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The Challenge:

- Observe the performance of aged batteries under the new PPC and CR tests outlined in the IEC 60095-8 draft standard.

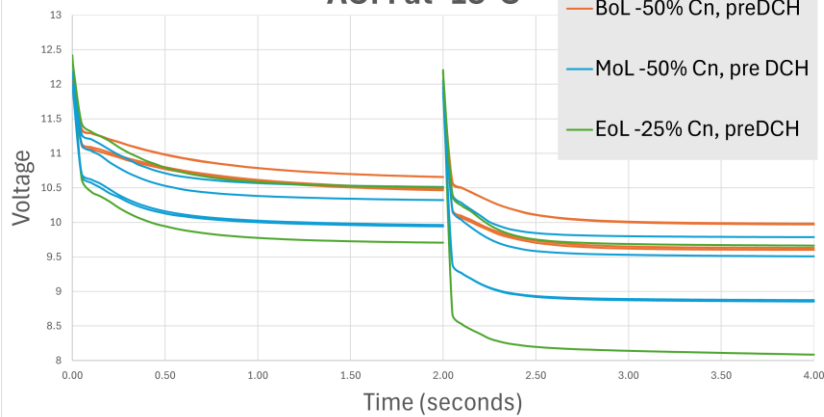
Methodology:

- Global Survey: Collected raw performance data from international battery manufacturers.
- Data Analysis: Comparative benchmarking of aged battery performance under new IEC conditions.
- Lifecycle Focus: Evaluating various metrics at BOL, MOL, and EOL
- Research is currently ongoing—we are still receiving data from various companies and we welcome your company to provide data

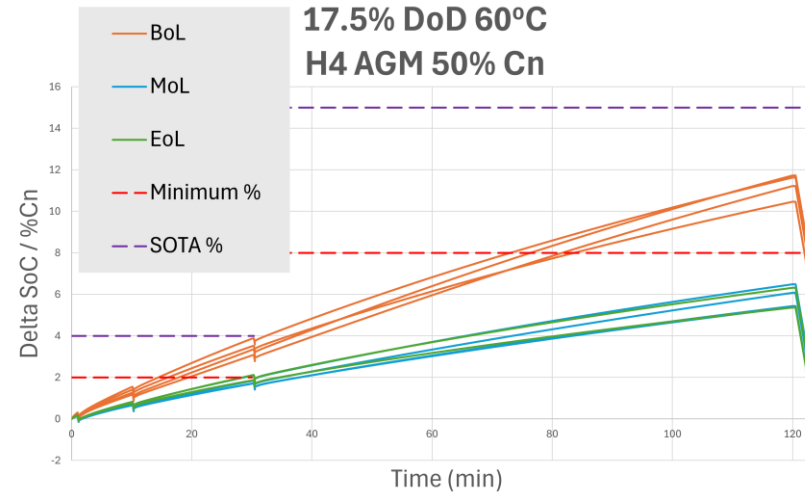
Company A - Summary



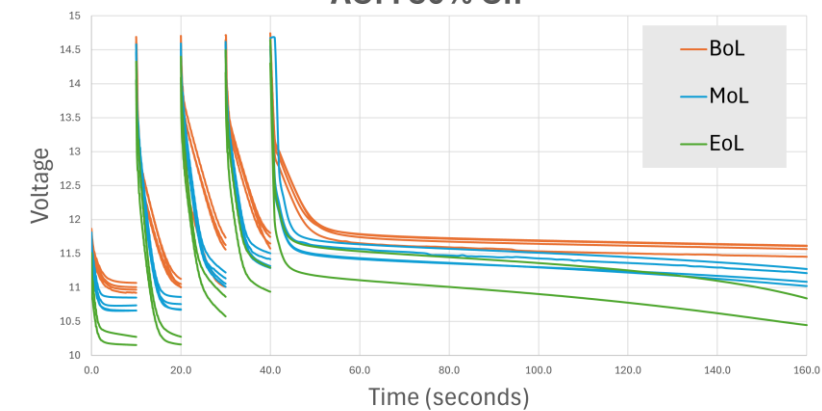
Pulse Power - 2 second Discharge Pulses
17.5% DoD 60°C
AGM at -18°C



SoC Recovery During Charge Test
17.5% DoD 60°C
H4 AGM 50% Cn



SoF Recovery During Charge Test
17.5% DoD 60°C
AGM 50% Cn



**Aging Condition
Definition**

MoL

EoL

9 Weeks

18 Weeks

Company A – PPC Table

Table 18 – PPC requirements (PP1): Beginning of Life (BOL)

PP1 / BOL		Step #	03	06
		I / I _{cc}	0.2	0.4
Category	(% of Cn discharged)	T / °C	U _{2s1}	U _{2s2}
1, 2, 3	0%	25	≥ 11,9 V	≥ 11,3 V
1	50%	-18	≥ 10,3 V	≥ 9,3 V
2, 3	20%		≥ 10,7 V	≥ 9,8 V

Table 19 – PPC requirements (PP1): End of Life (EOL)

PP1 / EOL		Step #	03	06
		I / I _{cc}	0.2	0.4
Category	(% of Cn discharged)	T / °C	U _{2s1}	U _{2s2}
1	25%	-18	≥ 10,3 V	≥ 9,0 V
2, 3	10%		≥ 10,5 V	≥ 9,4 V

Battery	Condition	% of Cn Discharged	°C	U_{2s1} $\left(\frac{I}{I_{cc}} = 0.2\right)$	U_{2s2} $\left(\frac{I}{I_{cc}} = 0.4\right)$
1	BoL	0%	25	12.07 V	11.32 V
	BoL	50%	-18	10.46 V	9.60 V
	EoL	25%	-18	9.71 V	8.08 V
2	BoL	0%	25	12.08 V	11.32 V
	BoL	50%	-18	10.49 V	9.63 V
	EoL	25%	-18	N/A	N/A
3	BoL	0%	25	12.12 V	11.58 V
	BoL	50%	-18	10.66 V	9.98 V
	EoL	25%	-18	N/A	N/A
4	BoL	0%	25	12.18 V	11.63 V
	BoL	50%	-18	10.67 V	9.97 V
	EoL	25%	-18	10.51 V	9.66 V

Company A – EoL CR Table

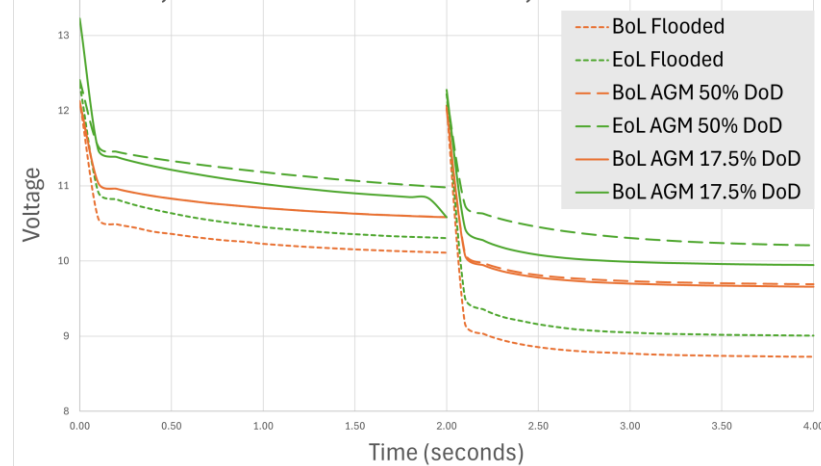
Table 22 – Charge recovery requirements

Functional Characteristics	Minimum requirement	<i>For information: Typical performance of state-of-the-art automotive batteries</i>	Battery 1 EoL Minimum Requirement	Battery 2 MoL Minimum Requirement	Battery 3 MoL Minimum Requirement	Battery 4 EoL Minimum Requirement
SOC Recovery after 30 minutes	$Q(30') \geq 2\% C_n$	$Q(30') \geq 4\% C_n$	1.9 %	1.7 %	2.1 %	2.1 %
SOC Recovery after 120 minutes	$Q(120') \geq 8\% C_n$	$Q(120') \geq 15\% C_n$	5.4 %	5.4 %	6.5 %	6.3 %
SOF Recovery after 1 minute	no requirement	$U_{10s}(1') - U_{10s}(0') \geq 0.2 \text{ V}$	0.01 V	0.02 V	0.01 V	0.002 V
SOF Recovery after 10 minutes	$U_{10s}(10') - U_{10s}(0') \geq 0.3 \text{ V}$	$U_{10s}(10') - U_{10s}(0') \geq 0.5 \text{ V}$	0.41 V	0.32 V	0.47 V	0.59 V
SOF Recovery after 30 minutes	$U_{10s}(30') - U_{10s}(0') \geq 0.5 \text{ V}$	$U_{10s}(30') - U_{10s}(0') \geq 0.7 \text{ V}$	0.78 V	0.58 V	0.76 V	1.02 V
SOF Recovery after 120 minutes	$U_{10s}(120') - U_{10s}(0') \geq 0.7 \text{ V}$	$U_{10s}(120') - U_{10s}(0') \geq 0.9 \text{ V}$	0.28 V	0.28 V	0.55 V	0.56 V

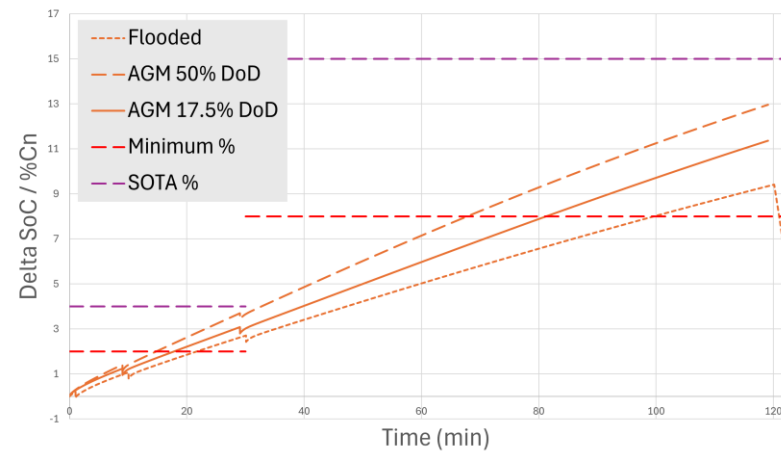
Company B - Summary



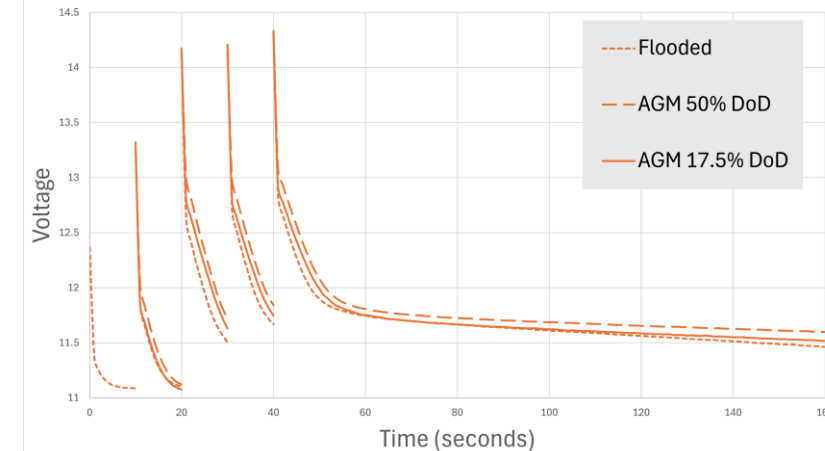
Pulse Power - 2 Second Discharge Pulses at -18°C
AGM; 17.5%/50% DoD vs. Flooded; 3 unit endurance



SoC Recovery During Charge Test - BoL
Flooded vs. AGM



SoF Recovery During Charge Test - BoL
Flooded vs. AGM



Aging Condition
Definition

EoL (Flooded)

3 Units of
Endurance Cycle

EoL (AGM)

360 Cycle at 50% DoD

18 Weeks at 17.5% DoD

Company B – PPC Table



Table 18 – PPC requirements (PP1): Beginning of Life (BOL)

PP1 / BOL		Step #	03	06
		I / I_{cc}	0.2	0.4
Category	(% of Cn discharged)	$T / ^\circ\text{C}$	U_{2s1}	U_{2s2}
1, 2, 3	0%	25	$\geq 11,9 \text{ V}$	$\geq 11,3 \text{ V}$
1	50%	-18	$\geq 10,3 \text{ V}$	$\geq 9,3 \text{ V}$
2, 3	20%		$\geq 10,7 \text{ V}$	$\geq 9,8 \text{ V}$

Table 19 – PPC requirements (PP1): End of Life (EOL)

PP1 / EOL		Step #	03	06
		I / I_{cc}	0.2	0.4
Category	(% of Cn discharged)	$T / ^\circ\text{C}$	U_{2s1}	U_{2s2}
1	25%	-18	$\geq 10,3 \text{ V}$	$\geq 9,0 \text{ V}$
2, 3	10%		$\geq 10,5 \text{ V}$	$\geq 9,4 \text{ V}$

Battery	Condition	% of Cn Discharged	$^\circ\text{C}$	U_{2s1} $\left(\frac{I}{I_{cc}} = 0.2\right)$	U_{2s2} $\left(\frac{I}{I_{cc}} = 0.4\right)$
B1 Flooded	BoL	0%	25	11.25 V	10.05 V
	BoL	50%	-18	10.11 V	8.73 V
	EoL	25%	-18	10.31 V	9.01 V
B2 AGM 50% DoD	BoL	0%	25	12.08 V	11.35 V
	BoL	50%	-18	10.58 V	9.69 V
	EoL	25%	-18	10.98 V	10.21 V
B3 AGM 17.5% DoD	BoL	0%	25	12.22 V	11.38 V
	BoL	50%	-18	10.58 V	9.66 V
	EoL	25%	-18	10.58 V	9.95 V

Company B – BoL CR Table



Table 22 – Charge recovery requirements

Functional Characteristics	Minimum requirement	<i>For information: Typical performance of state-of-the-art automotive batteries</i>
SOC Recovery after 30 minutes	$Q(30') \geq 2\% C_n$	$Q(30') \geq 4\% C_n$
SOC Recovery after 120 minutes	$Q(120') \geq 8\% C_n$	$Q(120') \geq 15\% C_n$
SOF Recovery after 1 minute	no requirement	$U_{10s}(1') - U_{10s}(0') \geq 0.2 \text{ V}$
SOF Recovery after 10 minutes	$U_{10s}(10') - U_{10s}(0') \geq 0.3 \text{ V}$	$U_{10s}(10') - U_{10s}(0') \geq 0.5 \text{ V}$
SOF Recovery after 30 minutes	$U_{10s}(30') - U_{10s}(0') \geq 0.5 \text{ V}$	$U_{10s}(30') - U_{10s}(0') \geq 0.7 \text{ V}$
SOF Recovery after 120 minutes	$U_{10s}(120') - U_{10s}(0') \geq 0.7 \text{ V}$	$U_{10s}(120') - U_{10s}(0') \geq 0.9 \text{ V}$

Battery 1 Flooded Minimum Requirement	Battery 2 AGM 50% DoD Minimum Requirement	Battery 3 17.5% DoD Minimum Requirement
2.7 %	3.7 %	3.0 %
9.4 %	N/A	N/A
0.02 V	N/A	N/A
0.42 V	0.60 V	0.55 V
0.58 V	0.72 V	0.67 V
0.38 V	0.48 V	0.44 V

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Battery Type	Aging Procedure	Battery	PPC BoL	PPC EoL	CR SoC	CR SoF
Flooded	Endurance Cycle Test IEC 60095-8 9.7.3; 3 units	Company B, B1	FAIL	FAIL	PASS	FAIL
	50% DoD 40°C; 66 Cycles	Company D, B1	N/A	PASS	FAIL	PASS
	50% DoD 40°C; 48 Cycles	Company D, B2	N/A	PASS	FAIL	PASS
AGM	17.5% DoD 60°C; 18 weeks	Company A, B1	PASS	FAIL	FAIL	FAIL
		Company A, B2	PASS	FAIL	FAIL	FAIL
		Company A, B3	PASS	FAIL	FAIL	FAIL
		Company A, B4	PASS	PASS	FAIL	FAIL
	50% DoD -18°C; 360 Cycles	Company B, B2	PASS	PASS	FAIL*	FAIL
	17.5% DoD 25°C; 18 weeks EN 50342-6 7.4	Company B, B3	PASS	PASS	FAIL*	FAIL
		Company C, B1	N/A	N/A	PASS	FAIL
	Micro Hybrid Test EN 50342-6 7.2	Company C, B2	N/A	N/A	PASS	PASS
* Data incomplete						

PPC/CR Aged Battery Data Collection and Initial Analysis



Battery Type	Aging Type	PPC MoL Data Collected+Upcoming	PPC EoL Data Collected+Upcoming	CR MoL Data Collected+Upcoming	CR EoL Data Collected+Upcoming
Flooded	> 10% DoD Cycle	0+0	3+1	0+0	2+1
	Shallow Cycle	0+1	1+1	0+1	0+1
	High Temperature	0+1	0+2	0+1	0+2
	Other	0+0	0+0	0+0	0+0
EFB	> 10% DoD Cycle	0+1	0+1	0+1	0+1
	Shallow Cycle	0+1	0+1	0+1	0+1
	High Temperature	0+1	0+1	0+1	0+1
	Other	0+1	0+1	0+1	0+1
AGM	> 10% DoD Cycle	0+1	2+2	1+1	3+2
	Shallow Cycle	0+1	0+2	1+1	2+2
	High Temperature	4+1	3+2	4+2	2+3
	Other	0+0	0+1	0+0	0+1

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