Acceptance and use of MOLECULAR REBAR®
in challenging new lead acid battery markets

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Black Diamond Structures, Austin TX USA

Who We Are

Black Diamond Structures is a developer, manufacturer, and marketer of innovative nanomaterial products and solutions based on revolutionary discrete carbon nanotube (dCNT) technology, **MOLECULAR REBAR®**

Our Partners

Global Adoption - MOLECULAR REBAR® Technology

Global Adoption:

- Products Commercially Available and being ***sold to*** Lead Acid Battery Manufacturers across multiple end-use applications
- Working with **>120** battery manufacturers worldwide, each at various stages of development and/or commercial sales.
- **Recent approval for use in major Automotive OEM batteries. (SLI)**
- **Have proven that Molecular Rebar can help battery manufacturers meet new OEM requirements for "Advanced Automotive Battery" applications.**
- Extremely large amount of data on full-scale production batteries.
- Invited to and participating in the CENELEC technical work group (Major Auto OEM's, Large battery MFR's, Limited supplier involvement).
- Approved to discuss three Mfr's publicly at this time (Eastman – India, Pacific Battery – Fiji, Tianjin Lantian Power Sources – China)

Why the rapid adoption?

- Technology is innovative, cutting-edge, and ***scientifically sound***
- Cost effective performance improvements over a wide variety of applications
- Low risk to use
- No (or very low) capital expenditure by manufacturer; very easy to use and implement
- Highly technical staff works hand in hand with your company during ramp up.
- World-class technical support from Black Diamond Structures

About Us – Lead Acid R&D Equipment

One of the largest battery testing labs in the World for lead acid material suppliers!

- **129 Circuit Bitrode full-scale battery testing lab**
  - (16ct 300A, 48ct 100A, 64ct 25A, 1ct 1500A)
- **JEOL Scanning Transmission Electron Microscope (STEM)**
- **JEOL Scanning Electron Microscope (SEM) with EDX capabilities.**
- **Energy-dispersive X-ray spectroscopy (XRD)**
- **8 Channel Solartron potentiostat**
- **FTIR and UV-VIS spectrometer**
- **Instron 3367 Tensile Tester**
- **Porosimeter, Moisture analyzer, Penetrometer, Colorimeter**
- **Arbin, 32 channel battery formation and tester**
- **Thermo gravimetric analyser, Differential Scanning Calorimeter (DSC), Dynamic Mechanical Analyzer (DMA)**
- **Fully equipped 2V lab**
  - 2ct Eirich EL1, lead paste mixers
  - Arbin, 32 channel battery formation and tester
  - Maker Bot 3D printer (Test Cell Production)
  - 5 circuits, 100A Arbin for specialty discharge

Analytical & testing investment > $2MM

About Us – Lead Acid R&D Equipment

PERRY JOHNSON REGISTRARS, INC.

Certificate of Registration

Perry Johnson Registrars, Inc., has audited the Quality Management System of:

Molecular Rebar Design
13477 Fitzhugh Road, Austin, TX 78736 United States

(Hereinafter called the Organization) and hereby declares that Organization is in conformance with:

ISO 9001:2015

This Registration is in respect to the following scope:

Production of Molecular Rebar Derivative Products and Product-Related Services

This Registration is granted subject to the system rules governing the Registration referred to above, and the Organization hereby covenants with the Assessment body duty to observe and comply with the said rules.

Terry Boboige, President
Perry Johnson Registrars, Inc. (PJR)
755 West Big Beaver Road, Suite 1340
Troy, Michigan 48084
(248) 358-3388

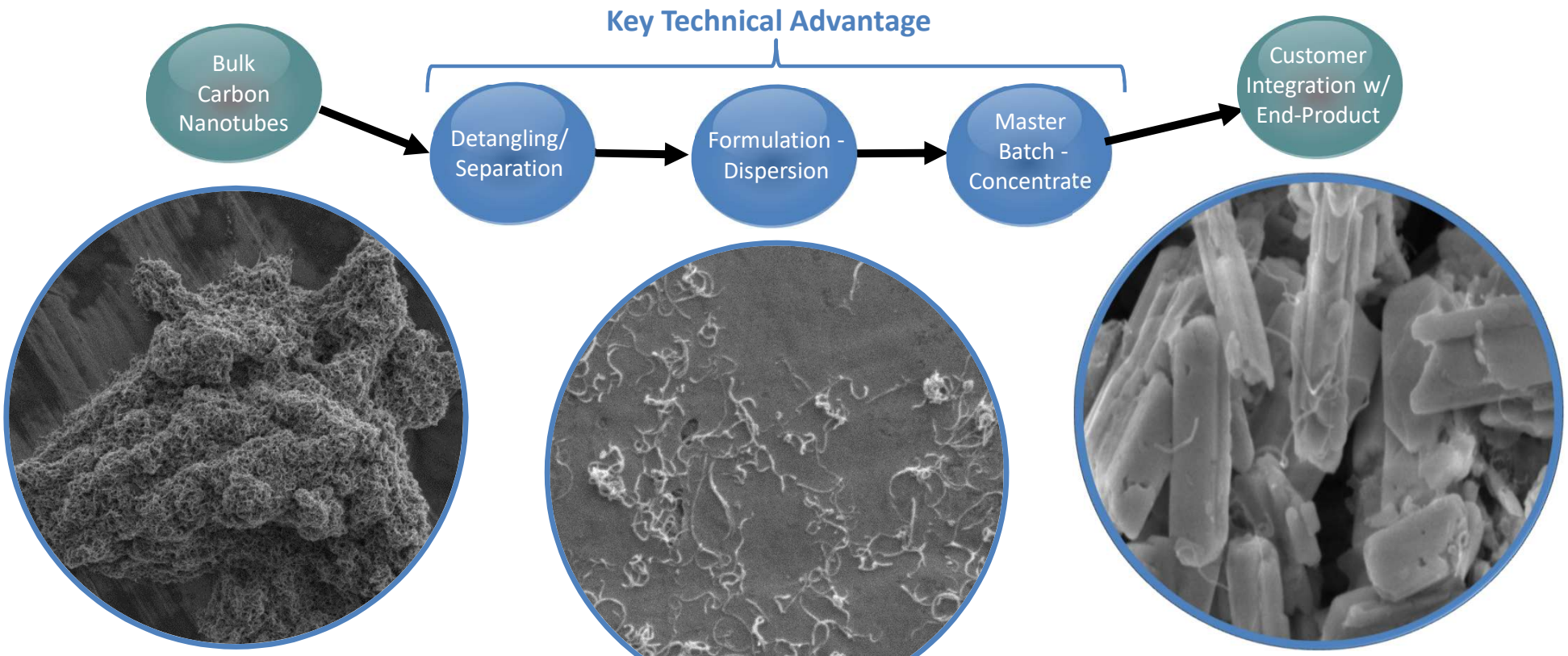
PERRY JOHNSON REGISTRARS, INC. UKAS MANAGEMENT SYSTEMS ANAB ACCREDITED

The use of the UKAS accreditation symbol is in respect to the activities covered by the Accreditation Certificate Number 0103.
The validity of this certificate is dependent upon ongoing surveillance.

Effective Date:	Expiration Date:	Certificate #No:
July 11, 2017	July 10, 2020	C2017-02096

- **Manufacturing Facility (Austin, Texas USA) - Fully operational unit since Q1 2014**
  - ISO certified
  - Experienced chemical operations team
  - Computer based control and data acquisition system
  - Detailed QA/QC process for materials and manufacturing to ensure:
    - Consistent product dispersion
    - Extended shelf life
    - Purity of final product
- **Recent investment has increased production rate from 1M liters/year to 3.3M liters/year**
- **The Technology and the Team:**
  - 15 PhD's & growing, 6 Additional Technology Professionals
  - 32 Patents Allowed and Granted, 90 additional Patent Filings Worldwide

MOLECULAR REBAR® Technology



Clumps of Dirty, Entangled CNT's

Clean, Detangled MR *Discrete, Individual Tubes*

MR in Lead Paste
(or other substrates)

BLACK DIAMOND STRUCTURES™

Challenging new lead acid battery markets

E-rickshaw

- Low design-warranty (6-12mo)
- Loss of backup (short fall in 3mo)
- Slow/Inefficient charging (more than 14hrs)
- High water loss

Solar

- Loss of backup (high warranty fails)
- Slow charging (more than 14hrs)
- Low PSoC performance
- Excess active material usage to attain warranty

Challenging new lead acid battery markets

- **Inconsistent performance throughout life**
  - Capacity/backup loss in 3 months as seen in E-rickshaw batteries
  - Capacity/backup loss near warranty term as seen in solar batteries
- **Poor charge acceptance / always on deficit charging**
  - Due to poor charging efficiency of battery active materials
  - Due to sunlight availability/ improper chargers
  - E-rickshaw batteries needs a day-charge after 3 months
  - Results in sulphation/ reduces life
- **Heavy water loss/ needs maintenance**
  - Due to poor charging efficiency of battery active materials
  - Power supplied wasted in gassing
- **Low Cycle life due to undercharge/ overcharge**
  - Sunlight availability
  - In-efficient and In-sufficient charging

New market applications

Sulphated negative plate

Deep Cycle Flooded: E-Rickshaw

Pb2100 and Pb2200 Series Products

Key Features:

- Used in Negative plate (Pb2100N-Flat; Pb2200N-Tubular)
- Improved Ah-in during charge
- Increases time between charges
- No daytime recharge needed
- Reduced water consumption
- More consistent capacity through life

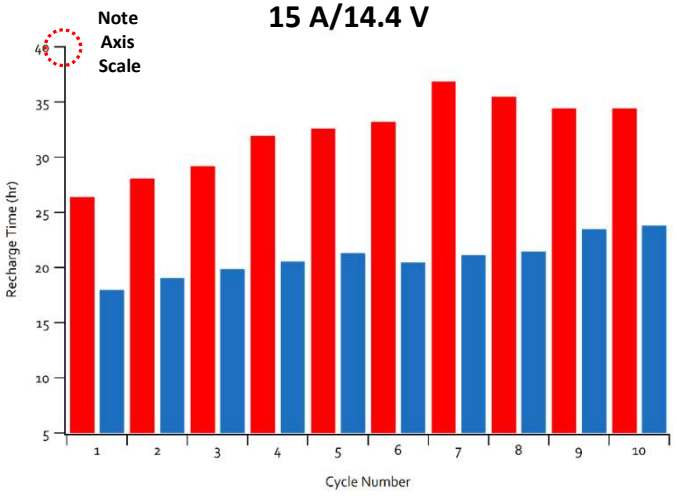
Batteries provided by Eastman (80Ah Tubular)

Deep Cycle Flooded: E-Rickshaw

Pb2100 and Pb2200 Series Products: Shorter recharge time with any charger

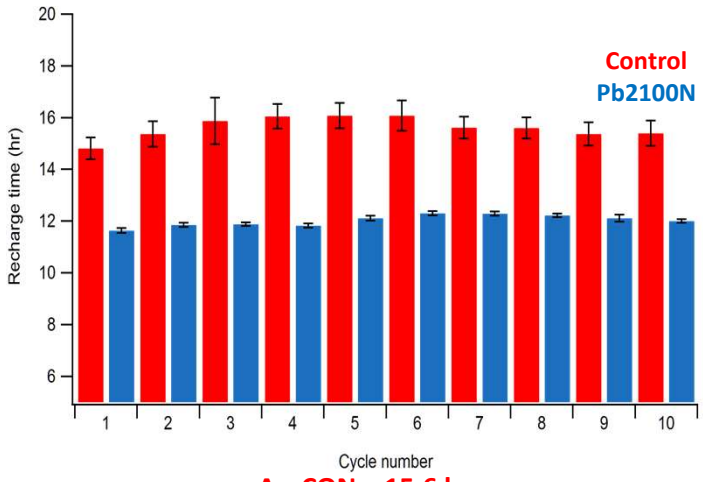
- **To maximize life, eRickshaw batteries must fully recharge every night (8-14h)**
  - To fully charge, a flooded battery must absorb >110% of its last discharge
  - Pb2100N decreases the time to reach this 110% return at various V/I (below)
    - Optimizable based on battery design, charger brand, desired recharge time
  - Pb2100N allows an eRickshaw to fully recharge in an overnight period to increase drive time, driver profits, and Ah throughput

15 A/14.4 V



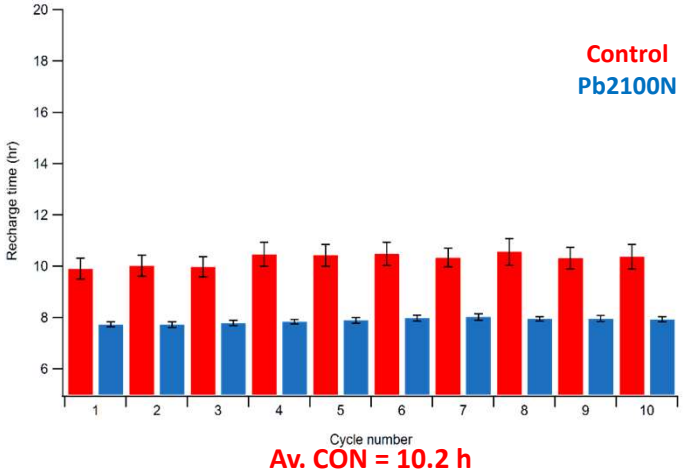
Av. CON = 32.3 h
Av. MR = 20.9 h

10 A/15.2 V



Av. CON = 15.6 h
Av. MR = 12.0 h

15 A/15.2V

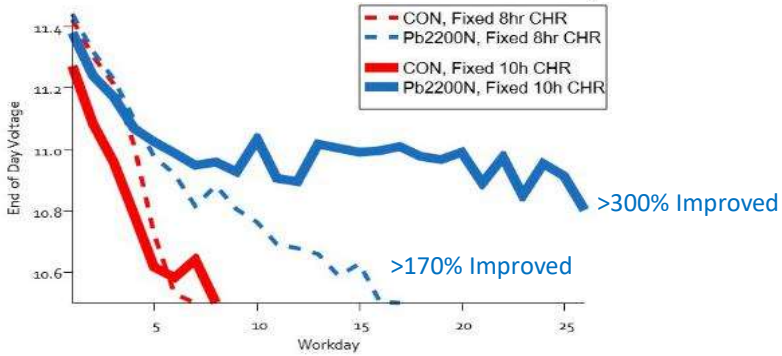


Av. CON = 10.2 h
Av. MR = 7.9 h

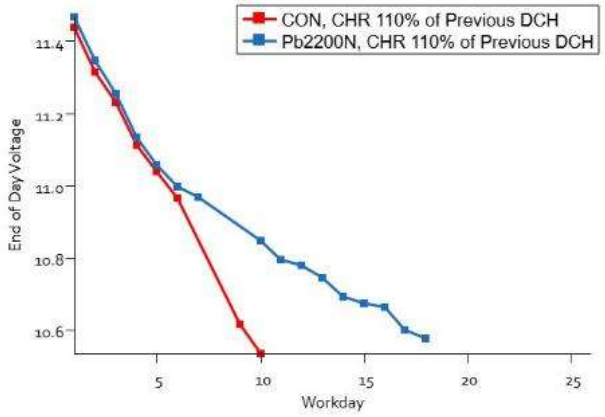
Deep Cycle Flooded: E-Rickshaw

Pb2100 and Pb2200 Series Products: Lab Simulation Testing

Recharged with 8hr and 10hr



Recharged with 110%Ah



- **Pb2100 and 2200 Series Products:**
  - Delay onset of daytime charge, enables more productive workdays
  - Convert more of Ah Input into useable capacity
  - Improve charge Efficiency
- **Control batteries experience capacity decay sooner across all recharge scenarios**

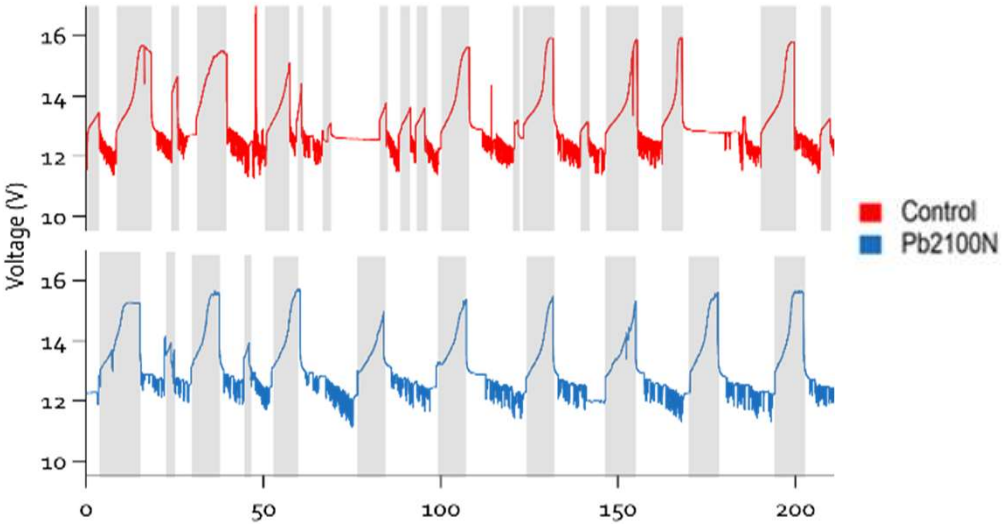
Protocol: "Workday" = 10 "trips" defined as 5x[30 min DCH + 10 min RST] resulting in 80% DOD over 10 h. At "Night", batteries are charge by one of 3 recharge scenarios: locked at 8 h, 10 h, or 110% Ah-return of previous DCH.

Deep Cycle Flooded: E-Rickshaw

Pb2100 and Pb2200 Series Products: Field Trial Data

Observations by Drivers & Owners using Pb2100N:

- Drivers using 4x80Ah Pb2100 batteries monitored for voltages, charging time and water loss
- Pb2100N batteries **DID NOT NEED A DAYTIME RECHARGE** (~11hr run before charging)
- Control batteries **needed a 2-3 hour recharge** (~5.25hr run before charging).
- Water consumption dramatically reduced (less maintenance)
- Drivers' earnings increased ~100 Rs/day due to lack of day time charge (+80km more)



Shaded Area Shows Charge Periods

BLACK DIAMOND STRUCTURES™

Pb2100 Series Tubular eRickshaw: Customer Testimonial

" Finally, we made a perfect e-rickshaw battery" – Customer

Customer Issue

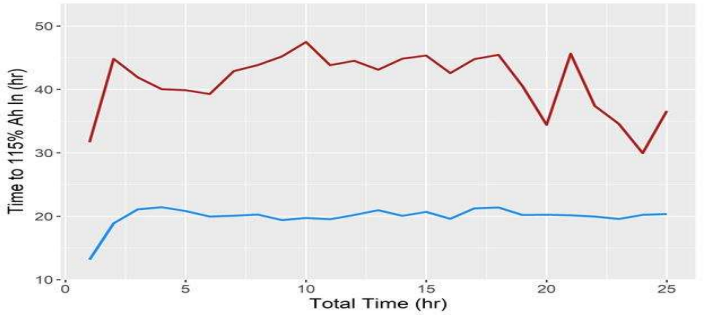
- Tubular e-rickshaw batteries produced had chronic sulphation due to poor charge acceptance
- Field failures resulted in a 20% Warranty Return Rate
- **Manufacturer had to stop producing e-rickshaw batteries**

Pb2100N as the Solution

- Customer is now using 34L of Pb2100N to improve charge acceptance and suppress sulfation, providing consistent performance and dramatically extended life
- Customer has launched a new line of Premium High Warranty e-rickshaw batteries into the market
- *Customer has also implemented Pb1100 Series for their Premium High Warranty Automotive – SLI Flooded batteries*

Lab Testing: 50% Reduction in Recharge Time

Recharge Time to 115% Ah Return



Control
Pb2100N

Field Results: Check @ 4 Months

Bend Test

After Bend Test – MR Plate Showing High Integrity

BLACK DIAMOND STRUCTURES™

Stationary: Solar

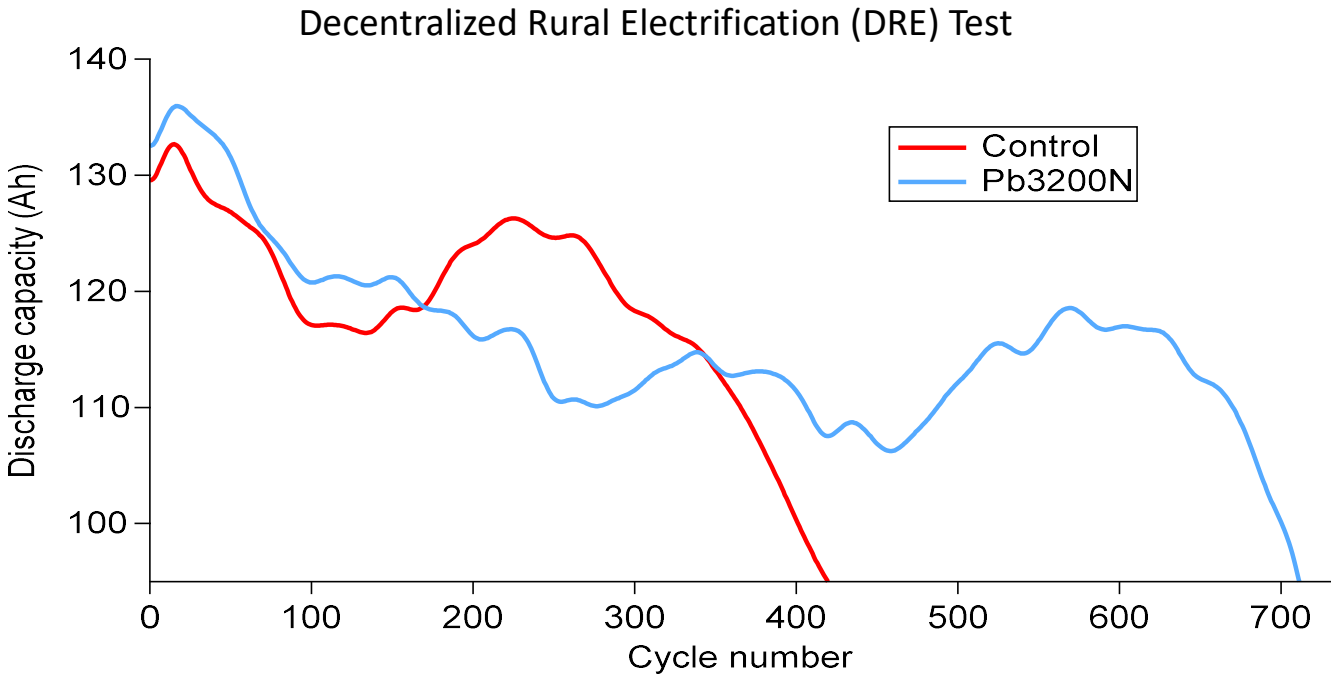
Pb3200 series product

Key Features:

- Reduced Deficit Charging
- Extended Life
- Faster Recharge Times
- Lower Water Consumption

Stationary: Solar

Pb3200 series product: DRE Life cycle test

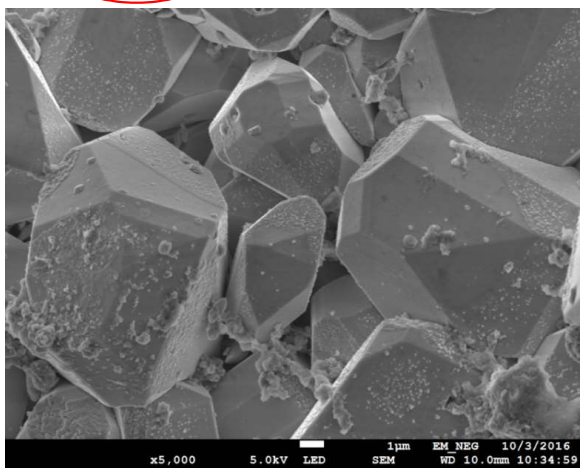


- Pb3200 series product extends capacity retention more than 70%
- Decentralized Rural Electrification simulation replicates real-world failures which Pb3200 series product delays (H_2O loss, deficit CHR, **sulfation**, AM loss)
- Pb3200 series product is taking in more Ah per charge <u>without increasing water loss</u>

Stationary: Solar

Pb3200 series product: DRE Life cycle test (Tear Down)

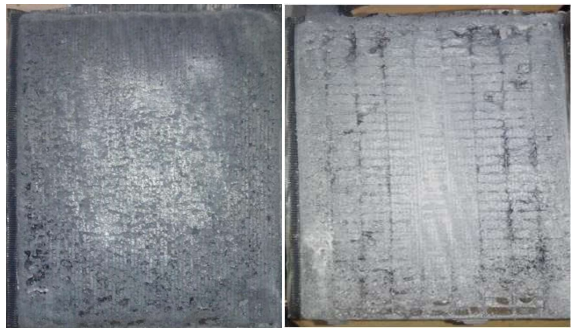
Control Negative

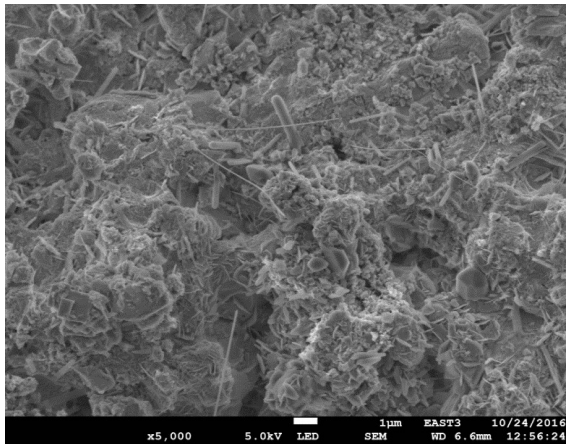


- Non-uniform material utilization
- Material soft and puffing/falling out
- **Heavily sulfated surface**
- **Large insulative Sulphate crystals**

- Shiny surface, plate still usable
- **No sulfate present on surface**
- **Smaller and uniformly sized crystals**

Pb3200N Negative





Packaging & How to use

- Material is shipped as a black pourable aqueous Solution which is added directly to the paste mixer
- MOLECULAR REBAR® products are formulated for ease of use and incorporation
- Sold in
  - 10L jugs for Samples
  - 55 gallon (208 L) Drums
  - 1,250L totes.
- A volume of pasting water is replaced with the MOLECULAR REBAR® liquid so total liquid volume remains the same

Summary

MOLECULAR REBAR® Enhances:

- **Performance of cyclic battery**
  - More consistent capacity through life
  - Improved Ah-in during charge
  - Increases time between charges
  - No daytime recharge needed
  - Reduced water consumption
- **Mechanical Durability**
- **CCA & Capacity Consistency Thru Life**
- **Charge Acceptance**
  - EN 50342-6 DCA
  - SAE J537 Charge Acceptance
  - Nissan 90% SOC Recharge
- **Cycle life as defined by:**
- **VDA Repetitive Over Discharge, Reserve Capacity Durability**
- **SAE J2185 & J240**
- **JIS D 5301 & 5302**
- **EN 50342-6 17.5% DoD, 50% DoD, MHT**
- **SBA S0101**
- **JIS C 8702**
- **eRickshaw Lab Simulations**
- **Decentralized Rural Electrification Model**
- **Many OEM and Other Customer Specifications**

Application		Product Series
Automotive	SLI – Conventional Flooded	Pb1100
	Start/Stop – Enhanced Flooded	Pb1200
	Advanced Auto - VRLA	Pb1300
	Motorcycle – VRLA	Pb1400
Motive Power	eRickshaw - Flooded (Tubular)	Pb2100
	eRickshaw - Flooded (Flat Plate)	Pb2200
	eVehicles - VRLA	Pb2300
	Forklift/ Lift Trucks – Flooded	Pb4100
Stationary	Inverter – Flooded	Pb3100
	Solar – Flooded	Pb3200
	Solar (PSOC)- VRLA	Pb3300
	Advanced Renewables & Utilities - VRLA	Pb3400
	Telecom VRLA	Pb3500

THANK YOU FOR YOUR ATTENTION ☺

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Special Thanks to Our Partners:

Eastman ®
....Let's grow together

JBI CORPORATION
Independent Battery Testing Laboratory

Eclipse ENERGY LABS

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