Lead battery technology evolution and future challenges

Francisco Trinidad | Asian Battery Conference | November 2021

Content

Introduction

- Lead-acid battery performance has steadily improved during the last century through **incremental developments that have accelerated in the last two decades.**
- The electrification of the automotive sector and, more recently, the increasing demand for energy storage are **the main drivers for battery innovation.**
- Both applications require maintenance free operation, **high specific power in charge and discharge** and moderate volumetric energy density.
- After the invention of starved electrolyte/valve regulated lead-acid (VRLA) batteries, initially through acid gel and later by glass mat absorption, **internal gas recombination reaction allowed full maintenance free operation.**
- It was, however, in this century that **VRLA batteries became a mass market product** ideally suited for both automotive and energy storage applications.
- To cope with these new market demands **while maintaining or reducing cost,** lead-acid battery technology was continuously evolving.

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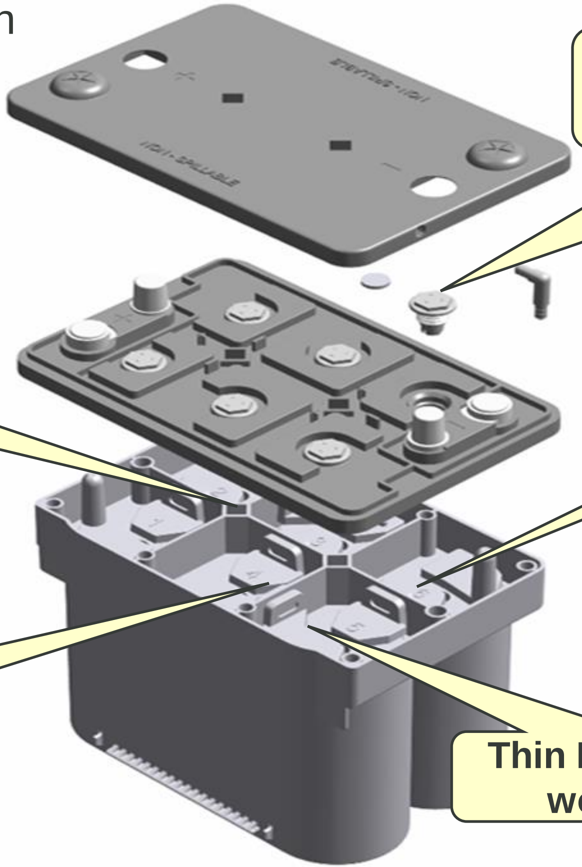
Lead Battery Technology Evolution

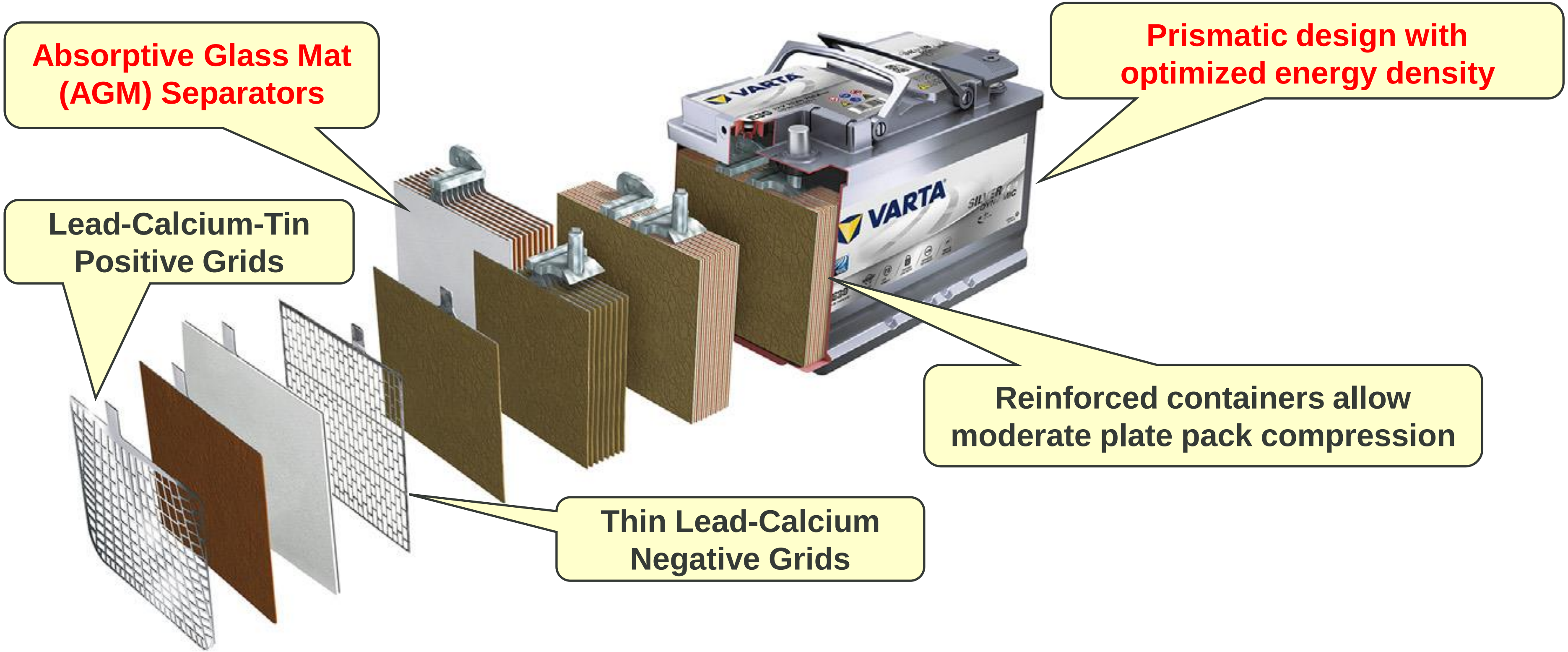
Spiral wound VRLA cell design



J. Valenciano, M. Fernández, F. Trinidad, L. Sanz / Journal of Power Sources 187 (2009)

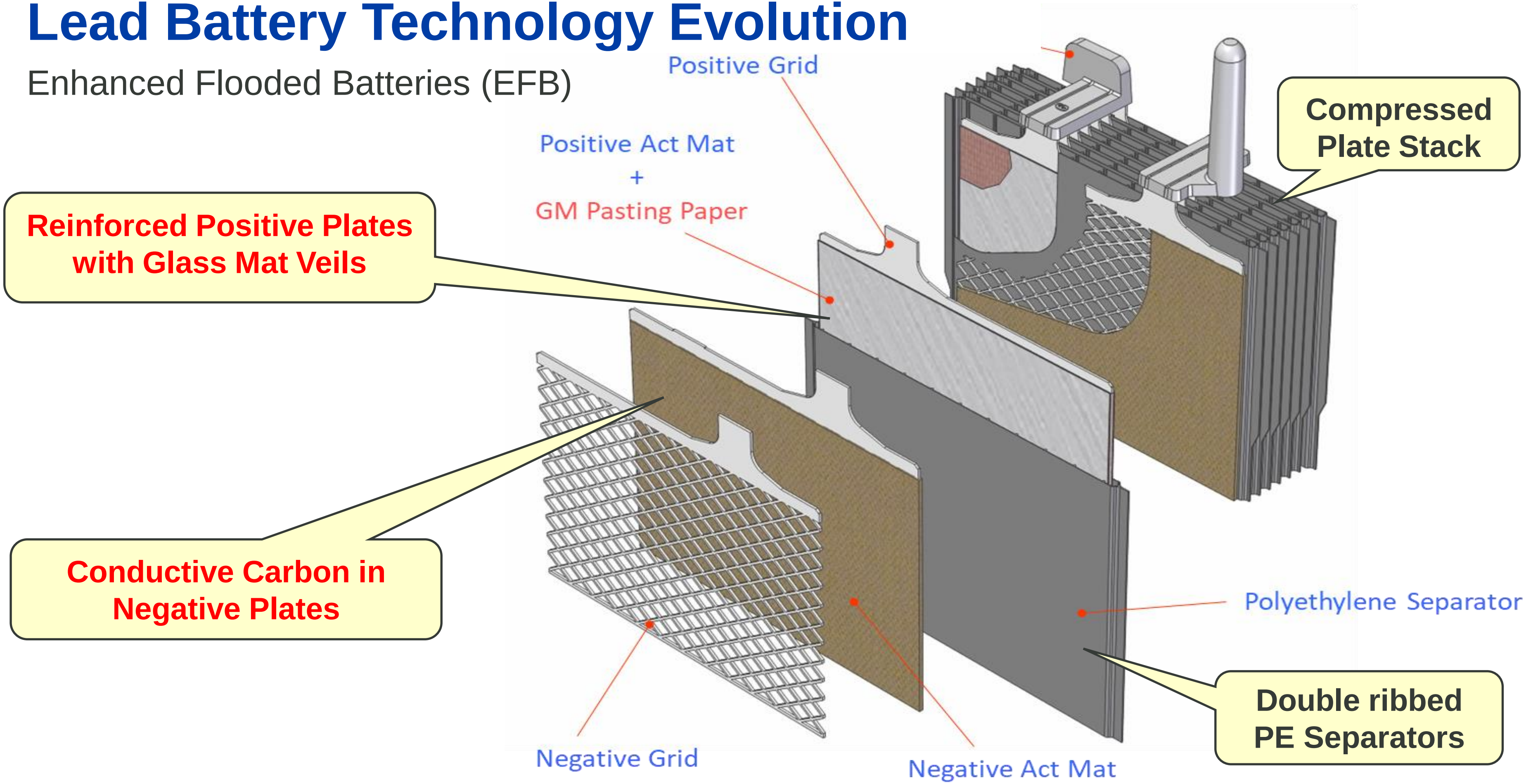
Lead Battery Technology Evolution

Flat Plate VRLA cell design



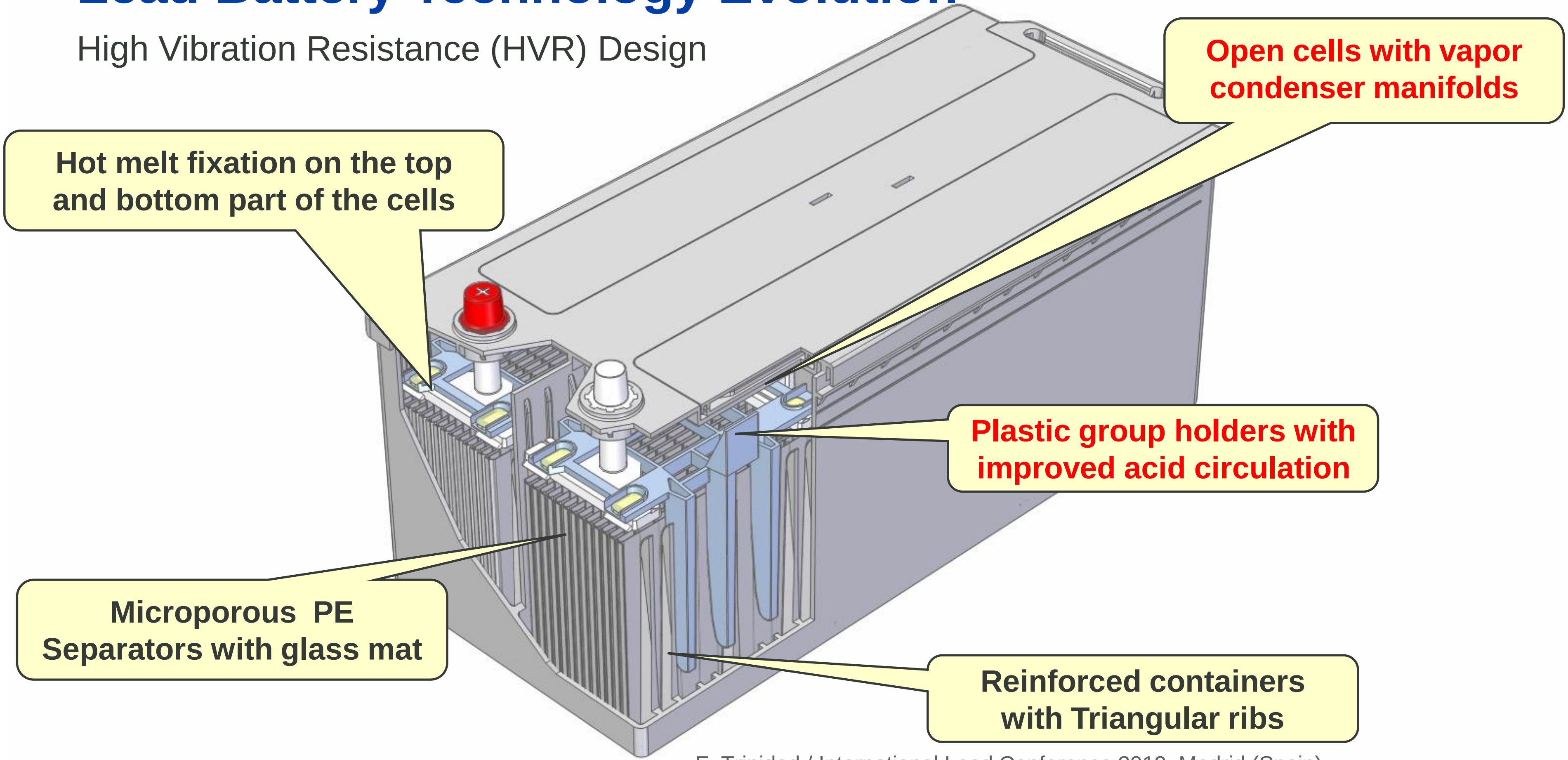
Lead Battery Technology Evolution

Enhanced Flooded Batteries (EFB)



Lead Battery Technology Evolution

High Vibration Resistance (HVR) Design



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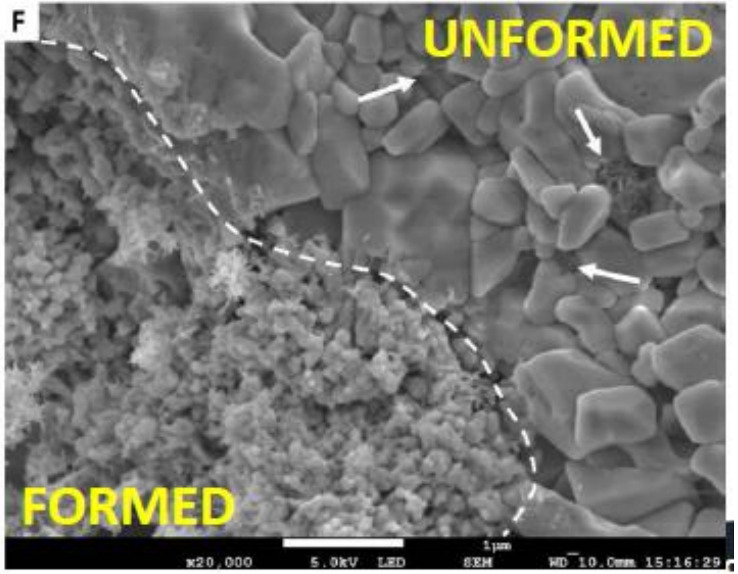
Recent Developments

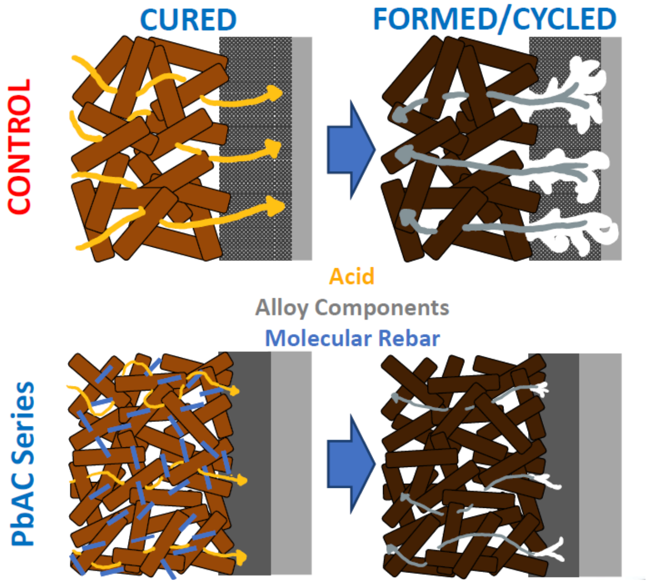
- Battery technology need to comply with highly demanding requirements like:
  - Improved **charge acceptance** to recuperate the energy from short charging events
  - Ability to maintain the battery performance and cycle life at **low-state-of-charge**
- Both VRLA and EFB products have been improved with the use of **new materials** that, coming from other applications, have been further developed for lead batteries.
- Among others, the following innovations have been recently introduced in both automotive and industrial applications:
  - **Carbon Nanomaterials**
  - **New Current Collectors**
  - **Hybrid Capacitors**
  - **Bipolar Plates**

Recent Developments

Carbon Nanomaterials

- Carbon Nanotubes (CNTs) improve charge acceptance and cycle life of the negative plate, even **at very low dosage** (thanks to its high conductivity and large aspect ratio l/d).
- Although not fully stable in the positive plate, CNTs **modify the microstructure of the grid/active material interphase,** improving initial performance and corrosion resistance.



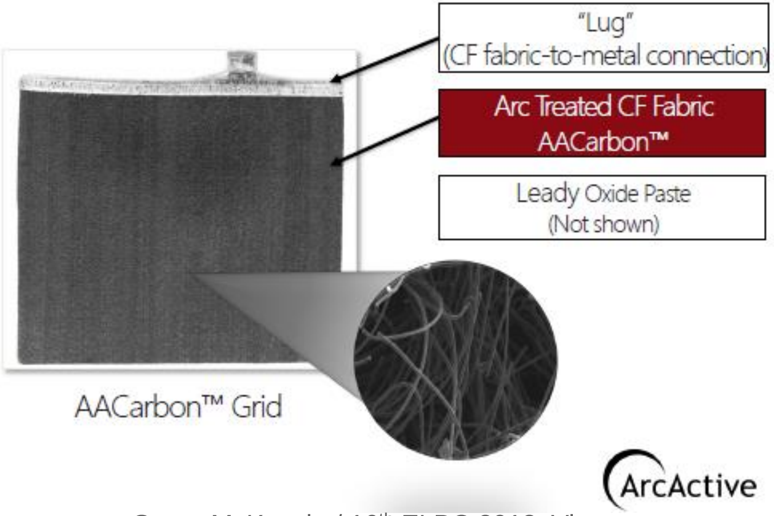


P. Everill, S. Swogger, R. De Guzman N. Sugumaran / LABAT´21 Virtual Conference (2021)

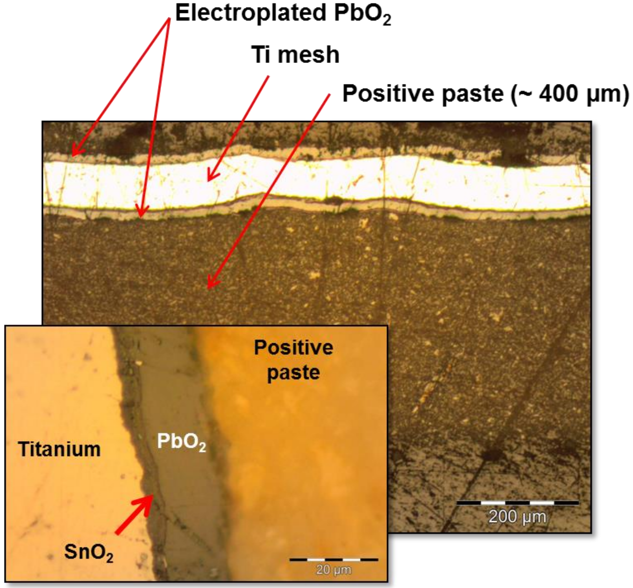
Recent Developments

New Current Collectors

- To reduce lead sulfation, **Carbon felts** can be used as current collectors for the negative electrode, thus increasing and maintaining charge acceptance at partial state of charge.
- There are other materials in development to replace lead positive grids, with a limited success up to now due the **highly corrosive environment of the positive electrode.**



Stuart McKenzie / 16th ELBC 2018, Vienna

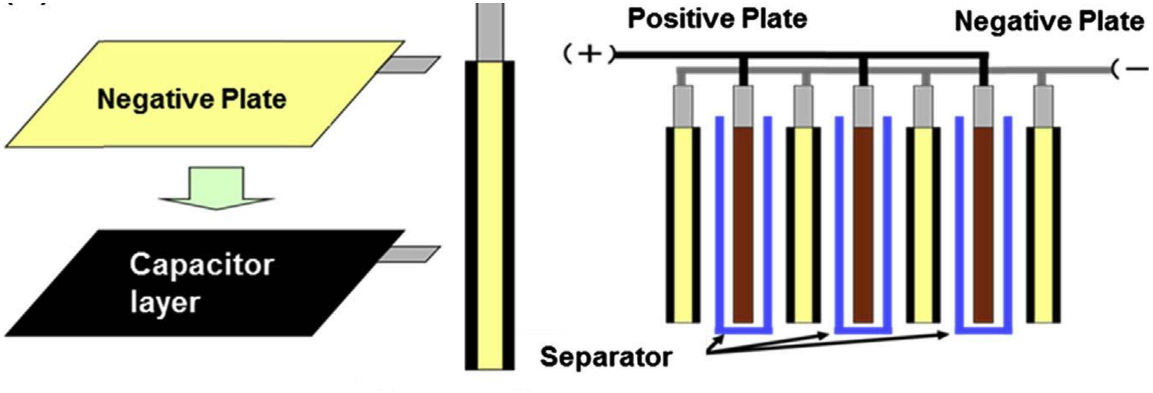


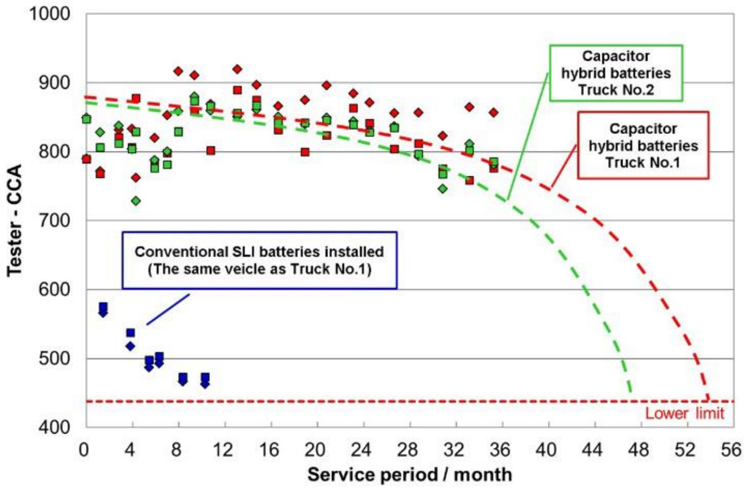
J. Lannelongue, A. Kirchev & M. Cugnet / LABAT'17, Varna (Bulgaria)

Recent Developments

Hybrid capacitors

- Hybrid capacitors originally consisted of twin **Carbon + Lead negatives** and standard PbO_2 positive plates.
- This innovative design has evolved to **Negative lead pasted electrode with external Capacitor layers**, that significantly improve battery performance during the service life.



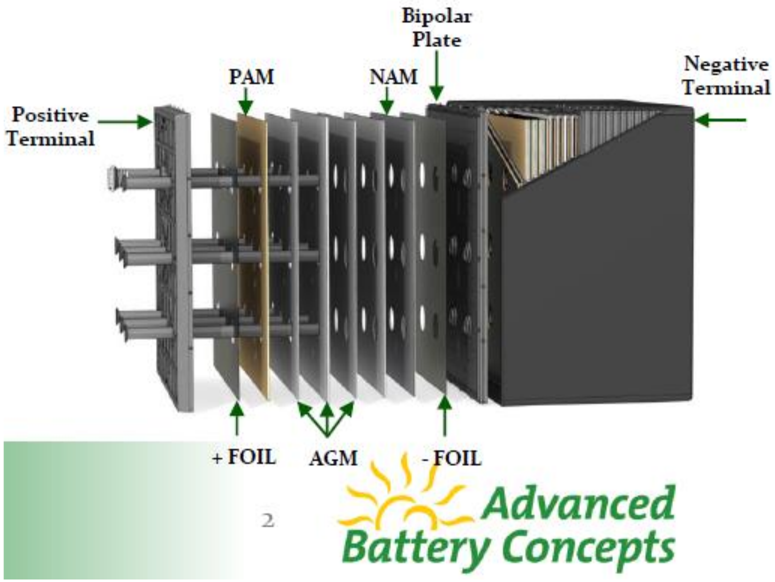


Recent Developments

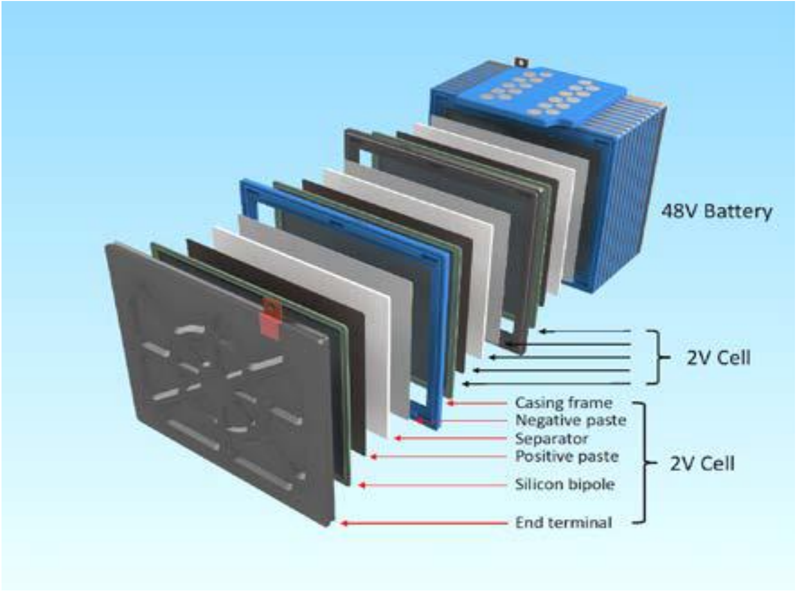
Bipolar plates

- Eliminate the top lead connectors, reducing weight and **improving energy density**.
- Still in development but with significantly improved designs and new material:

Polymer/lead foils **Silicon with metal coatings**



M. Everett / 17th Virtual ELBC 2020



S. Hinojosa & C. Mui / LABAT´21 Virtual Conference (2021)

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4. **Future Challenges**
5. Concluding Remarks

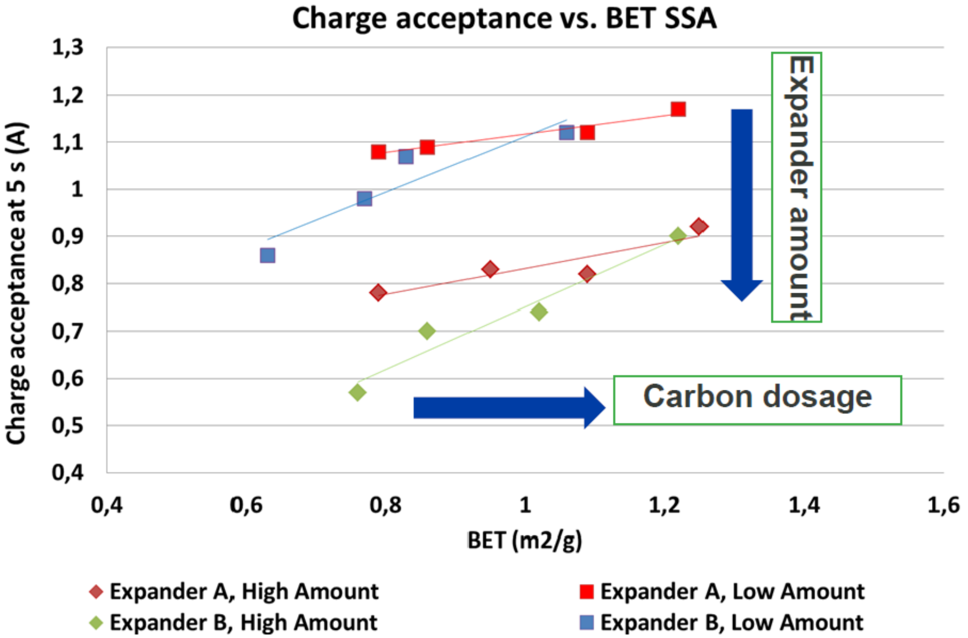
Future Challenges

- Despite the recent improvements, lead-acid batteries are facing **strong competition from Li-ion technologies** in the new booming markets of e-mobility and energy storage.
- The ability of the industry **to adapt to the new market requirements** with incremental future innovations is key to the long-term survival of lead batteries.
- In this regard, the following challenges should be addressed to keep a significant role in future:
  - **Dynamic Charge Acceptance**
  - **High Temperature Endurance**
  - **Deep Cycle Life**

Future Challenges

Dynamic Charge Acceptance

- Charge acceptance is mainly related to the **Negative Active Material (NAM) surface area**.
- **Organic expanders interact with Carbon** by reducing the electro-chemically active electrode area.
- In general, **Carbon dosage increases whereas the Expander amount reduces** charge acceptance.
- **New Carbon Nanomaterials at low dosages** may increase charge acceptance while improving initial performance and water loss.

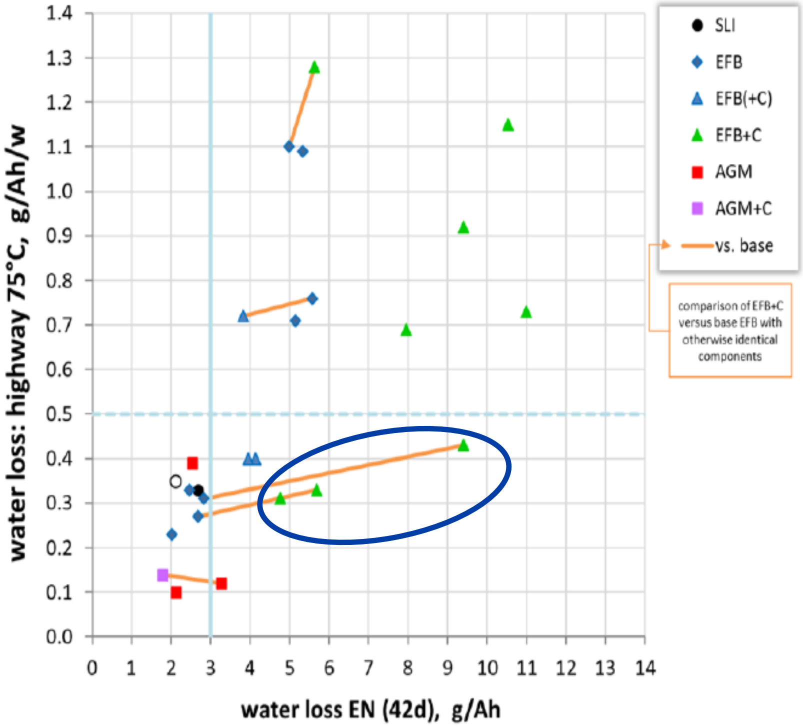


J. Valenciano, A. Couceiro & F. Trinidad / 16th ELBC (2018), Vienna

Future Challenges

High Temperature Endurance

- **High surface area carbon additives increase water loss** under the standard EN 50342 overcharge test conditions (60ºC).
- However, most recent data show that this is **not always the case in simulated highway hot environment conditions (75ºC).**
- The correlation between these two different tests is not straightforward for **batteries especially designed to improve charge acceptance (EFB+C).**
- **Carbon surface electro-chemistry and cell overcharge control** are probably the keys to reduce water loss at high temperature.

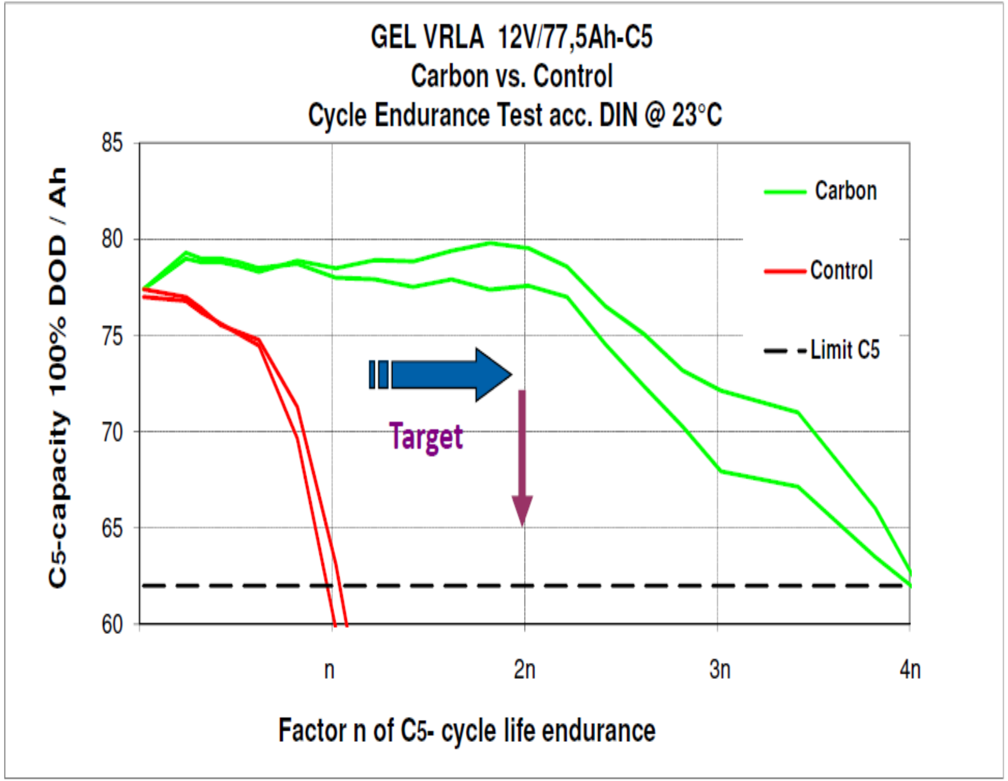


J. Wirth / EFB & Heat Virtual Workshop, November 2020

Future Challenges

Deep Cycle Life

- The addition of **Phosphoric acid to the electrolyte** improves deep cycle life but reduce the initial performance.
- **High surface area Carbon** reduces the overvoltage of the negative plate (enhancing the cell recharge ability).
- The **combination of Carbon and Phosphoric acid** produced an increase of up to 4x cycle life of gel blocks.
- **New additives in the electrolyte and highly compressed VRLA designs** may further improve deep cycle life while improving initial performance.



H. Niepraschk, F. Trinidad / International Lead Acid Battery Conference, Würzburg (2015)

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Concluding Remarks

- Lead batteries have been up to know the preferred technology for automotive and industrial use due to its low **cost and availability of raw materials.**
- However, Li-ion is challenging its dominant position due to the **cost reduction achieved with high volume production** for Electric Vehicle applications.
- The ability of the industry to adapt to the new automotive market requirements with incremental **future innovations is key to the long-term survival of lead batteries.**
- On the other hand, **significant improvements on performance and total cost of ownership (TCO) are needed** to compete with Li-ion in the industrial markets.
- Increasing both **fast charge ability and cycle-life** is key to retain some important markets (Energy Storage, Motive Power, Telecoms, UPS) that are now at risk.
- Finally, focusing on its well-known advantages (safety and sustainability) and developing more **environmentally friendly recycling processes** will also help to compete with other advanced technologies.

Thank you for your attention

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