

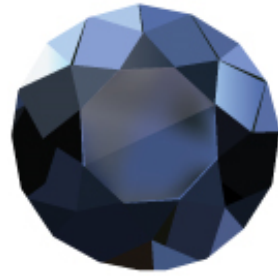
BLACK DIAMOND
STRUCTURES™

MOLECULAR REBAR®:
Discrete Carbon Nanotube Additives
Heavy Truck Performance & Cost Reduction Opportunities

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Vice President, Research & Development

BLACK DIAMOND
STRUCTURES™

Who We Are



BLACK DIAMOND STRUCTURES™

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**

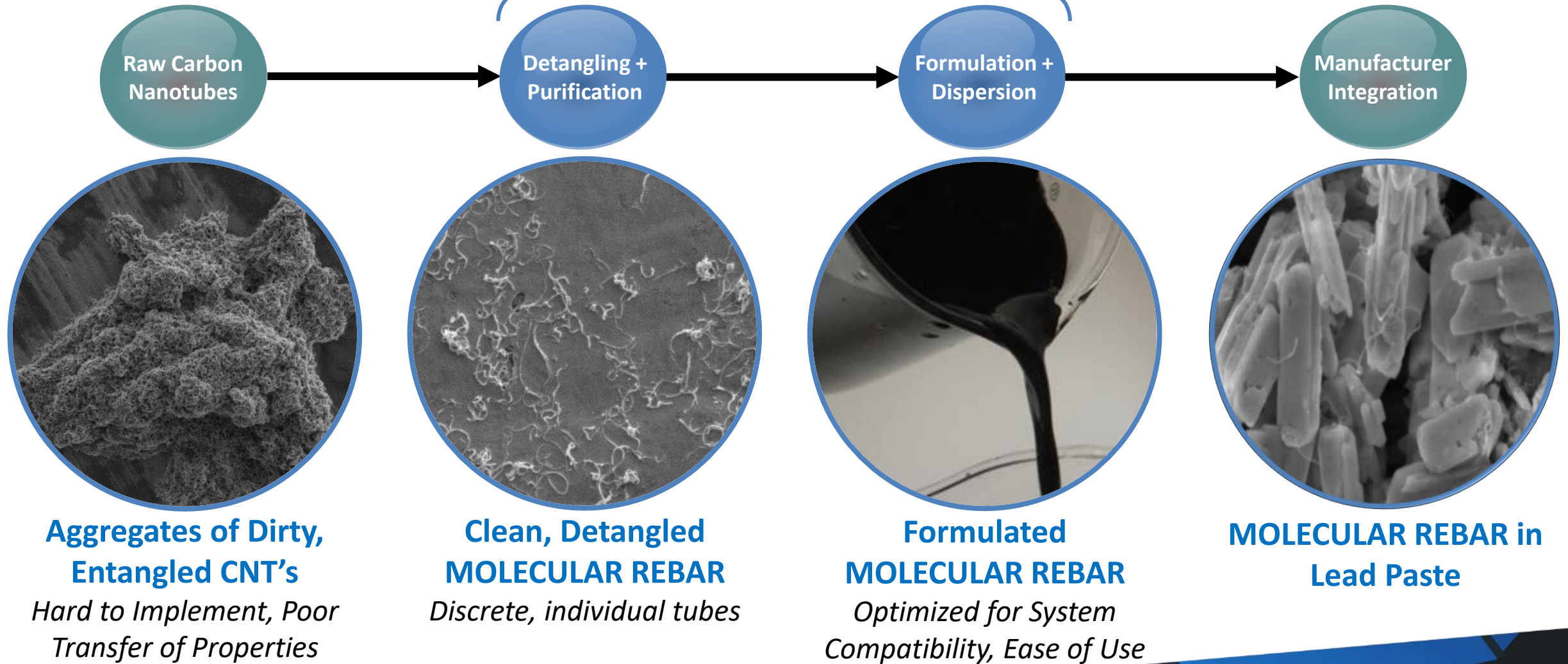
Our Partners



BLACK DIAMOND
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MOLECULAR REBAR Technology

Key Competitive Advantage



MOLECULAR REBAR Benefits For Your Battery

Enhances Consistency of Performance

- Improves Charge Acceptance >25%*
- Increases Cycle Life 25-300%*
- Enables Partial State of Charge Operations
- Reduces Irreversible Sulfation & Plate Growth
- Enhanced Plate Durability
- Improves Thermal Operational Ranges
- Provides opportunities to reduce active material / plates

Working with >150 battery manufacturers Globally
with sales into Automotive, Motive and Stationary



*Dependent on battery and test protocol

About Us: Products

	Application	NAM Product	PAM Product
Automotive	SLI & Heavy Truck – Conventional Flooded	Pb1100N	Pb1100P
	Start/Stop – Enhanced Flooded	Pb1200N	Pb1200P
	Advanced Auto - VRLA	Pb1300Nx	Pb1300Px
	Motorcycle – VRLA	Pb1400N	Pb1400P
Motive Power	eVehicles - Flooded (Tubular)	Pb2100N	
	eVehicles - Flooded (Flat Plate)	Pb2200N	
	eVehicles - VRLA	Pb2300N	Pb2300P
	Lift Trucks – Flooded	Pb4100Nx	Pb4100Px
Stationary	Inverter - Flooded	Pb3100N	
	Solar - Flooded	Pb3200N	
	Solar (PSOC)- VRLA	Pb3300N	Pb3300P
	Advanced Renewables & Utilities - VRLA	Pb3400Nx	Pb3400Px
	Telecom - VRLA	Pb3500Nx	Pb3500Px

Commercial Product / Active Validation

AUTOMOTIVE

SLI HEAVY TRUCK

- **Key Features:**

- Used in Negative and/or Positive Electrodes
- No change to existing paste process or recipe
- Improved Consistency in Capacity + CCA Throughout Life
- Extended Cycle Life / Reduced Warranty Failures
- Increased Electrical Performance
- Enhanced Plate Strength / Durability
- Meet challenging OEM specifications

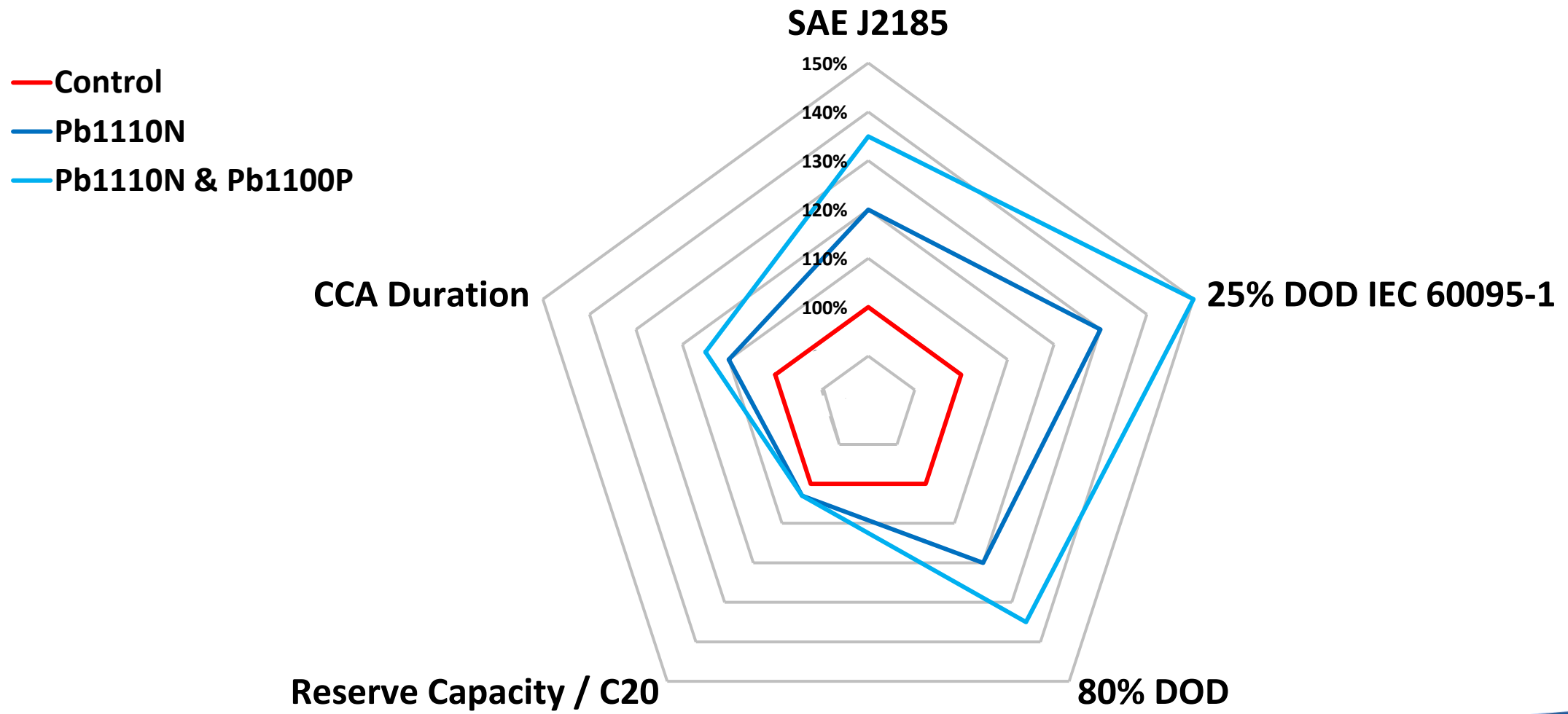
Reduce Cost by Removing Plates/Active Material While Maintaining Performance





Pb1100 Series: HEAVY TRUCK

Actual Customer Production-line Produced 12V testing examples

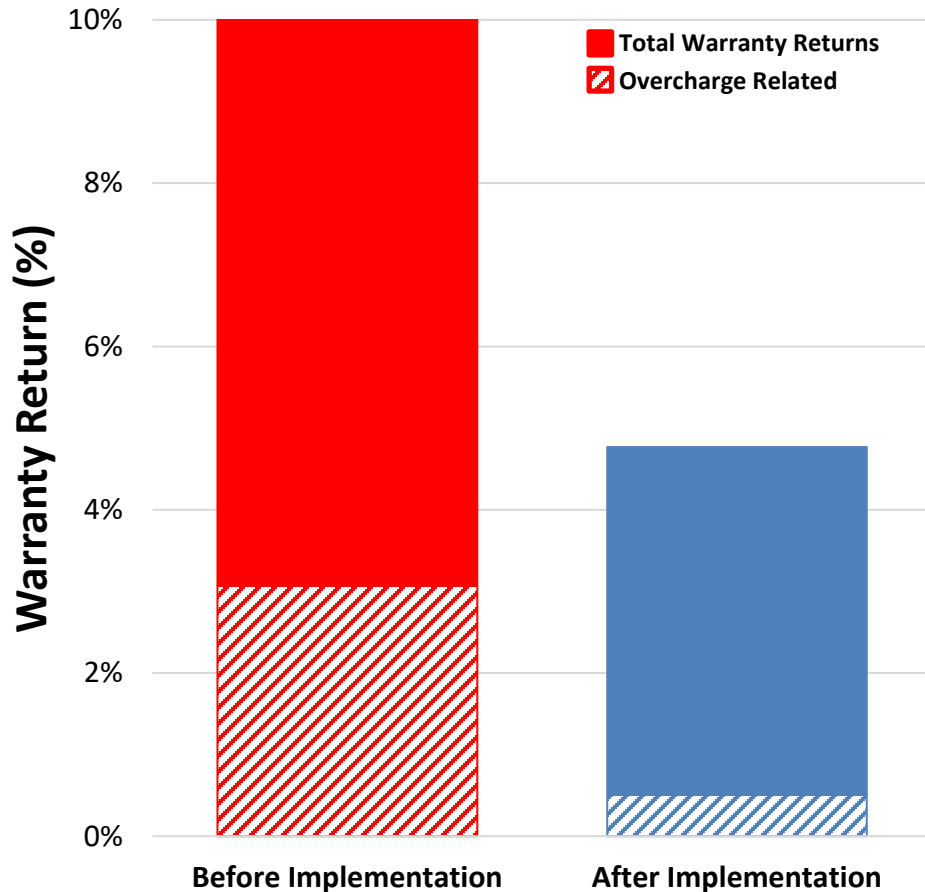


Customer Testimonial #1: Flooded Heavy Duty Truck Batteries



Pb1100 Series Products: Warranty Claim Reduction

Pb1110N reduced warranty claims by >50% with dramatic reduction in Overcharge/Water-Loss-based failures



170/180Ah 4D Size, 12 Months of field data, >20,000 batteries tracked

- **Customer Background**
 - Need fix for problematic ~10% warranty rate in Heavy Duty Truck
 - Located in “super hot” climate
- **Laboratory Testing**
 - 25% Increase in SAE J2185 w/ 10L Pb1110N (19 vs. 15wks)
 - Higher sustained HRD and improved active material integrity
- **Field Testing (12 Months data, >20,000 batteries)**
 - < 5% Warranty Return Rate, reduced by ~50%
 - Over-charge/water-loss field returns reduced by 70%
- **Result**
 - Implemented in **all** Heavy Truck product lines/sizes
 - Implemented in large percentage of Light SLI products
 - Customer seeing consistent results

Cost Reduction Opportunities With Molecular Rebar

Customers using Molecular Rebar-Based Products are innovating independently...

With proven results in improved performance and reduced warranty cost, customers have started leveraging Molecular Rebar to also remove active material and plates while maintaining performance

- Many historically added 10-15% excess lead via extra plates or active material to meet performance requirements

Customers have successfully reduced plates by integrating Molecular Rebar and achieved their necessary performance while reducing their net cost 2-10%

Cost Reduction Opportunities With Molecular Rebar

- **Heavy Truck SLI saw first commercial adoption of plate reduction; Light SLI and Deep Cycle have followed**
 - Generally, 1 NEG plate is removed but 1 NEG and 1 POS has also been proven possible
 - Various cost-benefit scenarios understood with plates to remove vs. MR added in NAM only or NAM and PAM
 - Minimal design changes necessary (acid sg, separator thickness, formation Ah input, etc.)
 - Reduced formation energy/time has been added benefit
- **Heavy Truck SLI**
 - Ability to maintain SAE J2185
 - HRD sustained (**ex. Customer Testimonial #2**)
 - Ability to maintain IEC 60095-1 (2006)
 - Capacity retention (**ex. Customer Testimonial #3**)
- **Light SLI**
 - Ability to maintain SAE J240 and SAE J2801 performance
 - HRD sustained

- **2-10% Net Cost Reductions being realized by manufacturers today using MR**
- **Additional benefits shared with BDS**
 - Increased production volume
 - Faster formation (less Pb/battery)
 - Opened new price sensitive markets
 - Less Pb market price volatility impact

Customer Testimonial #2: Flooded Heavy Duty Truck Batteries

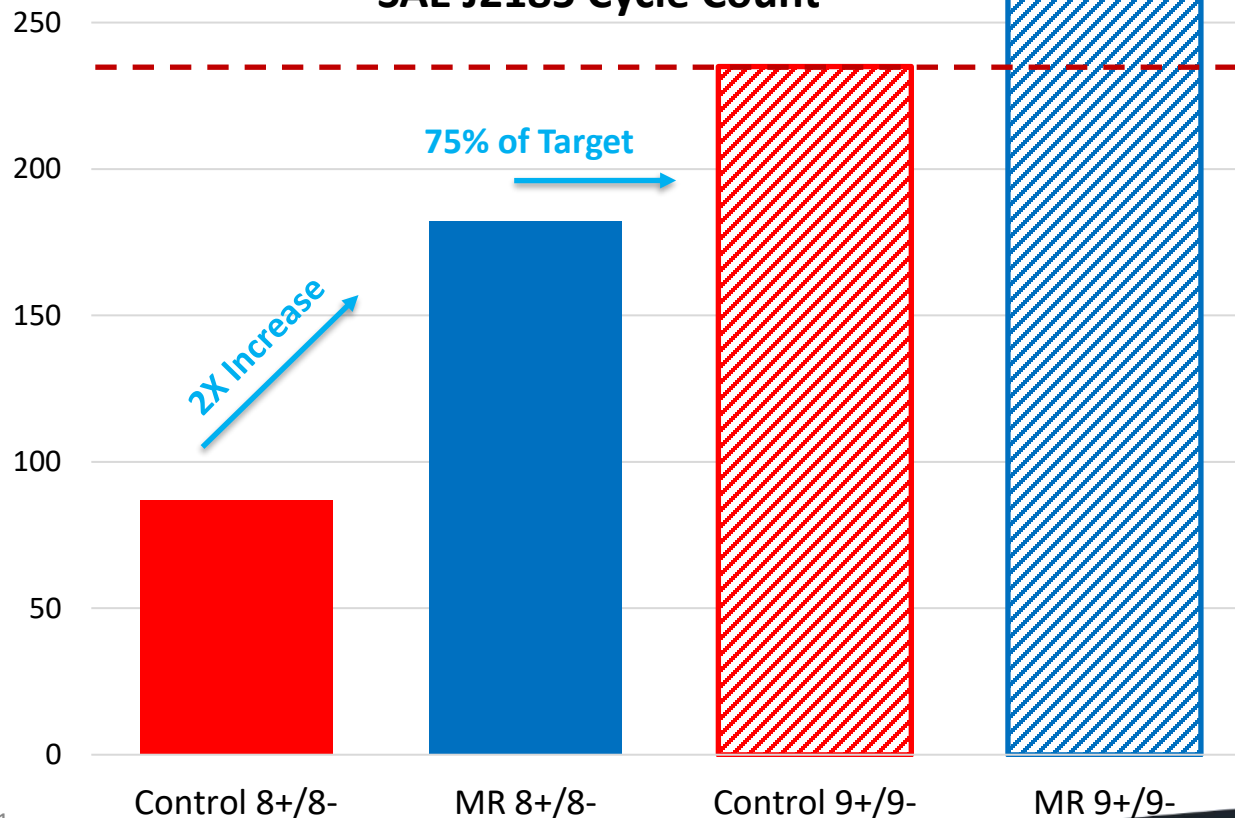


Pb1100 Series Products: Reduced Plate Count, Maintained J2185 Performance

- **Pb1100N was evaluated for After-Market Product Lines (110Ah G31 Size)**

- Pb1100N achieved ~10% increase in J2185, PAM corrosion was design limited; found higher sustained HRD and Capacity
- Control batteries were overbuilt with additional plates to meet J2185 targets, CCA/C₂₀ by 10%-15%
- Customer decided to drop from 9+/9- plate configuration to 8+/8- to see if Pb1100 could maintain performance

SAE J2185 Cycle Count



- **MR 8+/8- cycled 2X longer than Control 8+/8-**
 - 75% of the Target: Control 9+/9-
- **Both MR configurations failed on HRD while Control configurations failed both EODV and HRD**
- **Small changes recommended to hit target**
 - Reduced Formation Time/Ah-Input
 - Increased Separator (reduce void space)
 - Increased ending acid sg
- **Expected result = equal performance, lower cost**

Customer Testimonial #3: Flooded Heavy Duty Truck Batteries



Pb1100 Series Products: Reduced Plate Count, Maintained IEC 60095 Performance

Customer Background

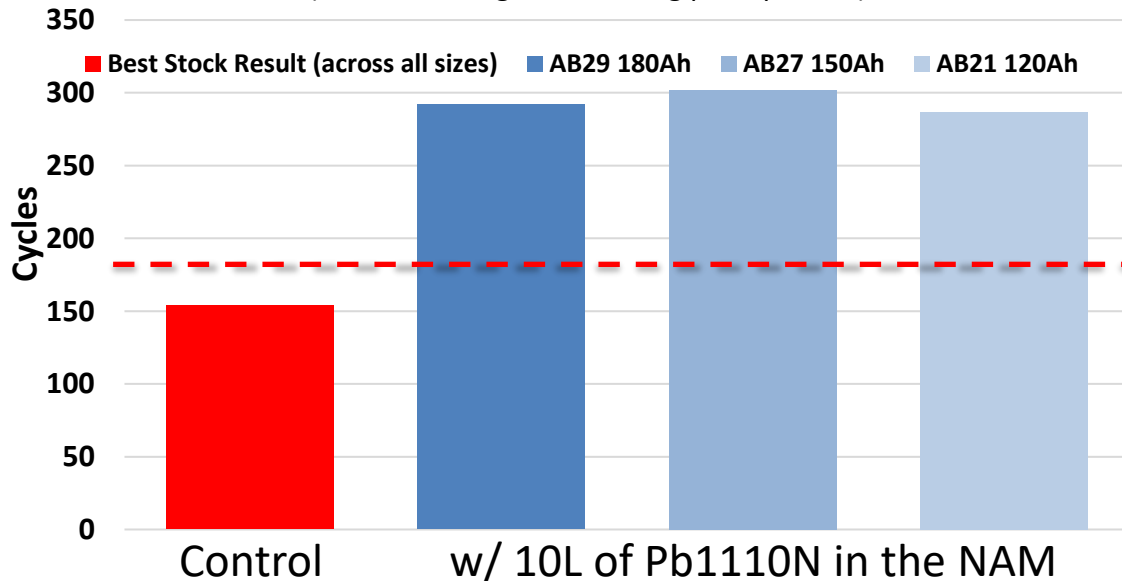
- Customer implemented Pb1100 Series for Heavy Truck Flooded 12V
- Initial success creating a premium battery product
- Explored options to reduce active material while maintaining performance (IEC 60095-1)
- Existing design overbuilt 5-20% to meet 25% DoD Cycling Requirements

**Plate Reduction using
Pb1110N Implemented:
~5-10% Net Cost Reduction**

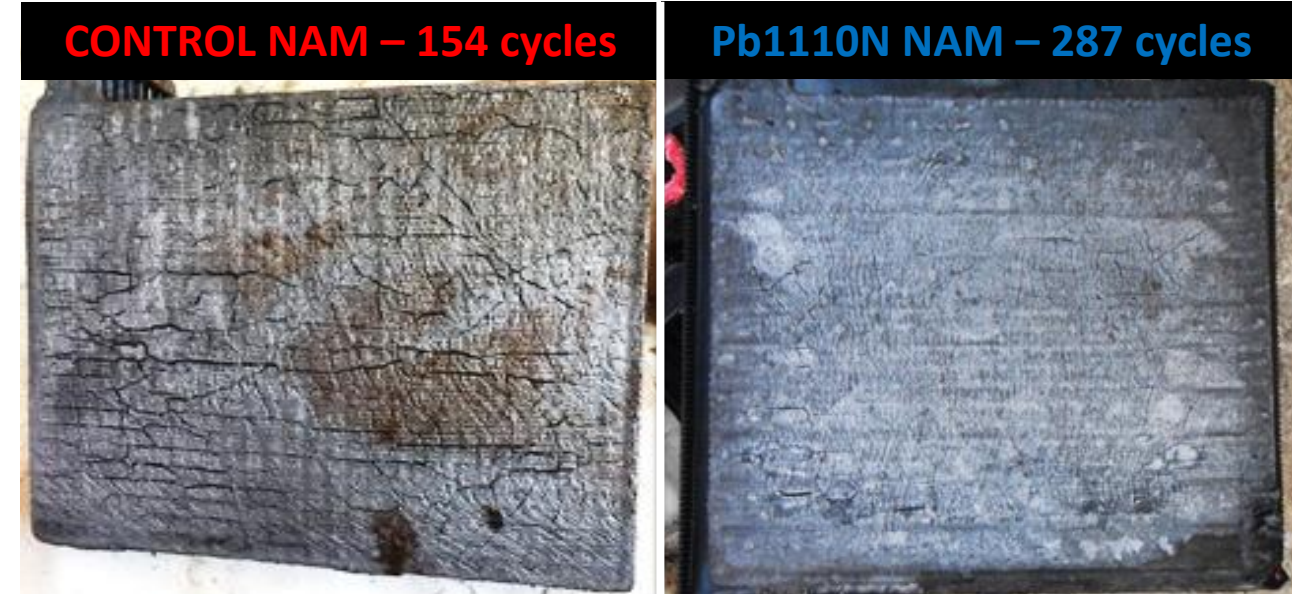
Pb1100N maintains plate integrity, performance consistency to successfully enable lowered plate count

IEC 60095-1 25% DoD Cycling Results

(after removing 1Pos & 1Neg plate per cell)



Tear Down Images Post Failure



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SLI and Heavy Truck Batteries: Pb1100 Series



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Innovative customers finding new opportunities where MR maintains performance levels in new designs

- *Reduced cost by removing plates*
- *Reduced cost by reducing active material per plate*
- *Other design changes seen in progress*

Come visit us at Booth #101

THANK YOU FOR YOUR ATTENTION!

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