TEST REPORT

BAE *SECURA OPzV*

STATIONARY VALVE REGULATED LEAD-ACID CELLS AND BATTERIES
WITH POSITIVE TUBULAR PLATE

OPzV block batteries and cells according to DIN EN 40744 and DIN 40742

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BAE
Energy from Batteries

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Product group: Valve regulated lead acid batteries
Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Capacity test (block batteries)**

Test, chapter: Capacity test, IEC 60896-21, Chapter 6.11

Test laboratory: BAE Batterien GmbH

Test performance:

Capacity tests are carried out for time ranges given by IEC 60896-21 Chapter 6.11.10:

10 h, 5 h, 3 h, 1 h, $\frac{1}{2}$ h

Tubular plate size: OPzV 50 Ah

Test data: Test subject: 12V 2 OPzV 100

Capacity test	C_{10} discharge	C_5 discharge	C_3 discharge	C_1 discharge
Discharge current[1]	10 A	17 A	25.3 A	53 A
Final voltage[1]	1.80 V	1.77 V	1.75 V	1.67 V
Nominal capacity[2]	100 Ah	85 Ah	76 Ah	53 Ah
Measured capacity	111.6 Ah = **112 %**	102.5 Ah = **121 %**	93.3 Ah = **123 %**	78.4 Ah = **148 %**

Test temperature: 20 °C (mean value)

Summary of test results:

In all capacity tests the nominal capacity was exceeded. The measured C_{10} capacity was in excess of the nominal capacity.

[1] The discharge current and the final voltage per cell are given by DIN EN 40 744.
[2] The calculation based on a multiplication of discharge time and discharge current.

Exemplarily measurement curves are shown at page 4 (from Figure 1).

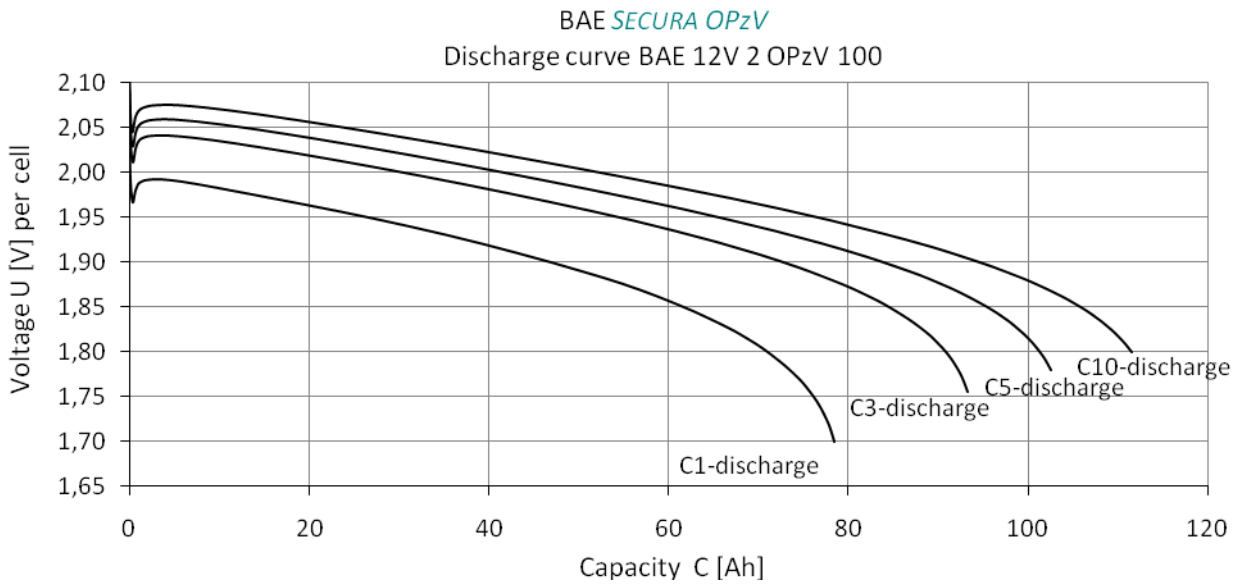

Figure 1 – *Capacity test (example BAE block 12V 2 OPzV 100).*

Product group: Valve regulated lead acid batteries

Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Internal resistance and short circuit current (block batteries)**

Test, chapter: Test for short circuit current and internal resistance, IEC 60896-21 Chapter 6.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on three 12V 2 OPzV 100 is in accordance with the above standard. This means the internal resistance and the short circuit current can be calculated from the current-voltage relationship given by two points in a discharge curve. The first point is obtained after 20 sec of discharge at a current $I_{point\_1} = 4\ I_{C10} \ldots 6\ I_{C10}$ (at this example the discharge current was 50 A), the voltage and the current shall be recorded. The discharge should be interrupted for 25 sec without recharge. After an open circuit stand of 2 min to 5 min, the second point can be determinated. After 5 sec of discharge at the current of $I_{point\_2} = 20\ I_{C10} \ldots 40\ I_{C10}$ (at this example the discharge current was 350 A), voltage and the current shall be recorded.

The figures can be calculated from the following equations (see Figure 2 at page 6):

$$I_{sc} = \frac{U_1 I_2 - U_2 I_1}{U_1 - U_2} \ [A] \qquad [1]$$

$$R_i = \frac{U_1 - U_2}{I_2 - I_1} \ [\Omega] \qquad [2]$$

Results:

These are the results for the internal resistance [1] and short circuit current [2] for the positive tubular plate OPzV 50 Ah:

Internal resistance: R_i = 4 mΩ per plate, per cell

Short circuit current: I_{sc} = 520 A

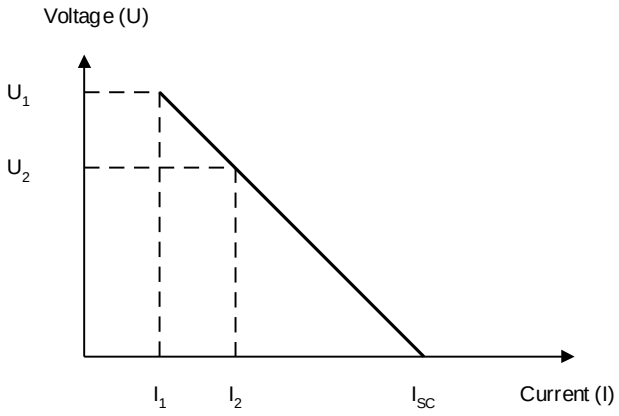

Figure 2 – *Discharge characteristic U= f(I).*

Product group: Valve regulated lead acid batteries
Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Charge retention (block batteries)**

Test, chapter: IEC 60896-21 Chapter 6.12

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on two block batteries 12V 2 OPzV 100 is in accordance with the above standard. The block batteries were stored with open circuit for a period of 3 months. Before and after the test the capacity was measured (C_{10} discharge). The mean test temperature was 20 °C.

Results:

The measured capacity after 3 months storage was 95.08% of the capacity at the beginning of the test. This corresponds to a self-discharge rate of 1.64% per month.
This is clearly well below the stated value of 3% per month.

An example of the measurement is shown at page 8 (Figure 3).

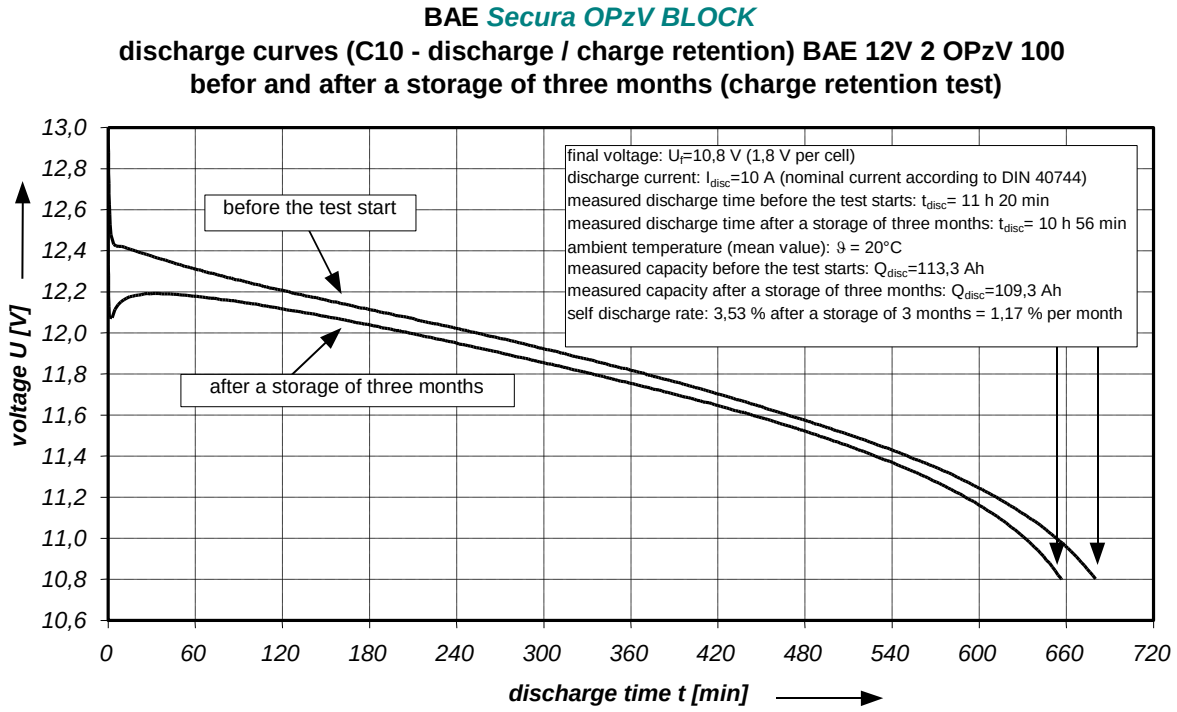

Figure 3 – *Test of charge retention (self-discharge) on BAE 12V 2 OPzV 100 block battery*.

Product group: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 2 OPzV 100 - 6 OPzV 300

Test: **Capacity test (50 Ah plate)**

Test, chapter: Capacity test, IEC 60896-21, Chapter 6.11

Test laboratory: BAE Batterien GmbH

Test performance:

Capacity tests are carried out for time ranges given by IEC 60896-21 Chapter 6.11.10:

10 h, 5 h, 3 h, 1 h, $\frac{1}{2}$ h

Tubular plate size: OPzV 50 Ah

Test data: Test subject: 6 cells 5 OPzV 250

Capacity test	C_{10} discharge	C_5 discharge	C_3 discharge	C_1 discharge
Discharge current[3]	25 A	43 A	62.67 A	133 A
Final voltage[3]	1.80 V	1.77 V	1.75 V	1.67 V
Nominal capacity[4]	250 Ah	215 Ah	188 Ah	133 Ah
Measured capacity	295.1 Ah = **118 %**	260.8 Ah = **121 %**	231.5 Ah = **123 %**	181.3 Ah = **136 %**

Test temperature: 20 °C (mean value)

Summary of test results:

In all capacity tests the nominal capacity was exceeded. The measured C_{10}-capacity was in excess of the nominal capacity.

Exemplarily measurement curves are shown at page 10 (Figure 4).

[3] The discharge current and the final voltage per cell are given by DIN EN 40 742 chapter 4.

[4] The calculation bases on a multiplication of discharge time and discharge current.

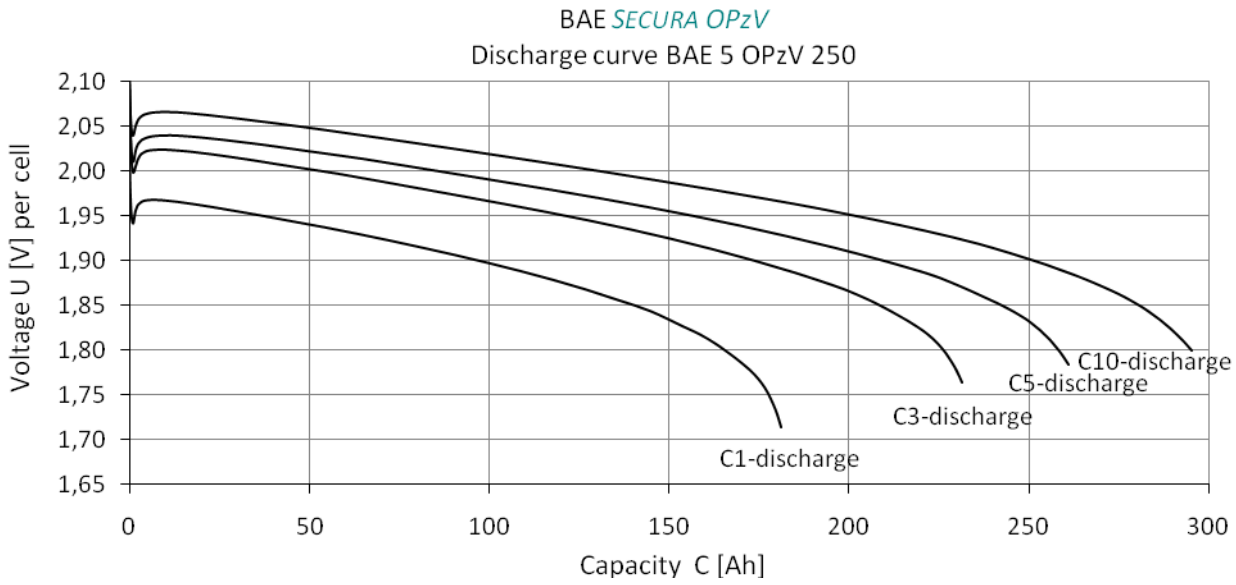

Figure 4 – *Capacity test OPzV 50 plate (example BAE cells 5 OPzV 250).*

Product group: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 5 OPzV 350 - 7 OPzV 490

Test: **Capacity test (70 Ah plate)**

Test, chapter: Capacity test, IEC 60896-21, Chapter 6.11

Test laboratory: BAE Batterien GmbH

Test performance:

Capacity tests are carried out for time ranges given by IEC 60896-21 Chapter 6.11.10:

10 h, 5 h, 3 h, 1 h, $\frac{1}{2}$ h

Tubular plate size: OPzV 70 Ah

Test data: Test subject: 6 cells 7 OPzV 490

Capacity test	C_{10} discharge	C_5 discharge	C_3 discharge	C_1 discharge
Discharge current[3]	49 A	84 A	122.67 A	259 A
Final voltage[3]	1.80 V	1.77 V	1.75 V	1.67 V
Nominal capacity[4]	490 Ah	420 Ah	368 Ah	259 Ah
Measured capacity	624.3 Ah = **127 %**	554.1 Ah = **132 %**	488.7 Ah = **133 %**	379.5 Ah = **147 %**

Test temperature: 20 °C (mean value)

Summary of test results:

In all capacity tests the nominal capacity was exceeded. The measured C_{10}-capacity was in excess of the nominal capacity.

Exemplarily measurement curves are shown at page 12 (Figure 5).

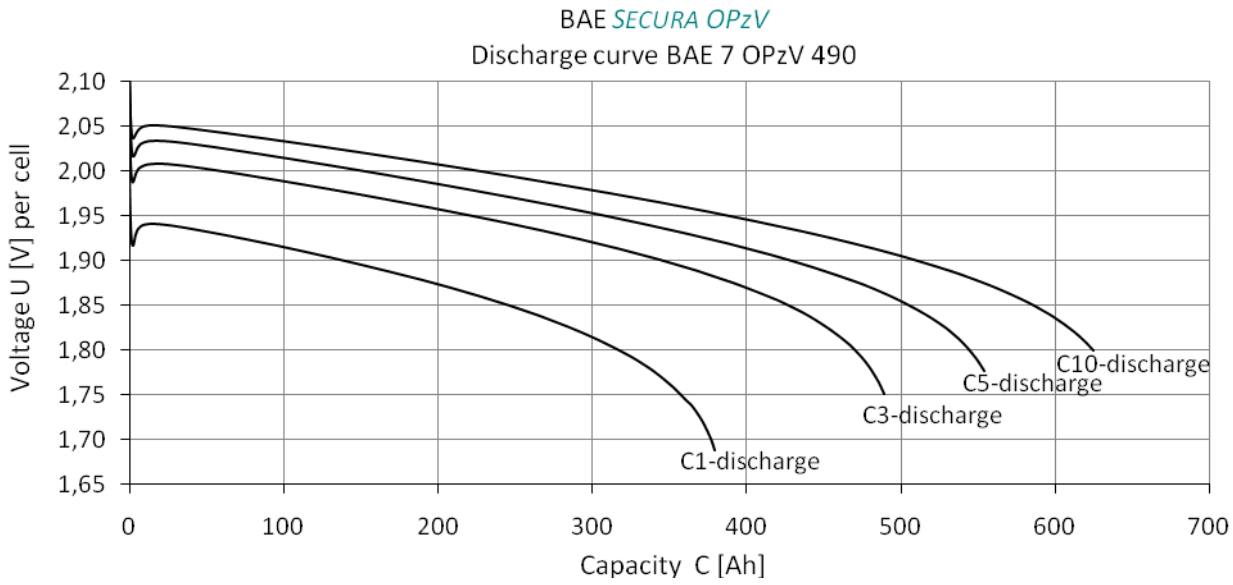

Figure 5 – *Capacity test OPzV 70 plate (example BAE cells 7 OPzV 490).*

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 6 OPzV 600 - 12 OPzV 1200

Test: **Capacity test (100 Ah plate)**

Test, chapter: Capacity test, IEC 60896-21, Chapter 6.11

Test laboratory: BAE Batterien GmbH

Test performance:

Capacity tests are carried out for time ranges given by IEC 60896-21 Chapter 6.11.10:

10 h, 5 h, 3 h, 1 h, $\frac{1}{2}$ h

Tubular plate size: OPzV 100 Ah

Test data: Test subject: 6 cells 6 OPzV 600

Capacity test	C_{10} discharge	C_5 discharge	C_3 discharge	C_1 discharge
Discharge current[3]	60 A	103.2 A	150 A	312 A
Final voltage[3]	1.80 V	1.77 V	1.75 V	1.67 V
Nominal capacity[4]	600 Ah	516 Ah	450 Ah	312 Ah
Measured capacity	727.9 Ah = **121 %**	642.7 Ah = **125 %**	578.0 Ah = **128 %**	432.3 Ah = **139 %**

Test temperature: 20 °C (mean value)

Summary of test results:

In all capacity tests the nominal capacity was exceeded. The measured C_{10}-capacity was in excess of the nominal capacity.

Exemplarily measurement curves are shown at page 14 (Figure 6).

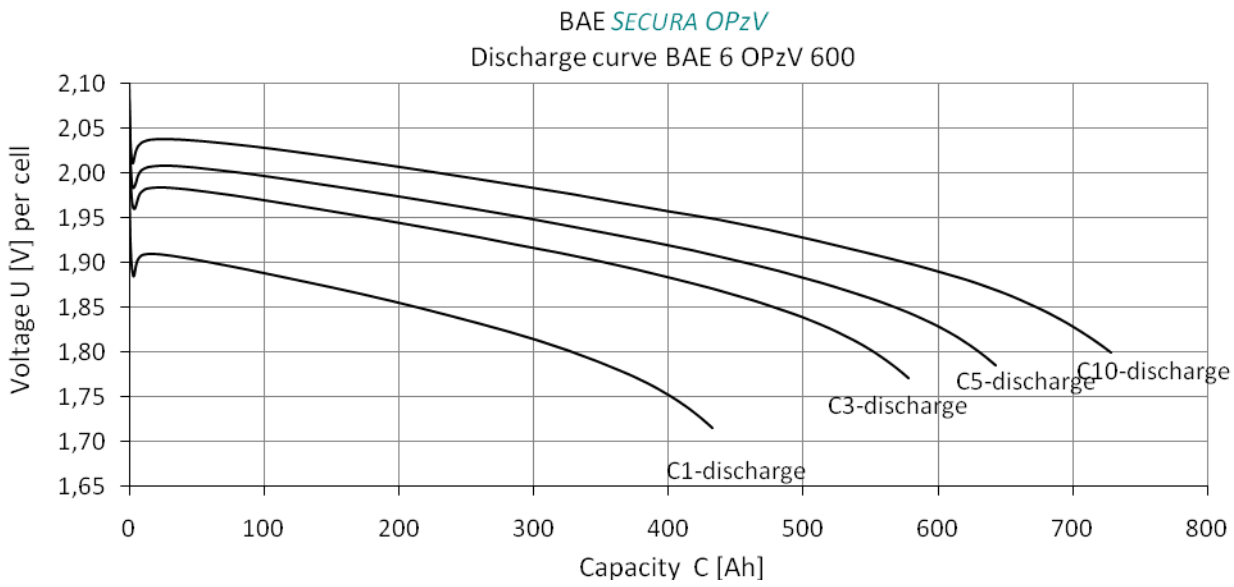

Figure 6 – *Capacity test OPzV 100 plate (example BAE cells 6 OPzV 600).*

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12 OPzV 1500 - 26 OPzV 3250

Test: **Capacity test (125 Ah plate)**

Test, chapter: Capacity test, IEC 60896-21, Chapter 6.11

Test laboratory: BAE Batterien GmbH

Test performance:

Capacity tests are carried out for time ranges given by IEC 60896-21 Chapter 6.11.10:

10 h, 5 h, 3 h, 1 h, $\frac{1}{2}$ h

Tubular plate size: OPzV 125 Ah

Test data: Test subject: 6 cells 12 OPzV 1500

Capacity test	C_{10} discharge	C_5 discharge	C_3 discharge	C_1 discharge
Discharge current[3]	150 A	252 A	372 A	744 A
Final voltage[3]	1.80 V	1.77 V	1.75 V	1.67 V
Nominal capacity[4]	1500 Ah	1260 Ah	1116 Ah	1067.4 Ah
Measured capacity	1682.3 Ah = **112 %**	1539.0 Ah = **122 %**	1387.6 Ah = **124 %**	1067.4 Ah = **143 %**

Test temperature: 20 °C (mean value)

Summary of test results:

In all capacity tests the nominal capacity was exceeded. The measured C_{10}-capacity was in excess of the nominal capacity.

Exemplarily measurement curves are shown at page 16 (Figure 7).

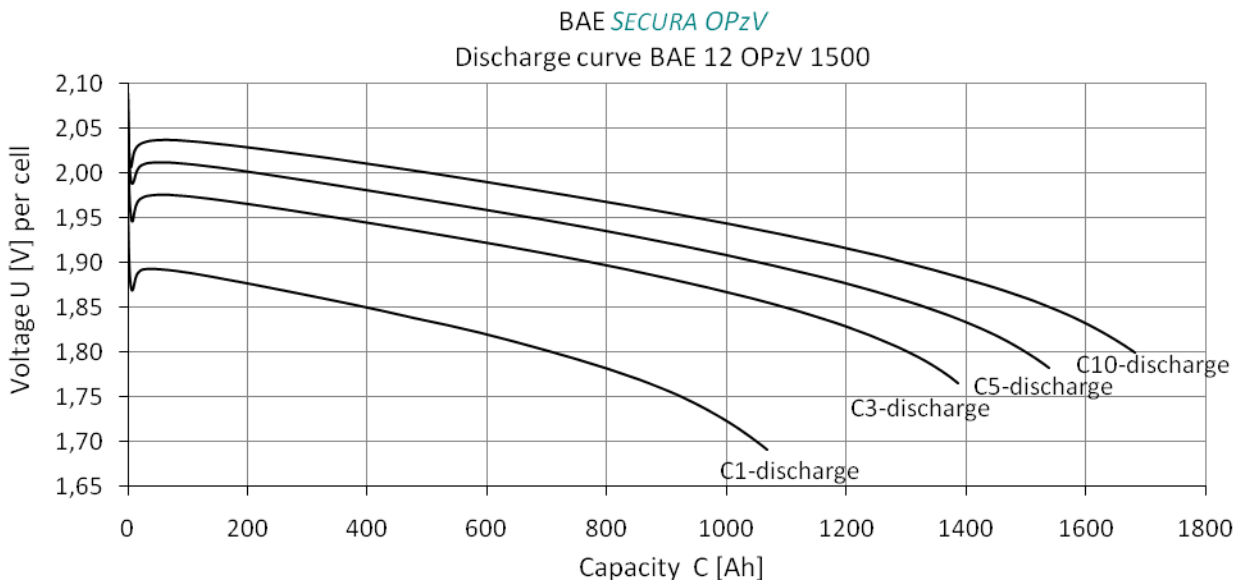

Figure 7 – *Capacity test OPzV 125 plate (example BAE cells 12 OPzV 1500).*

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 2 OPzV 100 - 6 OPzV 300

Test: **Internal resistance and short circuit current (50 Ah plate)**

Test, chapter: Test for short circuit current and internal resistance,
IEC 60896-21 Chapter 6.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on 6 units 6 OPzV 300 is in accordance with the above standard. This means the internal resistance and the short circuit current can be calculated from the current-voltage relationship given by two points in a discharge curve. The first point is obtained after 20 sec of discharge at a current $I_{point\_1} = 4\ I_{C10}$ … $6\ I_{C10}$ (at this example the discharge current was 150 A), the voltage and the current shall be recorded. The discharge should be interrupted for 25 sec without recharge. After an open circuit stand of 2 min to 5 min, the second point can be determinated.

After 5 sec of discharge at the current of $I_{point\_2} = 20\ I_{C10}$ ... $40\ I_{C10}$ (at this example the discharge current was 900 A), the voltage and the current shall be recorded.

The figures can be calculated from the equations [1] and [2] at page 5.

Results:

These are the results for the internal resistance [1] and short circuit current [2] for the positive tubular plate OPzV 50 Ah:

Internal resistance: $R_i = 4.8\ m\Omega$ per plate

Short circuit current: $I_{sc} = 430$ A per plate

Internal resistance and short circuit current

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 5 OPzV 350 - 7 OPzV 490

Test: **Internal resistance and short circuit current (70 Ah plate)**

Test, chapter: Test for short circuit current and internal resistance,
IEC 60896-21 Chapter 6.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on 6 units 6 OPzV 420 is in accordance with the above standard. This means the internal resistance and the short circuit current can be calculated from the current-voltage relationship given by two points in a discharge curve. The first point is obtained after 20 sec of discharge at a current $I_{point\_1} = 4\ I_{C10}$ … $6\ I_{C10}$ (at this example the discharge current was 210 A), the voltage and the current shall be recorded. The discharge should be interrupted for 25 sec without recharge. After an open circuit stand of 2 min to 5 min, the second point can be determinated.

After 5 sec of discharge at the current of $I_{point\_2} = 20\ I_{C10}$ ... $40\ I_{C10}$ (at this example the discharge current was 1260 A), the voltage and the current shall be recorded.

The figures can be calculated from the equations [1] and [2] at page 5.

Results:

These are the results for the internal resistance [1] and short circuit current [2] for the positive tubular plate OPzV 70 Ah:

Internal resistance: $R_i = 3.57\ m\Omega$ per plate

Short circuit current: $I_{sc} = 577$ A per plate

Internal resistance and short circuit current

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 6 OPzV 600 - 12 OPzV 1200

Test: **Internal resistance and short circuit current (100 Ah plate)**

Test, chapter: Test for short circuit current and internal resistance,
IEC 60896-21 Chapter 6.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on 6 units 6 OPzV 600 is in accordance with the above standard. This means the internal resistance and the short circuit current can be calculated from the current-voltage relationship given by two points in a discharge curve. The first point is obtained after 20 sec of discharge at a current $I_{point\_1} = 4\ I_{C10}$ … $6\ I_{C10}$ (at this example the discharge current was 350 A), the voltage and the current shall be recorded. The discharge should be interrupted for 25 sec without recharge. After an open circuit stand of 2 min to 5 min, the second point can be determinated.

After 5 sec of discharge at the current of $I_{point\_2} = 20\ I_{C10}$ ... $40\ I_{C10}$ (at this example the discharge current was 1850 A), the voltage and the current shall be recorded.

The figures can be calculated from the equations [1] and [2] at page 5.

Results:

These are the results for the internal resistance [1] and short circuit current [2] for the positive tubular plate 100 Ah:

Internal resistance: $R_i = 2.70\ m\Omega$ per plate

Short circuit current: $I_{sc} = 763$ A per plate

Internal resistance and short circuit current

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12 OPzV 1500 - 26 OPzV 3250

Test: **Internal resistance and short circuit current (125 Ah plate)**

Test, chapter: Test for short circuit current and internal resistance,
IEC 60896-21 Chapter 6.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test carried out on 6 units 12 OPzV 1500 is in accordance with the above standard. This means the internal resistance and the short circuit current can be calculated from the current-voltage relationship given by two points in a discharge curve. The first point is obtained after 20 sec of discharge at a current $I_{point\_1} = 4\ I_{C10}$ … $6\ I_{C10}$ (at this example the discharge current was 500 A), the voltage and the current shall be recorded. The discharge should be interrupted for 25 sec without recharge. After an open circuit stand of 2 min to 5 min, the second point can be determinated.

After 5 sec of discharge at the current of $I_{point\_2} = 20\ I_{C10}$ ... $40\ I_{C10}$ (at this example the discharge current was 3000 A), the voltage and the current shall be recorded.

The figures can be calculated from the equations [1] and [2] at page 5.

Results:

These are the results for the internal resistance [1] and short circuit current [2] for the positive tubular plate 125 Ah:

Internal resistance: $R_i = 2.88\ m\Omega$ per plate

Short circuit current: $I_{sc} = 715$ A per plate

Suitability for floating battery operation (cells)

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Suitability for floating battery operation (cells)**

Test, chapter: Suitability for floating battery operation
IEC 896 - 2 Chapter 5.2

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test was carried out on 6 units 6 OPzV 300. The cells were tested for their suitability for float charge operation. The cells of the battery were connected to a power supply with a voltage of 13.38 V (2.23 V per cell). The float charge voltage was examined over a test period of 3 and 6 months. A 10 hour discharge (test of the nominal capacity) was carried out as a capacity trial before and after the test.

Results:

The following results were found:

Reference temperature: 20 °C

Voltage per cell (V):

Cell	1	2	3	4	5	6	**Mean value**
Test start	2.231	2.233	2.234	2.234	2.232	2.233	2.231 ± 0.001
After 3 months	2.235	2.241	2.240	2.234	2.236	2.237	2.230 ± 0.002
After 6 months	2.231	2.231	2.226	2.235	2.228	2.233	2.235 ± 0.005

The maximum difference from mean value given by BAE is +0.2 / -0.01 V.
The measured values demonstrate that the float voltage was distinct less than the limiting values given by the manufacturer.

Capacity test:

Capacity before the examination starts: 377.5 Ah = 125.6% of the nominal capacity. Measured capacity after float charge over a period of 6 months: 389.5 Ah = 129.8% of the nominal capacity (see Figure 8).
The measured capacity C_{10} before and after float charge was in excess of the nominal capacity.

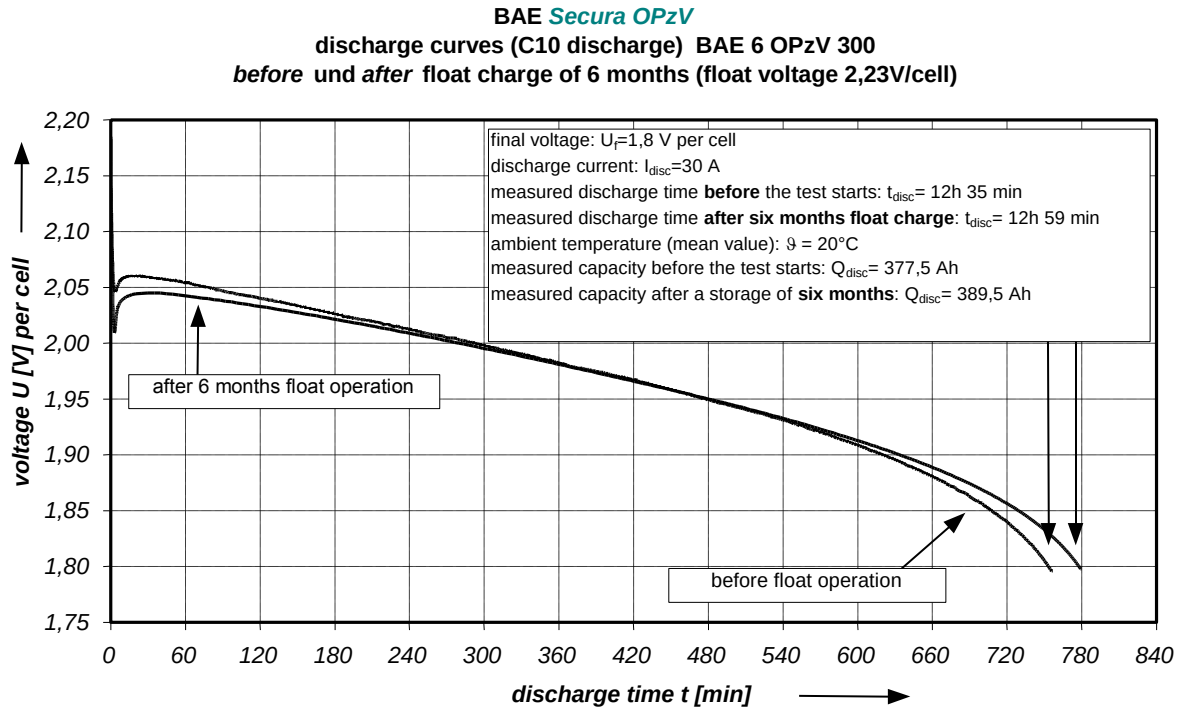

Figure 8 – *Capacity test before and after a float charge of 6 months.*

Endurance in cycles (cells)

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Endurance in cycles (cells)**

Test, chapter: Endurance in cycles, IEC 896 - 2 Chapter 5.3

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test was carried out on 6 units 6 OPzV 420 in accordance with the above standard, i.e. 1 cycle per day. Each cycle comprises a discharge for 3 h at a discharge current of $I = 2.0\ I_{C10}$ (84 A) and a charge for 21 h immediately following the discharge. The charge voltage should not extend 2.40 V per cell and the current at the beginning of the charge should be limited to $I_{max} = 2.0 \times I_{C10}$ (84 A). The cycles should be continued until $C_a = 0.8\ C_r$ (80 % of the nominal capacity).

Results:

After 1750 cycles and approx. 6 years under standard conditions (mean ambient temperature of the test field 20 °C) the C_{10}-capacity (measured nominal capacity) was in excess of 80% (80.8% C_{10}).

Capacity development and test measurements for this test are illustrated by Figure 9 (page 24).

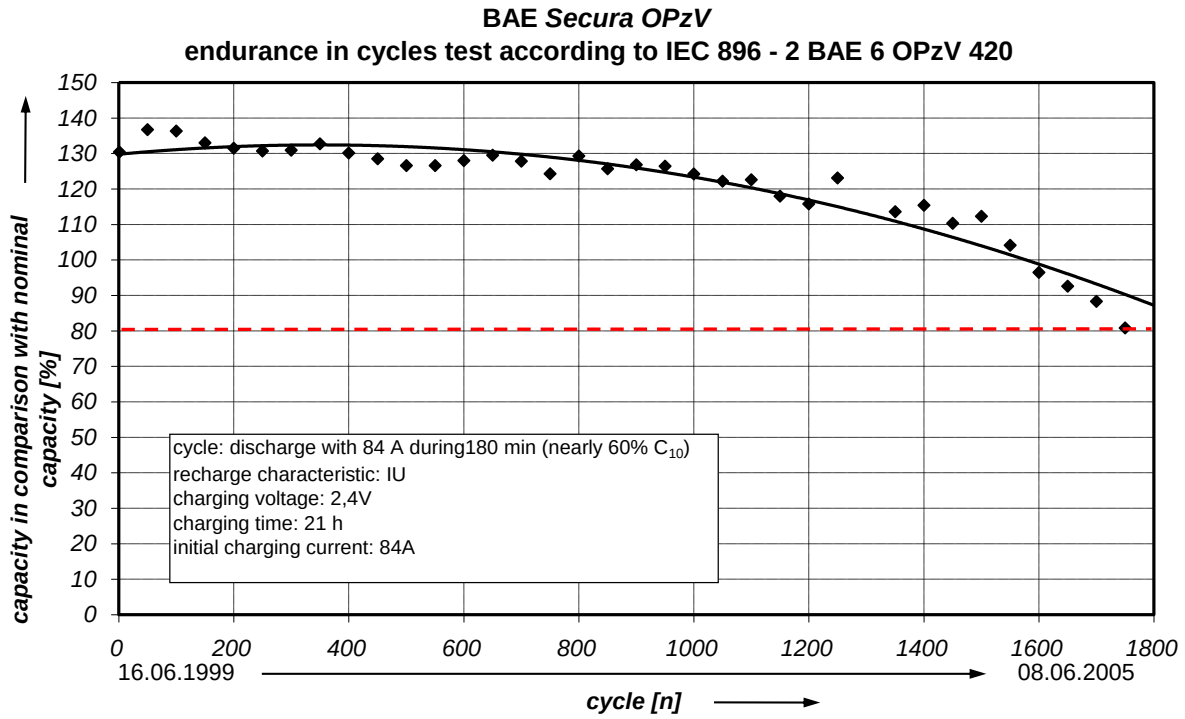

Figure 9 – *Endurance in cycles (6 OPzV 420 cells).*

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Endurance in cycles (cells / German Railways)**

Test, chapter: Endurance in cycles, demands given by German Railways

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test was carried out on 6 units 6 OPzV 600 in accordance with the demands given by German Railways, i.e. 1 cycle per day. Each cycle comprises a discharge for 144 min at a discharge current of I = 2.5 I_{C10} (150 A) and a charge for **15 h** immediately following the discharge. The charge voltage should not extend 2.40 V per cell and the current at the beginning of the charge should be limited to I_{max} = 2.0 × I_{C10} (120 A). The cycles should be continued until C_a = 0.8 C_r (80% of the nominal capacity).

Results:

After 2050 cycles and 5½ years under standard conditions (mean ambient temperature of the test field 20 °C) a C_{10}-capacity (measured nominal capacity) has reached the 80% value. This means the end of the test.

Capacity development and test measurements for this test are illustrated in Figure 10 (page 26).

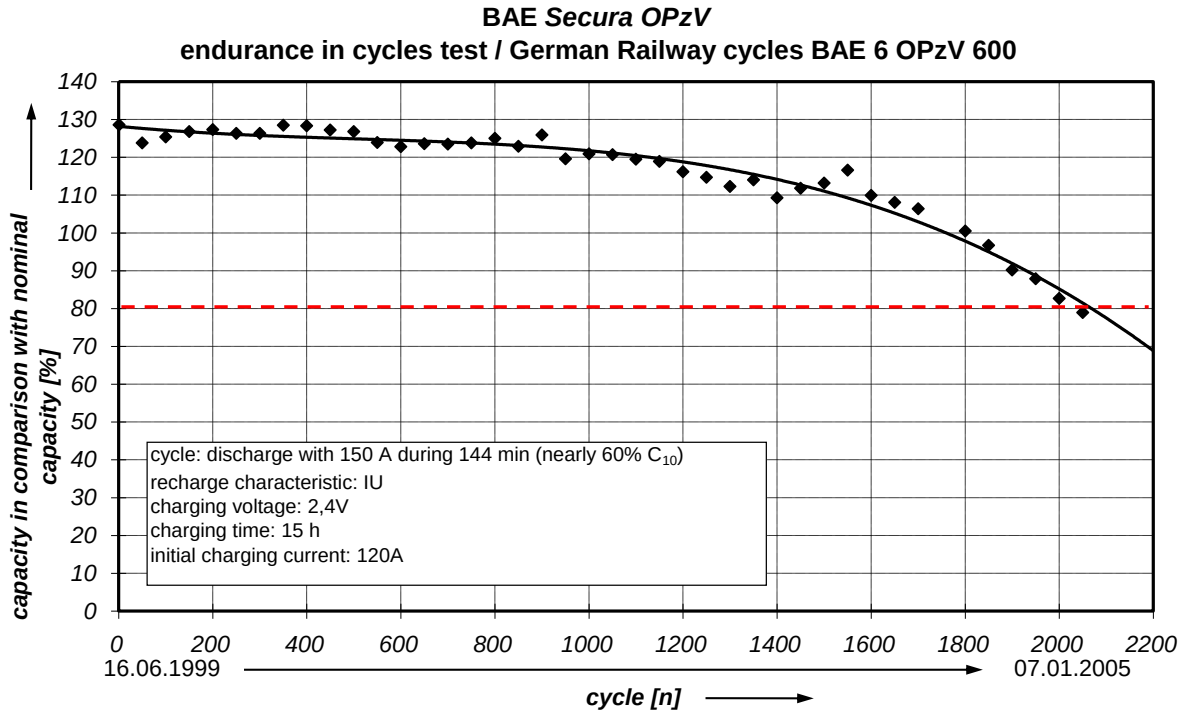

Figure 10 – *Endurance in cycles (6 OPzV 600 cells).*

Product range: Valve regulated lead acid batteries

Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Charge retention (cells)**

Test, chapter: Charge retention, IEC 896 - 2 Chapter 5.4
(Draft: November 1992)

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The test was carried out on 6 cells 12 OPzV 1500 in accordance with the above standard. The cells were stored with open circuit for a period of 3 months. Before and after the test the capacity was measured (C_{10} discharge). The mean test temperature was 20 °C.

Results:

The measured capacity after 3 months of storage was 96.98 % of the capacity at the beginning of the test. This corresponds to a self-discharge rate of 1.04 % per month. This is clearly well below the stated value of 2 % per month.
An exemplarily measurement is shown at page 28 (Figure 11).

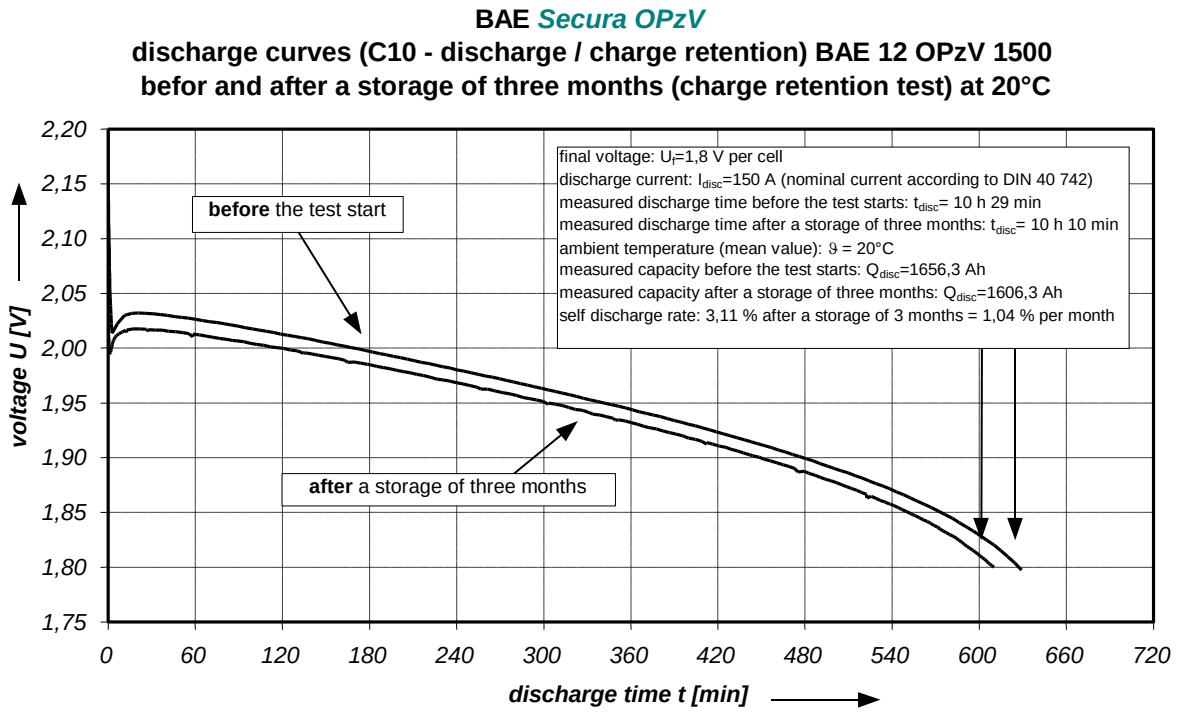

Figure 11 – *Test of charge retention (self-discharge) on BAE 12 OPzV 1500 cells.*

Product range: Valve regulated lead acid batteries

Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Vibration (sinusoidal), bump (endurance in impacts), cells**

Test, chapter: Vibration (sinusoidal),
IEC 60068-2-6 Chapter 5.3.1 and Annex C

Bump (endurance in impacts),
IEC 60068-2-29 Chapter 5.1, 5.2 and Annex A

Test laboratory: AUCOTEAM GmbH Berlin

Test temperature: 20 °C (mean value)

Test performance:

The vibration test was carried out on a 2V 6 OPzV 300 single cell. The test subject was exposed to sinusoidal vibrations:

Frequency	3 Hz - 5 Hz	5 - 300 Hz
Acceleration	10 m/s^2 (1 g)	20 m/s^2

Frequency sweeping: 1 octave/min

Number of axes: 3

Duration of the test: 90 min (30 min per axis)

The bump (endurance in impacts) test was carried out on a 2V OPzV 300 single cell. The test subject was exposed to impacts.

Impact form: half sinusoidal

Acceleration: 250 m/s^2

Impact duration: 6 ms

Number of axes: 3 (with two directions)

Number of impacts: 6000 (1000 per axis and direction)

Before and after the vibration and bump test the capacity (10 h-discharge) of the test subject should be measured. Before, during and after the vibrations and bump test the example should be examined for fissures, deformations and other mechanical damages.

Results:

After mechanical stress with impacts and vibration no mechanical defects or other changes were detected. The examination for mechanical stability found no reasons for complaints.

The measured capacity, before the vibration test are carried out, was 124.2 % (372.5 Ah compared with nominal capacity of 300 Ah at 10h-discharge). After the mechanical stress with sinusoidal vibrations the measured capacity was at 126.0 % (378.0 Ah).

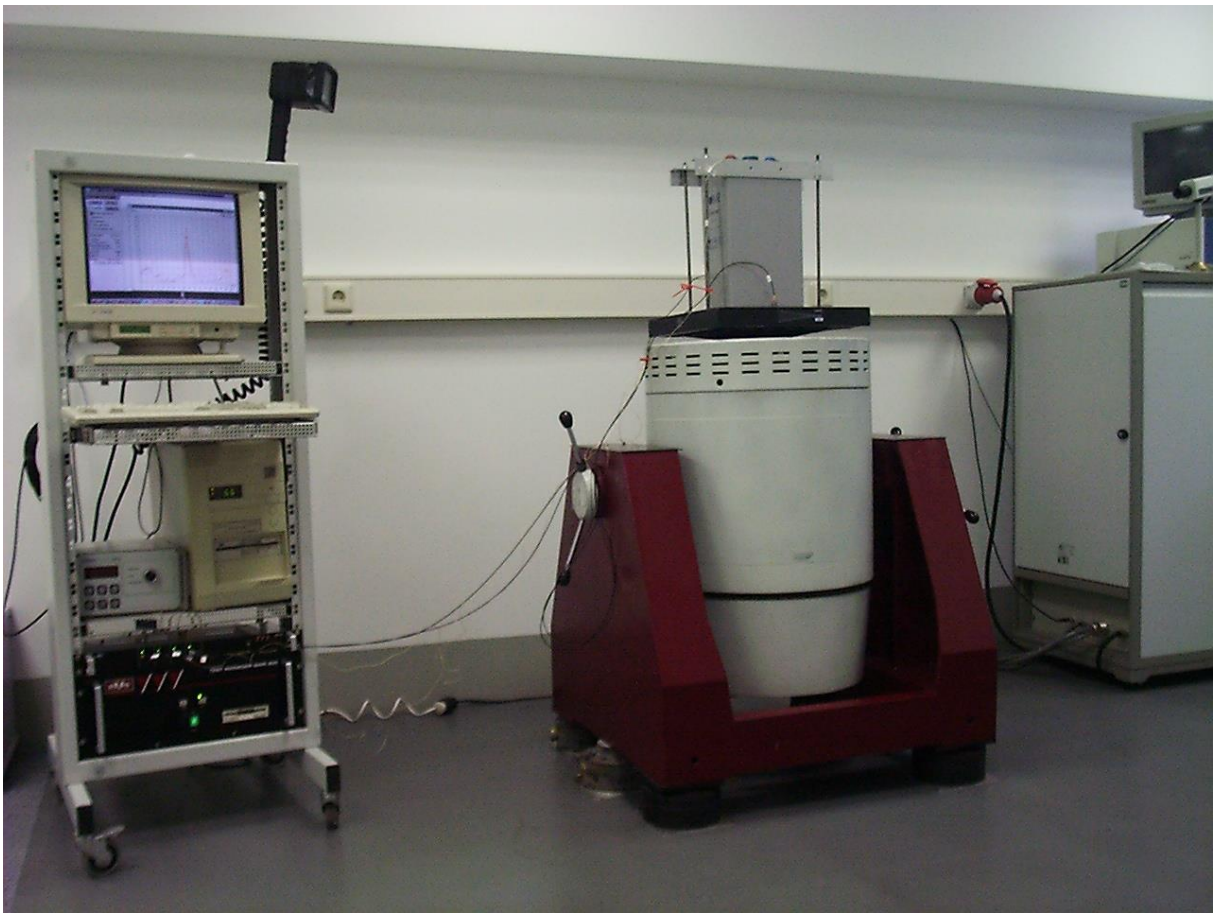

Figure 12 – *Test configuration of OPzV cell for mechanical stress.*

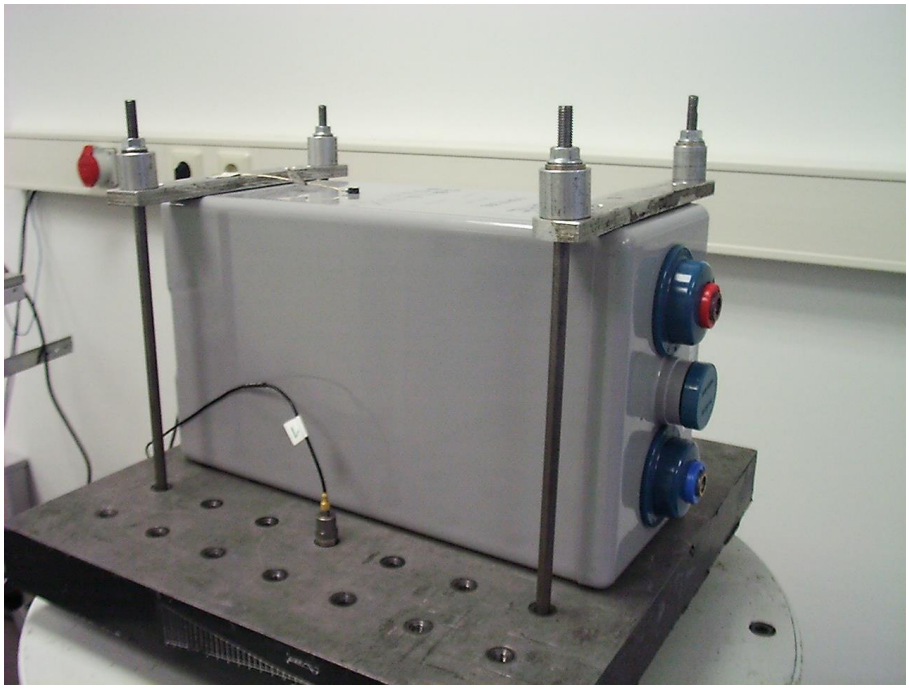

Figure 13 – *Mechanical test on 2 V 6 OPzV 300 – X axis.*

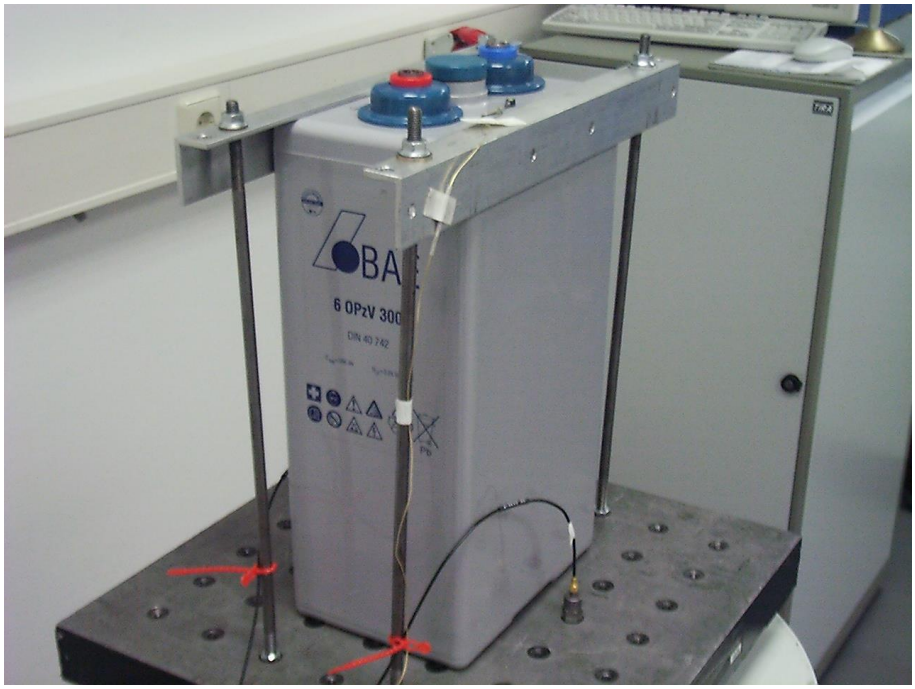

Figure 14 – *Mechanical test on 2 V 6 OPzV 300 – Z axis.*

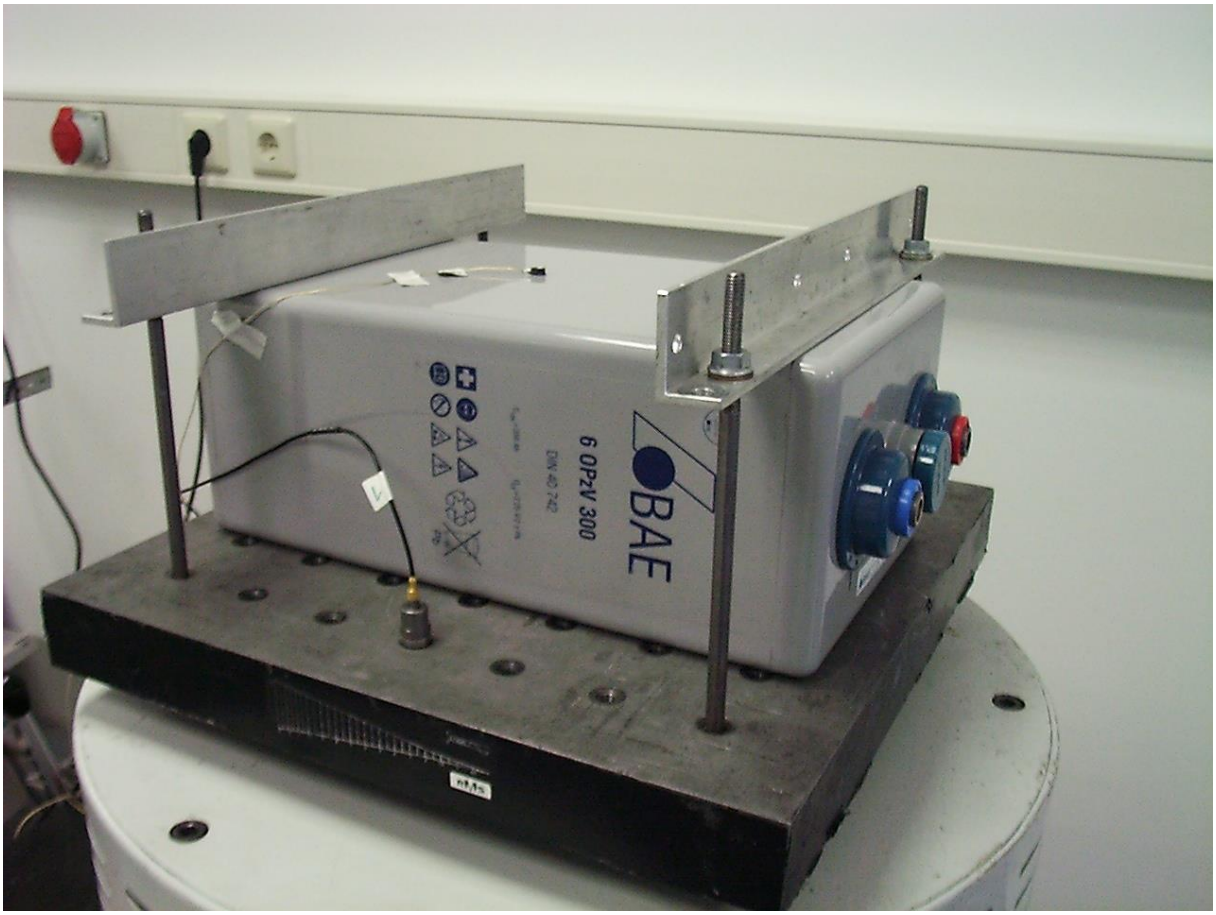

Figure 15 – *Mechanical test on 2 V 6 OPzV 300 – Y axis.*

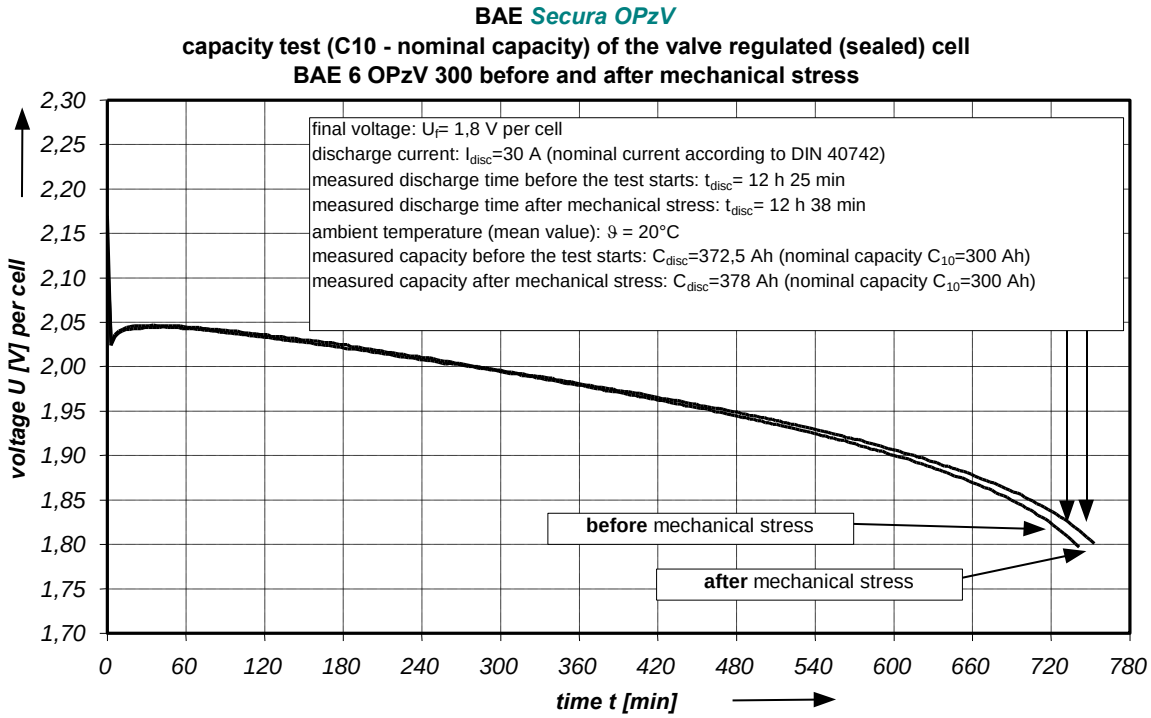

Figure 16 – *Capacity of cell before and after mechanical test.*

Product range: Valve regulated lead acid batteries
Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Vibration (sinusoidal), bump (endurance in impacts), block batteries**

Test, chapter: Vibration (sinusoidal),
IEC 60068-2-6 Chapter 5.3.1 and Annex C

Bump (endurance in impacts),
IEC 60068-2-29 Chapter 5.1, 5.2 and Annex A

Test laboratory: AUCOTEAM GmbH Berlin

Test temperature: 20 °C (mean value)

Test performance:

The vibration test was carried out on a 12V 2 OPzV 100 block battery. The test subject was exposed to sinusoidal vibrations:

Frequency	3 Hz - 5 Hz	5 - 300 Hz
Acceleration	10 m/s^2 (1 g)	20 m/s^2

Frequency sweeping: 1 octave/min

Number of axes: 1

Duration of the test: 30 min

The bump (endurance in impacts) test was carried out on a 12V 2 OPzV 100 block battery. The test subject was exposed to impacts.

Impact form: half sinusoidal

Acceleration: 250 m/s^2

Impact duration: 6 ms

Number of axes: 1 (with two directions)

Number of impacts: 2000 (1000 per axis and direction)

Before and after the vibration and bump test the capacity (10h-discharge) of the test subject should be measured. Before, during and after the vibrations and bump test the example should be examine for fissures, deformations and other mechanical damages.

Results:

After mechanical stress with impacts and vibration no mechanical defects or other changes were detected. The examination for mechanical stability found no reasons for complaints.

The measured capacity, before the vibration tests are carried out, was 100.2 % (105.0 Ah compared with nominal capacity of 100 Ah at 10 h-discharges). After the mechanical stress with sinusoidal vibrations the measured capacity was at 106.2 % (106.2 Ah).

Figure 17 – *Test configuration of OPzV block battery for mechanical stress.*

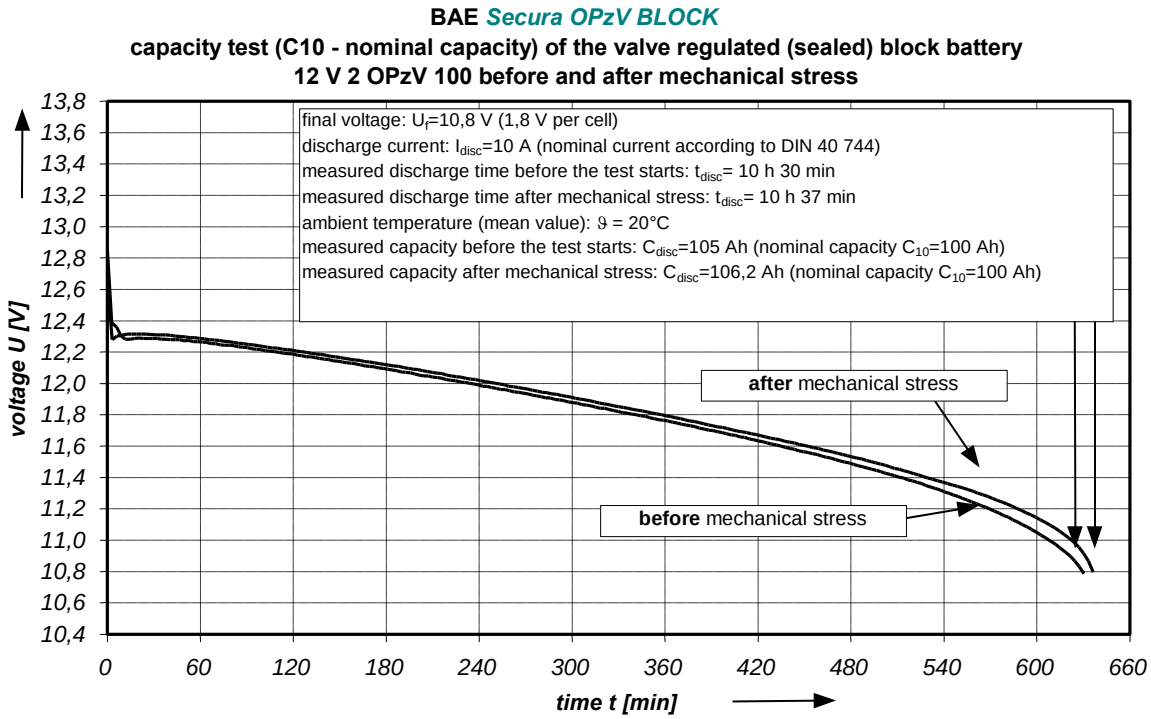

Figure 18 – *Capacity of block battery before and after mechanical test.*

Product range: Valve regulated lead acid batteries
Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Temperature dependency of the capacity (block batteries)**

Test laboratory: BAE Batterien GmbH

Test temperature: -40 °C, -18 °C, -5 °C and 20 °C

Test performance:

The test was carried out on two BAE block batteries 6V 4 OPzV 200. The test subjects were charged and put in a climatic chamber at the temperature of -40 °C, -18 °C, -5 °C and 20 °C during 24 h. After climatic stress the capacity was measured at the above mentioned temperatures.

Results:

After climatic stress no mechanical defects or other changes were detected. The measured C_{10} capacity at 20 °C (nominal temperature) was in excess of the nominal capacity. The capacity difference (at -40 °C, -18 °C and -5 °C) from the measured capacity at nominal temperature was in normal range.

0.315 × capacity (C_{10}, 20 °C) = capacity (C_{10}, -40 °C)

0.623 × capacity (C_{10}, 20 °C) = capacity (C_{10}, -18 °C)

0.824 × capacity (C_{10}, 20 °C) = capacity (C_{10}, -5 °C)

Capacity behaviour depends on the temperature variation (see at page 39, Figure 22).

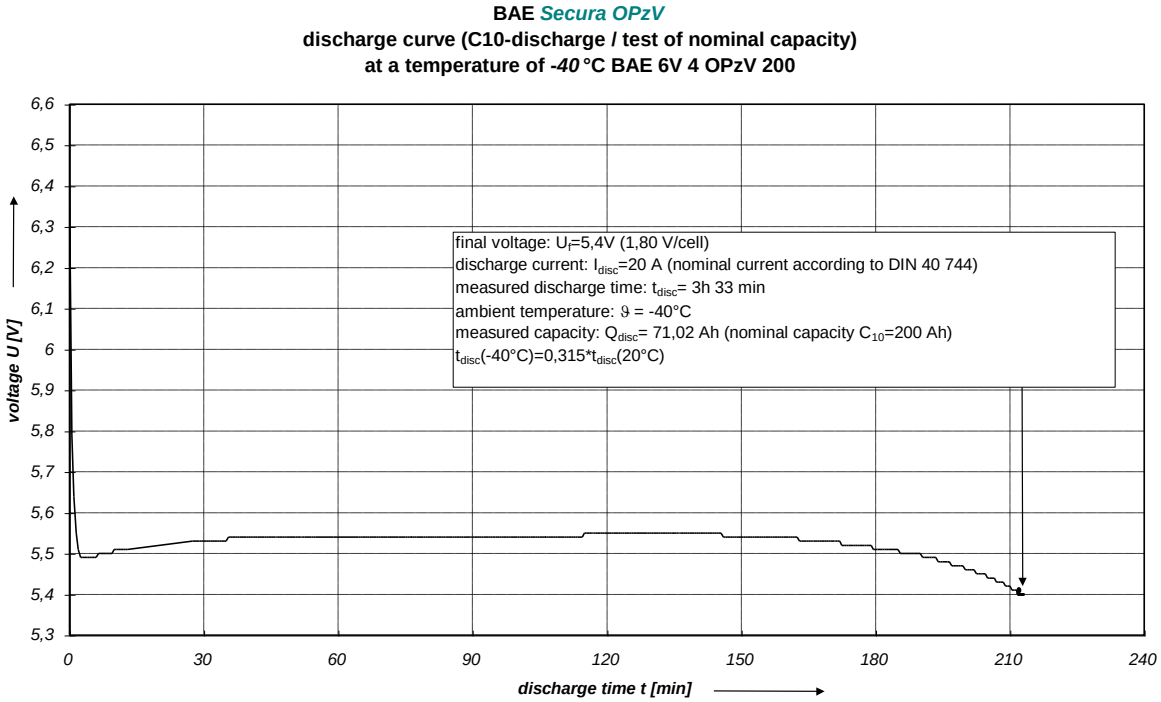

Figure 19 – *Capacity behaviour (C_{10}) at -40 °C of BAE 6V 4 OPzV 200 block batteries.*

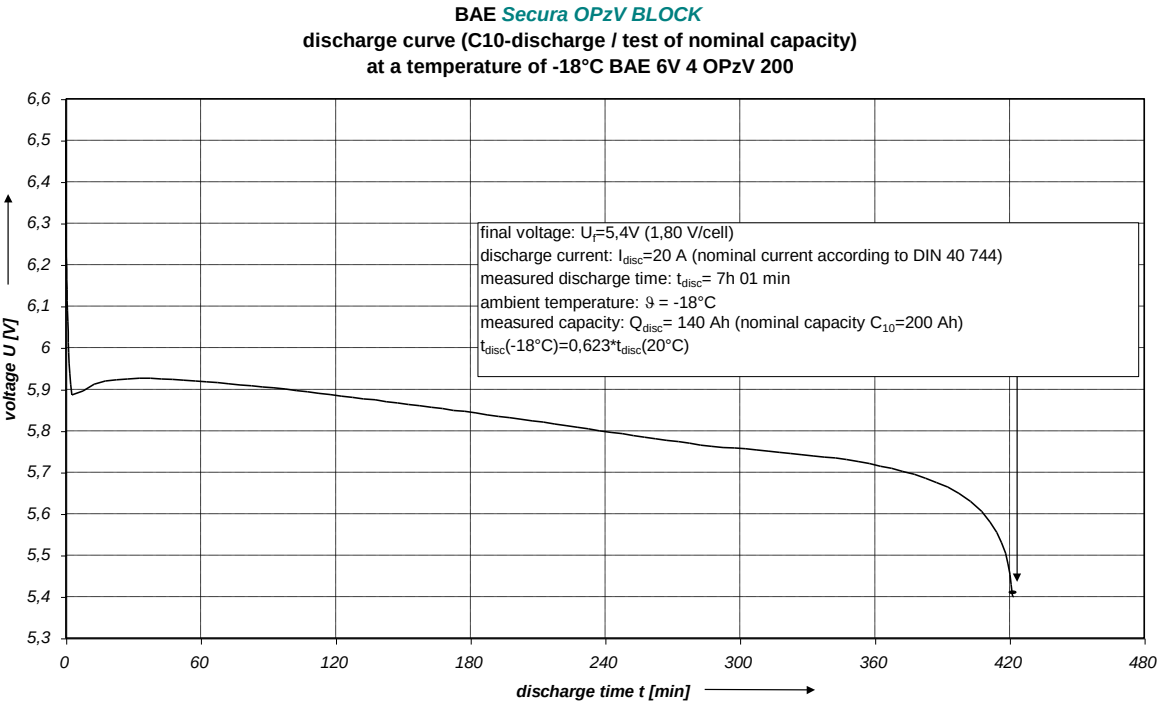

Figure 20 – *Capacity behaviour (C_{10}) at -18 °C of BAE 6V 4 OPzV 200 block batteries.*

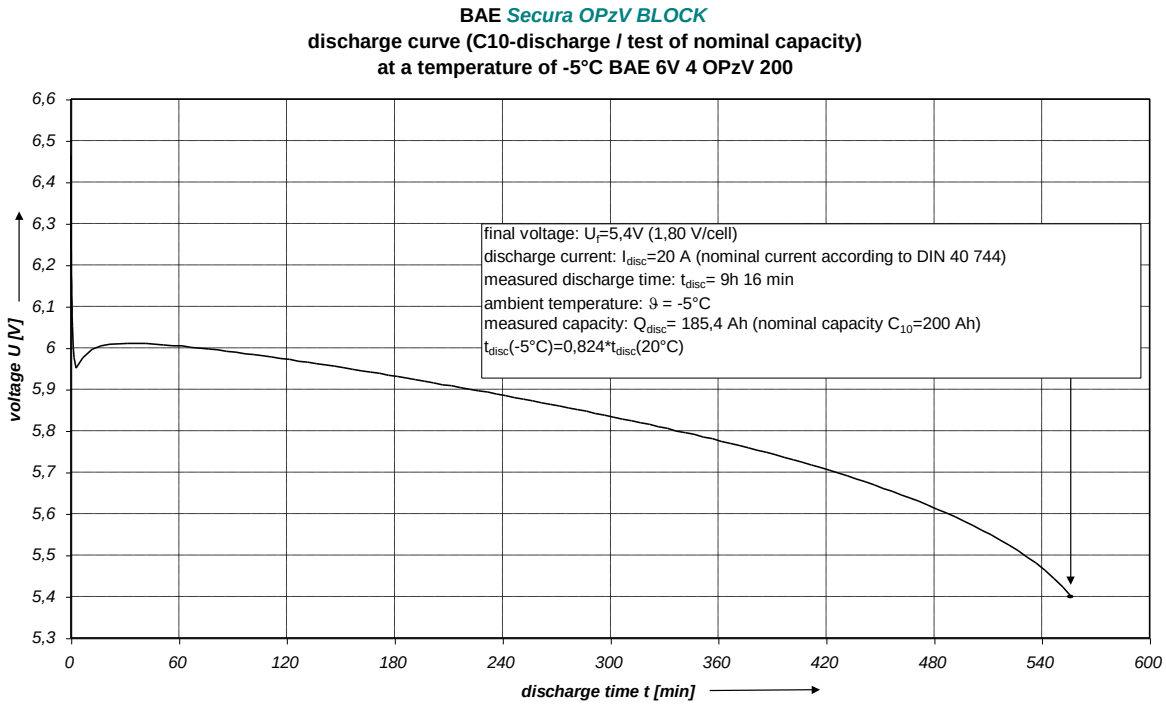

Figure 21 – *Capacity behaviour (C_{10}) at -5 °C of BAE 6V 4 OPzV 200 block batteries.*

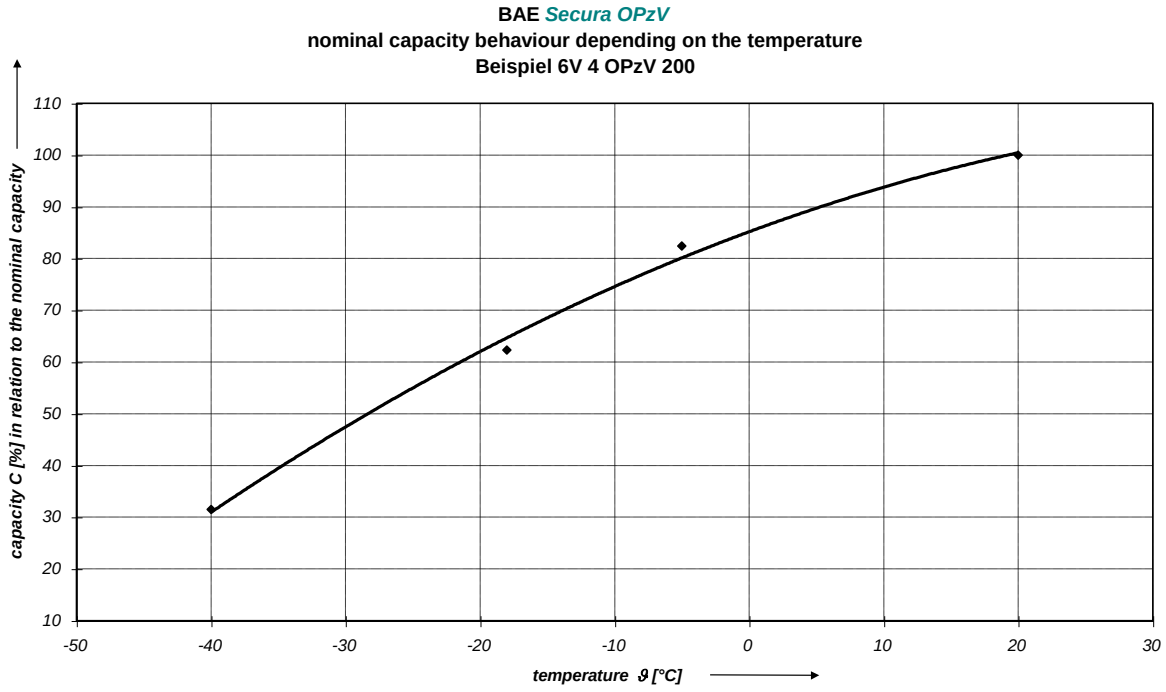

Figure 22 – *Capacity behaviour depending on the temperature.*

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Stability against cyclic over-discharge**

Test, chapter: High current safety tests,
IEC 896-2 Annex A / BS 6290

Test laboratory: BAE Batterien GmbH

Test temperature: 20 °C (mean value)

Test performance:

The 6 test cells of 2 OPzV 100 were tested at the 3 h-rate. Then, a deep discharge with the 10 h current down to an average of 1.25 V was performed for 5 times with a recharge at float over 168 h. In addition, the 3 h test was repeated.

	C_3 / Ah	C_3 / %	Standard deviation
Before the test	95.9	108.7	+/- 1.16 %
After 5 deep discharge cycles	98.7	111.9	+/- 0.92 %

The excellent results demonstrate the stability of the OPzV battery against deep discharges.

Discharge behaviour

Product range:	Valve regulated lead acid batteries Stationary block batteries and cells with positive tubular plates BAE ***SECURA OPzV***
Type designation:	12V 1 OPzV 50 - 12V 3 OPzV 150 6V 4 OPzV 200 - 6V 6 OPzV 300 2V 4 OPzV 600 - 2V 6 OPzV 900
Type designation:	2 OPzV 100 - 6 OPzV 300 5 OPzV 350 - 7 OPzV 490 6 OPzV 600 - 12 OPzV 1200 12 OPzV 1500 - 26 OPzV 3250
Test:	**Stability of OPzV batteries against deep discharges**
Test, chapter:	High current safety tests, IEC 896-2 Annex A/BS 6290 part 4/DIN 43539 Teil 5
Test laboratory:	BAE Batterien GmbH
Test temperature:	20 °C (mean value)

Test performance:

A 6 OPzV 300 cell was discharged and bridged with a cable with a resistance of 1.8 mOhm, to simulate the case of a breakdown for many hours or even days, where the battery is not disconnected. The battery was deeply discharged. In this way the battery voltage was kept at 0 Volt over 30 days (see Figure 23).

Figure 23 – B*ridged 2V 6 OPzV 300 single cell*

Before and after deep discharge the 10 h-capacity was tested and recorded.

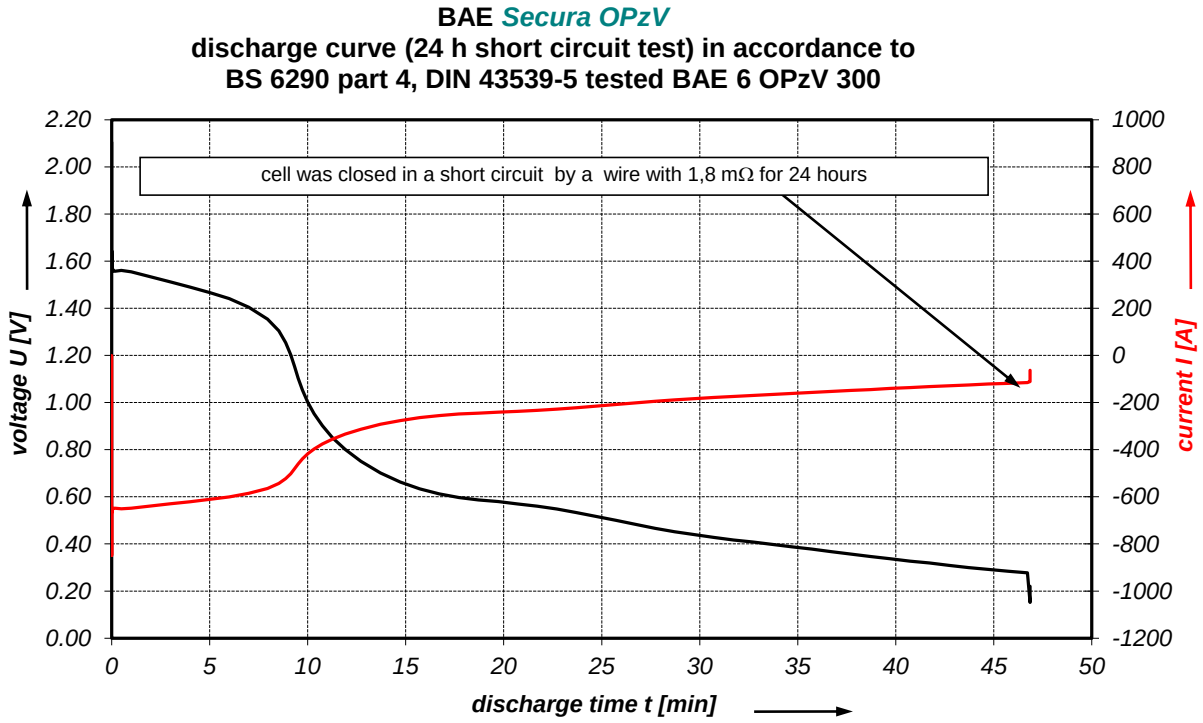

Figure 24 – *Voltage and current discharge curve during 24 h short circuit test*

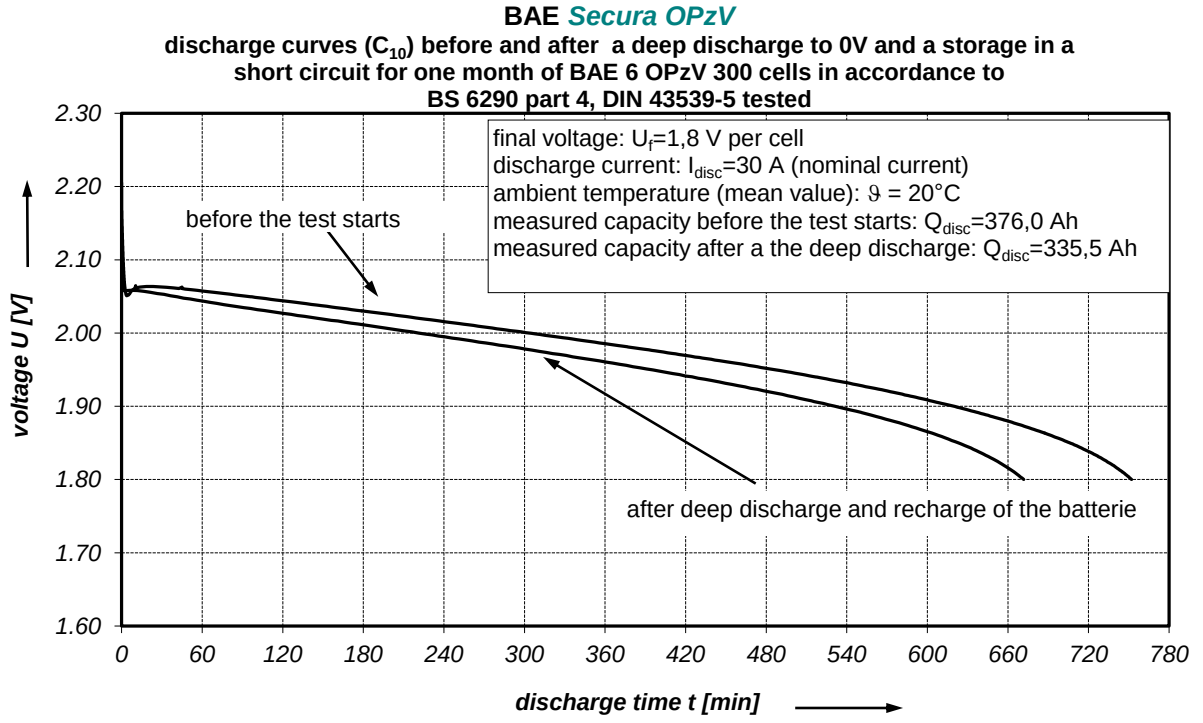

Figure 25 – *Capacity comparison before and after deep discharge.*

The recovery charge were performed after the deep discharge at 2.40 V over 24 h. The comparison of the capacity before and after the test is explored at Figure 25 page 42.

Result:
The cells have shown outstanding results regarding the current carry capability and deep discharge recovery. In relationship to the initial capacity after the short circuit the cell capacity was recovered to 89.1 %. After the deep discharge the battery capacity was still higher than the nominal capacity (see Figure 25 page 42). During the discharge by short circuit no burns or any mechanical damages were detected. The experiment proofs the very good stability against occasional deep discharges of the BAE – GEL batteries.

Mechanical abuse

Product group: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation:
4 OPzV 200 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 24 OPzV 3000

Test: **Mechanical abuse test**

Test, chapter: Stability against mechanical abuse of units during installation, IEC 60896-21, chapter 6.21

Test laboratory: BAE Batterien GmbH

Test measurements:
1. Two consecutive drops on the shortest edge with a torque-free release system over a triangular support profile according to IEC 60896-21, chapter 6.21 (Figure 26a).
2. Two consecutive drops on the same corner with a torque-free release system over a triangular support profile according to IEC 60896-21, chapter 6.21 (Figure 26b).
3. Inspection of the units for gas and liquid leaks.

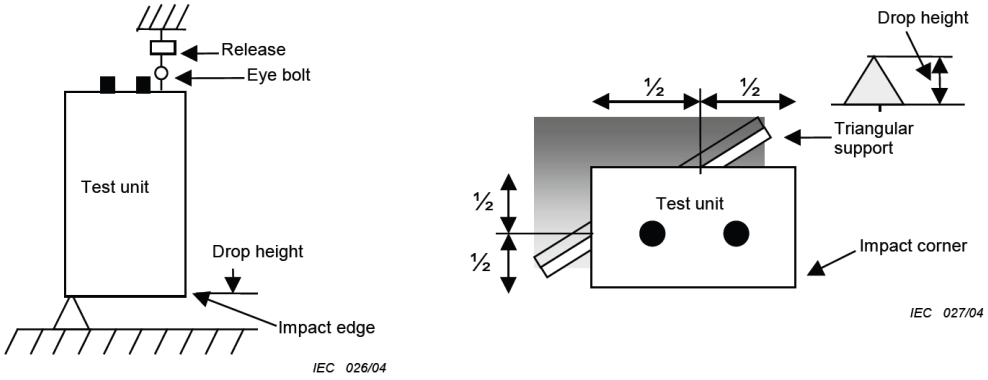

Figure 26 - Test setup for drop test on a) shortest edge and b) corner [IEC60896-21:2004]

Test subject:

BAE ***SECURA OPzV*** 2 cells	8 OPzV 800
Serial numbers:	10317292/1; 10317292/2
Container material:	ABS
Weight per cell:	68.8 kg
Drop height:	50 mm

The cells were connected with a crane by a torque free release system and lifted to the required drop height. The drop was then triggered with the release system. All drops were performed on the positive terminal side of the cells.

BAE *SECURA OPzV* Cells 8 OPzV 800 - Drop on Corner

Experimental Set-Up:
Two consecutive drops on the same corner of cell 10317295 / 01.
Set-up according to IEC 60896-21, Chapter 6.21.4, Drawing 11.

Figure 27 – *Test set-up for the drop on one corner.*

Results:
No movement of the terminals could be observed. The open-circuit voltage of the cell after the test was U_{OCV} = 2.111 V.

The surface of the corner was slightly dented in the area of the lower radius. Also, the base-profile of the container was slightly deformed, fitting the impact angle. No leakage or cracks could be observed. The deformations were only found by focused search and were better to be found tactile than visible. In order to detect leaking acid the cells were kept on an indicator mat for 48 hours after the test. After a discharge/recharge cycle (build-up of pressure) the cells were re-examined for leakage. Again, no leakage or cracks could be observed and no acid could be found leaking during test period of 48 hours.

Conclusion:
The electric function of the cells was not impaired by the tests. No leakages or cracks could be observed on the containers. Small dents and deformations were found but proved irrelevant for the mechanical integrity of the containers.

BAE *SECURA OPzV* Cells 8 OPzV 800 - Drop on Shortest Edge

Experimental Set-Up:
Two consecutive drops on the same short edge of cell 10317295 / 02.
Set-up according to IEC 60896-21, Chapter 6.21.4, Drawing 11.

Figure 28 – *Test set-up for the drop on the shortest edge.*

Results:
No movement of the terminals could be observed. The open-circuit voltage of the cell after the test was U_{OCV} = 2.110 V.

Both corners of the impact edge wore slight scratches on the surface. The base-profile of the container was minimally deformed on the corners. No leakage or cracks could be observed. The deformations were only found by focused search and were better to be found tactile than visible. In order to detect leaking acid the cells were kept on an indicator mat for 48 hours after the test. After a discharge/recharge cycle (build-up of pressure) the cells were re-examined for leakage. Again, no leakage or cracks could be observed and no acid could be found leaking in 48 hours.

Conclusion:
The electric function of the cells was not impaired by the tests. No leakages or cracks could be observed on the containers. Small scratches and deformations were found but proved irrelevant for the mechanical integrity of the containers.

Low temperature service

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Low temperature service**

Test, chapter: Low temperature service,
IEC 896-2, 11/2000 draft

Test laboratory: BAE Batterien GmbH

Test temperature: -18 °C (mean value)

Test performance:

A telecom battery in a very cold environment is in an air-conditioned room of 20 °C. Power supply fails, the battery is discharged to 1.80 V with the 10 h rate, the temperature falls down to -18 °C. The question is, if the battery can be recharged and brought to normal function after the power supply recovery? For this situation the 11/2000-draft of the IEC 896-2 defines a low temperature service test.

Figure 29 – *Picture of test sample during low temperature discharge test: The side walls bulge by about 4 mm.*

After 72 h at -18 °C the cells are charged at room temperature for 168 h at 2.25 V/cell.

	C_{10} / Ah	C_{10} / %	Standard deviation
Before test	115	115	+/-0.84 %
After first test	121	121	+/-1.28 %
After second test	115	115	+/-1.38 %
After third test	112	112	+/-1.43 %

OPzV-batteries can withstand those frosty temperatures in the discharged state. The side walls bulge during the low temperature discharge by about 4 mm according to Figure 29, but the bulging is reversible and no damages occur.

Product range: Valve regulated lead acid batteries
Stationary block batteries with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Test: **Test for gas emissions (block batteries)**

Test, chapter: Test for gas emissions IEC 896-2, Annex D page 45 to 51

Test laboratory: BAE Batterien GmbH

Test performance:
1. Float for 30 days at 2.23 V per cell.
2. Measure current, temperature and gas volume over a period of further 14 days.
3. Discharge at 57.6 A (C_3-current) to 1.6 V per cell, measure gas volume and temperature.
4. Recharge at 2.23 V per cell/57.6 A, measure gas volume, current and temperature over a time period of 2 days.
5. Continue charge for 14 days at 2.23 V per cell, measure gas volume, current and temperature.

Test subject: BAE ***SECURA OPzV*** 4 × 6V 4 OPzV 200

Initial weights:

Block number	**1**	**2**	**3**	**4**
Weight in kg	48.139	47.983	48.021	48.161

Measured current, temperature and gas volume over a period of further 14 days at float charge:

Block number	**Gas volume [ml] per block**	**Mean value of float charge current [mA]**
1	1932	13.8
2	1703	12.2
3	1788	12.5
4	1954	13.9

Mean gas value per block (V_{gas1}): 1845 ml
Mean temperature: 21.1 °C

Measured gas volume and temperature at a discharge with 57.6 A to 1.6 V per cell over 3 hours.

Block number	Gas volume [ml] per block
1	326
2	310
3	315
4	335

Mean gas value per block (V_{gas2*}): 322 ml
Mean temperature: 23.8 °C

Measured gas volume, current and temperature over 2 days.

Block number	Gas volume [ml] per block	Mean value of float charge current [mA]
1	138	55.9
2	131	53.2
3	134	54.1
4	145	58.7

Mean gas value per block (V_{gas2**}): 548 ml
Mean temperature: 20.8 °C

Measured gas volume, current and temperature at a charge with 2.23 V per cell over 14 days.

Block number	Gas volume [ml] per block	Mean value of float charge current [mA]
1	1433	18.0
2	1350	17.3
3	1270	16.0
4	1501	18.5

Mean gas value per block (V_{gas3}): 1389 ml
Mean temperature: 20 °C

Normalized gas volumes by the equation:

$$V_{gas} = \frac{P \times 293 \times gas}{P_0\,(T + 273)}$$

V_{gas} is the normalized volume in cubic centimeters / ml

gas is the recorded gas volume in cubic centimeters / ml

P is the ambient atmospheric pressure at the time of measurement in kilo pascal

P_0 = 101.3 kPa

T is the ambient temperature of the measuring cylinder in degrees Celsius

$$V_{gas} = \frac{P \times 293 \times V_{gas,1}}{P_0\,(T_1 + 273)} + \frac{P \times 293 \times V_{gas,2^*}}{P_0\,(T_{2^*} + 273)} + \frac{P \times 293 \times V_{gas,2^{**}}}{P_0\,(T_{2^{**}} + 273)} + \frac{P \times 293 \times V_{gas,3}}{P_0\,(T_3 + 273)}$$

$$V_{gas} = \frac{101.5\,kPa \times 293 \times 1845 ml}{101.3\,kPa\,(21.1\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 322\,ml}{101.3\,kPa\,(23.8\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 137\,ml}{101.3\,kPa\,(20.8\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 1389 ml}{101.3\,kPa\,(20\,°C + 273)}$$

$$V_{gas} = 1846\,ml + 319.1\,ml + 137.2\,ml + 1394\,ml$$

$$= \frac{3696.3\,ml}{200\,Ah} = 18.5\frac{ml}{Ah}$$

V_{gas} = 18.5 ml / Ah per block = <u>6.16 cm³ / Ah per cell</u>

Limit value given by IEC 896-2, Annex D:
Gas evolution during 30 days (see page 2) 30 cm³ / Ah per cell.

Result:

BAE OPzV cells passed the test with a safety factor of **4.9**.

Gas development test for OPzV cells

Product range: Valve regulated lead acid batteries
Stationary cells with positive tubular plates
BAE SECURA OPzV

Type designation:
4 OPzV 200 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 24 OPzV 3000

Test: **Test for gas emissions (cells)**

Test, chapter: Test for gas emissions, DIN EN 60896 - 2 (IEC 896 - 2)
Annex D page 45 to 51

Test laboratory: BAE Batterien GmbH

Test performance: The test carried out on 6 units 5 OPzV 350 (50 Ah plate).

1. Float for 30 days at 2.25 V per cell.
2. Measure current, temperature and gas volume over a period of further 14 days.
3. Discharge at 107 A (C_3-current) to 1.75 V per cell, measure gas volume and temperature.
4. Recharge at 2.25 V per cell / 107 A, measure gas volume, current and temperature over a time period of 2 days.
5. Continue charge for 14 days at 2.23 V per cell, measure gas volume, current and temperature.

Test subject: BAE ***SECURA OPzV*** 6 cells × 5 OPzV 350

Initial weights:

Cell number	**1**	**2**	**3**	**4**	**5**	**6**
Weight in kg	31.059	31.295	31.249	31.401	31.143	31.389

Measured current, temperature and gas volume over a period of further 14 days at float charge:

Cell number	**Gas volume [ml] per cell**	**Mean value of float charge current [mA]**
1	1324	24.8
2	1420	26.7
3	1060	27.8
4	1325	32.0
5	1134	26.9
6	1258	23.0
Average	1253.5	27.0

Mean gas value per block (V_{gas1}): 1253 ml
Mean temperature: 22.7 °C

Measured gas volume and temperature at a discharge with 107 A to 1.6 V per cell over 3 hours.

Cell number	Gas volume [ml] per cell
1	270
2	288
3	230
4	219
5	234
6	256
Average	249.5

(Temperature was measured at positive cell pole during the discharge.)

Mean gas value per cell (V_{gas2*}): 249.5 ml
Mean temperature: 24.3 °C

Measured gas volume, current and temperature over 2 days with charging voltage of 2.25 V after the recharge of the battery with C_3 current as initial charging current and 2.25 V float voltage.

Cell number	Gas volume [ml] per cell	Mean value of float charge current [mA]
1	176	90
2	189	115
3	178	113
4	200	125
5	176	105
6	165	93
Average	180.7	106.8

Mean gas value per cell (V_{gas2**}): 180.7 ml
Mean temperature: 20.8 °C

Measured gas volume, current and temperature at a charge with 2.25 V per cell over 14 days.

Cell number	Gas volume [ml] per cell	Mean value of float charge current [mA]
1	5089	33.2
2	4378	28.9
3	4780	34.5
4	3489	33.0
5	4560	24.6
6	3837	27.9
Average	4355.5	30.35

Mean gas value per cell (V_{gas3}): 4355 ml
Mean temperature: 20.2 °C

Normalized gas volumes by the equation:

$$V_{gas} = \frac{P \times 293 \times gas}{P_0\ (T + 273)}$$

V_{gas} is the normalized volume in cubic centimeters / ml

gas is the recorded gas volume in cubic centimeters / ml

P is the ambient atmospheric pressure at the time of measurement in kilo pascal

P_0 = 101.3 kPa

T is the ambient temperature of the measuring cylinder in degrees Celsius

$$V_{gas} = \frac{P \times 293 \times V_{gas,1}}{P_0\ (T_1 + 273)} + \frac{P \times 293 \times V_{gas,2^*}}{P_0\ (T_{2^*} + 273)} + \frac{P \times 293 \times V_{gas,2^{**}}}{P_0\ (T_{2^{**}} + 273)} + \frac{P \times 293 \times V_{gas,3}}{P_0\ (T_3 + 273)}$$

$$V_{gas} = \frac{101.5\,kPa \times 293 \times 1253.5\,ml}{101.3\,kPa\ (22.7\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 249.5\,ml}{101.3\,kPa\ (24.3\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 180.7\,ml}{101.3\,kPa\ (20.8\,°C + 273)} + \frac{101.5\,kPa \times 293 \times 4355\,ml}{101.3\,kPa\ (20.2\,°C + 273)}$$

$$V_{gas} = 1242\,ml + 246.4\,ml + 180.7\,ml + 4352\,ml$$

$$= \frac{6021.1\,ml}{350\,Ah} = 17.2\,\frac{ml}{Ah}$$

V_{gas} = 17.2 ml / Ah per cell

Limit value given by IEC 896-2, Annex D:
Gas evolution during 30 days (see page 2) 30 cm^3 / Ah per cell.

Result:

BAE OPzV cells passed the test with a safety factor of **2**.

Tightness test

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Tightness test**

Test, chapter: Tightness test for valve regulated batteries

Test laboratory: BAE Batterien GmbH

Test performance:

Every produced cell or block battery is tested before delivery for the tightness of the pole bushing and carrier with a pressure of 200 mbar during 60 seconds. After the equalization of the pressure, the pressure lost should be not higher than 0.1 mbar (measurement uncertainty) during 5 sec.

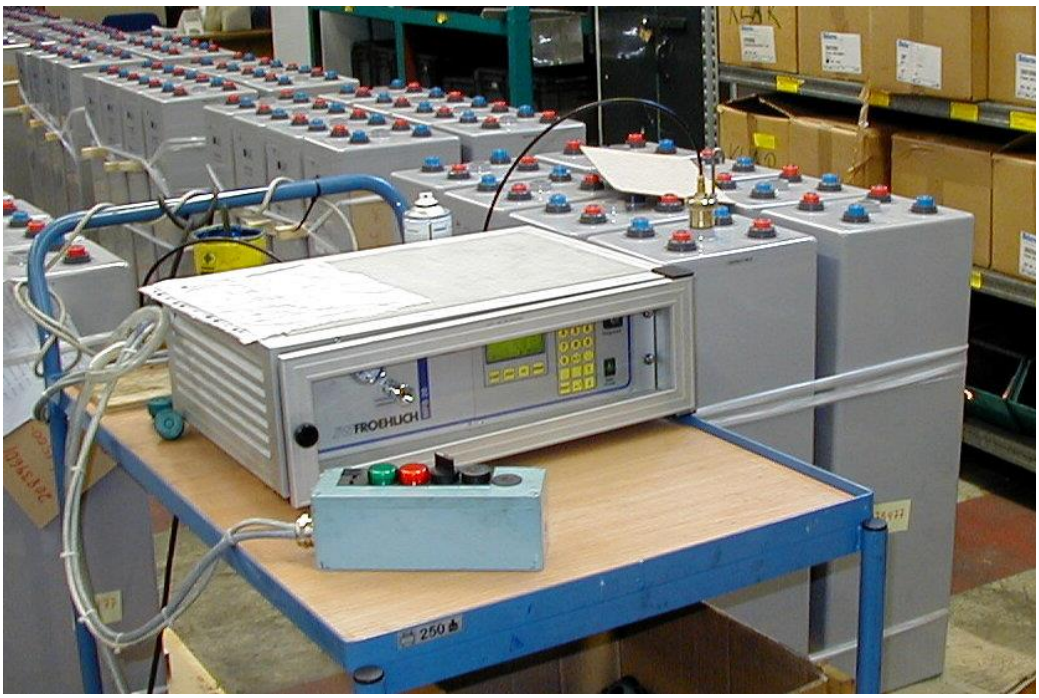

Figure 30 – *Tightness test of 12 OPzV 1500 single cells.*

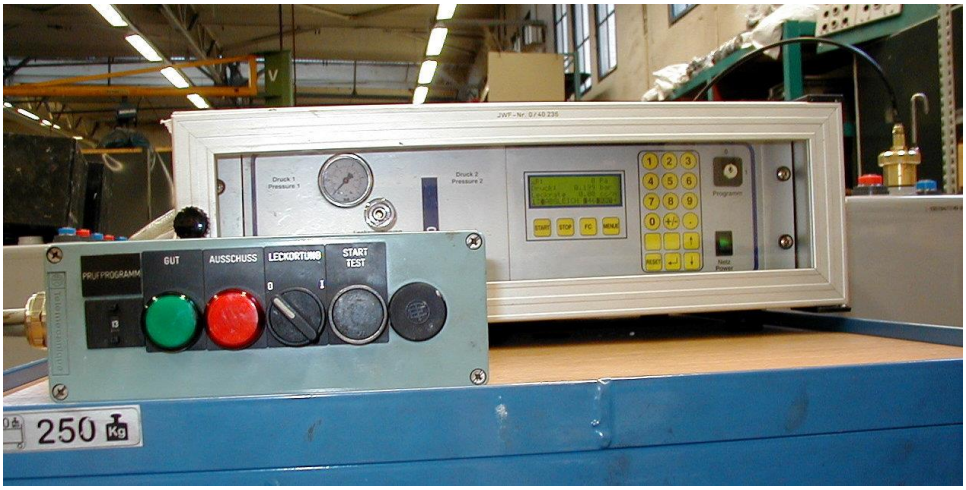

Figure 31 – *Test equipment.*

Figure 32 – *Measurement of tightness with over pressure.*

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Opening and closing pressure of the valve**

Test laboratory: BAE Batterien GmbH

Test performance:

BAE VRLA batteries are equipped with a valve enabling the escape of gas at certain internal pressures. The battery (6 OPzV 300 cell) was overcharged with 1.33 C_{10} current. The pressure on the valve was measured with a pressure sensor during the overcharge and after the overcharge. For the OPzV and OGiV block batteries opening pressures of 100 mbar ± 20 mbar and closing pressures of 50 mbar ± 10 mbar are normal.

Test of the valves for the opening and closing pressure (example):

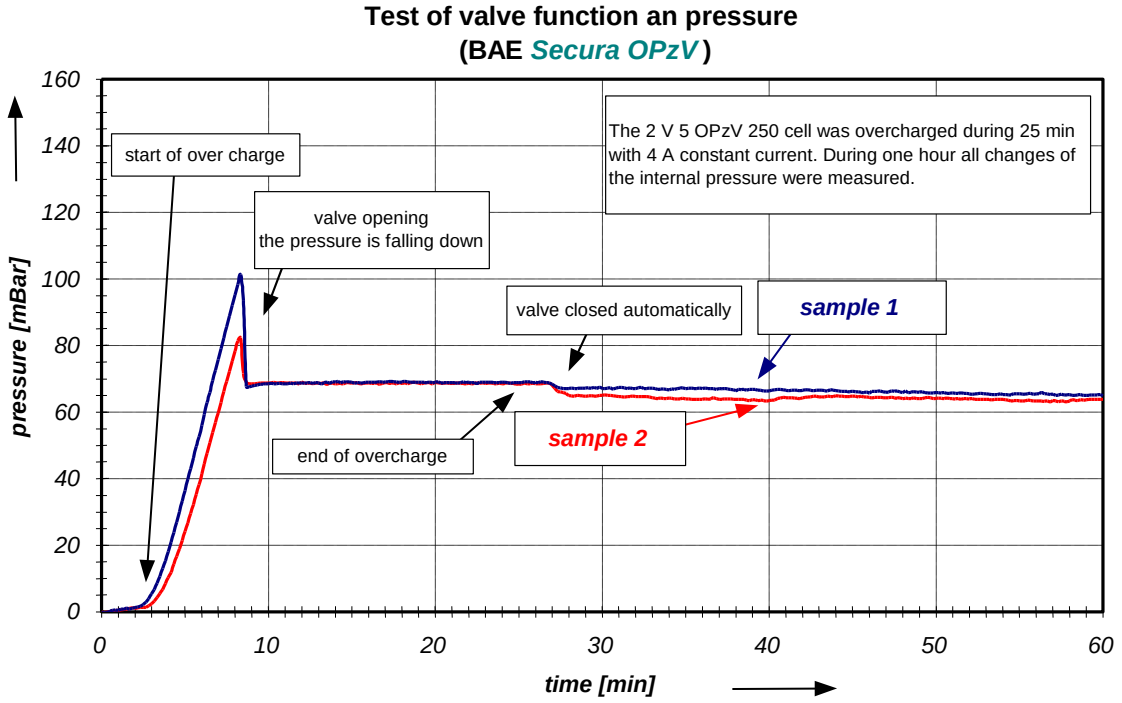

Figure 33 – *Measurement of opening and closing pressure.*

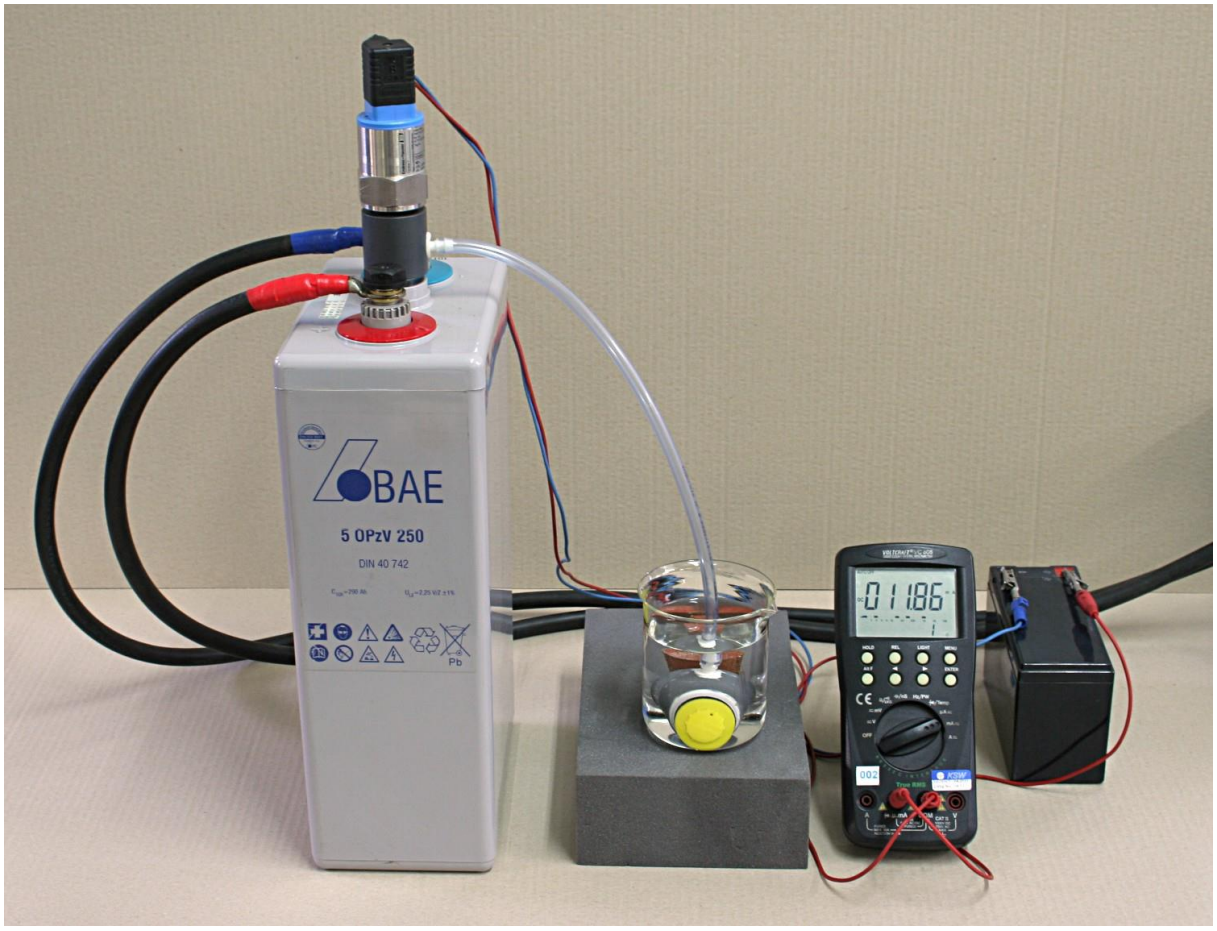

Figure 34 – *Test configuration for pressure measurement.*

Material test for acid resistance

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Material tests**

Test, chapter: Valve regulated batteries

Test laboratory: BAE Batterien GmbH

Test performance:
In accordance with the BAE specification every material and part of the battery (separators, containers, valves plugs and so on) has to be tested to gain approval for use in the production. The tests are performed at the chemical laboratory. The material hast to pass the contact to sulphuric acid (acid density of 1.28 kg/l) during 336 h (14 days) at a temperature of 80 °C. After the test the mass loss should be lower than 0.5 % of the whole mass of the test subject.

Ventilation test for valves

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Ventilation test**

Test, chapter: NEMA Norm IB 7-1.02 A / valve regulated batteries

Test laboratory: BAE Batterien GmbH

Test performance:

Both tests were carried out in accordance with the requirements of the NEMA Norm IB 7-1.02 A (1980). Both tests were passed at the BAE electrical test field.

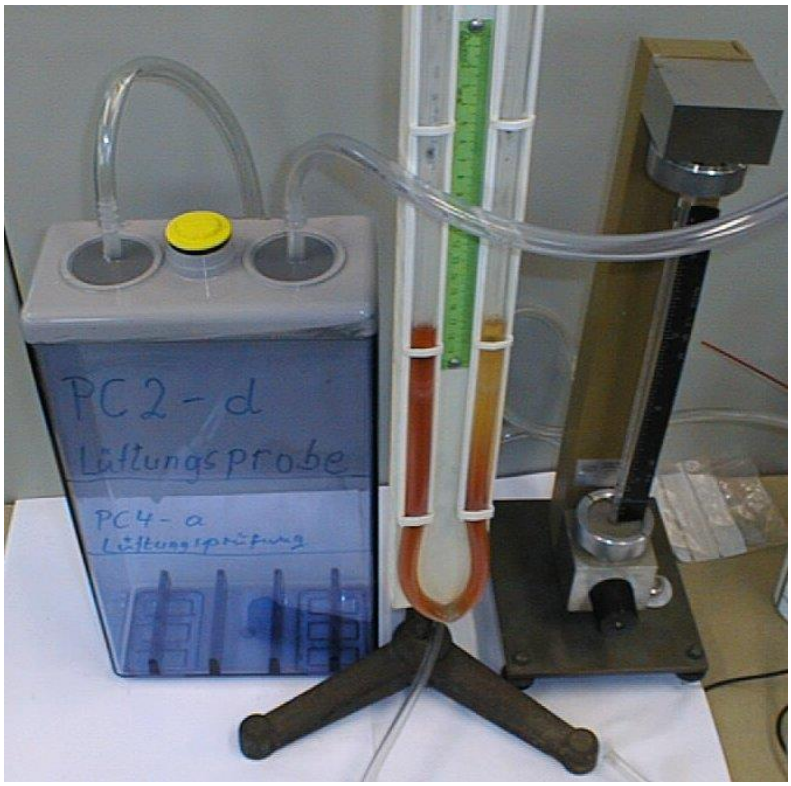

Figure 35 – *Ventilation test.*

Safety test against flammability

Product range: Valve regulated lead acid batteries
Stationary block batteries and cells with positive tubular plates
BAE ***SECURA OPzV***

Type designation: 12V 1 OPzV 50 - 12V 3 OPzV 150
6V 4 OPzV 200 - 6V 6 OPzV 300
2V 4 OPzV 600 - 2V 6 OPzV 900

Type designation: 2 OPzV 100 - 6 OPzV 300
5 OPzV 350 - 7 OPzV 490
6 OPzV 600 - 12 OPzV 1200
12 OPzV 1500 - 26 OPzV 3250

Test: **Spark test**

Test, chapter: Valve regulated batteries

Test laboratory: BAE Batterien GmbH

Test performance:

The test was carried out 6 OPzV 600 cells. The cells were overcharged with 60 A during 10 min. A spark was evaluated by the electronic spark machine with 1 kV. No explosion was examined inside the valve regulated and vented cell during 5 min flashing time.

Annex A

Absolute measurement uncertainties:

Discharge current	± 0.5 % of setting value
Voltage	± 0.1 % of measured value
Current	± 0.1 % of measured value
Time	± 0.5 s
Temperature	± 2 °C

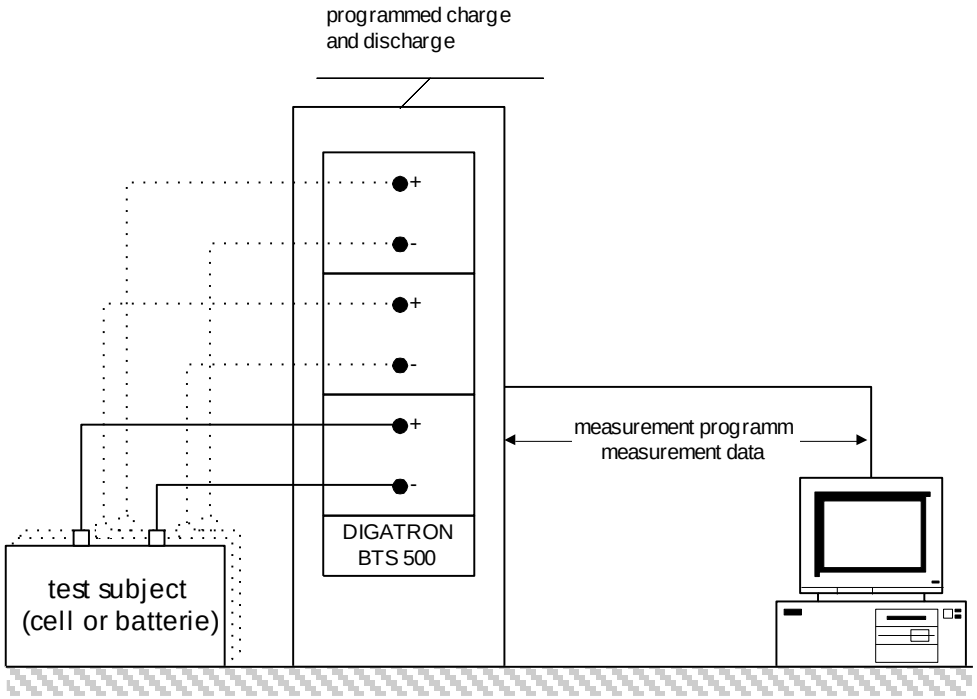

Figure 36 – *Test configuration.*