Technology Competence and Innovative Solutions - Lead Acid Battery Separator

Naveen Prabhu.S, Technical Service – Daramic

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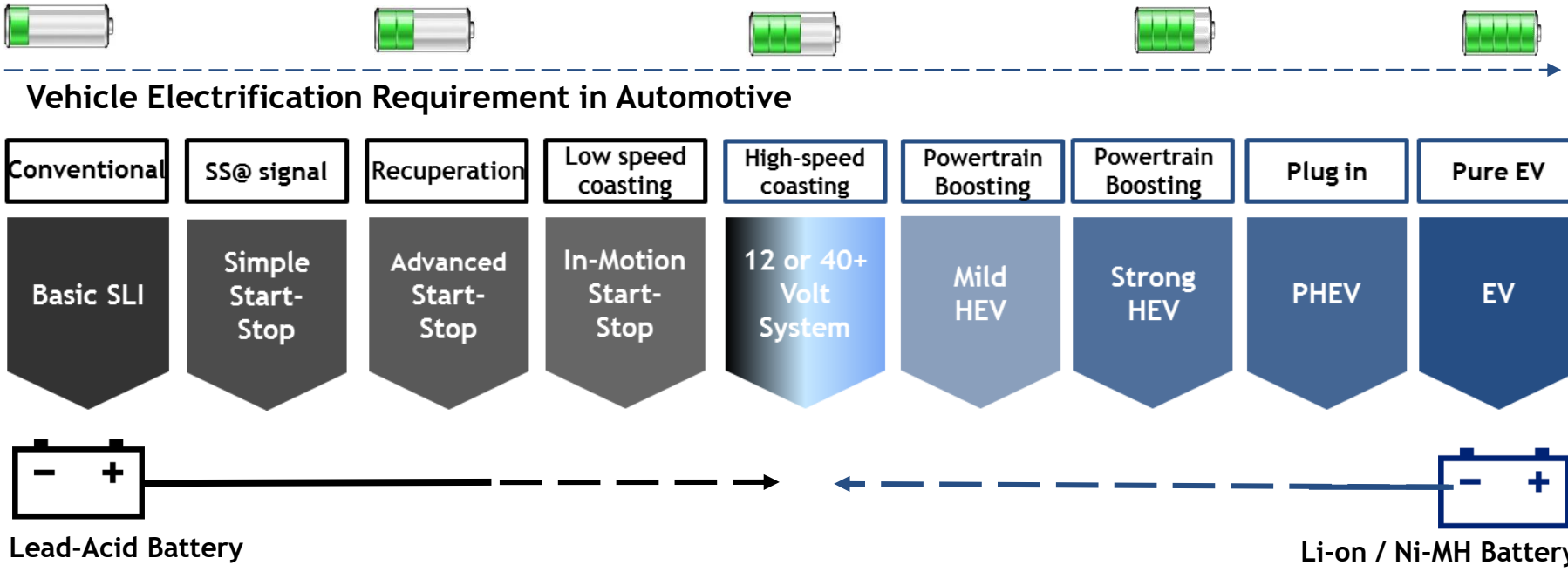
Who Is Daramic?



Daramic — Hipore/Celgard

World largest lead-acid separator manufacturer

DARAMIC

AsahiKASEI

World largest Li-ion separator manufacturers

HIPORE CELGARD

As the global leader in lead-acid separator industry, Daramic / Asahi Kasei provide full innovative Automotive battery separator solutions

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Daramic Market and Applications

Transportation

Automotive

- Cars
- Buses
- Trucks
- Motorcycles

Deep Cycle

- Golf Cart
- Marine
- Aircraft

Industrial

Motive Power

- Forklift
- Mining
- Railroad
- Submarine

Stationary/Specialty

- Renewable Energy
- Inverter
- UPS
- Telecom

Market leader operating in Transportation & Industrial business segments

Technology and Innovation Leader

- **Material science**
  - Innovations in material structures and electrochemistry
  - Complete analytical facilities to test a wide variety of physical, chemical and electrochemical properties
- **Fully-functional battery test capability**
  - Full range of battery testing
  - Full post-mortem analysis on batteries
- **Technical service**
  - Design input, post mortem analysis, test method development and support of the battery processing equipment

Daramic Technical Centers in Owensboro, US; Sélestat, France and Gujarat, India

Dedicated to innovation to meet ever-changing industry needs

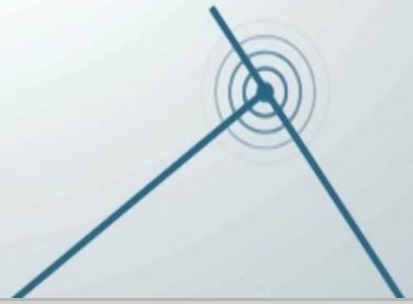
Daramic Global Market

Supplying more than 50% of the world's demand for high performance polyethylene battery separators

Daramic Keeps the World in Motion

Superior Performance

Superior product quality of Daramic ensures higher productivity, lower scrap rates & fewer returns at customer end



Industry-leading Quality and Reliability

- **Daramic plants are equipped with product inspection equipment & all products tested as per standard (BS-TE) & other customer specific requirements**

- **Complete analytical facilities to test a wide variety of**
  - Physical,
  - Electrochemical &
  - Chemical properties

- **Product quality screening system & standard with multiple inspection steps ensure industry-leading quality and reliability**

- **All Daramic facilities utilize standard test methods developed in matching many of the National Standards**

Daramic continuously strive to enhance overall product quality, improved processes & minimized variations

Separator Testing Laboratory - Gujarat

- Daramic manufacturing plants & finishing plants are integrated with Separator test laboratories for periodic product testing for quality assurance with every supply lot

Well equipped laboratory for testing Raw material to the finished product

Puncture Resistance testing

- **Puncture Resistance property of the separator in a battery plays major role in battery life by protecting the battery from internal short between the positive and negative electrode that occurs due to,**
  - Sharp edges
  - Loose Paste
  - Lead Run / Foreign Particles
  - Plate Side Paste
  - Bottom Paste

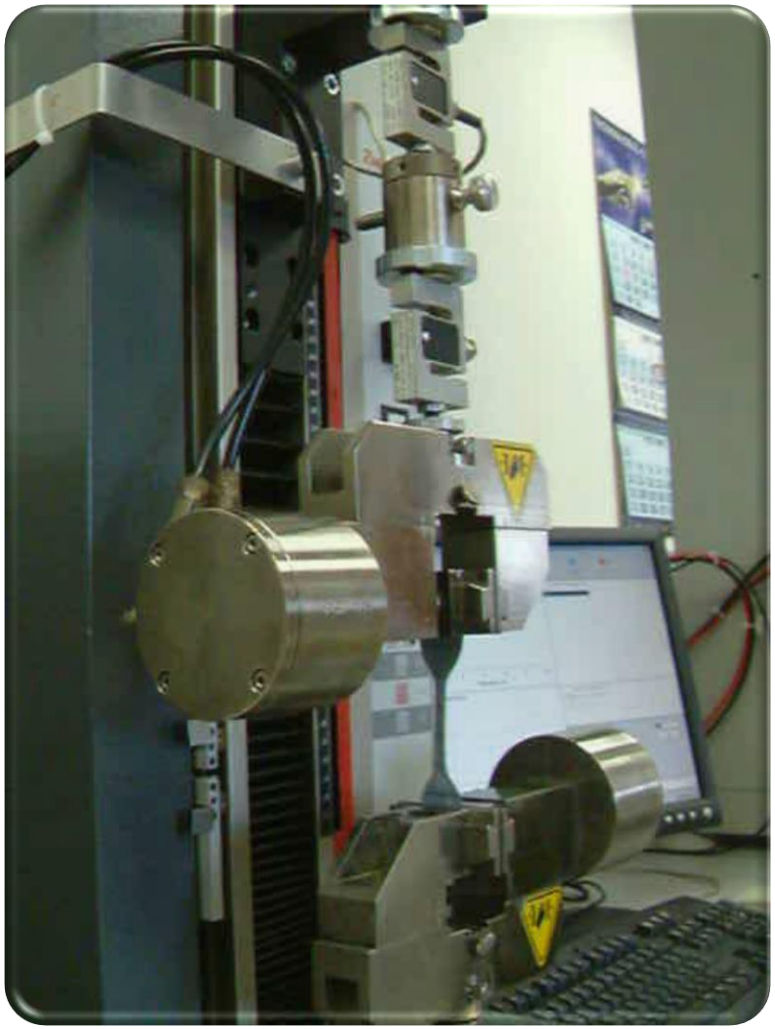
- **Puncture Resistance property PE separator supports high reliability & enhanced cycle life of the battery**

Higher the Puncture Resistance, lower the internal short rejection

Elongation & Sealing Strength testing

- **Cross Machine Direction (CMD) Elongation property of a battery separator gives better flexibility to the separator and protects the battery against the following failure mode**
  - Internal short due to separator puncture while plate insertion in assembly &
  - Other internal shorts during service life of battery (from plate expansion)

- **Sealing Strength of Daramic finished products is checked for ensuring good sealing properties so that the product does not open up during assembly or service life**

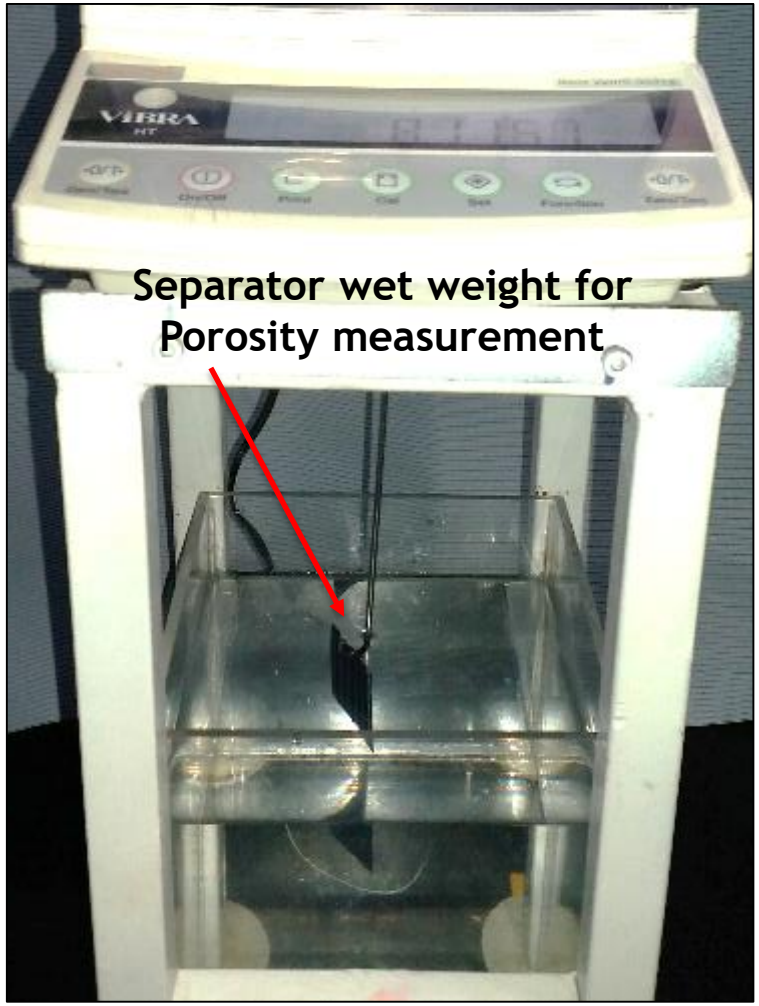


Better the Separator Elongation & Sealing Strength, lesser the in-process & field rejection

Porosity testing

- **High Porosity of PE separator is a preferred feature since it provides high surface area & lower electrical resistance compared to other type of separators**

- **This property supports efficient transfer of ions & acid through the separator between the electrodes thereby gives**
  - High cranking efficiency,
  - Improved Charging characteristics
  - Desired backup capacity

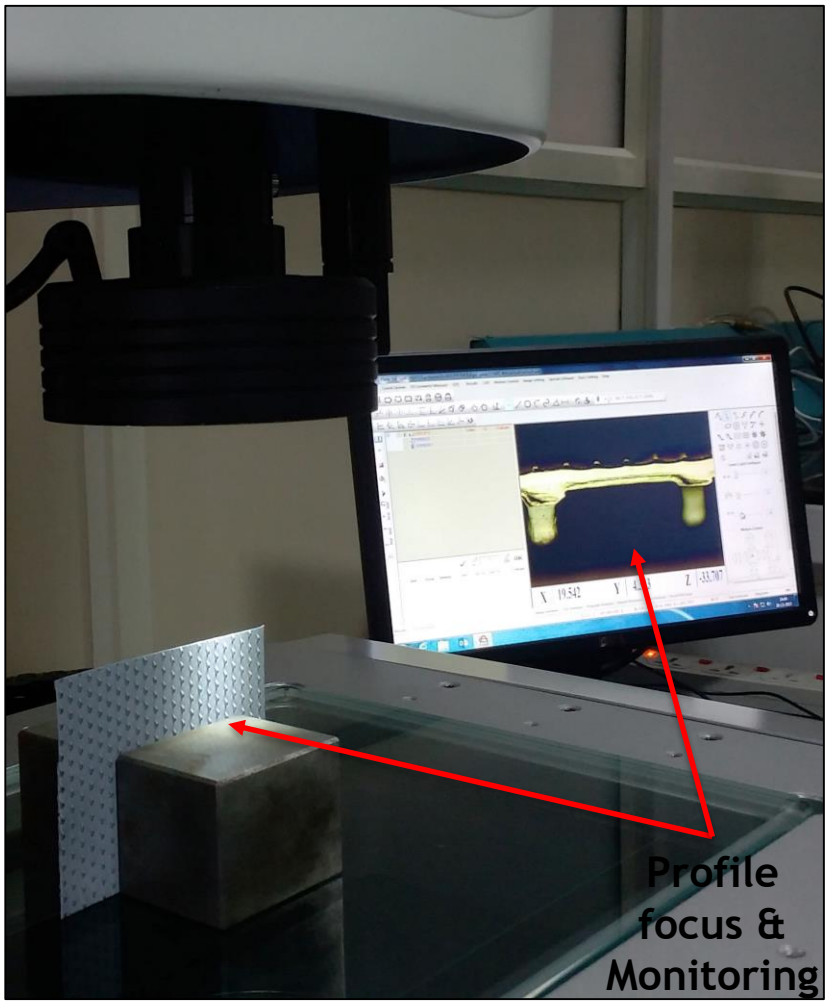


Maintaining specified Porosity in a separator is important since it facilitates efficient Electrochemical reactions in a battery

Profile Projection study

- **The profile projection study helps in inspecting the following product finishing parameters**
  - Rib structure & alignment
  - Web thickness & uniformity
  - Rib pattern & continuity
  - Rib spacing & consistency

- **This study supports in ensuring consistent product output as per specification that will ensure reliable performance in the battery**



Appropriate rib pattern & exact web / rib thickness as per design ensures the product quality delivered to customers

Well-organized Process Control

Uniform control over the complete process & product parameter enables Daramic products to have Superior Performance, High Reliability & Consistency

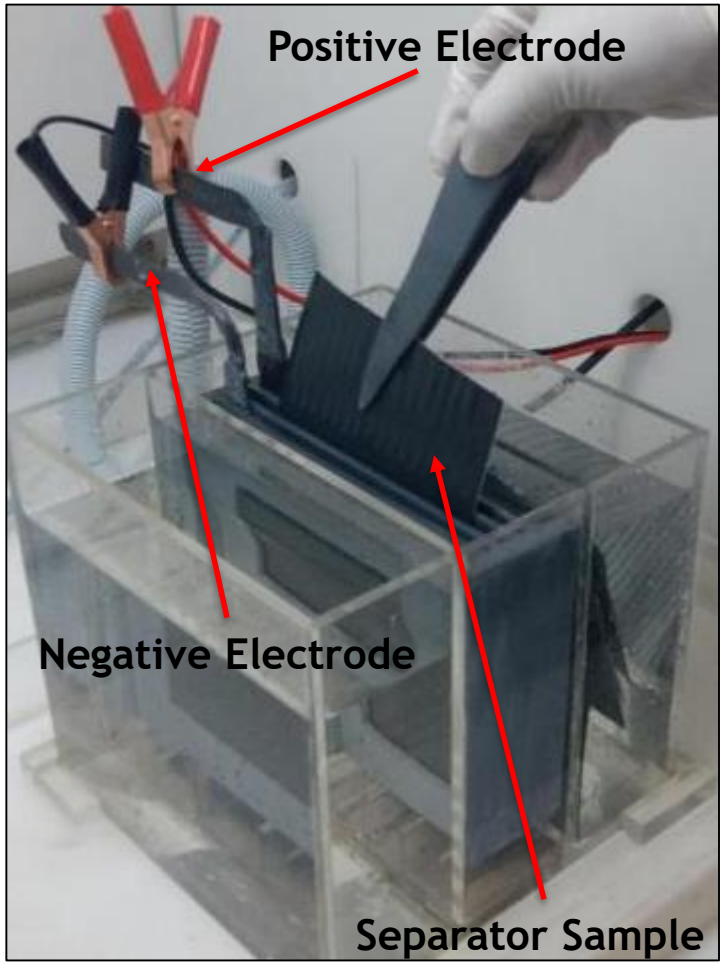
Electrochemical testing

Electrical Resistance

Electrical Resistance property of a battery separator explains the ability of the separator to enable ion diffusion between the electrodes thereby giving the following benefits

- High cranking efficiency (high CCA),
- Improved Charging characteristics
- Desired backup capacity

Improves battery performance in adverse usage conditions like undercharging & low operating temperatures



Daramic Auto PE separators have the least Electrical Resistance as desirable in a SLI PE separator

Chemical testing

Trace Elements Testing

- Following are the impurities that impact on battery life
- Daramic maintain lower impurity levels in its product through its superior raw material quality & periodic trace element analysis at its facilities

Sl. No	Element (Impurity)	Specific Effect of Impurity in Lowering Battery Life
1	**Copper**	Oxidizes organic separators and lowers on-charge voltage
2	**Chromium**	Causes self-discharge and severely attacks separators.
3	**Iron**	Increases self-discharge by local action at both plates and retards formation.
4	**Chlorine**	Voltage & Gravity decline - depresses positive plate potential.
5	**Manganese**	Severely oxidizes separators and will deposit on the positive plate.
6	**Nickel**	Intense in lowering on-charge voltage.

Test method: BST-518

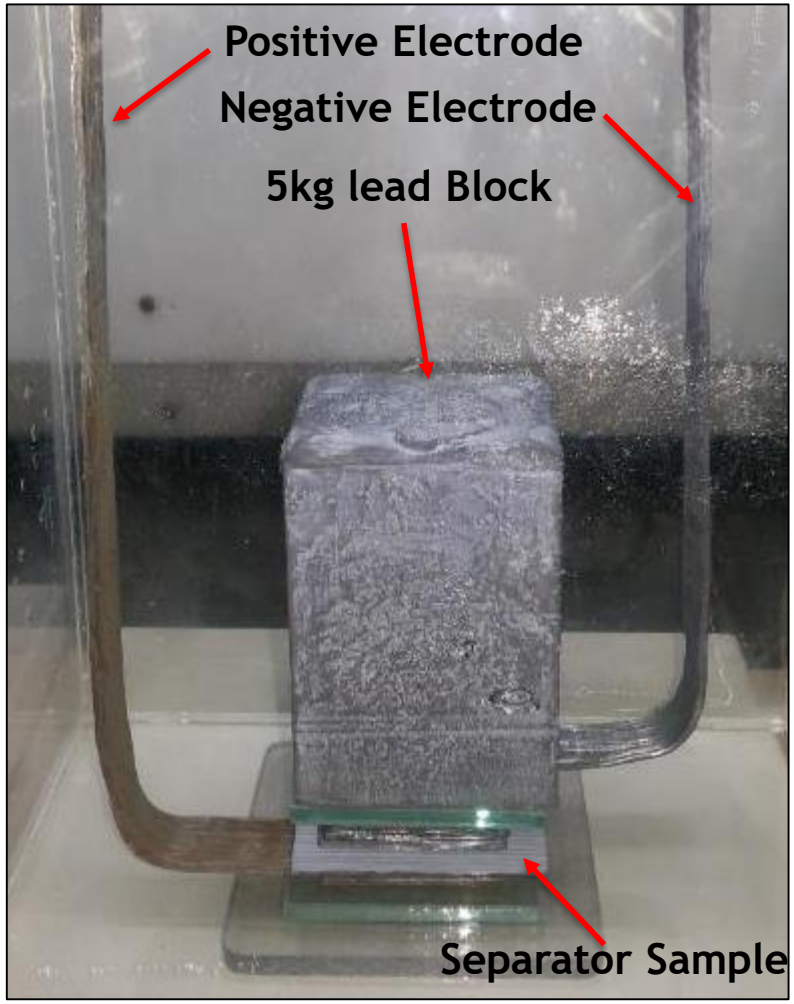
The Impurity levels of Daramic Separators are much lower than the other products in market

Electrochemical testing

Oxidation Resistance

Oxidation Resistance property of a battery separator explains the robustness of the separator in the highly oxidative environment that occurs inside the battery.

- Separator sample placed between a positive & negative electrode made of pure lead at certain pressure
- Durability of the separator checked under overcharge condition at elevated temperature up to 75 deg C



Higher Oxidation Resistance is desirable in a PE separator for longer life in high temperature & overcharge conditions of the battery

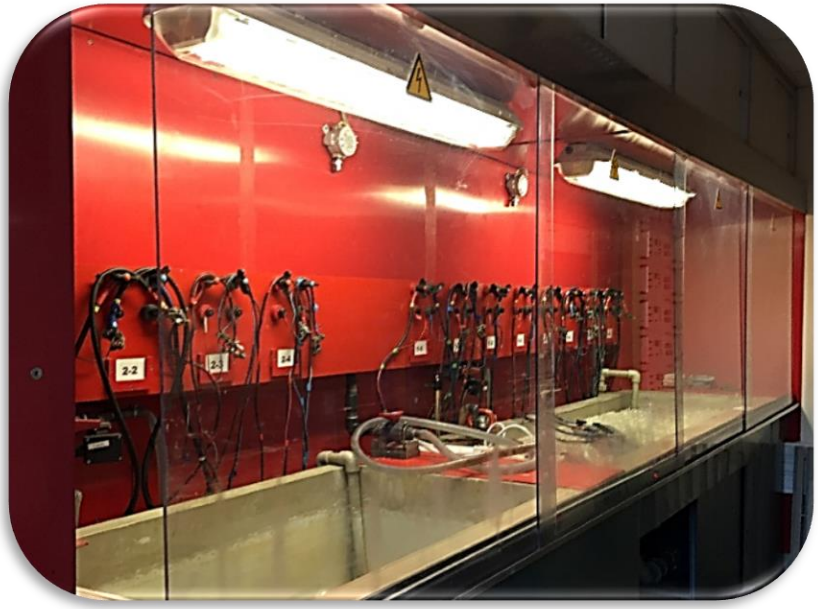
Research & Development

Daramic Research & Development team work to enhance customer's product & create business opportunity

Fully-functional Battery Test Capability

- **Daramic R&D centers in USA, Europe and India have highly sophisticated battery testing laboratories to test the performance of separators by fitting in batteries**
  - ~200 battery testing stations
  - Full range of battery testing
  - Full post-mortem analysis on batteries

Daramic Technical Center (DTC) in Owensboro, US



Europe Technical Center (ETC) in Selestat

The R&D centers support in new development, product upgradation, performance validation & tear down analysis

India Technical Center (ITC), Gujarat

- **Daramic's ATC in Bangalore shifted to Gujarat plant as ITC and continues to supports new product development & customer technical service**
  - Evaluation of New Separators
  - Life Cycle & High Rate testing
  - Temperature-controlled baths
  - Conduct battery teardowns & failure mode analysis
  - Technical Service to Customers

Life Cycle, Charge Acceptance & HRD Test Equipment

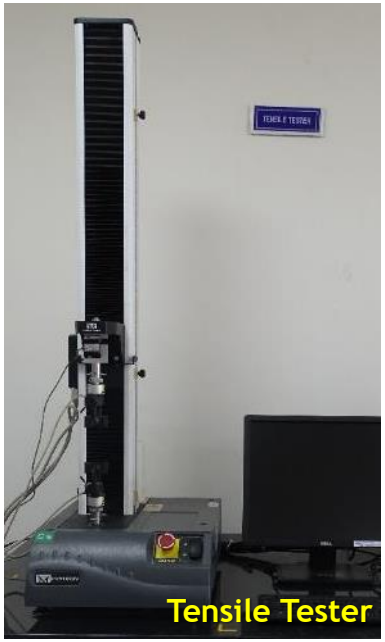
Temperature Controlled Water baths

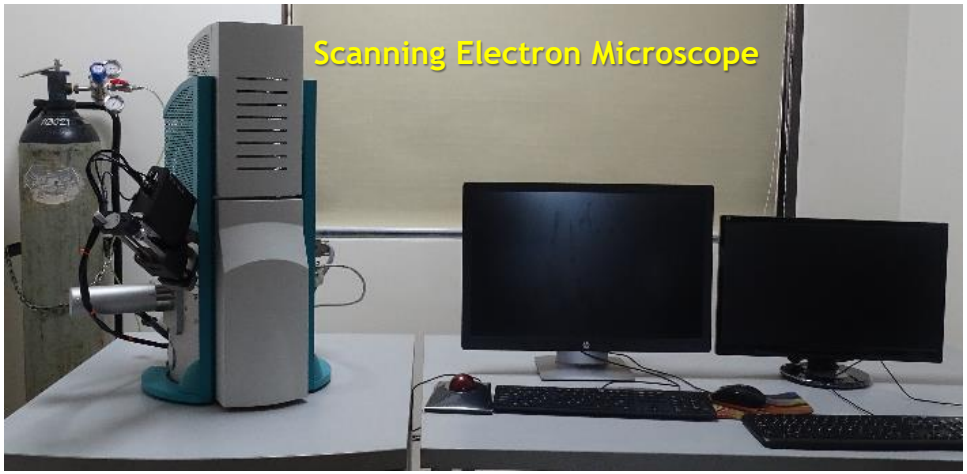
Daramic's ITC since inception has already contributed to new product introductions like HiCharge, XCharge™ & Ricklife

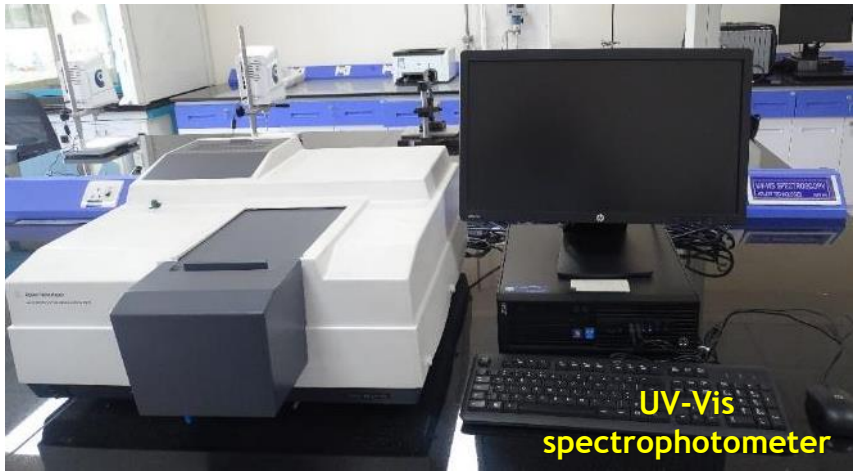
ITC - Electrochemical Lab Facilities

Potentiostat, Galvanostat	Mercury Porosimeter
FTIR spectrometer	Digital microscope
UV-Vis spectrophotometer	Scanning Electron Microscope (SEM)
Electrical resistance tester	X-Ray Diffraction (XRD)
Tensile Tester	Profile Projector

Profile Projector


Tensile Tester


Scanning Electron Microscope


UV-Vis spectrophotometer

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Daramic innovations for Deep Cycle Battery Application

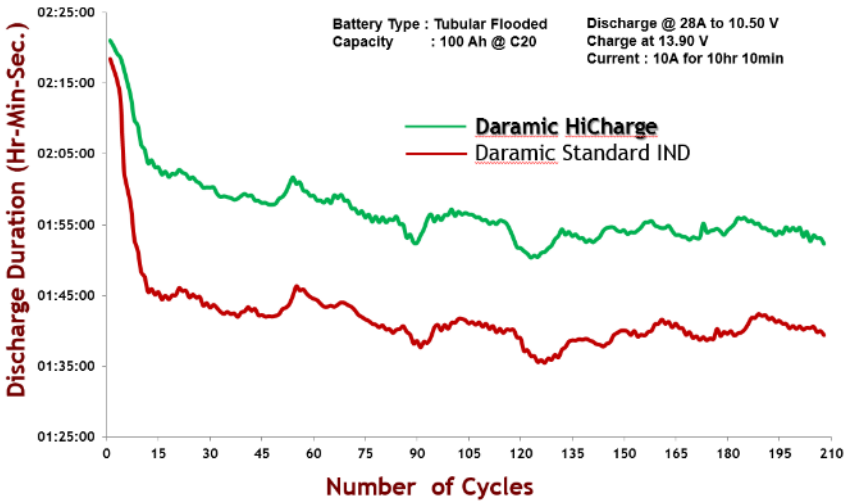
Products	Battery Type	Battery Application & Patent Details	Benefits in Battery Performance
HiCharge Lagao, Backup Badhao	Flooded Tubular	Inverter, Solar, Traction, Golf cart, E-Rickshaw, Railway ✓ Patented	a) More backup time b) Better rechargeability c) Low water loss d) Reduced sulphation incidences
Daramic® XCharge™	Flooded Flat Plate Industrial	Inverter and Solar ✓ Patented	a) Enhanced capacity b) Improved charge acceptance c) Reduced rate of grid corrosion d) Increased cycling capability
Daramic® XCharge™ RickLife	Flooded Flat Plate E-Rickshaw	E-Rickshaw ✓ Patented	a) Increased power output b) Less degradation of capacity c) Low water loss d) Reduced rate of grid corrosion e) Increased service life

Daramic HiCharge Separator for Tubular Batteries

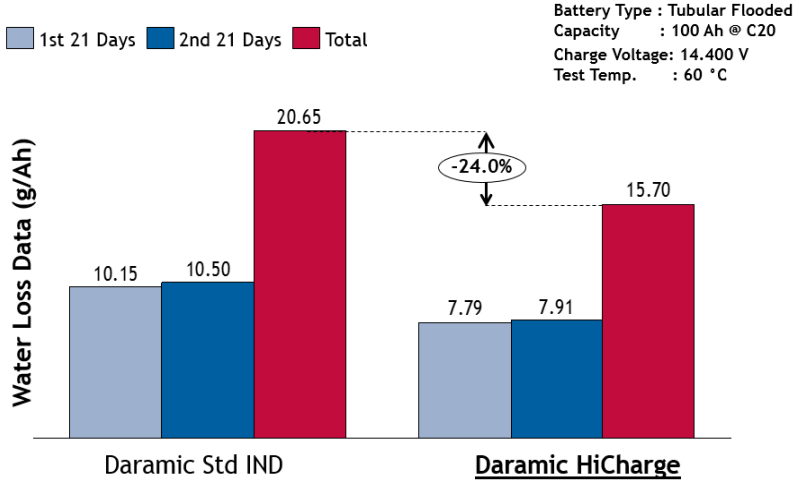
HiCharge vs Standard Separator – Validation Results

#	HiCharge Benefit	Customer Value
1	~24% lower water loss	Reduces maintenance interval (for top-up)
2	~25% lower float current	Reduces grid corrosion and increases battery life
3	~7%-10% higher back-up time	Improves the deliverable power to end user
4	Better specific gravity trend	Enhances battery life by reducing acid stratification
5	Better re-chargeability and lower end of charge current	▪ Reduces negative plate sulphation in service ▪ Reduces grid corrosion Thus enhances battery life

Inverter Battery Cycling Test @ 100% DoD - Back Up Time



Average Water Loss Test Data (g/Ah)



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Separator Condition after 2 years of LCT

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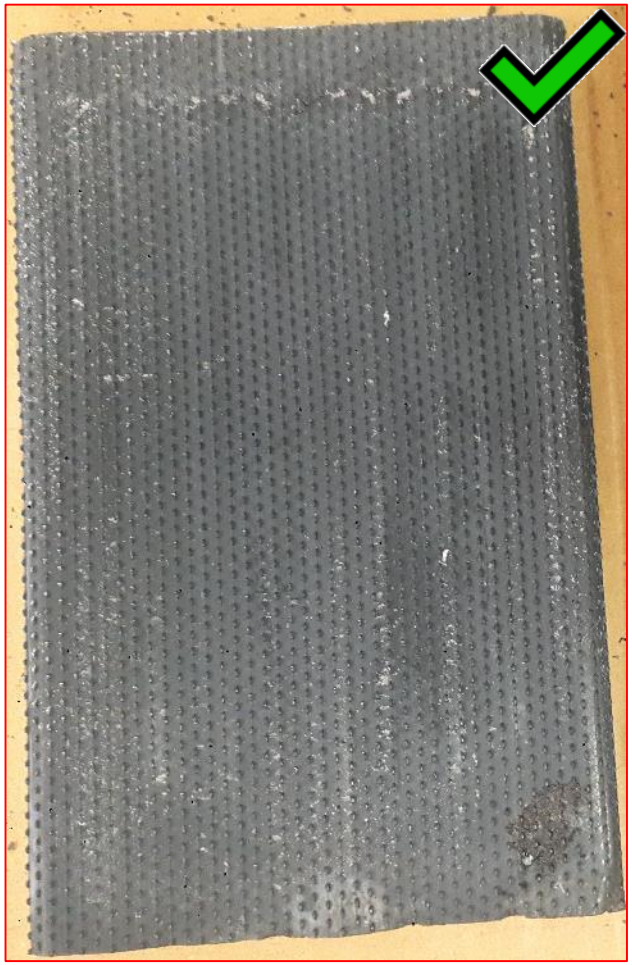
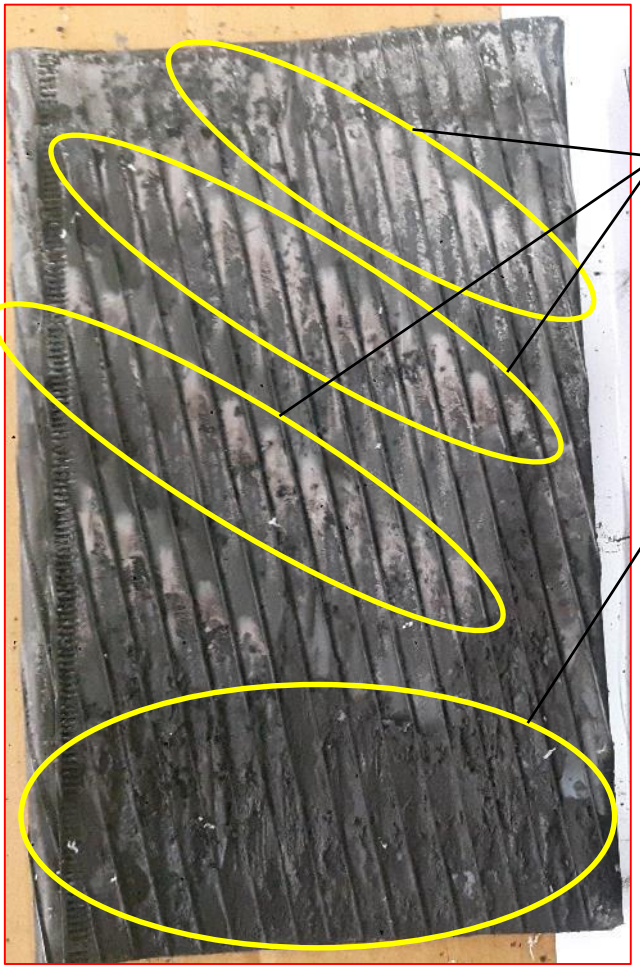
HiCharge Separator Battery



Standard Industrial Separator Battery



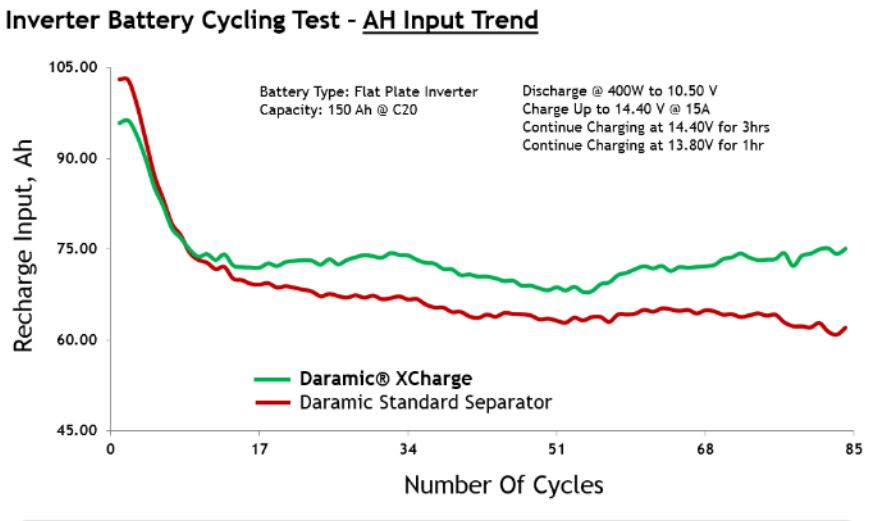
*Sulphation around the gauntlet touching backweb**

*Paste softening and deposition on separator at the plate bottom**

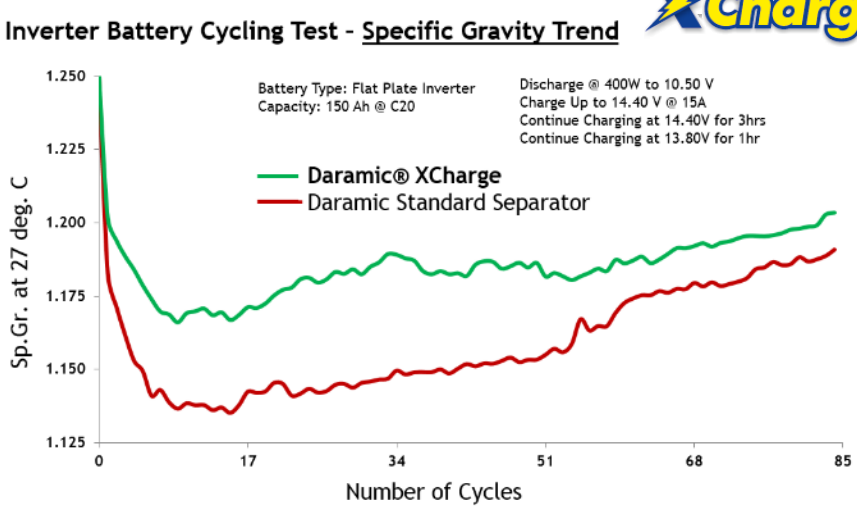
** Hinders acid availability and acid circulation between plates*

Performance and life of battery are enhanced with HiCharge separators

Daramic XCharge for Flat Plate Cycling Batteries



Daramic® XCharge battery accepts more charge (AH Input) compared to the battery using standard separator

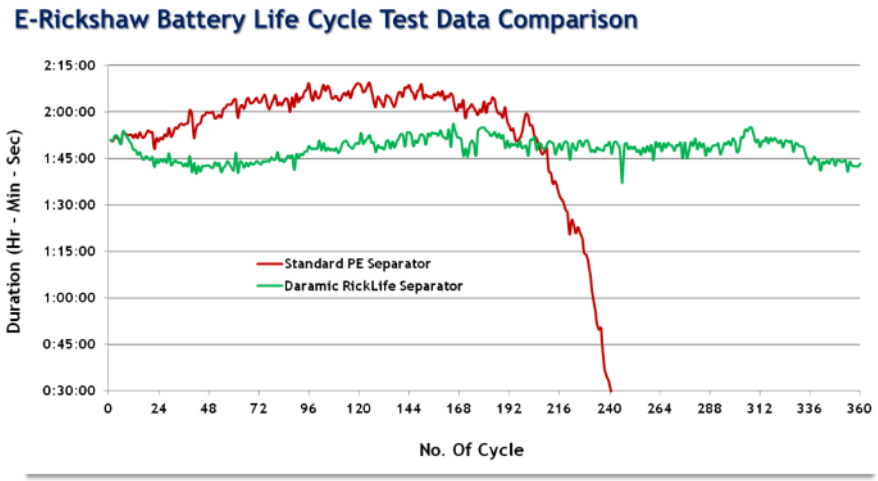


Daramic® XCharge battery shows better specific gravity trend over the battery with standard separator

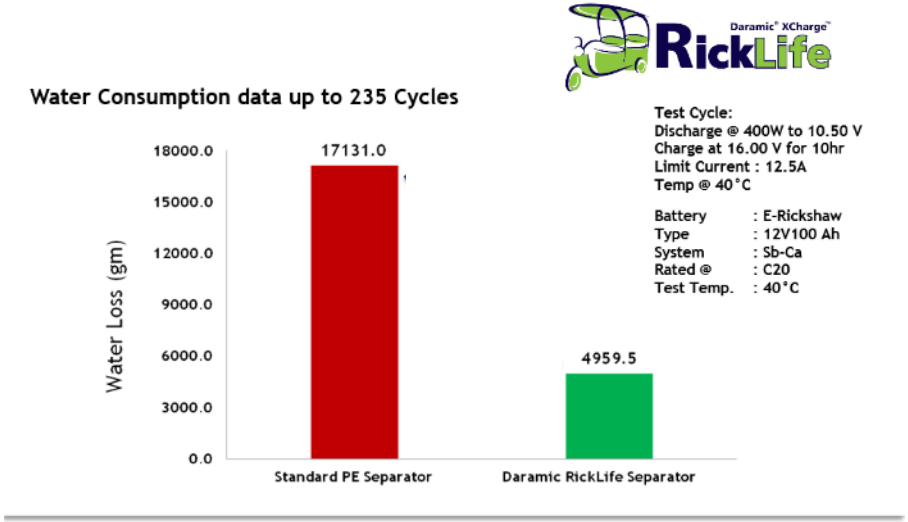
XCharge vs Standard Separator – Validation Results

#	Daramic Benefit	Customer Value
1	**~8 to 12%** higher back-up time during cycling	Increases deliverable power to end user
2	Improved specific gravity trend	Reduces acid stratification & enhances battery performance & life
3	Better re-chargeability	Reduces negative plate sulphation & thereby increases battery life
4	**~24%** lower water loss	Reduces maintenance interval (for top-up)
5	**~20% to 25%** lower float current	Helps reduce grid corrosion and thus enhances battery life

Daramic RickLife for E-Rickshaw Batteries



RickLife separator extends battery life by providing an effective overcharge protection in the battery

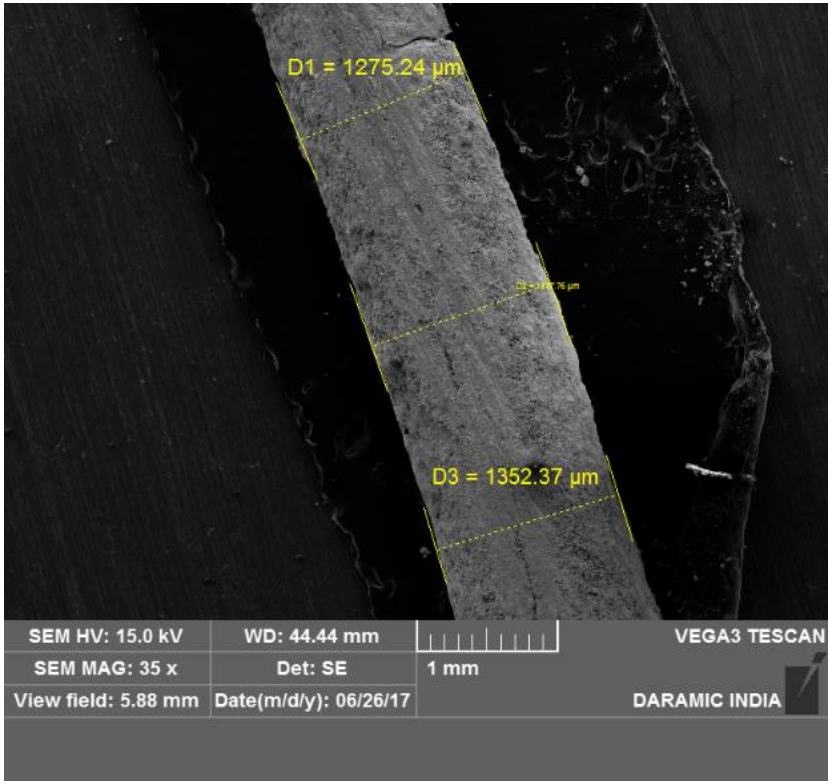


RickLife separator greatly reduces the water consumption during deep cycling operation of E-Rickshaw batteries

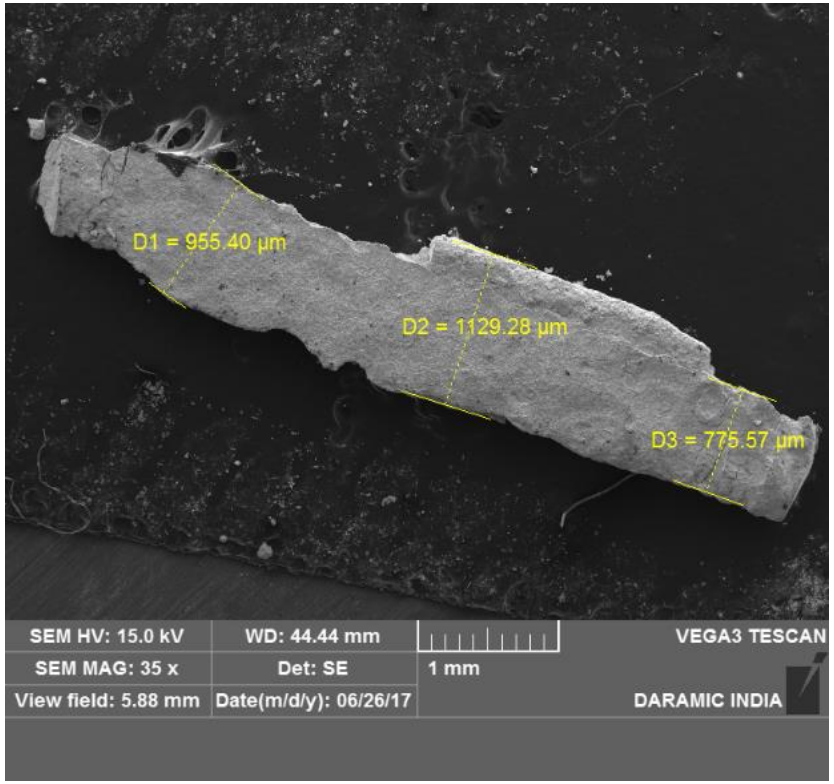
RickLife vs Standard Separator – Validation Results

Features	Benefits
Inbuilt Overcharge protection	Greatly reduces grid corrosion due to an effective overcharge protection resulting in significantly lower end of charging currents
	Lowers water loss by ~50% or more and thereby reduces the frequency of topping-up in the field
Very low overall thickness	Very low overall thickness enables use of thick glass mat (~1 to 1.2mm) for deep cycling applications
	Use of thick glass mat (~1 to 1.2mm) effectively arrests Positive Active Material (PAM) shedding in heavy duty applications
Improved rechargeability	Special rib (Negative Cross Rib) profile reduces electrolyte stratification and thus improves rechargeability
	Improves mechanical strength and durability

Positive grid comparison (plate bottom) - After 6 months of battery service in field (SEM images)



RickLife separator battery - Positive grid bottom SEM image shows consistent thickness with 1.32mm average



Standard separator battery - Positive grid bottom SEM image shows inconsistent thickness with 0.95mm average

The grid thickness comparison at bottom of the plate shows ~28% reduced grid corrosion in RickLife separator battery positive plates

Daramic Advantages

- ✓ Inventor of PE separators
- ✓ First movers by launching successful innovative designs
- ✓ First PE separator manufacturing plant in India
- ✓ 9 Manufacturing plants across the world
- ✓ Customized solution for market needs (Lami, BCS etc)
- ✓ Ultra High Molecular Weight Polyethylene usage
- ✓ Lowest ER (higher CCA)
- ✓ Low Water Loss feature (low top up)
- ✓ Consistent Quality Products

Daramic, a generic name for PE separators across the world

Thank you

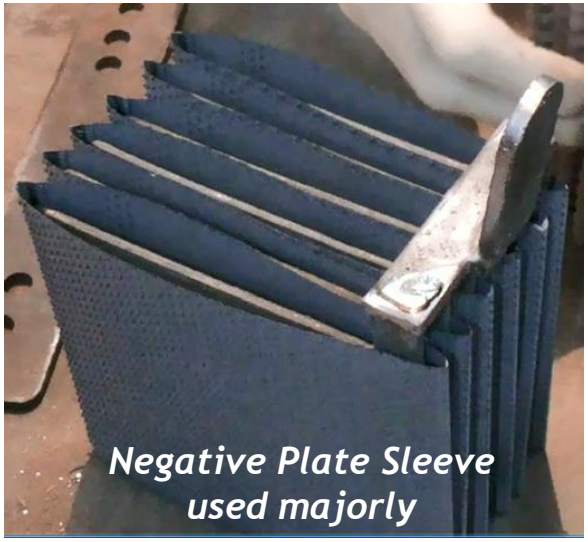
Annexure

New Form of Separator in Battery with HiCharge

Different Forms of Using HiCharge Separator -Currently used

- **Daramic HiCharge separator can be used in different forms and it is current used as,**

  - **Negative Sleeve**
    - Regular form widely used



  - **Positive Sleeve**
    - HiCharge can be used in positive plate sleeve form

Group Assembly Process Examples
- Currently Adopted

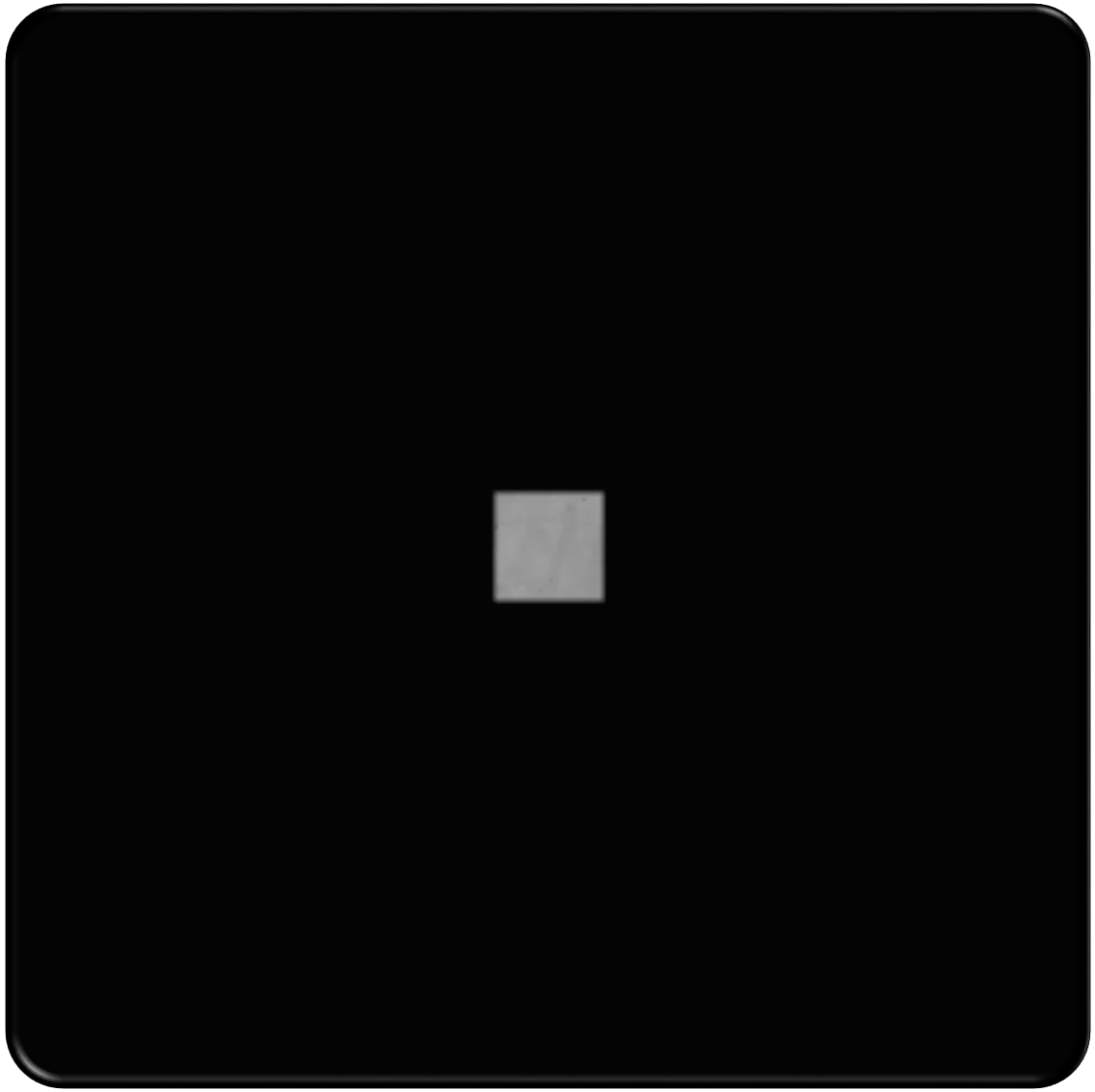
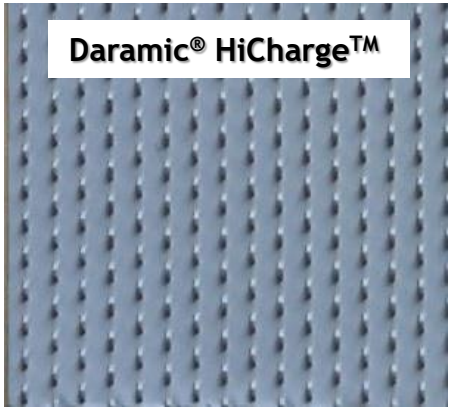


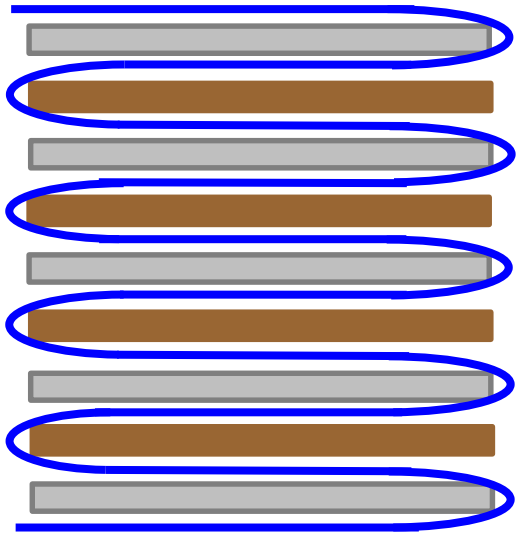
Plate Wrap with HiCharge – Unique Feature



For Demonstration:

Battery type – Flooded tubular

Cell details – 4 positive + 5 negative plates

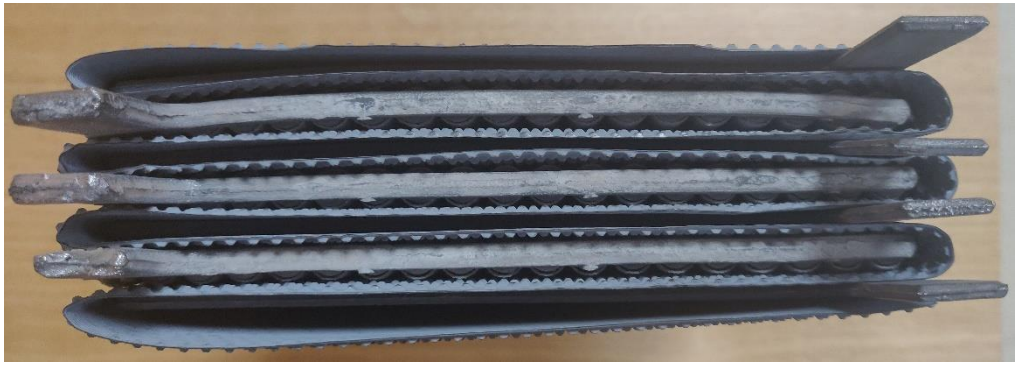


- Positive Plate
- Negative Plate
- HiCharge Separator

A new form of separator usage is invented with Daramic HiCharge separator which is an unique feature of this product

Plate Wrap with HiCharge – Unique Feature

Cell Top View



Cell Bottom View

A new form of separator usage is invented with Daramic HiCharge separator which is an unique feature of this product

Plate Wrap with HiCharge
-Machine Concept

Daramic developed a machine model for HiCharge Plate Wrap concept

The new product form and machine details would be discussed in detail @ Daramic stall 36-38, Hall A

HiCharge Plate Wrap Form

- Plate wrap concept is applicable to HiCharge separator exclusively
- HiCharge separator enables automation in tubular battery group assembly thereby improving productivity
- The plates can be wrapped with HiCharge separator as it has serrated rib pattern to enhance acid circulation
- Daramic developed a Machine concept for plate wrapping with HiCharge separator
- Further trials and testing are in progress

A new form of separator usage is invented with Daramic HiCharge separator which is an unique feature of this product