

**BLACK DIAMOND
STRUCTURES™**

Contemporary Applications of MOLECULAR REBAR®

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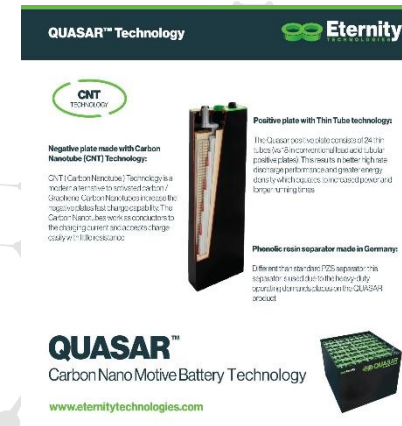


20TH ASIAN BATTERY
Conference and Exhibition

MOLECULAR REBAR® Technology Global Adoption

Our products are adopted in various countries around the world. We...

- ...work with >190 manufacturers, at various stages of development and/or commercialization
- ...completed >500 industrial scale trials since 2013
- ...provide in-depth technical support and product integration services
- ...support our customers with our global network, technically and commercially
- ...help our customers differentiate their brands. Selected examples:



ADVANCED WITH AMERICAN TECHNOLOGY

ADVANCED WITH AMERICAN TECHNOLOGY

BLACK DIAMOND STRUCTURES™

MOLECULAR REBAR® Technology Global Adoption

MOLECULAR REBAR® is adopted across a variety of global applications. Selected examples:

- OEM use **MOLECULAR REBAR®** for Automotive, Power Sports, and Deep Cycle batteries
- Batteries containing **MOLECULAR REBAR®** operates in London's Heathrow airport
- Several thousands of E-rickshaw drivers uses **MOLECULAR REBAR®** batteries every day
- **MOLECULAR REBAR®** batteries are available from automotive hardware stores in the USA
- **MOLECULAR REBAR®** provides market-leading performance to EFB batteries in Africa and Europe

Outside of our commercial pursuits, Black Diamond Structures is proud to push Lead-Acid Battery technology forward

Co-authoring a journal article proposing a novel, in situ, electrochemical analytical tool capable of determining the state of PAM decay without the need for invasive chemical analysis

- Lithium-Ion data analysis tools, applied to lead-acid chemistry for the 1st time
- Under review at the Journal of Power Sources, expected publication date before End of Year

Answered the U.S. Department of Energy's call to support AUX battery development

- **MOLECULAR REBAR**[®] and complementary materials to increase service life and reduce costs
- 12 V prototypes to be produced by East Penn Manufacturing under grant DE-FOA-0002893

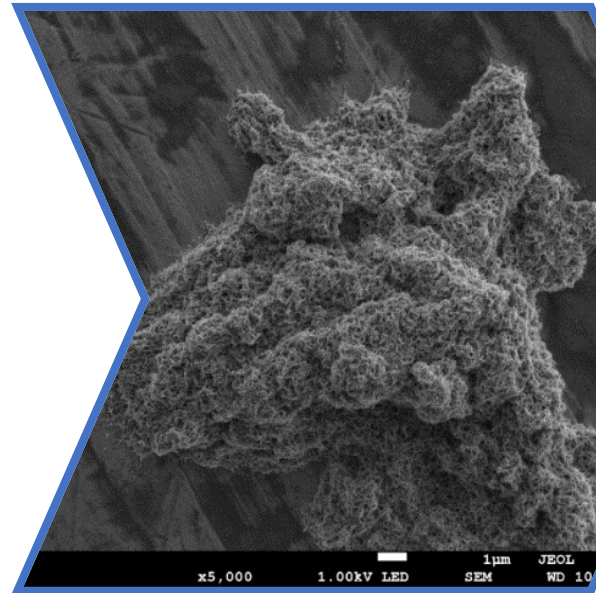
MOLECULAR REBAR® Technology Global Adoption

MOLECULAR REBAR® adoption is extremely cost effective, adding <1-3% to the total battery cost

- Cost offset by reduced warranty returns, higher warranty products, and direct cost reductions
- Products are optimized to deliver required performance at low loading levels (<0.1% wrt PbO)
- We have optimized the price over time to support expanding usage of **MOLECULAR REBAR®**

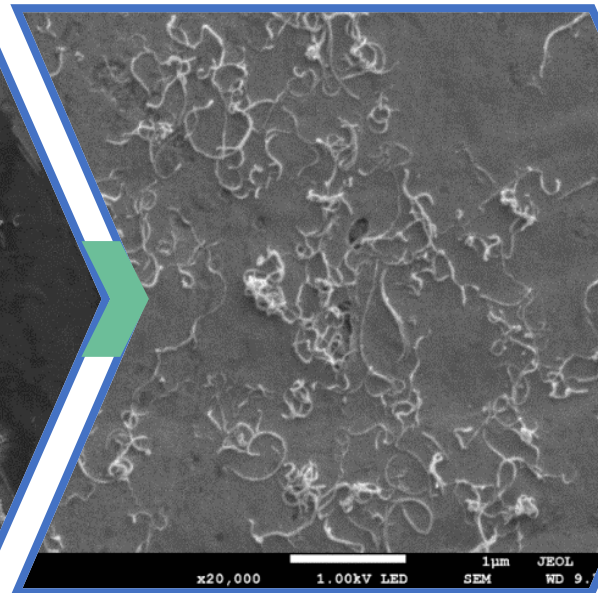
MOLECULAR REBAR[®] Technology

Raw Carbon Nanotubes



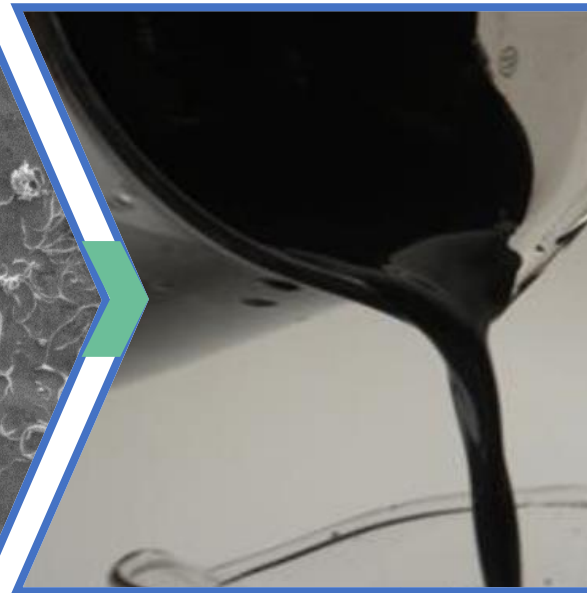
Aggregates of Dirty, Entangled CNT's
Hard to Implement, Poor Transfer of Properties

Detangling + Purification



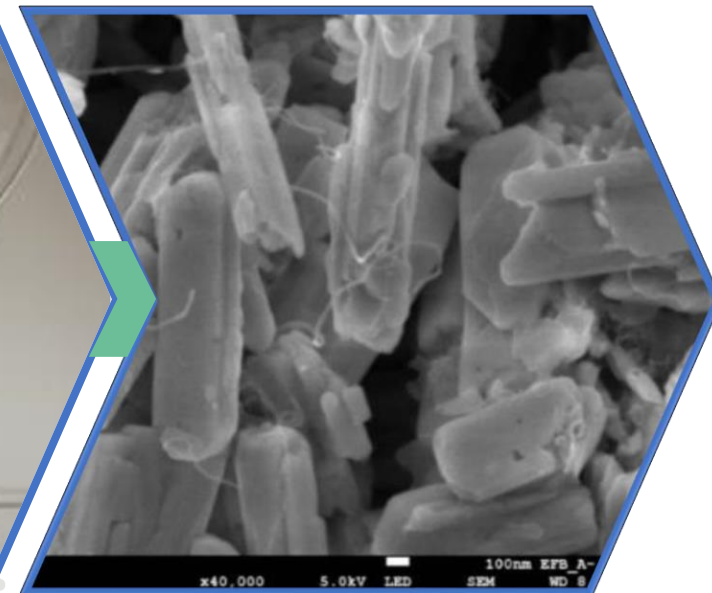
Clean, Detangled MOLECULAR REBAR[®]
Discrete, individual, patent-protected material

Formulation + Dispersion



Formulated MOLECULAR REBAR[®]
Optimized for System Compatibility, Ease of Use

Manufacturer Integration



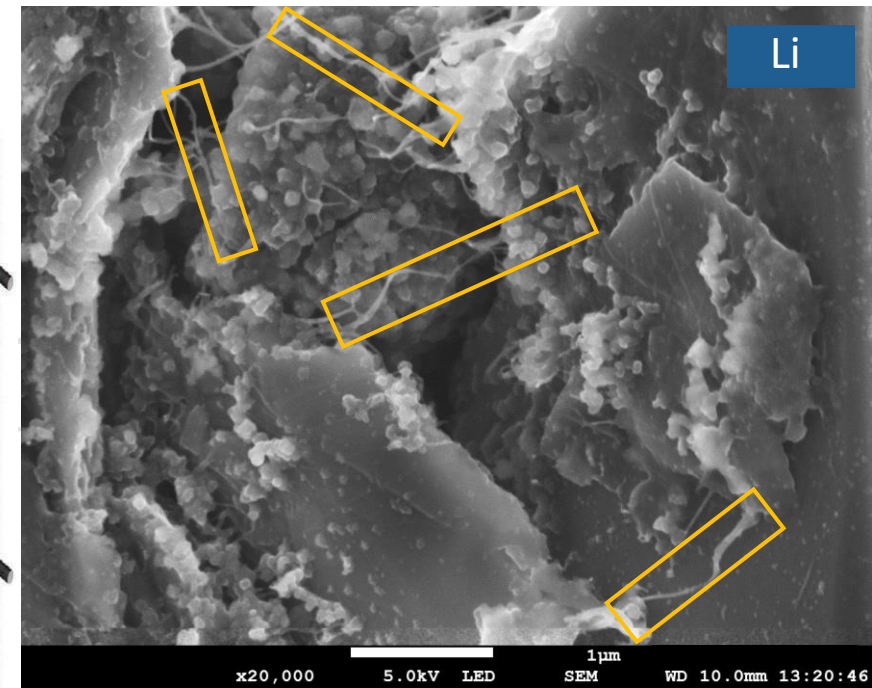
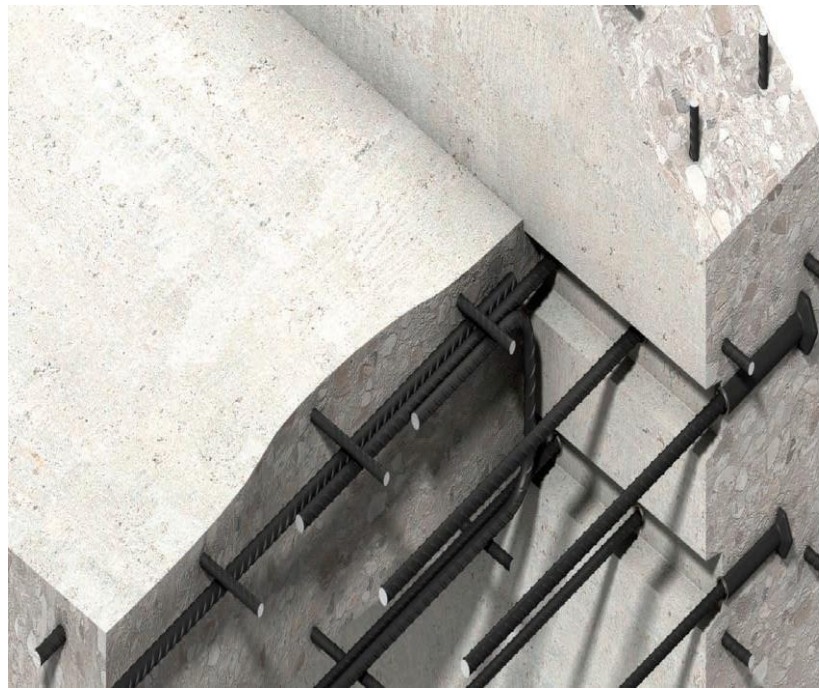
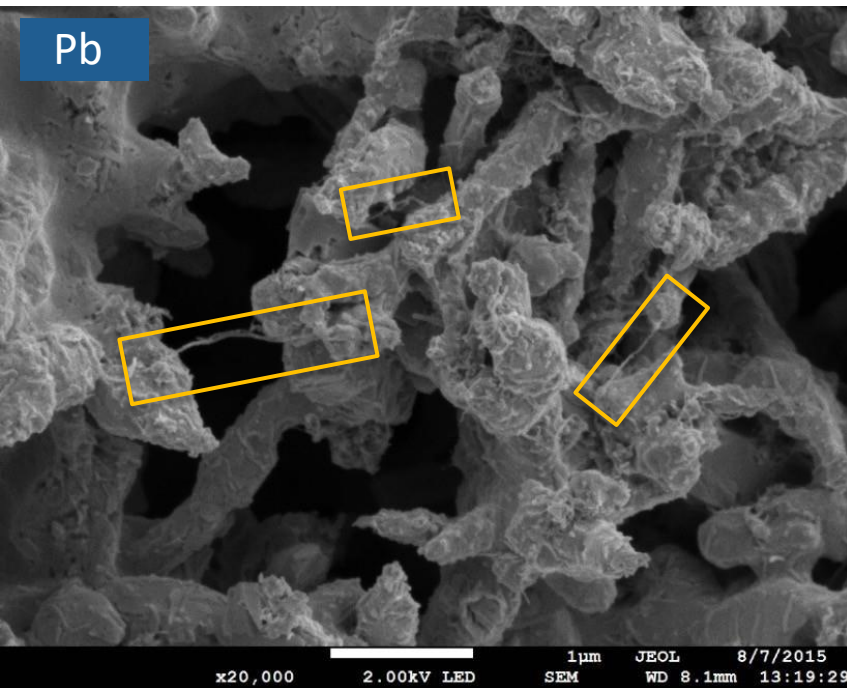
MOLECULAR REBAR[®] Enhanced Lead Paste
Provides high performance

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Augmenting Battery Material with MOLECULAR REBAR®

MOLECULAR REBAR® based products provide nanoscale, electroactive reinforcements which:

- Bring active material together, reinforcing electrode structure → **Enhanced robustness and durability**
- Alter interparticle morphology to enhance active material structure → **Improved electrical performance**
- Overcome structural and chemical limitations that induce failure → **Consistency of performance**



“Molecular Rebar Products Change the “DNA” of Your Battery”

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Innovation Across the Energy Storage Landscape

Lead-Acid Batteries

Charge Acceptance
>25%



Cycle Life
>25-300%



Enables Partial State
of Charge Operation



Improved Thermal
Operations Range



Energy Dense Lithium Anodes

Higher Energy Density
>20-45%



Longer Cycle Life
>20-100%



Increased Electrode
Strength >30-100%



NMC/LFP Lithium Cathodes

>15 min Fast Charging
Enablement (4C Rate)



Enhanced High-Power
Discharge Capability

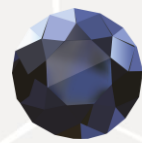


>5-10% Longer Cycle
Life



*Our tailor-made MOLECULAR REBAR® - based formulations
provide solutions for today's energy storage challenges*

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Advanced Automotive Batteries

Pb1200 Series

Our Proven Approach

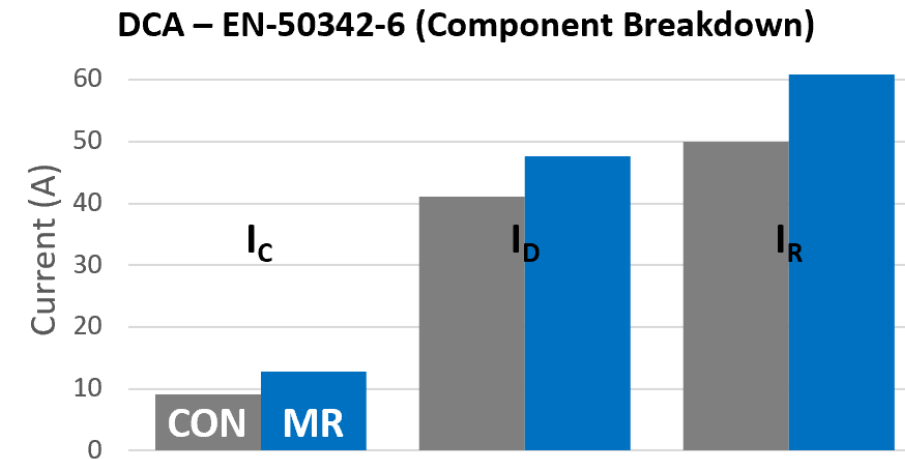
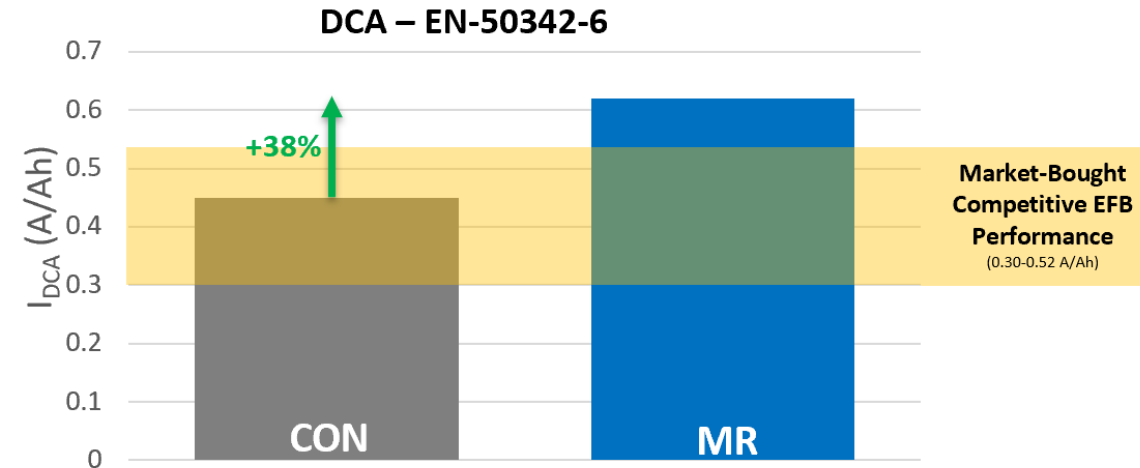
“Black Diamond Structures Does Not Prescribe to a One-Size-Fits-All method”

- Evaluate your needs and the target battery’s current design, performance, and challenges
- Recommend a **MOLECULAR REBAR®**-based product and loading
 - Derived from our >100y of global lead-acid battery experience
 - Tried and tested with >190 manufacturer engagements
- Application Development Engineers works with you to ensure optimal incorporation of **MOLECULAR REBAR®** into your paste
- Monitor your electrical validation via data analysis and reporting, or support your evaluation with our Bitrode circuits

Ex: Willard Batteries Achieves Market-Leading DCA



- Evaluation of Needs:** AutoX / Willard Batteries (S. Africa) sought improved DCA with no CCA / H₂O loss detriment
- Product Recommendation:** After thorough analysis, we believed NAM could be rebalanced with 60% less carbon and a customized loading of MOLECULAR REBAR[®]
- Implementation:** Our Application Manager worked with AutoX / Willard's team to ensure optimal integration
- Performance Analysis:** 38% improvement in Dynamic Charge Acceptance (3rd party lab)



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Ex: Balance Achieved; No CCA / H₂O Loss Detriment



Per, Manufacturer's request, our recommendation had no detrimental effect on:

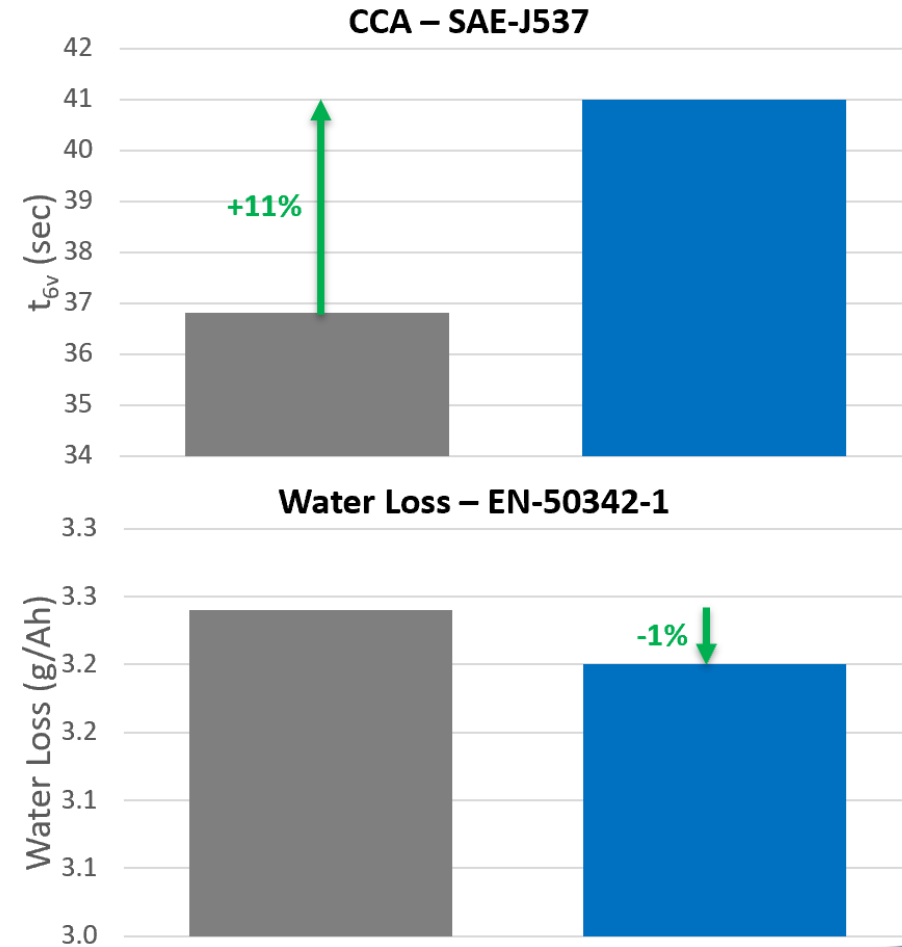
CCA (SAE-J537)

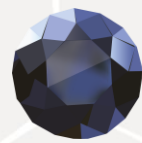
- 11% increase in t_{6V}
- Improved voltage (V_{30s})

Water Consumption (EN 50342-1)

- Maintained W3 rating (-1.2% reduction)

Results duplicated in additional models, inc. L1





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e-Vehicles Auxiliary Batteries

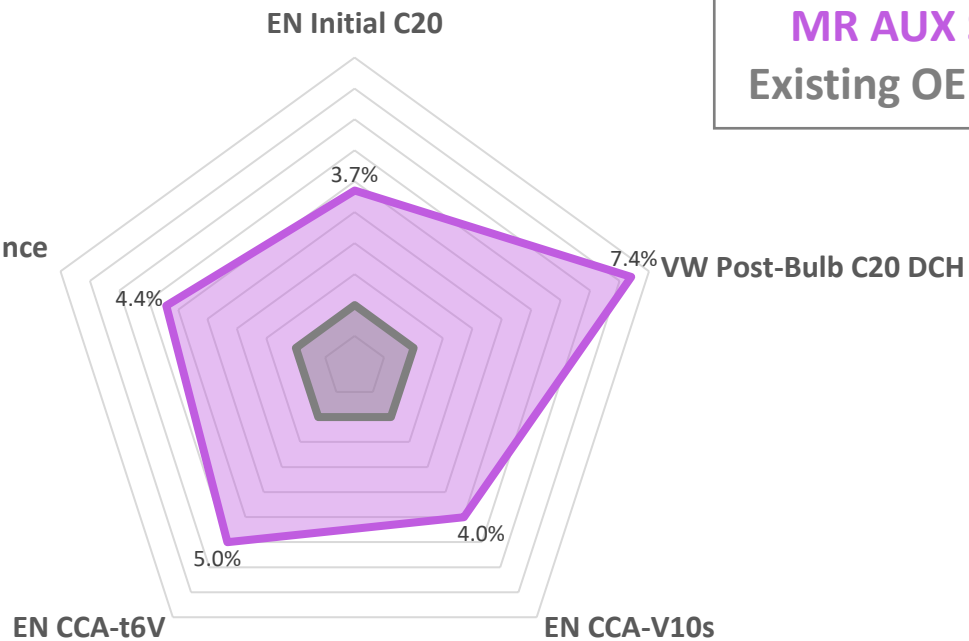
Pb1300 Series

+ Co-developed Addenda Expander

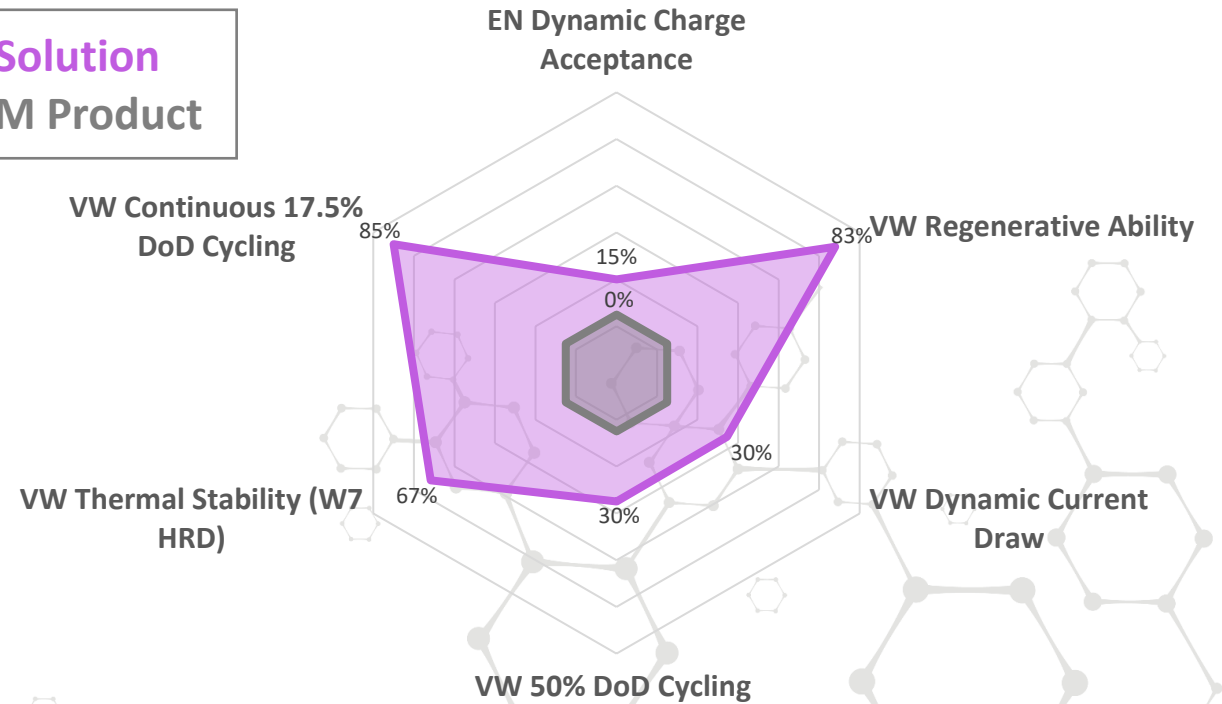
Our AUX Solution Provides Broad Benefits

We validated our **AUX Solution** (MOLECULAR REBAR[®] and a jointly-developed Addenda expander package) in a European, OEM-approved, L1 (49 Ah, 540 A) sold for start/stop and AUX applications

Initial Characterization Improvements



Charge Acceptance + Life Improvements



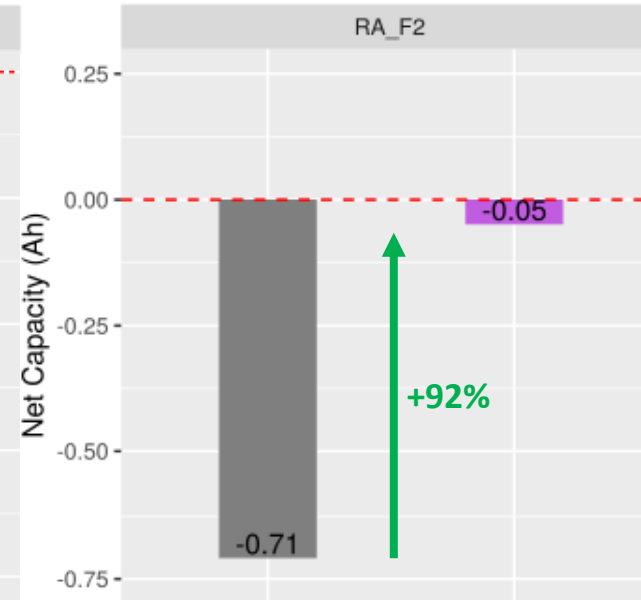
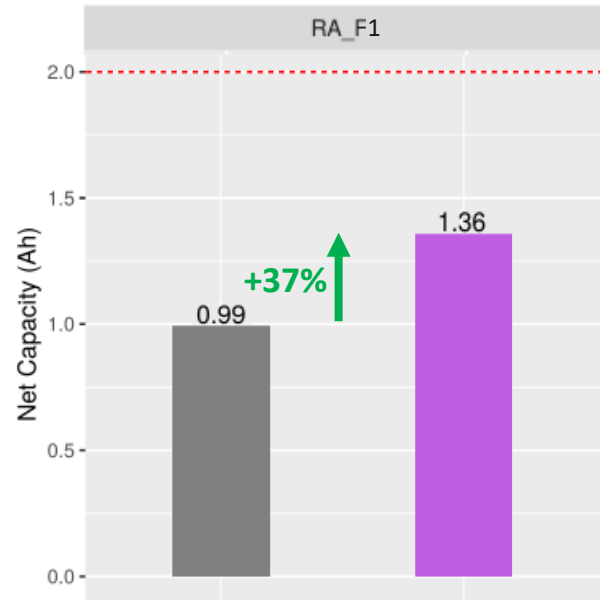
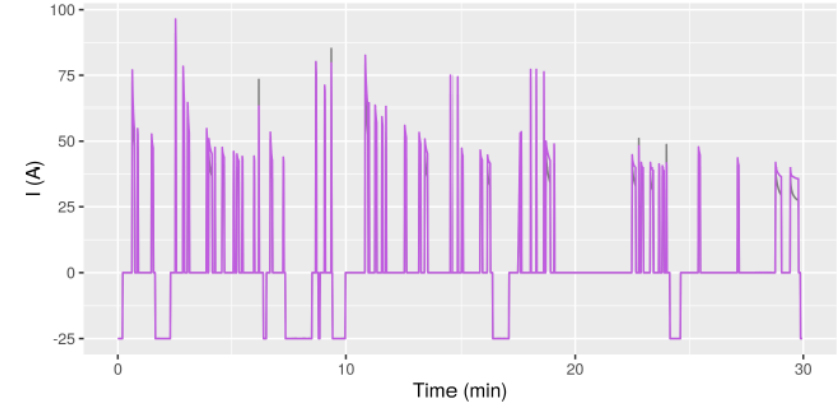
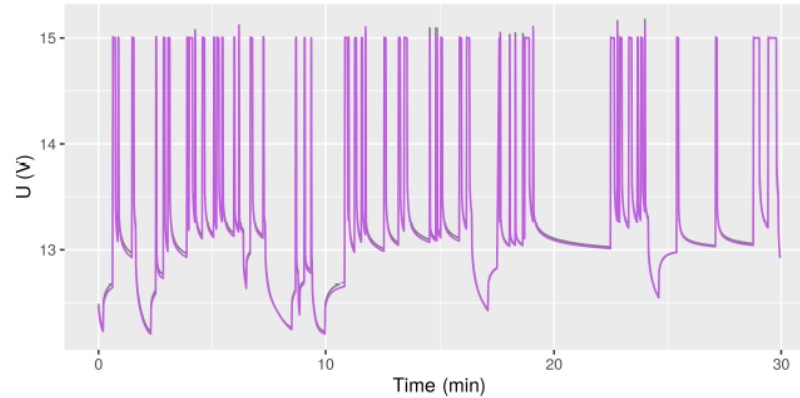
Improved VW Regenerative Ability with MR

- In drive models, the **AUX Solution** provides gains where few other packages can

- VW 75073:2020-7.10
- Protocol overview, top

- The **AUX Solution** offers performance more typically observed in costly VRLA

- Benefits seen across F1-F3:
 - F1 = 37% improvement
 - F2 = 92% improvement
 - F3 = 122% improvement



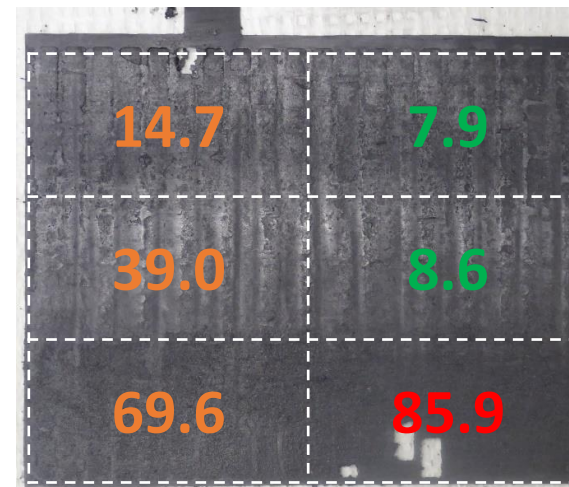
“Results were unparalleled in manufacturer’s experience”

VW 17.5% Failure Mode Mitigated by AUX Solution

- This **AUX Solution** reduces sulfation build-up by 40%
 - Lower sulfation, despite 85% longer life
 - Upper four plate sections “like new” (fresh Pb)
- Improved uniformity of plate utilization
 - Upper four plate sections had excellent uniformity
 - No left/right non-homogeneity, as with Control
- Stratification-based failure delayed
 - 20% lower SG differential, despite 85% longer life
 - Contributed to keeping the plate healthier, longer
 - May remove the need for passive mixing elements

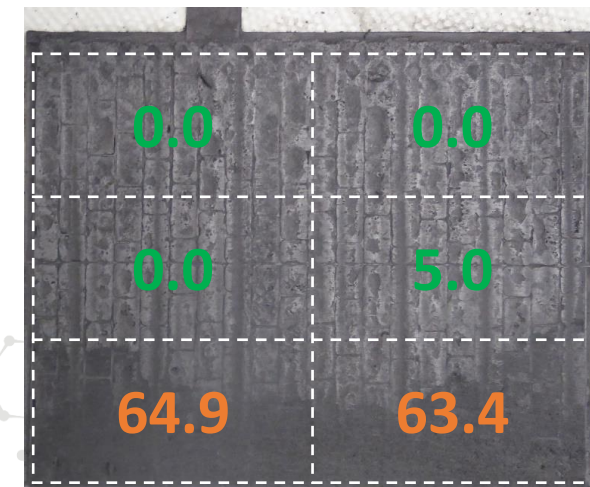
Existing OEM Design

Average PbSO_4 = 37.7%; Total Cycles = 390

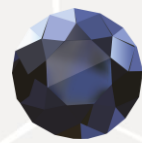


AUX Solution

Average PbSO_4 = 22.2%; Total Cycles = 726



Numbers indicate PbSO_4 Composition by XRD



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e-Rickshaw batteries

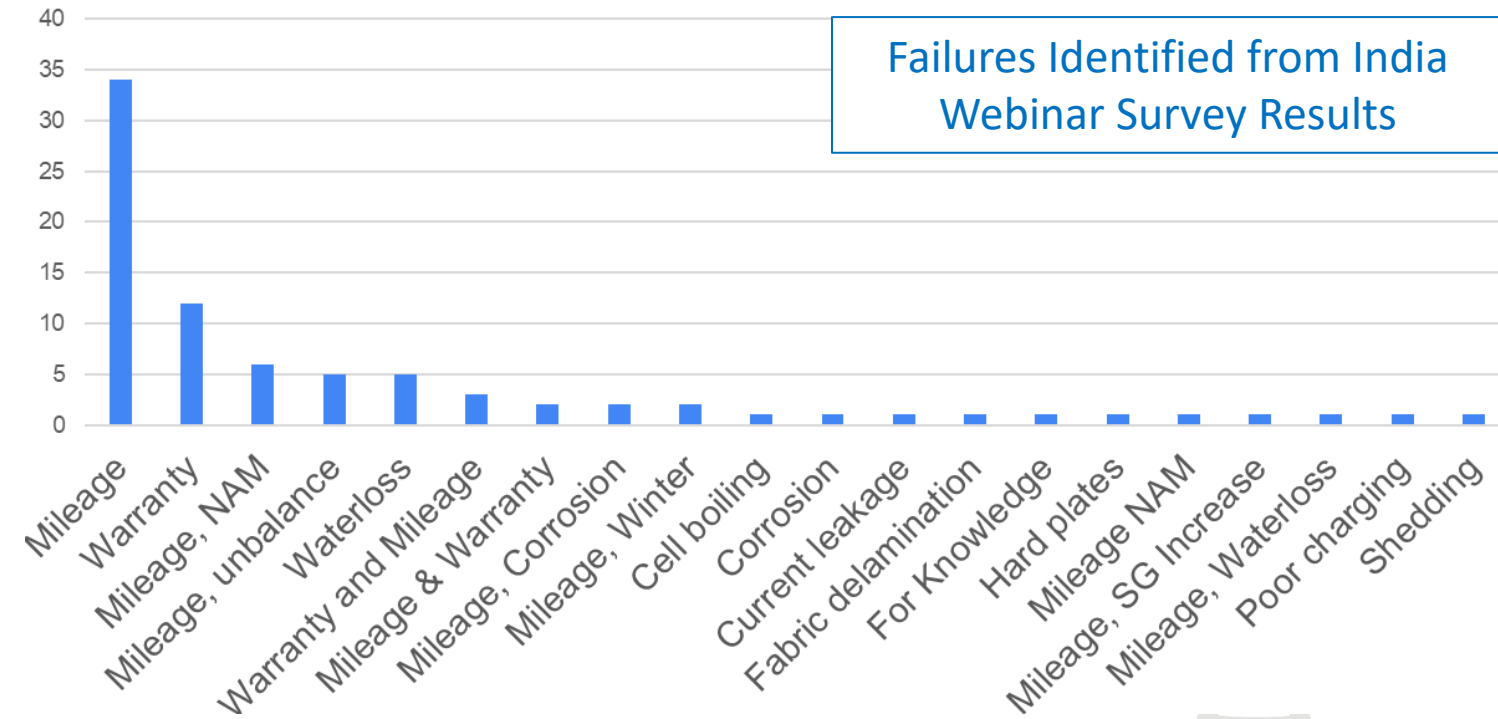
Pb2100 Series

Evolution of High Warranty e-Rickshaw Batteries



Problems in e-Rickshaw batteries:

- Batteries are not fully charged; need >10 hrs to reach 100% SoC with a market-bought charger
- Battery operates in partial state of charge (PSoC) during rickshaw work hours
- Battery not recharged immediately; the rest/idle time allows hard sulphate to grow



Mileage loss and eventually high warranty returns are the outcomes of underlying failure modes such as negative plate/active material degradation and positive plate corrosion

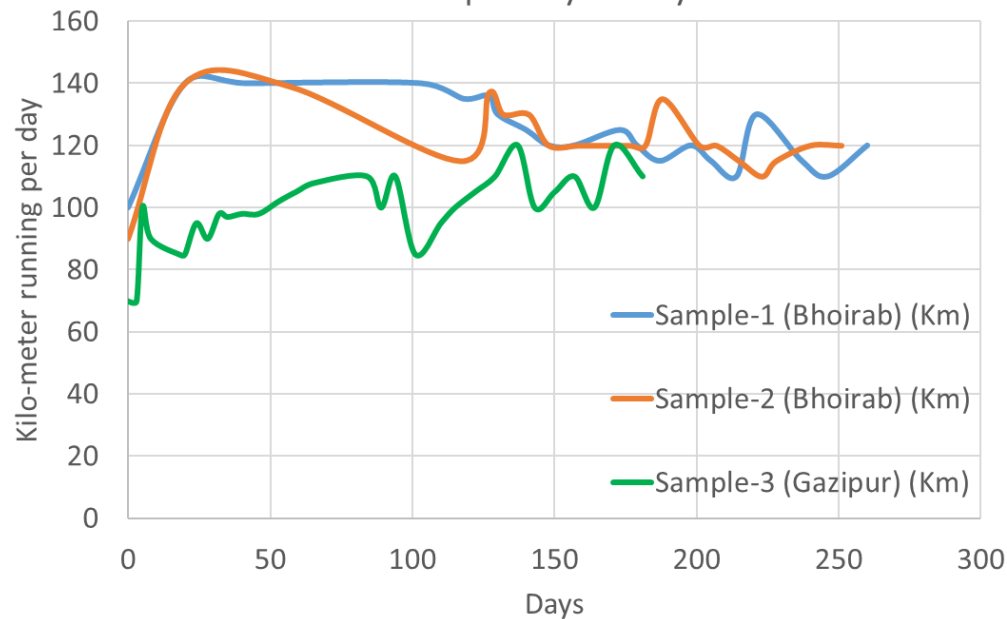
Evolution of High Warranty e-Rickshaw Batteries



MOLECULAR REBAR® when added in negative plates...

- ...can increase the field life of the E-rickshaw batteries dramatically
- ...enables quick and efficient charging that keeps sulphation and water loss at minimum

Ex. 6-month warranty battery running >9-months with stable capacity (i.e., workday duration)



km/day measured by data logger in 3 different rickshaws in 2 cities.

“Customers in Asia successfully developed a 24-month warranty E-rickshaw batteries with the help of MOLECULAR REBAR®”

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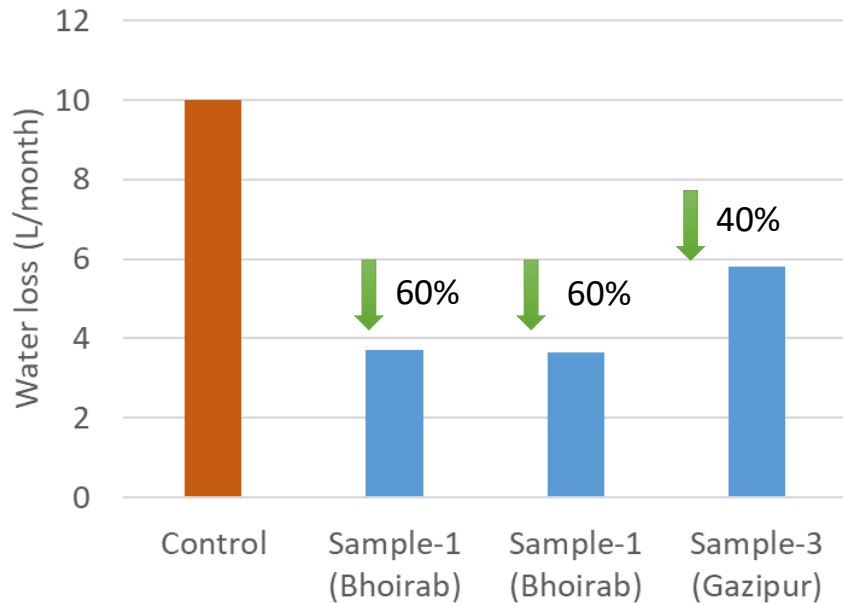
Evolution of High Warranty e-Rickshaw Batteries



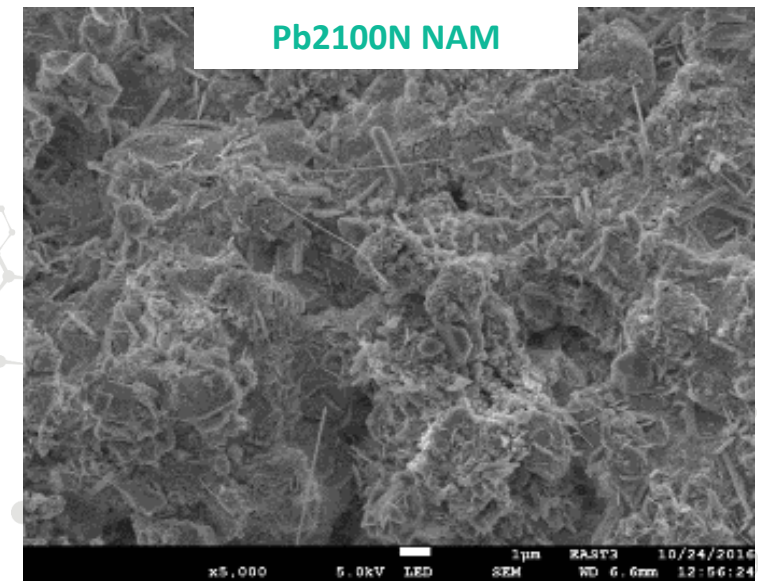
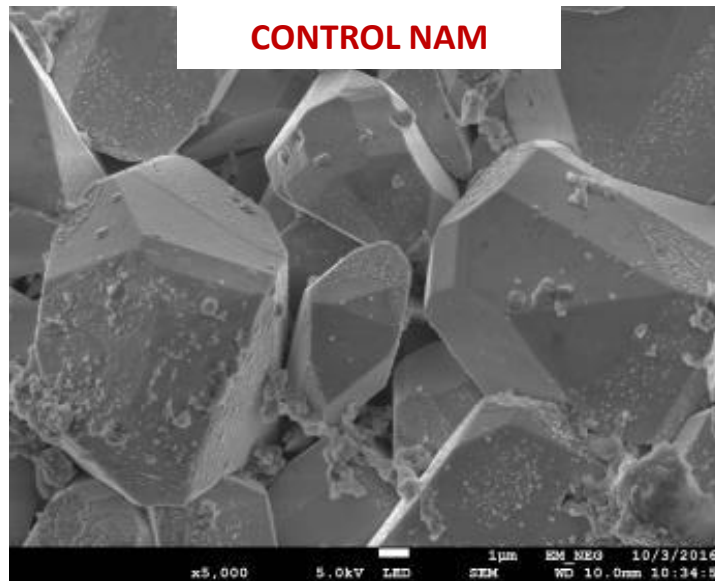
MOLECULAR REBAR® when added in negative plates...

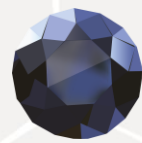
- ...can increase the field life of the E-rickshaw batteries dramatically
- ...enables quick and efficient charging that keeps sulphation and water loss at minimum

Ex. 6-month warranty battery running >9-months with stable capacity (i.e., workday duration)



Water loss measured by service agent over 9 months





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e-Bike batteries

Pb2300N Series

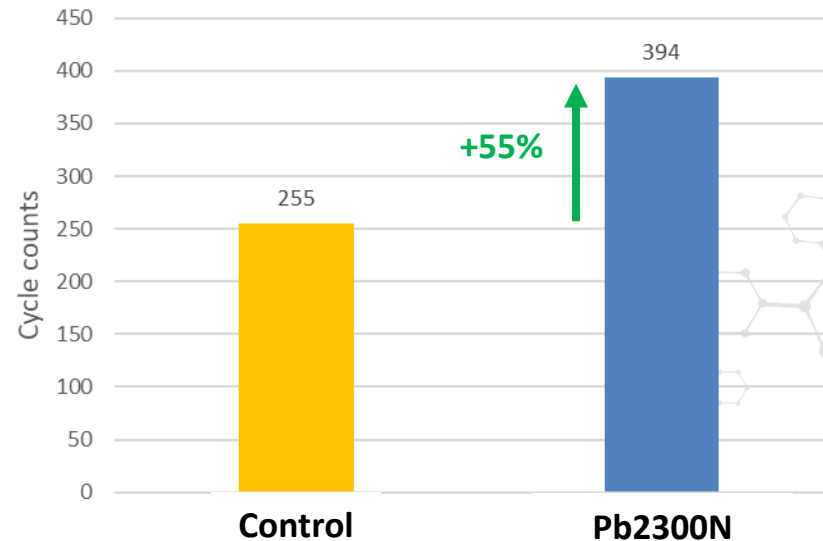
Step Up Your E-bike Lead-Acid Battery



“Produce Lead-acid batteries that are competitive through low price, high cycle life and high-power density”

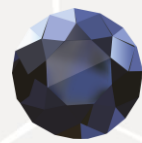
MOLECULAR REBAR® when added in negative plates...

- ...enables faster recharging
- ...reduces sulfation and enhances charge-discharge efficiency
- ...improves life cycle 30-50% from the baseline
- ...enables weight reduction, by offsetting costly overbuilding



100% DoD Cycling

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Solar batteries

World's Leading Solar Designs Use MR Products



- Black Diamond Structures is pleased to support Eternity technologies with the material they need to build next generation Solar products
- Following our Collaborative Approach, we provided nanomaterial implementation support, materials analysis reports, and electrical testing
- In advanced designs, MOLECULAR REBAR®:
 - Increases fast charge capability
 - Reinforces active materials
 - Increases PSoC capability
 - Provides consistent capacity return

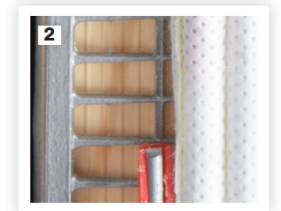
QUASAR™ Thin Tube Lead Carbon Technology



1. Positive plate

Positive plate with Thin Tube technology...

The QUASAR positive plate consists of 24 thin tubes (vs 18 in conventional lead acid tubular positive plates). This results in better high rate discharge performance and greater energy density which equates to increased power and longer running times



2. Negative plate

Negative plate made with Carbon Nanotube (CNT) Technology...

CNT (Carbon Nanotube) Technology is a modern alternative to activated carbon / Graphene. Carbon Nanotubes increase the negative plates fast charge capability. The Carbon Nanotubes work as conductors to the charging current and accepts charge easily with little resistance

Enhanced consistency of performance

Improved charge acceptance & discharge performance

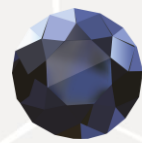
Increased cycle life

Partial State of Charge Operations (PSOC)

Improved Thermal Operational Ranges



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THANK YOU !



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Improved CCA and Life cycle in 2-Wheeler VRLA



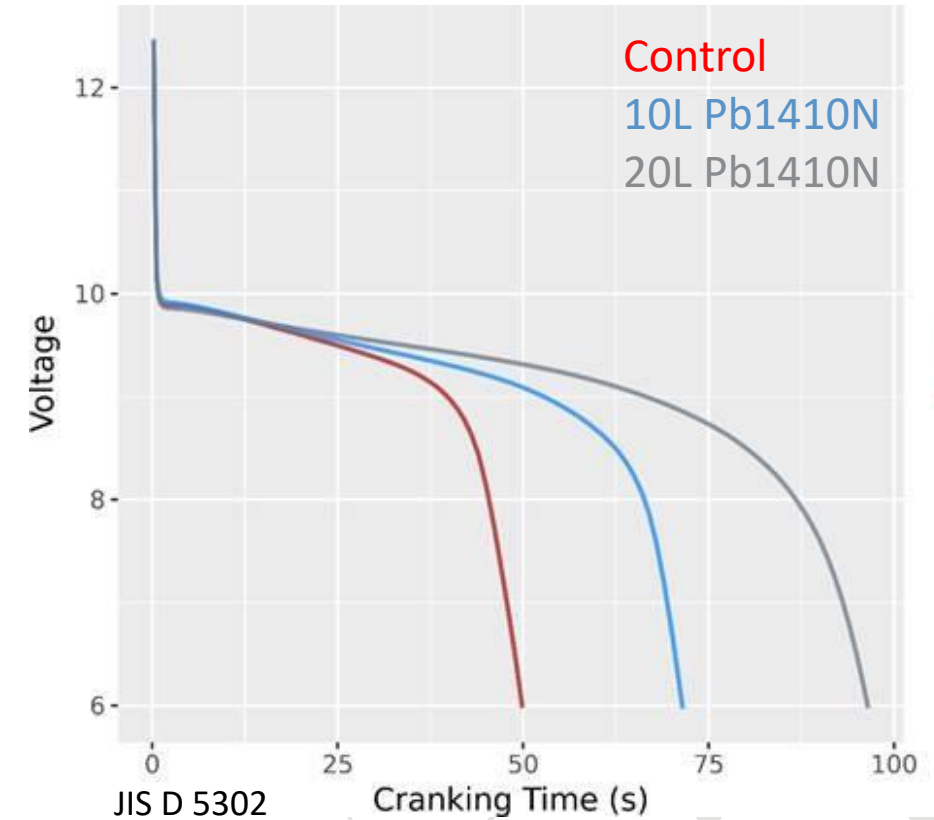
Products:

- Pb1410N & Pb1400P

Key Features:

- CCA enhanced and maintained thru cycling
- 50% increase with 10L of Pb1410N
- 100% increase with 20L of Pb1410N

MOLECULAR REBAR® provides higher CCA



**BLACK DIAMOND
STRUCTURES™**

Improved CCA and Life cycle in 2-Wheeler VRLA



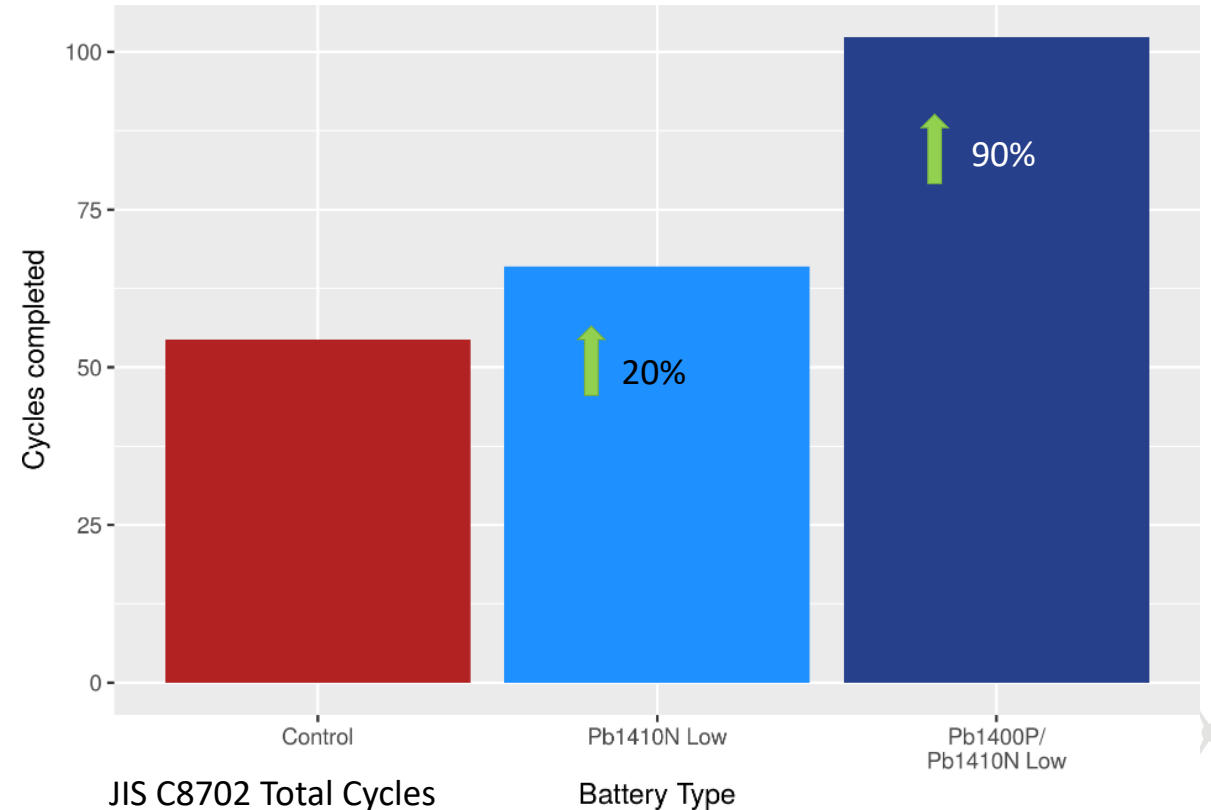
Products:

- Pb1410N & Pb1400P

Key Features:

- CCA enhanced and maintained thru cycling
- Better charge acceptance
- Better capacity retention
- Pb1400P with Pb1410N further enhances
- Life cycle is significantly increased
 - 50% DoD OEM Test
 - JIS C8702
 - JIS D5302 Light Load Test

MOLECULAR REBAR® provides higher cycle life



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Introducing PbLite

Key Features:

- █ Increases production output and consistency
- █ A process, not performance, additive
- █ Adoption can pay for itself

PbLite provides:

- █ Production value, felt within MINUTES OF PASTING
 - █ Fewer rejected plates, less waste, more batteries per batch
- █ Commercial value, from higher quality, more consistent products
 - █ Enhanced battery-to-battery uniformity
 - █ Improved customer satisfaction
- █ Long-term value, from decreased warranty returns in the field, extrapolated from measurable performance improvements
 - █ 10-20% improved charge recovery
 - █ Consistency of capacity and CCA
 - █ Increased plate strength
 - █ *And more...*



2.5 L / 1000 kg PbO

A product to make your batteries more consistent and provide you with meaningful manufacturing value, fast

**BLACK DIAMOND
STRUCTURES™**