Design Description
Battery Regulation Article 10 - Performance and Durability

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1 Part A – Accompanying document

Information to the performance and durability of electric vehicle batteries according to Art. 10 Paragraph 1 and Annex IV of the Regulation (EU) 2023/1542.

Performance and durability[1] parameters		
Type designation	**B8 408 01 1, B8 213 01 1**	**B8 413 01 1[2]**
Rated capacity	157Ah	314Ah
Capacity fade[3]	10%	10%
Power	206kW	412kW
Power fade[3]	8%	8%
Internal resistance	124mΩ	62mΩ
Internal resistance increase[3]	8%	8%
Energy round trip efficiency	96%	96%
Energy round trip efficiency fade[3]	1%	1%
Expected minimum lifetime of the battery under reference conditions, for which it is designed for[4].	500MWh of total energy throughput[5] or 12 years, whichever comes first.	1000MWh of total energy throughput[5] or 12 years, whichever comes first.

1 Information according to the regulation (EU) 2023/1542. The mentioned values refer to the reference conditions and are not guaranteed values. The actual values in vehicle use can vary depending on various factors like the ambient temperature and battery temperature, state of charge and the user profile. Tips and advice for using and charging the vehicle can be found in the vehicle manual.

2 B8 413 01 1 is two B8 213 01 1 packs connected mechanically in parallel. Electrically it performs like two B8 213 01 1, therefore the rated capacity, power, internal resistance and expected minimum lifetime are considered accordingly.

3 All results refer to test conditions with SOC window of 7-82% at 25°C and during 0.75C/1C charge/discharge cycles after 400MWh of total energy throughput.

4 Minimum lifetime of the high-voltage battery according to the warranty conditions, 7-82% SOC window and charge rate of C/2.

5 The total accumulated charged and discharged energy

2 Part B – Sub-technical documentation

Introduction

The following document presents an elaborated description of the required data given in part A, Annex IV. How the data has been achieved and for what conditions they are valid are given in section 2.1, Performance. Their change within the battery lifetime is given in section 2.2, Durability.

2.1 Performance

Table 1 presents the variance between rated capacity and installed energy between different battery types.

Type designation	Rated capacity [Ah]	Installed energy [kWh]
B8 408 01 1	157	104
B8 413 01 1	314	208
B8 213 01 1	157	104

Table 1. The B8 408 01 1 and B8 213 01 1 installed battery energy is 104 kWh, based on the rated capacity (157Ah) and the nominal system voltage (661V). A B8 413 01 1 battery corresponds to two B8 213 01 1 batteries which generates double capacity and installed energy.

2.1.1 Capacity

In Table 2 the nominal system capacity is given. The system capacity is calculated by the cell capacity multiplied with the number of parallel interconnections in the system.

Capacity measurements to approve the minimum nominal cell capacity and determine capacity fade over lifetime are done according to IEC 62660-1:2018 (Test 7.3 - Capacity) with C/3 charge and C/3 discharge current rate at T=25°C. The capacity is evaluated from the third of three capacity cycles. See TR7078649.

Rated capacity [Ah] [1]	157

[1] Rated system capacity.

Table 2: Rated system capacity at beginning of life.

2.1.2 Energy Round Trip Efficiency

The energy round trip efficiency was determined from the capacity measurement specified in section 2.1.1 according to Equation 1.

$$\eta = \frac{E_{DCH}}{E_{CH}}$$

Equation 1

The initial energy efficiency was directly measured on cell level 7-82% SOC window. Since no system data were available, it is assumed, that the system energy efficiency is equal to the cell energy efficiency, see Table 3. The charge and discharge rate used is C/3 at T=25°C. See TR7081139.

Cell [-]	96%
System [-]	System eff. = Cell eff.

Table 3: Energy round trip efficiency at beginning of life.

2.1.3 Internal resistance

The measuring method for determining internal resistance according to the IEC 62660-1:2018 standard (Test 7.5 - Power). The tested temperature was limited to 25°C. The pulse SOC were measured at 5% SOC, 10% SOC, 20% SOC, 35% SOC, 50%, 65% SOC, 80% SOC, 85% SOC and 90% SOC. The internal resistance was evaluated for 50% SOC at 25°C after 30s in a 1C discharge pulse. See TR7093506.

The internal resistance is measured on cell level and scaled to the system level according to the system configuration, see Table 4. Consider Equation 2 for series connections.

$$R_{system} = \sum_{i} R_i \, , where \; i \; is \; the \; numeber \; of \; resistances \; (cells) \; in \; series$$

Equation 2

Cell [mOhm]	0.69
System [mOhm] [2]	124

[2] S*caled from cell level according to Equation 2 not considering the effect of system interconnections.*

Table 4: Internal resistance at beginning of life

2.1.4 Power

The measuring method for power determination according to IEC 62660-1:2018 (Test 7.5 - Power) with the following parameters: T=25°C, SOC=20%, 50%, 80%, 30s discharge pulse. See TR7093506.

The power values were determined by using Equation 3Equation .

$$P\_30s = U_{30s} * I\_pulse$$

Equation 3

Measurements are done at cell level. The discharge power scaled up to system level according to the battery connection 180s1p by multiplying the cell power by the number of cells in the system, according to Equation 4. See Table 5.

$$P_{Sys} = P_{cell} * N, where \; N \; is \; the \; number \; of \; cells \; in \; the \; system$$

Equation 4

	Cell	System
SOC	Power (W)	Power (kW)
20%	981	177
50%	1145	206
80%	1233	222

Table 5. *Discharge power at beginning of life.*

Disclaimer:

In vehicle application, the system power can be further restricted by the battery management system operating strategy.

The power to energy ratio

The power to energy ratio is requested in Annex IV B of the battery regulation and given in Table 6. The installed battery energy is 104 kWh, based on the rated capacity (157Ah) and the nominal system voltage (661V). The nominal power corresponds to the system power at 50% SOC (see Table 5).

Power/Energy Ratio [W/Wh]	206kW / 104 kWh = 1.98 W/Wh

Table 6*:* The power to energy at beginning of life.

2.2 Durability

Changes of the performance parameters rated capacity, internal resistance, power and energy round trip efficiency are shown in Table 7 considering calendric and cyclic aging effects until expected minimum lifetime. Total energy throughput is the sum of charged and discharged energy.

Capacity fade @400MWh of total energy throughput (TR7081139)	10%
Internal resistance increase (TR7081139 – Appendix)	8%
Power fade (TR7081139 – Appendix)	8%
Energy round trip efficiency fade*	1%
Calendric aging after 300 days, TR7094744	2%

**Data and measurements to estimate the fade are taken from the source described in TR7081139.*

Table 7: Changes of performance parameters until estimated minimum lifetime. All results refer to test conditions with SOC window of 7-82% at 25°C and during 0.75C/1C charge/discharge cycles.

The battery tests used for calendric and cyclic aging analysis are specified in Table 8.

Test	Integration level
Calendric aging at: T = 25°C 80% SOC	Cell
Calendric aging at: T=25°C 80% SOC	Module
Cycle life test*:* Drive cycle test with 7-82% SOC, current charging rate C/2, at 25°C	Cell

Table 8: Calendric and cyclic aging tests used for the lifetime analysis and the simulation approaches used for modeling the calendar and cyclic aging in the minimum lifetime.

3 Attachments

4 Change Notes

Change	ECO Number	Section	Change Description	Date	Sign
A	778216	Part A - Accompanying document Part B - Sub-Technical documentation	Correction of battery type designation.	2024-06-04	rkrcmg