

BLACK DIAMOND
STRUCTURES™

Sodium Cell Benchmarking in AUX Applications

Paul Everill

05-16-26

Sodium Cell Benchmarking in AUX Applications

Paul Everill, peverill@bd-structures.com

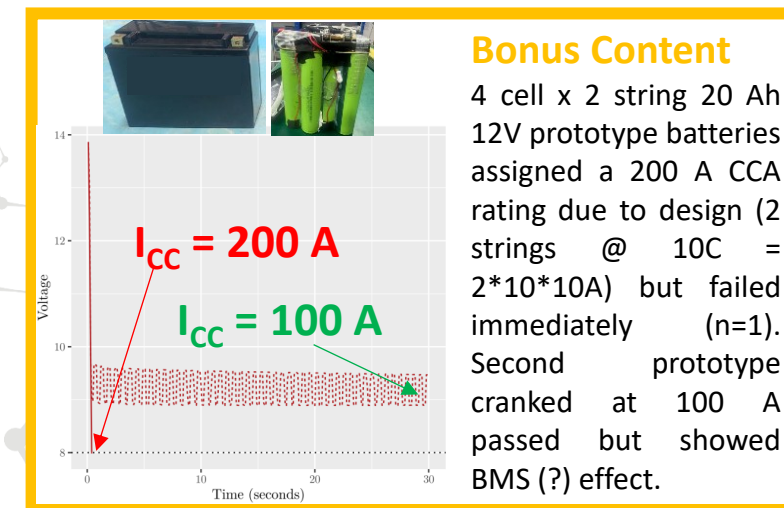
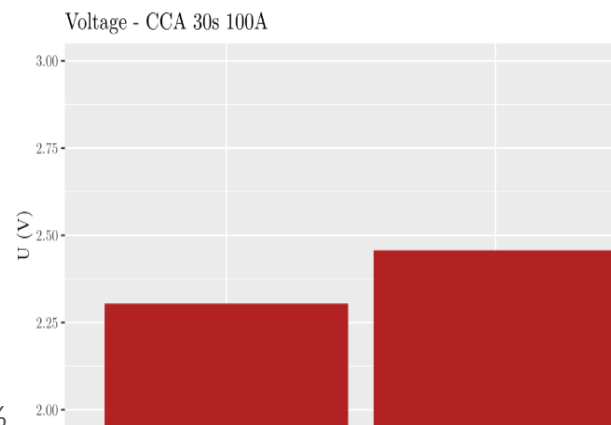
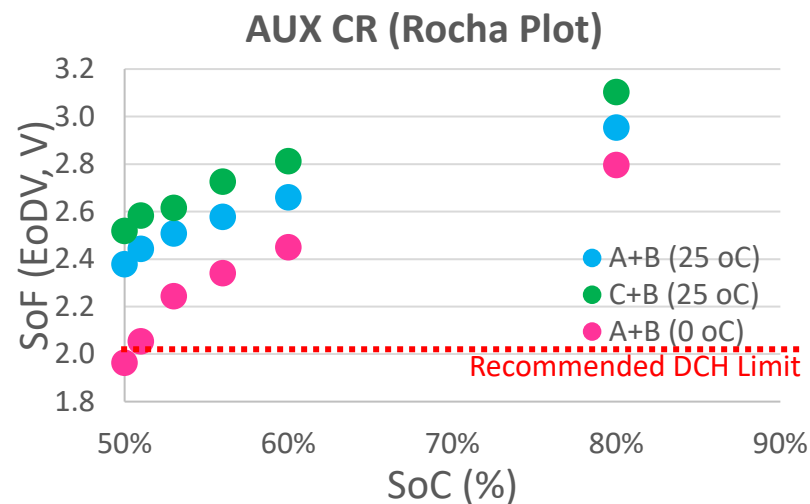
Na-Ion batteries recently (<5y) arose as a competitor to Pb-Acid based on price, capability, and safety

- Similar benefits to low-end Li-Ion regarding rate, life, and energy density
- Similar detriments to low-end Li-Ion regarding cold temp performance, recyclability, and flammability

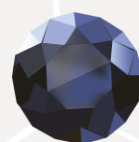
We sought to explore Na-Ion cells/batteries as a drop-in replacement for Pb-Acid in standard tests

- As expected, Na-Ion showed excellent capacity and rate capability but was severely limited at cold temp

End Users will find “drop-in” 12 V Na-Ion unreliable without right BMS, chemistry, especially <0 °C



**BLACK DIAMOND
STRUCTURES™**



BLACK DIAMOND
STRUCTURES™

Sodium Cell Benchmarking in AUX Applications

Paul Everill

05-16-26

Impetus for Research

Evaluate a commercial sodium-ion cell's ability to perform various Cold Crank and AUX protocols

- Discuss versus Pb-Acid battery performance
- Identify weaknesses, strengths
- Consider the Na-Ion battery a drop-in replacement for a Pb-Acid battery (it is not)

Bonus Content

- Review a 12 V prototype system built by a novice pack maker with an eye on aftermarket 12 V replacement



3

CP19:ALBA26

Directions

Confirm rated performance and explore IEC-60095-8 Charge Recovery capability

- How does cold temperature affect performance?
- Modified CR protocol charges only to SoC levels expected of a Pb-Acid battery (handicapped)
- Can a Na-Ion battery be a drop-in replacement for a Pb-Acid battery, without accommodations

Serial Number	Project	Standard	Remark
1	Nominal capacity@5.95	10.0	0.5C discharge @25°C
2	Rated voltage	3.0	V
3	AC internal resistance	<3	mΩ AC 1kHz 3.2V
4	DC internal resistance	<10	mΩ 2C 30mA 3.2V
5	Battery weight	270±5	g
6	Battery size	Height: 140±0.3 Diameter: 33.2±0.2	mm
7	Charge cutoff voltage	3.9	V 0°C≤T<10°C
8	Charge cut-off	5000.05CJ	mA 10°C≤T≤0°C
9	Discharge cutoff voltage	2.0	V T>0°C T≤-10°C Can be discharged to 0V
10	Standard maximum charging current	5000	mA 0.5C
11	Maximum charging current	30000	mA 3C CC to 3.95V >90% temperature rise≤20°C
12	Standard maximum discharge current	5000	mA 0.5C
13	Maximum discharge current	30000	mA 3C CC to 2V Discharge >90% temperature rise≤20°C





"Bonus Content" uses a prototype Asian 12 V Na-Ion battery using 2 strings of 4 cells (~12 V, 20 Ah), a basic BMS, and standardized casing.

Source: Zhongke Haina

中科海钠 HINA BATTERY

BLACK DIAMOND STRUCTURES™

4

CP19:ALBA26

Application Relevance

1) Cost Reduction: How Does Your Work Allow Battery Makers to Do More, With Less?

- Understanding strengths / weakness of the competition can help you hone designs smartly and efficiency
- If you soundly beat the competition in Test "X", and you had to add "Y" to do so, perhaps "Y" is unneeded?
 - Ex. over build, passive mixing elements, etc.

2) OEM Engagement: How Does Your Work Benefit the End User (OEM's Customers)?

- Helps OEM understand limitations of Na-Ion (and Pb-Acid) to better make their selection

3) Competition: How Does Your Work Increase Pb-Acid Competitiveness?

- Showcases / Confirms where Pb-Acid will dominate (cold temperature pulse power)
- Identify areas where performance is lacking versus competition



BLACK DIAMOND STRUCTURES™

5

Test Plan

1. C10 = 96% of Rated

- EN 50342-1

2. C1 = 96% of Rated

- Modified EN 50342-1

3. PHCA = PASS

- Partial High-temp Cranking Amp
- 25 oC, 5s, 10C, V>2.0 VPC (or 1.2 VPC)

4. MCA = PASS

- Marine Cranking Amps
- 0 oC, 30s, 10C, V>2.0 VPC (or 1.2 VPC)

5. PCCA = PASS

- Partial Cold-temp Cranking Amperage
- -18 oC, 5s, 10C , V>2.0 VPC (or 1.2 VPC)

6



CP19:ALBA26

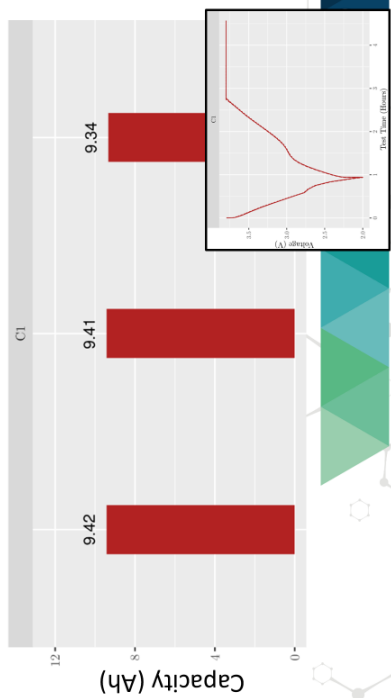
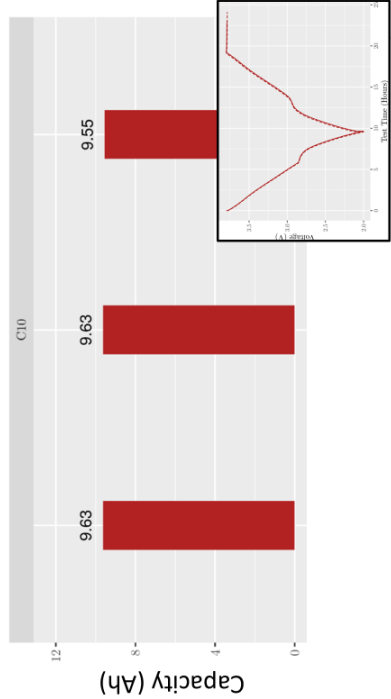
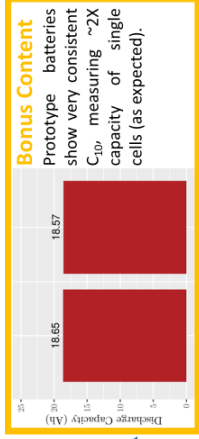
Capacity Checks

C₁₀ Rate

- DCH: 1 A to 2.0 V, CHR: 1 A to 3.7 V, 25 °C
- Rated capacity is 10 Ah
- Cells are very consistent

C₁ Rate

- DCH: 10 A to 2.0 V, CHR: 1 A to 3.7 V, 25 °C
- Rated capacity is 10 Ah
- Cells are very consistent
- C₁ = 97.8% of C₁₀ (puts Pb to shame!)



8

CP19:ALBA26

Partial High-temperature Cranking Amperage

Concept

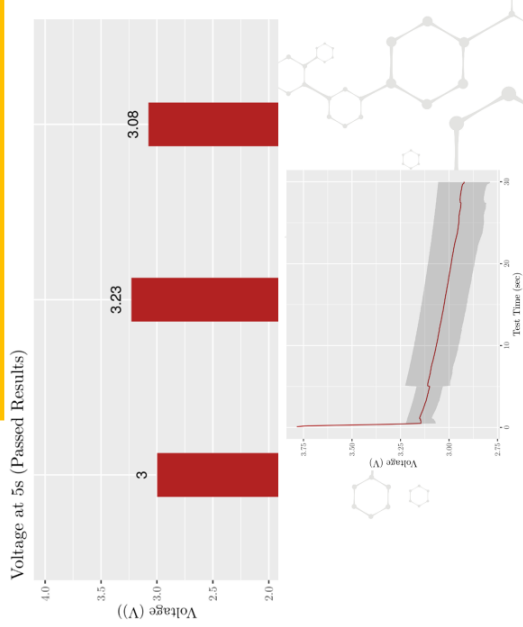
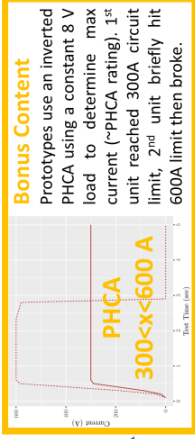
- Cranks for 5s @RT for modern application relevancy
- Used 10 C rate as “CCA” (PHCA) rating

Protocol

- DCH: 100 A to 2.0 V or 5 s, 25 °C
- Ran to 30 s
- CHR: 1 A to 3.7 V, 25 °C

Result

- PASS
- EoDV = 12.41 V equivalent (4 cell system)



9



Marine Cranking Amperage

Concept

- Crank for leisure boats (no one sails <0 °C for fun)
- Used 10 C rate as “CCA” (**MCA**) rating

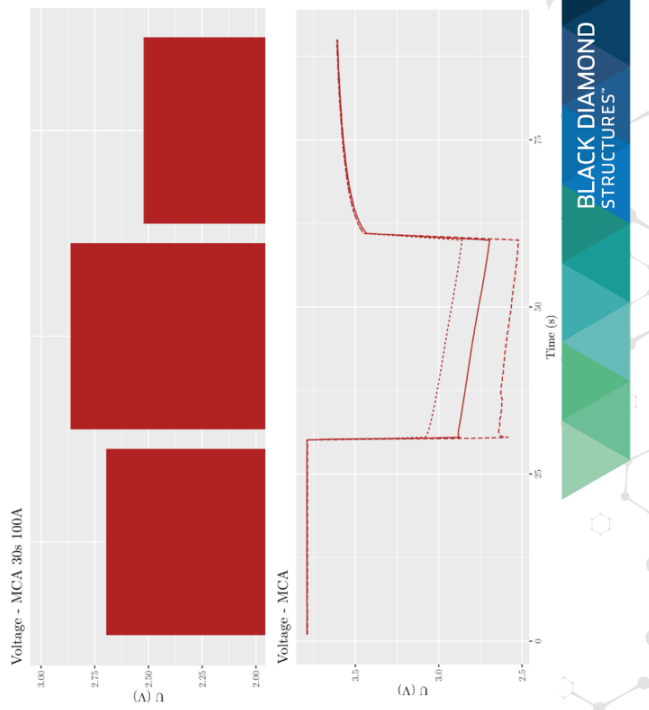
Protocol

- DCH: 100 A to 2.0 V or 30 s, **0 °C**
- CHR: 1 A to 3.7 V, 25 °C

Result

- **PASS**
- EoDV = 10.75 V equivalent (4 cell system)
- Variation much more pronounced at low temp

10



CP19:ALBA26

Partial Cold-temperature Cranking Amperage

Concept

- Cranks for 5s @RT for modern application relevancy
- Used 10 C rate as “CCA” (**PCCA**) rating

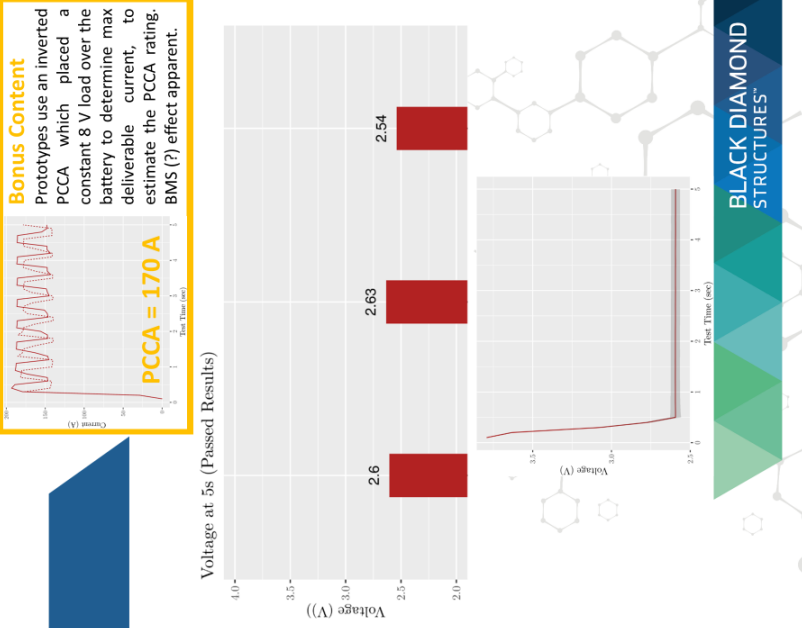
Protocol

- DCH: 100 A to 2.0 V or 5 s, **-18 °C**
- CHR: 1 A to 3.7 V, 25 °C

Result

- **PASS**
- EoDV = 10.36 V equivalent (4 cell system)
- Significant drop in voltage on DCH initialization

11



Bonus Content
 Prototypes use an inverted PCCA which placed a constant 8 V load over the battery to determine maximum deliverable current, to estimate the PCCA rating. BMS (?) effect apparent.

CP19:ALBA26

Cold Cranking Amperage

Concept

- Used 10 C rate as “CCA” (**CCA**) rating

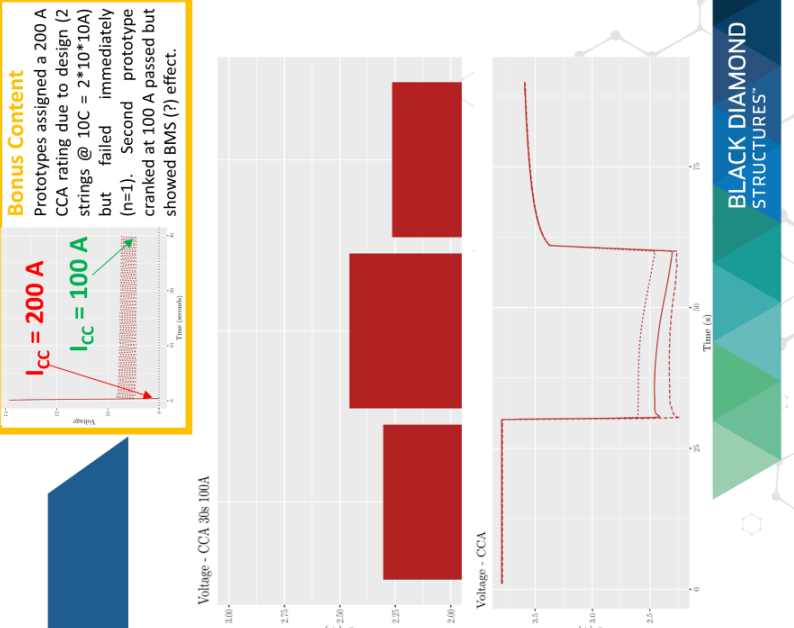
Protocol

- DCH: 100 A to 2.0 V or 30 s, **-18 °C**
- CHR: 1 A to 3.7 V, 25 °C

Result

- **PASS**
- EoDV = 9.35 V equivalent (4 cell system)
- Note: V varies over test. Likely that spec will be set as V_{min}

12



Bonus Content
 Prototypes assigned a 200 A CCA rating due to design (2 strings @ 10C = $2 \times 10^3 \times 10A$) but failed immediately ($n=1$). Second prototype cranked at 100 A passed but showed BMS (?) effect.

IEC 60095-8 Charge Recovery Modifications

Modifications act to “handicap” a Na-Ion cell during the charge phase of the IEC-60095 so that it recovers similar SoC as a Pb-Acid battery, then conducts an SoF pulse.

Program A

- IEC 90095-8 CR DCH (T11, S1-5)
- 25 °C, 0 °C, or -18 °C

Program B

- IEC-CR charge w/ Ah lock
- Ah-in approximates Pb Ah-in
- 25 °C, 0 °C, or -18 °C

	DCH	CHR
Na-IEC-CR #1	A (50%, 25 °C)	B (25 °C)
Na-IEC-CR #2	C (50%, 25 °C)	B (25 °C)
Na-IEC-CR #3	A (50%, 0 °C)	B (0 °C)
Na-IEC-CR #4	C (50%, 0 °C)	B (0 °C)
Na-IEC-CR #5	A (50%, -18 °C)	B (-18 °C)
Na-IEC-CR #6	C (50%, -18 °C)	B (-18 °C)

Pending...

Modified Charge Recovery (A+B, 25 °C)

Method

- IEC 60095-8 with locked SoC return
- Room temperature

Results

- No issues on SoF pulse discharge at RT
- High current pulse (SoF) charges acceptable
- CHR to set SOC% occurs rapidly, all in CC mode:
 - 20s to add 1%
 - 32s to add 2%
 - 44s to add 3%
 - 56s to add 4%
 - 248s to add 20%

Modified Charge Recovery (C+B, 25 °C)

Method

- IEC 60095-8 with pulsed discharge to 50%
- IEC 60095-8 with locked SoC return
- Room temperature

Results

- No issues on SoF pulse discharge at RT
- High current pulse (SoF) charges acceptable
- CHR to set SOC% occurs rapidly, all in CC mode:
 - 20s to add 1%
 - 32s to add 2%
 - 44s to add 3%
 - 56s to add 4%
 - 248s to add 20%

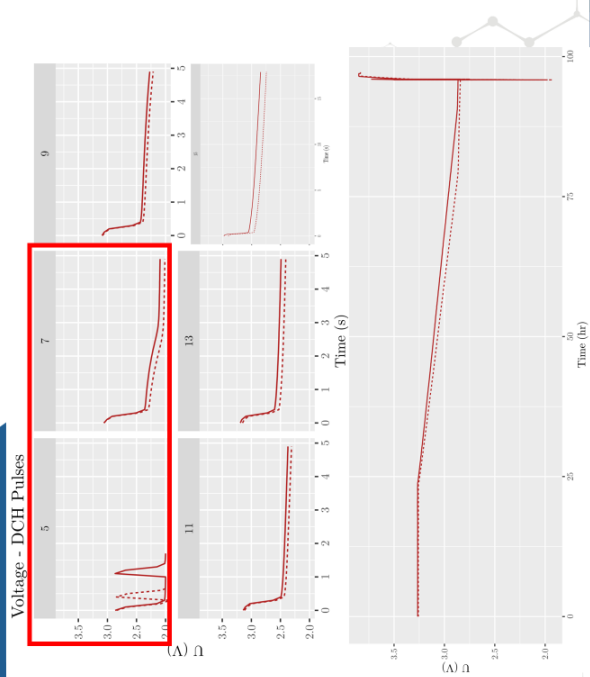
Modified Charge Recovery (A+B, 0 °C)

Method

- IEC 60095-8 with locked SoC return
- 0 °C temperature

Results

- Failure to pulse at 50% and 51%
- Only at 53% could battery effectively pulse
- Warming?
- CHR to set SOC% occurs **rapidly**, all in CC mode:
 - 20s to add 1%
 - 32s to add 2%
 - 44s to add 3%
 - 56s to add 4%
 - 248s to add 20%



16

Pending...

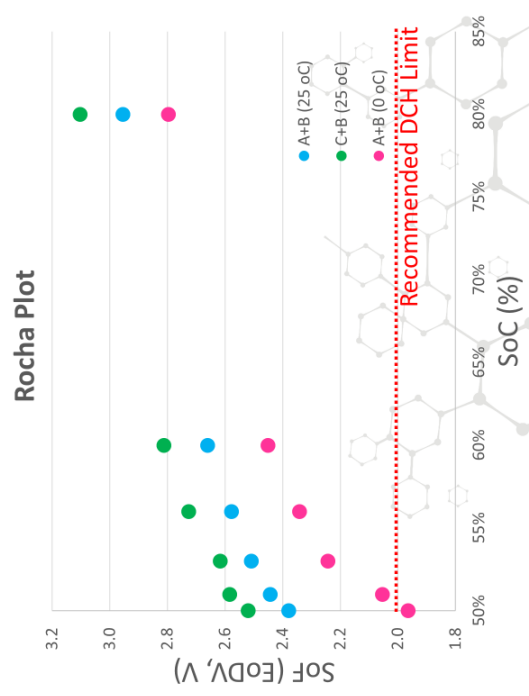
Conclusions and Questions

Results

- Na-Ion cells are capable of hi-rate charging through 80%, all in constant current
- Effectiveness of low-temp charge an issue for SoF
 - Failure to pulse at 0 °C
 - Issue overcome rapidly (~1% SoC, seconds)
 - Likely worst at -18 °C
- Note: cell maker claims cell can be discharged to 0 V, so is 2.0 V (spec sheet) a false failure?
 - 4 cell equivalent is still 8 V

Questions

- Why is C+B higher SoF than A+B?
- Application-centric minimum voltages for SoF?



18