

Group standard

VW 75073

Issue 2020-03

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Batteries for 12-V Electrical Systems

General Test Conditions

Previous issues

VW 75073: 1958-09, 1970-08, 1984-09, 1986-01, 1994-05, 1998-08, 2001-08, 2010-04, 2012-07, 2017-08, 2018-07, 2019-10

Changes

The following changes have been made to VW 75073: 2019-10:

- a) **Section 7.11:** In the "Requirements" section, the sentence "No requirements exist for this at present." was changed to "There are no requirements for batteries suitable for hot countries. For all other batteries, the cold-start requirement $V_{f,10} \geq 7,5 \text{ V}$ applies."

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1 Scope

This Volkswagen standard (VW) contains the minimum requirements and tests for new batteries for commercial and industrial vehicles with 12 V or 24 V electrical system voltage. This standard applies to maintenance-free, rechargeable lead-acid batteries. All values refer to the nominal voltage of 12 V. If the nominal voltage differs, the specified voltage values must be converted according to the number of cells.

2 Definitions

Absorbent glass mat (AGM) The sealed "absorbent glass mat" (AGM) battery (also referred to as a valve-regulated lead-acid battery (VRLA)) meets the strictest requirements as per section 7.7, section 7.9, and section 7.13. The higher self-heating of the AGM battery resulting from the recombination of the generated oxygen and hydrogen is evaluated in section 7.7, section 7.9, and section 7.11 in terms of thermal runaway and increased corrosive activity.

An AGM battery is referred to as "sealed" because the following conditions are met: 1. In the normal state, sealed tight with pressure relief via valves in the event of internal overpressure; 2. Leakproof throughout service life, even in the event of housing damage and overcharging in every position; testing as per Technical Supply Specification TL 82506

- Advanced flooded battery (AFB)** The "advanced flooded battery" (AFB) meets even stricter requirements for start-stop applications as specified in table 3 and tests as per section 7.5, section 7.9, section 7.12, and section 7.13. As for EFB+ batteries, a reduced cold start discharge time as per DIN also applies to AFB batteries; see section 7.2.1.
- Battery capacity in Ah** The battery capacity K_{20} is the amount of electricity in ampere-hours (Ah) associated with a battery. It must be possible for this to be extracted with a defined current I_{20} (nominal discharge current) in 20 h up to a defined discharge voltage of 10,5 V at $(26 \pm 1)^\circ\text{C}$: $K_{20} = I_{20} \times 20$, with K in Ah and I in A
- Battery suitable for hot countries** A battery is designated "suitable for hot countries" if it fulfills the following requirements: 1. Increased requirements in the overcharge test with constant voltage as per section 7.7, 2. Increased requirements in the thermal stability test at $(75 \pm 2)^\circ\text{C}$ as per section 7.11, and 3. Self-discharge test at $(75 \pm 2)^\circ\text{C}$ as per section 7.15 (for wet batteries only).
- Current $I_{20, \text{ACT}}$ in A** The current $I_{20, \text{ACT}}$ is the discharge current associated with the determined actual capacity and output by the battery during the defined discharge period. $I_{20, \text{ACT}}$ is defined by the equation $I_{20, \text{ACT}} = \frac{K_{20, \text{max}}}{20}$. $K_{20, \text{max}}$ is the highest capacity determined for the particular battery during the initial measurement.
- Enhanced flooded battery (EFB/EFB+)** The "enhanced flooded battery" (EFB/EFB+) meets stricter cyclical requirements for start-stop applications as specified in table 3 and tests as per section 7.5, section 7.6, section 7.7, section 7.9, section 7.12, and section 7.13. Due to the higher test current for low temperature, a reduced cold start discharge time applies for EFB+ batteries as per DIN; see section 7.2.1.
- Maintenance-free battery (cool point of use)** A battery is referred to as "maintenance-free, cool point of use" if the total water consumption determined as per section 7.7 (after 42 days) is no more than 6 g/Ah of the battery capacity. This use case is only relevant to AGM batteries.
- Maintenance-free battery (warm point of use)** A battery is referred to as "maintenance-free, warm point of use" if the total water consumption determined as per section 7.7 (after 42 days) is no more than 3 g/Ah of the battery capacity.
- Nominal voltage in V** The nominal voltage is determined from $V = 2 \text{ V}$ multiplied by the number of cells connected in series.
- Rated discharge current in A** The rated discharge current I_{20} is the discharge current associated with the battery capacity and output by the battery during the defined discharge period. I_{20} is defined by the equation $I_{20} = \frac{K_{20}}{20}$.
- Room temperature** Room temperature (RT) is defined as room temperature VW 50554 – 2.
- Standard wet-cell battery** The standard wet-cell battery is the classic lead-acid battery for starting, lighting, and ignition (SLI). It meets the requirements as specified in table 2.
- Terminal voltage $V_{f, x}$** The terminal voltage $V_{f, x}$ refers to the voltage drawn from the battery between the terminals at a time x s after the test sequence begins.

Test currents for low temperature in A The test currents for low temperature as per SAE/GS and EN/DIN (DIN EN 50342-1) are two high discharge amperages that are associated with the battery type and can be used, above all, to evaluate the starting behavior at low temperatures and under given discharge conditions. The test current for low temperature $I_{SAE/GS}$ as per SAE/GS is identical to test current for low temperature I_{cc} as per DIN EN 50342-1. The test current for low temperature I_{DIN} as per DIN is generally based on the rounded value of $0,6 \times I_{cc}$ as per DIN EN 50342-1.

Wet-cell batteries "Wet-cell" batteries refers to all battery technologies that are not leakproof as per TL 82506.

3 Requirements

3.1 Basic requirements

Approval of first supply and changes as per Volkswagen standard VW 01155

For release and evaluation, further tests may be necessary, e.g., additional function checks and road tests.

In particular, these include:

- Tests of the interplay between battery and battery sensor system; see appendix "Tests for the battery sensor" from TL 82506
- Reliability testing in durability road testing and in fleet tests.

This list is not exhaustive.

3.2 Voltage

If tolerances are not specified for voltages, a tolerance of $\pm 0,04$ V applies.

4 Equipment

4.1 Electrical measuring instruments

The measurement range of the voltmeters and ammeters used must be matched to the values to be measured.

4.1.1 Voltmeters

Measuring instruments of class 0,5 with an internal resistance of at least $300 \Omega/V$ of the voltage range are used.

4.1.2 Ammeters

Measuring instruments of class 1 are used.

4.1.3 Battery internal resistance measuring instrument

Measuring instruments with a resolution of 0,01 mΩ and with a measurement range of up to 3 Ω are used, e.g., Hioki model BT3554 ¹⁾ (used within the Volkswagen Group) or comparable. Documentation of the comparability to instruments used at Volkswagen must be provided.

4.2 Thermometers

Thermometers as per DIN 12775 – E 0,5/-30/70 and E 0,5/0/100 must be used.

4.3 Acid density measuring instruments

The reading uncertainty may be ±0,005 kg/l.

4.4 Scale

The inaccuracy of the scale for determining the water loss must be no more than ±1 g.

4.5 Leak test equipment

Measuring instruments of class 0,5 must be used.

5 Preconditions for performing the tests

For all devices under test (DUTs) with a 2-D code, the code must be scanned or the textual information must be entered.

The documentation is entered in the notes field of the test record. The same applies to all company codes/branding marks.

5.1 Packaging of DUTs sent via airfreight

When sending DUTs, the following applies: If binders are used to absorb any possible escaping acids (e.g., vermiculite), then only the use of so-called "spill bags" is permitted. Loose bulk goods can cause respiratory and skin irritation due to dusts inhaled as well as due to skin contact when unpacking. Moreover, intensive cleaning of the batteries is required, particularly the easily clogged battery vents. If loose, dusty binders are used, the DUTs will be therefore rejected/scrapped or returned carriage forward. An example of OK packaging is shown in [appendix B](#).

5.2 Sampling

The tests must be performed with new, untested batteries.

The following applies to these batteries:

- Formation date no older than 100 days
- Breaks between the individual tests must be no longer than those necessitated by weekends or holidays.
- All voltages and internal resistances must be measured directly at the terminals of the battery.
- All tests and storage times between the tests occur at room temperature, unless specific temperatures are prescribed in the individual tests. For tests that are performed in a water bath,

¹⁾ Hioki 3554 is the product designation by manufacturer HIOKI E.E. CORPORATION. This information is only intended for informational purposes for the users of this in-house standard. This does not signify an endorsement of the mentioned product by the Volkswagen Group. Equivalent products may be used if it can be verified that they lead to the same results.

the height of the water level must be (140 ± 5) mm for LN boxes and (135 ± 5) mm for LBN boxes, measured from the bottom of the battery.

5.3 Charging, residual charging current, and acid density

5.3.1 Charging as per IU characteristic curve

Unless otherwise described, the standard procedure is to charge the battery at $(26 \pm 1)^\circ\text{C}$ in a water bath for 24 h at a voltage of 16 V and $I_{\text{max}} = 5 \times I_{20}$.

For AGM batteries, the maximum charging voltage is 14,8 V. The respective charging voltage can be reduced depending on the technology following consultation with Research and Development.

After a cold start test, the charging time is shortened to 16 h.

For batteries that failed during service life testing, it must be ensured that the battery is tempered to $(26 \pm 1)^\circ\text{C}$ before charging starts. Failed batteries are charged for 5 h with a voltage in accordance with the technology and with $I_{\text{max}} = 5 \times I_{20}$.

5.3.2 Measurement of residual charging current and acid density

The residual charging current is measured:

- At the end of charging after the second cold start
- At the end of charging after cold start testing following exhaustive discharge

The acid densities are measured as specified in table 1.

Table 1

Condition	Desired acid density kg/l at 27°C
As-received condition	1,27 to 1,295 ^{a)}
After charging following 2nd cold start	1,27 to 1,295 ^{a)}
During exhaustive discharge test, after the 7-day discharge with a 10-W incandescent lamp	No specification
During exhaustive discharge test, after charging after exhaustive discharge	No specification
Before the start of "cycles with 50% depth of discharge"	No specification
After failure or the end of "cycles with 50% depth of discharge"	No specification
Before all tests with "cycles with 17,5% depth of discharge" except for $+60^\circ\text{C}$	No specification
After all tests or failure of "cycles with 17,5% depth of discharge" except for $+60^\circ\text{C}$	No specification
a) Maximum density difference between the cells of a battery is 0,01 kg/l.	

Inaccessible wet-cell batteries must be spot-drilled in order to measure the acid density. Wet-cell batteries with mixing elements must be drilled on the side opposite the mixing element. The drill holes must then be sealed tight to continue the testing.

Measurement of the acid density is omitted for AGM batteries and for batteries 1, 2, and 3 as per table 2 and for batteries 1, 2, 3, and 8 as per table 3 in the case of wet-cell batteries.

The density measured at other temperatures T must be corrected using the following formula:

$$\text{Density (27 °C)} = \text{reading} + 0,0007 (T - 27)$$

6 Test sequence

Unless otherwise stated, all tests are performed in a water bath at $(26 \pm 1) ^\circ\text{C}$.

Table 2 – Test sequence for standard wet-cell batteries. When selecting the DUTs for the individual tests, the following sequence applies to the weight (lightest to heaviest): 1 – 2 – 5 – 6 – 3 – 4

No.	Test	Section	Battery					
			1	2	3	4	5	6
1	Visual inspection, weights, and acid density		x	x	x	x	x	x
2	Open-circuit voltage and internal resistance	Section 5.2, item 3	x	x	x	x	x	x
3	Cold start test, 0th cold start EN/DIN	Section 7.2.1			x			
4	Capacity test	Section 7.1		x	x	x	x	x
5	Cold start test, 1st cold start EN/DIN	Section 7.2.1		x	x	x		x
6	Capacity test	Section 7.1		x	x	x		x
7	Cold start test, 2nd cold start EN/DIN	Section 7.2.1				x		x
8	Cold start test, 2nd cold start SAE/GS	Section 7.2.2		x	x			
9	Measurement of residual charging current and acid density	Section 5.3.2		x	x	x		x
10	Capacity test	Section 7.1		x	x	x		x
11	Exhaustive discharge test	Section 7.3					x	
12	Static current draw	Section 7.4				x		
13	Dynamic current draw	Section 7.8		x				
14	Cycles with 50% depth of discharge	Section 7.5					x	
15	Cycles with 17,5% depth of discharge at $26 ^\circ\text{C}$	Section 7.6						x
16	Overcharging at constant voltage	Section 7.7		x				
17	Dynamic current draw	Section 7.8		x				
18	Thermal stability test at $75 ^\circ\text{C}$	Section 7.11			x			
19	Freeze-through test	Section 7.14				x ^{a)}		
20	Self-discharge test at $75 ^\circ\text{C}$	Section 7.15	x ^{b)}					
21	Vibration resistance test	Section 9.1				x ^{a)}		
Approximate test duration in weeks			11	13 to 19	14 to 22	6	10	10

a) May be omitted following consultation with the department responsible for release.
b) Relevant for the release of batteries suitable for hot countries, otherwise the result is solely informative

Table 3 – Test sequence for EFB/EFB+/AFB batteries When selecting the DUTs for the individual tests, the following sequence applies to the weight (lightest to heaviest): 1 – 2 – 5 – 6 – 7 – 11 – 8 – 10 – 3 – 4 – 9

No.	Test	Section	Battery										
			1	2	3	4	5	6	7	8	9	10	11
1	Visual inspection, weights, and acid density		x	x	x	x	x	x	x	x	x	x	x
2	Open-circuit voltage and internal resistance	Section 5.2, item 3	x	x	x	x	x	x	x	x	x	x	x
3	Cold start test, 0th cold start EN/DIN	Section 7.2.1			x								
4	Capacity test	Section 7.1		x	x		x	x	x	x		x	x
5	Cold start test, 1st cold start EN/DIN	Section 7.2.1		x	x			x	x	x		x	x
6	Capacity test	Section 7.1		x	x					x		x	x
7	Cold start test, 2nd cold start EN/DIN	Section 7.2.1								x		x	x
8	Cold start test, 2nd cold start SAE/GS	Section 7.2.2		x	x								
9	Measurement of residual charging current and acid density	Section 5.3.2		x	x					x		x	x
10	Capacity test	Section 7.1		x	x					x		x	x
11	Exhaustive discharge test	Section 7.3					x						
12	Dynamic current draw	Section 7.8		x									
13	Cycles with 50% depth of discharge	Section 7.5					x						
14	Cycles with 17,5% depth of discharge at 26 °C	Section 7.6											x
15	Overcharging at constant voltage	Section 7.7		x									
16	Dynamic current draw	Section 7.8		x									
17	Cycles with 17,5% depth of discharge at 60 °C	Section 7.9								x			
18	Regenerative ability	Section 7.10				x							
19	Thermal stability test at (75 ±2) °C	Section 7.11			x								
20	Cycles with 17,5% depth of discharge at 3 °C	Section 7.12										x	
21	Continuous cycle test with 17,5% depth of discharge	Section 7.13						x ^{a)}	x ^{b)}		x ^{c)}		
22	Freeze-through test	Section 7.14				x ^{d)}							
23	Self-discharge test at 75 °C	Section 7.15	x ^{e)}										
24	Vibration resistance test	Section 9.1				x ^{d)}							
Approximate test duration in weeks			11	19	14 to 22	6	15	11 to 14	11 to 14	16	8 to 12	11	22

a) Test in the water bath

b) Test on the rocker. Deleted if static mixing elements are not installed

c) Test is conducted for informational reasons. If necessary and in consultation with the supplier, batteries older than 4 weeks may be recharged to make up for self-discharge losses. The aim is to conduct the continuous cycle test with 17,5% depth of discharge without pretesting in future.

Table 3 (continued)

d)	May be omitted following consultation with the department responsible for release.
e)	Relevant for the release of batteries suitable for hot countries, otherwise the result is solely informative

Table 4 – Test sequence for AGM batteries, cool point of use When selecting the DUTs for the individual tests, the following sequence applies to the weight (lightest to heaviest): 1 – 2 – 5 – 6 – 3 – 4

No.	Test	Section	Battery					
			1	2	3	4	5	6
1	Visual inspection, weights		x	x	x	x	x	x
2	Open-circuit voltage and internal resistance	Section 5.2, item 3	x	x	x	x	x	x
3	Cold start test, 0th cold start EN/DIN	Section 7.2.1			x			
4	Capacity test	Section 7.1		x	x		x	x
5	Cold start test, 1st cold start EN/DIN	Section 7.2.1		x	x			x
6	Capacity test	Section 7.1		x	x			x
7	Cold start test, 2nd cold start EN/DIN	Section 7.2.1						x
8	Cold start test, 2nd cold start SAE/GS	Section 7.2.2		x	x			
9	Measurement of residual charging current	Section 5.3.2		x	x			x
10	Capacity test	Section 7.1		x	x			x
11	Exhaustive discharge test	Section 7.3					x	
12	Dynamic current draw	Section 7.8		x				
13	Cycles with 50% depth of discharge	Section 7.5					x	
14	Overcharging at constant voltage	Section 7.7		x				
15	Dynamic current draw	Section 7.8		x				
16	Regenerative ability	Section 7.10				x		
17	Thermal stability test at (75 ±2) °C	Section 7.11			x			
18	Continuous cycle test with 17,5% depth of discharge	Section 7.13	x ^{a)}					x
19	Freeze-through test	Section 7.14				x ^{b)}		
20	Vibration resistance test	Section 9.1				x ^{b)}		
Approximate test duration in weeks			17	19	14	7	19	19

a) Test is conducted for informational reasons. If necessary and in consultation with the supplier, batteries older than 4 weeks may be recharged to make up for self-discharge losses. The aim is to conduct the continuous cycle test with 17,5% depth of discharge without pretesting in future.

b) May be omitted following consultation with the department responsible for release.

Table 5 – Test sequence for AGM batteries, warm point of use When selecting the DUTs for the individual tests, the following sequence applies to the weight (lightest to heaviest): 1 – 2 – 5 – 6 – 7 – 8 – 9 – 3 – 4

No.	Test	Section	Battery								
			1	2	3	4	5	6	7	8	9
1	Visual inspection, weights		x	x	x	x	x	x	x	x	x
2	Open-circuit voltage and internal resistance	Section 5.2, item 3	x	x	x	x	x	x	x	x	x
3	Cold start test, 0th cold start EN/DIN	Section 7.2.1			x						
4	Capacity test	Section 7.1		x	x		x	x		x	x
5	Cold start test, 1st cold start EN/DIN	Section 7.2.1		x	x			x		x	x
6	Capacity test	Section 7.1		x	x			x		x	x
7	Cold start test, 2nd cold start EN/DIN	Section 7.2.1						x		x	x
8	Cold start test, 2nd cold start SAE/GS	Section 7.2.2		x	x						
9	Measurement of residual charging current	Section 5.3.2		x	x			x		x	x
10	Capacity test	Section 7.1		x	x			x		x	x
11	Exhaustive discharge test	Section 7.3					x				
12	Dynamic current draw	Section 7.8		x							
13	Cycles with 50% depth of discharge	Section 7.5					x				
14	Overcharging at constant voltage	Section 7.7		x							
15	Dynamic current draw	Section 7.8		x							
16	Cycles with 17,5% depth of discharge at 60 °C	Section 7.9								x	
17	Regenerative ability	Section 7.10				x					
18	Thermal stability test at (75 ±2) °C	Section 7.11			x						
19	Continuous cycle test with 17,5% depth of discharge	Section 7.13						x	x ^{a)}		
20	Freeze-through test	Section 7.14				x ^{b)}					
21	Vibration resistance test	Section 9.1				x ^{b)}					
Approximate test duration in weeks			1	19	14 to 22	7	19	19	17	22	3
a) Test is conducted for informational reasons. If necessary and in consultation with the supplier, batteries older than 4 weeks may be recharged to make up for self-discharge losses. The aim is to conduct the continuous cycle test with 17,5% depth of discharge without pretesting in future. b) May be omitted following consultation with the department responsible for release.											

7 Electrical tests

7.1 Capacity test

Before the 1st capacity test, the batteries are not charged, except battery no. 3.

Before starting the test, the acid temperature must be (27 ±5) °C.

The battery must be discharged with I_{20} in a water bath that is kept at a constant temperature of $(26 \pm 1) ^\circ\text{C}$.

The discharging must be stopped when a discharge voltage of 10,5 V is reached.

After the discharging is stopped, the battery is charged as per section 5.3.1 (does not apply to battery no. 5 before exhaustive discharge).

7.2 Cold start tests

7.2.1 Cold start tests as per EN/DIN

This test is conducted based on DIN EN 50342-1.

Battery no. 3 is never charged before the 0th cold start test.

The following applies to all other batteries:

After a dwell time of at least 24 h up to a maximum of 96 h at room temperature following the end of charging, the fully charged battery must be conditioned in a cooling chamber with forced air circulation to a battery temperature of $(-18 \pm 1) ^\circ\text{C}$. The minimum tempering time is 24 h. It must be ensured that the temperature has been reached inside the battery. The dwell time before low-temperature aging in the initial measurement must be documented.

For cold start tests at the end of tests as per section 7.3, section 7.5, section 7.6, section 7.7, section 7.9, section 7.12, section 7.13, and section 7.15, the dwell time can be extended to a maximum of 1 week.

The battery must be discharged for 10 s with the allocated, constant test current for low temperature I_{EN} ($\pm 0,5\%$). This must occur either within the cooling chamber or immediately after the cooling time (within 2 min) outside the cooling chamber.

After a pause of 10 s, the battery is discharged with the allocated test current for low temperature I_{DIN} without interruption down to a cutoff voltage of 6 V. The terminal voltage $V_{f, 10}$ must be at least 7,5 V 10 s after the start of discharge with the test current for low temperature I_{EN} . The terminal voltage $V_{f, 40}$ must be at least 9 V 20 s after the start of discharge with the test current for low temperature I_{DIN} . The duration of the discharge to 6 V with I_{DIN} (t'_{6V}) must be at least $t'_{6V} = 150 \text{ s} -$

$\left(\frac{I_{\text{EN}}}{I_{\text{DIN}}}\right) \times 10 \text{ s}$ for standard wet-cell and EFB batteries.

Computation of the discharge time t'_{6V} with test current for low temperature I_{DIN} , using the 60 Ah 280 A DIN, 480 A EN battery as an example:

$$t'_{6V} = 150 \text{ s} - (480 \text{ A} / 280 \text{ A}) \times 10 \text{ s} = 133 \text{ s} \quad (1)$$

For EFB+/AFB batteries, the following deviating value applies: $t'_{6V} = 103 \text{ s}$

The calculated discharge time t_{6V} is $t_{6V} = \frac{I_{\text{EN}}}{I_{\text{DIN}}} \times 10 \text{ s} + t'_{6V}$ and is documented in the test record.

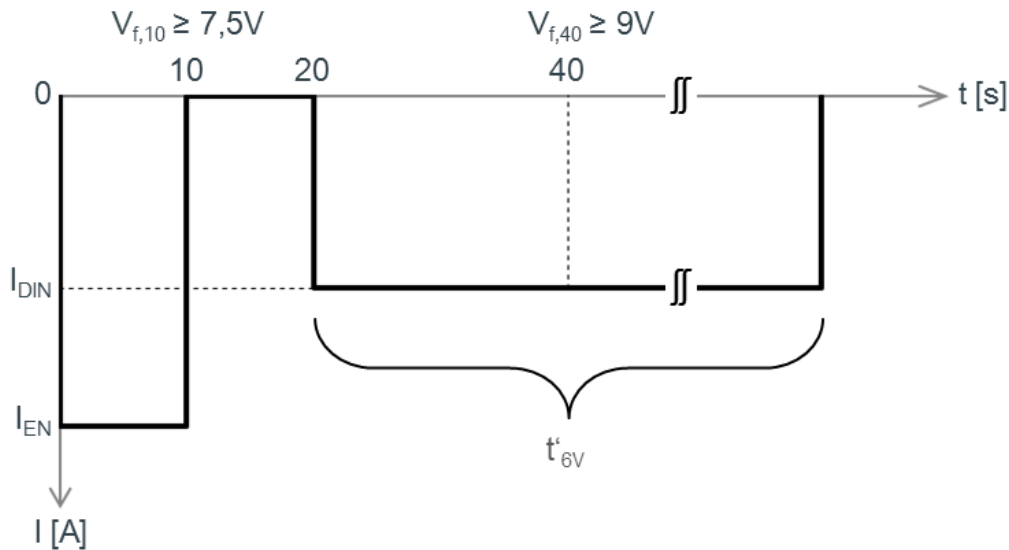


Figure 1 – Schematic representation of the cold start test (EN/DIN)

Immediately after cold start testing (see figure 1), the battery must be tempered in a water bath at $(26 \pm 1) ^\circ\text{C}$. Charging as per section 5.3.1 must begin after at least 2 h.

Requirements for the 0th cold start:

The requirements are: $V_{f,10} \geq 7,5 \text{ V}$ and $V_{f,40} \geq 9 \text{ V}$.

When testing up to 30 days after the end of formation, discharging to 6 V with the associated test current for low temperature I_{DIN} must take at least 90 s:

$$t'_{6V} \geq 90 \text{ s}$$

7.2.2 Cold start tests as per SAE/GS

This test is conducted based on SAE J537 [1] or GSO 35:2007 [2].

After a dwell time of at least 24 h up to a maximum of 96 h at room temperature following the end of charging, the fully charged battery must be conditioned in a cooling chamber with forced air circulation to a battery temperature of $(-18 \pm 1) ^\circ\text{C}$. The minimum tempering time is 24 h. It must be ensured that the temperature has been reached inside the battery. The dwell time before low-temperature aging must be documented.

The battery must be discharged with the allocated, constant test current for low temperature $I_{\text{SAE/GS}}$ ($\pm 0,5\%$). This must occur either within the cooling chamber or immediately after the cooling time (within 2 min) outside the cooling chamber.

Terminal voltage V_f must be recorded throughout the test procedure with a sampling rate of at least 10 Hz. Terminal voltage V_f must meet the following requirement after 10 s of discharging:

$$V_{f,10} \geq 7,5 \text{ V}$$

The current is switched off after 30 s of discharging. The battery must meet the following requirement:

$$V_{f,30} \geq 7,2 \text{ V}$$

Immediately after cold start testing (see figure 2), the battery must be tempered in a water bath at $(26 \pm 1) ^\circ\text{C}$. Charging as per section 5.3.1 must begin after at least 2 h.

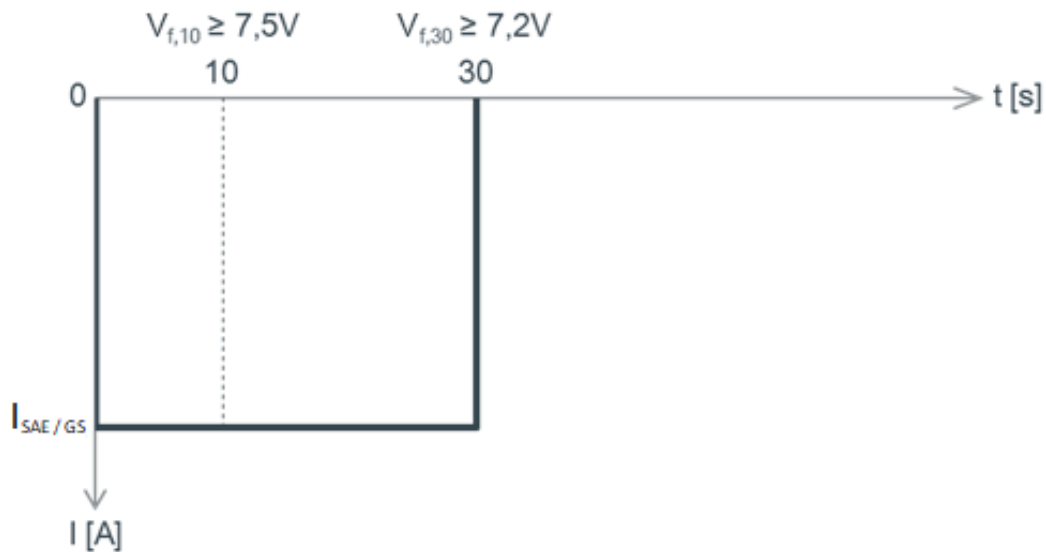


Figure 2 – Schematic representation of the cold start test (SAE/GS)

7.3 Exhaustive discharge test

Battery no. 5 is used; it is not charged after the 1st capacity test.

- The battery is discharged within 24 h after the capacity test at a temperature of $(26 \pm 1) ^\circ\text{C}$ for a duration of 7 days with a 10-W incandescent lamp.
- Afterwards, the acid density in cells 2 and 5 is measured.
- Within four hours after disconnecting the incandescent lamp, the battery is charged as per section 5.3.1. The current draw after exhaustive discharge must have at least the following (table 6) rise over time:

Table 6

Time after charging begins	1 min	5 min	10 min
Current draw after exhaustive discharge	$\geq 2 \times I_{20}$	$\geq 3 \times I_{20}$	$= 5 \times I_{20}$

It must be recorded whether buffering was necessary during the current draw after exhaustive discharge. Buffering means that in order to start the charging unit in the first few seconds, due to the low voltage of the battery that has been exhaustively discharged, a second battery must be connected in parallel so that the charging unit begins charging. If buffering takes longer than 10 s, this must be noted in the notes section of the test record. In addition, the time after which the maximum charging current of $5 \times I_{20}$ is reached must be documented in the test record as tl-target.

- The acid density in cells 2 and 5 is measured.
- Capacity test as per section 7.1
The capacity determined after the exhaustive discharge must be at least 90% of the battery capacity.
- Charging as per section 5.3.1
- Cold start as per section 7.2.1

The cold start discharge time determined after exhaustive discharge must be recorded, but the requirement as per section 7.2.1 does not apply.

– Charging as per section 5.3.1

The residual charging current after the last charge and the charging amount with which the battery is charged during recharging after exhaustive discharge must be documented in the report. For AGM batteries, the charging amount with which the battery is charged must be no more than twice the actual capacity after exhaustive discharge.

Following the exhaustive discharge test, the "cycles with 50% depth of discharge" test is performed as per section 7.5.

7.4 Static current draw (only for standard wet-cell batteries)

Battery no. 4 is discharged for 5 h at $2 \times I_{20, ACT}$, which was determined in the initial measurement.

Afterwards, the battery is cooled in a room at a temperature of $(0 \pm 1) ^\circ\text{C}$ at least until the acid temperature of a center cell has reached $(0 \pm 1) ^\circ\text{C}$.

Immediately afterwards, the battery is charged for 10 min at $(14,4 \pm 0,05) \text{ V}$ in air at $23 ^\circ\text{C}$ to $25 ^\circ\text{C}$.

After 10 min, the charging current must be at least $5 \times I_{20}$. The maximum current supply is 100 A. The charging amount with which the battery is charged must be recorded.

Then, the battery is charged as per section 5.3.1.

7.5 Cycles with 50% depth of discharge at $(40 \pm 1) ^\circ\text{C}$ in water bath

The test must be performed within 1 week of the exhaustive discharge test as per section 7.3.

The test consists of the following:

1. Weigh the outwardly dry battery and measure the acid density in all cells and the internal resistance at room temperature.
2. Discharge for 2 h with $5 \times I_{20}$; switch-off criterion: battery voltage $\leq 10 \text{ V}$.
3. Charge for 5 h at:
 - $16 \text{ V}^{2)}$ for standard wet-cell batteries
 - $15,6 \text{ V}^{2)}$ for EFB, EFB+, and AFB batteries
 - $14,4 \text{ V}^{2)}$ for AGM batteries
 - Current limitation $5 \times I_{20}$.
4. Perform points 2 and 3 a total of 120 times for standard wet-cell batteries; the test must be performed 240 times for EFB and EFB+ batteries and 360 times for AFB and AGM batteries, without reaching the switch-off criterion in each case.
5. 3-day dwell time (72 h) at $(40 \pm 1) ^\circ\text{C}$.
6. Measure the internal resistance at the end of the 3-day dwell time or upon removal from the $(40 \pm 1) ^\circ\text{C}$ water bath.

Weigh the battery, note the weight loss in the report, measure the acid density, and perform a cold start as per section 7.2.1 without prior recharging. The terminal voltage must be at least 6 V 10 s after the start of discharge with the test current for low temperature as per $I_{SAE/GS}$. Terminal voltage $V_{f, 40}$ must be at least $7,2 \text{ V}$. Afterwards, the battery is recharged for 5 h as per item 3.

Then, an OK/not OK evaluation is performed after opening the battery.

²⁾ The charging voltage may be adapted to the technology following consultation with the department responsible for release.

Water must not be added during the entire test.

7.6 Cycles with 17,5% depth of discharge at $(26 \pm 1)^\circ\text{C}$

This test is conducted for standard wet-cell batteries. EFB/EFB+ batteries are only tested if only 1 020 cycles (instead of the required 1 530 cycles) are reliably fulfilled in the continuous cycle test as per section 7.13.

1. The test must be conducted within one week of completing the capacity test as per section 7.1.
2. Weigh the outwardly dry battery and measure the acid density in all cells as well as the internal resistance.
3. Discharge for 2,5 h with $4 \times I_{20}$ at $(26 \pm 1)^\circ\text{C}$; switch-off criterion: battery voltage $\leq 10\text{ V}$.
4. Perform the following cycles a total of 85 times at $(26 \pm 1)^\circ\text{C}$:
Charge for 40 min at $7 \times I_{20}$ and $(14,4 \pm 0,05)\text{ V}$.
Discharge for 30 min at $7 \times I_{20}$.
Switch-off criterion: battery voltage $\leq 10\text{ V}$.
5. Equalizing charge for 18 h at $(26 \pm 1)^\circ\text{C}$ with $2 \times I_{20}$ and $(16 \pm 0,05)\text{ V}$.
6. Perform the capacity test as per section 7.1. Deviating from section 5.3.1, the subsequent re-charging occurs over 23 h at $(16 \pm 0,05)\text{ V}$ and $I_{\text{max}} = 2 \times I_{20}$ for standard wet-cell batteries and with $I_{\text{max}} = 5 \times I_{20}$ for EFB/EFB+ and AFB batteries.

Items 3 to 6 form a unit. Standard wet-cell batteries must pass 6 units except for capacity. EFB/EFB+ batteries must pass 18 units, provided that 1 530 cycles are not passed in the continuous cycle test as per section 7.13.

In future, the test option as per section 7.6 will be omitted for EFB/EFB+ batteries.

Failed batteries will be charged as per section 5.3.1.

Weigh the outwardly dry battery, enter the weight loss in the report, and measure the acid density and the internal resistance.

Perform a cold start as per section 7.2.1. The terminal voltage must be at least 6 V 10 s after the start of discharge with the test current for low temperature $I_{\text{SAE/GS}}$. Terminal voltage $V_{f,40}$ must be at least 7,2 V. Deviating from section 5.3.1, the following charging time is limited to 5 h.

7.7 Overcharging at constant voltage

No later than 1 week after charging is completed, the outwardly dry battery is weighed to $\pm 1\text{ g}$, and the internal resistance is measured.

Then, the battery with standard screwed plugs is charged in a water bath for 21 days at a voltage of $(14,4 \pm 0,05)\text{ V}$ and a temperature of $(60 \pm 2)^\circ\text{C}$. Afterwards, the outwardly dry battery must be weighed again (first dry it off/blow it off with compressed air) and the internal resistance must be measured. Then, the battery is charged again for 21 days at a voltage of $(14,4 \pm 0,05)\text{ V}$ and a temperature of $(60 \pm 2)^\circ\text{C}$. The dried battery is weighed again and the internal resistance measured. The weight losses and internal resistances must be documented.

The maximum permitted values for the weight loss with respect to the battery capacity must be taken from table 7 and table 8.

Table 7 – Applies to standard wet-cell batteries, EFB, EFB+, and AFB batteries

Permissible total weight loss after 42 days at 60 °C	
"Maintenance-free battery (warm point of use)"	≤ 3 g/Ah

EFB/EFB+, AFB, and AGM batteries and standard wet-cell batteries suitable for hot countries are charged for another 42 days at a voltage of (14,4 ±0,05) V and a temperature of (60 ±2) °C. After every 21 days, the battery is dried, weighed, and the internal resistance is measured. The weight losses and internal resistances are documented. The test therefore takes 4 x 3 weeks.

For EFB/EFB+ and AFB batteries, which are not suitable for hot countries, there is no weight-loss criterion after 84 days.

Table 8 – Applies to AGM batteries and batteries suitable for hot countries

Permissible total weight loss after 84 days at 60 °C	
AGM "maintenance-free (cool point of use)"	≤ 6 g/Ah
AGM "maintenance-free (warm point of use)"	≤ 3 g/Ah
AGM "suitable for hot countries"	≤ 3 g/Ah
Standard wet-cell battery, EFB, and EFB+, each "suitable for hot countries"	≤ 5 g/Ah

Following the overcharge test, a cold start is performed as per section 7.2.1 for all batteries. Terminal voltage $V_{f,40}$ must be at least 8,5 V for AGM batteries and 7,5 V for all other batteries. Then, the dynamic current draw is measured as per section 7.8. Afterwards the battery is opened and checked for corrosion and growth of the positive electrode (including dishing). Excessive damage results in rejection.

For AGM batteries, the charging current must not "run away". The test is terminated and considered to be failed if the charging current is permanently over $2 \times I_{20}$.

7.8 Dynamic current draw

The fully charged battery must be discharged with a constant current of $2 \times I_{20,ACT}$ (±0,5%) for 1 h (i.e., to a state of charge of 90%) in a water bath at a temperature of (26 ±1) °C. Following a 24-h pause after discharging, the battery is charged at a temperature of (26 ±1) °C and at a constant voltage of (14,8 ±0,05) V for 60 s with the current limited to $40 \times I_{20}$. Batteries > 100 Ah are charged with a maximum of 200 A. The charging current must be recorded at a sampling rate of 10 Hz or better for 60 s immediately after the start of charging.

Afterwards, the battery is discharged at a constant current of $2 \times I_{20,ACT}$ (±0,5%) for 1 h (i.e., by 10%) at an ambient temperature of (26 ±1) °C. In addition, the amount of current (capacity) with which the battery was charged in the prior charging must be drawn at $2 \times I_{20,ACT}$ (i.e., discharging to a state of charge of 80%). Then, following another 24-h pause, the battery must be charged at a temperature of (26 ±1) °C and at a constant voltage of 14,8 V for 60 s. The charging current must be recorded at a sampling rate of 10 Hz or better immediately after the start of charging.

The charging voltage and charging current must be shown graphically as a function of the charging time. The values for the charging current (see table 9 for requirements) must be listed in a table for the charging times of 1 s, 10 s, 30 s, and 60 s. The ampere-hours (Ah) with which the battery is charged in the charging time period from 0 s to 10 s, 10 s to 30 s, and 30 s to 60 s must be documented separately in a table. The charging current must be specified standardized to I_{20} .

This test sequence is repeated 4 times, so that the last 60-s charge takes place at a battery state of charge of 60% of $K_{20, \max}$. Then, the battery is charged as per section 5.3.1.

Table 9 – Minimal charging currents for dynamic current draw

State of charge ($K_{20, \max}$)	Time after start of charging in s	Minimum charging current in A
90%	1	$10 \times I_{20}$
	10	
	30	
	60	$8 \times I_{20}$
80%	1	$20 \times I_{20}$
	10	
	30	
	60	$12 \times I_{20}$
70%	1	$30 \times I_{20}$
	10	
	30	
	60	$16 \times I_{20}$
60%	1	$40 \times I_{20}$
	10	
	30	
	60	$20 \times I_{20}$

7.9 Cycles with 17,5% depth of discharge at $(60 \pm 2) ^\circ\text{C}$

The test is conducted analogously to section 7.6, except at $(60 \pm 2) ^\circ\text{C}$ in a water bath and with the following changes:

1. For AGM batteries, the switch-off voltage is $\leq 11,5 \text{ V}$ during preliminary discharging and in cyclical operation. For wet-cell batteries, the switch-off voltage is $\leq 11 \text{ V}$ in cyclical operation.
2. The charging voltage in the cycles is $(14 \pm 0,05) \text{ V}$.
3. The charging voltage during equalizing charge and recharging after the capacity test is $(14 \pm 0,05) \text{ V}$ for AGM batteries and $(15,4 \pm 0,05)^3 \text{ V}$ for EFB/EFB+ and AFB batteries.
4. The charging current limit is always $2 \times I_{20}$ during the recharge and equalizing charge processes.

18 units must be passed for AGM batteries "warm point of use", 15 units for AFB batteries, and 12 units for EFB/EFB+ batteries.

Failed batteries are charged as per section 5.3.1.

This is followed by an assessment of the open battery, whereby corrosion, the growth of the positive electrode, sulfation, and the extent of acid stratification are evaluated. Excessive damage to the battery results in rejection.

³⁾ Following consultation with the department responsible for release, a fixed charging voltage between 14 V and 15,4 V may be selected.

7.10 Regenerative ability

This test is used to validate the regenerative ability of EFB, EFB+ and AGM batteries in a dynamic driving cycle F (see appendix C) with a duration of 1 800 s and the following boundary conditions:

- Initial state of charge (SOC): 80% of the determined actual capacity of the DUT
- Electrical system load: 25 A in 9 stop phases (245 s), 0 A in the first driving cycle (F1) and subject to battery size as per table 12 in the second and third driving cycles (F2, F3) in 59 pause and discharge phases (1 326 s).
- Charging voltage: 15,0 V in 51 charge phases (229 s) at maximum current supply of 200 A

During the test procedure as per table 10, the battery is situated in a water bath at $(26 \pm 1) ^\circ\text{C}$. If mixing elements are used, the test steps of sequence numbers 4 and 6 take place in air on the rocker (see description in section 7.13), rather than in the water bath. Driving cycle F is performed a total of 3 times, yielding the driving cycles F1, F2, and F3 (numbering corresponds to the chronological sequence). In contrast to driving cycles F2 and F3, only discharging occurs in the stop phases in driving cycle F1.

7.10.1 Test sequence

The conditioning of the storage medium and the translation of the driving cycle (F) into various driving phases is described below as a schematic program sequence in table 10.

Table 10 – Schematic program sequence

Consecutive number	Program	Voltage in V	Current in A	Duration	Result
1	Charge	14,8	max. $5 \times I_{20}$	12 h	Start of conditioning
2	Capacity determination as per section 7.1 without charging	Limit 10,5	$1 \times I_{20}$	Variable	Determine actual capacity
3	Charge	14,8	max. $5 \times I_{20}$	24 h	End of conditioning
4	Discharge		$2 \times I_{20, \text{ACT}}$	2 h (to 80% SOC of actual capacity)	
5	Pause			24 h	
6	Driving cycle F, see section 7.10.2	max. 15	max. 200	30 min	
7	Charging	14,8	max. $5 \times I_{20}$	12 h	

Table 10 (continued)

Consecutive number	Program	Voltage in V	Current in A	Duration	Result
8	2x repetition of steps 4 – 7 yields the driving cycles ^{a)} F1, F2, F3				Determining the charge balance $Q_{\text{bal Ah}}$
9	Charging	14,8	max. $5 \times I_{20}$	12 h	End of test or follow-up measurement
a) The following applies to the three driving cycles to be performed: Driving cycle F1: All discharge phases are pauses with 0 A (test circuit pause) Driving cycles F2, F3: All discharge phases with discharge current as per table 12					

7.10.2 Determining the charge balances

Driving cycle F1: Electrical system load 25 A in stop phases and 0 A in discharge phases (pauses).

The test is passed if the charge balance does not fall below the required minimum value specified in table 11. The result to be documented is the charge balance from the charge phases and stop phases (see formula (2)).

$$Q_{\text{bal Ah F1}} = \text{Ah charged in 51 charge phases} - \text{Ah withdrawn in 9 stop phases} \quad (2)$$

Driving cycle F2, F3: Electrical system load 25 A in stop phases and as per table 12 in discharge phases:

The test is passed if a charge balance ≥ 0 Ah over all phases is determined in driving cycles F2 and F3 with the specified electrical system load. The individual charge balance values determined from F2 and F3 are documented (see formula (3)).

$$Q_{\text{bal Ah F2, F3}} = \text{Ah charged in 51 charge phases} - \text{Ah withdrawn in 9 stop phases} - \text{Ah withdrawn in 59 discharge phases} \quad (3)$$

If the charge balance is positive in both driving cycles, F2 and F3, an additional driving cycle, F4, with an increased electrical system load in the discharge phases, can be run subsequently. The increase in electrical system load is yielded based on the following equation (see formula (4)).

$$I_{\text{elec. sys., additional}} = Q_{\text{bal Ah}} \times \frac{3\,600}{1\,326\text{ s}} \quad (4)$$

Example:

A positive charge balance of 0,37 Ah results in an increase in electrical system load in driving cycle F4 of $I_{\text{elec. sys., additional}} = 1$ A. The increase in electrical system load, $I_{\text{elec. sys., additional}}$, for driving cycle F4 is rounded to whole amperes.

The graphical evaluation of driving cycles F1, F2, and F3 comprises representation of current over time, voltage over time, and charge balance over time.

Table 11 – Requirement for driving cycle F1

Battery size	Required charge balance $Q_{\text{bal Ah}}$ in F1, Ah
LN1	2,0
LN2	3,0
LN3	4,0

Table 12 – Requirements for driving cycles F2 and F3

Battery size	Specification for electrical system load in discharge phases for F2, F3 in A	Required charge balance $Q_{\text{bal Ah}}$ in F2, F3, Ah
LN1	8,0	≥ 0
LN2	11,0	
LN3	14,0	

Specifications for other battery box sizes will be defined at a later stage.

7.11 Thermal stability test at $(75 \pm 2) ^\circ\text{C}$

This test simulates the failure pattern caused by corrosion and grid growth as a consequence of continuously high temperatures.

The test begins no earlier than 24 h and no later than 5 days after completion of charging following the last capacity test. Before beginning the test, the battery must be weighed at room temperature, the internal resistance measured, and, for wet-cell batteries, the electrolyte levels marked and documented. During the test, the battery is situated in a water bath at $(75 \pm 2) ^\circ\text{C}$. After tempering for 16 to 24 h at $(75 \pm 2) ^\circ\text{C}$, the internal resistance and the electrolyte levels must be measured again and documented.

The test sequence comprises:

1. 18 s discharging with 25 A
2. 30 min charging at 14,2 V (current limit: 25 A)
3. 15 min discharging with 3 A
4. 30 min charging at 14,2 V (current limit: 25 A)
5. 18 s discharging with 25 A
6. 30 min charging at 14,2 V (current limit: 25 A)
7. 15 min discharging with 3 A
8. 30 min charging at 14,2 V (current limit: 25 A)
9. 15 min discharging with 3 A
10. 29 min 24 s charging at 14,2 V (current limit: 25 A)
11. Steps 1 to 10 are performed 6 times.
12. 15 min discharging with 10 A
13. 4 h 15 min charging at 14,2 V (current limit: 25 A)
14. Steps 1 to 13 are performed 5 times.
15. Steps 1 to 10 are performed another 4 times.
16. 15 min discharging with 10 A

17. 2 h charging at 14,2 V (current limit: 25 A)
18. 28 h to 33 h pause (must be recorded), then open-circuit voltage measurement. If the voltage is below 12 V, the test is terminated.
19. Discharging with 50 A to 9 V
20. Repeat steps 1 to 19

Every week, in step 18 at the end of the approx. 30-h pause, the battery is weighed again (the battery must be externally dry), the internal resistance is measured, and the electrolyte levels are marked, for which the battery is removed from the water bath for no more than 30 min. The weight, internal resistance, and change in electrolyte levels compared to the initial state at $(75 \pm 2)^\circ\text{C}$ must be documented. The electrolyte levels are not marked on **AGM** batteries.

Termination criteria:

For wet-cell batteries:

- The weight loss relative to the battery capacity must not exceed 10 g/Ah (12 g/Ah for batteries suitable for hot countries).
- After the end of testing, the electrolyte level difference between the cells measured at room temperature must not exceed 12 mm.

For **AGM** batteries:

- Internal resistance increase by a factor $\geq 1,6$ and for **AGM** batteries suitable for hot countries $\geq 1,8$ compared to the initial value at $(75 \pm 2)^\circ\text{C}$.
- Reduction in the discharge capacity in the 50-A discharge to less than 75% of the discharge capacity in the first test sequence.

For wet-cell and **AGM** batteries:

- If the residual charging current in step 17 is more than three times the residual charging current of the first unit, the test must be terminated after step 18.
- Leaks during the test (e.g., cell plugs, cracks in the box)

Requirement:

At least 10 test sequences (18 test sequences for batteries suitable for hot countries) must be passed before it is permissible for one of the termination criteria to be met.

After the end of testing, the battery must be aged in a water bath tempered to $(26 \pm 1)^\circ\text{C}$.

24 h to 28 h after aging begins, the internal resistance and, for wet-cell batteries, the electrolyte levels must be measured again and documented. Charge the battery as per section 5.3.1, provided that there is no apparent fault in the battery.

Then, conduct a capacity test as per section 7.1. After that, perform a cold start as per section 7.2.1. The Ah charged in each case, the capacity values, and the cold-start voltages must be documented. There are no requirements for batteries suitable for hot countries. For all other batteries, the cold-start requirement $V_{f,10} \geq 7,5 \text{ V}$. The weight, the internal resistance, and the electrolyte levels must be documented again at the end of testing.

This is followed by an assessment of the open battery: In particular, the positive corrosion, the positive grid growth, and the cell connectors are evaluated. The plastic coatings of the terminal bushings must be checked on the inside for cracking. Cracks are not permissible. PE separators must be undamaged and must not exhibit a high loss in elasticity. Excessive corrosion damage results in

rejection. The growth of the positive grid must not exceed 3 to 4 mm and the PE separator overhang must be at least 1 to 2 mm. The permissible positive grid growth and the still required PE separator overhang for batteries suitable for hot countries will be specified at a later time.

NOTE: For the purpose of future test optimization, this test will or can be carried out with other batteries for information purposes. To do this, either the charging voltage is varied (13,6 V instead of 14,2 V) or the 50-A discharge occurs before the pause (step 18) instead of after the pause. If the 50-A discharge occurs before the pause, the termination criterion < 12 V in step 18 no longer applies.

7.12 Cycles with 17,5% depth of discharge at 3 °C

For EFB and EFB+ batteries, the test is performed as described in section 7.6, except at (3 ± 1) °C in a water bath with the following additional changes:

1. The preliminary discharging (see point 3 in section 7.6) takes place at the specified temperature over 2,5 h with $3,4 \times I_{20}$.
2. The charging voltage in the cycles is $(14,8 \pm 0,05)$ V.

6 units must be passed. Failed batteries are charged for 5 h as per section 5.3.1.

For AFB batteries, the test is performed as described in section 7.13, except at (3 ± 1) °C in a water bath with the following additional changes:

1. The preliminary discharging (see point 2 in section 7.13) takes place at the specified temperature over 2,5 h with $3,4 \times I_{20}$.
2. The charging voltage in the cycles (see point 2 in section 7.13) is $(14,8 \pm 0,05)$ V.

The AFB battery must meet the following criteria: $12 \times 85 = 1\,020$ cycles without reaching the switch-off voltage of 10 V.

Then, weigh the battery, note the weight loss in the report, and measure the acid density above the bridges and at the bottom as well as the internal resistance.

Afterwards, evaluate the open battery: The sulfation and extent of acid stratification are evaluated.

7.13 Continuous cycle test with 17,5% depth of discharge

If no mixing elements are used, the test is performed in a water batch at (26 ± 1) °C. If mixing elements are used, one battery is tested on a rocker at an ambient temperature of (23 ± 2) °C and a second battery is tested statically in a water bath at (26 ± 1) °C, see table 3, battery no. 6/no. 7, as an effectiveness reference for the mixing element.

1. Weigh the outwardly dry battery and measure the acid density above the bridges and at the bottom as well as the internal resistance.
2. Discharge the battery on the active rocker or in the water bath for 2,5 h with $4 \times I_{20}$ and perform the following cycles:
 - Charge for 40 min at $7 \times I_{20}$ and $(14,4 \pm 0,05)$ V.
 - Discharge for 30 min at $7 \times I_{20}$.

Switch-off criterion for the battery voltage for EFB, EFB+, and AFB batteries ≤ 10 V, AGM batteries $\leq 11,5$ V.

3. Weigh the battery, note the weight loss in the report, and, for EFB, EFB+, and AFB batteries, measure the acid density above the bridges and at the bottom as well as the internal resistance.

4. **AGM** battery only: After the cycle test is successfully completed, perform a capacity test as per section 7.1 no more than 72 h later without first charging the battery.
5. **AGM** battery only: Perform a capacity test again as per section 7.1.
6. **AGM** battery only: Perform a cold start test as per section 7.2.1.
7. **AGM** battery only: Weigh the battery again, measure the internal resistance, and note the values in the test record.
8. The following criteria must be fulfilled by the various battery technologies:
AGM batteries:
 - $24 \times 85 = 2\,040$ cycles without reaching the switch-off voltage of 11,5 V.
 - 1st capacity after the cycle test at least 50% of the battery capacity
 - 2nd capacity after the cycle test at least 70% of the battery capacity
 - The following values must be achieved in the cold start test after the cycle test:
 $V_{f, 10} \geq 7,5 \text{ V}$
 $V_{f, 40} \geq 9 \text{ V}$
 $t'_{6V} \geq 60 \text{ s}$**EFB, EFB+, and AFB** batteries:
 - If $18 \times 85 = 1\,530$ cycles are achieved without reaching the switch-off voltage of 10 V, this means that the **EFB**, **EFB+**, and **AFB** technologies have passed this test without requiring a further test as per section 7.6.
 - For **EFB** and **EFB+**, if at least 1 020 cycles but fewer than 1 530 cycles are reached in this test, a release is alternatively possible if the test requirement as per section 7.6 is reached in addition. This alternative does not exist for **AFB**.

Charge failed batteries as per section 5.3.1 for 5 h.

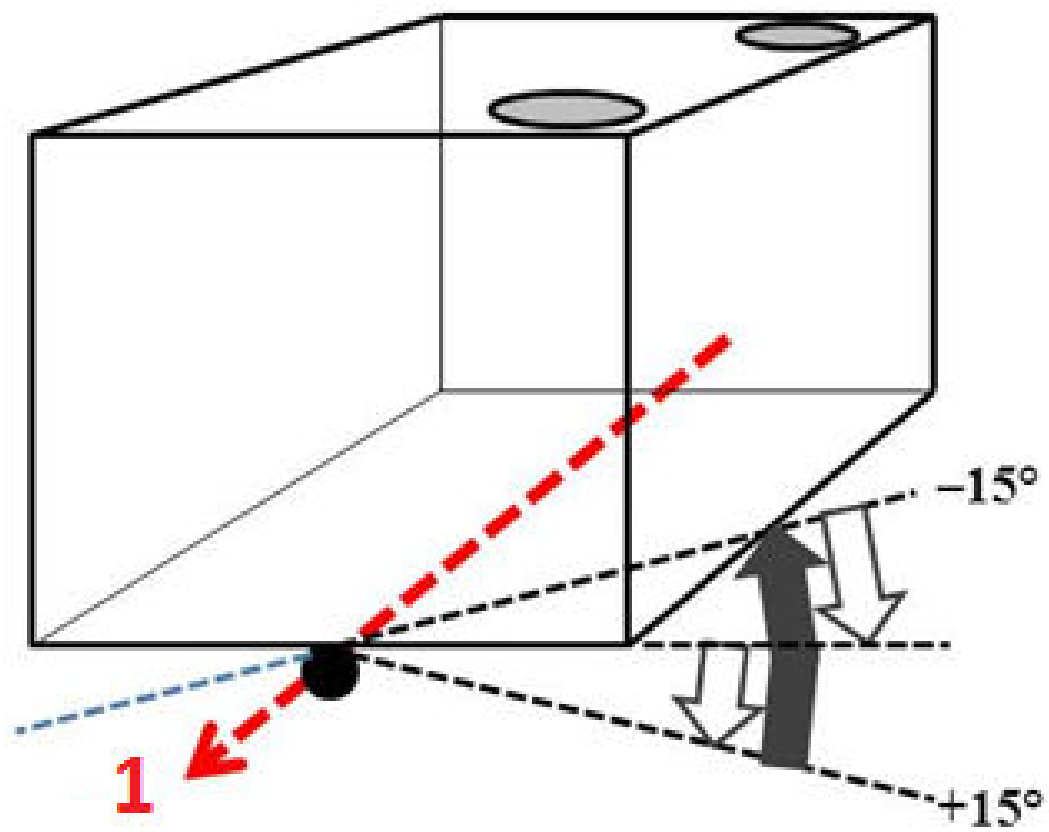
For **EFB**, **EFB+**, and **AFB** batteries:

After the cycle test has been passed, charge the battery as per section 5.3.1, test the capacity as per section 7.1, and then perform a cold start as per section 7.2.1. Deviating from section 5.3.1, the following charging time is limited to 5 h.

Note on rocker test when using mixing elements:

The mechanical movement is achieved by a rocking device that rocks the battery along its longitudinal axis. The battery is rocked every 2,5 min twice in both directions with a tilting angle of 15° and an acceleration of 0,27 g; see figure 3. The duration of the rocking motion is 12 s; see figure 4. The acceleration is generated by a sinusoidal jerk.

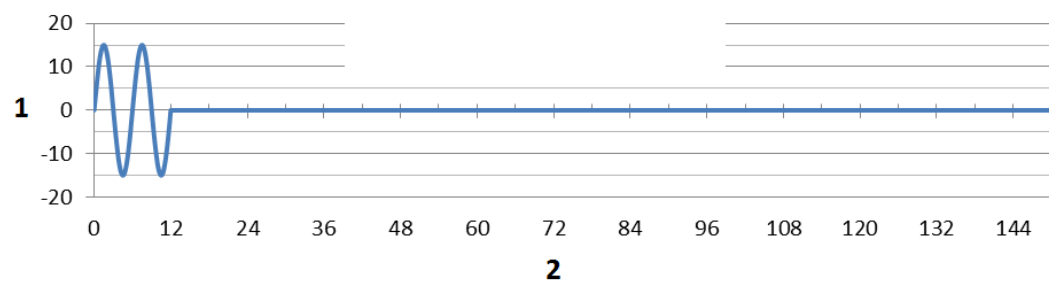
The test is performed for **EFB**, **EFB+**, **AFB**, and **AGM** batteries with a second DUT; see table 3, table 4 and table 5. The second DUT is subjected directly to the continuous cycle test with 17,5% depth of discharge without electrical pretesting. First, test data must be collected with the aim of omitting the pretest for the continuous cycle test in future.



Legend

1 X-axis

Figure 3 – Diagram of the rocking motion



Legend

1 Tilting angle [°]
2 Time [s]

Figure 4 – Tilting angle over time in the rocker test

7.14 Freeze-through test

Test the mechanical strength of the battery box by freezing it completely:

- Discharge with I_{20} to 10,5 V in a water bath at $T = (26 \pm 1) ^\circ\text{C}$
- Within 12 h after discharging, cool to $-18 ^\circ\text{C}$ for 48 h
- Thaw the battery at room temperature and check for acid leakage/damage to the box

No electrolyte may leak out at any time during the test.

7.15 Self-discharge test at $(75 \pm 2) ^\circ\text{C}$

The self-discharge test is release-relevant for wet-cell batteries suitable for hot countries. While the test is obligatory for batteries that are not suitable for hot countries, the result is merely informative. The test is performed in the as-received condition:

1. Measure the open-circuit voltage, internal resistance, weight, and, for wet-cell batteries, the height of the electrolyte levels at room temperature. All values must be documented.
2. Without a preceding electrical test, the battery is placed in a water bath tempered to $(75 \pm 2) ^\circ\text{C}$ for 10 weeks. At the earliest 16 h and at the latest 24 h afterwards, the internal resistance, open-circuit voltage, and, for wet-cell batteries, the electrolyte levels of all 6 cells are measured and documented as start values. The voltage progression of the battery must be recorded continuously, at least weekly. Every week, the battery must be weighed, the internal resistance must be measured, and the electrolyte level must be documented for wet-cell batteries, whereby the battery may be removed from the water bath for no longer than 30 min. Anomalies must be documented.
3. Immediately after completing the 10-week dwell time, the battery must be aged in a water bath tempered to $(26 \pm 1) ^\circ\text{C}$. 16 h to 24 h after aging begins, the electrolyte levels in wet-cell batteries must be measured and documented again. Recharging as per section 5.3.1 then begins immediately or no more than 5 days later. The charged Ah must be documented.
4. Immediately after charging in step 3, the capacity test is conducted as per section 7.1.
5. This is followed by a cold start test as per section 7.2.1. Deviating from section 5.3.1, the following charging time is limited to 5 h.
6. At least 24 h after charging ends, the electrolyte levels in wet-cell batteries must be measured and documented again. The battery weight must also be documented. The battery can then be stored until it is opened for assessment.

Requirements:

The weight loss must not exceed 1,5 g/Ah of the battery capacity. In addition, the electrolyte level difference measured after the test at room temperature must not exceed the initial value at room temperature before being stored at $75 ^\circ\text{C}$ by more than 5 mm.

The capacity test must yield at least 100% of the battery capacity. In the cold start test, the voltage requirements $V_{f, 10}$ and $V_{f, 40}$ must be met. The discharge time t'_{6V} must be at least 90 s.

Assessment with the battery open:

The positive grid corrosion and the positive plate growth are evaluated. The PE separators must not exhibit damage or a high loss in elasticity. Excessive positive corrosion/excessive positive grid growth result in rejection. The plastic coatings of the terminal bushings must be checked on the inside for cracking. Cracks are not permissible.

8 Evaluation and test results

Within the test sequences as per section 6, the nominal values must always be achieved in the capacity and cold start tests. In the event of deviation in the 1st capacity, the deviation must be comprehensibly substantiated.

8.1 Production deviation

The production deviation compared to the build sample inspection batteries must be no more than 5% in terms of the average values of the capacity and no more than 0,3 V in the cold start as per section 7.2.1 at $V_{f,10}$, $V_{f,30}$, and $V_{f,40}$. Standard and drawing specifications must always be fulfilled, which means 100% capacity, $V_{f,10} \geq 7,5$ V, $V_{f,30} \geq 7,2$ V, $V_{f,40} \geq 9$ V.

Example:

At a $V_{f,10}$ of 8,2 V in the build sample inspection, a minimum voltage $V_{f,10}$ of 7,9 V is required in the subsequent production delivery.

9 Physical tests

9.1 Vibration resistance test

9.1.1 Test sequence

The vibration test is performed as per DIN EN 50342-1, level V2

1. First, the leak test must be conducted as per TL 82506, , "Battery leak-tightness" section (does not apply to AGM batteries).
2. Before the vibration test, the fully-charged battery as per section 5.3.1 is subjected to a "hot start" based on section 7.2.1 at room temperature. The terminal voltage $V_{f,40}$ and the duration of the discharges down to 6 V must be documented. Then, the battery is charged for 16 h as per section 5.3.1.
3. Vibration testing as per DIN EN 50342-1, level V2.
4. Then, the leak test as per TL 82506, , "Battery leak-tightness" section is repeated (does not apply to AGM batteries).
5. The battery is subjected to a "hot start" based on section 7.2.1 at room temperature. The terminal voltage $V_{f,40}$ and the duration of the discharges down to 6 V must be documented. Then, the battery is charged for 16 h as per section 5.3.1.

The reduction in terminal voltage $V_{f,40}$ after vibration must be no more than 0,3 V, and the reduction in discharge time down to 6 V must be no more than 20 s. The leak-tightness requirement as per item 1 must be fulfilled before and after vibration. No components in the battery must be destroyed (optional assessment with the battery open).

9.1.2 Permissible bracing methods for the vibration resistance test

The battery be attached to the shaker table by a method similar to the method used in the vehicle. The tightening torque of the clamping plate (minimum width 40 mm, material thickness 2,5 mm) is 15 Nm to 20 Nm.

10 **Applicable documents**

The following documents cited are necessary to the application of this document:

Some of the cited documents are translations from the German original. The translations of German terms in such documents may differ from those used in this standard, resulting in terminological inconsistency.

Standards whose titles are given in German may be available only in German. Editions in other languages may be available from the institution issuing the standard.

TL 82506	SLI Batteries; Requirements
VW 01155	Vehicle Parts; Approval of First Supply and Changes
VW 50554	Standard Atmospheres and Room Temperatures; Requirements on Standard Atmospheres
DIN 12775	Laboratory glassware - Laboratory thermometers, scale values 0,1 °C, 0,2 °C and 0,5 °C
DIN EN 50342-1	Lead-Acid Starter Batteries – Part 1: General Requirements and Methods of Test

11 **Bibliography**

- [1] SAE J537 "Storage Batteries"
- [2] GSO 35:2007 "Methods of Test for Lead-Acid Starter Batteries Used for Motor Vehicles and Internal Combustion Engines"

Appendix A (normative) Documentation

When documenting data from battery tests as per table 2, table 3, table 4, and table 5, the standard test record provided by the department responsible for release must be used. Furthermore, the following graphical standards must be adhered to:

Table A.1

Test	Representation	Comments
Overcharge test	Time curve I/V/T, charged Ah	
Self-discharge test at 75 °C	Time curve V/T Weight loss over weeks	
Thermal stability test at (75 ±2) °C	Electrolyte reduction over weeks In a diagram: electrolyte levels before test start at room temperature, directly after test start at +75 °C, at test end at +75 °C, and after test end after cooling to room temperature Time curve I/V/Q/T Curve in the units from section 7.11: Step 16: Cutoff voltage Step 17: The capacity charged during the two-hour charging process Step 18: Residual charging current at the end of charging Step 19: Open-circuit voltage at the end of the dwell time Step 20: Duration of discharging with 50 A	
50% cycle test	1. Time curve I/V/T 2. Charge factor in cycles 3. Cutoff voltage in cycles 4. Final charging currents in cycles	
17,5% cycle test (at all temperatures)	1. Time curve I/V/T 2. Charge factor in cycles 3. Cutoff voltage in cycles 4. Capacities across cycle (if in test scope)	
Cold start	Time curve I/V/T	– For the initial measurement, show all batteries in a single diagram for each test with its consecutive number – Highlight impermissible areas in color

Table A.1 (continued)

Test	Representation	Comments
Capacity	Time curve I/V/T	For the initial measurement, show all batteries in a single diagram for each test with its consecutive number
Static current draw	Time curve I/V/T	Highlight impermissible areas in color
Dynamic current draw	– Time curve (60 s) of charging currents for all SOC's – Time curve (24 h) of open-circuit voltage for all SOC's	– All charging currents in one diagram – All open-circuit voltages in one diagram
Exhaustive discharge test	Time curve V	Voltage range: – 0 V – 13 V – 0 V – 2 V
Regenerative ability	Time curve I/V/Q for F1, F2, and F3	The following must be shown in each case in a separate diagram: – I for F1 – I for F2 and F3 – V for F1 – V for F2 and F3 – Q for F1, F2, and F3

Appendix B (normative) Correct packaging of batteries

Packaging of batteries, e.g., for air transport, with loose absorption material is impermissible (see figure B.1).



Figure B.1 – Not OK (NOK) – loose absorption material

The absorption material must be packed in dust-proof bags (see figure B.2).



Figure B.2 – OK – absorption material in dust-proof bags

The cardboard box is filled with the required number of absorption bags (see figure B.3).



Figure B.3 – Absorption bags in cardboard box

The battery wrapped in a plastic film bag is placed on the absorption bag (see figure B.4).



Figure B.4 – Wrapped battery in cardboard box

The cardboard box is filled up with foam material to rule out slipping or tipping of the battery (see figure B.5).



Figure B.5 – Cardboard box filled with foam material

The box is then taped shut and the required labels are attached (see figure B.6).



Figure B.6 – Cardboard box taped closed and labeled

Appendix C (normative) Driving cycle regenerative ability (based on the “worldwide harmonized light vehicle test procedure” WLTP)

Evaluating the sequence of charge, discharge, and pause phases described in table C.1 allows the ability of the storage medium to sustain electrical system loads during driving operation to be assessed.

Table C.1 – Chronological sequence of battery handling in the driving cycle

The driving cycle is translated as follows into individual phases:	
1. Stop phase: 13 s discharging with 25 A	2. 25 s pause (F1) or discharge (F2, F3)
3. 7 s charging with 15 V (current limit: 200 A)	4. 7 s pause (F1) or discharge (F2, F3)
5. 2 s charging with 15 V (current limit: 200 A)	6. 35 s pause (F1) or discharge (F2, F3)
7. 5 s charging with 15 V (current limit: 200 A)	8. 5 s pause (F1) or discharge (F2, F3)
9. Stop phase: 40 s discharging with 25 A	10. 13 s pause (F1) or discharge (F2, F3)
11. 2 s charging with 15 V (current limit: 200 A)	12. 18 s pause (F1) or discharge (F2, F3)
13. 4 s charging with 15 V (current limit: 200 A)	14. 8 s pause (F1) or discharge (F2, F3)
15. 5 s charging with 15 V (current limit: 200 A)	16. 45 s pause (F1) or discharge (F2, F3)
17. 3 s charging with 15 V (current limit: 200 A)	18. 3 s pause (F1) or discharge (F2, F3)
19. 9 s charging with 15 V (current limit: 200 A)	20. 7 s pause (F1) or discharge (F2, F3)
21. 1 s charging with 15 V (current limit: 200 A)	22. 18 s pause (F1) or discharge (F2, F3)
23. 6 s charging with 15 V (current limit: 200 A)	24. 24 s pause (F1) or discharge (F2, F3)
25. 2 s charging with 15 V (current limit: 200 A)	26. 8 s pause (F1) or discharge (F2, F3)
27. 6 s charging with 15 V (current limit: 200 A)	28. 8 s pause (F1) or discharge (F2, F3)
29. 2 s charging with 15 V (current limit: 200 A)	30. 29 s pause (F1) or discharge (F2, F3)
31. 2 s charging with 15 V (current limit: 200 A)	32. 11 s pause (F1) or discharge (F2, F3)
33. 1 s charging with 15 V (current limit: 200 A)	34. 11 s pause (F1) or discharge (F2, F3)
35. Stop phase: 8 s discharging with 25 A	36. 10 s pause (F1) or discharge (F2, F3)
37. 6 s charging with 15 V (current limit: 200 A)	38. 28 s pause (F1) or discharge (F2, F3)
39. 2 s charging with 15 V (current limit: 200 A)	40. 4 s pause (F1) or discharge (F2, F3)
41. Stop phase: 70 s discharging with 25 A	42. 10 s pause (F1) or discharge (F2, F3)
43. 2 s charging with 15 V (current limit: 200 A)	44. 5 s pause (F1) or discharge (F2, F3)
45. Stop phase: 4 s discharging with 25 A	46. 12 s pause (F1) or discharge (F2, F3)
47. 2 s charging with 15 V (current limit: 200 A)	48. 16 s pause (F1) or discharge (F2, F3)
49. 1 s charging with 15 V (current limit: 200 A)	50. 2 s pause (F1) or discharge (F2, F3)
51. Stop phase: 34 s discharging with 25 A	52. 52 s pause (F1) or discharge (F2, F3)
53. 8 s charging with 15 V (current limit: 200 A)	54. 2 s pause (F1) or discharge (F2, F3)
55. 1 s charging with 15 V (current limit: 200 A)	56. 15 s pause (F1) or discharge (F2, F3)
57. 5 s charging with 15 V (current limit: 200 A)	58. 13 s pause (F1) or discharge (F2, F3)
59. 3 s charging with 15 V (current limit: 200 A)	60. 8 s pause (F1) or discharge (F2, F3)
61. 1 s charging with 15 V (current limit: 200 A)	62. 48 s pause (F1) or discharge (F2, F3)
63. 5 s charging with 15 V (current limit: 200 A)	64. 33 s pause (F1) or discharge (F2, F3)
65. 5 s charging with 15 V (current limit: 200 A)	66. 10 s pause (F1) or discharge (F2, F3)

Table C.1 (continued)

The driving cycle is translated as follows into individual phases:	
67. 8 s charging with 15 V (current limit: 200 A)	68. 59 s pause (F1) or discharge (F2, F3)
69. 1 s charging with 15 V (current limit: 200 A)	70. 15 s pause (F1) or discharge (F2, F3)
71. 1 s charging with 15 V (current limit: 200 A)	72. 9 s pause (F1) or discharge (F2, F3)
73. 4 s charging with 15 V (current limit: 200 A)	74. 45 s pause (F1) or discharge (F2, F3)
75. 6 s charging with 15 V (current limit: 200 A)	76. 13 s pause (F1) or discharge (F2, F3)
77. 8 s charging with 15 V (current limit: 200 A)	78. 6 s pause (F1) or discharge (F2, F3)
79. Stop phase: 43 s discharging with 25 A	80. 24 s pause (F1) or discharge (F2, F3)
81. 6 s charging with 15 V (current limit: 200 A)	82. 2 s pause (F1) or discharge (F2, F3)
83. 1 s charging with 15 V (current limit: 200 A)	84. 24 s pause (F1) or discharge (F2, F3)
85. 1 s charging with 15 V (current limit: 200 A)	86. 14 s pause (F1) or discharge (F2, F3)
87. 1 s charging with 15 V (current limit: 200 A)	88. 19 s pause (F1) or discharge (F2, F3)
89. 1 s charging with 15 V (current limit: 200 A)	90. 4 s pause (F1) or discharge (F2, F3)
91. 12 s charging with 15 V (current limit: 200 A)	92. 10 s pause (F1) or discharge (F2, F3)
93. 1 s charging with 15 V (current limit: 200 A)	94. 204 s pause (F1) or discharge (F2, F3)
95. 10 s charging with 15 V (current limit: 200 A)	96. 8 s pause (F1) or discharge (F2, F3)
97. 1 s charging with 15 V (current limit: 200 A)	98. 5 s pause (F1) or discharge (F2, F3)
99. 6 s charging with 15 V (current limit: 200 A)	100. 18 s pause (F1) or discharge (F2, F3)
101. 8 s charging with 15 V (current limit: 200 A)	102. 14 s pause (F1) or discharge (F2, F3)
103. 2 s charging with 15 V (current limit: 200 A)	104. 7 s pause (F1) or discharge (F2, F3)
105. 5 s charging with 15 V (current limit: 200 A)	106. 6 s pause (F1) or discharge (F2, F3)
107. 1 s charging with 15 V (current limit: 200 A)	108. 8 s pause (F1) or discharge (F2, F3)
109. Stop phase: 28 s discharging with 25 A	110. 47 s pause (F1) or discharge (F2, F3)
111. 5 s charging with 15 V (current limit: 200 A)	112. 98 s pause (F1) or discharge (F2, F3)
113. 4 s charging with 15 V (current limit: 200 A)	114. 96 s pause (F1) or discharge (F2, F3)
115. 16 s charging with 15 V (current limit: 200 A)	116. 23 s pause (F1) or discharge (F2, F3)
117. 22 s charging with 15 V (current limit: 200 A)	118. 5 s pause (F1) or discharge (F2, F3)
119. Stop phase: 5 s discharging with 25 A	

Appendix D (informative) Guideline for creating the findings for batteries

This guideline applies, by way of example, to battery nos. 2, 5, and 6 as per table 2.

Battery 2: Overcharging at constant voltage

- PE separators: Wash the separators and examine them for holes (if this was not already performed for battery 1).
- Growth of positive grid: The outer plates are not taken into account. Place the negative and positive grids on top of one another and compare their growth. Growth of up to 2 mm is acceptable. To determine the original height, if necessary, consult the product description or preferably the positive grid of an untested battery or a battery that has only been subjected to the initial measurement completely or partially (test steps number 1 to maximum number 10 as per table 2, table 3, table 4 and table 5).
- Grid corrosion (use the following scale):
 - A: OK
 - A to B: OK, slight corrosion, anomalies in certain areas
 - B: NOK, considerable corrosion of the grids
 - B to C: NOK, very significant corrosion of the grids
 - C: NOK, mass remains suspended below, and it is not possible to remove the grid without destroying it

Battery 5: Cycles with 50% depth of discharge at (40 ± 1) °C in water bath

- Corrosion: Remove the positive grid, examine it, and determine the corrosion level.
- PE separators: Wash the separators and examine them for holes and irregularities (e.g., white spots, dendritic growth).
- Negative mass: Examine whether there is significant leakage of the negative mass.
- Positive mass: Grind the mass between your fingers and determine whether any core remains.

Battery 6: Cycles with 17,5% depth of discharge at (26 ± 1) °C

- Sulfation level: Use a lead streak test to determine the height up to which (viewed from below) the grid does not have any metallic gloss.
- Positive grid: With positive grids, a three-way separation is typical. The upper and lower parts are not as involved in the reaction, which is why the consumption of the mass is lower here. The middle part is most involved in the chemical reactions. Examine the mass in this area for a core (e.g., has the mass broken down).

General points to evaluate when the battery is opened:

1. Cell connectors (check for misalignment, cast-on strap lead filter, lead overflow, lead spatters, and fracture pattern. Plastic inclusions, channels to the outside, and rim welds are not permissible.)
2. Connection of the lugs (check for positive meniscus, pore-free connection, melted lugs, outer lugs pressed on too strongly, lug/plate connected at an angle)
3. Terminals (terminal weld ≥ 4 mm, labyrinth (= transition of terminal bushing to cover plastic) sealed)
4. Box:
 - Are there marks on the inside of the bottom of the box?
 - Are there conspicuous areas? (damage, white discoloration, etc.)

5. PE separators (separator overhang of at least 5 mm, no separator misalignment, separator welding is leak-tight)
6. Plates (check for "crooked" connection, complete pasting, mass crumbs, one-sided or two-sided pasting, no bent edges/grid bars)
7. Grid (for cast grids, check casting quality: check for missing bars, shrinkage cavities in the frame; for extended metal grids: check for expansion faults; for punched grids: check for even side frame thickness and even grid mesh, no punch offset)
8. Electrolyte levels after tests (unevenly decreased electrolyte levels result in rejection)

Check of the internal structure:

- Height of the cell connector welds
- Height of the bridge