

Charge Recovery Test

-BOL vs MOL for JIS-type flooded batteries-

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Test Batteries

Models

Manufacturer	Technology	Model	Cn
Energywith (EW)	FLA	JIS-B19	32Ah
Furukawa Battery (FB)	FLA	JIS-B24	45.9Ah
GS Yuasa Energy (GYE)	FLA	JIS-D23	60Ah
GS Yuasa (GY)	FLA	JIS-D26	67Ah

Purpose

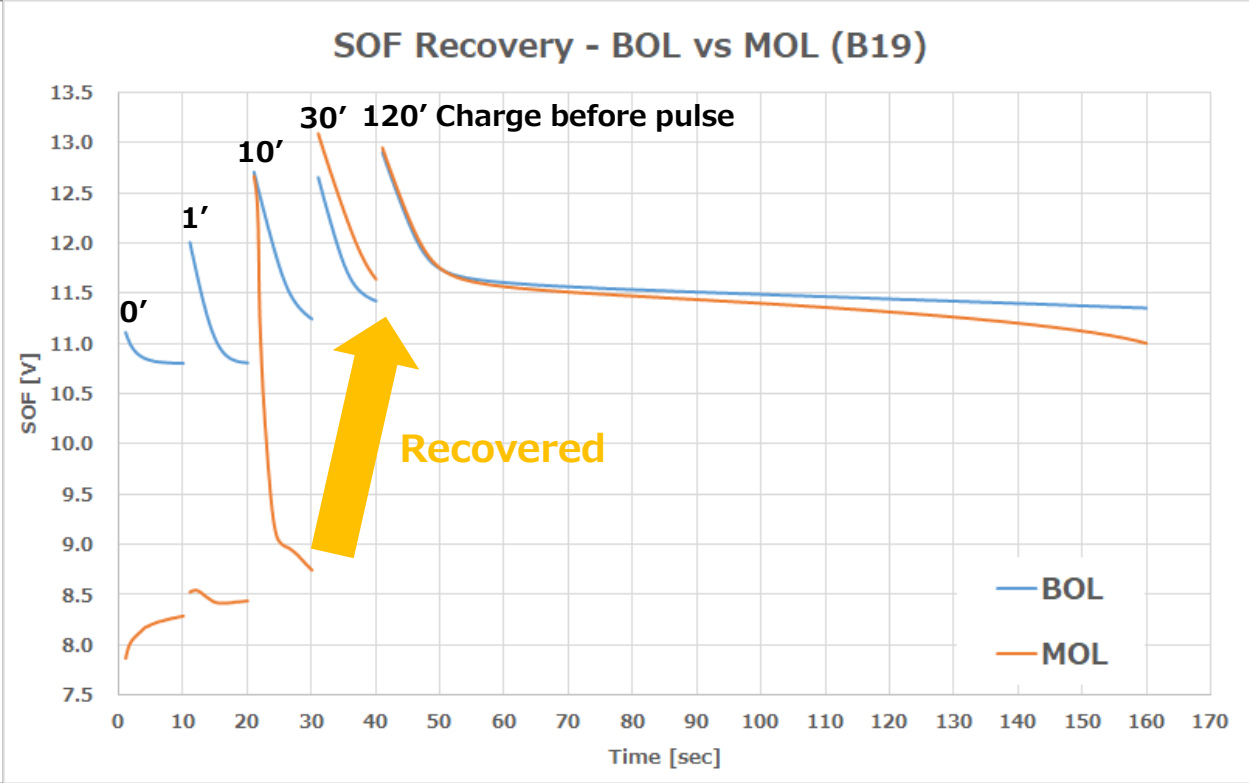
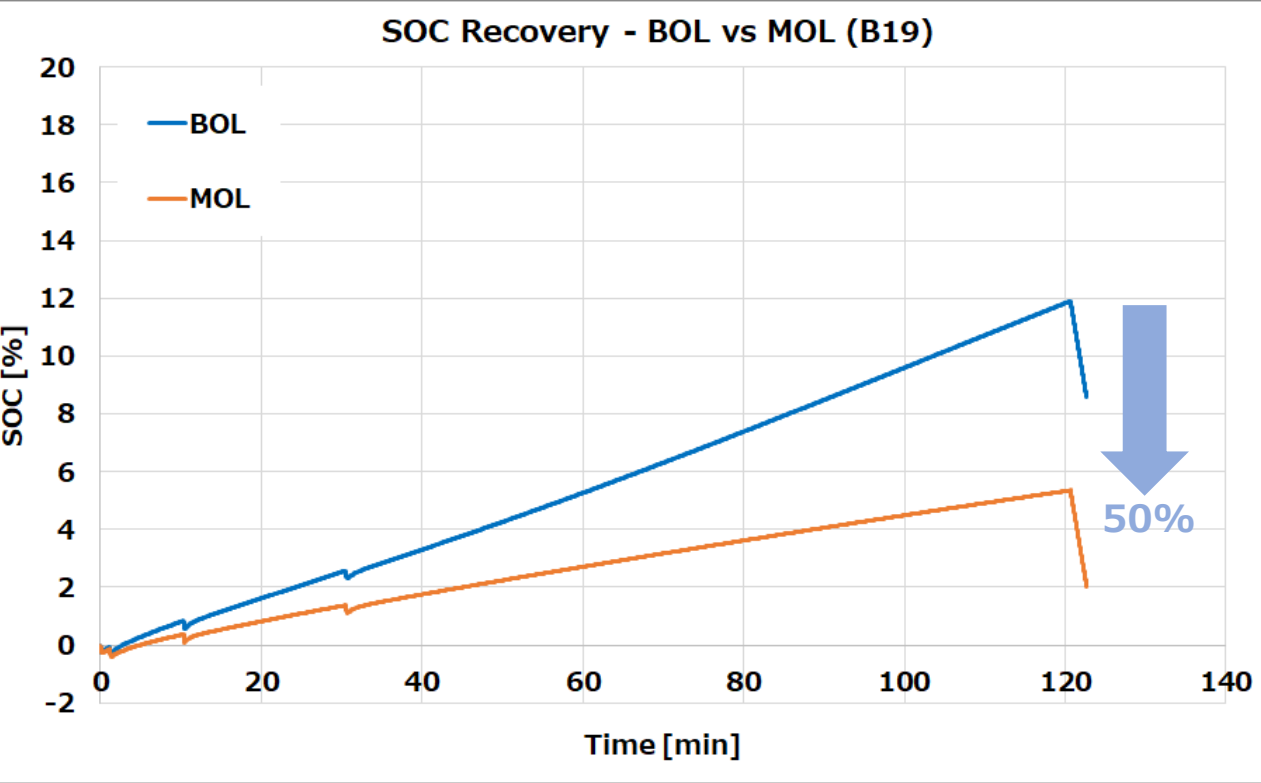
- ✓ Understanding/investigating SOC & SOF recovery characteristics for JIS-type flooded batteries after lifecycle test.

Test Procedure

Step	Test	Note
1	20hR Capacity Check Ce	
2	Charge Recovery – BOL	Discharge to 50% Ce by $In^{(*1)}$ at 25°C (*1) IEC-8: 38% Cn by In at 25°C + 12% Cn by $0.033In$ at -18°C
3	Optional Endurance Cycle Test (Light Load Lifecycle Test)	Cycles terminated at JIS Minimum requirement^(*2) (*2) B19: 1200 cycles, B24: 1800 cycles D23: 3800 cycles, D26: 3800 cycles
4	Remaining 20hR Capacity Check	Direct discharge after Step 3 to 10.5V
5	20hR Capacity Check SOH	Full charge after Step 4 then discharge to 10.5V
6	Charge Recovery – MOL	Discharge 0%^(*3), 30%^(*4) Cn by In at 25°C before charge test (*3) B19, D23 only (*4) B19, B24, D23, D26

CR Test Results – B19

Discharge 30% Cn before charge test



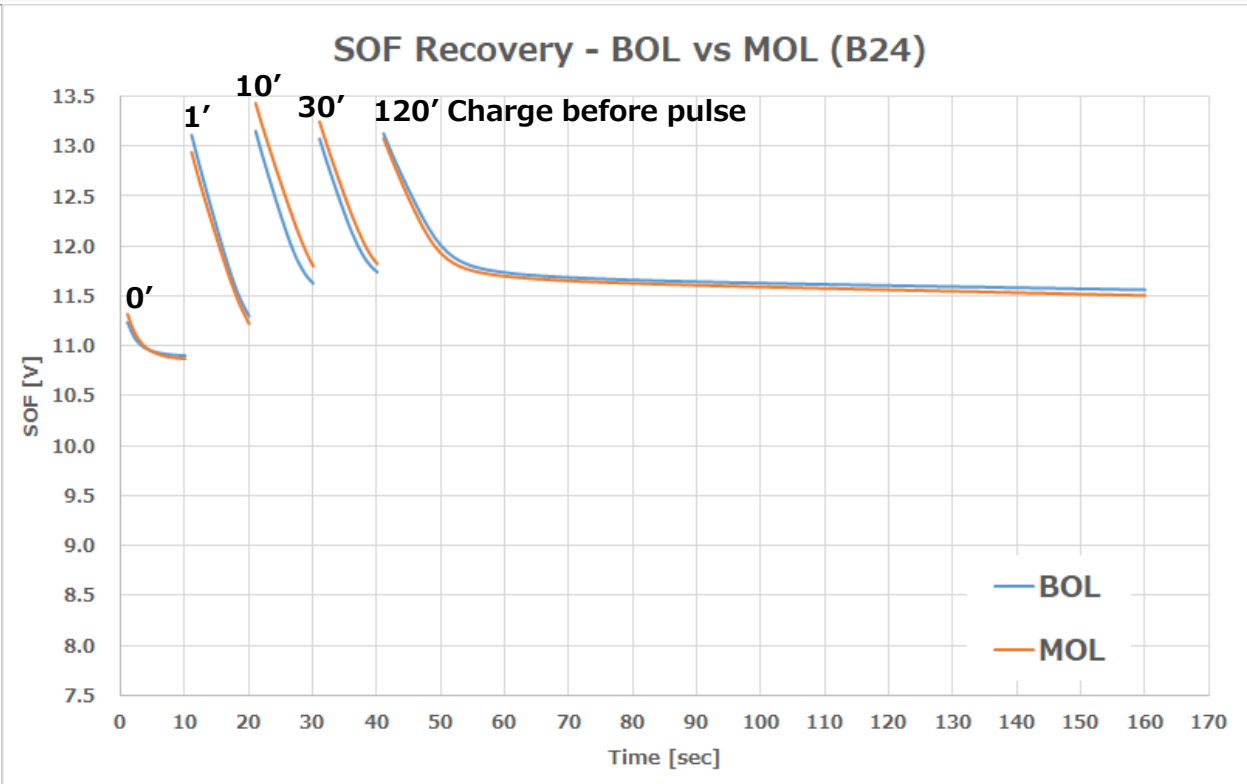
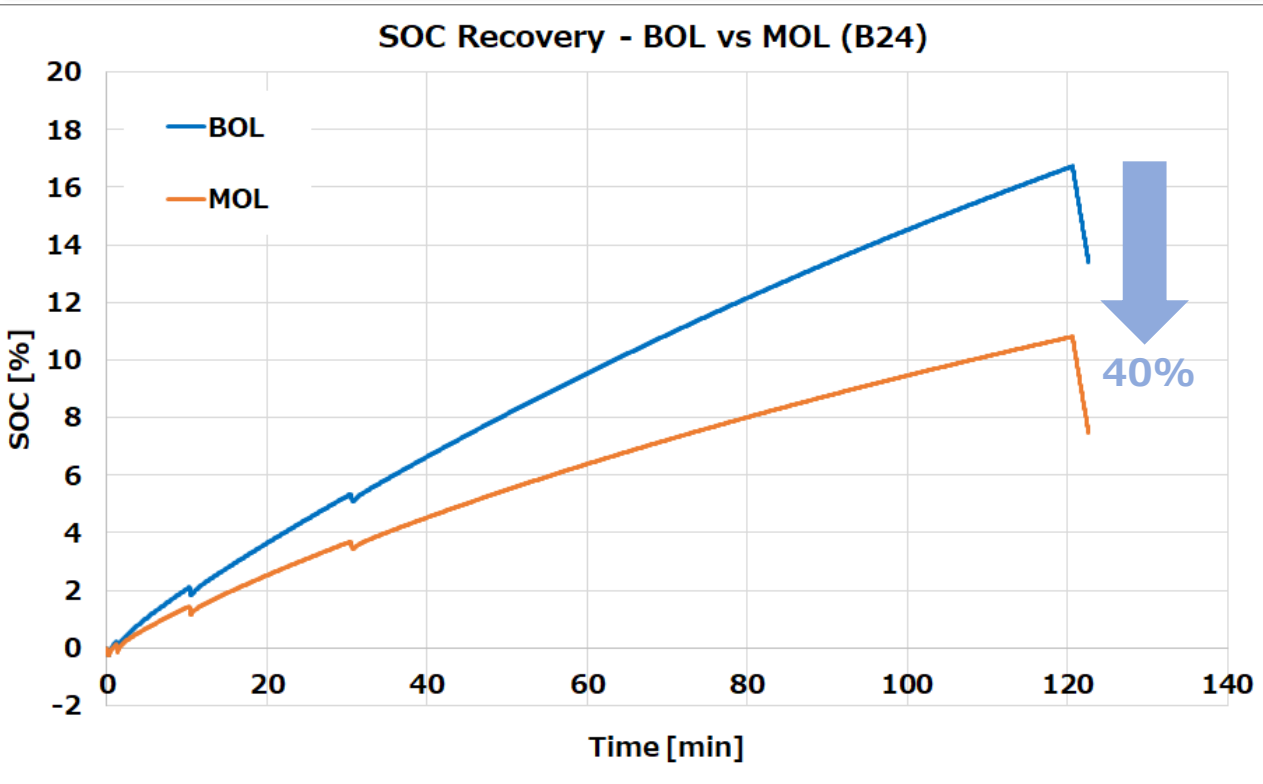
B19	Ah/Cn (30') [%]	Ah/Cn (120') [%]	Uf10 (0') [V]	Uf10 (1') [V]	Uf10 (10') [V]	Uf10 (30') [V]	Uf10 (120') [V]	Uf10(1') -Uf10(0') [V]	Uf10(10') -Uf10(0') [V]	Uf10(30') -Uf10(0') [V]	Uf10(120') -Uf10(0') [V]
Rqmt*	≥ 2	≥ 8	-	-	-	-	-	-	≥ 0.3	≥ 0.5	≥ 0.7
BOL	2.6	11.9	10.80	10.80	11.24	11.42	11.74	0.01	0.45	0.63	0.95
MOL	1.4	5.4	8.29	8.44	8.75	11.64	11.75	0.15	0.46	3.35	3.46

*IEC60095-8, Only for BOL

- ✓ SOC recovery reduced approx.50% vs BOL.
- ✓ SOF recovered the same level as the BOL after 30min-charge.

CR Test Results – B24

Discharge 30% Cn before charge test



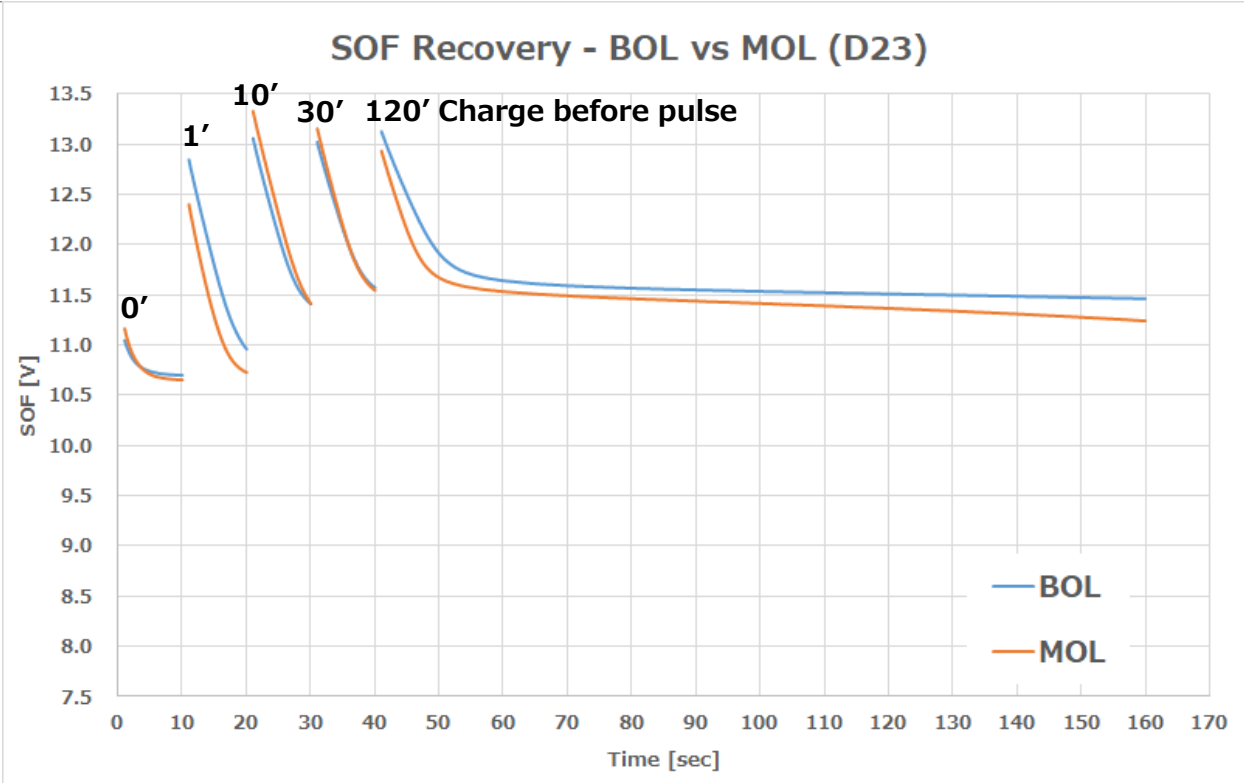
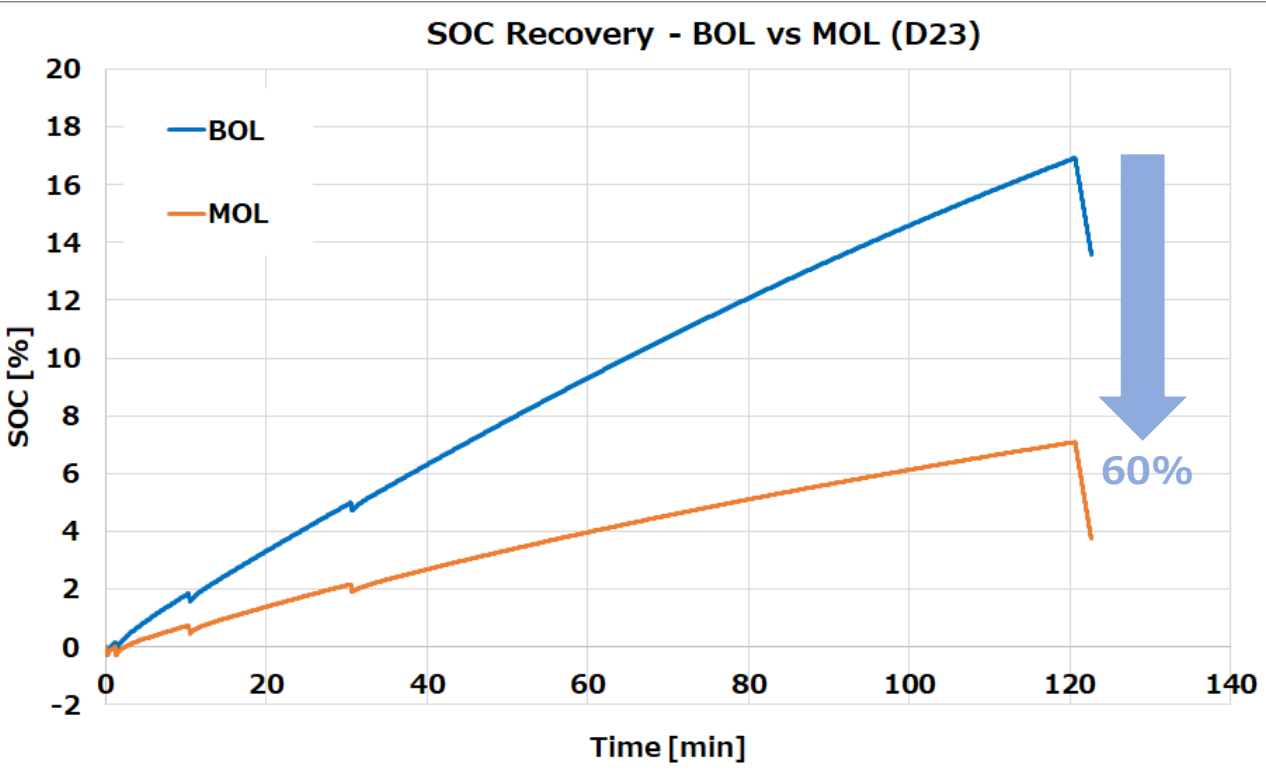
B24	Ah/Cn (30') [%]	Ah/Cn (120') [%]	Uf10 (0') [V]	Uf10 (1') [V]	Uf10 (10') [V]	Uf10 (30') [V]	Uf10 (120') [V]	Uf10(1') -Uf10(0') [V]	Uf10(10') -Uf10(0') [V]	Uf10(30') -Uf10(0') [V]	Uf10(120') -Uf10(0') [V]
Rqmt*	≥ 2	≥ 8	-	-	-	-	-	-	≥ 0.3	≥ 0.5	≥ 0.7
BOL	5.4	16.7	10.88	11.12	11.55	11.72	11.91	0.24	0.67	0.84	1.03
MOL	3.7	10.8	10.86	11.22	11.96	11.82	11.92	0.35	1.09	0.95	1.06

*IEC60095-8, Only for BOL

- ✓ SOC recovery reduced approx.40% vs BOL.
- ✓ SOF was the same level as BOL at all conditions.

CR Test Results – D23

Discharge 30% Cn before charge test



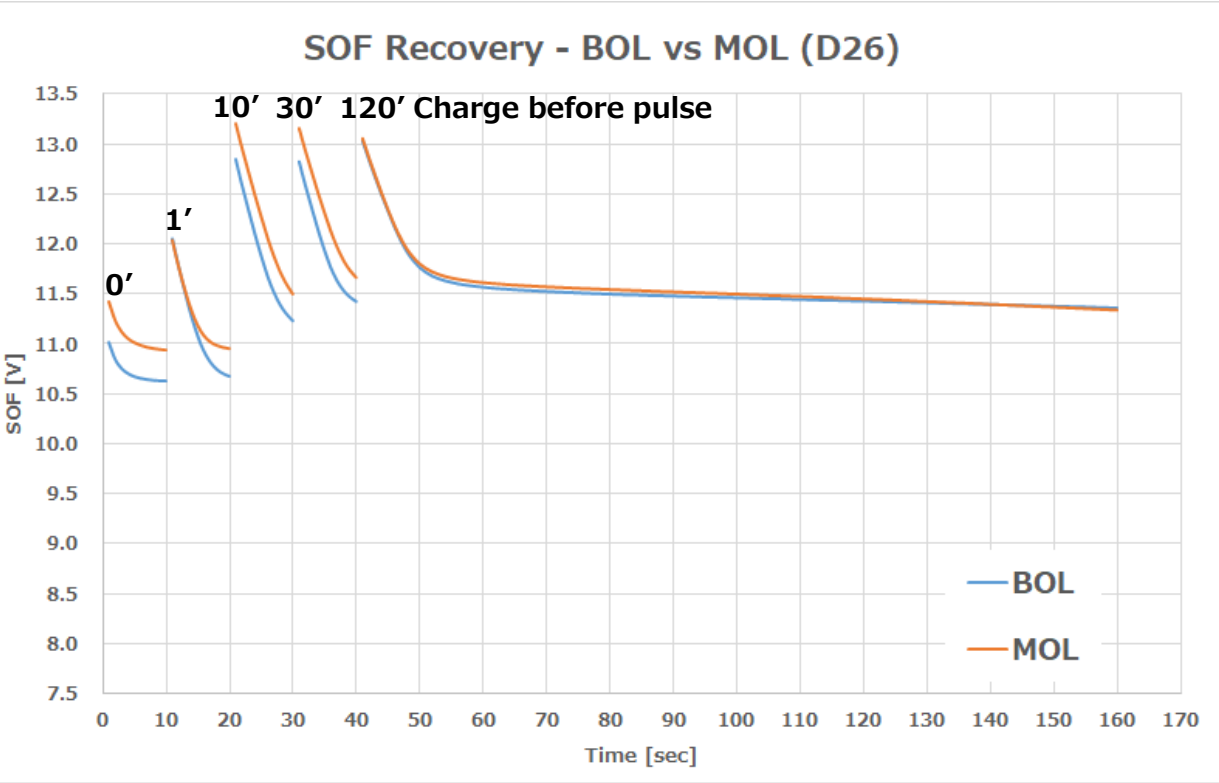
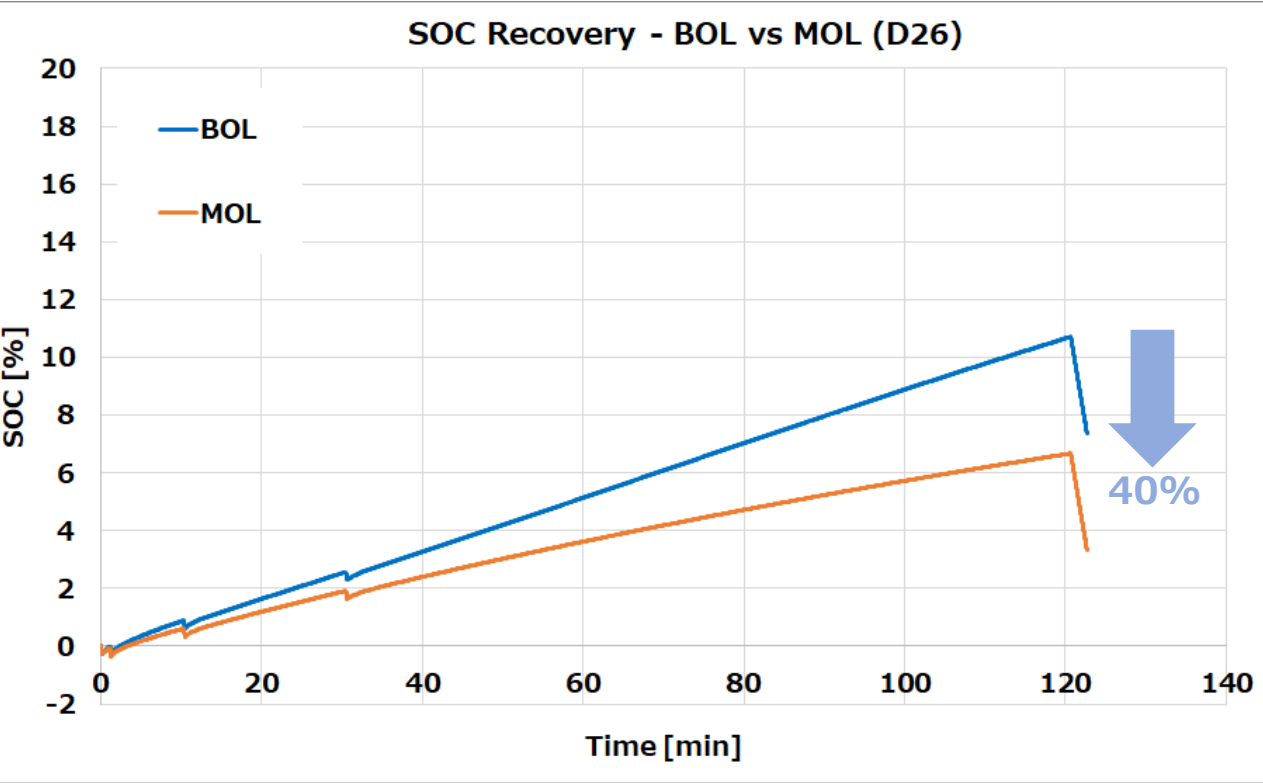
D23	Ah/Cn (30') [%]	Ah/Cn (120') [%]	Uf10 (0') [V]	Uf10 (1') [V]	Uf10 (10') [V]	Uf10 (30') [V]	Uf10 (120') [V]	Uf10(1') -Uf10(0') [V]	Uf10(10') -Uf10(0') [V]	Uf10(30') -Uf10(0') [V]	Uf10(120') -Uf10(0') [V]
Rqmt*	≥ 2	≥ 8	-	-	-	-	-	-	≥ 0.3	≥ 0.5	≥ 0.7
BOL	5.0	16.9	10.71	10.97	11.42	11.58	11.92	0.26	0.71	0.87	1.21
MOL	2.2	7.1	10.66	10.73	11.41	11.54	11.67	0.08	0.76	0.89	1.02

*IEC60095-8, Only for BOL

- ✓ SOC recovery reduced approx.60% vs BOL.
- ✓ SOF was the same level as BOL at all conditions.

CR Test Results – D26

Discharge 30% Cn before charge test



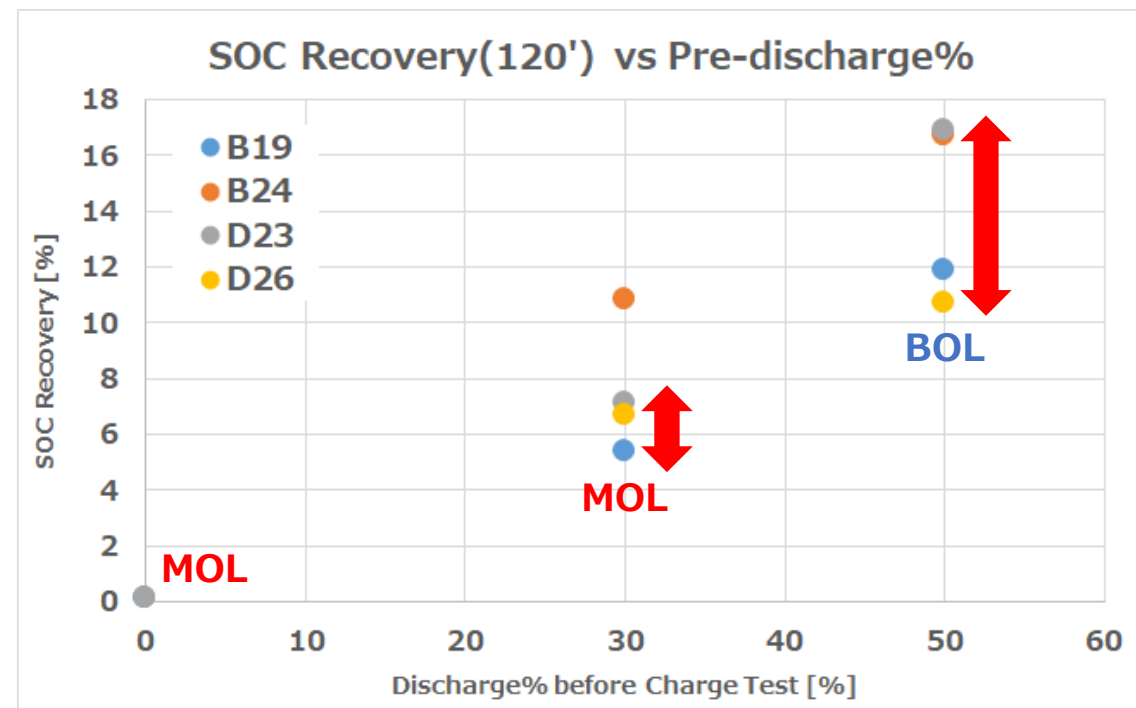
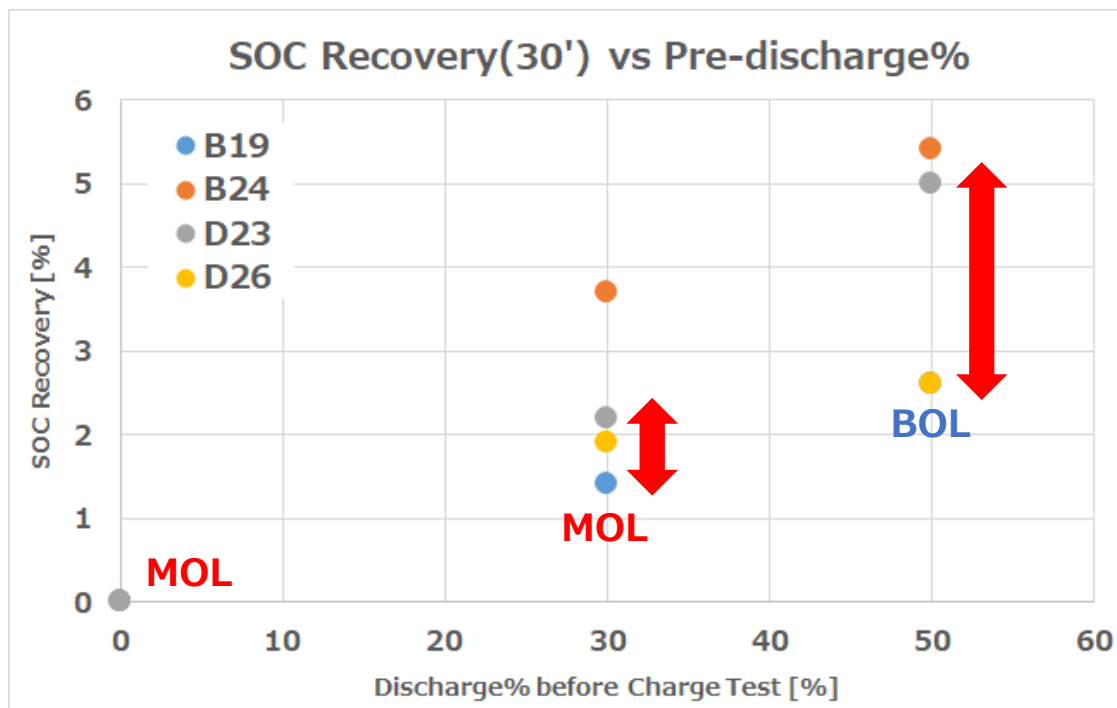
D26	Ah/Cn (30') [%]	Ah/Cn (120') [%]	Uf10 (0') [V]	Uf10 (1') [V]	Uf10 (10') [V]	Uf10 (30') [V]	Uf10 (120') [V]	Uf10(1') -Uf10(0') [V]	Uf10(10') -Uf10(0') [V]	Uf10(30') -Uf10(0') [V]	Uf10(120') -Uf10(0') [V]
Rqmt*	≥ 2	≥ 8	-	-	-	-	-	-	≥ 0.3	≥ 0.5	≥ 0.7
BOL	2.6	10.7	10.63	10.68	11.23	11.43	11.77	0.05	0.60	0.79	1.13
MOL	1.9	6.7	10.94	10.96	11.50	11.67	11.81	0.02	0.56	0.73	0.87

*IEC60095-8, Only for BOL

- ✓ SOC recovery reduced approx.40% vs BOL.
- ✓ SOF was slightly higher than BOL at all conditions.

Considerations / Findings – SOC Recovery

- ✓ SOC recovery reduction(BOL→MOL) was approx. 40 – 60% with 30%-discharge before charge test.
- ✓ Regardless of SOH, SOC recovered approx.2% after 30min-charge and approx.6% after 120min-charge at MOL(except for B24).
- ✓ The B19/D23 batteries did not accept charging at all without discharging before charge test.
- ✓ SOC recovery at MOL may be controlled by discharge% before charge test.



Considerations / Findings – SOF Recovery

- ✓ Regardless of SOH, SOF was recovered after 30min charge and all batteries show an equivalent value.
- ✓ This indicates that SOF recovery can look better (like B19) if the initial SOF is lower.
- ✓ Acid stratification and polarization may affect SOF as well.
- ✓ PPC-EOL test procedure/requirements on IEC60095-8 assumes that 50% reduction of SOH, while the sensitivity to degradation for CR-EOL may be smaller than in PPC.
- ✓ It is concerned that the FLA batteries can not be discharged 25% at EOL for PPC-EOL test.

