

SO26 - ALBA+ Drive Cycle Simulation at IBR - Charging Recommendation at high Temperature

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ALBA+ Drive Cycle Simulation at IBR - Charging Recommendation at high Temperature

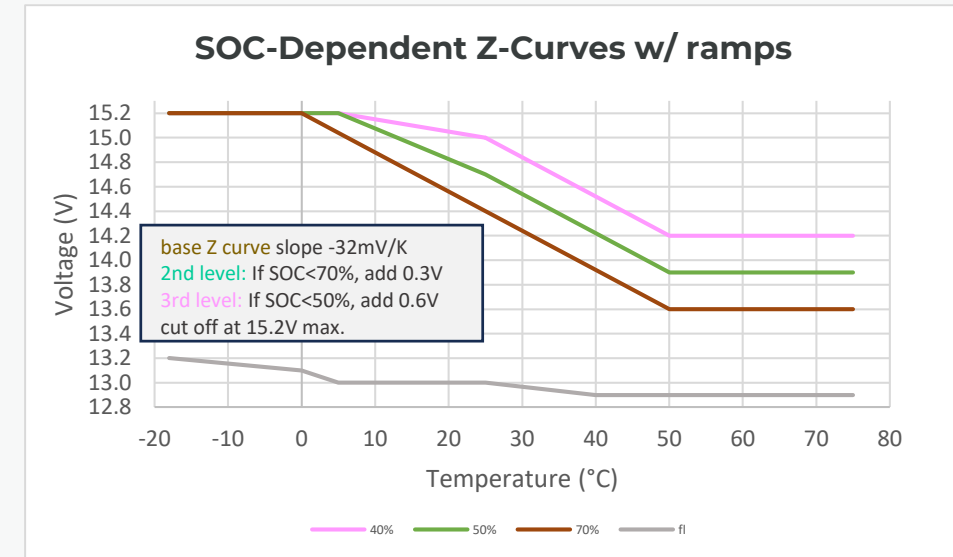
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Summary

Charging recommendations from previous ALBA workshops:

- Undercharged batteries are still the main cause for vehicle breakdowns – even in EV.
- Traditional temperature dependent Z-Curve and/or float charging can be replaced by an SOC-dependent set of Z-curves to allow efficient charging with higher voltages at lower state-of-charge (SOC).
- Harmful side-reactions. e.g. gasing, corrosion, can be minimized by limiting the charging current (very difficult to implement even in DC/DC controlled charging in EV) or voltage ramps at the beginning of the charging event.
- The current controlled strategy has been demonstrated in previous ALBA workshops, while the latter one with voltage ramps has been investigated in a CBI sponsored ALBA+ project at IBR.



Experimental Set-up

- Bench measurements in IBR laboratory of simulated drive cycle with e-Gas measurements
- Two scenarios: Back-up battery with Sales agent driving profile and Main 12V-battery in kindergarten cycles
- 3 charging strategies: one traditional Z-curve with minimum float charging voltage and two different SOC-dependent Z-curves with ramps

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High Temperature Driving Cycles

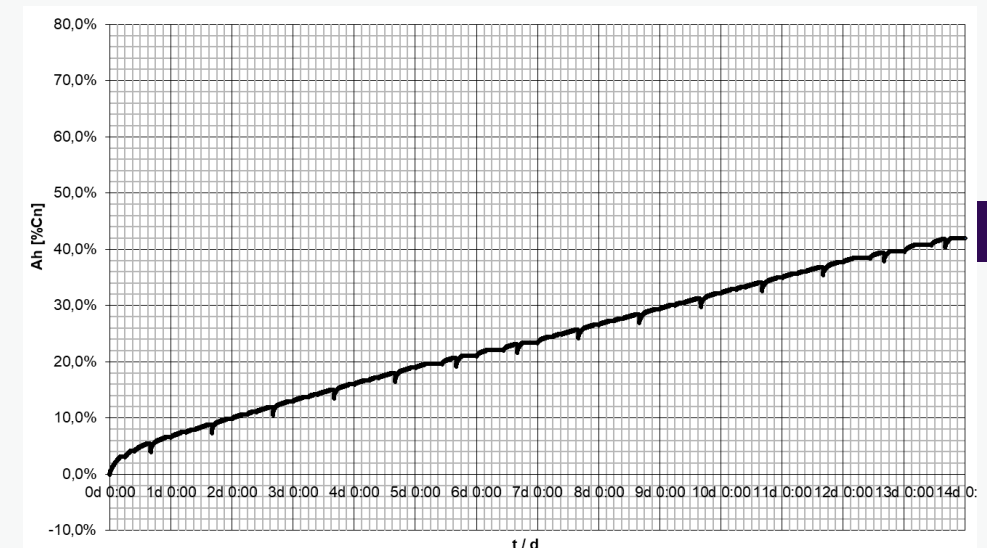
Back-up battery with Sales agent driving profile with long highway drives (long charging times) at elevated temperatures (60°C/75°C) have been applied for two weeks in each charging strategy.

Key Findings:

- Low flow voltages cannot keep battery SOC constant. Ultimately battery will fail because of undercharge:
 - 13.2V (60°C) // 2 weeks → - 4% SOC
 - 13.1V (75°C) // 2 weeks → - 11% SOC
- Effect of voltage ramps could not be proven as voltage set-points were based on test bench Ah-counter. Thus, the battery was assumed fully charged and a reduced voltage have been applied.

Question:

Should effectiveness of voltage ramps at higher temperatures investigated further?



Low Temperature Driving Cycles

Back-up battery with Sales agent driving profile at low temperatures was too aggressive (high overnight discharge by parking lights) to evaluate charging strategies and have been repeated → SO25 – Sebastian Mauer

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Details for drive cycle and charging strategies

• “Backup” cycle

- high temp (75°C)
- Salesman, high-mileage driver, highway use case
- backup strategy

• “Backup” cycle

- high temp (60°C)
- Salesman, high-mileage driver, highway use case
- backup strategy

• 3 different charging strategies

- Float MIN
 - Z-curve with low voltage
 - 13.3V if SOC < 50% (80% if on plug)
 - 13.1V if SOC ≥ 50% (80% if on plug)

• 3 different charging strategies

- Float MIN
 - Z-curve with low voltage
 - 13.6V if SOC < 50% (80% if on plug)
 - 13.2V if SOC ≥ 50% (80% if on plug)

• “As needed”

- with 5min Ramps
- SOC based voltage set points

SOC thre	0	10	20	30	40	50	60	70	80	90	100
75	14,6	14,6	14,0	13,8	13,5	13,5	13,5	13,5	13,5	13,5	12,9
SOC thre	0	10	20	30	40	50	60	70	80	90	100
60	14,8	14,8	14,6	14,2	14,0	13,8	13,8	13,8	13,8	13,8	12,9

• Z-curve “-32mV/K

- with 5min Ramps
- SOC based voltage set points

SOC thre	0	10	20	30	40	50	60	70	80	90	100
75	14,2	14,2	14,2	14,2	14,2	13,9	13,9	13,6	13,6	13,6	12,9
SOC thre	0	10	20	30	40	50	60	70	80	90	100
60	14,2	14,2	14,2	14,2	14,2	13,9	13,9	13,6	13,6	13,6	12,9

days 1 - 5	sales agent extended
	7:00 trip 2h
	9:00 on-plug 0.5h
	9:30 trip 1.5h
	11:00 park 2h
	13:00 trip 2h
	15:00 park 1.5h
	16:30 trip 2.5h
	19:00 on-plug 0.5h
	19:30 trip 2h
	21:30 park 1.5h
	23:00 on-plug 6h
	5:00 park 2h
days 6-7	sales agent extended
	7:00 trip 4h
	11:00 park 6.5h
	17:30 trip 1.5h
	19:00 on-plug 0.5h
	19:30 trip 2h
	21:30 park 1.5h
	23:00 on-plug 2h
	1:00 park 6h

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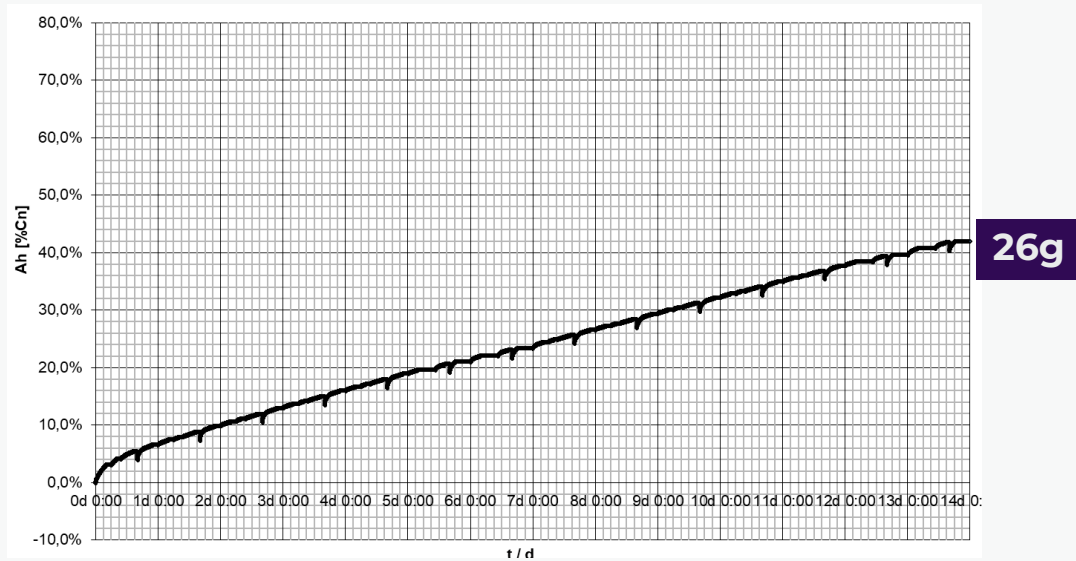
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Low Float Strategy at 60°C

“**Back-Up**” drive cycle at 60°C: High mileage driver with battery always on charge when possible

“**Low float**” charging strategy: 13.2V at 60°C, independent of SOC.



Ah-counter of vehicle (test bench) indicates a high overcharge portion leading to a SOC gain of 42% Cn.

However:

- Real SOC based on acid gravity measurements before and after trip indicate a SOC loss of 4% Cn in 2 weeks.
- Vast majority of positive charge (+42% Cn) balance goes into side reactions. The battery weight decreases by 26g in 2 weeks, i.e. 0.4 g/Ah weight loss.

→ **Low Float charging cannot keep SOC constant and already leads to water loss.**

Can voltage ramps improve the ratio of accepted charge to side reactions?

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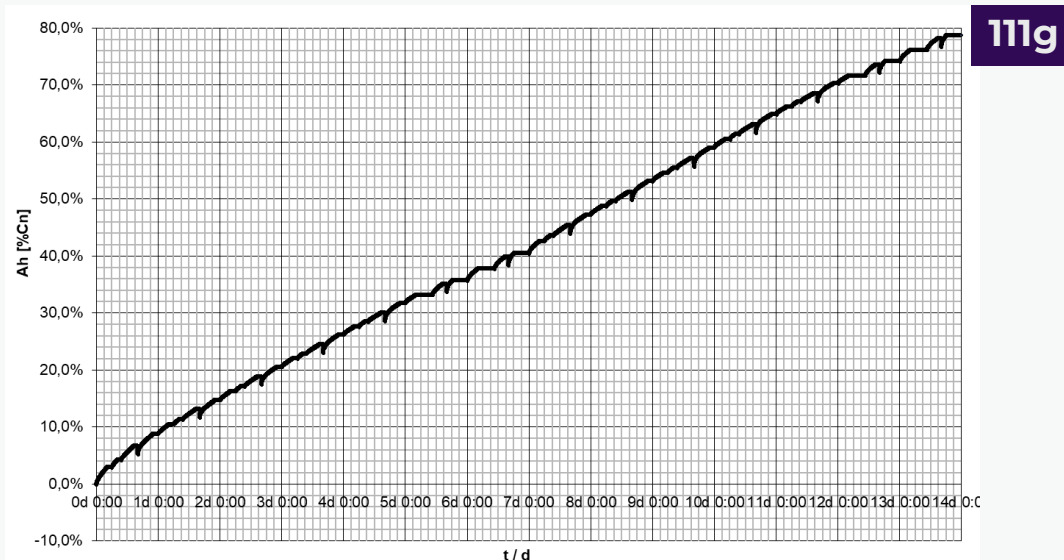
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Low Float Strategy at 75°C

“Back-Up” drive cycle at 75°C: High mileage driver with battery always on charge when possible

“Low float” charging strategy: 13.1V at 75°C, independent of SOC.



Ah-counter of vehicle (test bench) indicates a high overcharge portion leading to a SOC gain of 78% Cn.

However:

- Real SOC based on acid gravity measurements before and after trip indicate a SOC loss of 11% Cn in 2 weeks.
- Vast majority of positive charge (+78% Cn) balance goes into side reactions. The battery weight decreases by 111g in 2 weeks, i.e. 1.6 g/Ah weight loss.

→ **Low Float charging cannot keep SOC constant** and already leads to water loss.

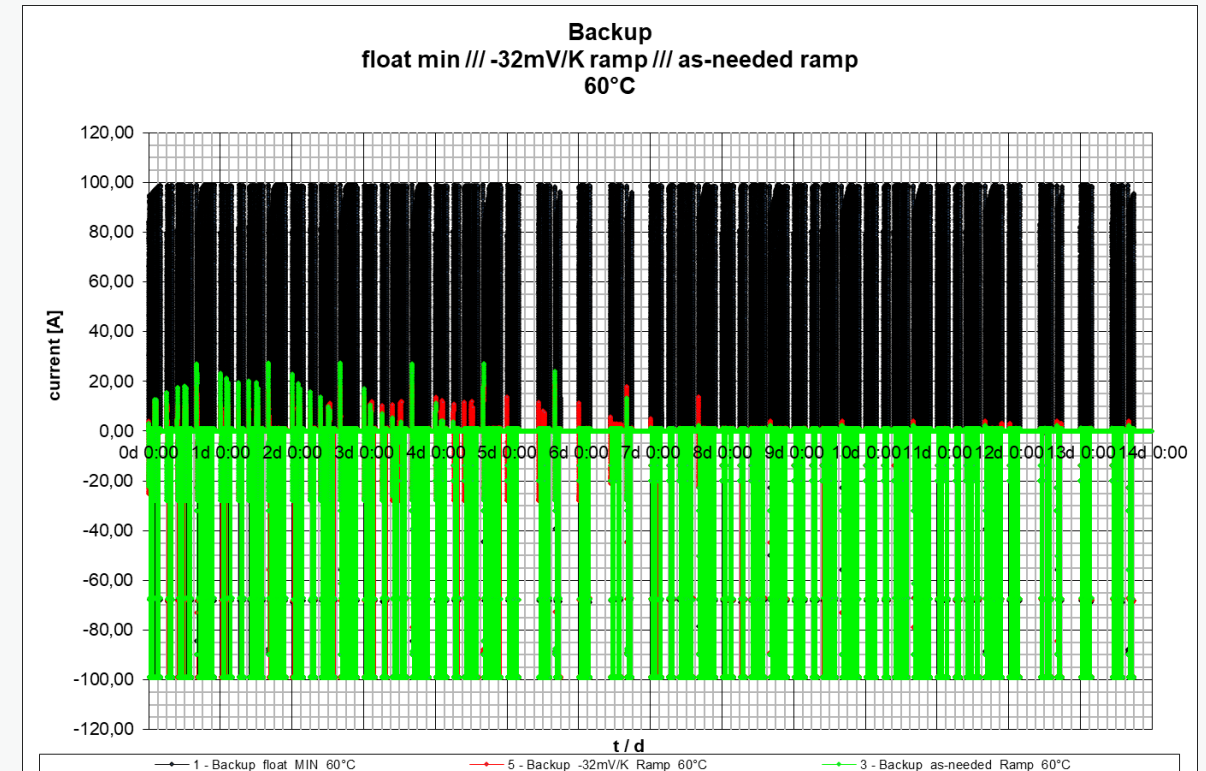
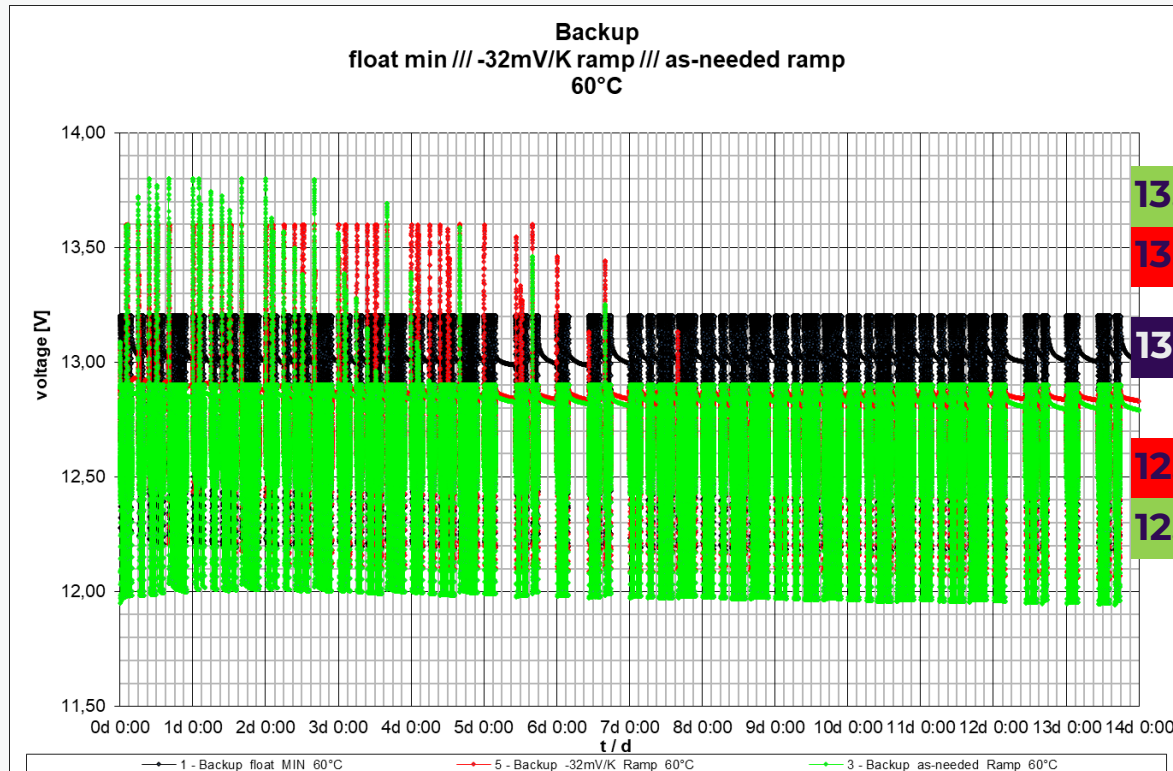
Can voltage ramps improve the ratio of accepted charge to side reactions?

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60° Measurements

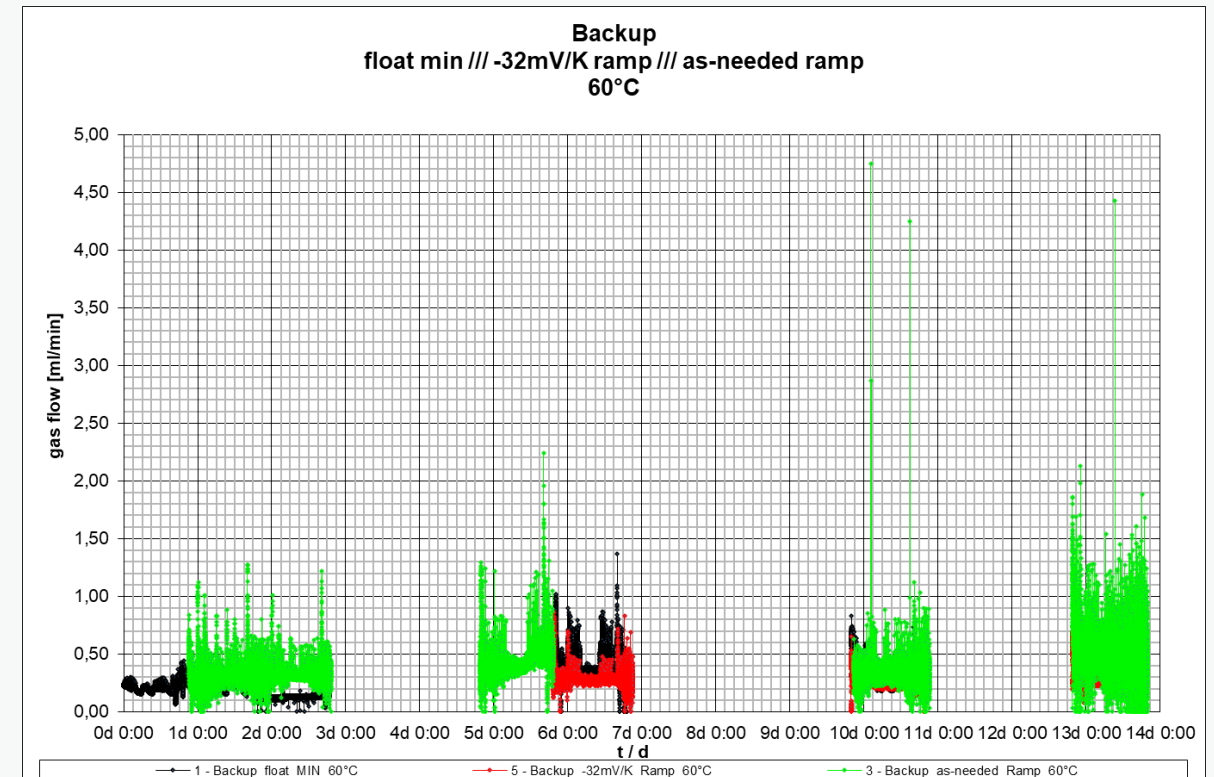
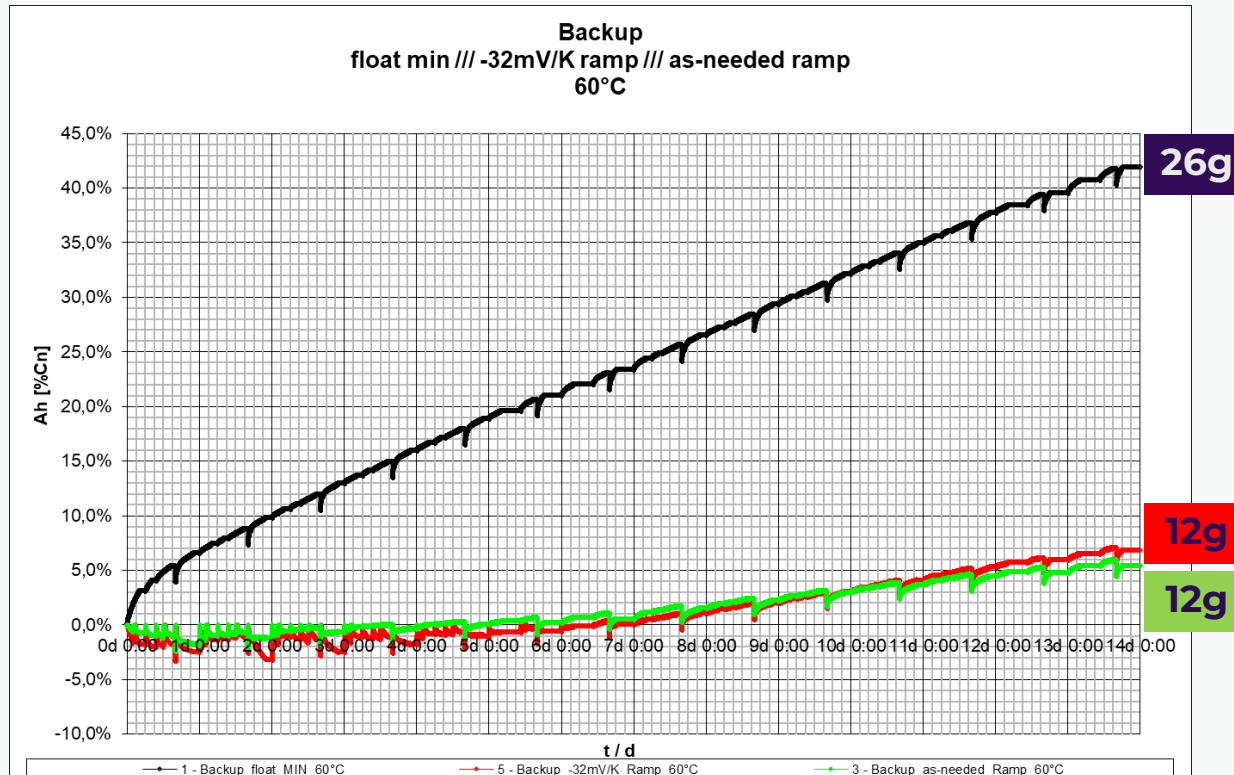


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60° Measurements

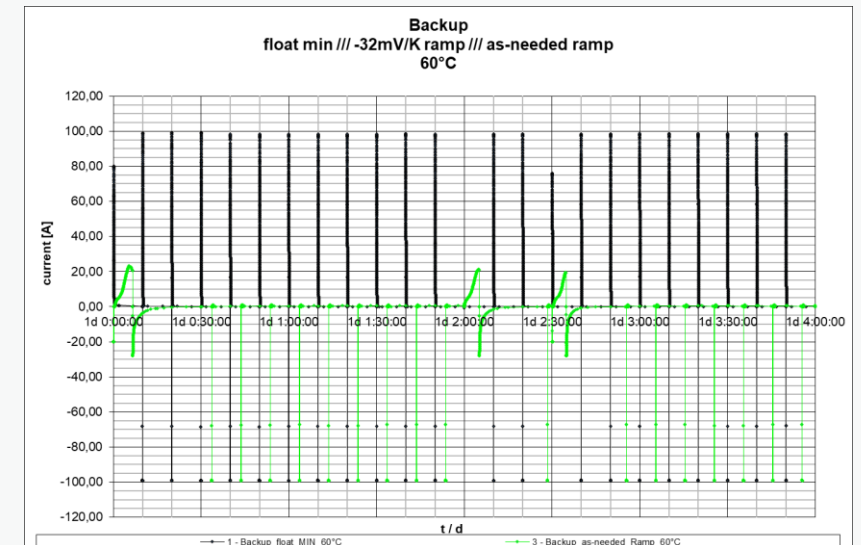
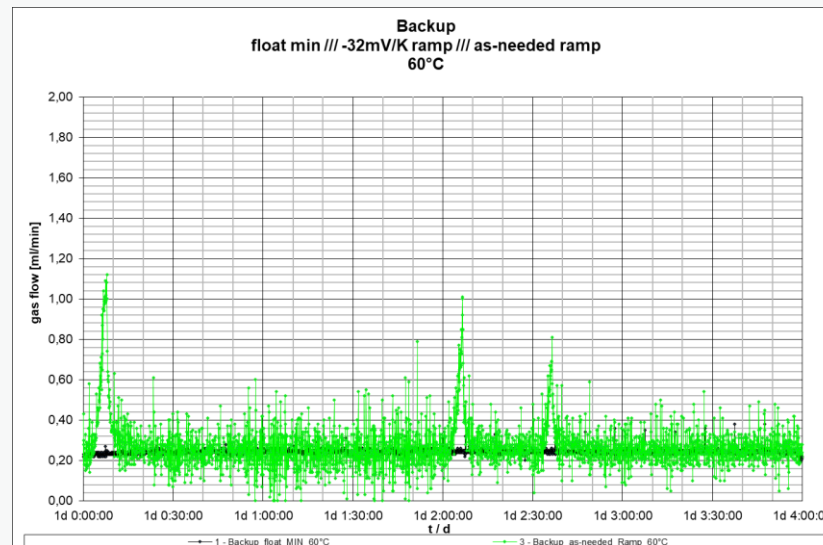
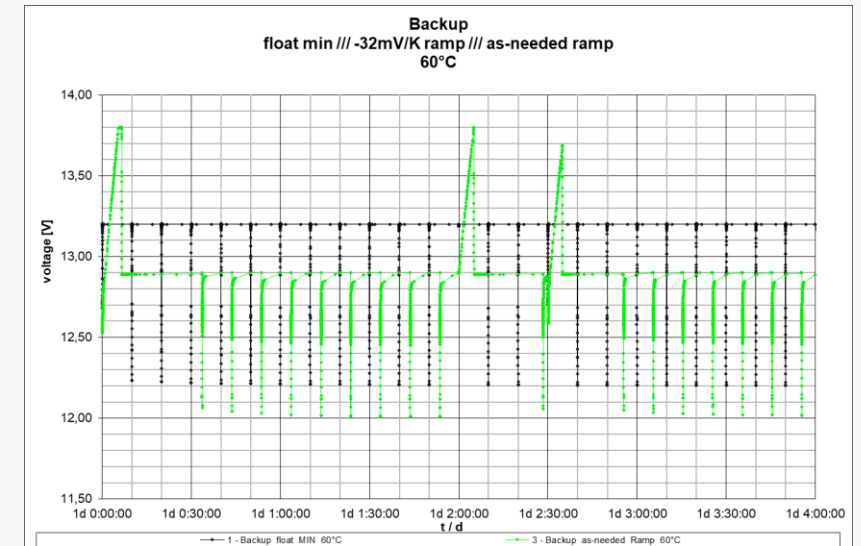
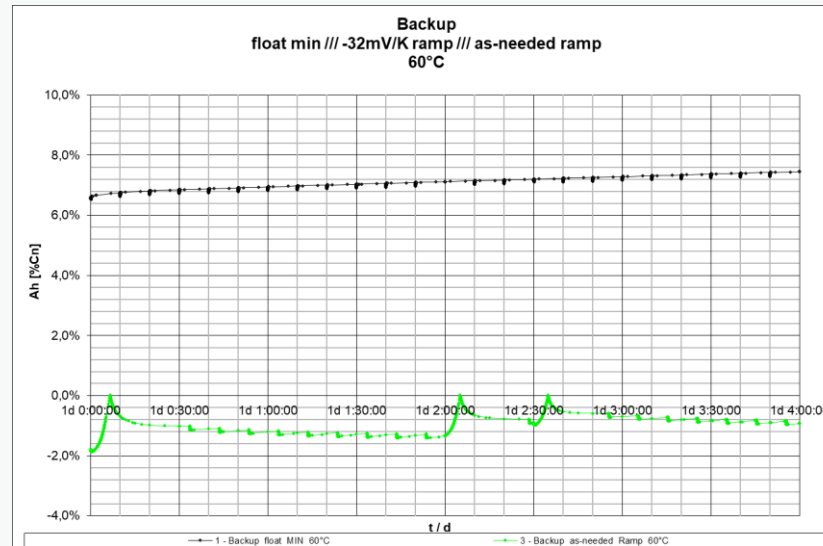


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60° Measurements



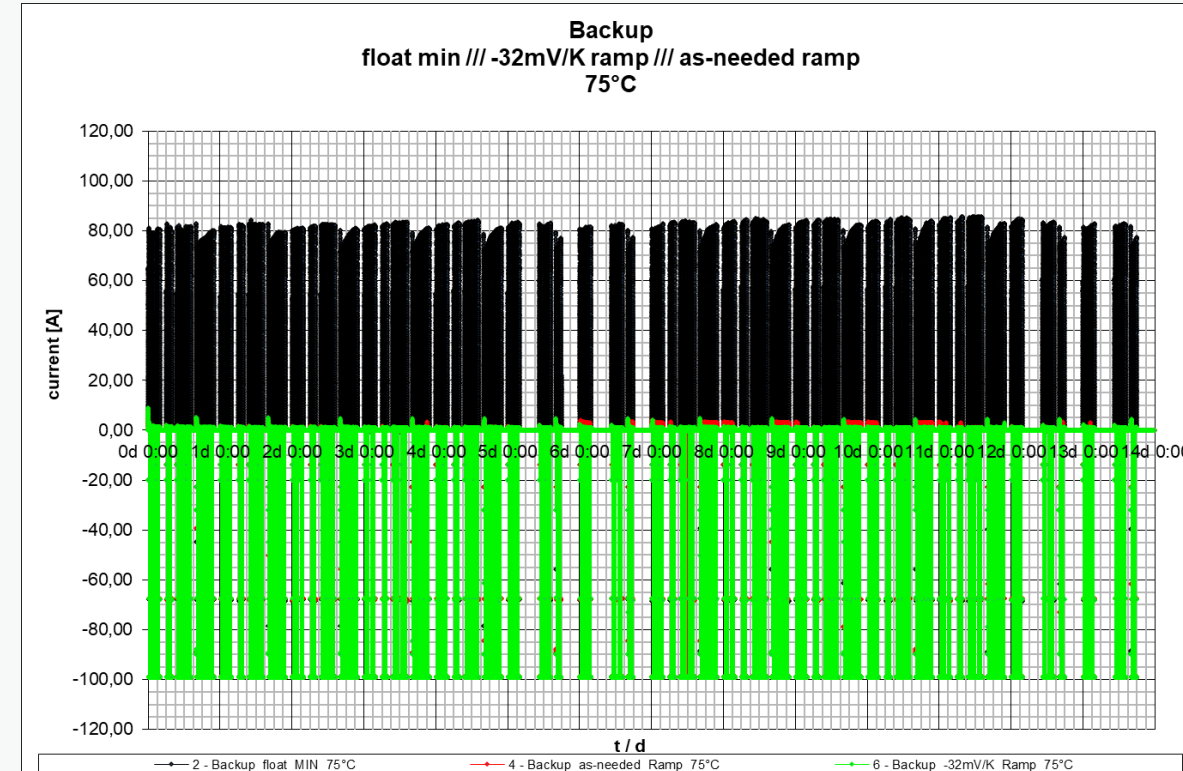
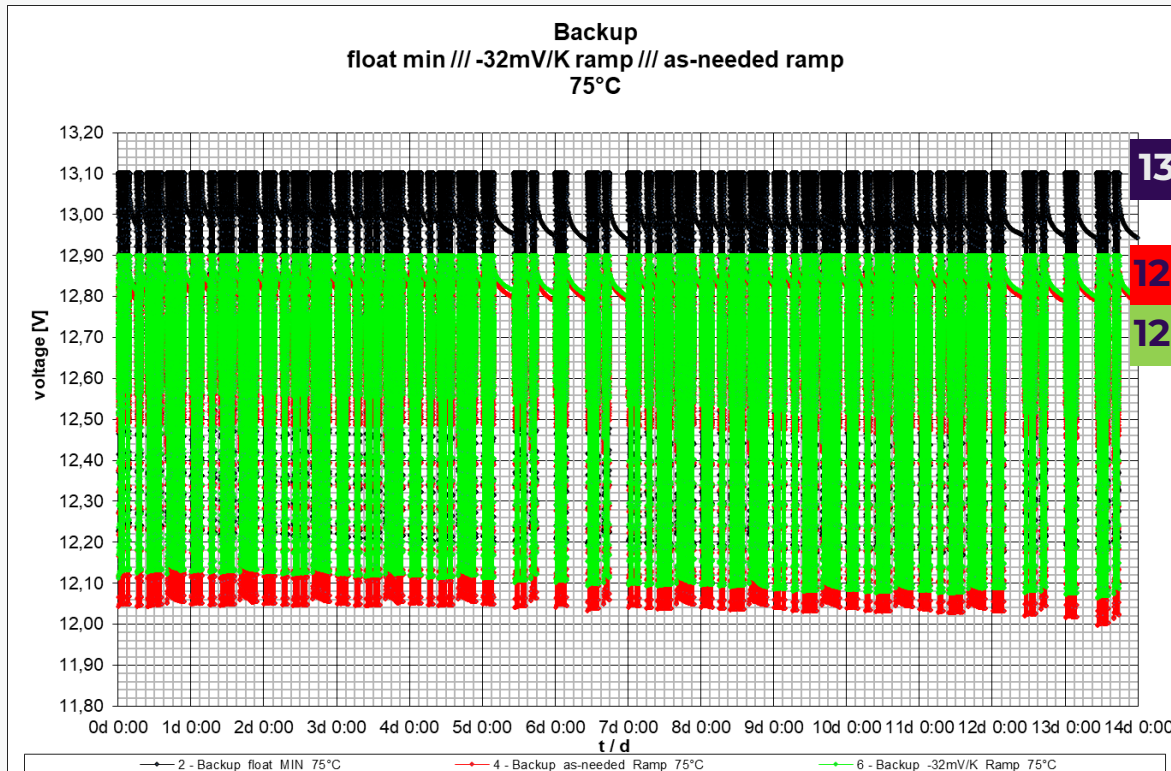
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75° Measurements

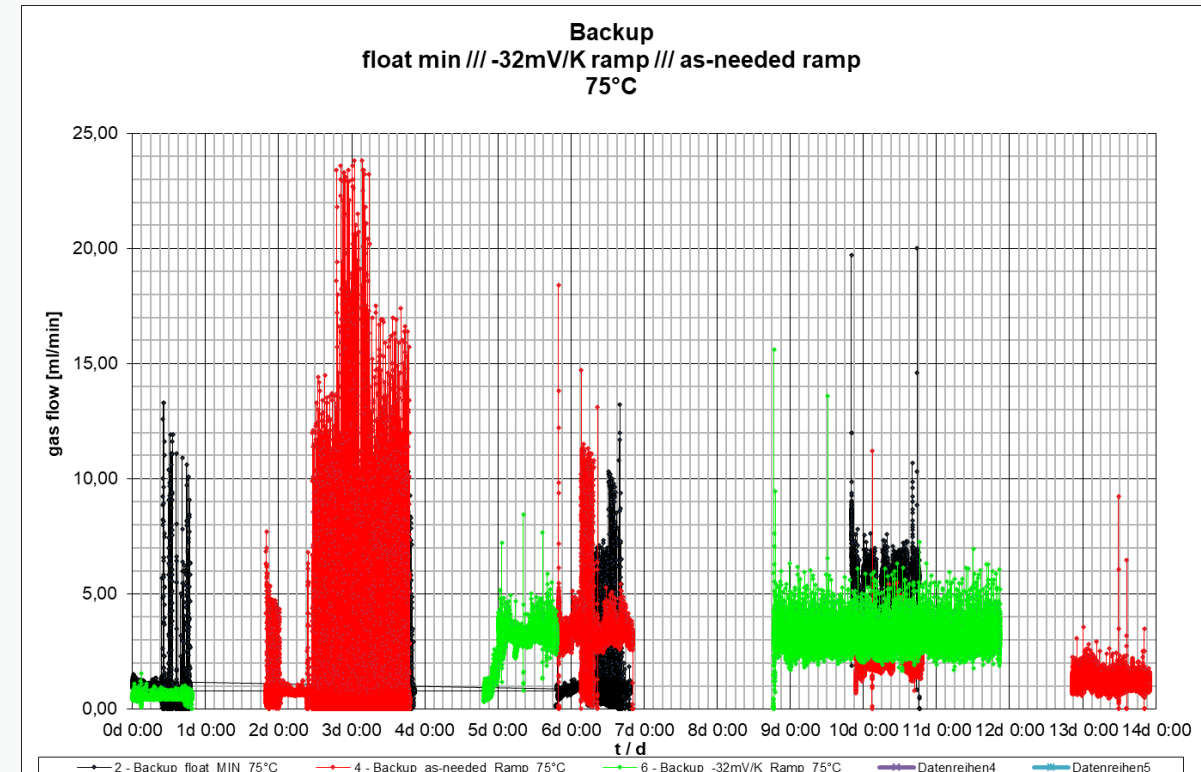
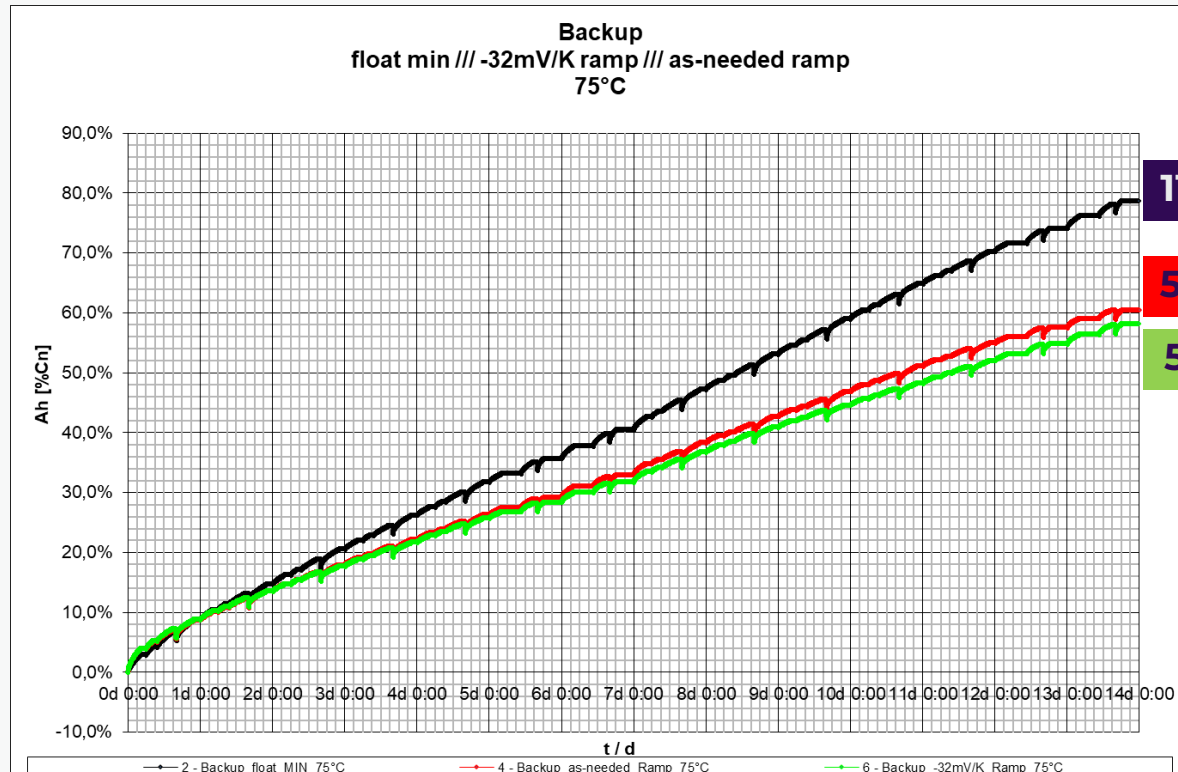


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75° Measurements



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Lessons Learned

A repetition of the high temperature measurements should consider the following

- Use fresh batteries for each trial. Otherwise starting SOC might be different.
- E-Gas measurements always on the same time stamp (for example every Day 2 of drive cycle)
- Choose parameters of charging strategy carefully – do not reduce too flow charging too early (Ah counter of test bench does not consider side reactions, i.e. real charging factor is much less than 1)
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Potential Next Steps

Repeat in easier set-up to validate ramps, i.e. can gasing be efficiently suppressed?

- City cycle and high mileage driver
- 1 battery with alternating charging strategies (no ramps, short ramp (30s ?), 5 min)
- Voltage at highest recommended voltage
- e-Gas measurements for one day (after 1 week drive-in)

Long term trial (without e-Gas) to validate charging efficiency of strategies, i.e. stable SOC