

Tabulation and Comparison of Different Test Procedures for Starter Lead-Acid Batteries from Various Standards

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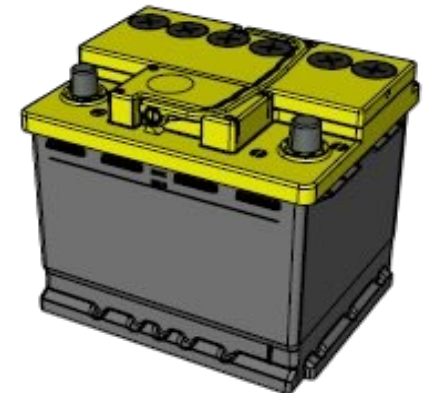
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Background

- Product standards for starter lead-acid batteries have developed in parallel over time, mostly driven by regions that have strong automotive industries like Europe, Japan, and the US
- Standard test procedures for starter lead-acid batteries have been instituted in different regional product standards like EN 50342, JIS D5301/D5302, and BCI-SAE
- Because of limitations in testing capabilities, climate differences, and other considerations, test procedures for performance characteristics like capacity, high-rate discharge characteristics, charge acceptance, cycle durability, etc. can vary significantly across different standards
- Changes in the automotive technologies, most notably the start-stop/micro-hybrid architecture, has significantly changed the requirements for starter lead-acid batteries, especially in charge acceptance, cycle durability, and corrosion resistance
- Such changes in application details apply not only for starter batteries for passenger car and light commercial vehicles but also for other automotive applications like motorcycles, which now have start-stop capabilities
- Moreover, starter battery formats <30 Ah are at times used also for auxiliary applications, which has its own performance requirements

The Study

- The present study tabulates the procedures for different test types in different standards, highlighting the similarities and differences across these tests
- Typical charts comparing the behavior of the battery at different variations of different tests ,e.g. charge acceptance, as well as pictures of failure modes of different cycle durability tests are shown
- The ultimate goal should be to harmonize the test procedures/requirements for batteries for starter applications across different regions, but initially, a comparison of these different test methods may provide better understanding on the goals of each



3D PERSPECTIVE VIEW

Responsibility		Updated		Needs to be updated		completed		to be moved to table 3														Motorcycle	
		Torsten	Torsten	Torsten	Torsten	Torsten	Torsten	Torsten	Torsten	John													
		IEC 60095-1:2018	IEC 60095-6:2019	IEC 60095-7:2019	IEC 60095-8	CENELEC EN 50342-1:2015 + A1:2018 + A2:2021	CENELEC EN 50342-6:2025	CENELEC EN 50342-7:2015		SAE J537:2023	BCIS-04	SAC GB/T 5008.1:2023	JSA JIS D 5301:2019 - new version ?	AS60095.1:2022	SBA-50404	VDA 08xx	D5302 2022						
Requirements on battery age before start of test		45 days after the production date of the manufacturer in the case of filled batteries		Same as IEC 60095-1	Samples shall be tested not later than 30 days after production date of the manufacturer for wet batteries or not later than 60d after shipment for dry charged batteries		Same as EN 50342-1	Samples shall be tested not later than 60 days after production date of the manufacturer						• 45 days after the production date of the manufacturer in the case of filled batteries • 60 days after the production date of the manufacturer in the case of dry-charged batteries.									
Capacity	Option 1	20 h capacity C_{20A} at 25 °C ± 2 °C in water bath with $I_{20} = C_{20A}/20$ h until 10.5 V	Same as IEC 60095-1 Option 1	10 h capacity C_{10A} at 25 °C ± 2 °C in water bath with $I_{10} = C_{10A}/10$ h until 10.5 V	Same as IEC 60095-1	20 h capacity C_{20A} at 25 °C ± 2 °C in water bath with $I_{20} = C_{20A}/20$ h until 10.5 V	Same as EN 50342-1	10 h capacity C_{10A} at 25 °C ± 2 °C in water bath with $I_{10} = C_{10A}/10$ h until 10.5 V	Reserve capacity at electrolyte temperature range of 24 °C to 32 °C with 25 A until 10.5 V. Result corrected to 27 °C given in minutes.	Same as SAE J537	as IEC	5 h capacity C_{5A} at 25 °C ± 2 °C in water bath with $I_5 = C_{5A}/5$ h until 10.5 V	20 h capacity C_{20A} at 25 °C ± 2 °C in water bath with $I_{20} = C_{20A}/20$ h until 10.5 V										
	Option 2	Reserve capacity at 25 °C ± 2 °C in water bath with 25 A until 10.5 V. Result given in minutes.	-	-	Same as IEC 60095-1	-	-	-			as IEC	as IEC (preferred option)	Reserve capacity at 25 °C ± 2 °C in water bath with 25 A until 10.5 V. Result given in minutes.										
Cold cranking	Option 1	-18 °C ± 1 °C Discharge 10 s with I_{CC} Pause 10 s Discharge with 0.6 I_{CC} until 6.0 V $U(10s) \geq 7.5$ V total $t_{tot} \geq 90$ s	Same as IEC 60095-1	-18 °C ± 1 °C Discharge 30 s I_{CC} $U(30s) \geq 7.2$ V	-18 °C ± 1 °C Discharge 10 s I_{CC} $U(30s) \geq 7.2$ V	-18 °C ± 1 °C Discharge 10 s with I_{CC} Pause 10 s Discharge with 0.6 I_{CC} until 6.0 V $U(10s) \geq 7.5$ V total $t_{tot} \geq 90$ s	Same as EN 50342-1	Same as EN 50342-1	-18 °C ± 1 °C Discharge 30 s with rated current $U(30s) \geq 7.2$ V	Same as SAE J537	as IEC	-18 °C ± 1 °C Discharge 30 s I_{CC} Pause 20 s Discharge with 0.6 I_{CC} until 6.0 V $U(10s) \geq 7.5$ V $U(30s) \geq 90$ s (preferred option)	-18 °C ± 1 °C Discharge 30 s I_{CC} Pause 20 s Discharge with 0.6 I_{CC} until 6.0 V $U(10s) \geq 7.5$ V $U(30s) \geq 7.2$ V total $t_{tot} \geq 90$ s (optional)										
	Option 2	-18 °C ± 1 °C Discharge 30 s I_{CC} $U(30s) \geq 7.2$ V	Same as IEC 60095-1	-	Recommendation to use cold cranking test as defined by one of the procedures in IEC 374 60095-1,	-	-	-	-29 °C ± 1 °C Discharge 30 s with rated current $U(30s) \geq 7.2$ V		as IEC	-15 °C ± 1 °C: Discharge until 6.0 V Type specific requirements for $U(5s)$, $U(30s)$ and total t_{tot}	-18°C ± 1 °C (if specified) Discharge 30 s I_{CC} $U(30s) \geq 7.2$ V										
Cranking performance test – Very cold climates		-29 °C ± 1 °C Discharge 30 s with rated current $U(30s) \geq 7.2$ V	Same as IEC 60095-1	-	-	-	-	-						NA									
High current discharge test at low temperature		-18 °C ± 1 °C Discharge with 0.6 I_{CC} $U(30s) \geq 7.2$ V	-	-	-	-18 °C ± 1 °C Discharge with 0.6 I_{CC} $U(30s) \geq 7.2$ V	Same as EN 50342-1	-						NA									
Charging regime	flooded or vented batteries	Sizes according IEC 60095-2 (passenger car batteries): Constant voltage 16.0 V ± 0.05 V and max 5 I_{10} for 24 h Sizes according IEC 60095-4 (truck batteries): Constant voltage 16.0 V ± 0.05 V and max 5 I_{10} for 20 h and constant current I_{10} for 4 h	Same as IEC 60095-1	Flooded 16,00 V ± 0.05 V and max 2,5 I_{10} for 24 h	Constant voltage 16,0 V ± 0.05 V and max 5 I_{10} for 24 h	Sizes according EN 50342-2 (passenger car batteries): Constant voltage 16.0 V ± 0.05 V and max 5 I_{20A} for 24 h Sizes according EN 50342-4 (truck batteries): Constant voltage 16.0 V ± 0.05 V and max 5 I_{20A} for 20 h and constant current I_{20A} for 4 h	Same as EN 50342-1	Flooded 16,00 V ± 0.05 V and max 2,5 I_{10} for 24 h	Option 1: Charging with constant current to be calculated by different battery parameters Option 2: Charging with constant voltage and additional constant current phase with parameters according manufacturers recommendations until temperature corrected voltage (± 0.008V per cell) per hour over three consecutive one-hour intervals	Option 1: Charging with constant current to be calculated by different battery parameters until temperature corrected specific gravity is constant (± 0.002) per hour over three consecutive one-hour intervals, Option 2: Charging with constant voltage and additional constant current phase with parameters according manufacturers recommendations until temperature corrected voltage (± 0.008V per cell) per hour over three consecutive one-hour intervals	as IEC	Option 1: Constant current I_{SA} until voltage or electrolyte density stabilization Option 2: Constant current 2 I_{20A} until voltage or electrolyte density stabilization Option 3: Constant volatage 14.8 V and max 5 I_{20A} for 18 h and constant current I_{20A} for 6 h	Constant voltage 16.0 V ± 0.05 V and max 5 I_{10} for 24 h Sizes according IEC 60095-4 (truck batteries): Constant voltage 16.0 V ± 0.05 V and max 5 I_{10} for 20 h and constant current I_{10} for 4 h										
	valve regulated batteries	Constant voltage 14.8 V ± 0.05 V and max 5 I_{10} for 24 h	Same as IEC 60095-1	VRLA 14,80 V ± 0.05 V and max 2,5 I_{10} for 24 h	Constant voltage 14,8 V ± 0.05 V and max 5 I_{10} for 24 h	Constant voltage 14.8 V ± 0.05 V and max 5 I_{20A} for 24 h	Same as EN 50342-1	VRLA 14,80 V ± 0.05 V and max 2,5 I_{10} for 24 h	Charging in accordance with the recommendation of the manufacturer.	Same as SAE J537	as IEC	-	Constant voltage 14.8 V ± 0.05 V and max 5 I_{10} for 24 h										
Charge Acceptance - static		At 25 °C discharge with $I_0 = C_{20} / 10$ h for 5 h to 50 % Ce. Cool down to 0 °C ± 1 °C for 20 h. Charge at 0 °C ± 1 °C with 14,40 V ± 0,10 V for 10 minutes. $I_{CA}(10\ min) \geq 2 I_0$	Same as IEC 60095-1	At 25 °C discharge with $I_0 = C_{20} / 10$ h for 5 h to 50 % Ce. Cool down to 0 °C ± 1 °C for 20 h. Charge at 0 °C ± 1 °C with 14,40 V ± 0,10 V for 10 minutes. $I_{CA}(10\ min) \geq 1,5 I_0$	Same as IEC 60095-1	At 25 °C discharge with $I_0 = C_{10} / 10$ h for 5 h to 50 % C_{10} . Coll down to 0 °C ± 1 °C for 15 h. Charge at 0 °C ± 1 °C with 14,40 V ± 0,05 V for 10 minutes with $I_{max} = 50$ A for batteries according to EN 50342-2 and $I_{max} = 100$ A for batteries according to EN 50342-4. $I_{CA}(10\ min) \geq 2 I_0$	-	-	At 25°C Discharge battery at the Reserve Capacity Rate (25A) until 10.5V, place battery in test chamber until electrolyte temperature is stabilized at 0°C± 1°C Charge Battery at 14.40 V ± 0.07 V, record value at 10 minutes	Same as SAE J537			At 25°C Discharge battery at the 0.10 x rated 20hr capacity for 5 hours, place battery in test chamber until electrolyte temperature is stabilized at 0°C± 1°C Charge Battery at 14.40 V ± 0.07 V, in 25°C test condition, record value at 10 minutes										
Charge Acceptance - dynamic	Option 1	-	Same as SBA test 2	-	-	-	Charge pulses after charge-history (Ic) and after discharge-history (Id) and simulated drive cycle pattern (Ir). Level D1: IDCA(Ic, Id, Ir) ≥> 0, 1 A/AH Level D2: IDCA(Ic, Id, Ir) ≥> 0, 3 A/AH	-						NA									
	Option 2		Same as DCA EN 50342-6	-	-	-	-	-						NA									
Charge recovery		-	-	-	Charge pulses after 1', 10', 30' and 120' discharge $Q(30') \geq 2\% C_n$, $Q(120') \geq 8\% C_n$, $U10s(10') - U10s(0') \geq 0.3$ V, $U10s(30') - U10s(0') \geq 0.5$ V, $U10s(120') - U10s(0') \geq 0.7$ V	-	-	-						NA									
Pulse Power Chracterisation BOL		-	-	-	-	-	-	-						NA									
Pulse Power Chracterisation EOL		-	-	-	-	-	-	-						NA									

Acceptance criteria for pre testing	Capacity and cranking performance requirements shall be met in at least one of three required executions.		Capacity and cranking performance requirements shall be met in at least one of three required executions.		Capacity and cranking procedures can be performed up to three times according test matrix. All measured capacities according test matrix have to fulfill a statistic requirement: Mean of max value of each single battery minus standard deviation needs to be bigger or equal to 0.95 of nominal capacity.	Same as EN 50342-1 Capacity and cranking procedures can be performed up to three times according test matrix. All measured capacities according test matrix have to fulfill a statistic requirement: Mean of max value of each single battery minus standard deviation needs to be bigger or equal to 0.95 of nominal capacity.	Capacity performance shall be met in one of three possible trials.	Same as SAE J537	Capacity and cranking performance requirements shall be met in at least one of three required executions.	Capacity and cranking performance requirements shall be met in at least one of three possible executions.	Capacity and cranking procedures can be performed up to three times according test matrix. All measured capacities according test matrix have to fulfill a statistic requirement: Mean of max value of each single battery minus standard deviation needs to be bigger or equal to 0.95 of nominal capacity.
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Document	EN 50342-1:2015 + A1:2018 + A2:2021		EN 50342-6:2025	EN 50342-6:2025	IEC 60095-1 Ed 8.0 2018-11		
Name	50% DoD		50% DoD after deep discharge	17.5 % DoD	50% DoD		Optional Endurance Test
Battery type	Car	Truck	Car	Car	Car	Truck	Car (≤ 100 Ah)
Temperature	40°C	25°C	40°C	25°C	40°C	25°C	40°C
Starting SOC	100%	100%	100%	50% (DCH at 2.5 h, 4·I _n at the start and after every 85 cycles)	100%	100%	100%
Depth of discharge	50%	50%	50%	17.5%	50%	50%	1.7-6%
Charging regime	VRLA: 14.4 V Flooded: 15.6V	VRLA: 14.4 V Flooded: 15.6V	VRLA 14.4 V Flooded 15.6 V	14.4 V, 7·I _n max	VRLA: 14.4 V Flooded: 15.6V	15.6V	14.8 V, 25 A max
Unit Cycle Regime	DCH: 2h, >10.5V, 5·I _n A CHA: ≤5h, U _c V, 5·I _n A, then ≤1h, I _n A; terminate when C _{rch} ≥ 0.54 C _n	DCH: 2h, >10.5V, 5·I _n A CHA: ≤5h, U _c V, 5·I _n A, then ≤1h, 2.5·I _n A; terminate when C _{rch} ≥ 0.55 C _n	DCH: 2h, >10V, 5·I _n A CHA: ≤5h, U _c V, 5·I _n A, then ≤1h, 2.5·I _n A; terminate when C _{rch} ≥ 0.54 C _n	CHA: 2400 s, U _c V, 7·I _n A DCH: 1800 s, >10V, 7·I _n A	DCH: 2h, >10.5V, 5·I _n A CHA: ≤5h, U _c V, 5·I _n A, then ≤1h, I _n A; terminate when C _{rch} ≥ 0.54 C _n	DCH: 2h, >10.5V, 5·I _n A CHA: ≤5h, U _c V, 5·I _n A, then ≤1h, 2.5·I _n A; terminate when C _{rch} ≥ 0.55 C _n	DCH: 240 s, 25.0 A CHA: 600 s, U _c V
Unit Cycle Duration [h]	8	8	8	1,167	8	8	0,233
Check up	HCD at -18°C, 0.6·I _{cc} , then C _e check after target cycles	HCD at -18°C, 0.6·I _{cc} , then C _e check after target cycles	HCD at -18°C, 0.6·I _{cc} , then C _e check after target cycles	C _e check after every 85 cycles	HCD at -18°C, 0.6·I _{cc} , then C _e check after target cycles	HCD at -18°C, 0.6·I _{cc} , then C _e check after target cycles	HCD for 30-s at I _{dch} = I _{cc,n} every 165-182 h (429-480 cycles / 100-112 h + 65-70 h rest)*
Cut-off criteria	$U_{EOD} \geq 10.5 \text{ V}$ HCD $U_{30s} \geq 7.2 \text{ V}$ C _e ≥ 0.5·C ₂₀	$U_{EOD} \geq 10.5 \text{ V}$ HCD $U_{30s} \geq 7.2 \text{ V}$ C _e ≥ 0.5·C ₂₀	$U_{EOD} \geq 10.5 \text{ V}$ HCD $U_{30s} \geq 7.2 \text{ V}$ C _e ≥ 0.5·C ₂₀	$U_{EOD} > 10.5 \text{ V}$ C _e ≥ 0.5·C ₂₀	$U_{EOD} \geq 10.5 \text{ V}$ HCD $U_{30s} \geq 7.2 \text{ V}$ C _e ≥ 0.5·C ₂₀	$U_{EOD} \geq 10.5 \text{ V}$ HCD $U_{30s} \geq 7.2 \text{ V}$ C _e ≥ 0.5·C ₂₀	HCD $U_{30s} \geq 7.2 \text{ V}$
Failure mode	Active mass degeneration	Active mass degeneration	Active mass degeneration	Active mass degeneration	Active mass degeneration	Active mass degeneration	
Acceptance Criteria	E1 ≥ 80 cycles E2 ≥ 150 cycles E3 ≥ 230 cycles E4 ≥ 360 cycles	E1 ≥ 80 cycles E2 ≥ 150 cycles E3 ≥ 230 cycles E4 ≥ 360 cycles	M1 ≥ 150 cycles M2 ≥ 240 cycles M3 ≥ 360 cycles	M1 = 765 cycles / 9 units M2 = 1275 cycles / 15 units M3 = 1530 cycles / 18 units	Flooded ≥ 60 cycles VRLA ≥ 250 cycles	Flooded ≥ 60 cycles VRLA ≥ 250 cycles	≥34·RC - 581 28 Ah (32 min RC) ≥ 507 cycles 100 Ah (170 mins RC) ≥ 5199 cycles
Energy throughput requirement [C _n]	E1 = 40 E2 = 75 E3 = 115 E4 = 180	E1 = 40 E2 = 75 E3 = 115 E4 = 180	M1 = 75 M2 = 120 M3 = 180	M1 = 143 M2 = 238 M3 = 286	Flooded = 30 VRLA = 125	Flooded = 30 VRLA = 125	28 Ah (32 min RC) = 30 100 Ah (170 mins RC) = 87
Duration [d]	E1 = 27 E2 = 50 E3 = 77 E4 = 120	E1 = 27 E2 = 50 E3 = 77 E4 = 120	M1 = 50 M2 = 80 M3 = 120	M1 = 63 M2 = 105 M3 = 126	Flooded = 20 VRLA = 84	Flooded = 20 VRLA = 84	28 Ah (32 min RC) = 7 100 Ah (170 mins RC) = 56

Additional ideas:

Provide typical charts for each type of endurance test

Provide typical teardwon pictures of failures from these endurance tests for different battery types, e.g. MF, VRLA-AGM

Put together historical contexts and other 'stories' on derivation of tests, e.g. adaption of tests from one standard to another, original intended applicability of test procedures for climate conditions, drive cycles, etc.

Check if correlations between field performance and lab endurance tests are available and can be put together - BCI service life data may be useful

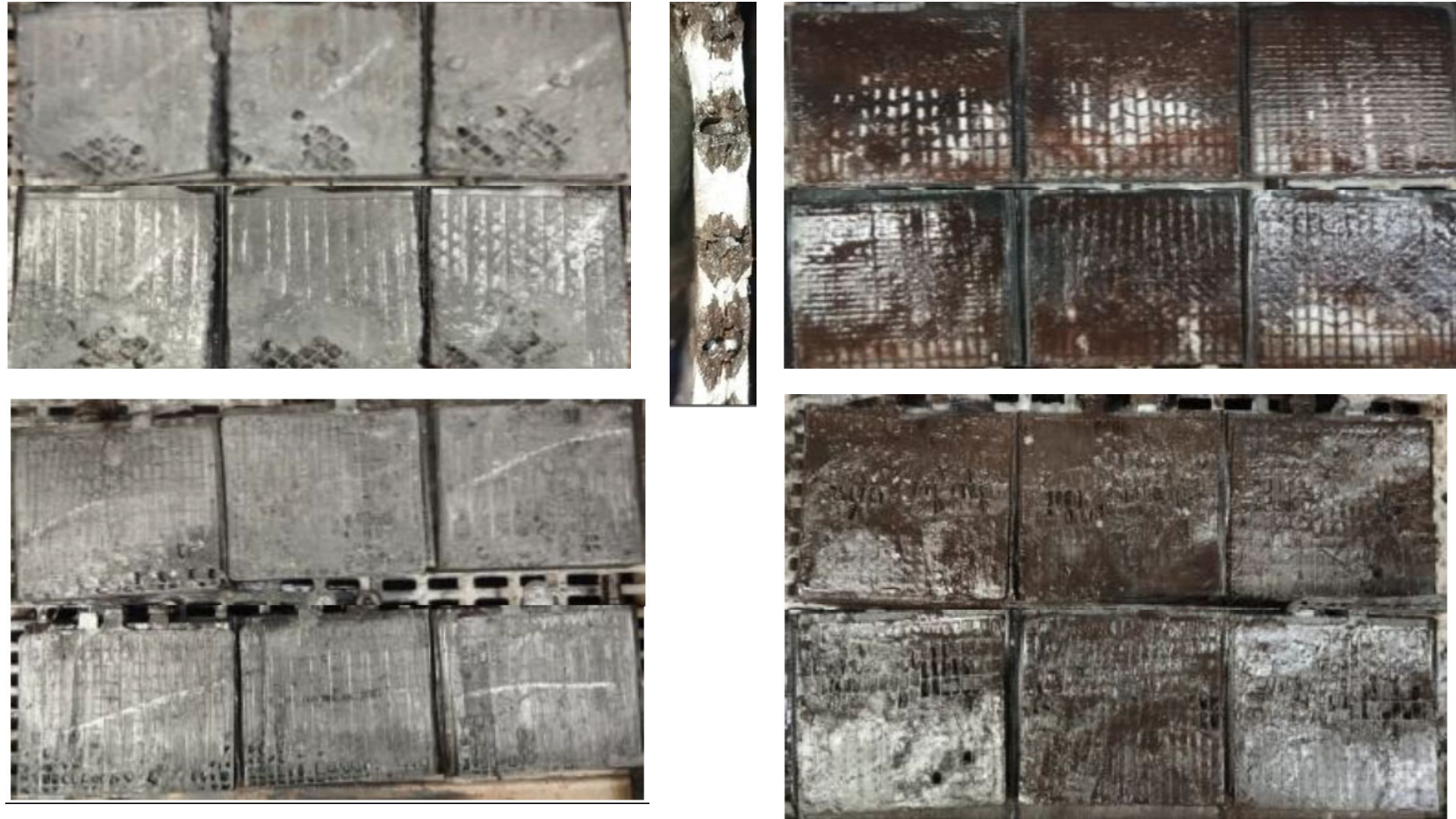
*Choose 441 cycles (102.9 h) + 65.1

JIS D5301 2019	JIS D5302 2022	EN 50342-7	OEM H	EN 50342-6:2025	SBA S 0101 2006	IEC 60095-6 Edition 01 2019
Light Load Endurance Test	Endurance Test for Motorcycle Batteries	Endurance Test for Motorcycle Batteries	Start-Stop Endurance Test for Motorcycle Batteries	MHT	SBA	
Class A: 28-81 Ah C20, 195-710 A CCA	Flooded/VRLA Motorcycle	Flooded/VRLA Motorcycle	VRLA Motorcycle	Car	Car	
40°C	40°C	40°C	15°C	40 °C	25 °C	
100%	100%	100%	100%	85%	100%	
2-6%	6,7%	50%	1%	2%	1.6% - 1.7%	
14.8 V, 25 A max	14.80 V, 10·I _{10,n} A max	Flooded: 15.6 V VRLA: 14.40 V (or as specified by mfr)	14.0 V	14.0 V / 100 A max	14.0 V / 100 A max	
DCH: 240 s, 25.0 A CHA: 600 s, U _c V	DCH: 240 s, 10·I _{10,n} A CHA: 600 s, U _c V	DCH: 2 h, >10.5 V, 2.5·I ₁₀ A CHA: ≤5 h, U _c V, 2.5·I ₁₀ A max, then ≤1 h, 0.5·I ₁₀ A; terminate anytime when C _{rch} ≥ 0.54 C _n	DCH: 32 s, 9·I ₁₀ A, then 1 s, 70·I ₁₀ CHA: 87 s, 14.0 V, 17.8·I ₁₀ A max			
0,233	0,233	8	0,033			
HCD for 30-s at I _{dch} = I _{cc,n} every 168 h (480 cycles / 112 h + 56 h rest)	HCD for 30-s at I _{dch} = 0.6·I _{cc,n} every 165-182 h (429-480 cycles / 100-112 h + 65- 70 h rest)*		HCD 1-s at Idch = 100·I ₁₀ after every 1680 h (36000 cycles - 10 x 3600 cycles / 10 x (120 h + 48 h rest)	Remaining capacity and capacity after full charge	only 40 - 48 h rest every week, no capacity check-up	
HCD U _{30s} ≥ 7.2 V	HCD U _{30s} ≥ 7.2 V	U _{EOD} ≥ 10.5 V	U _{EOD} ≥ 9.5 V HCD U _{1s} ≥ 9.5 V	U (EOD) _{300 A} ≥ 9.5 V, normalized mean R _{dyn} increase ≤ 1.5, C _e ≥ 50 % of C _n	U (EOD) < 7.2 V	
				No failure expected	Lug thinning, sulfation	
Min (28Ah/195A) ≥ 900 cycles Max (81Ah/710A) ≥ 5000 cycles	Flooded ≥ 2880 cycles VRLA ≥ 3840 cycles	None; comparative only	Min 36000 cycles Can be stopped after 54000 cycles			
Min (28 Ah, 195 A) = 53 Max (81 Ah, 710 A) = 103	Flooded = 192 VRLA = 256		Min = 358 Can be stopped at 537			
Min (28Ah/195A) = 14 Max (81Ah/710A) = 73	Flooded = 49 VRLA = 63		Min (36000 cycles) = 70 Max (54000 cycles) = 105			

h rest to have a 168-hr cycle

*Choose 441 cycles (102.9 h) + 65.1 h rest to have a 168-hr cycle

Typical failure mode of batteries that went through 17.5% DoD cycle test



Acid stratification and subsequent degeneration / sulfation of active masses, particularly at the bottom parts of the plates; Lug thinning may also be observed in some layouts



Typical failure mode of batteries that went through SAE J2801 cycle test



Positive grid corrosion and electrolyte loss are the typical failure modes

Document		IEC 60095-1 2018; AS 60095.1 2022; EN 50342-1 2015	JIS D5301 2019 Test 1	JIS D5301 2019 Test 2	MS 45 2009 2015	AS 2149 2003	BCI SAE J537 2023	IEC 60095-6 2018 SBA 0101	IEC 60095-6 2018; EN 50342-6 2018
Test		Charge Acceptance	Charge Acceptance	Charge Acceptance	Charge Acceptance	Charge Acceptance	Charge Acceptance	Specific Charge Acceptance	Dynamic Charge Acceptance
DCH	Temp	25±2°C	25±2°C	25±2°C	27±2°C	Not specified	Not specified	25±2°C	25±2°C throughout <i>Pre-cycling</i> : RC dch, full rch, rest, RC dch, full rch, C20 dch, full rch (~100 hrs) <i>qDCA</i> : rest, DCApp, charge , rest, 10% dch, rest, DCApp, 10% dch, rest (~74 hrs) <i>DCRSS</i> : cycles of short dch-cha (~131 hrs) Total Time: ~305 hrs (~2 weeks)
	I_{dch}, t_{dch}	$2 \cdot I_{20} \text{ A, 5 h}$	$2 \cdot I_{20} \text{ A, 5 h}$	$3.42 \cdot I_{20} (I_5) \text{ A, 2.5 h}$	$3.42 \cdot I_{20} (I_5) \text{ A, 2.5 h}$	25 A (RC rate), until 10.5 V	25 A (RC rate), until 10.5 V	$3.42 \cdot I_{20} (I_5) \text{ A, 0.5 h}$	
	C_{dch}	50% of C_{20}	50% of C_{20}	42.65% of C_{20} (50% of C_5)	42.65% of C_{20} (50% of C_5)	100% C_{20}	100% C_{20}	8.55% of C_{20} (10% of C_5)	
REST		Cool down to 0°C	Cool down to 0°C	Cool down to 0°C	Cool down to 0°C	Cool down to 0°C	Cool down to 0°C	16-24 hrs	
CHA	Temp	0±1°C	0±1°C	0±1°C	0±1°C	0±1°C	0±1°C	25±2°C	
	U_{cha}	14.4±0.1 V; 14.40±0.05 V for EN	14.4±0.1 V	14.4±0.1 V	14.4±0.1 V	14.4 V	14.4 V	14.50±0.03 V	
	Measure	$I_{cha, 10 \text{ mins}} [\text{A}]$	$I_{cha, 10 \text{ mins}} [\text{A}]$	$I_{cha, 10 \text{ mins}} [\text{A}]$	$I_{cha, 10 \text{ mins}} [\text{A}]$	$I_{cha, 10 \text{ mins}} [\text{A}]$	$I_{cha, 10 \text{ mins}} [\text{A}]$	$Q_{cha, 10 \text{ s}} [\text{As}] = \int_0^{10 \text{ s}} (I_{cha} dt)$	$I_{DCA} [\text{A/Ah}] = (0.512I_c + 0.223I_d + 0.218I_r - 0.181C_n)/C_n$
Requirement		$\geq 0.2 \cdot C_{20} [\text{Ah}]$	$\geq 0.1 \cdot C_{20} [\text{Ah}]$	$\geq 0.1 \cdot C_{20} [\text{Ah}]$	$\geq 0.1 \cdot C_{20} [\text{Ah}]$	$\geq 0.04 \cdot CCA [\text{A}]$	$\geq 0.03 \cdot CCA [\text{A}]$	$Q_{cha, 10 \text{ s}} [\text{As}] > 10 \cdot C_{20} [\text{Ah}]$ or $I_{cha, \text{ave } 10 \text{ s}} [\text{A}] > C_{20} [\text{Ah}]$	$I_{DCA} [\text{A/Ah}] \geq 0.1$

Document		JIS D5301 2019 IEC 60095-1 2018	EN 50342-1 2015	MS 45 2009 (confirmed 2015)	EN 50342-1 2015 IEC 60095-1 2018
Test		Water Consumption	Water Consumption	Water Consumption	Corrosion
CHA	Water Bath Temp	40±2°C	60±2°C	70±2°C	60±2°C
	U _{cha}	14.40±0.05 V	14.40±0.05 V	14.40±0.05 V	14.00±0.05 V
	Duration	500 hrs	21 days (504 hrs) 42 days (1008 hrs) 84 days (2016 hrs)	21 days (504 hrs)	13 days
REST	Water Bath Temp				60±2°C
	Duration				13 days
	Condition				Open circuit
CHA	Water Bath Temp				Cooldown to and stay at 25±2°C; add purified water during cooldown, if needed and possible
	U _{cha}				16.00±0.05 V for flooded 14.80±0.05 V for VRLA max current of 5 · I ₂₀
	Duration				6 hrs
DCH	Water Bath Temp				Rest at 25±2°C for 20 hrs, then discharge
	I _{dch} , t _{dch}				0.6 · I _{cc} , 30 s
Measure		C ₂₀ ; battery weights before and after overcharging	C ₂₀ ; battery weights before and after overcharging	C ₂₀ ; battery weights before and after overcharging	U _{30-s} ; repeat unit cycle if ≥ 7.2 V, discontinue if < 7.2 V
Requirement		Low Water Loss Battery: ≤4 g/Ah Very Low Water Loss Battery: ≤1 g/Ah	W1: ≤24 g/Ah after 21 days W2: ≤16 g/Ah after 21 days W3: ≤ 8 g/Ah after 42 days W4: ≤ 4 g/Ah after 42 days W5: ≤ 4 g/Ah after 84 days	< 6 g/Ah	≥ 4 unit cycles