v per cell), and all higher than those of SLI expander.

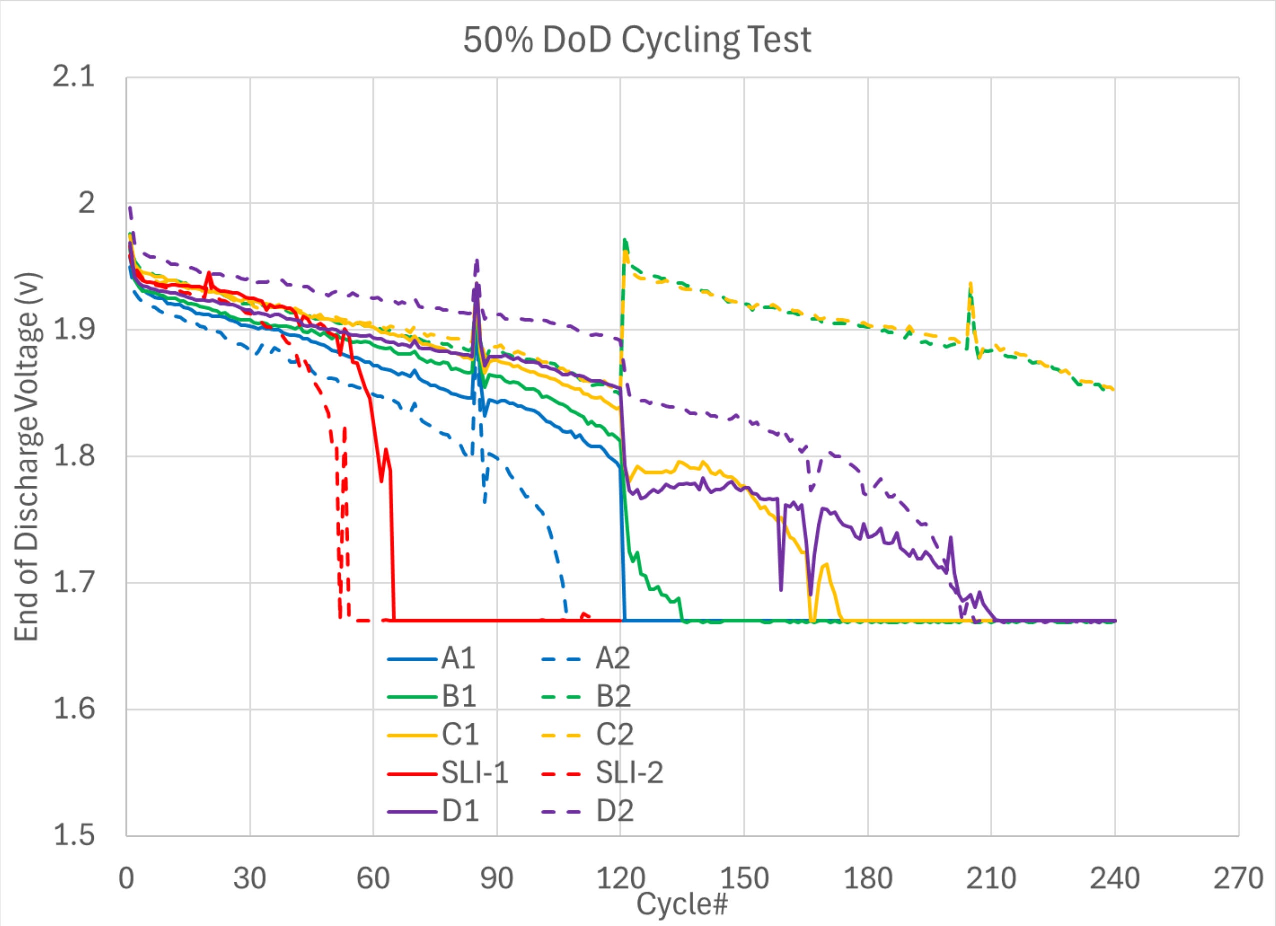
Cell Test – Gassing





- The biggest difference in gassing is in negative potentials. EFB D negative shows more negative potential during the gassing test than others, which means it has the lowest gassing.

Cell Test – 50% DoD Cycling



- One EFB A cell failed at cycle 106, and the other failed at cycle 121.
- One EFB B cell failed at cycle 135, and the other one passed 240 cycles.
- One EFB C cell failed at cycle 176, and the other one passed 240 cycles.
- One EFB D cell failed at cycle 203, and the other one failed at cycle 212.
- One SLI cell failed at cycle 52, and the other failed at cycle 65.

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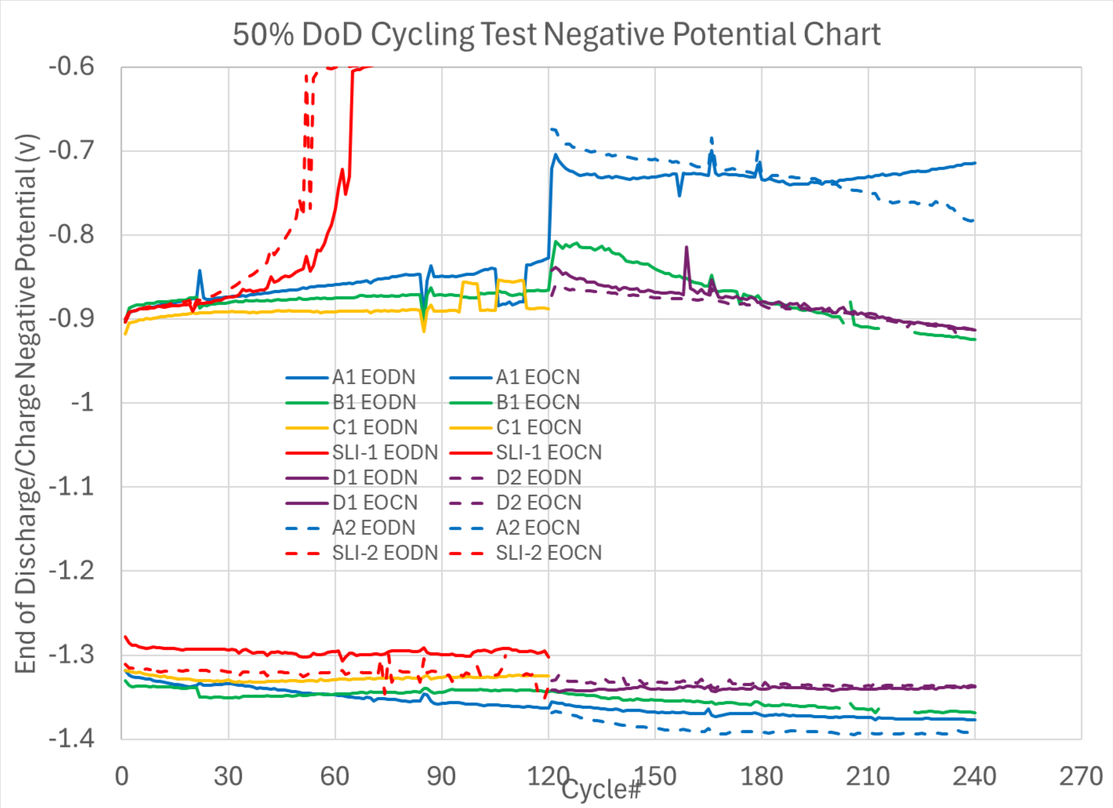
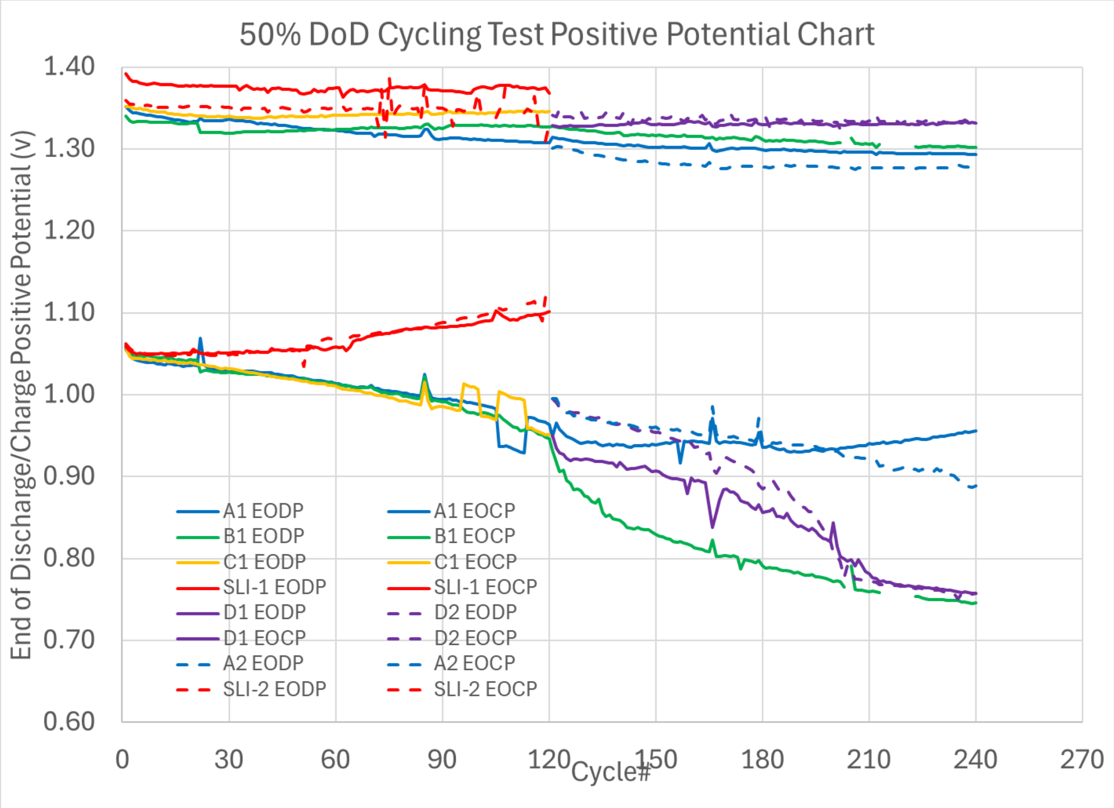
Cell Test – 50% DoD Cycling





- At 50% DoD cycling test, SLI and EFB A cells failed by negatives, EFB B, EFB C and EFB D failed by positives.

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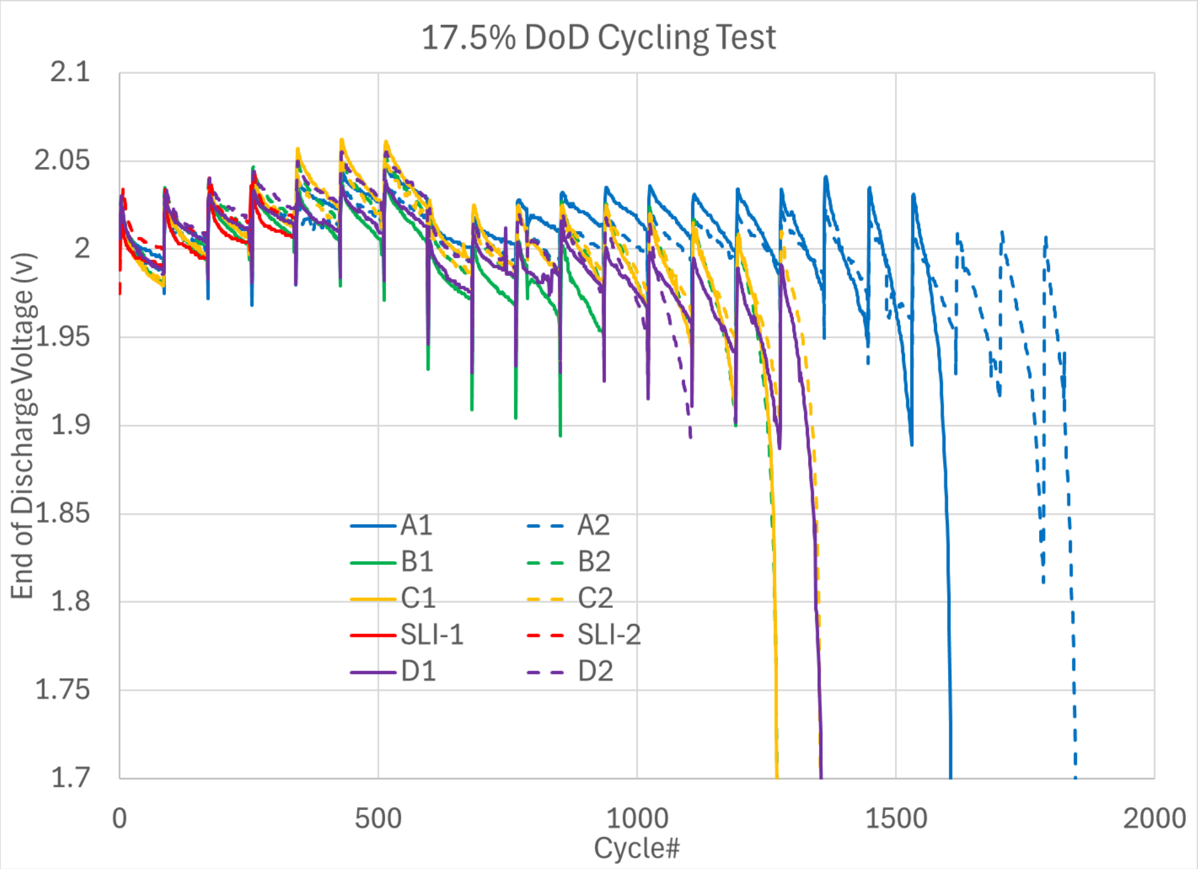
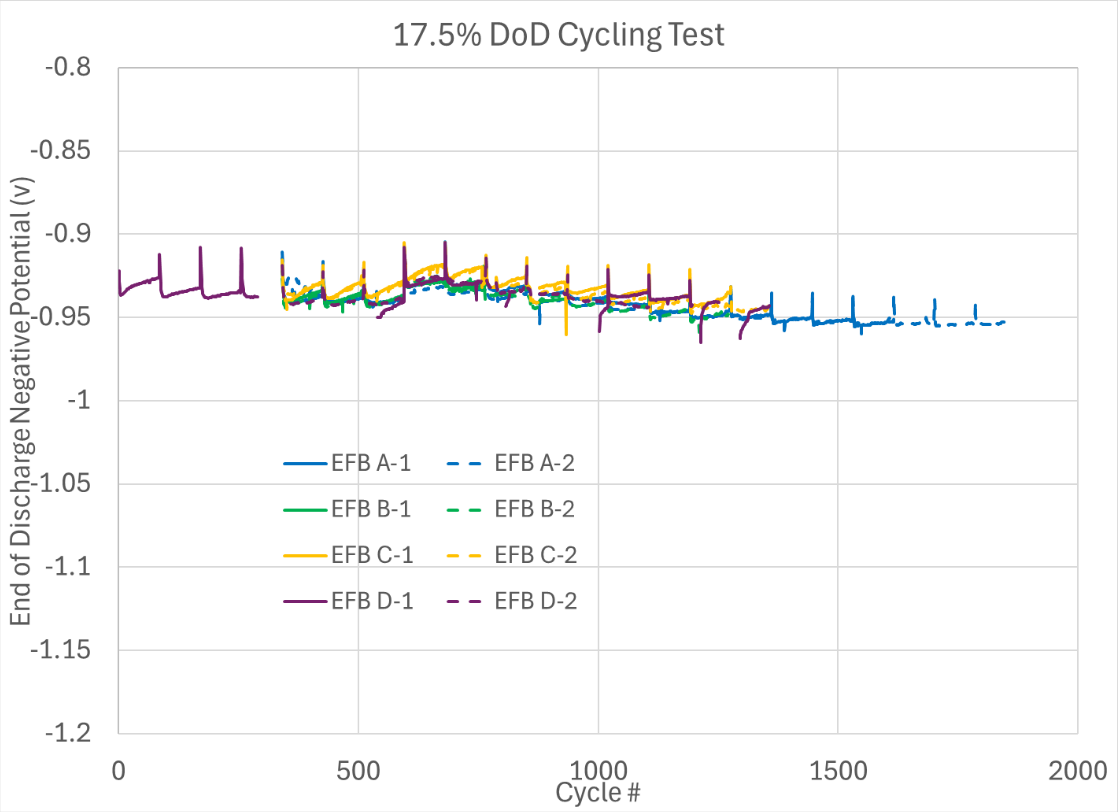
Cell Test – 17.5 DoD Cycling

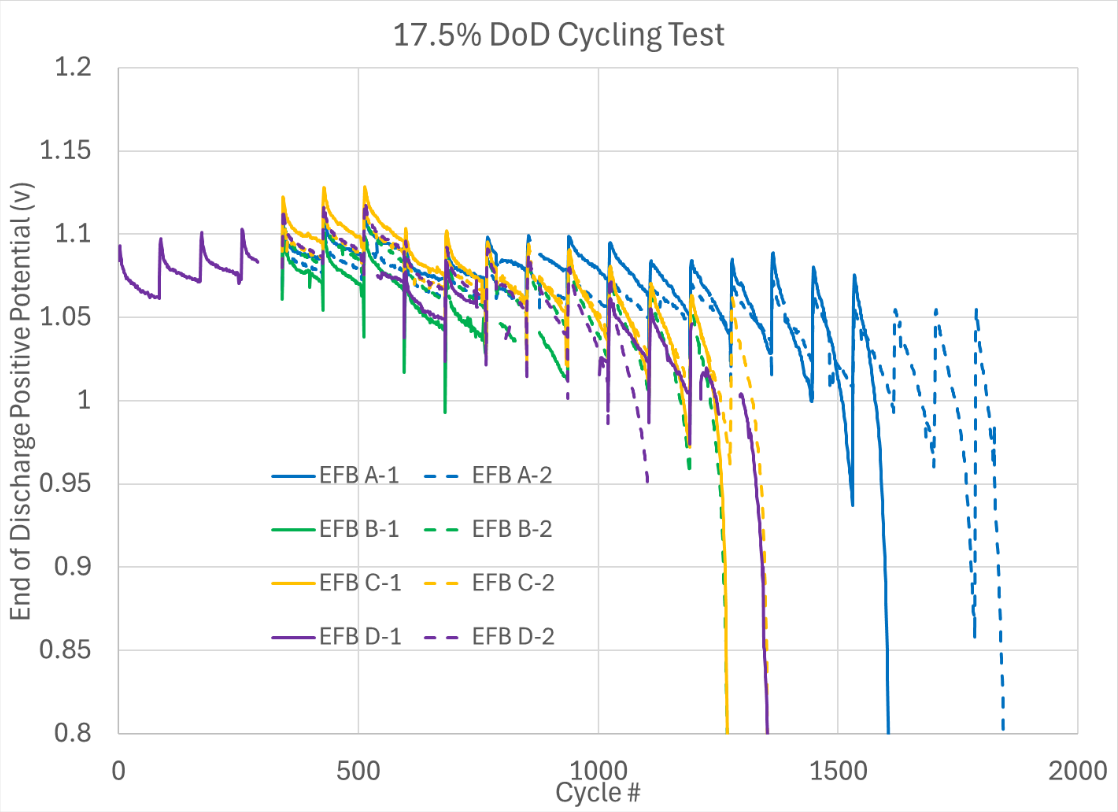


OBSERVATIONS:

- SLI cells have not finished 17.5% cycling test yet.
- EFB A showed the best 17.5% DoD cycle life (18 & 21 units).
- EFB B showed the least 17.5 DoD cycle life (9 & 11 units).
- EFB C cells passed 15 & 16 units.
- EFB D cells passed 14 & 16 units.

Cell Test – 17.5 DoD Cycling, End of discharge potentials





- In the 17.5% DoD test, all EFB cells were limited by positives.
- All EFB negatives were in good health conditions at the end of discharge, but positives deteriorated gradually during cycling.

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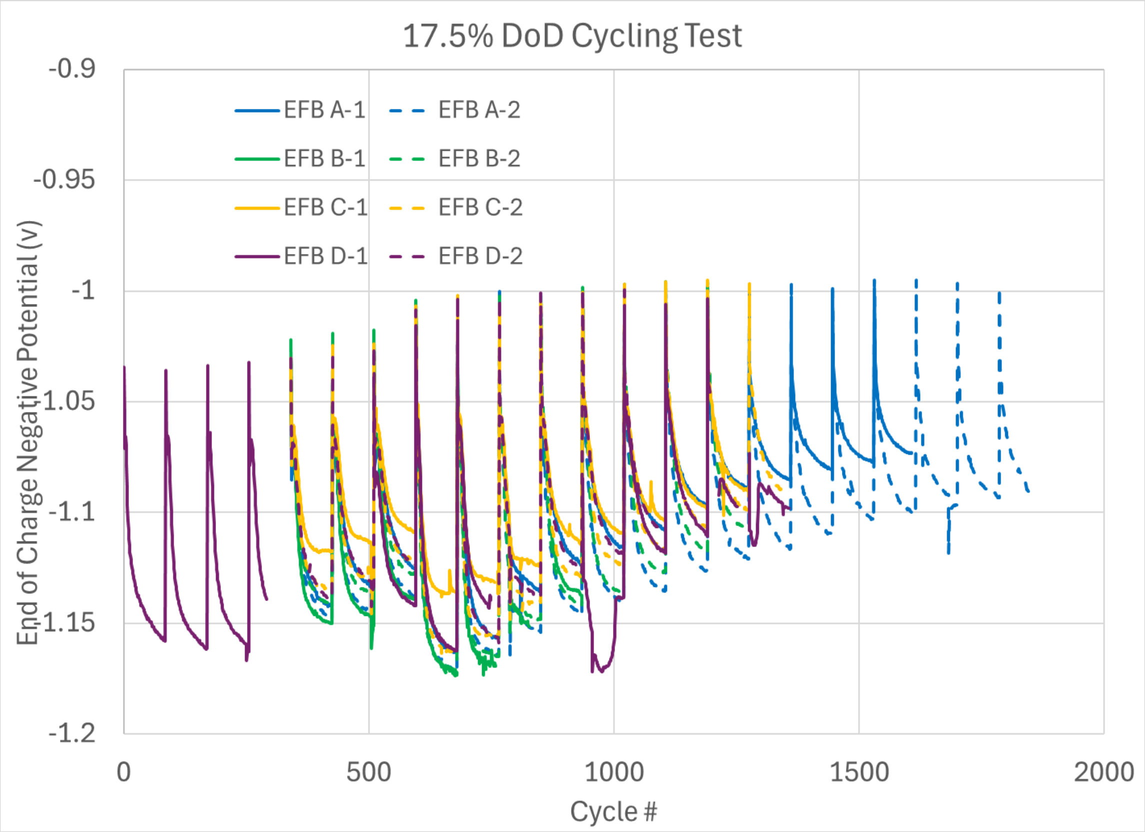
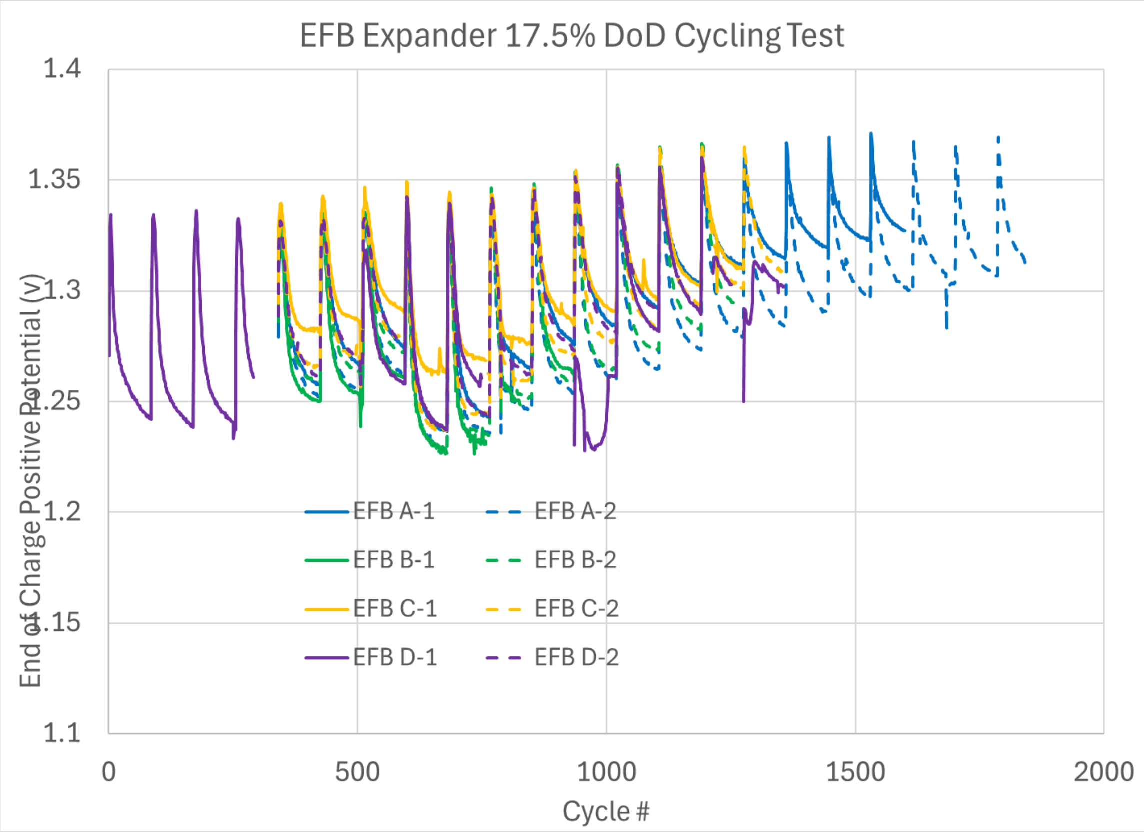
Cell Test – 17.5 DoD Cycling, End of charge potentials





- During the cycling test, both end of charge positive and negative potentials shifted slightly to positive directions.
- Considering capacities limited by positives, positive plates were sulfated during cycling.

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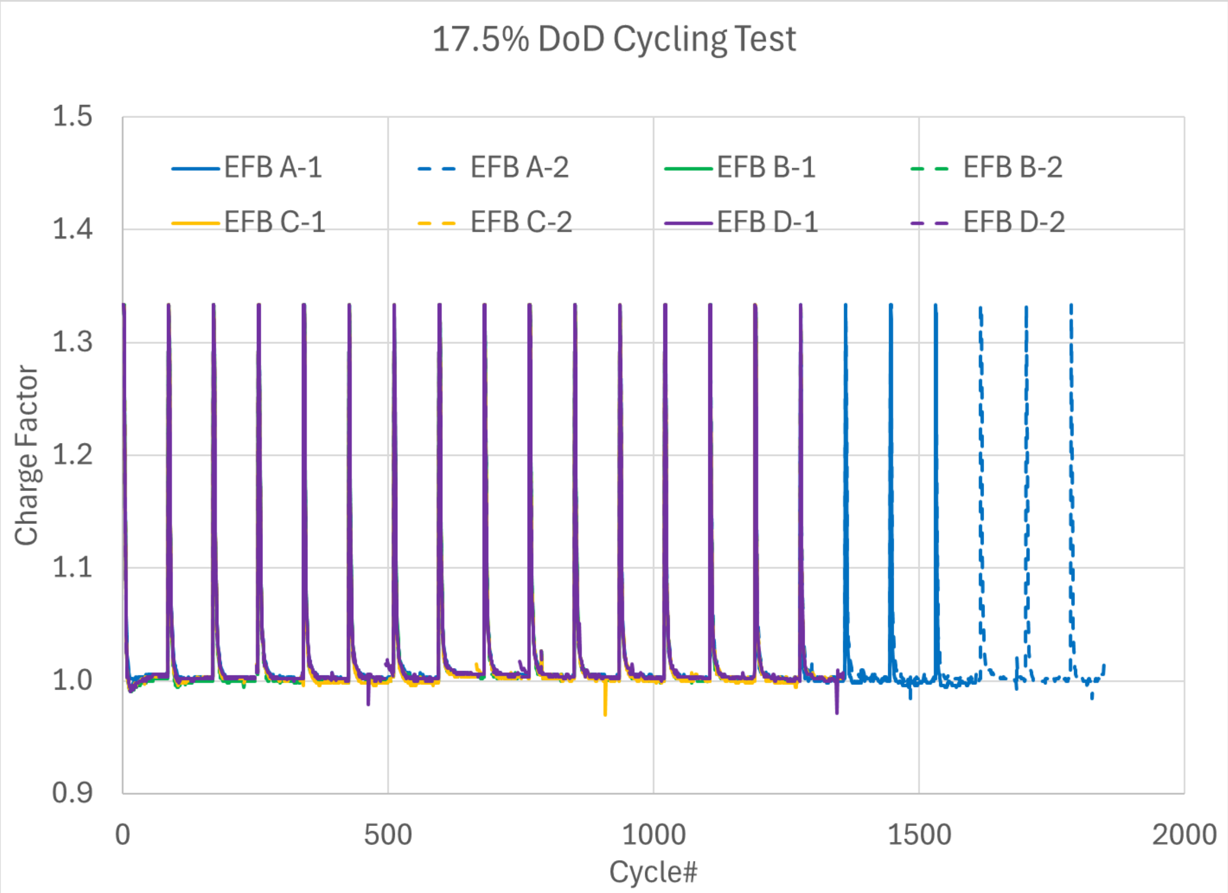
Cell Test – 17.5 DoD Cycling, charge factor



- Charge factor-wise, no significant difference observed between each expander during the 17.5% DoD cycling test.
- EFB D expander's very low gassing did not affect its charge factor during cycling.

12 V EFB battery test result

C20-1	%	105%
CCA-1	10 s V	pass
	time to 6v	pass
C20-2	%	101%
CCA-2	10 s V	pass
	time to 6v	pass
CA	%	330%
SAE J2801	Cycle	pass
Water loss	g/Ah	23.0%

- The water loss of the battery with EFB D expander is significantly lower than the control EFB expander.

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Conclusions

1. Carbon material added to the negative paste increases the BET surface area of the negative active material (NAM) in both cured and formed plates.

2. There is no significant difference in C20, RC, and CCA among these 4 EFB expanders.

3. In the 50% DoD cycling test, all EFB expanders exhibited significantly better cycle life than the SLI expander. The cycle life of SLI and EFB A expanders were lower than other EFB expanders, and their performance was limited by the negative plate. Whereas other EFB expanders showed longer cycle life and their capacities were limited by the positive plate.

Conclusions

4. In the 17.5% DoD cycling test, all cells failed due to the positive plates, with EFB A demonstrating the best cycle life.

5. In both the 50% and 17.5% DoD cycling tests, all other cells failed due to the positive plates, except for EFB A, which showed lower cycle life in the 50% DoD test. Since all cells used the same positive plates, this suggests that the negative formula can significantly affect the performance of the positive plates in cycle life tests..

6. Hammond composite lignin in EFB expander achieved similar capacity, charge acceptance, CCA performance with very low water loss.

Thank you!

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