Flooded vs AGM Batteries (Indian Automotive Batteries)

Understanding the Differences for Micro-Hybrid Applications

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Presentation Outline

1. Introduction

2. Micro-Hybrid Vehicles

3. 17.5 % DoD test results for VRLA / Flooded

4. 50 % DoD test results for VRLA / Flooded

5. Explaining difference between VRLA/Flooded

6. Concluding remarks

CSIR-Central Electrochemical Research Institute
(A premier National R&D Lab in Electrochemistry)

- Electrochemical Power Sources
- Corrosion & Material Protection
- Electrochemical Process Engineering
- Electroplating & Electrometallurgy
- Electrodics and Electrocatalysis
- Electro organic & Materials Electrochemistry

Groups - Electrochemical Power Sources

- Polymer Electrolyte Fuel Cells
- CSIR-BPTEC
- Lithium Batteries
- Redox Flow Batteries (Zn-Br)
- Super Capacitors

CSIR-BPTEC

State of the Art Battery Test Facility

Total Budget : 15 Crores
Dedicated Testing Space : 7500 Sq. ft

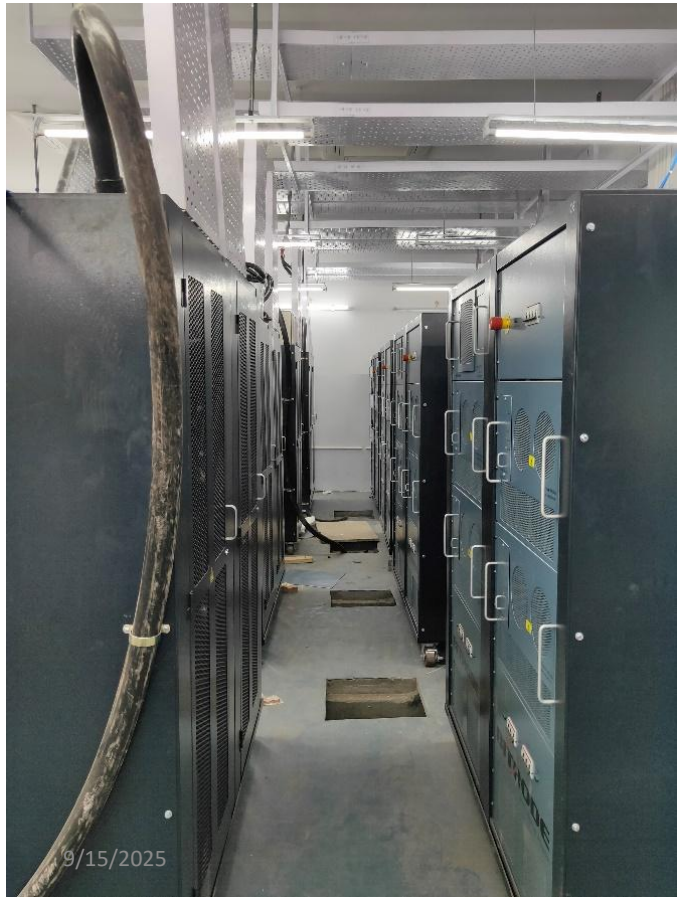
CSIR-Battery Performance Testing & Evaluation Centre (CSIR-BPTEC)

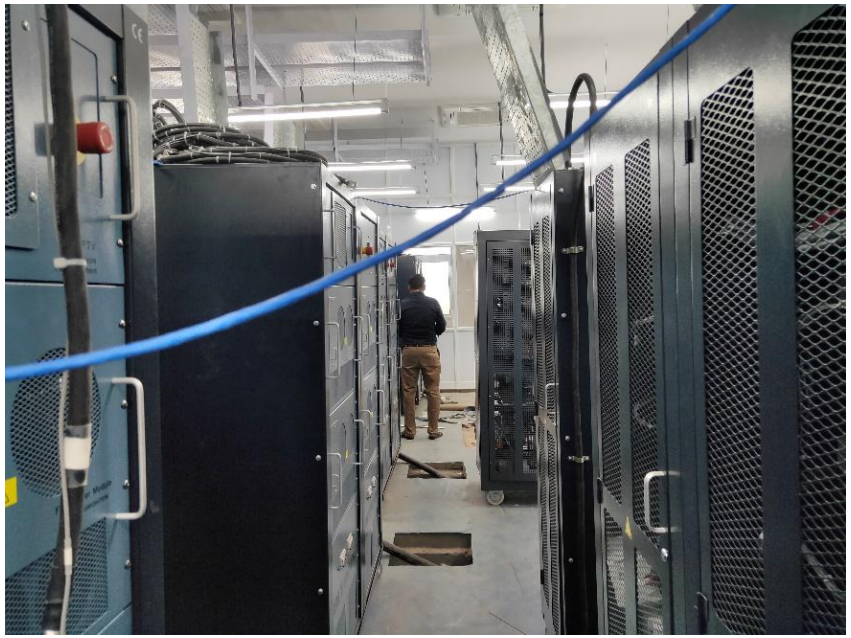
POWERED BY

- Digiqual -

BITRODE
PARTNER IN POWER

SPECTRAL DYNAMICS





CSIR- Battery Performance Testing & Evaluation Centre (BPTEC) NABL Accredited

ISO/IEC 17025: 2017 ACCREDITED
BATTERY TEST LAB

NABL Accredited since 2014

Battery Testing & Certification

- IS 16270 :2014 (Solar PV Batteries)
- IS 14257: 1995 (Motor Vehicles)
- IEC 63193 : 2020 (e-Rickshaw Batteries)
- IS 7372: 1995 (Motor Vehicles)
- IS 13369: 1992 (Inverter Batteries)
- IS 1651:2013 (Inverter-Tubular Positive)
- IS 15549 : 2005 (VRLA Stationary)
- IRS 88/2004 (LM LAB Railways S&T)
- IRS - S 93/96 (VRLA Indian Railways)
- JIS C 8702-1: 2009 (Small sized VRLA)

BIS /MNRE/RDSO Recognized Laboratory

Nodal Battery Test Lab for Solar PV Applications under MNRE

MNRE accredited Battery Testing facility (IS 16270 : 2014)

SECONDARY CELLS AND BATTERIES FOR SOLAR PHOTOVOLTAIC APPLICATION — GENERAL REQUIREMENTS AND METHODS OF TEST

Member : MNRE Technical committee on Batteries/Cells for SPV Applications
Member : BIS Technical Committee for Secondary Batteries & Cells (ETD-11)
Member : BIS Technical Committee for Primary Batteries & Cells (ETD-10)
NABL Technical Expert : Assessing Battery Test Labs as per ISO 17025:2017

Making Battery Standards for India (BIS Standard)

1. **Batteries for Solar Photovoltaic Applications - IS 16270 : 2023**
2. **Advanced Chemistry Cells: 17882:2022**
3. **Batteries for Drone Applications**
4. **Batteries for e-Rickshaws**

One Stop Solution Services for Industries

Apart from Battery Testing.....

Surface Area , Porosity (Carbon /Active mass) (Pore size/Pore Volume)	BET/Mercury Porisometer	Structure – Property Correlation
Particle Size/Morphology/Porosity (Carbons / Active mass)	FE-SEM/TEM/HR-TEM	New Additive Evaluation
Structural Characterization (Carbons/Active mass)	XRD/RAMAN/FTIR/XPS	Tear Down Analysis
Electrochemical Characterization (HER/OER/Impedance/Polarization	Multi-Channel Poteniostat	Battery Failure Mechanism
Grid Alloy Composition	Optical ES/XRF	

New Additive Evaluation
Expert Advise to MSMEs
Cut Open / Tear Down Analysis

Major Select Customers

Bharti Infratel Limited

indus TOWERS

Livguard energy unlimited

Reliance Industries Limited

EXIDE INDUSTRIES LIMITED

TVS

Schneider Electric

SAKTHI POWER TO LEAD

DURACELL

Beacon POWER TO PERFORM

JAS

OBJECTIVE OF THE STUDY

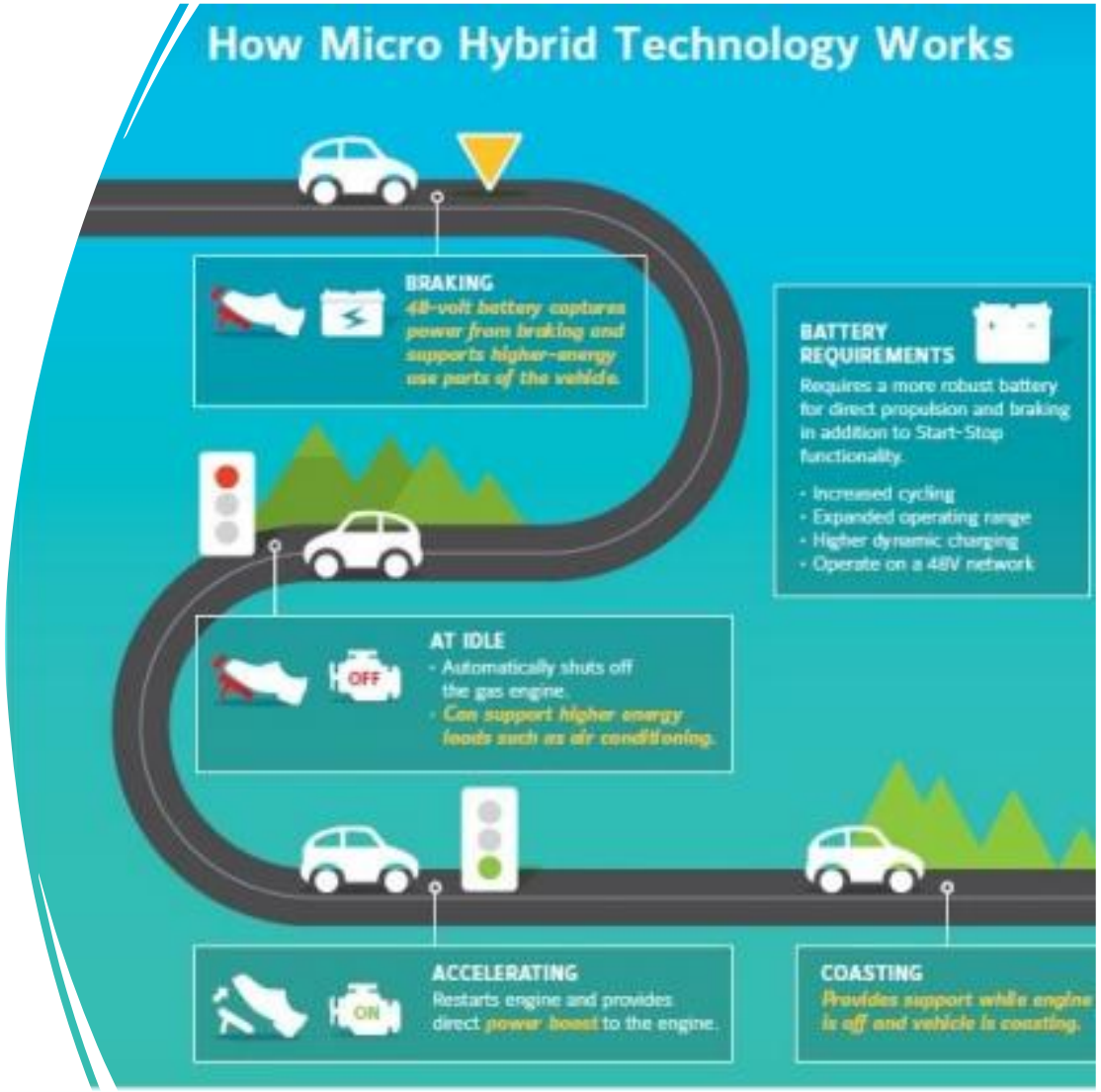
This study aims to evaluate the performance of Indian Automotive Batteries (Flooded & VRLA), with a particular focus on identifying key performance limitations, regarding:

- **17.5% DoD cycling performance as per EN 50342-6 (micro-cycle endurance)**
- **50% DoD cycling performance as per EN 50342-6 (deep cycle endurance).**

To understand difference in Failure mechanism between "VRLA & Flooded LAB"

What is Micro hybrid Vehicles ?

- Unlike full hybrid drive systems, micro-hybrid vehicles do not rely solely on electric propulsion but utilize the battery more extensively than traditional cars.
- A key feature is the “Start-Stop system”, where the Integrated Starter Generator (ISG) automatically shuts off the engine when the vehicle stops.
- During vehicle stops, the battery supports high energy loads such as AC, MP3 players, GPS, and lights.When the accelerator is pressed, the battery instantly re-starts the engine.
- This ISG system helps reduce engine idling time, leading to fuel savings of up to 8-10% compared to conventional ICE vehicles .



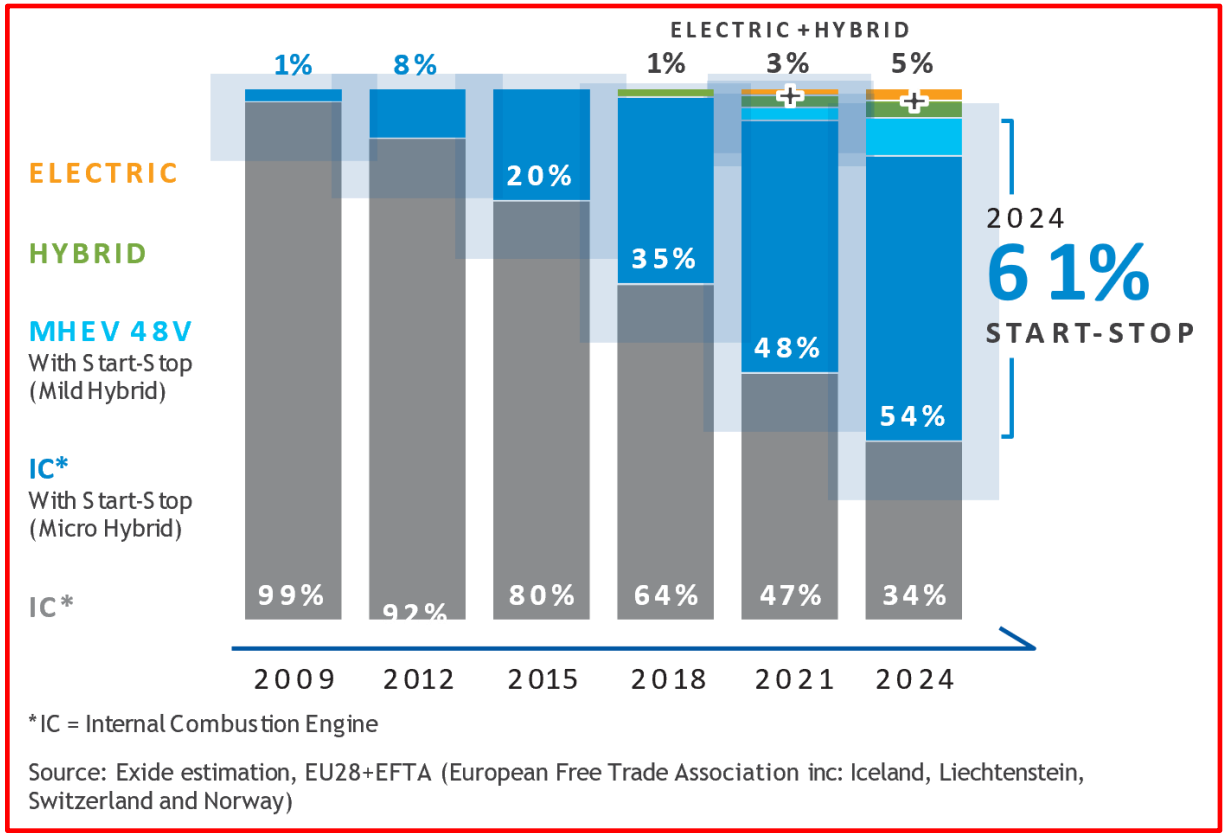
Fuel Efficiency

Car Battery

Credits : Johnson Controls

Market for EV in Europe

Automotive Start-Stop Battery Market size in Europe to exceed $3bn by 2026



START-STOP HYBRIDS : 61 %

PURE EV : 5 %

IC-ENGINE : 34 %

Eminent LAB market players : Clarios, East Penn Manufacturing Co.,Exide Technologies, Enersys, Leoch International Technology Limited, Crown Battery Manufacturing Company, GS Yuasa Corporation, Trojan Battery Company, Braille Battery, NorthStar Battery Company LLC Inc, amongst others.

Market for Start-Stop in India

Micro-Hybrid Cars : LAB (2017)

2017	Maruthi Suzuki, Mahindra (only select models)
2021-2023	VW, Skoda, Suzuki, Mahindra, Honda, Toyota, Tata

Market for Start-Stop LAB is steadily growing in India & by 2030 (70 %)

Source: Financial Express & Team bhp

Micro-Hybrid Technology for Two- Wheelers (only in INDIA)

Yamaha unveils Fascino 125 Fi with hybrid technology

"Indian Market is Unique"

TVS Ronin launched in India with 1st-In-Segment mild-hybrid technology

Battery Technology considered in this study (for Micro-Hybrid Vehicles)

Flooded Battery (SLI)

- Reinforced separators with Scrims
- Advanced grid technology
- Typically used in Indian cars

Car Battery : 12 V/ 45 Ah

Make 1 – Batt 1

Make 2 – Batt 2

Make 3 – Batt 3

Vs.

AGM VRLA (SLI)

- Electrolyte absorbed in glass mat (VRLA)
- Better vibration resistance, sealed design
- Typically used in Indian 2-Wheelers

2-Wheeler : 12 V / 5Ah

Make 1

Make 2

Make 3

Make 4

Make 5

EN 50342-6: Defines Test methods for Micro-Hybrid Vehicles

Why 17.5% DoD is Important for Micro-Hybrid Batteries

- Start-stop vehicles usually **don't fully discharge batteries**.
- Instead, the battery is used in **short bursts** (engine restart, supplying electrical loads at traffic stops, short regenerative events).
- Typical operation happens at **Partial State of Charge (PSoC)**, with shallow discharges.
- Testing at 17.5% DoD simulates this **real driving condition**.

17.5% DoD cycling represents the start-stop operational regime of micro-hybrid vehicles.

Why 50% DoD is Used in Testing?

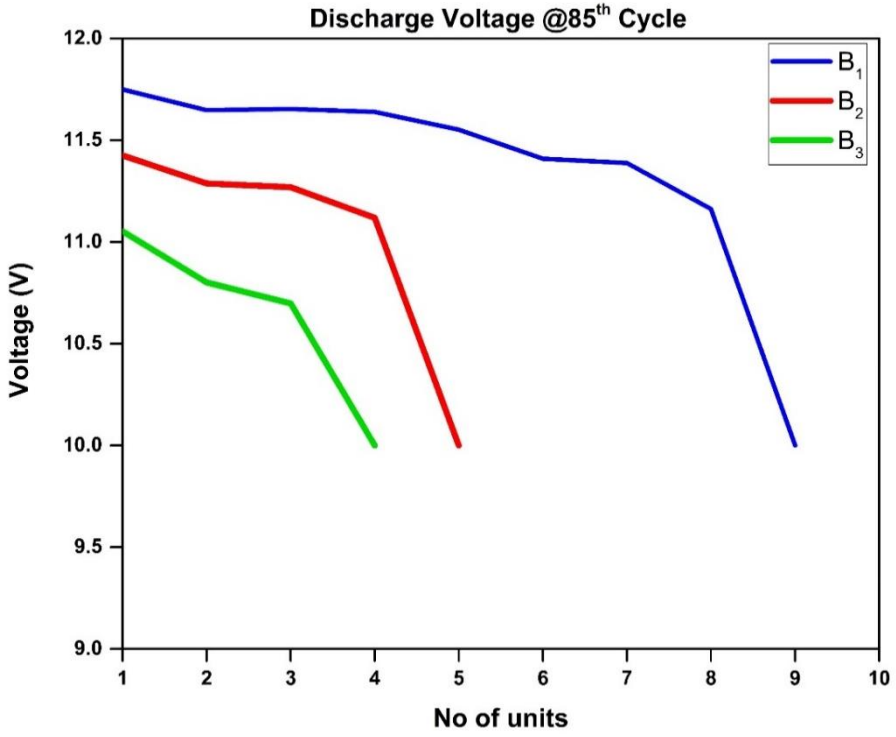
To simulate stressful driving scenarios:

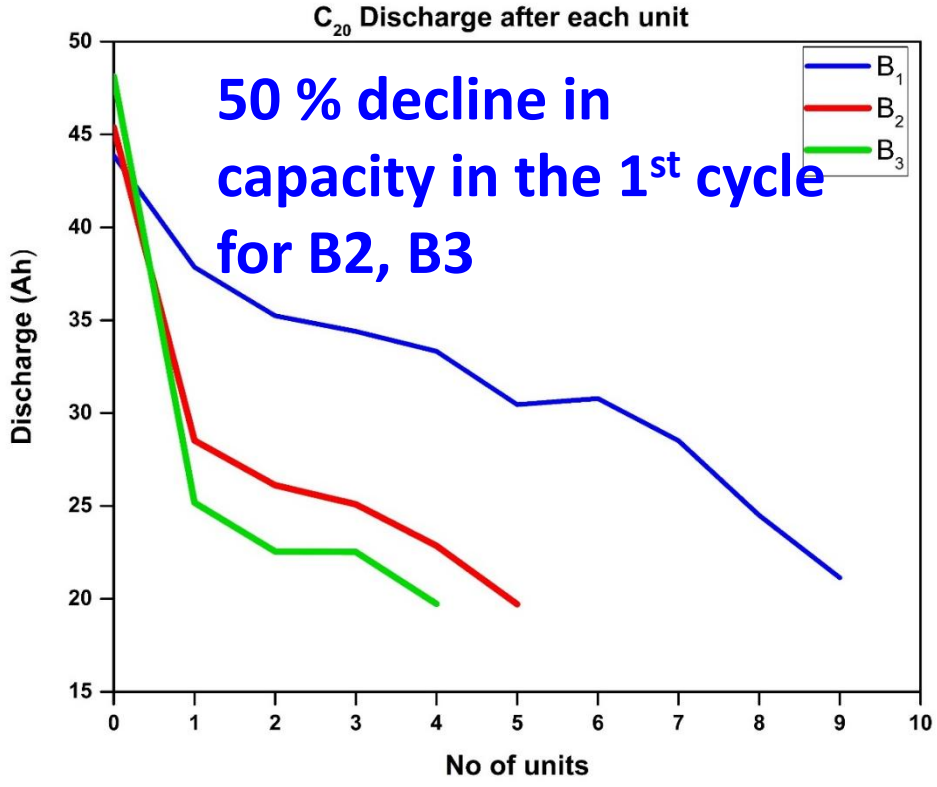
- Heavy electrical loads while engine is off (AC, infotainment, lights).
- Stop-and-go urban traffic with high accessory demand.
- Frequent start-stop plus regenerative braking with incomplete charging.

50 % DoD checks the true endurance limit of the battery under demanding duty cycles.

Battery	17.5 % DoD
B1 (Make-1)	8 Units (8 x 85 = 680)
B2 (Make-2)	5 Units (5 x 85 = 425)
B3 (Make-3)	4 Units (4 x 85 = 340)

17.5 % DoD : Performance of Flooded SLI





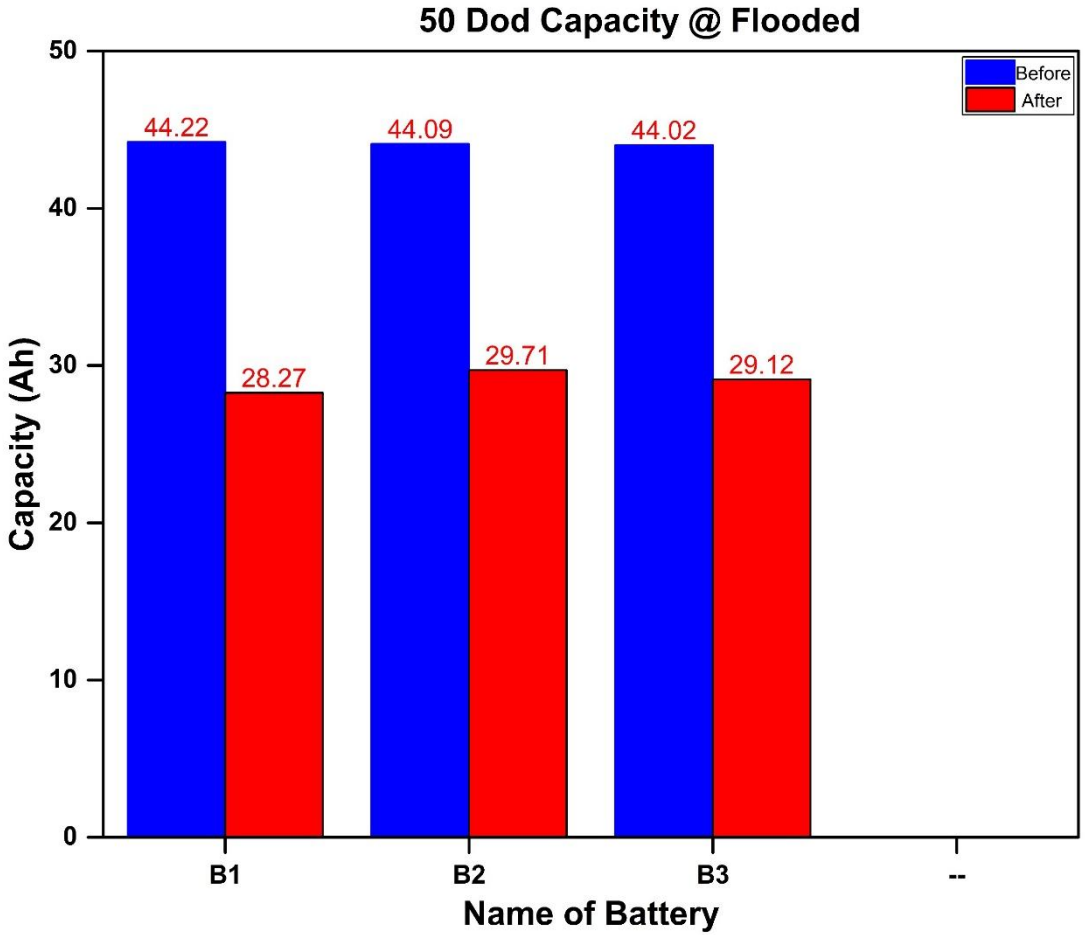
Section	Test	Level M1	Level M2	Level M3
EN 50342-6:2015,7.4	50 % DoD cycle test	≥ 150 cycles	≥ 240 cycles	≥ 360 cycles
EN 50342-6:2015,7.5	17.5 % DoD cycle test	≥ 9 units	≥ 15 units	≥ 18 units

17.5 % DoD Test : Cut-Open Images of Flooded SLI Batteries

Observation : Removal of separator was found to be easy at the top portion of the positive plate, whereas peeling off was difficult at the Bottom Portion. It is a physical indicator of electrolyte stratification.

50 % DoD : Performance of Flooded SLI

Battery	50 % DoD
Make-1	43 CYCLES
Make-2	16 CYCLES
Make-3	18 CYCLES



Performance of B1> B3> B2
> 40 % decline in capacity

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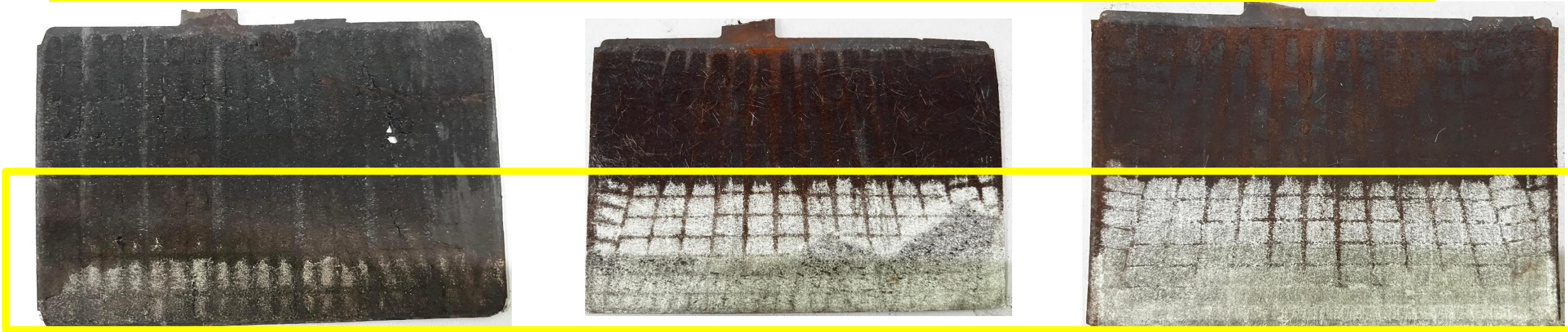
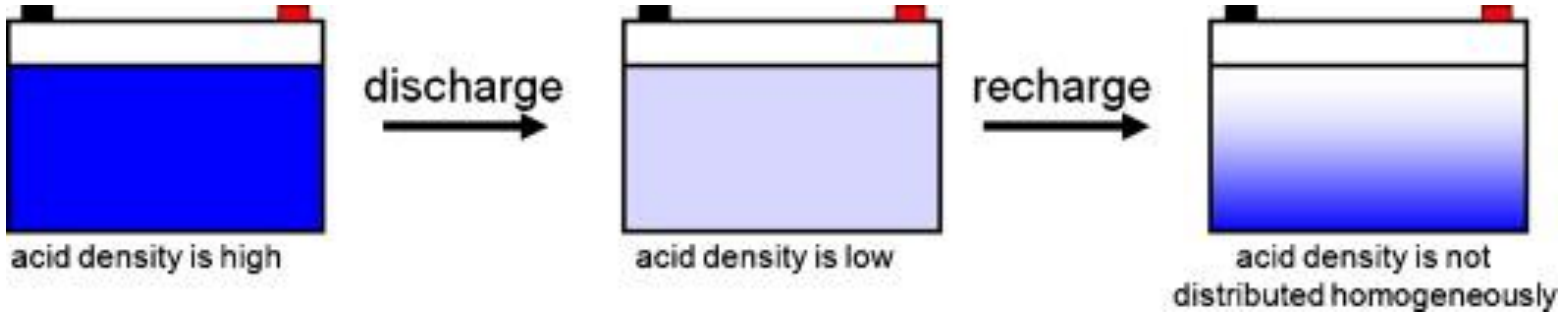
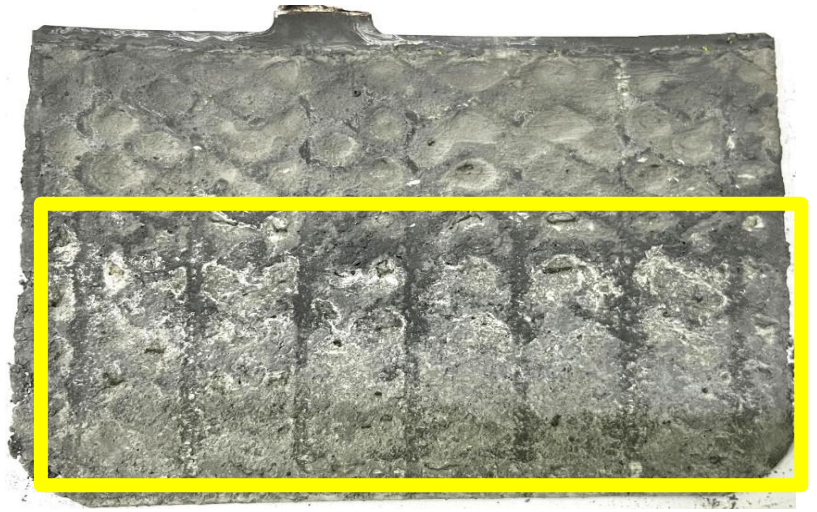
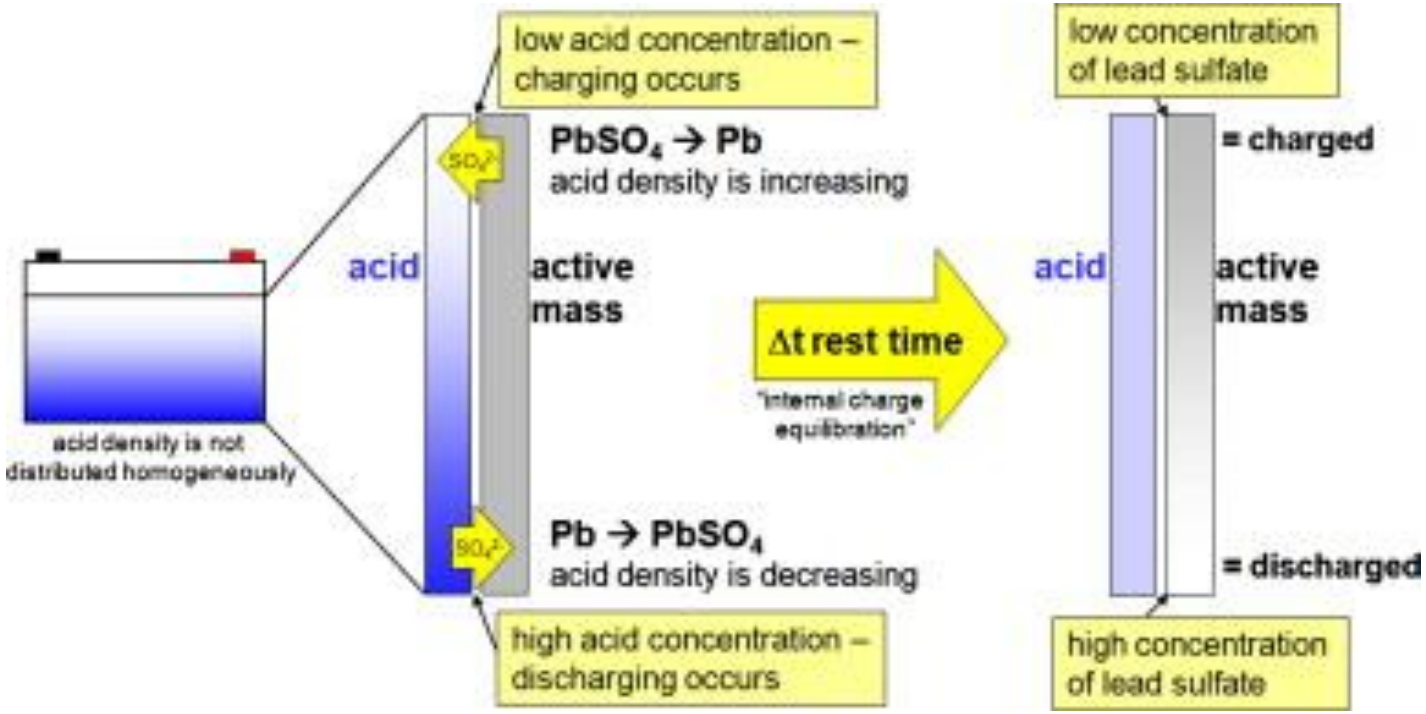


Common Failure Mechanism : Premature aging due to Stratification



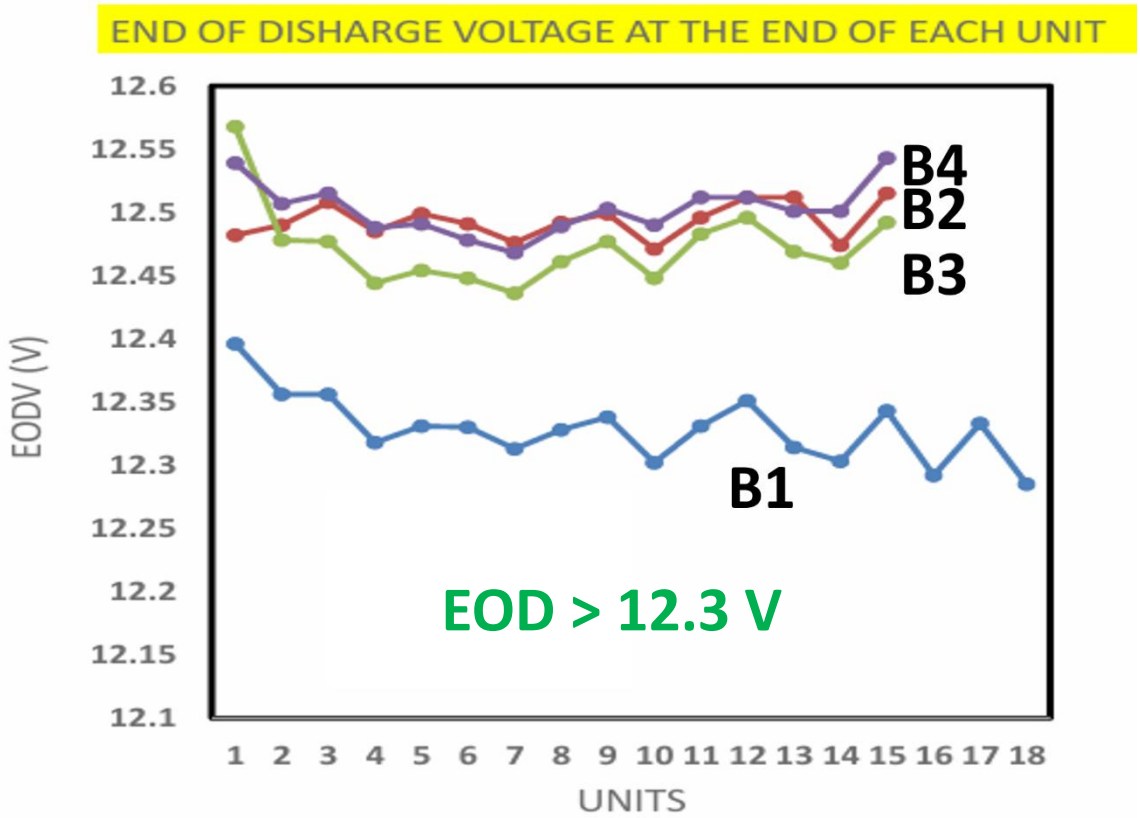




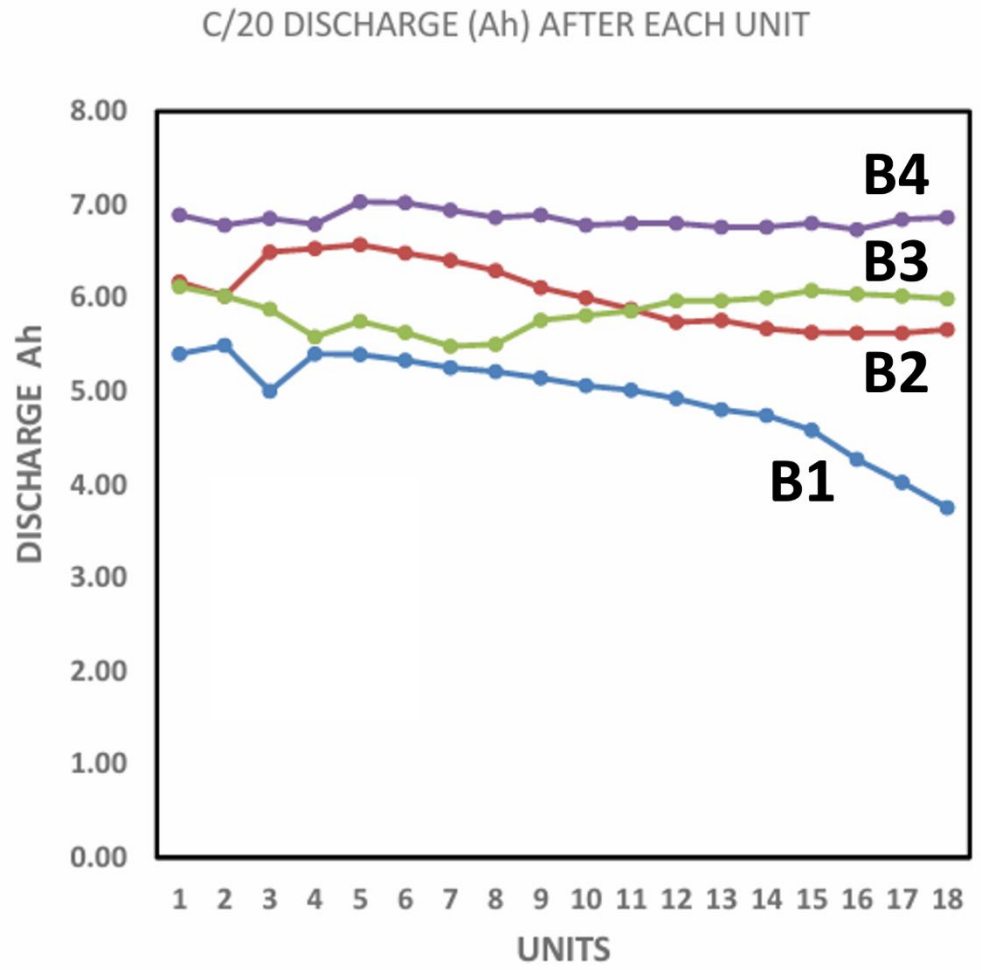
J Power Sources 196 (2011) 3993-4002

17.5 % DoD : VRLA SLI Results

Battery Type	17.5 % DoD
Make-1: B1	18 units (M3)
Make-2: B2	18 units (M3)
Make-3: B3	18 units (M3)
Make -4: B4	18 units (M3)
Make -5: B5	18 units (M3)



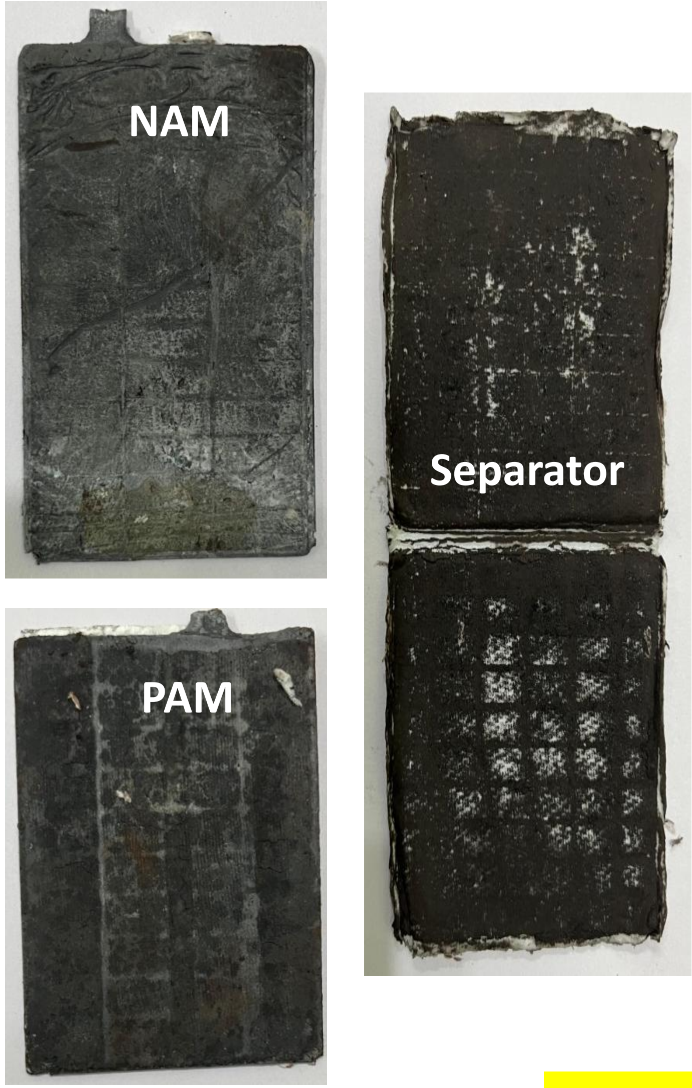
EOD > 12.3 V

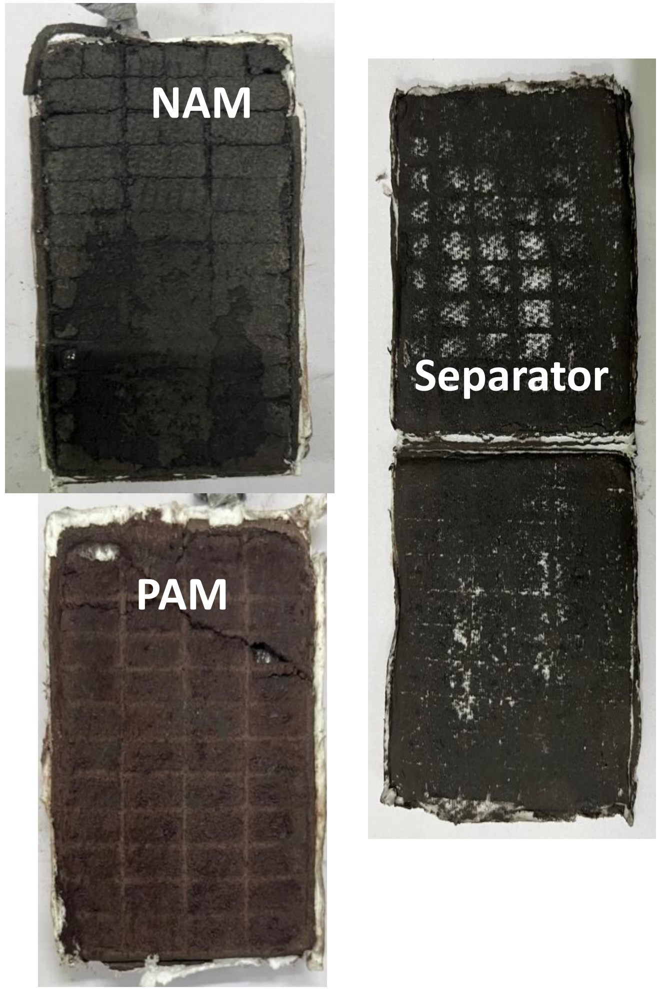


No significant capacity Loss after 18 units

31% (B1) > 9.5 % (B2) > 3 % (B4) > 2.7 % (B3)

17.5 % DoD Test : Cut-Open Images of SLI VRLA : SOFTENING

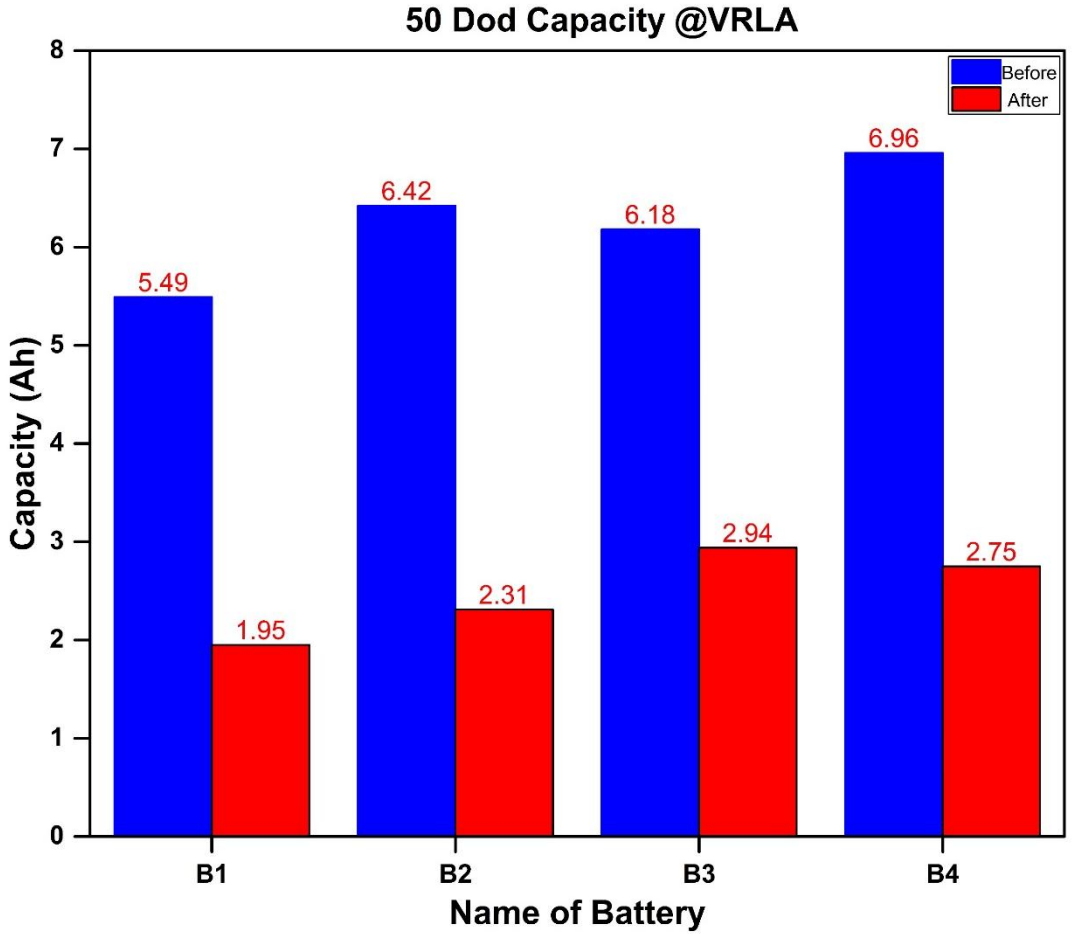




PAM Softening
PAM is still intact

Suitability of Indian Flooded VRLA for 50 % DoD tests

Battery Type	50 % DoD
Make-1: B1	212 (M1)
Make-2: B2	309 (M2)
Make-3: B3	158 (M1)
Make-4:B4	125 (Not Qualified)
Make -5:B5	304 (M2)



Loss in capacity > 50 %

Performance is different at 50 % DoD

Section	Test	Level M1	Level M2	Level M3
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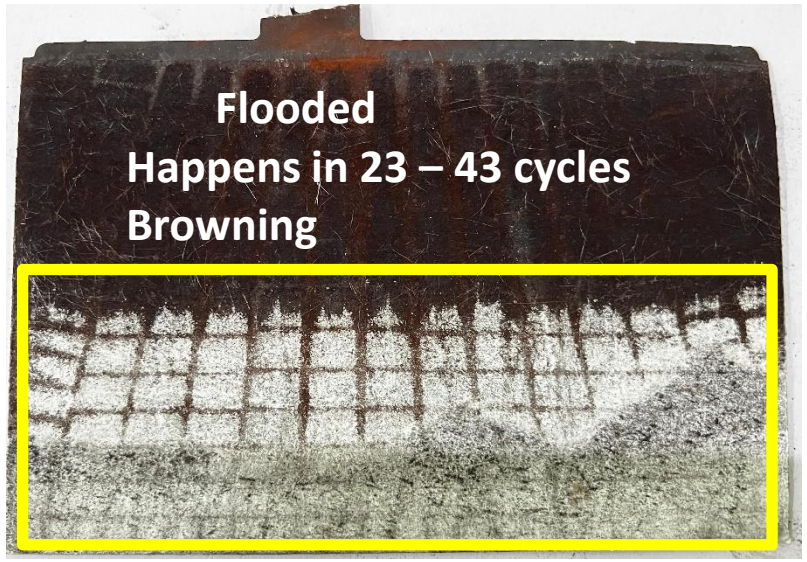
EN 50342-6:2015,7.5	17.5 % DoD cycle test	≥ 9 units	≥ 15 units	≥ 18 units

50 % DoD Test : Cut-Open Images of SLI VRLA

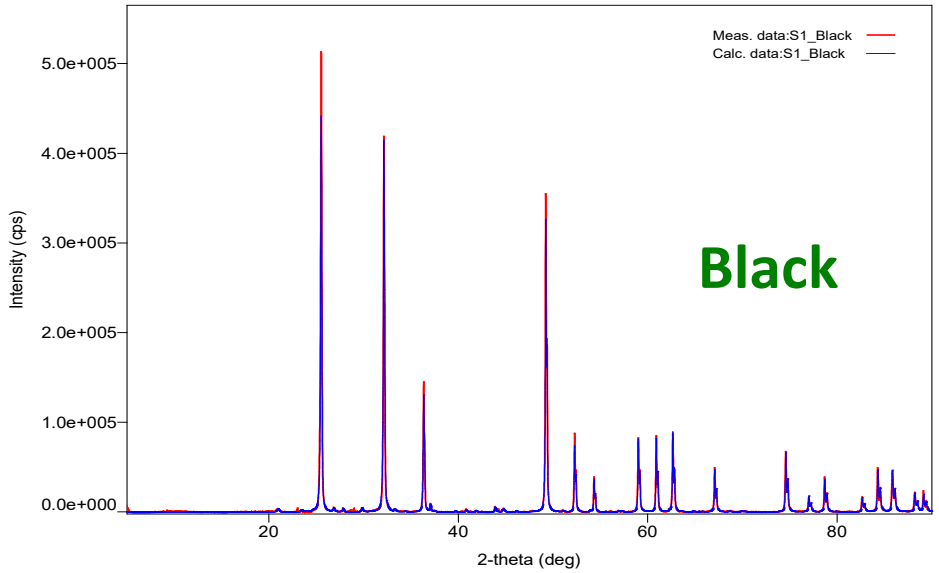
PAM turns Chocolate Brown as compared to Black

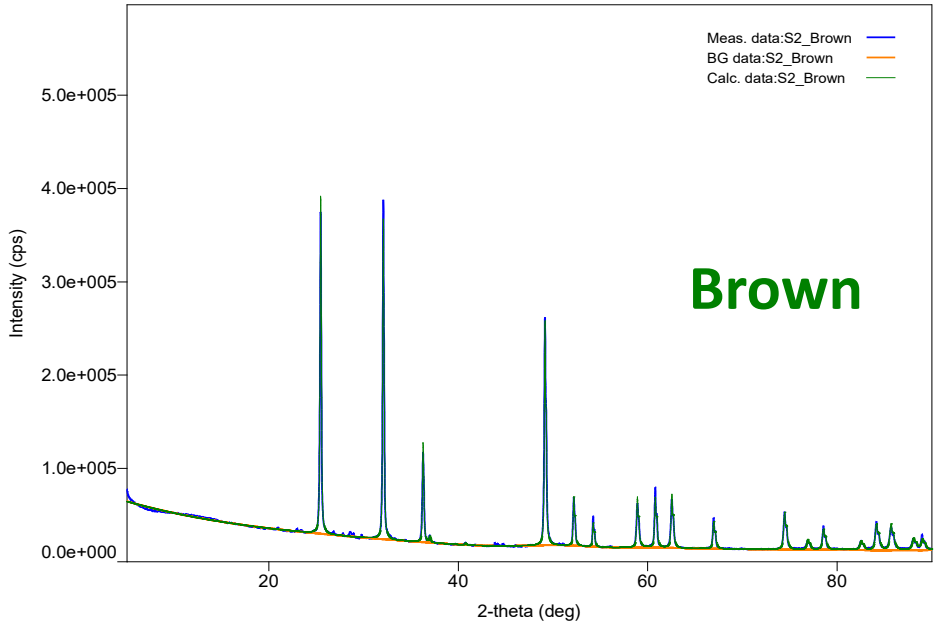
Flooded (EN-50342-6) vs VRLA (EN 50342-6)



Vs

Decoding Brown vs Black in PAM PbO2



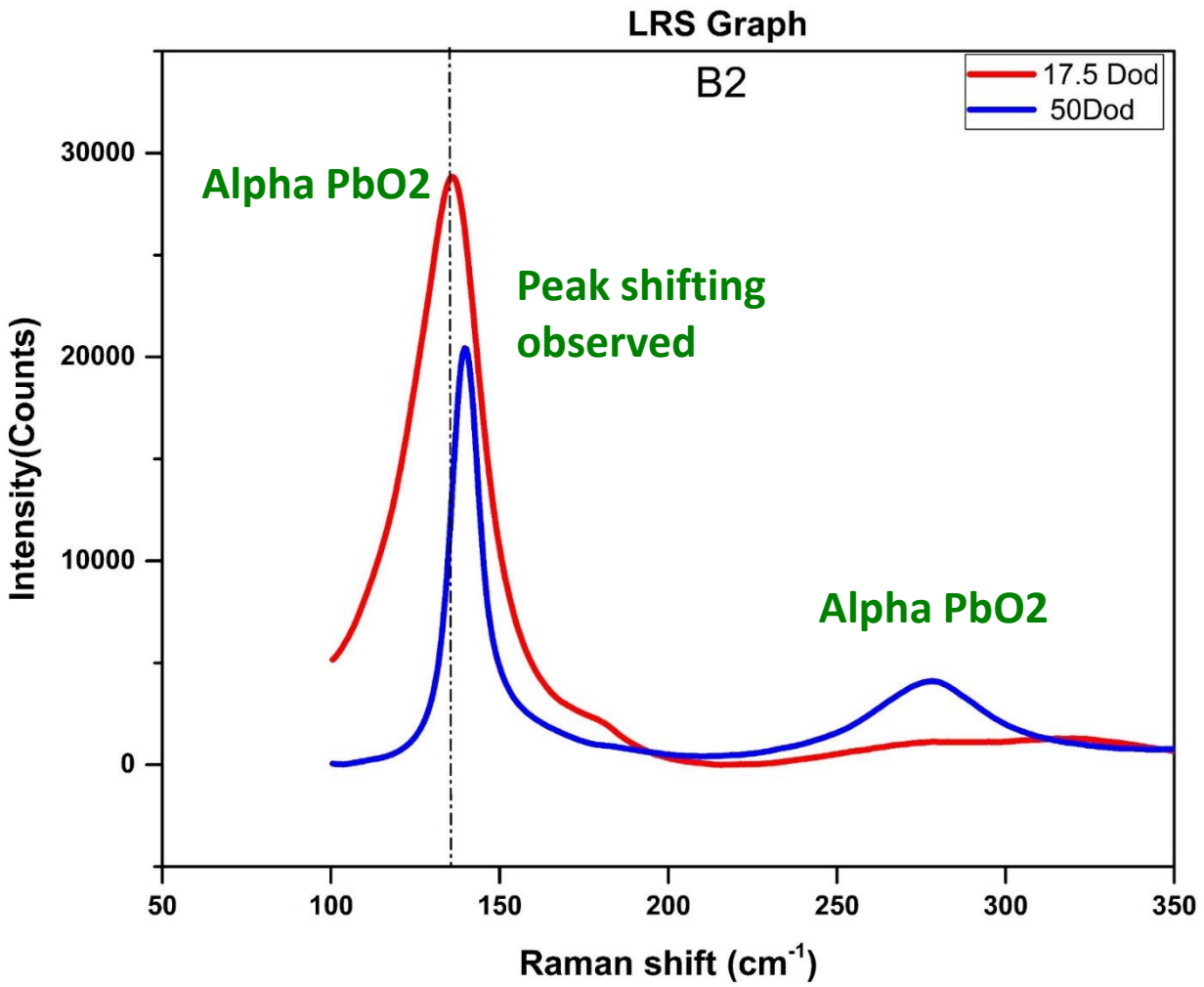


17.5 % DoD : Black PAM

XRD shows no significant difference between Black vs Brown PbO2

50 % DoD : Black PAM

Raman spectroscopy: α-PbO2



Browning = Confirms full conversion of β-PbO2 to α- PbO2

Black = Partial conversion of β-PbO2 to α- PbO2

Partial State of Charge (PSoC) Cycling

- Incomplete recharge of $PbSO_4$
- Residual Pb^{2+} at positive plate
- Local acid remains dilute
- Unstable $Pb^{2+} \rightarrow Pb^{4+}$ oxidation
- Formation of α-PbO_2 (brown, resistive)
- Plate develops high resistance + shedding

Battery capacity loss & failure

Why PAM turns brown (α-PbO2) quickly in Flooded as compared to VRLA ???

FLOODED BATTERY

- Large reservoir of free liquid electrolyte → fast ionic transport possible.
- But during charge, acid stratification develops (dense acid near bottom, dilute near top).
- This creates local concentration gradients → near the positive plate, Pb^{2+} and SO_4^{2-} are transported unevenly.

Result: non-uniform current density + high local over potentials → rapid, porous α-PbO_2 nucleation (kinetic product).

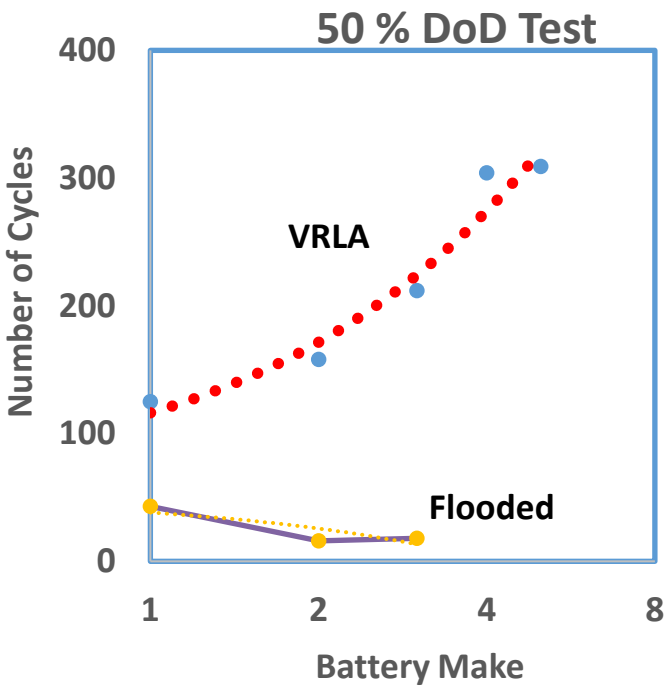
VRLA (AGM/Gel)

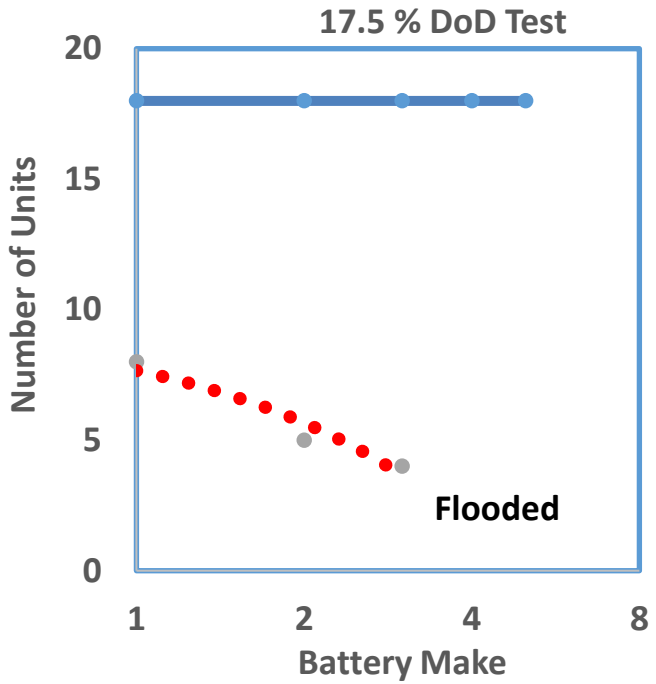
- Electrolyte immobilized in glass mat or gel → restricted diffusion of ions.
- Acid stratification is strongly suppressed.
- Mass transport is slower and more uniform → current density is smoother, over potentials are moderated.

This promotes α-PbO_2 formation at slower rate.

Fast, uneven mass transport → unstable conditions → α-PbO_2.

Summary and Outlook





In the 17.5 % DoD Units graph, the performance trend of Flooded batteries does not follow the same parallel progression as VRLA.
Flooded curve is displaced to lower performance values, indicating a different degradation behavior (STRATIFICATION) rather than a simple downward shift.

- Significant difference exists between VRLA batteries (makes) for 50 % DoD cycling.
- Flooded SLI shall not used for Micro-Hybrid Vehicles.
- Best in-class Indian SLI VRLA can be used directly for Car & 2-Wheelers
- Testing of EFB is in progress (whether they can run parallel to VRLA ??????????????)

Flooded vs VRLA Comparison

Parameters	Flooded	VRLA
17.5 % DoD	4 to 8 units	18 units (M3)
Failure	Stratification (NAM & PAM) Sets in 35 days	Softening (PAM) However, no significant drop in capacity even after 18 units
50 % DoD	16 to 43 cycles	125 to 309 cycles (M2)
Failure	Stratification (NAM & PAM) Sets in 5 days/ Browning	PAM browning / NAM intact.
Browning	Conversion of β to α- PbO_2	Conversion of β to α- PbO_2
Rate of browning	Faster (Poor cycle life)	Slower (High cycle life)

SLI Flooded durability drops under shallow / high stress conditions, whereas SLI VRLA retains a more balanced performance across both conditions.

Acknowledgement

TEAM CSIR-BPTEC & OUR PROUD CUSTOMERS

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