The Future for Lead Batteries: A Technical Review of Recent Developments and Future Performance Enhancements

CBI: Research tied to Market Trends

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Next edition coming soon!

Technical Roadmap 2021

Research and innovation pathways for next-generation advanced lead batteries





Future of Lead Batteries Rests in New Markets

Auxiliary and ESS will be important for different reasons

- The rocky and tumultuous EV transition has destabilized the SLI (AGM and EFB included) 12 V automotive market.
 - Current ~0-3% CAGR depending on area in China, US, Europe, Brazil.
 - India and SE Asia still growing above average, Africa and Middle East hard to follow.
- Forecasting continues to back this trend, with a starker market by 2030.
- Some correction may occur due to rapid cooling of the EV market in US and Europe.
- LAB and LIB are major players in a key <u>offset</u> market for 12 V automotive, auxiliary battery applications.
 - The LIB penetration is due to Tesla and BYD.





Auxiliary Choice is Up in the Air

But not really for technical reasons...

- Lead batteries are uniquely suited for auxiliary applications, offering robust, well-known, high power, and reliable solutions.
- Developments must center around integrating lead batteries into battery management and sensor arrays.
- Increasing service life and charge recovery are crucial from a research perspective we may be able to leverage DCA improvements!
- The need for research is overlaid by a need to productize and much more importantly –

communicate to automotive OEMS about lead battery solutions.





Pushing DCA to New Plateaus

Quick Update on MHT and Stop-Start

- Low DCA has been a persistent issue for lead batteries since microhybrid/start-stop 12 V battery performance came under heavy scrutiny in Europe in the mid-2000s.
- DCA values have risen over the last ten years from 0.2 A/Ah to 0.5 A/Ah commonly.
- There are several advancements to watch, that while more directly applicable to micro-hybrid/start-stop, are also useful for auxiliary/low voltage EV (and maybe other markets!).
 - Carbon additives
 - Other types of additives
 - New types of lead batteries
 - Optimization of current designs
- Must be balanced against CCA and high temperature durability!!!
- Still important outside of Europe, especially India and US.



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ALBA and SSOF





Charge Recovery

Need: CA 3 A/Ah and DCA above 1A/Ah.

State of the art is above 2A/Ah DCA and above 3.5 A/Ah CA for products in the pipeline, 0.7 A/Ah and 2 A/Ah for current.

- CBI is helping by:
 - Working with ALBA initiatives to produce a charge recovery test
 - Research in additives to improve life
 - Inhibit negative plate sulfation
 - Funding projects to improve charge recovery in <u>all</u> <u>products</u> and understanding high power performance crank.
- The industry has:
 - Many (and I mean many) methods of improving charge behavior, we just need to identify DCA improvements that improve charge recovery.

Service Life

Need: 5-7 year battery life across different duties. State of the art – 5 years

- CBI is helping by:
 - Supporting the standardization of how auxiliary lead batteries should be treated and communicating the info, such as IEC60095-8.
 - Research in additives to improve life
 - Inhibit negative plate sulfation
 - Fix positive grid corrosion as the designed failure mode.
 - Active database cataloging drive cycles and simulations, providing info for sensor and battery manufacturers to use in productization efforts.
- The industry has:
 - Developed competitive products, capable of meeting OE requirements and adhering to ISO 26262 and ASIL needs.
 - Many manufacturers are conducting failure mode analyses and warranty studies.

Our industry meets OE requirements today and can as well in the future. We must establish a new paradigm in OE vendor engagement.



Future of Lead Batteries Rests in New Markets



• Unprecedented opportunity for growth, 50 GWh opportunity in BTM by 2030.

- The FTM market to watch has not really formed yet, long duration (+10 hours, LDES).
- Represents billions of dollars of market expansion, even in a situation where Pb shares the market with competitors.
- Beyond B2B and B2C, there are mountains of public avenues for growth.
- CBI is performing research and supporting product development to help lead batteries into key markets.



Generating Products in the Most Important Market

Lead Batteries are a natural fit for ESS applications

- Must increase cycle life and lower cost (LCOS or capex).
- There are key markets in ESS for lead batteries:
 - C&I (EV fast charger backup)
 - Residential
 - LDES
- Need to productize, no more batteries, need systems!
- CBI is attending to these needs in many ways, but the industry is making rapid advancements.





Cycle Life (Energy Throughput) is Key in ESS!





Advancement in Lead Batteries for ESS

Cycle Life and Energy Density

Cycle Life

- Battery management is key, and CBI has developed BMS with SEL.
- Bipolar and advanced AGM are showing incredible performance enhancement.
- Realistic Testing Regimes are being developed to understand performance



Energy Density

- Bipolar is dropping 40% of the weight out of lead batteries.
- Packing an ESS, the actual design for max density in an ESS, is being researched by CBI.
- Manufacturing (and Capex) improves with better energy density.

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Advancement in Lead Batteries for ESS



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CBI Blueprint Project: Lead battery ESS to back up EV fast charging







Lead Batteries Powering Residential ESS and Backup

Multiple Levels of Innovation Providing Best in Class Solutions



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LDES – Huzhou City

Massive system for industrial center established in March 2023

- High performance PbC batteries (small e-bike type battery) have been utilized.
- 1.1 GWh, 100 MW, this system cost 140 million. An additional 60 million was also used to update the AC side. \$127/kWh...
- Started as demo unit, 10 MWh in September 2021.
- Tianneng perfected the product in this time, total construction and commissioning took ~3 months for the expansion.





Motive Power Across the World

Forklifts, E-rickshaw, and much more

- 3 billion dollar (LAB market share) forklift market for lead batteries is under heavy competition from lithium on new trucks and multiple shift service.
- Lithium doesn't need battery change out, watering, and can opportunity charge.
- This advantage extends not just into forklift, but into growing markets like Erickshaw.
- The industry is making maintenance free products now (i.e. Enersys with Nexsys, C&D Trojan with Pure Lead AGM) – now we need to study opportunity charging knowledge and infrastructure (CBI).

Investigating multi-step current charging methods

Trial 4, 100A, 2.34V, IU charging

- 1. After fully charge cells, then rest 10mins,
- Discharge to 30% SoC with 0.2C5 current for 3.5hrs, then rest 10 mins
- 3. Charge from 30% SoC to 80% SoC:
 - $I_0 = 0.80 \text{ C5} = 100.00 \text{ to } 2.34 \text{VPC}$, rest $\Delta t = 0.5 \text{ min}$
 - $I_1 = 0.70 \text{ C5} = 87.50 \text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - I₂ = 0.60 C5 = 75.00A to 2.34VPC, rest Δt= 0.5 min
 - $I_3 = 0.55 \text{ C5} = 68.75 \text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - $I_4 = 0.50 \text{ C5} = 62.50 \text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - $I_5 = 0.45 \text{ C5} = 56.25\text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$ ■ $I_6 = 0.40 \text{ C5} = 50.00\text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - $I_6 = 0.40 \text{ CS} = 50.00\text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$ • $I_7 = 0.35 \text{ CS} = 43.75\text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - $I_8 = 0.30 \text{ C5} = 37.50 \text{ to } 2.34 \text{ VPC}$, rest $\Delta t = 0.5 \text{ min}$
 - $I_8 = 0.25 \text{ C5} = 31.25 \text{ A}$ to 2.34VPC, rest $\Delta t = 0.5 \text{ min}$
 - $I_{11} = 0.20 \text{ C5} = 25.00 \text{ to } 2.34 \text{VPC}$, rest $\Delta t = 0.5 \text{ min}$
 - $I_{12} = 0.15 \text{ C5} = 18.75 \text{ A to } 2.34 \text{VPC}$, rest $\Delta t = 0.5 \text{ min}$
 - I₁₃ = 0.10 C5 = 12.50A to 2.34VPC, until 103% return of 0.5C5 capacity.

. Rest 5 hours

5. Top charge battery with 6 hours, IU charging: 18A to 2.45VPC.

50% SOC charging in ~ 55 minutes



Lead Batteries are Rapidly Evolving

New types and new advancements in current designs

 Lead batteries are moving into systems, and manufacturers here at ELBC are now changing their perspective.

- Battery management is key and is now becoming a bigger piece of the solution.
- Lots of market potential, and solutions are forming or ready.



THANK YOU!

Please reach out to me at matt.raiford@batteryinnovation.org



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