High End Lead Acid Battery to Support Latest Automotive Powertrain

21 ABC **ASIAN BATTERY CONFERENCE**

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Modern Vehicle – Market Trend

- *Conventional ICE → HEV and BEV*
- *Micro and Mild Hybrid vehicle already established a significant share*
- *Adoption of Strong Hybrid, Plug-in Hybrid, BEV to increase steadily over the next years*
- *Modern vehicle demands high performance, efficiency & reliability from Battery*

Fuel-Wise Domestic Vehicle Sales - India			
Vehicle Type	FY 2024 (Million Units)	FY 2025 (Million Units)	Change
Petrol	2.66 M	2.48 M	-6.6%
Diesel	0.76 M	0.80 M	+4.6%
CNG	0.63 M	0.84 M	+34%
Hybrid	0.09 M	0.11 M	+18%
Electric	0.10 M	0.12 M	+19%

Source: Society of Indian Automobile Manufacturers (SIAM)

Shift Towards Electrification

Micro Hybrid	Mild Hybrid	Strong Hybrid	Plug in Hybrid	Battery Electric Vehicle
				
M&M Scorpio	MSIL Ertiga	Toyota Hyryder	Volvo XC40	M&M BE 6

Technology Change in Modern Vehicle

Less Carbon Footprint to meet stringent emission norms

[EURO by European Union, CAA in US, CAFÉ in India]

Improved Fuel Economy by increasing battery utilization

[Lowering Battery Charging Voltage & More Ah Throughput from Battery]

Climate Change Agreements & Net Zero Emission Commitment

KYOTO PROTOCOL | COP 3 | 1997

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

UNITED NATIONS
PARIS CLIMATE
AGREEMENT
SIGNING CEREMONY
22 APRIL 2016

UN CLIMATE
CHANGE
CONFERENCE
UK 2021
IN PARTNERSHIP WITH ITALY

*** INDIA'S NET ZERO EMISSIONS TARGET BY 2070 ***

United Nations
Climate Change

COP29
Baku
Azerbaijan

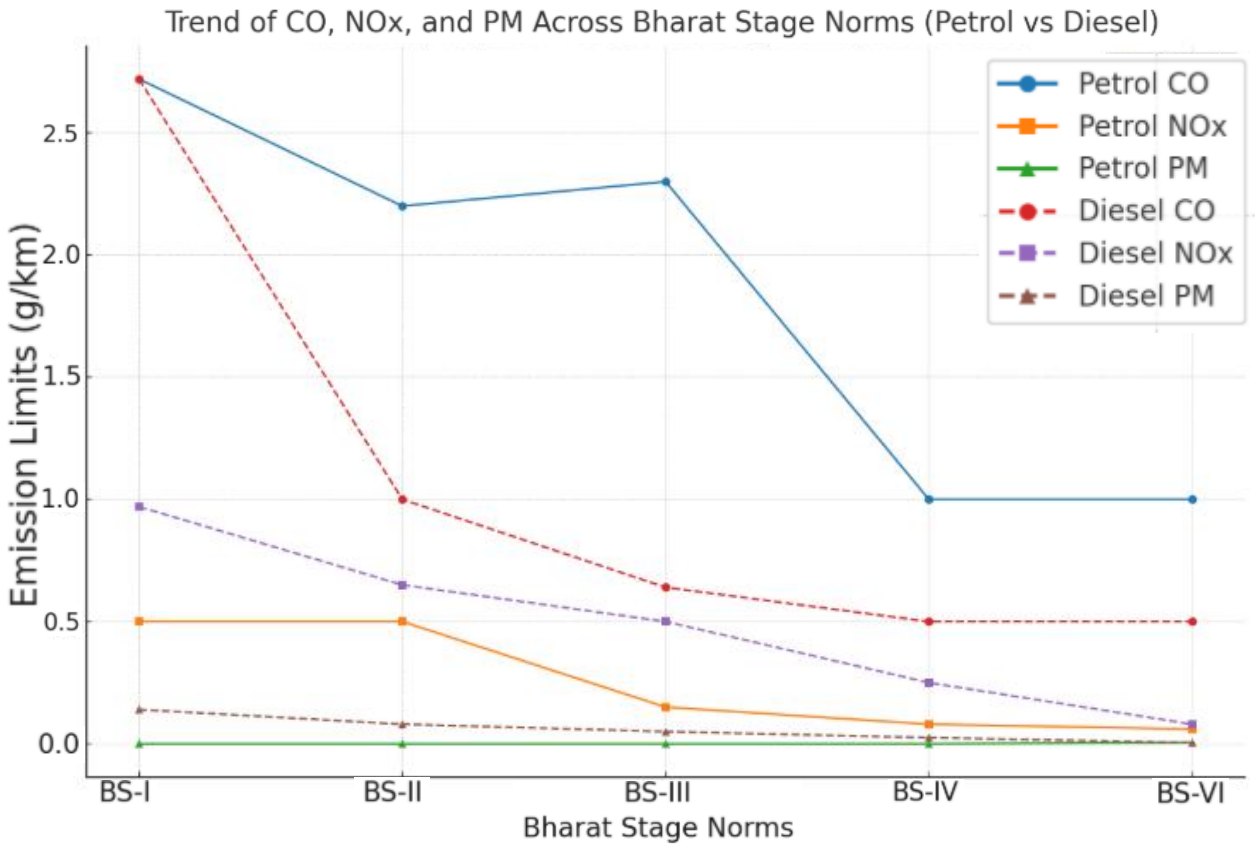
Decarbonization of Transport

Push For Renewable Energy Sources

Focus on Sustainability

Change in Pollution & Emission Norms in India

Bharat Stage (ES) : Pollutant Emission Norm



2000 **2005** **2010** **2017** **2020**

Corporate Average Fuel Efficiency (CAFE) : CO_2 Emission Norm

Phase	Year	CO_2 Limit (g/km, fleet average)	Equivalent Fuel Economy
No CO_2 norms	Pre-2017	–	–
CAFE I	2017–2022	130 g/km	~18.2 km/l
CAFE II	2022–2030	113 g/km	~22.2 km/l
CAFE III (proposed)	~2030	~95 g/km	~26 km/l (depends on final rule)

Above norms drives the vehicle transformation in Indian Market

Technology Change in Modern Vehicle

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Improved Fuel Economy by increasing battery utilization

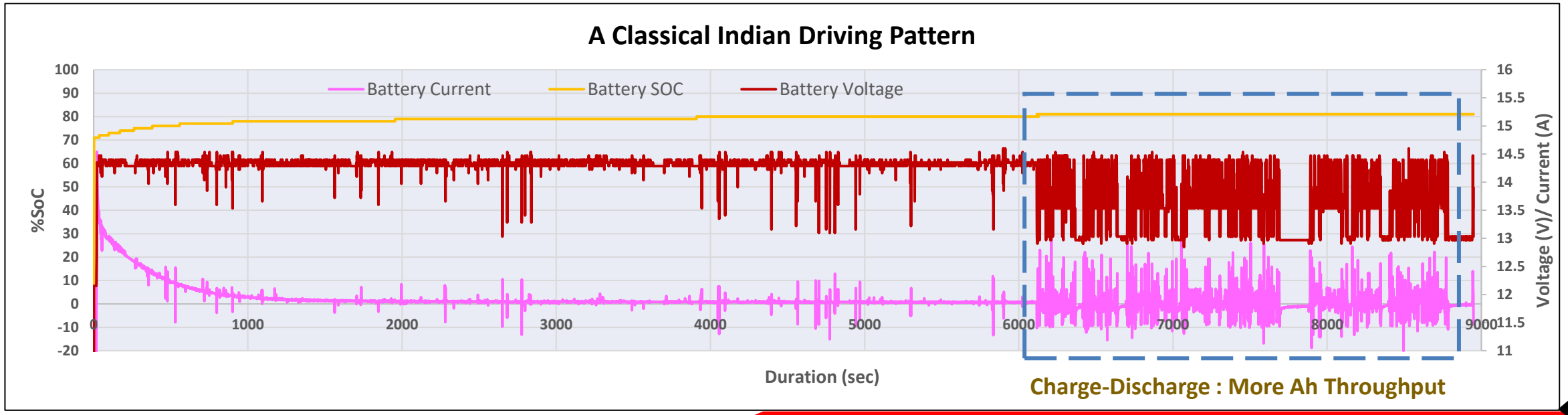
[Lowering Battery Charging Voltage & More Ah Throughput from Battery]

Vehicle Transformation in Indian Market

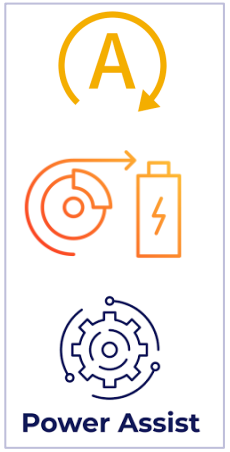
Scenario 1 : Change in Charging Voltage pre & post CAFÉ I & CAFÉ II

Mode	Battery Charging Voltage before 2017 (V)	Battery Charging Voltage after 2017 (V)	Battery Charging Voltage after 2022 (V)
No load	14.4	14.1	13.9
Day mode (with AC)	14.3	14	13.8
Night Mode (with AC + Head Lamp)	14.1	13.8	13.7

Scenario 2 : Variable charging voltage > 80%SoC

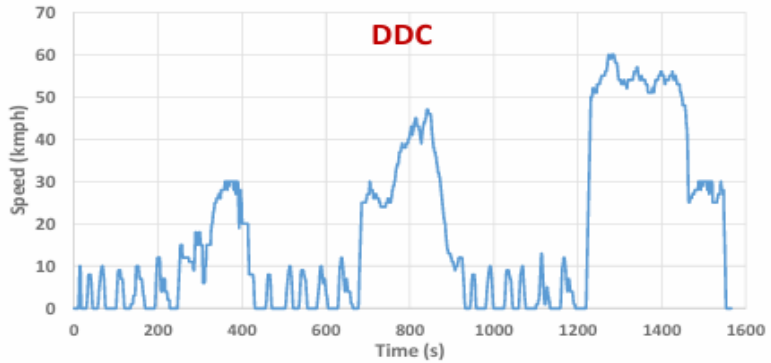


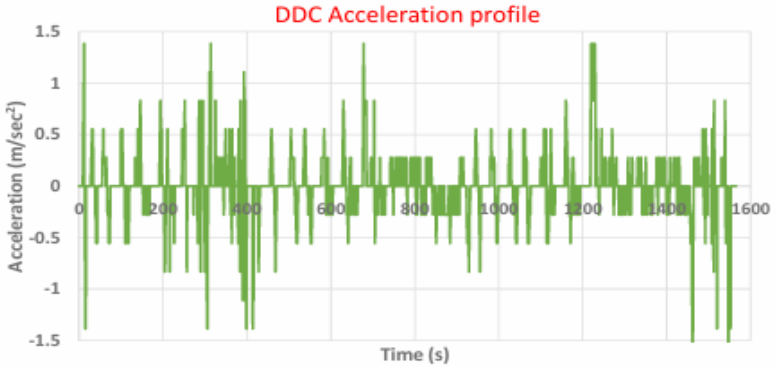
Features in Modern Vehicles

Feature		Effect on Car	Effect on Battery
▪ *Stop-Start*		*For reduced emission & better fuel economy*	*Operate at lower SoC*
▪ *Regenerative Breaking*		*Recuperation of energy when brake is applied*	*Ability to capture recuperation energy*
▪ *Torque/ Propulsion Assist*		*Support from battery during acceleration*	*Operate at lower SoC*
▪ *Smart Alternator*		*To achieve better fuel economy*	*PSoC operation*
▪ *High Electrical Load*		*Large infotainment, ECUs, power seat, ADAS*	*Operate at lower SoC*
▪ *Increased Parasitic Drain*		*Shift from mechanical to digital control*	*PSoC operation*

Key Features

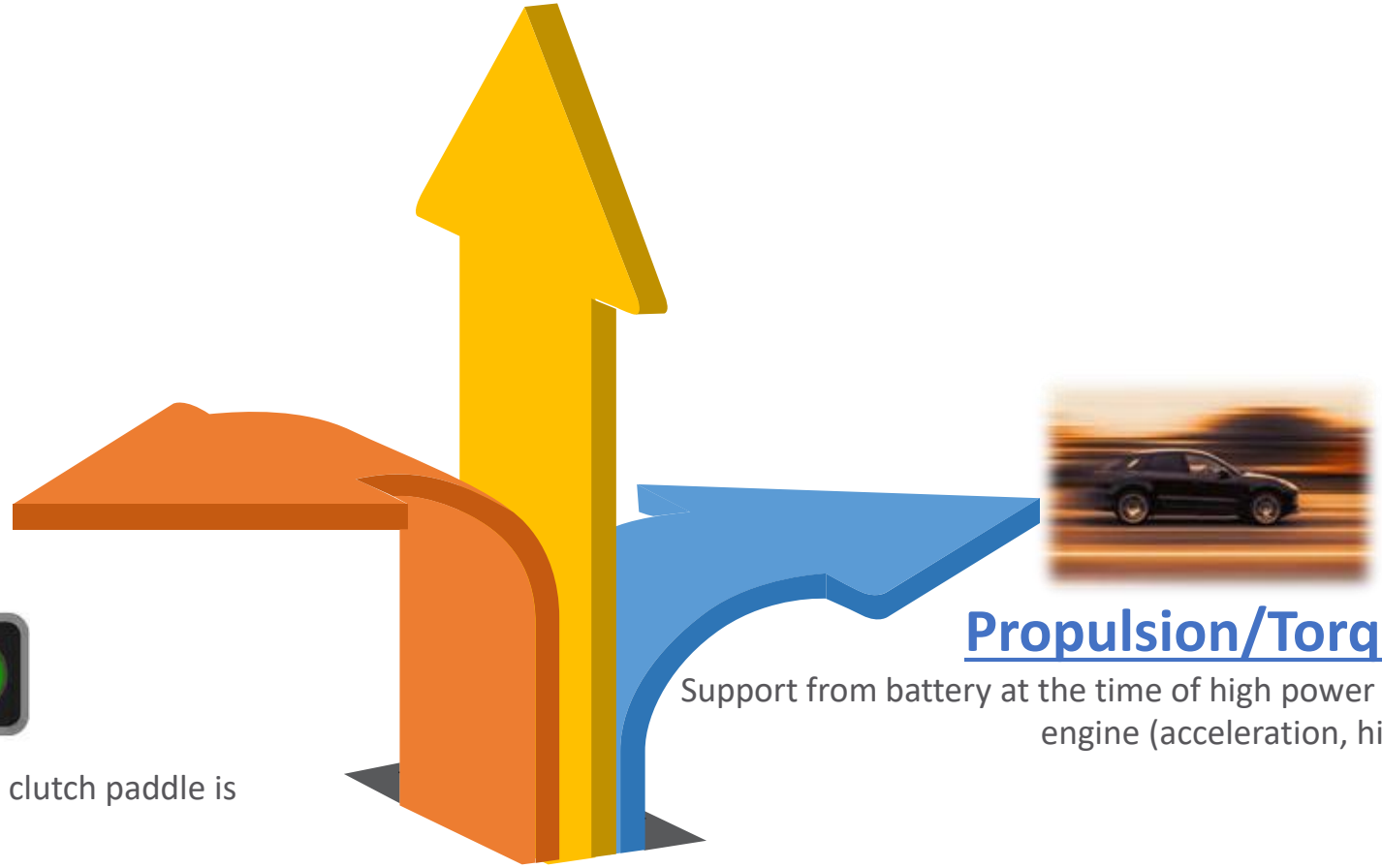
Drive Cycles





Brake Energy Recuperation

When the driver decelerates, the electric machine (motor/generator) turns the kinetic energy of the wheels into electricity → This energy is stored in a battery → Energy used to: help accelerate the vehicle/ power electrical systems/ reduce engine load (saving fuel)



Propulsion/Torque Assist

Support from battery at the time of high power requirement of engine (acceleration, hill climbing etc.)

Start-stop

Engine stop at idle rpm & start when gear change/ clutch paddle is pressed → Frequent cranking at signals

Features in Modern Vehicles

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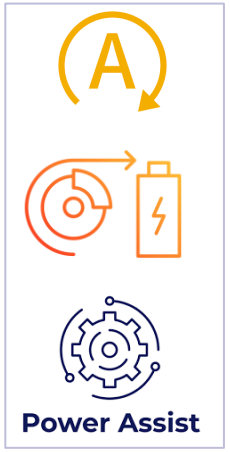
▪ *Stop-Start*		*For reduced emission & better fuel economy*	*Operate at lower SoC*
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Smart Alternator

Use

Along with Stop-Start & Hybrid cars, now smart alternator is used in **Conventional (Non-Hybrid) ICE Vehicles**

Advantage

Improve fuel efficiency by optimizing charging based on driving conditions (1 – 3% MPG gain)

How it works?

ECU controlled voltage regulation based on driving conditions

Reduced charging during acceleration (Lower engine load)

Increased charging during deceleration/coasting

Features in Modern Vehicles

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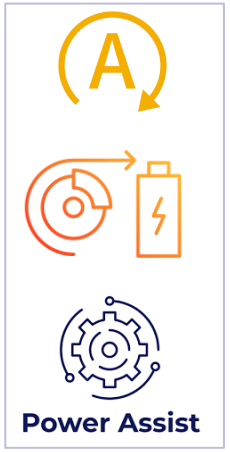
▪ *Stop-Start*		*For reduced emission & better fuel economy*	*Operate at lower SoC*
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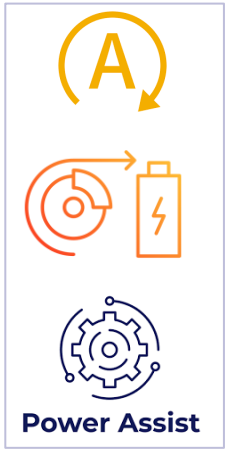
High Electrical Loads

Loads on Battery during Vehicle Standby / Parked

- *Standby power to security & parking sensors*
- *Luxury features viz. Ventilated seats, Sunroof, Air purifier, USBs, Wireless Mobile Charger*
- *ECUs & memory*
- *Door locking + Remote access*

					
Parking Sensors	Telematics	Keyless Entry	Ventilated Seats	GEO Fencing	Dash CAM

Features in Modern Vehicles

Feature		Effect on Car	Effect on Battery
▪ *Stop-Start*		*For reduced emission & better fuel economy*	*Operate at lower SoC*
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Our Study on Modern Vehicles

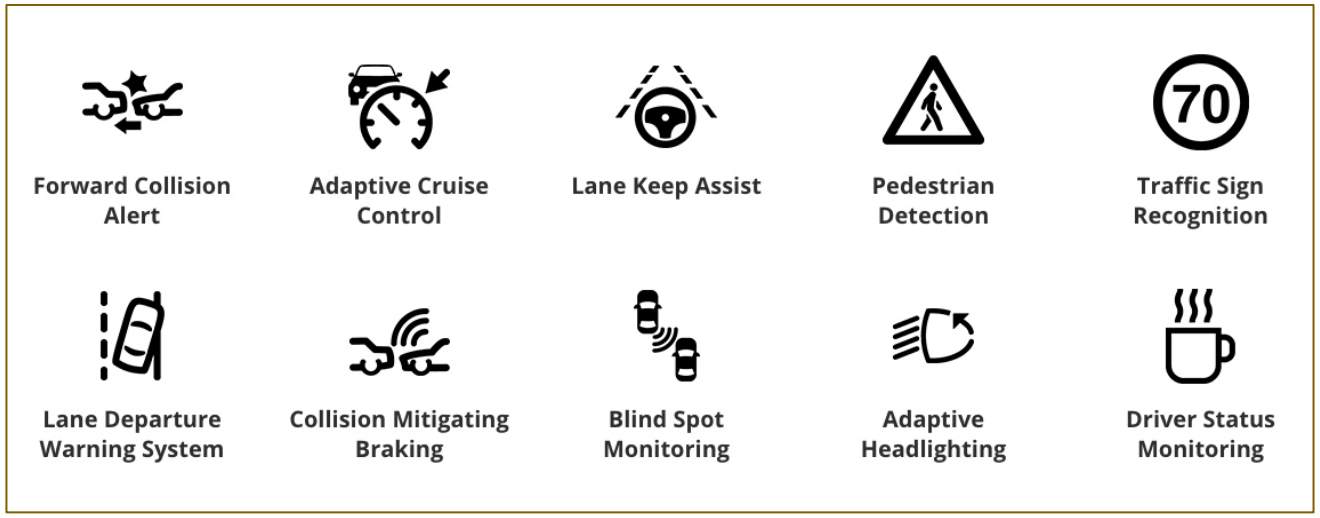
Key Findings

Vehicle Feature	Observed values on Battery	Remarks
ISG (Integrated Starter Generator)	*Low Inrush (approx. 200A – 300A)*	*Suitable for stop-start operation at lower SoC*
Varying Charging Voltage	*13V to 13.9V at different loading condition*	*Low charging voltage triggers PSoC condition & better fuel economy*
Power Assist	*Transient accessory load transfer on battery (up to 25A)*	*Support required from battery*
Regenerative Braking	*Sudden increase in voltage (from 13V to 14.5V) & current (from 1A to 26A)*	*Battery has the capability of absorbing the charge*

Advanced Driver Assistance System (ADAS)

- ✓ Set of **electronic systems in vehicles that assist the driver** in driving and parking functions
- ✓ **Increase vehicle safety** and **reduce human error**

Features under ADAS



ADAS engage below components as & when required

- ***Cameras & Radar sensors***
- ***Lidar units***
- ***Control units (ECUs) & Display systems***
- ***Actuators (for steering/braking assist)***

Note :

- ✓ Above components powered by **Battery/ Alternator**
- ✓ Doesn't consume **very high current**, but as the number of features increases, the **cumulative electrical load** becomes significant

Requirement from Battery

- ✓ **Higher PSoC Cycle Life** – Batteries must withstand frequent charge/discharge cycles (start-stop vehicles) → **High Ah Throughput**
- ✓ **Fast Charging Capability** – Improved charge acceptance for regenerative braking and auxiliary power → **Dynamic Charge Acceptance (DCA)**
- ✓ **Deep Discharge Resistance** – Critical for commercial and hybrid vehicle applications
- ✓ **High Cold Cranking Amps (CCA)** – Essential for reliable cold-weather performance
- ✓ **High key-off load** viz. Large infotainment, Door sensors, Mobile app. connectivity, ADAS, TPMS, Valves & sensors etc.

Above shift creates a demand for EFB and AGM batteries, which offer improved performance, durability and efficiency compared to regular batteries

EFB Technology

- **Advantage**

  - ✓ *Lower state of charge operation and superior deep-cycling performance*
  - ✓ *Support for a high number of engine starts and extended engine-off periods*
  - ✓ *Improved charge acceptance compared to conventional flooded batteries*

- **Battery operate at lower SoC (65% - 75%)**

Product Feature

- ✓ ***Optimised Plate Design***
- ✓ ***Corrosion Resistant alloy***
- ✓ ***Holding of Active mass in Cycling***
- ✓ ***Advanced Separator***
- ✓ ***Low Water Loss***

EFB : Design Considerations

Improved Plate Making

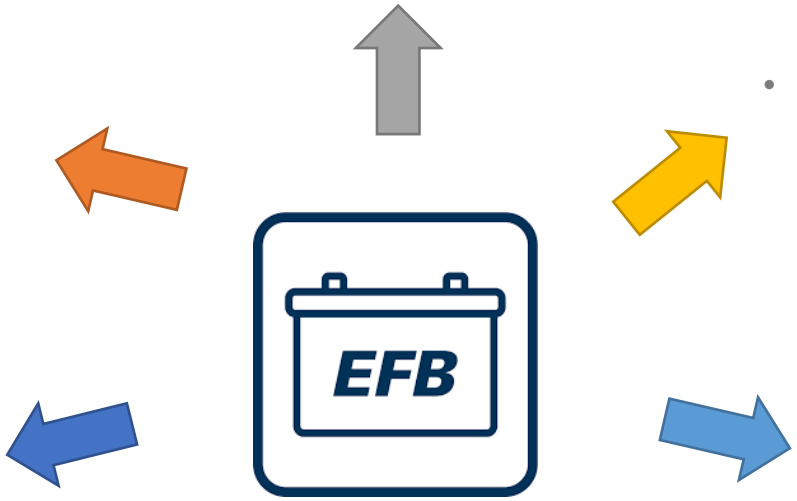
- *Negative paste recipe with high conductive carbon → Increase charge acceptance*
- *Special paper coating on plate → Prevent shedding*
- *Optimise curing schedule for better bonding*

Enveloping

- *Positive enveloping enhances Negative plate performance*
- *Remove Glass mat to reduce IR → Ensure cranking at PSoC condition*

Double Lid

- *Reduce water loss*
- *To meet stringent physical tests*



Superior Grid Technology

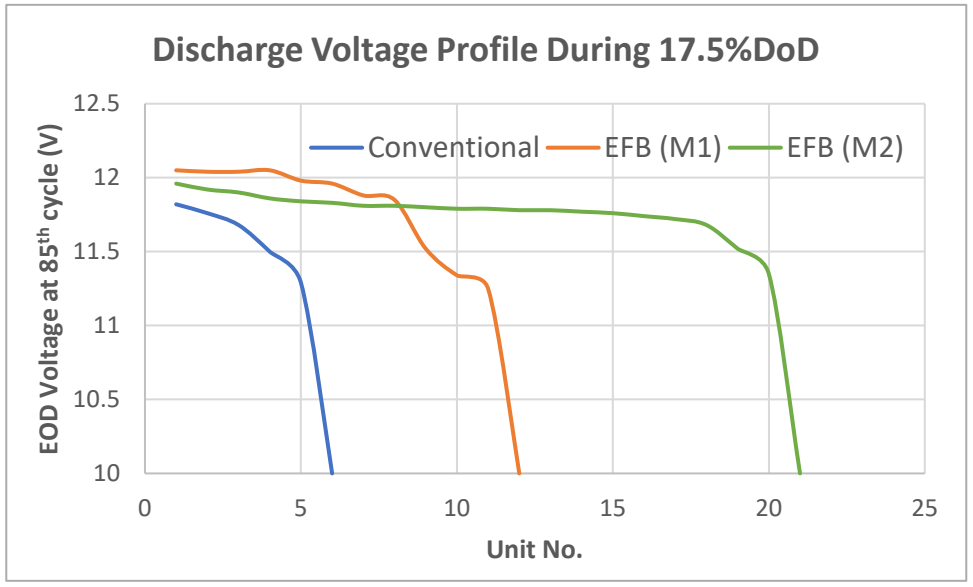
- *Improve power to weight ratio*
- *Corrosion Resistant Alloy → Less water loss*

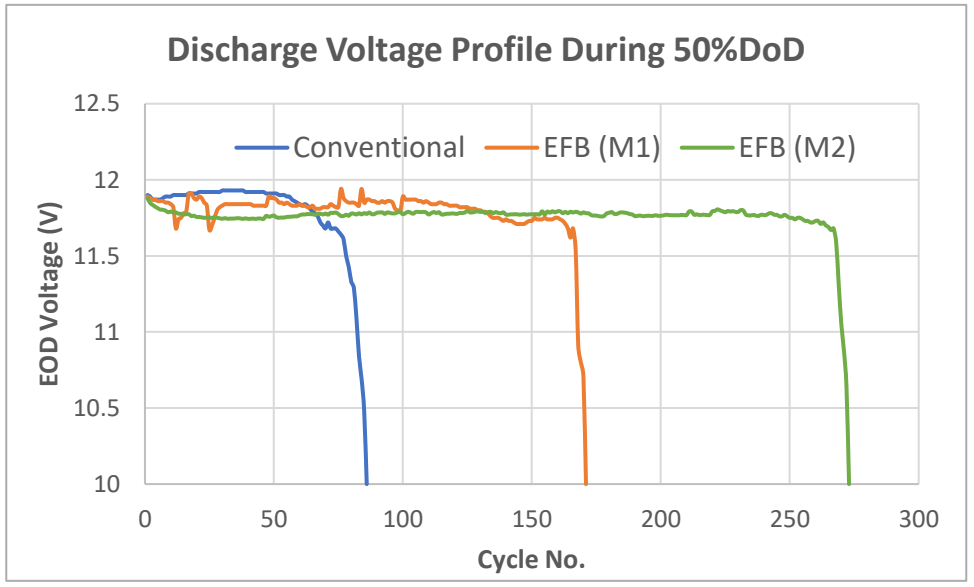
Formation

- *Optimize charging regime → better conversion*
- *Less variation in final Sp. Gravity*

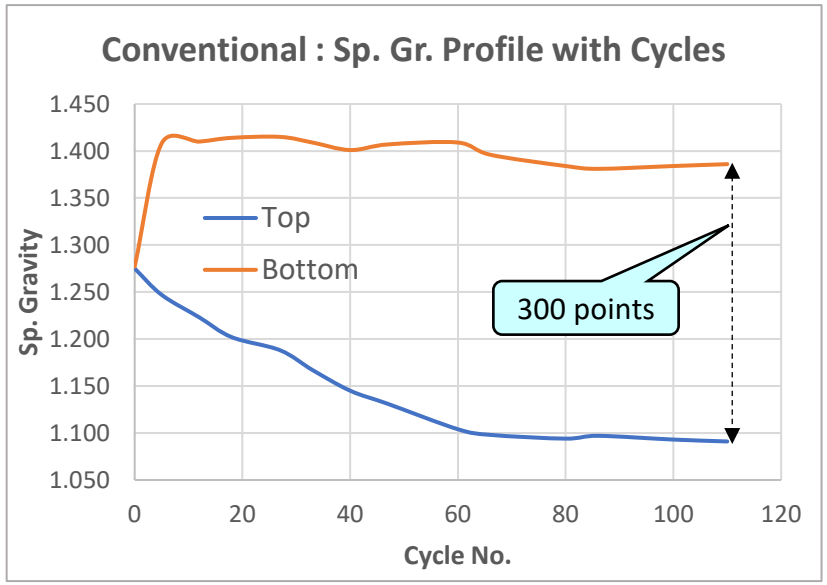
PSoC Test Results as per EN50342-6

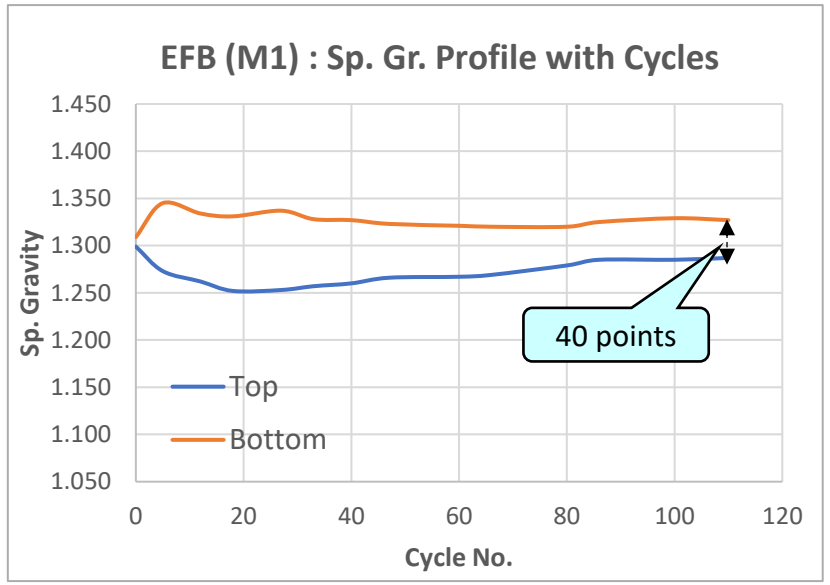
Test types	Conventional Battery	EFB (M1)	EFB (M2)
17.5%DoD at 25°C	5 units	11 units	20 units
50%DoD at 40°C	85 cycles	170 cycles	271 cycles
Water Loss at 60°C	1.4 gm/ Ah (21 days)	1.1 gm/Ah (21 days)	1 gm/Ah (21 days)

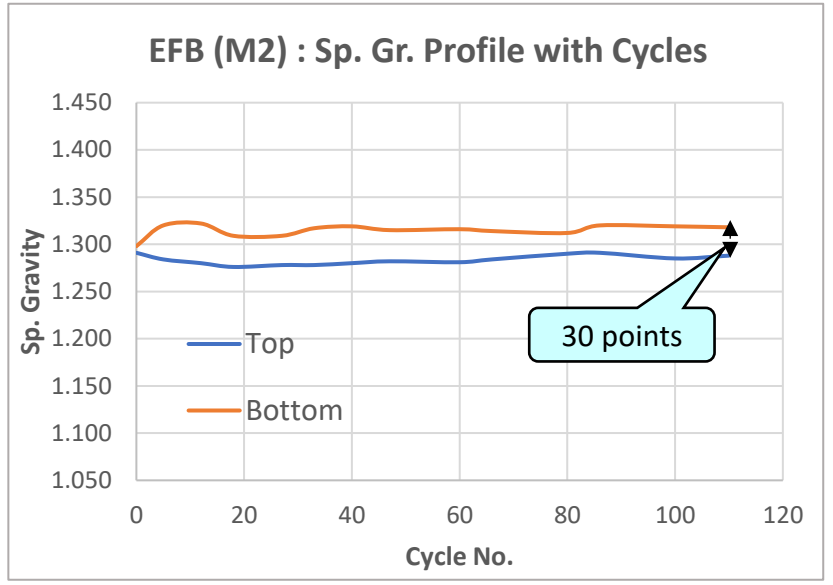


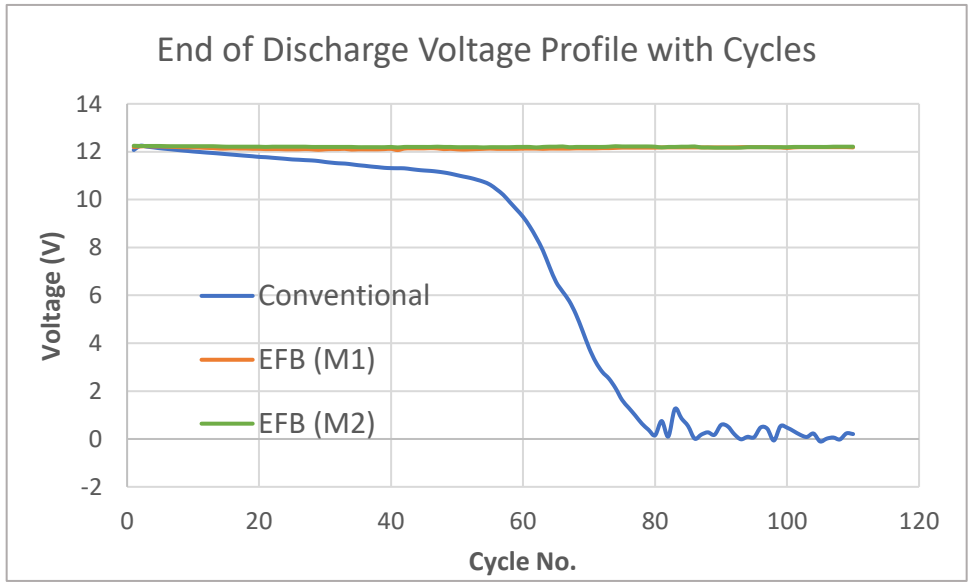


Simulated PSoC Cycling Test in Lab









❖ Simulative Test Protocol from Classical Indian Driving Pattern

- ***Test Temperature 27±2°C***
- ***Take full charge battery***
- ***Discharge @4*I20A for 1.25 hrs (25%DoD)***
- ***Charge at 14V (limit current 14.5*I20A) for 2.25 hrs.***
- ***Repeat above cycles for 110 times***

Observation

- ***Acid stratification in conventional battery***
- ***Ah Input 100% - 102%, however drop in voltage observed in conventional battery***

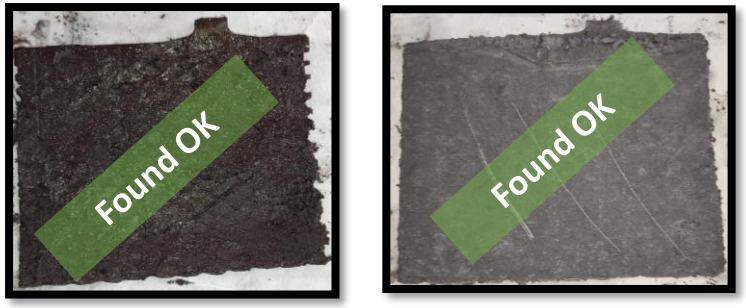
Failure Modes of Conventional Battery

Root Cause Analysis

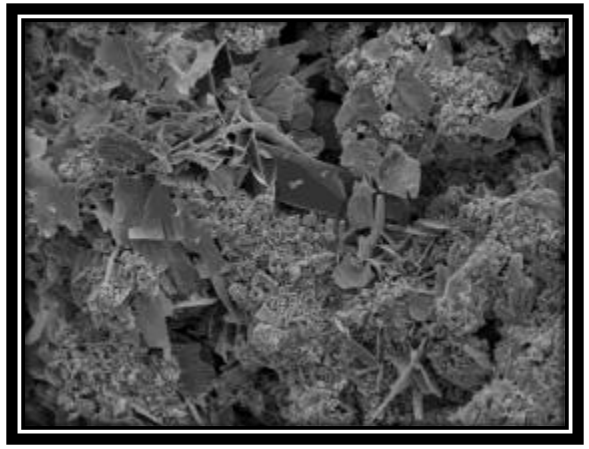
- ✓ *High DoD operation (25% - 35%)*
- ✓ *Inadequate charging resulting sulphated negative*
- ✓ *PSoC operation resulting paste shedding*

Cut Open Observation : Conventional battery

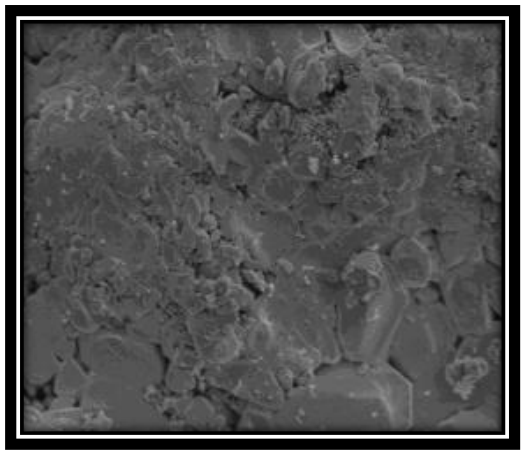
Cut Open Observation : EFB



SEM Analysis of NAM



Freshly formed : nano sized Pb crystals with occasional metallic deposition



Failed batteries : large agglomerates of $PbSO_4$ crystals with substantially reduced reactive surface area

Magnification : 5000 X

AGM Battery

- **Advantage**
  - ➢ Support for a high number of engine starts and extended engine-off periods
  - ➢ Support High DCA
  - ➢ Leak proof & no maintenance
  - ➢ Low water loss
- **Battery operate at lower SoC (65% - 75%)**
- **Sensitive to overcharging & heating → Thermal runway**

50Ah SLI AGM

60Ah SLI AGM

Product Feature

Superior Grid Technology	• *Punched or Cast grid technology with corrosion resistant lead alloy* ➢ *Enhanced mechanical strength* ➢ *Good electrical conductivity* ➢ *Low water loss at elevated temperature*
Improved Plate processing	• *Special additives in Positive active mass to improve bonding & cycle life* • *Optimised Negative paste recipe to get high DCA* • *Special surface treatment to restrict hydration short (Punch plate)*
Higher Boxing tightness	• *Reduce active material shedding* • *Maintains physical integrity under high vibration & repeated cycling* • *Enhance charge acceptance under PSoC condition*

Design of Experiments

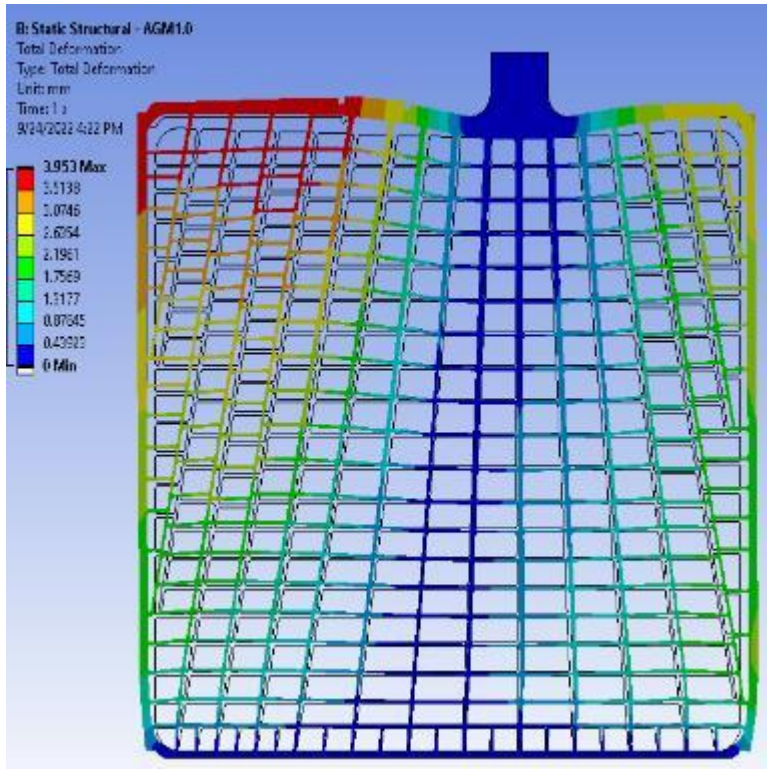
- DOE with different plate types to meet Global Standards

Tests/ Specification	Target	Cast-Cast	Cast-Punch	Punch-Punch
	DIN60			
C20	60Ah	✓	✓	✓
CCA	640A	✓	✓	✓
17.5% DoD (25°C/60°C)	18 Units	✓	✓	✓
50% DoD (40°C)	360 Cycles	✓	✓	Up to 100 Cycles
Corrosion Test (60°C)	5 Units	✓	✓	✓
Water Loss (42 days)	<4 gm/Ah	✓	✓	✓
Weight Spec. for OEM Customers	A	A++	A+	A

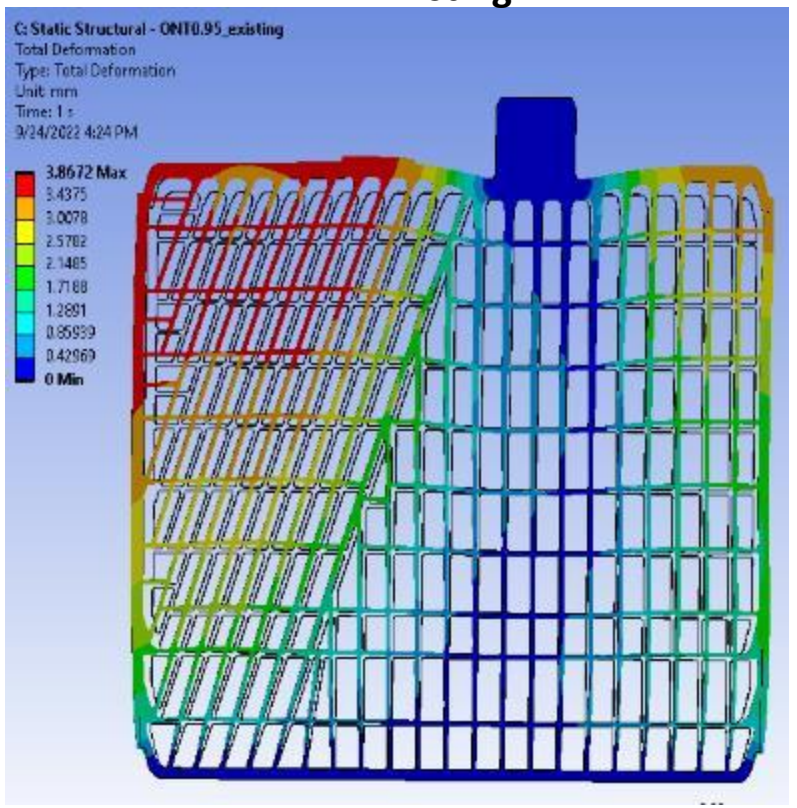
Punch-Punch Grid Development

- Benchmarking on Globally available AGM batteries
- Further optimization on grid structure

AGM



Existing



✓ Average Deformation reduced by 9% over existing grid
✓ Area of high deformation zone reduced significantly

Design of Experiments

- DOE with different plate types to meet Global Standards

Tests/ Specification	Target	Cast-Cast	Cast-Punch	Punch-Punch
	DIN60			
C20	60Ah	✓	✓	✓
CCA	640A	✓	✓	✓
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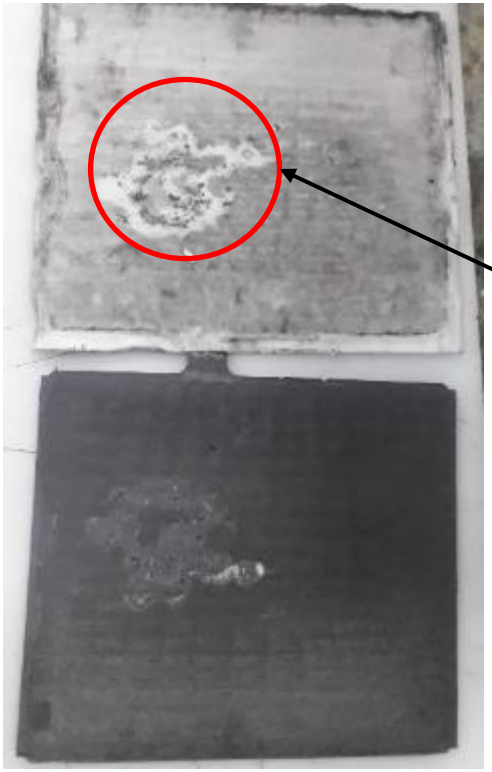
50% DoD (40°C)	360 Cycles	✓	✓	Up to 100 Cycles
Corrosion Test (60°C)	5 Units	✓	✓	✓
Water Loss (42 days)	<4 gm/Ah	✓	✓	✓
Weight Spec. for OEM Customers	A	A++	A+	A

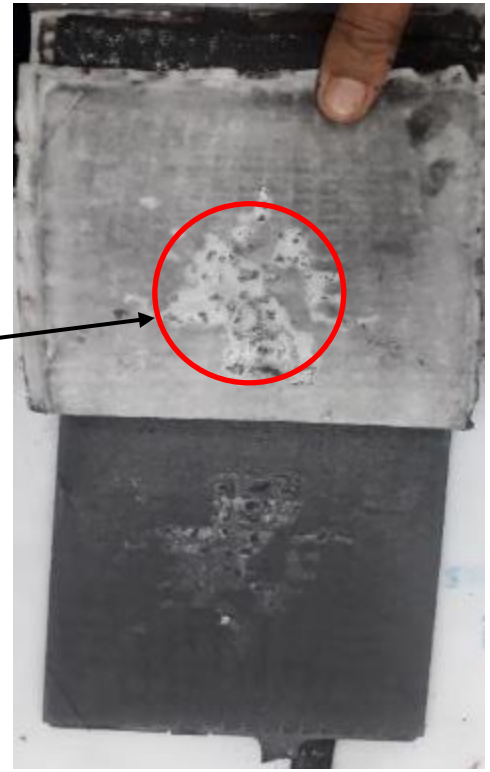
50% DoD Failure Mode: Hydration Short

- Internal short circuit during deep discharge and subsequent charging. In this scenario, lead sulfate, which forms on the plates during discharge, dissolves into the electrolyte and penetrates the separators. When the battery is recharged, the lead sulfate is converted back to lead, creating a short within the cell



Plates from Life cycles failed batteries

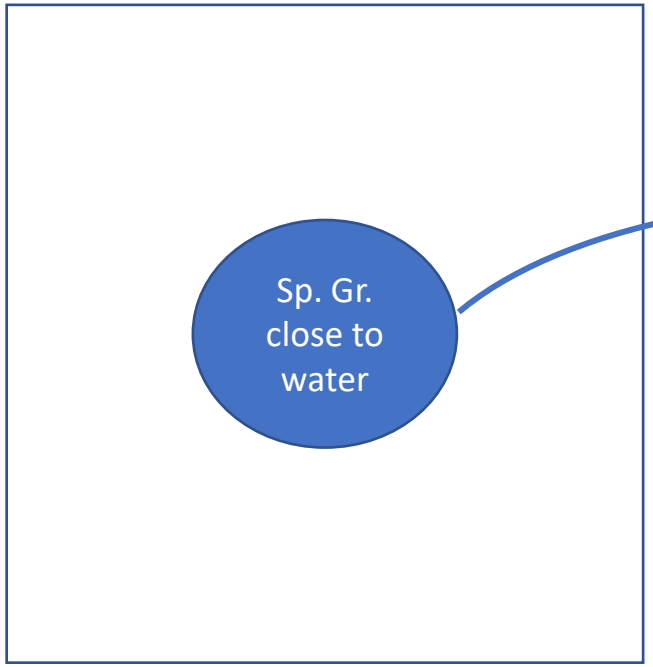
Marks on AGM indicating Hydration Short



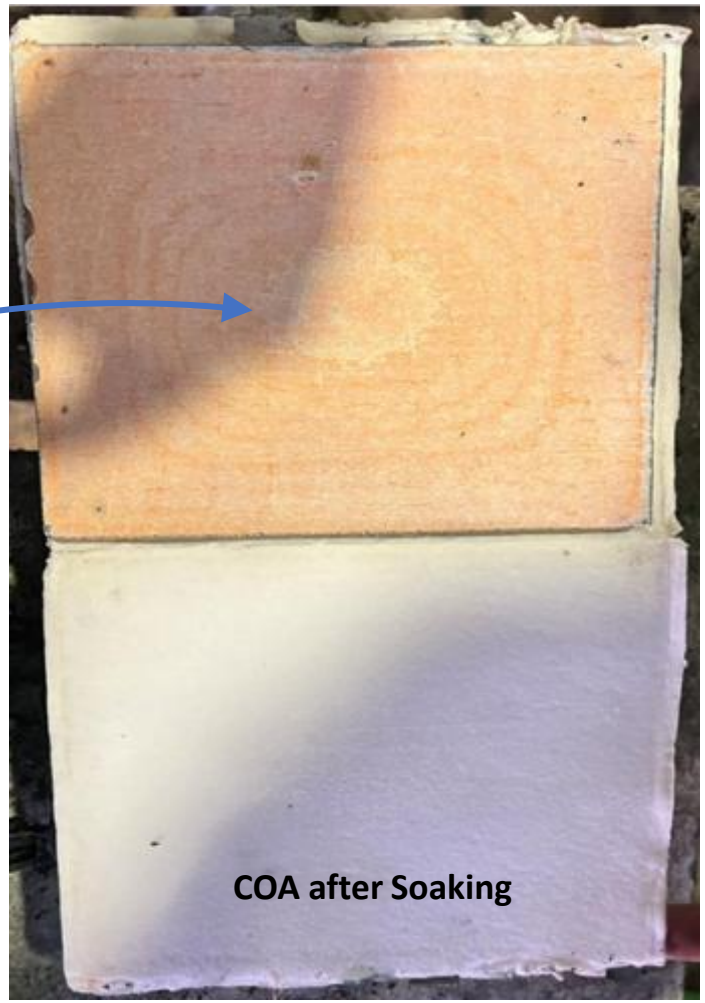
Plates from Life cycles failed batteries

Non-Uniformity in Soaking

- Non-uniform electrolyte distribution creates hotspots during charging which accelerates hydration short



Electrolyte soaking in AGM

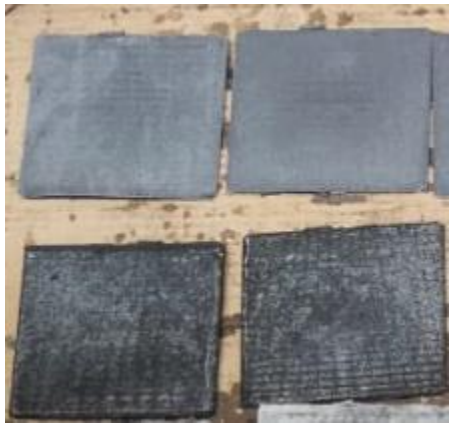


COA after Soaking

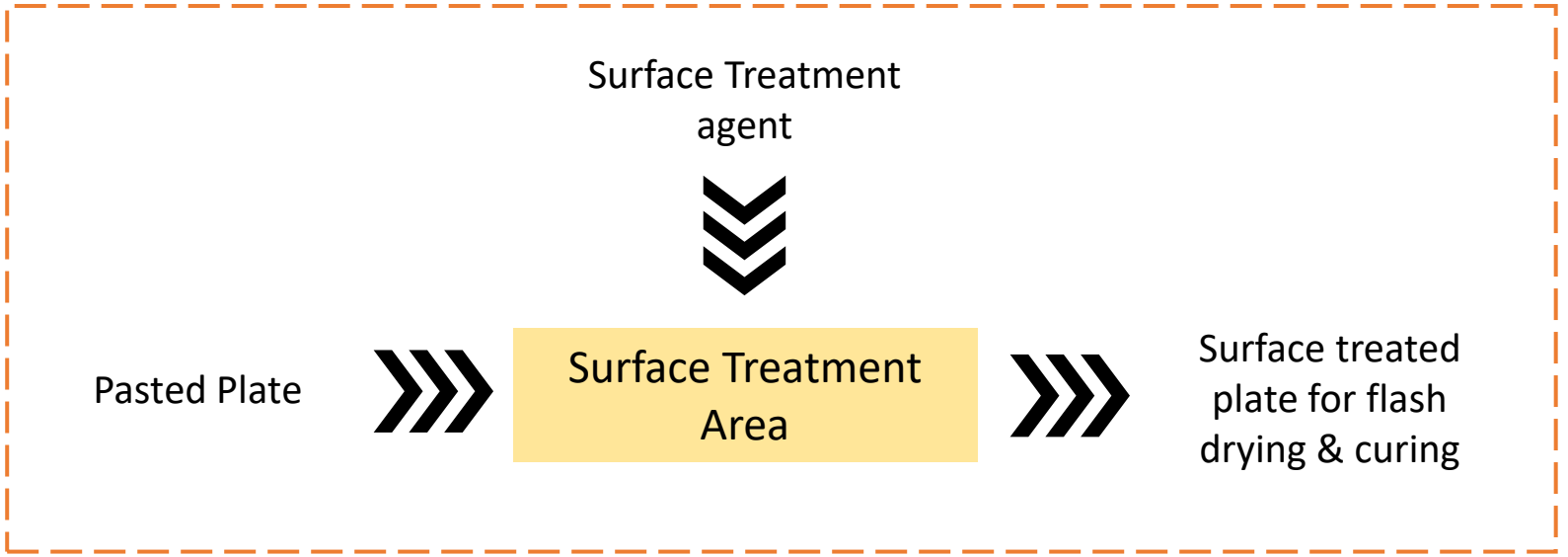
COA of failed sample

Action : Special Surface Treatment

- ✓ Due to **hot and humid climatic conditions (with relative humidity as high as 90%),** hot water or steam is generated adjacent to the plate during soaking, which causes lead sulphate to dissolve. During charging or cycling, this can lead to a hydration short.
- ✓ The amount of CO_2 generated increases due to carbonization. This phenomenon occurs when the cellulose component in the pasting paper on the surface of the plate decomposes due to heat generation



Surface treated plate : No indication of short on surface after charging



AGM before Treatment

AGM after Treatment

Optimization : Filling & Formation

- Optimized filling regime
- High-capacity vacuum pump

- Hot spot before optimization of filling regime

- No abnormality after optimization of filling regime

Test Result on SLI AGM Battery

DIN50 SLI AGM		
Test	**Requirement**	**Result**
DCA	0.1A/ Ah	***0.32***
50%DoD at 40°C	360 cycles	***560 – 665****
17.5%DoD at 25°C	18 units	***20***
SAE J2801 Life at 75°C	11 units	***12***
Water Loss Test at 60°C	<4 gm/Ah	***1.5***

*Test in progress

DIN60 SLI AGM		
Test	**Requirement**	**Result**
DCA	0.1A/ Ah	***0.29***
50%DoD at 40°C	360 cycles	***734 – 740***
17.5%DoD at 25°C	18 units	***22***
SAE J2801 Life at 75°C	11 units	***13***
Water Loss Test at 60°C	<4 gm/Ah	***1.4***

AUX Battery for Hybrid Vehicles & EVs

Indian Market Scenario

1. Increase in EV population
2. Light commercial vehicles also started converting into EVs
3. EVs require a 12V battery to support auxiliary loads
4. OEMs asking for regular battery with LLE, HLE specifications
5. No standard yet for AUX battery performance validation
6. OEM specific powertrain, low charging voltage to save HV power

Concern

- Conventional battery struggling
- Plate sulfation & PAM softening are predominant failure mode

Auxiliary Battery (AUX)

Key Features

Used in Hybrid & Electric Vehicles (EVs)

- ✓ *Acts as a **12V backup** for ECUs and safety systems when the **high-voltage (HV) battery** is disconnected*
- ✓ *Ensures critical systems stay on even if the main EV battery is depleted*

Powers Auxiliary Systems When Engine is Off

- ✓ *Runs **infotainment, lights, climate control, and ECU memory** without draining the main battery*
- ✓ *Essential for **keyless entry, alarm systems, and telematics***

Supports Start-Stop Systems

- ✓ *Provides power to relevant ECUs to restart the engine smoothly after auto-stop*
- ✓ *Prevents voltage drops that could affect electronics*

Backup Power for Safety & Luxury Features

- ✓ *Ensures **emergency systems** (e.g., SOS calls, hazard lights) remain functional if the main battery fails*
- ✓ *Powers **high-end features** (massage seats, advanced driver-assist systems)*

Variety of AUX Battery

As per **IEC 60095-8 draft** specification AUX battery falls under 3 categories

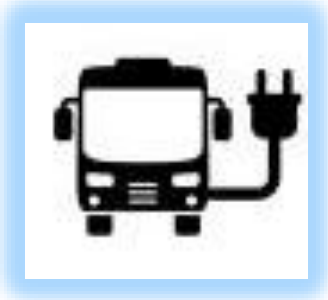
Parameter	Category 1	Category 2	Category 3
Supporting function	Parking, vehicle activation, over-the air update, transient power delivery and absorption, voltage stabilization	Voltage stabilization, emergency power for sensitive and safety-relevant electrical components	Stabilize system voltage during engine restart
Vehicle category	**EV**	**EV**	**Stop/start or micro-hybrid vehicles**
Requirement	**Significant capacity throughput** during life and appropriate voltage response when supporting high rate discharge currents (during HV Battery activation)	**Limited capacity throughput** during life and appropriate voltage response when supporting high rate discharge currents (during HV Battery activation)	Relevant capacity throughput during life and limited power requirements
Cycle requirement	**Higher cyclic requirement** with greater DoD	Moderate/ low cyclic requirement with reasonable DoD	Low cyclic requirement with short DoD

Note : In India most of the AUX batteries for EV falls under Category 1

Future Challenges

Auxiliary Battery for CAR application in EV

- *OEMs use AUX power in there own way (**transformation from high power to moderate power & high energy battery**)*
- *Most of the OEMs not providing voltage cut-off to restrict deep discharge*
- *Few OEM kept auto battery charging facility at parking but for limited time **(not full charge)***



Auxiliary Battery in Commercial EV

- *To adhere government rules most of the vehicles are using **after market tracking & safety devices (local make)***
- *It consumes **high leakage current with ageing***
- ***No battery cut-off** to restrict deep discharge*
- *Lower Charging Voltage to save HV bank power*

Improvement in DCA without affecting

- *Water Loss Performance (target spec. : <3 gm/Ah in 84 days)*
- *PSoC cycle life tests (target spec. : 17.5%DoD at 25°C : 40 units, 50%DoD at 40°C : >470 cycles)*
- *SAE J2801 Life at 75°C (target spec. : 18 units)*

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THANK YOU
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