Application of Domestic Graphite as A Component of New and Improved Lead-Acid Batteries

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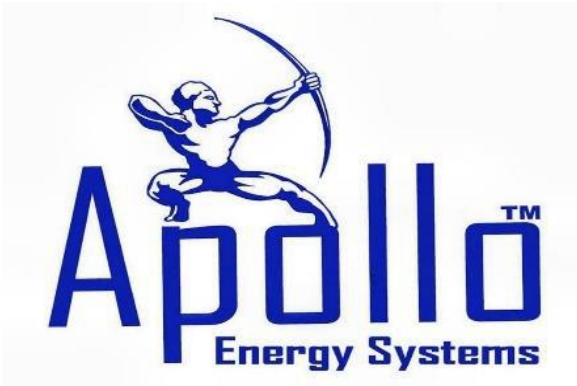

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OVERVIEW

- Background
- AETC and Apollo Battery Technology Partnership
- The Market of Graphite & Carbon for Lead Acid Batteries
- Why natural graphite? Why domestic?
- Cell and battery construction, system manufacturability
- Performance characterization
- Opportunities for Materials Suppliers in the Lead Acid Battery Market
- Advantages for Lead-Acid Battery Manufacturers
- Conclusions

A Real Life Company

- An Illinois woman-owned privately held business (Founded in 2009)
- As of Dec 2022, we have 100+ customers for our products and services with foreign customer hubs in Europe, Canada and Australia
- Raw Materials long term Supply Agreements: focus on domestic
- Footprint (current and under construction): 40,000+ sf
- Top-of-the-line R&D laboratory / pilot plant, dedicated to support sales of our products into the battery, fuel cell, advanced carbon & graphite, and advanced coatings industries
- Manufacturing facility to produce industrial graphite and carbon for advanced energy systems; pilot plant to produce full scale form-factored batteries
- In late 2021 AETC acquired an industrial site which is currently undergoing renovations and build-out and will become an expansion facility for our operations in the first quarter of 2023
- A proud member of the domestic supply chain of EV batteries
- Approved supplier of advanced materials to at least 10 battery manufacturers, including DOD primes

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Apollo Energy Systems

- Apollo is a company with 60-years' experience in development of batteries, fuel cells and electric vehicle systems which incorporate those products. Apollo's roots go back to 1953 when it built its first battery plant in Puerto Rico.
- The Apollo Tri-polar Advanced Lead-Acid Batteries have the flexibility to be utilized in many markets from electric vehicles and forklift trucks, to load leveling, solar-powered applications, and grid storage. This technology is based on 50-years' manufacturing experience and will prove to be the future of energy storage for off-grid locations.
- In 1994, Robert Aronsson (1923-2020) Incorporated Apollo Energy Systems, Inc. (AES) with headquarters in Fort Lauderdale, FL, to manufacture "Lead Cobalt" Batteries, Alkaline Fuel Cells, Electric Propulsion System Components and Electric Cars.
- Electric Auto Corporation has a rich history of electric car and battery development including;
  - The competition winning Mars I, Mars II and Silver Volt EVs.
  - Manufacturing in Puerto Rico, Korea, China, Bahamas and USA.
  - 27 Patents in Lead-Acid Batteries and Electric Cars in 14 Countries.

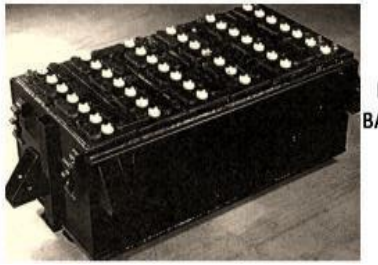
In 2006, Apollo was awarded US Patent 7,037, 620 B2 on Multi-Cell Battery; and in 2020 & 2022, Device & Method for Manufacturing Metal Foams for new lead- acid batteries.

- In 2017, Apollo commenced their collaboration with AETC and successfully carried out several projects with graphite to enhance the high rate, lifetime and charge efficiency of cells

APOLLO'S HERITAGE AND FUTURE

THE TPX BATTERY WAS ORIGINALLY DEVELOPED FOR SILVER VOLT ELECTRIC CAR DEVELOPED BY APOLLO'S PREDECESSOR ELECTRIC AUTO CORPORATION

THE SILVER VOLT REPRESENTS OUR HERITAGE, OVER 30 YEARS OF RESEARCH AND DEDICATION TO ALTERNATIVE POWER



REAR BATTERY PACK

FRONT BATTERY PACK

THE ALKALINE FUEL CELL (AFC) – SEE FOLLOWING PAGES – WAS ORIGINALLY CONCEIVED AS AN ALTERNATIVE POWER UNIT (APU) FOR THE SILVER VOLT ELECTRIC CAR. AS EXPLAINED BELOW, THE AFC HAS MANY STATIONARY APPLICATIONS AND IS NOW THE FOCUS OF APOLLO'S FUTURE.....

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AETC – Apollo Partnership in the Headlines

NEW OPPORTUNITIES FOR AN ESTABLISHED TECHNOLOGY – THE REBIRTH OF THE LEAD-ACID BATTERY IN GREEN TECH

Updated: Dec 22, 2021

"Clean Energy for the 21st Century"

New Opportunities for an Established Technology – The Resurgence of the Lead-Acid Battery in the Green Energy Environment

American Energy Technologies Co. (AETC) is delighted to announce its collaboration with Apollo Energy Systems, Inc. (AES). AES has been a customer of AETC's graphite products for several years. AES has been developing, commercializing and manufacturing advanced lead-acid batteries for more than 20-years. Further improvements are expected with the use of new graphite-derived materials in the very near future. These improvements will incorporate some of the recently discovered outstanding material and electrical properties of graphene. Recently, the two companies decided to extend their collaboration by launching a new and unique technology development / demonstration program which is open to existing and aspiring materials suppliers into the lead-acid battery industry. The objective of the program is to develop and demonstrate lightweight advanced lead-acid batteries with enhanced performance.

As part of this initiative, under the supervision of engineers and scientists of AES, AETC has installed a pilot assembly line for in-house manufacturing of fully functional prototype batteries rated for a variety of segments of the lead-acid battery market. The advanced battery designs are produced under the direction of Dr. Joe Gnanaraj, AETC's R&D Director Renewable Energy Systems. These improved batteries are expected to fill the growing market demand in start-stop applications, photovoltaic grid energy storage systems, Starting, Lighting, and Ignition (SLI), backup energy storage / Uninterrupted Power Supply (UPS), and electric vehicles. AETC is able to leverage its expertise in industrial graphite and carbon products to complement lead-acid battery platforms designed with improved performance in mind.

NAATBatt
Advanced Battery Weekly

Summary:

For the September 10th issue of NAATBatt's Advanced Battery Weekly, we highlight recent sector activities.

Lithium carbonate prices increased w/w, while Cobalt sulfates and Flake graphite prices were flat w/w.

Read the most recent Executive Director's Notes commentary in the NAATBatt blog. To view the blog, please go to http://www.naatbatt.org/latest-news/

Key Highlights:

Toyota Motor is planning to spend approximately 1.5 trillion yen ($13.6 billion) by 2030 to develop batteries and its battery supply system. The company is projecting its electric vehicles (EVs) to consume up to 200 gigawatt-hours (GWh) of batteries. Toyota is also developing a lithium ion (li-ion) battery that could be at least 30% lower cost through the development of materials and structures. *(Source: Toyota Motor)*

EcoPro BM has secured a 3-year deal worth about 10 trillion won ($8.5 billion) to supply materials for **SK Innovation's** high-nickel batteries. The two companies agreed to strengthen their partnership through joint investment in material business and cooperation in recycling waste batteries. *(Source: Aju Business Daily)*

POSCO Chemical has acquired a 13% stake in **Qingdao Zhongshuo New Energy Technology** (**QZNET**) for 4.9 billion won ($4.2 million). QZNET has an annual production capacity of 25,000 tons of spherical graphite and will begin shipping to POSCO next year. *(Source: Yonhap)*

SK Innovation has signed a supply agreement with **Xpeng Motors** to provide batteries containing 80% nickel. The batteries will be produced at factories in **Huizhou**, **Guangdong Province**. The Huizhou plant is the company's 3rd battery plant in China. It has an annual capacity of 10 GWh. *(Source: KrAsia)*

BMW Group has almost doubled its supply for battery cells – a volume of EUR 22.4 billion ($26.5 billion) has been agreed with suppliers for the 5th generation of its electric drive. Enough for 10 million of its all-EVs within 10 years. *(Source: BMW Group)*

Bridgestone and **EVBox** announced a 5-year partnership to install up to 3,500 EVBox AC and DC charging ports across **Europe**. The installations will take place across Bridgestone's European retail and service network, including the **Speedy** and **First Stop** brands. *(Source: EVBox)*

Saft has won a follow-on contract with **KSC Group** to deliver battery systems for emergency traction on the **Moscow Metro**. Under the contract, Saft will deliver up to 1,240 battery kits based on its **MSX** nickel technology cells for installation on the fleet of **Moskva-2020** trains, which are due to enter service by the end of 2023. The batteries will enable the vehicles to travel up to 6.5 kilometers (4 miles) to the next station. *(Source: Saft)*

American Energy Technologies (**AETC**) announced a collaboration with **Apollo Energy Systems** (**AES**). The companies are launching a technology development / demonstration program for materials suppliers into the lead-acid battery industry. *(Source: AETC)*

Wallbox has unveiled its **'Hypernova'** charging station that could fully charger an EV in under 15 minutes. The unit can deliver up to 350 kilowatts. *(Source: Wallbox)*

Honda announced that it will start a testing program for autonomous vehicles that will be launched under a collaboration with **Cruise** and **General Motors**. The companies will jointly work on the testing program at an operations test site to be established within a Honda facility in **Tochigi Prefecture**. *(Source: Honda)*

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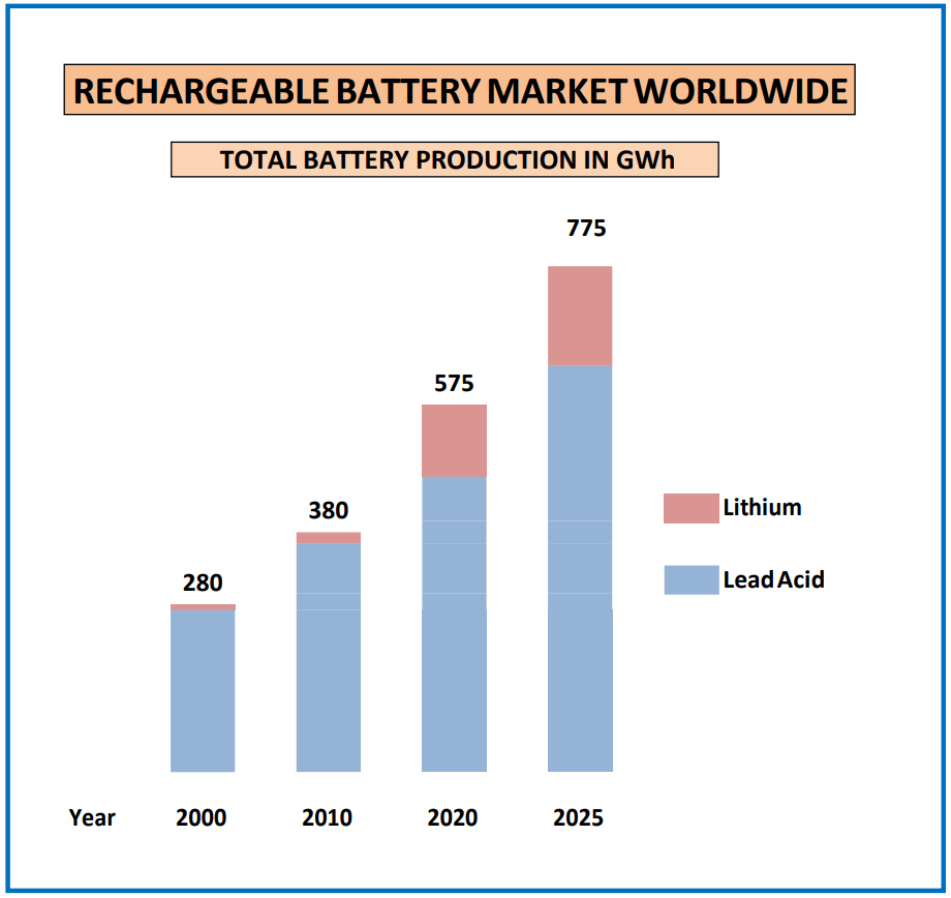
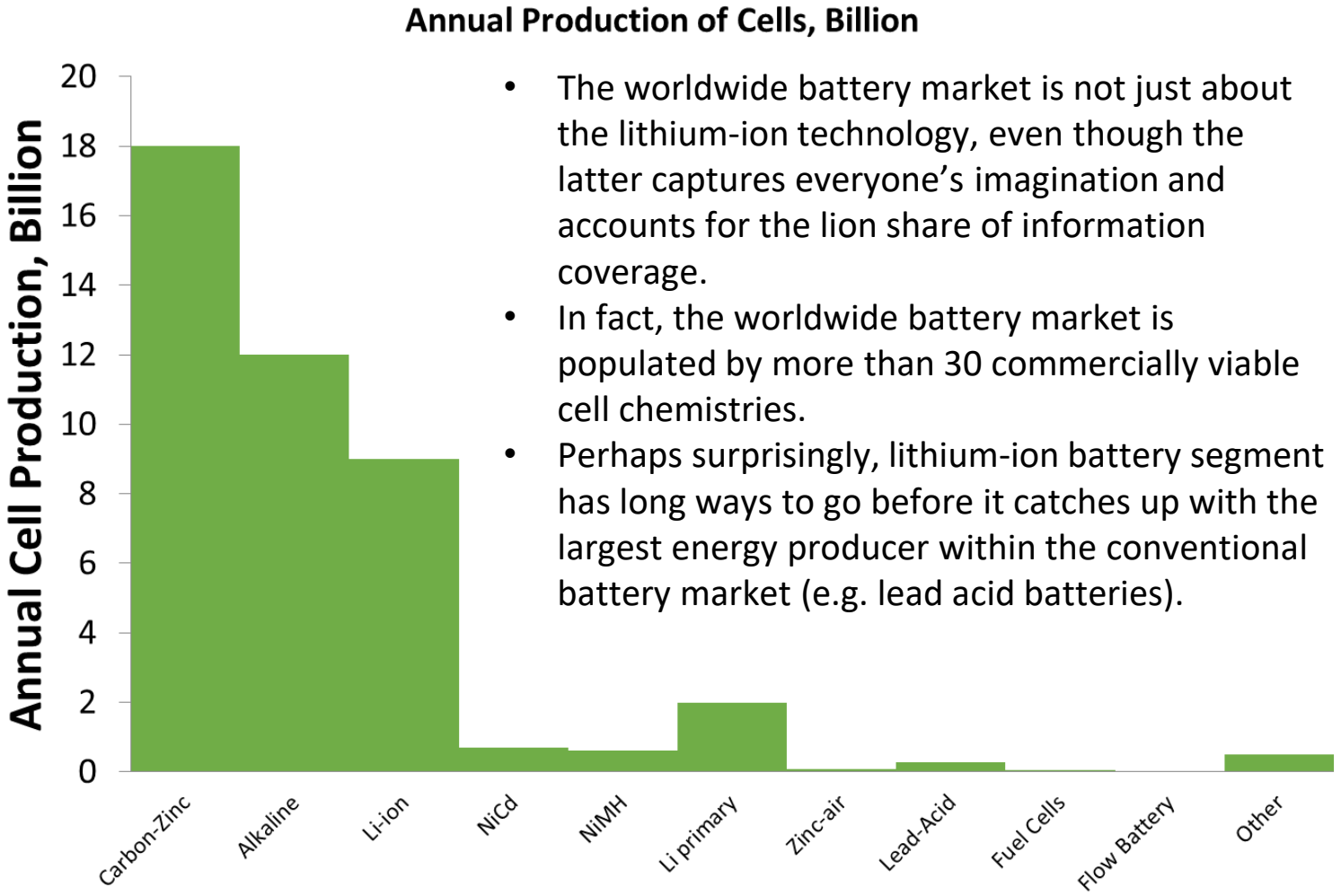
Worldwide Energy Generation by Lead Acid Batteries is Simply Unmatched by Other Battery Chemistries





- The worldwide battery market is not just about the lithium-ion technology, even though the latter captures everyone's imagination and accounts for the lion share of information coverage.
- In fact, the worldwide battery market is populated by more than 30 commercially viable cell chemistries.
- Perhaps surprisingly, lithium-ion battery segment has long ways to go before it catches up with the largest energy producer within the conventional battery market (e.g. lead acid batteries).

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A unique material sits in the heart of lead acid battery technology and assists it to successfully resist pressure from the incumbent lithium-ion batteries.

- Modern Lead-Acid Batteries incorporate natural flake and natural expanded delaminated graphite as part of composition of the “expander”.
- “Expander” is a powdered materials blend, which is added at 2 to 3 wt.% to the composition of negative electrodes.
- Legacy “expander” used to be composed of Barium sulfate, carbon black and ligna sulfonate, taken at approximately equal ratios;
- The addition of natural flake graphite to the ligna and carbon black results in significant boost of lead-acid battery performance, which manifests itself in greatly increased cycle life defined as pulsed charge-discharge shallow cycling.
- Traditional batteries are capable of supporting approximately 30,000 shallow cycles, while natural graphite-containing cells could deliver 55,000 to 75,000 cycles (depending on electrode design);
- Introduction of graphite has resulted in lead-acid batteries making inroads into several important lithium-ion markets.

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Industrial Graphite & Carbon for Expanders of Lead Acid Batteries: Market size

- April 2022 - President Joe Biden's announcement that graphite (among other critical battery materials) were designated as "essential to national defense" under the Defense Production Act (DPA) of 1950. A DPA Title III designation will "invoke the Defense Production Act to accelerate domestic production of lithium-ion battery materials, in particular graphite, manganese, cobalt, nickel, and lithium".
- AETC's production flowsheet for the manufacture of graphite for lithium-ion battery anodes has an ultra-high purity by-product stream which feeds the supply chains of lead-acid, alkaline, hearing aid, reserve (thermal), lithium primary batteries, supercapacitors and fuel cells.
- Lead Acid Batteries consume very significant amount of graphitic carbon:
  - An average lead acid battery can be assumed to have 1,500 Wh capacity (calculated as 250 Ah (nominal capacity @ 20 Hr rate) x 6 V (nominal voltage).
  - The lead acid battery market generated approximately 450 GWh of energy in 2021, which can be divided by the aforementioned capacity to 300 million batteries. An average battery contains 2 wt.% expander, 50% of which graphite and carbon. That amounts to around 0.5 kg of expander per battery (0.25 kg of graphite and carbon). Thus, this may be multiplied by 300 million batteries to reach a market size of 75,000 metric tons of graphite and carbon used in the lead acid battery market per year globally.
  - Since mid-2000's advanced forms of natural and expanded delaminated graphite have been actively winning spots in Bills of Materials of advanced Lead Acid Battery systems.

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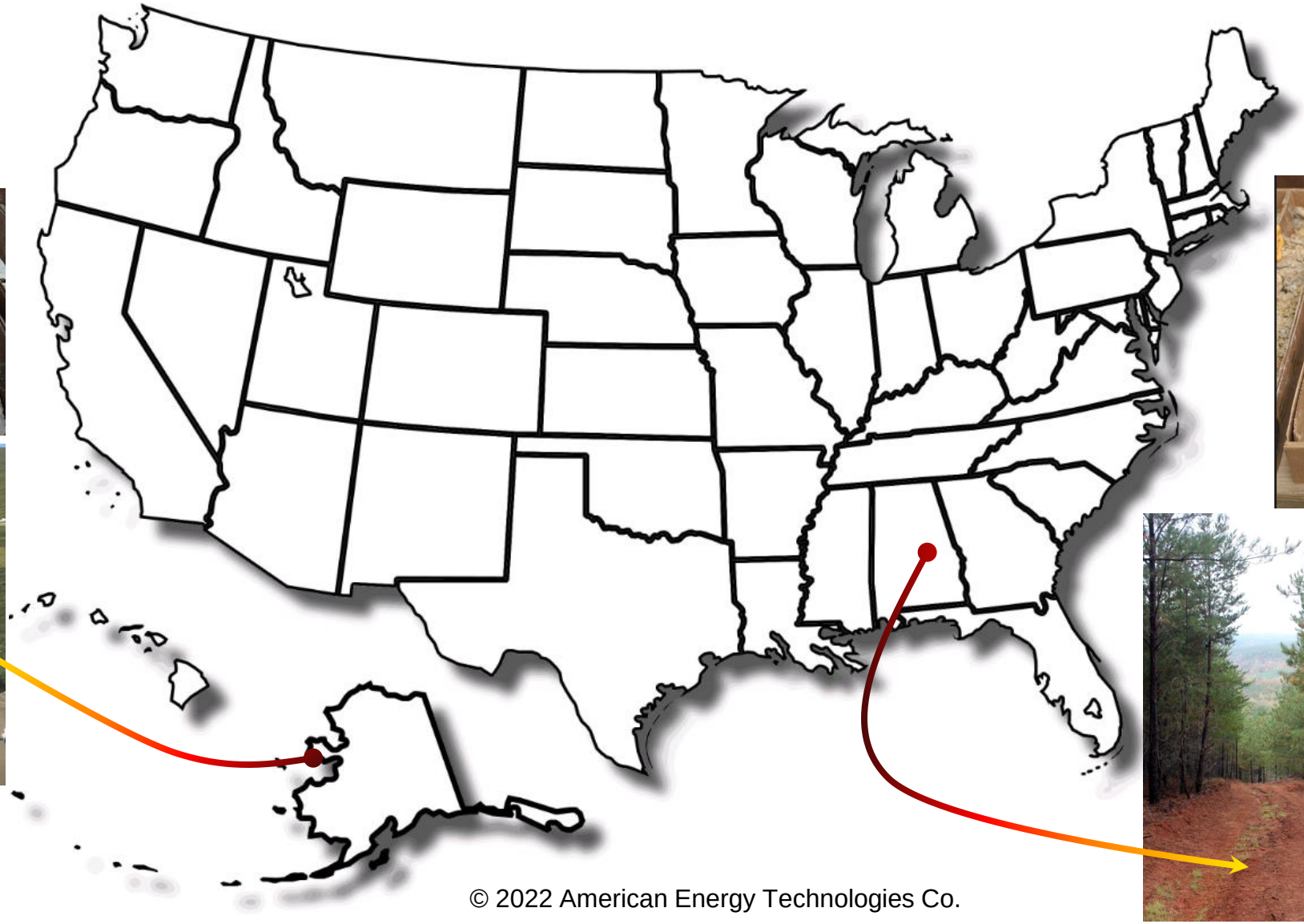
Two Large Domestic Resources for Natural Graphite – Near Teller, Alaska and Alabama Graphite Belt



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THE REBIRTH OF THE LEAD-ACID BATTERY IN GREEN TECH IS HAPPENING NOW

- Advanced Lead-Acid Battery Concepts utilizing modified graphite in the negative active material and in other components
- Innovative Vented and VRLA (absorbent glass mat, AGM)
- New Bipolar Configuration utilizing graphite composite plates – 80% higher Energy Density
- Greater Dynamic Charge Acceptance
- Greater Charge-Discharge Efficiency
- Less Divergence in State-of-Charge in Series Connected Cells
- Long Cycle Life – Especially at HRPSoC (High Rate Partial State of Charge) Cycles
- Greater Specific Energy at Higher Rates of Charge/Discharge

ADVANTAGES OF LEAD-ACID BATTERIES OVER LITHIUM

Compared to Lithium, Lead Acid Batteries…

- Have Lower Cost
- Have Worldwide Familiarity and Acceptance
- Do not Require Battery Monitoring System
- Do Not Require Cooling System
- Are Less Complex to Operate
- Have Easier Compliance with Building Codes
- Do not Suffer from Thermal Runaway
- Do not Catch Fire
- Are Easily Recycled in Existing Infrastructure
- Superior for Large Scale Energy Storage
- Will have a Majority of the Rechargeable Battery Market for the Foreseeable Future

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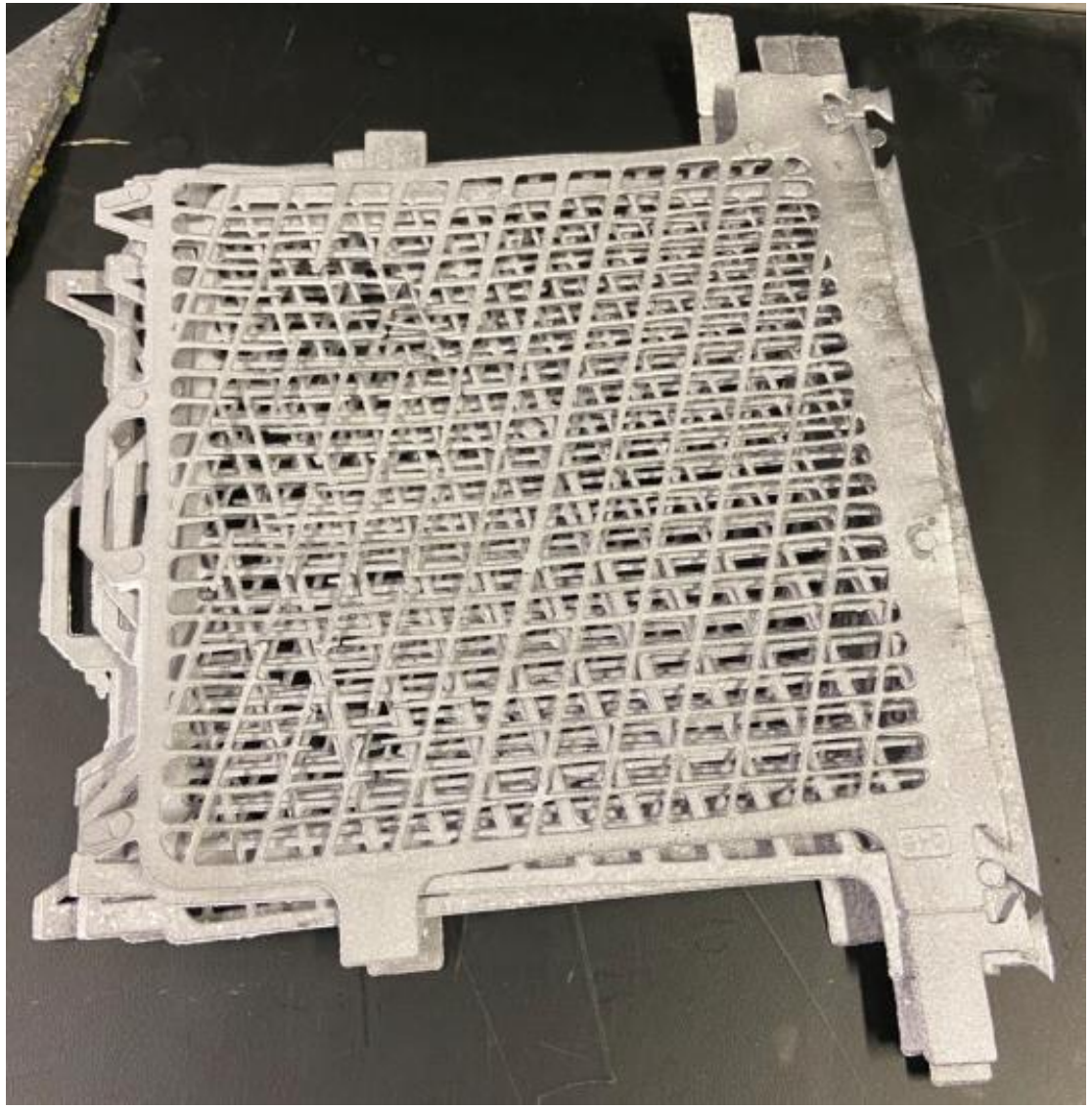
Lead Acid Battery Making at a Glance:
Ranging from 5 Ah cells to 500 Ah form-factored batteries



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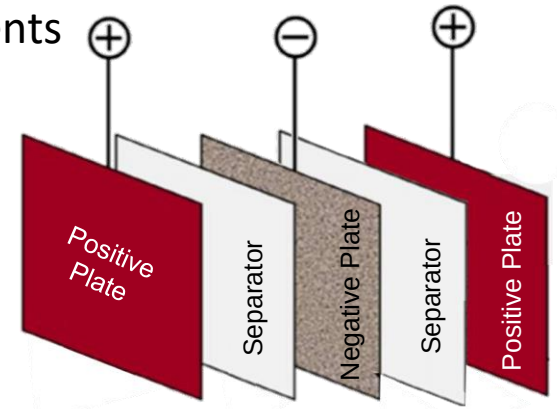
PRODUCTION OF LEAD ACID BATTERY CELLS AT AETC

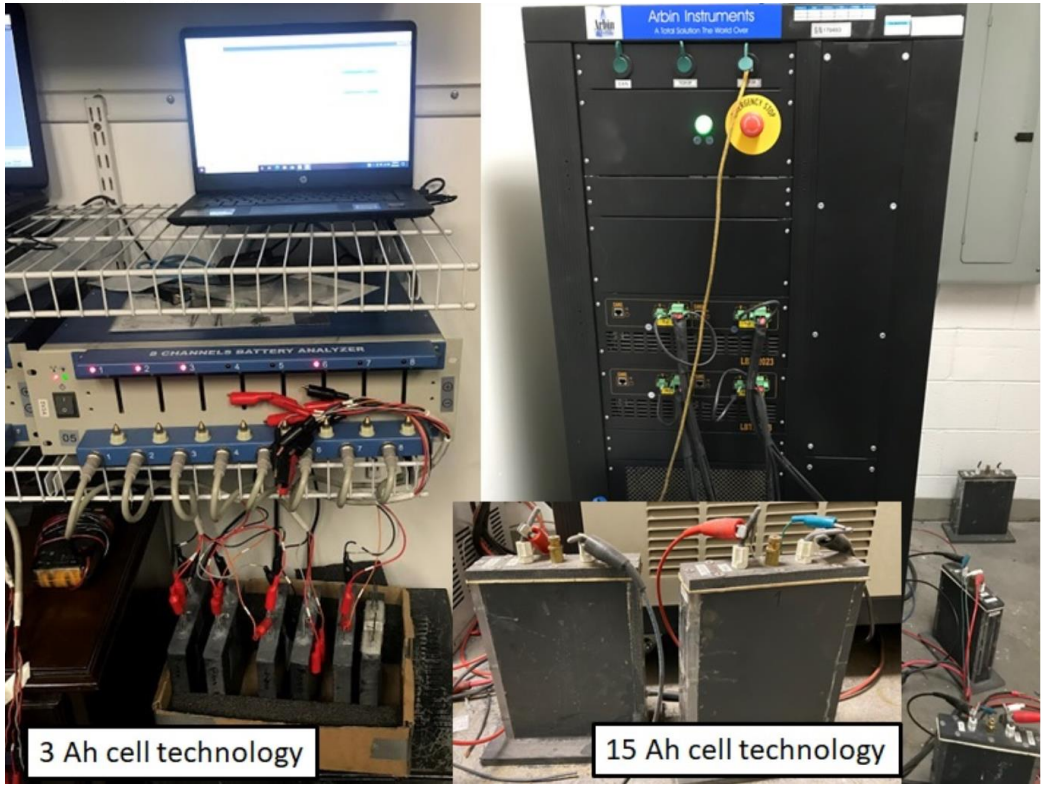
- Production of lead grids for both positive and negative plates
- Mixing Ingredients
- Pasting
- Curing
- Formation
- Inspection
- Cycling



Schematic diagram of our simplest three-electrode test cell containing 2 positive plates, 1 negative plate and 2 separator sheets.

Lead Acid Battery Test Cells after Formation

Battery Electrode Hydrothermal Drying Process



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Formation of Positive and Negative Plates

Initial formation of lead acid batteries goes through several stages and it is aimed to achieve **chemical conversion of precursor materials to the active α-PbO_2 and ß-PbO_2 phases.**

The α-PbO_2 shows a higher life-time and mechanical strength, being preferable to be formed in positive plate of stationary batteries.
The β-PbO_2 phase preferably occurs in acidic medium because it is more stable electrochemically and offers better performance, being interesting for SLI batteries

- Soaking in H_2SO_4 bath
- Formation of positive and negative plates
- The cells are charged slowly for 72 h at a constant current until the formation
- The entire process is kept between 35°C <T <55°C

The precursor materials initially are lead sulfate and lead oxide, have a white or yellow color. The final active material (PbO_2) is dark brown or black when in the presence of water. The heterogeneous distribution of these colors indicates a low efficiency of the electrochemical formation process, while the uniform distribution of black color indicates a high possibility of a complete formation

PAVLOV D. in: MACNICOL, B. D.; RAND, D. A. J. (Eds) (1984) **Power Sources for Electric Vehicles**. Elsevier, Amsterdam, p. 328.
PAVLOV, D. et al. (1972) Mechanism of the Processes of Formation of Lead-Acid Battery Positive Plates. **Journal of the Electrochemical Society**, v. 119, n. 1, p. 8-19
Bode H. (1977) ***Lead Acid Batteries****, Wiley-Interscience, New York, 1977..*

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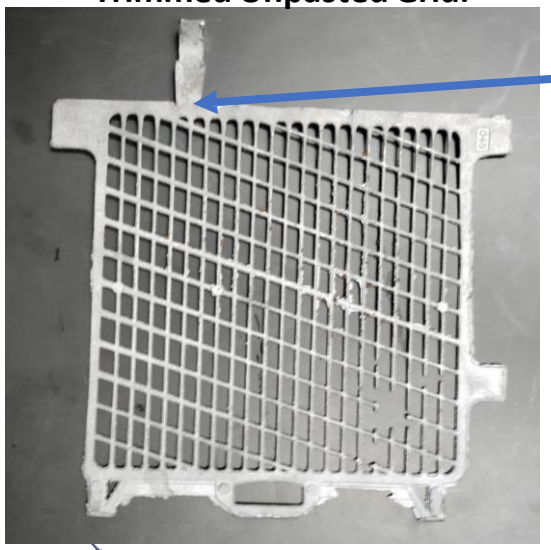
Engineering of Customized Lead Acid Test Cell Cases

- Form-factored cases that house lead acid electrodes are designed and constructed out of chemically resistant materials
  - Shims are used as needed to apply pressure between electrodes
- Boxes are fully sealed with epoxy on all edges and gasket at the top
- Top of the box contains a pressure relief valve and an electrolyte filling port

Trimmed Unpasted Grid:



Single Unpasted Grid in Box:

Box Cover:

Note: Cover will be screwed into body

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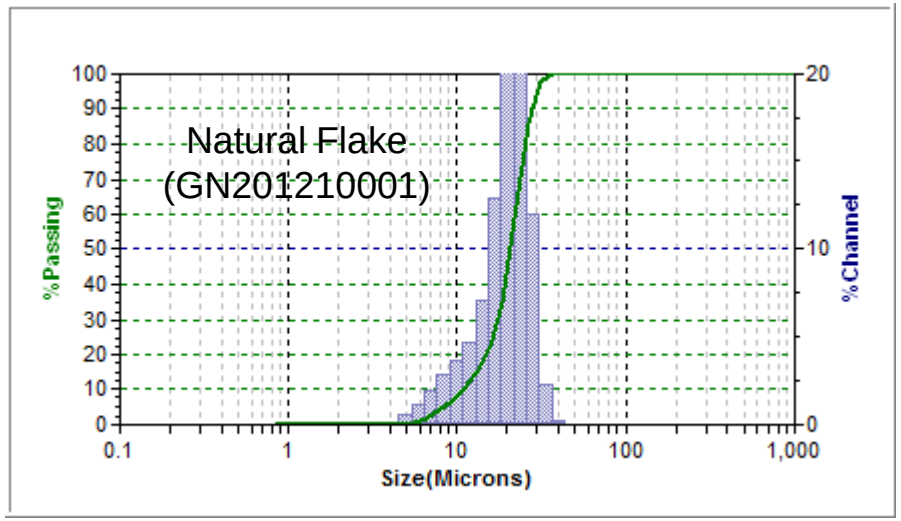
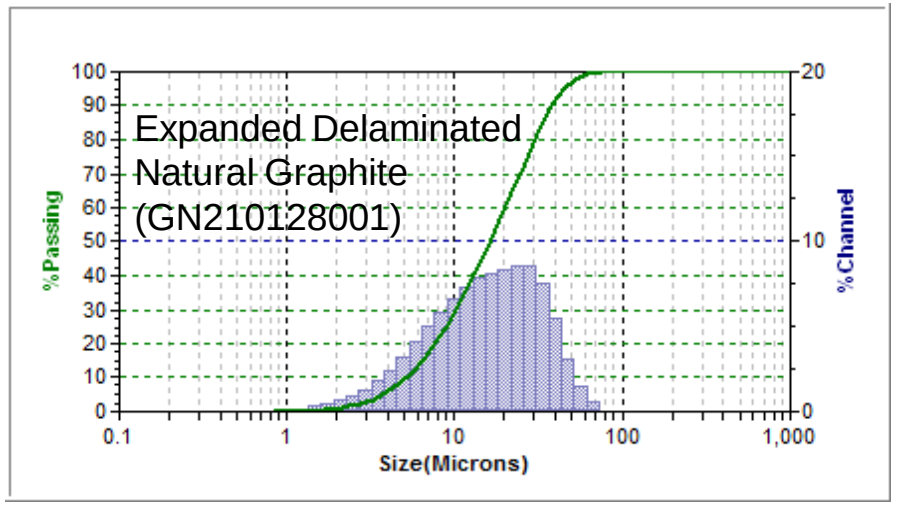
Lead Acid Battery Grade Graphites from a Resource within the Alabama Graphite Belt





Graphite Material	Tap Density, g/cc	Scott Volume, g/cc	Surface Area, m2/g	D10 (µm)	D50 (µm)	D90 (µm)	MV (µm)
Natural Flake (GN201210001)	0.36	0.18	1.07	10.85	20.79	27.39	20.11
Natural Expanded Delaminated (GN210128001)	0.22	0.12	12.2	5.19	16.19	37.69	19.27

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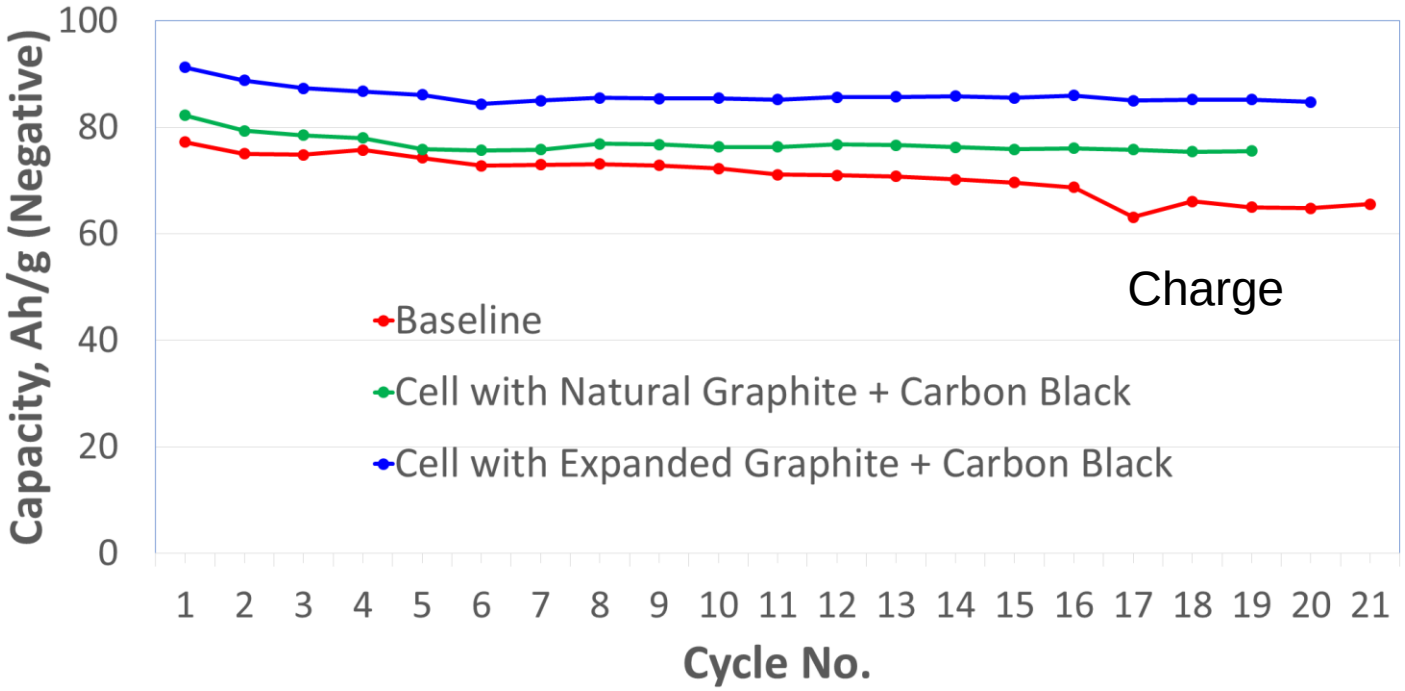
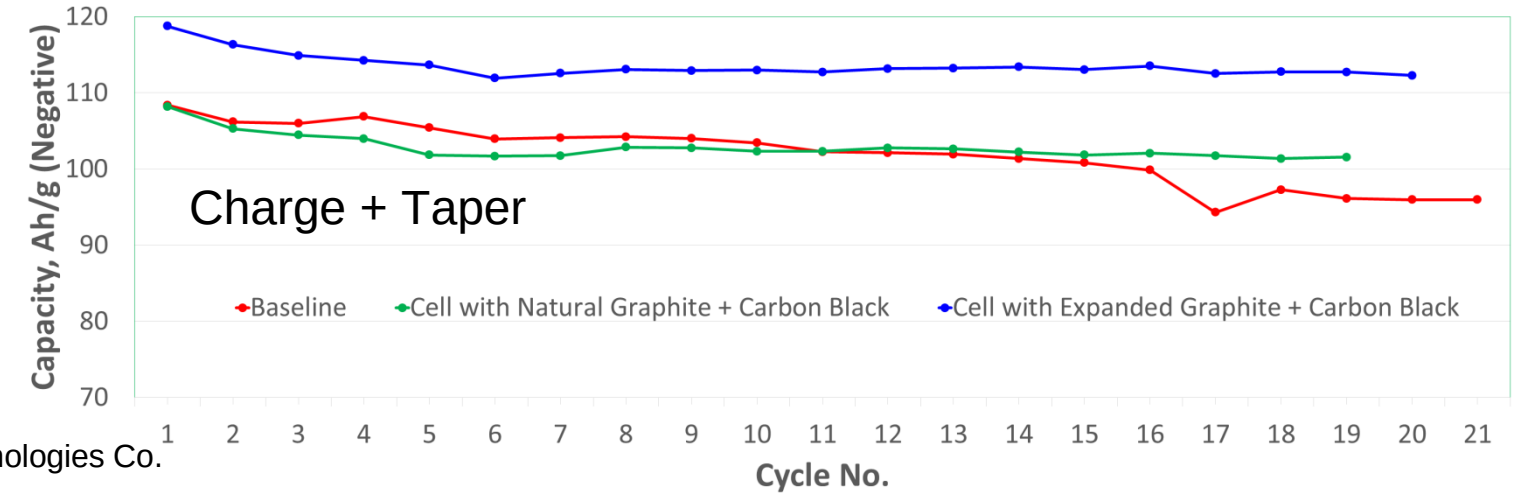
Lead Acid Battery Using Graphite from a Resource located within the Alabama Graphite Belt





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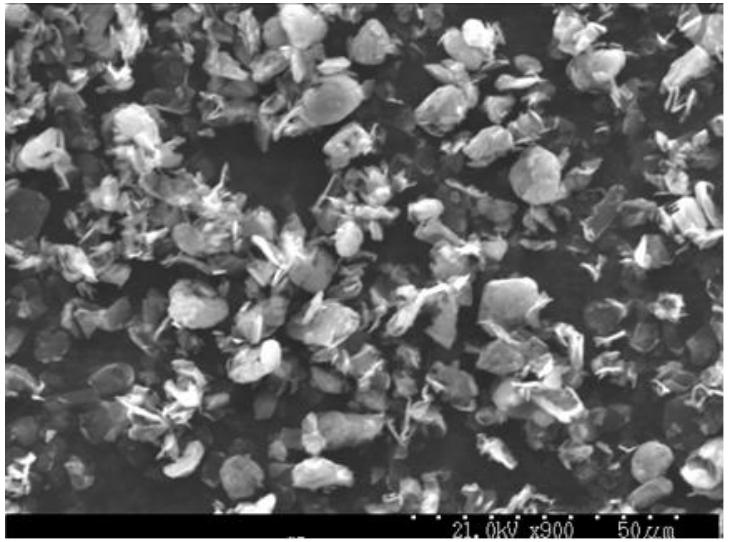
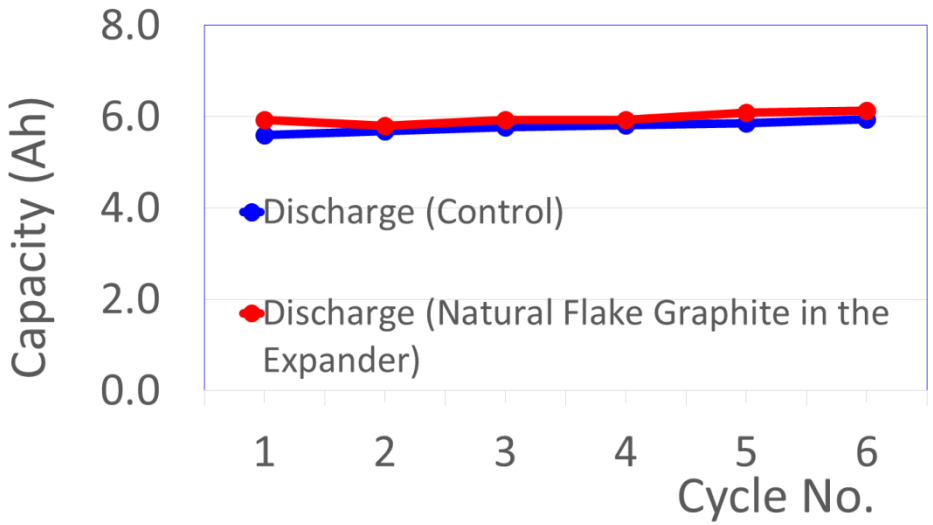
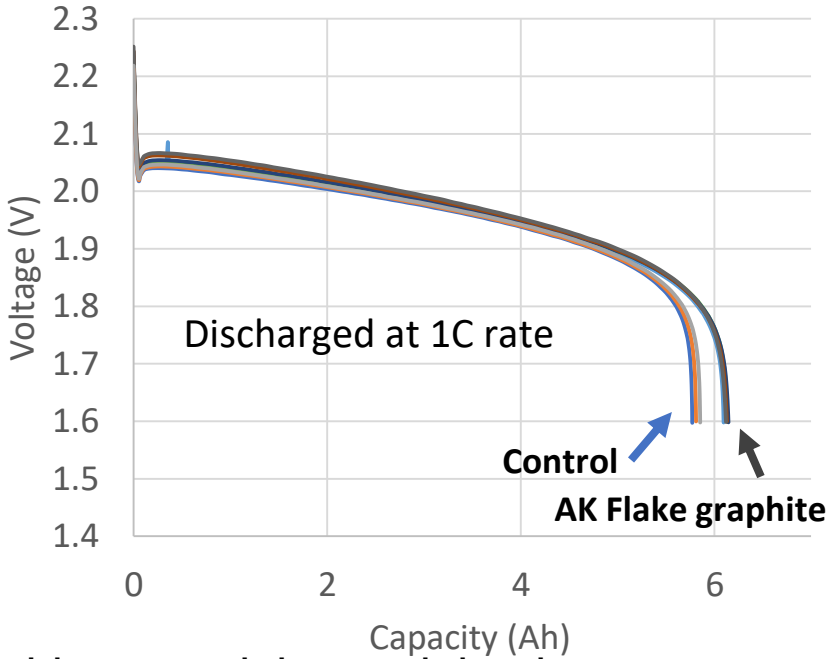
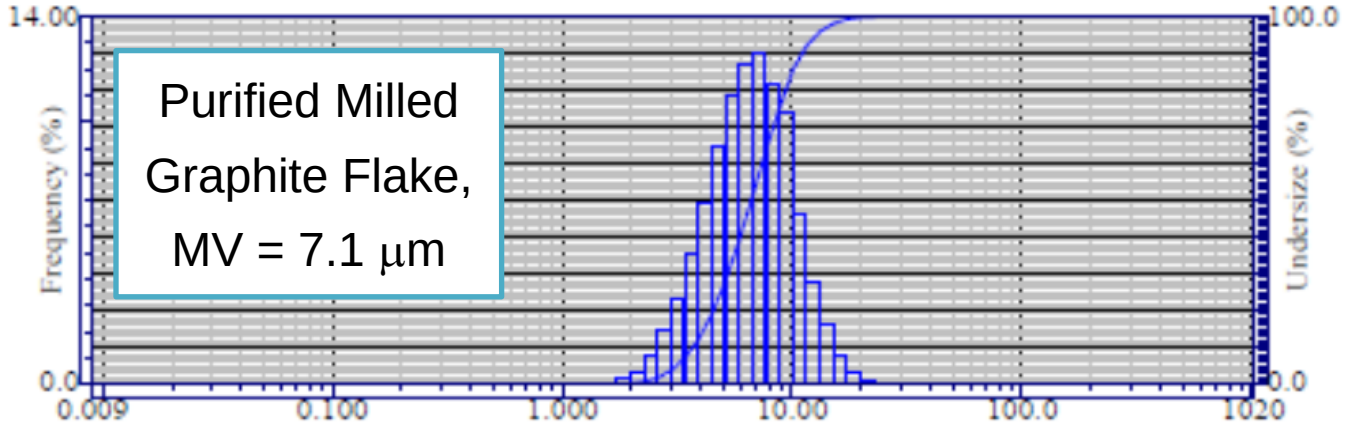
Lead Acid Battery Using Fine Graphite from near Teller, AK Natural Flake Resource in Expander Composition









Purified Milled Graphite Flake, MV = 7.1 μm

The Flake graphite material-containing battery, despite having been designed to deliver capacity of 5.5 Ah in fact consistently achieved values of around 6.3 Ah, producing a significant improvement of performance. The control formulation, in contrast, only ran at values approaching 5.75 Ah.

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Opportunities for Materials Suppliers and Lead Acid Battery Producers

- Lead Acid Battery Manufacturers are encouraged to take advantage of innovative graphite-based technologies for purpose of enhancing performance of their advanced battery products
- New graphite products for lead acid battery systems are available in commercial quantities from American Energy Technologies' plant in Arlington Heights, IL
- By means of the new AES-AETC Partnership, material suppliers into the lead-acid battery industry, including representatives of the industrial graphite & carbon community, can now conduct meaningful and unbiased tests of their products in lead-acid battery prototypes prior to marketing to established battery manufacturers.
- The collaboration between our two companies is not only limited to the prototype cell assembly and testing, but also extends its focus to various lead-acid battery cell component manufacturing, such as production of lead grids through advanced casting methods. Major opportunities exist in the optimization of pasted lead grids from the point of view of their weight reduction. This effort is expected to also enhance the capacity and lifetime of the batteries and improve their ability to accept and deliver high currents.

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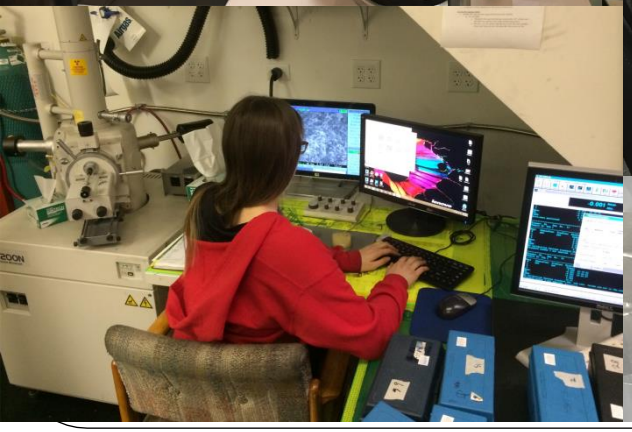


Thank you for your attention!

End-to-end graphite materials processing for battery applications and battery cell assembly and testing at the lab, pilot and full scale production levels

Contact American Energy Technologies Co.
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