BAE Batterien GmbH

Comparison GEL – AGM

M. Schiemann

Made in Germany – ISO 9001:2008 Quality Management by BAE

Made in Germany – ISO 14001:2009 Environmental Management by BAE

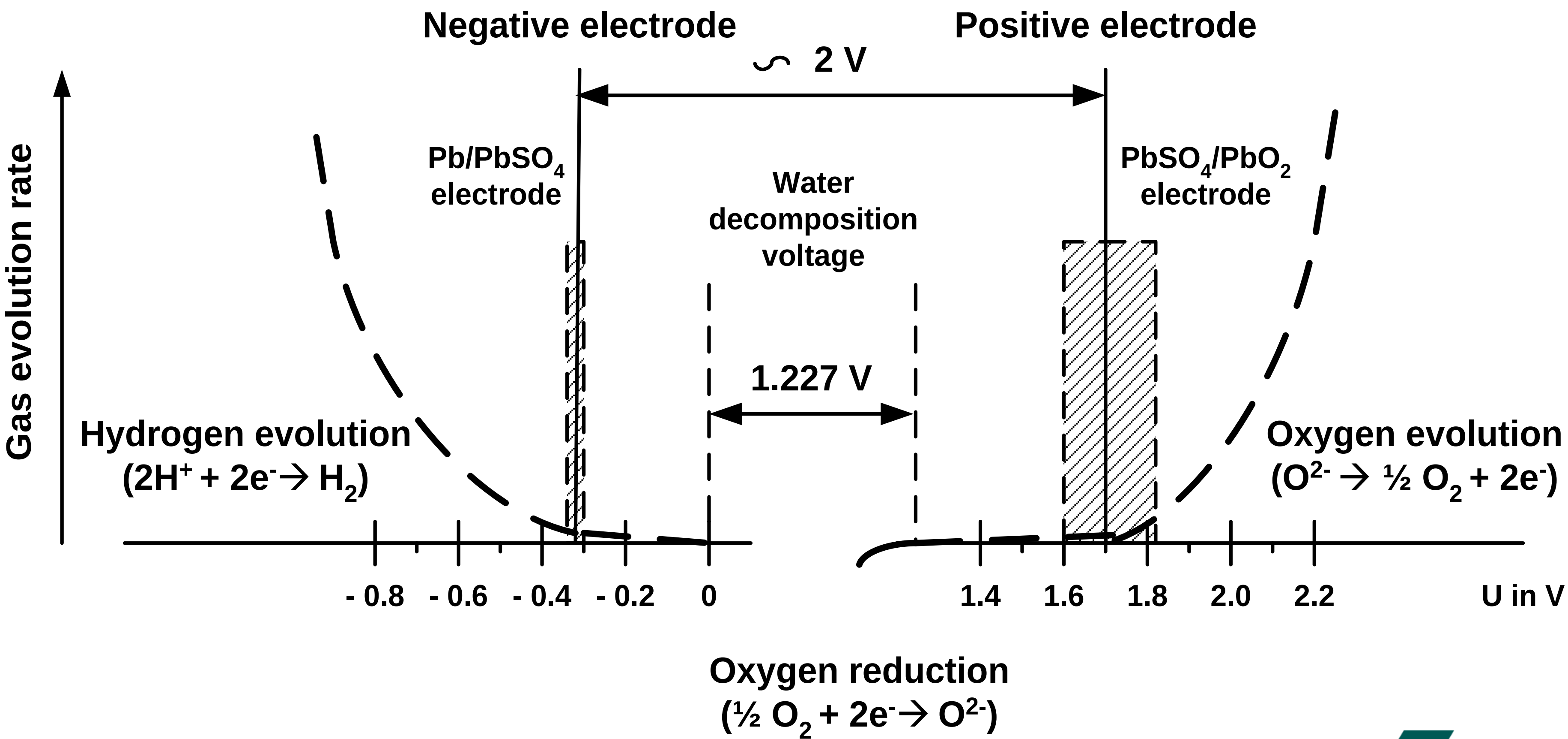
Made in Germany – OHSAS 18001:2007 Health and Safety Management by BAE

Made in Germany – ISO 50001:2011 Energy Management by BAE

BAE – Energy from Batteries

Water decomposition lead acid batteries

Water decomposition is a secondary reaction in lead-acid and nickel/cadmium batteries, which can't be avoided!



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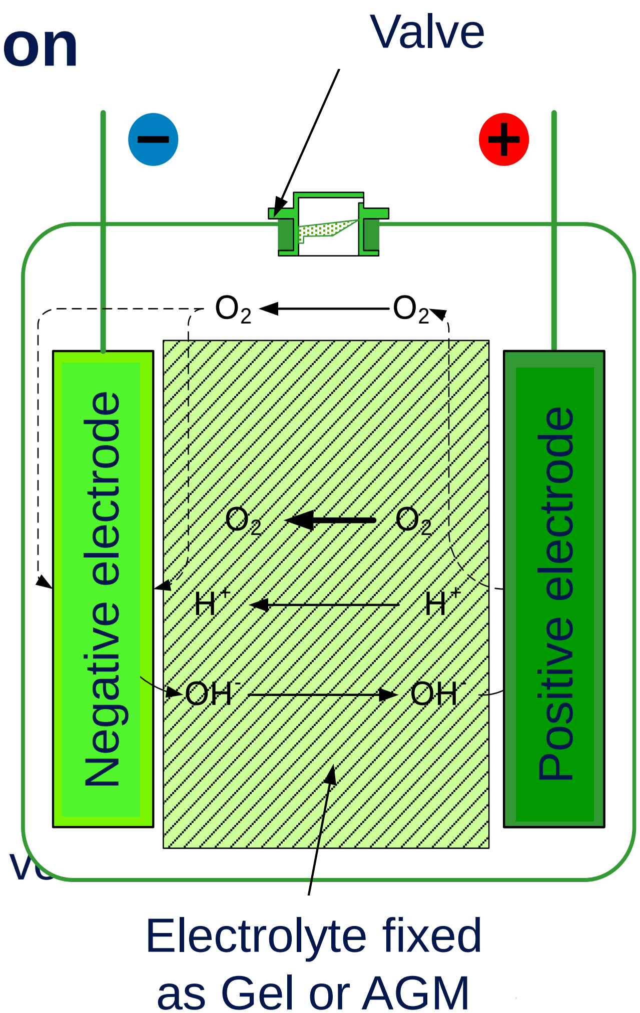
Energy from Batteries

Minimal requirements for recombination process:

- Internal oxygen cycle necessary for recombination of hydrogen and oxygen gas
- Oxygen – development at the positive electrode
- Hydrogen – development at the negative electrode
- Fast gas transport (oxygen) is for recombination at the negative electrode necessary
- No dilution of gas inside fluid electrolyte possible
- Fast gas transport only by diffusion possible, if free v inside electrolyte is available (Gel or AGM)



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Valve regulated/sealed lead acid batteries

➡ FREE Space inside electrolyte

Two technologies possible:

- Gel 3 – 10 % SiO_2 (electrolyte fixed by silica)
- flies mat (AGM absorbent glass mat) separators

Valve regulated/sealed lead acid batteries

Technology

Free space inside electrolyte:

GEL:

- from shrinking during solidification process results cracks inside the gel, which makes fast gas transport between the plates possible.

AGM:

- Fluid electrolyte is fixed by capillary power. The small pores of the fleece are filled with electrolyte, while larger pores are available for gas transport

→ 95% - 98 % efficiency of internal recombination cycle

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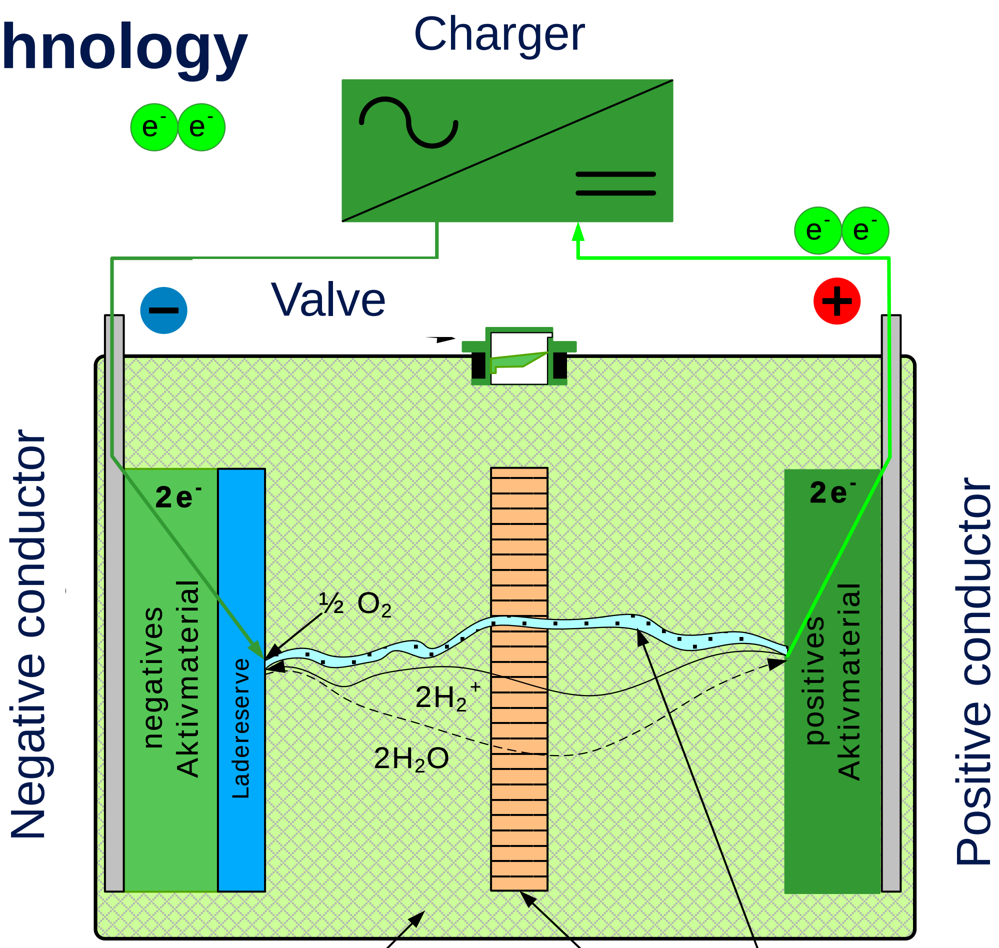
Valve regulated/sealed lead acid batteries

Technology



Pores inside AGM material or cracks inside Gel

Electrolyte fixed as Gel or in absorbed glass mat

Separator for Gel batteries

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Technology: Recombination process

Positive Electrode:

Development of oxygen gas obtained by water decomposition:

Negative electrode:

Development of hydrogen ions

$$2\ H_2O \rightarrow O_2 + 4H^{+} + 4e^{-}$$

positive electrode

negative electrode

Transfer of oxygen gas to the negative electrode through the free space

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Technology: Recombination process

Negative electrode:

Recombination of the oxygen gas – negative electrode develop continually lead sulphate (during battery life partially discharged)

$2\ Pb + O_2 \rightarrow 2\ PbO$

$PbO + H_2SO_4 \rightarrow PbSO_4 + H_2O$

Negative electrode:
Recharge of lead sulphate to lead

$PbSO_4 + 2H^+ + 2e^- \rightarrow Pb + H_2SO_4$

The recombination process at the negative electrode is accompanied by heat development → drying and aging of the battery

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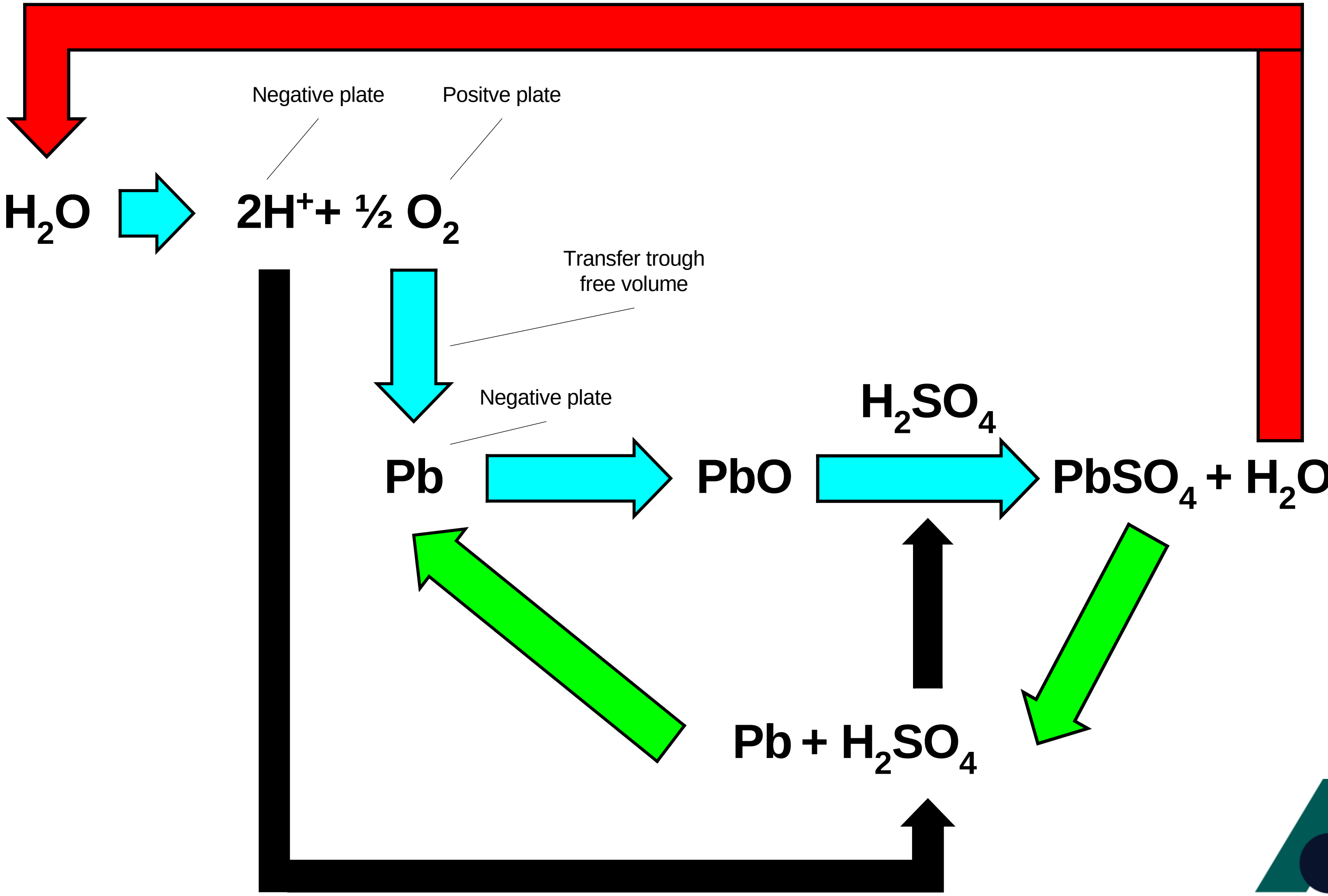
Technology: Recombination process



Energy from Batteries

Technology: GEL

Construction GEL

- Network of silicic acid particles with high surface (200 m²/g). The GEL can transferred to a fluid consistence by mixing.

Pore system:

- Between the network particles of silicic acid particles is a system of pores with a diameter from 0,1µ to 1µ

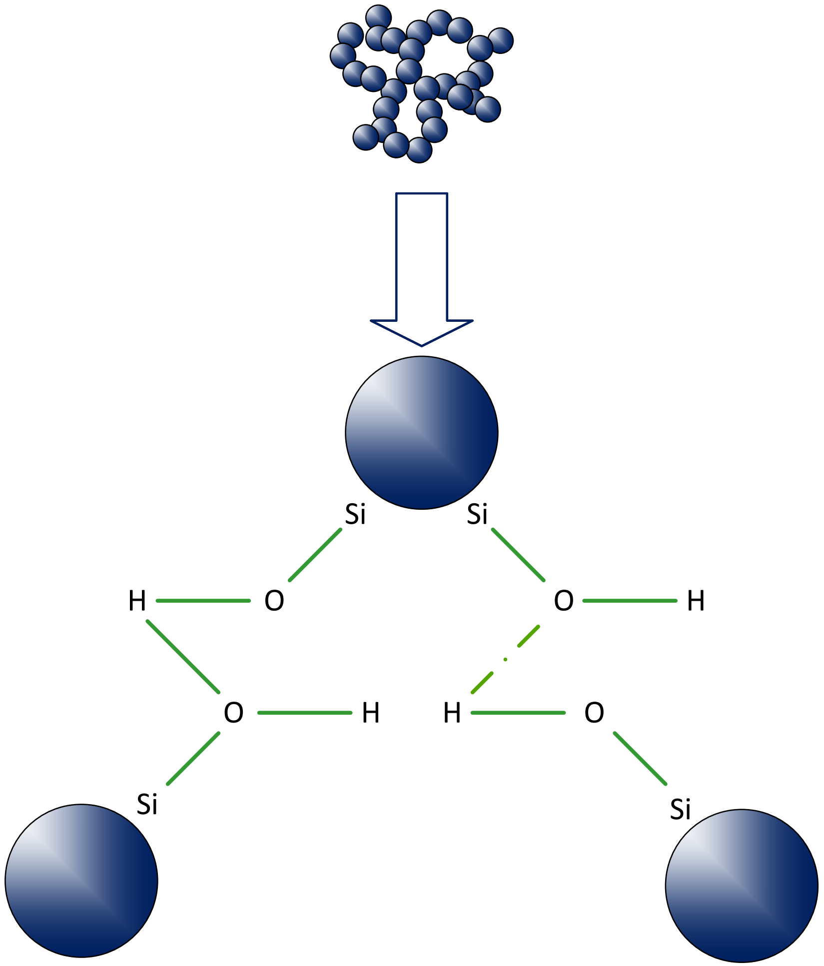
Fixing of electrolyte:

- Acid is fixed by capillary power and high surface of the particles and is changed to GEL (also well know from the principle of solid paint).

Technology: GEL

Battery construction:

- Filling at fluid consistence like acid. Then permanent mixing and gelling with acid during charge of batteries.



Technology: GEL

GEL

Cracks inside GEL
as gas channels

Electrode and Separator

Technology: AGM

Construction AGM

- Woven net of glass fibers with different thickness (0,25µ to 3µ)

Pore system

- Between the fibers is a system of pores with a diameter of 1µ to 10µ

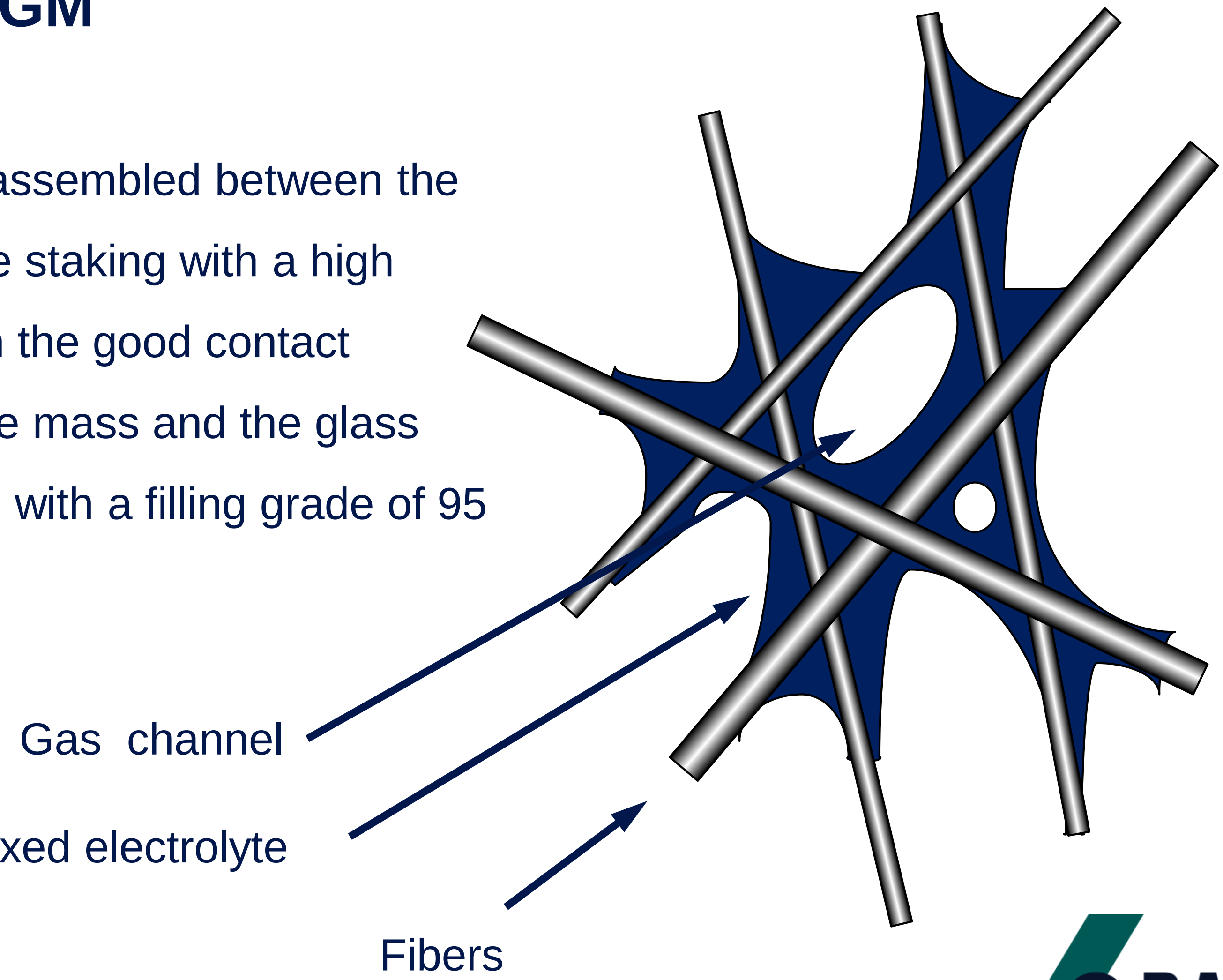
Fixing of electrolyte

- The sulfuric acid is absorbed and fixed by the capillary power like with a sponge

Technology: AGM

Battery construction

- The glass mat is assembled between the plates during plate staking with a high pressure to obtain the good contact between the active mass and the glass matt. Acid is filling with a filling grade of 95 % after assembly.



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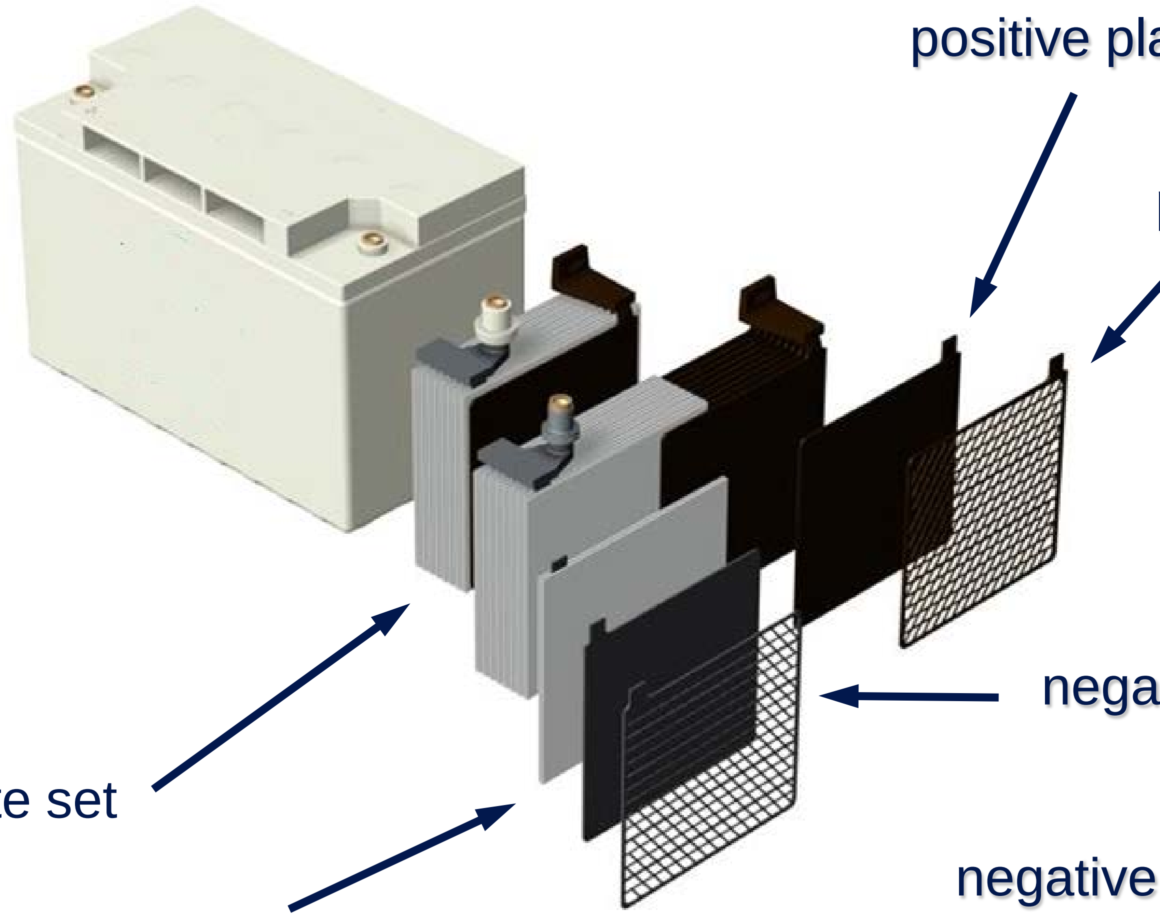
Construction and structure of AGM

Technology: AGM



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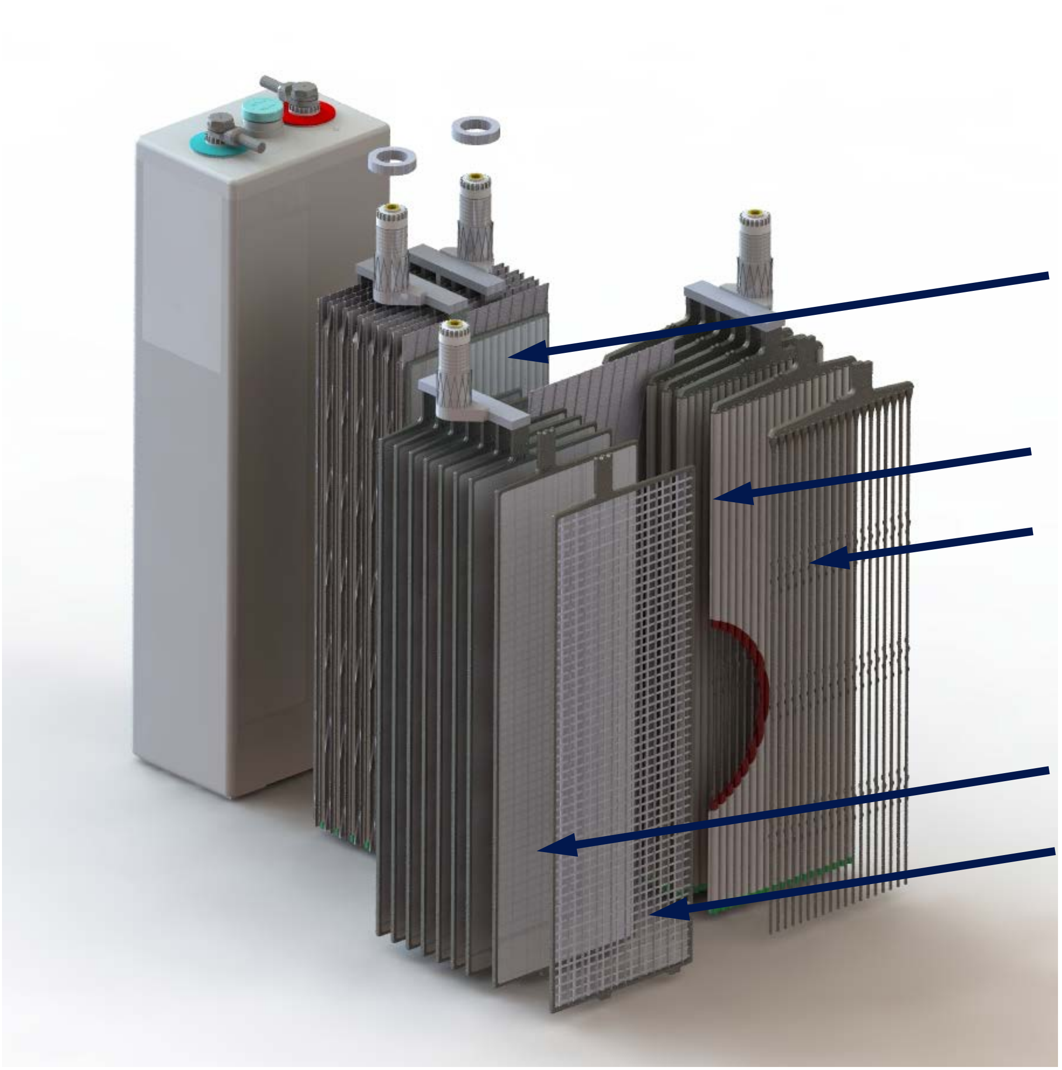
Construction and structure of OPzV

Technology: GEL



Benefits of BAE flash arresting valve

Technology: Valve

- Applied for OPzV single cell an bloc batteries and OGiV single cells
- Secure opening at 120 mbar+-30 %
- Secure closing above 50 mbar
- high precision rubber part with a lip seal
- Flash-arresting by a micro porous frit
- Perfect gas drying, no acid fumes outside
- The valve is securely screwed into the bayonet opening

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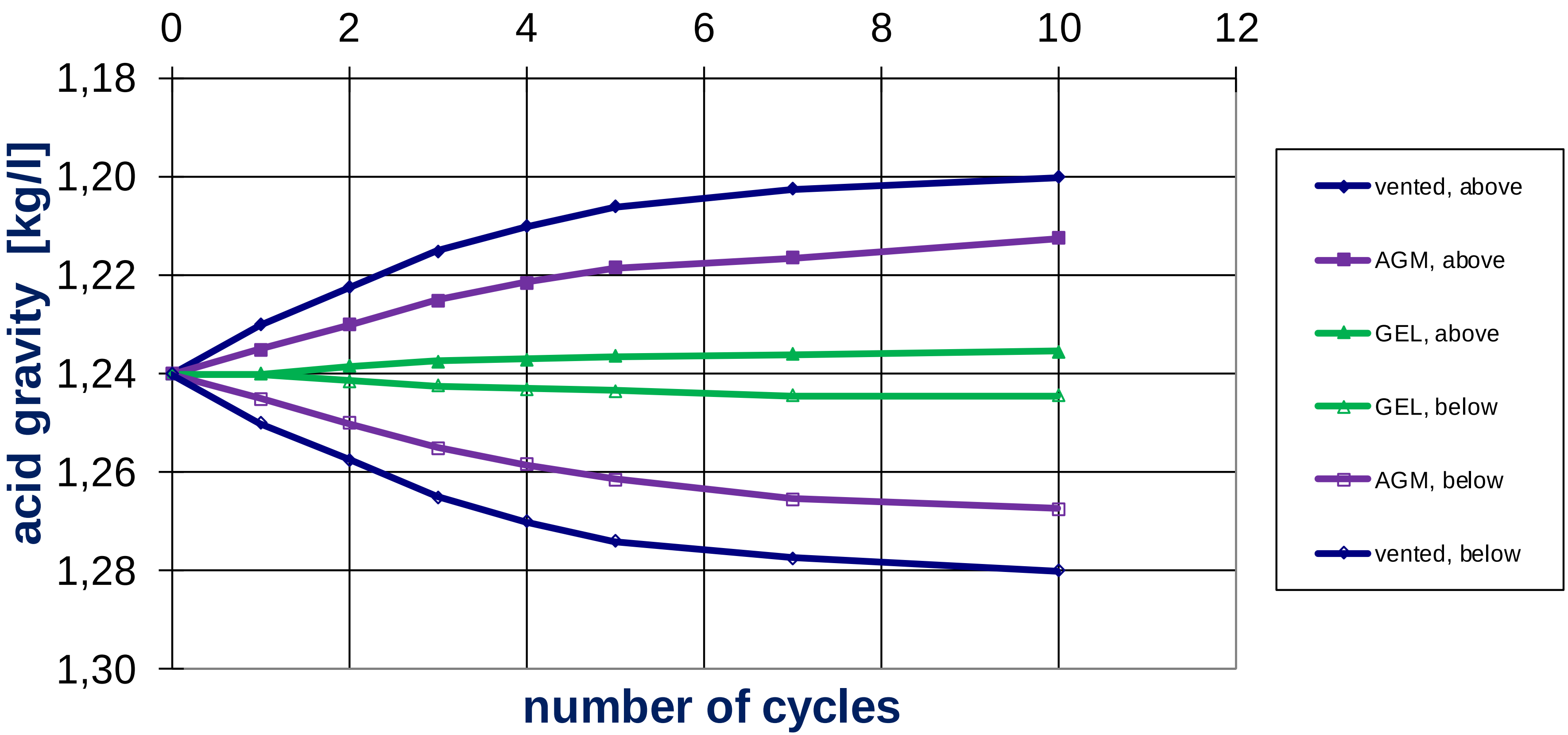
Comparison Gel and AGM Batteries

Technology comparison:

	GEL	AGM
Pore size	0,1µ to 1µ like positive/ negative mass (lead to high capillary power)	1µ to 10µ (low capillary power)
SiO_2 weight / acid weight	Up to 10 % SiO_2	Up to 10% SiO_2
Structure	Si-O-O-Si - molecular chains	0,25µ to 3µ thick SiO_2 fibres
Elasticity / plasticity	plastic, keeps contact to plates	Elastic in a small range
Location	contact to box, includes straps	only between the plates
Additional micro-porous separator	Yes	no

Comparison Gel and AGM Batteries

Acid stratification, obtained by low capillary power:



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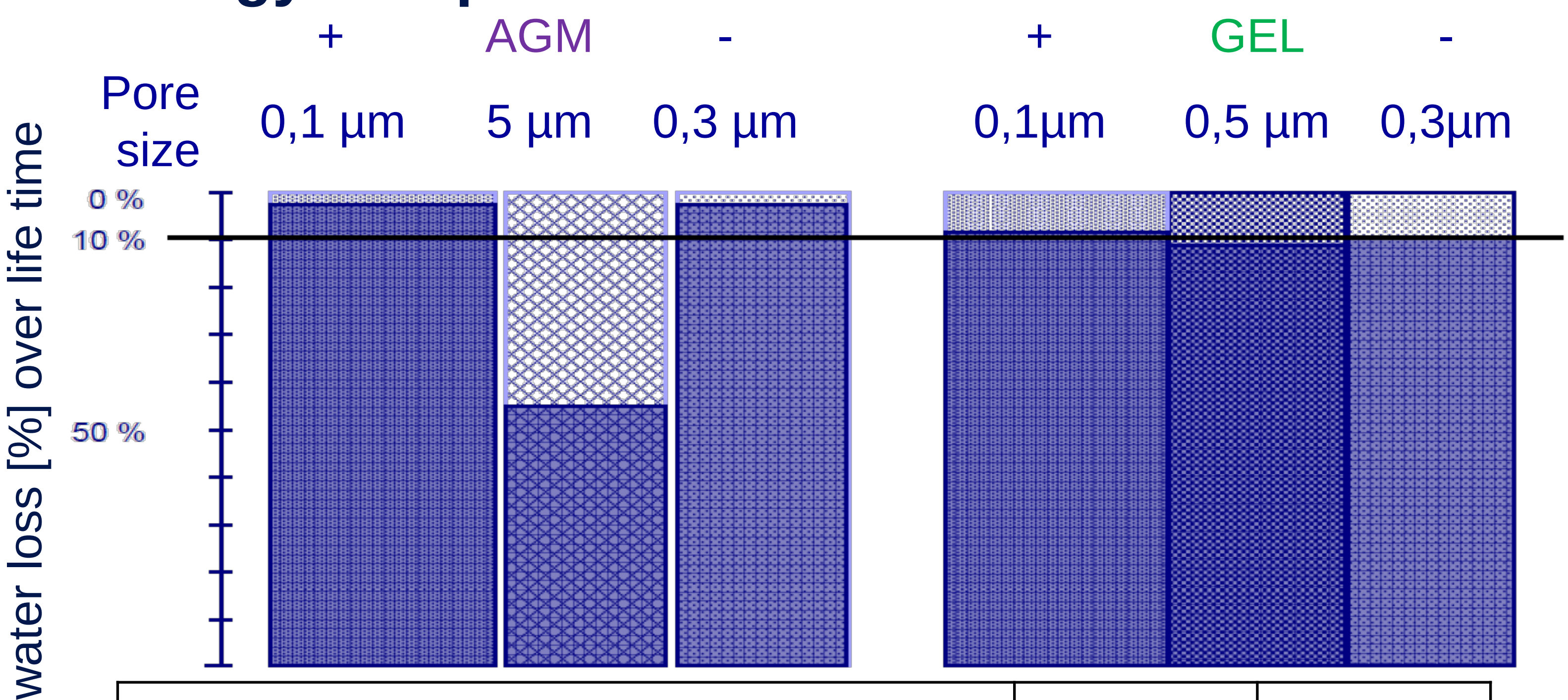
Comparison Gel and AGM Batteries

Technology comparison:



	AGM	GEL
Internal resistance new cell	1,4 mΩ	1,55 mΩ
Internal resistance after 10% water loss	2,4 mΩ	1,65 mΩ

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Comparison Gel and AGM Batteries

Technology comparison:

	GEL	AGM
Internal resistance	average, because GEL and the separator is present	very low, ideal for UPS systems
Power density	average average electrical losses, also low space requirement	good low electrical losses and low space requirement
Cycle life time	excellent, because no acid stratification, small pores, mass protection at tubular plates by gauntlets	average, limitation by acid stratification at large cells and lack of contact
Costs (initial ivest)	average, besides the separator the GEL costs are additional	low, because the glass-mat is cheaper than the microporous separator

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Comparison Gel and AGM Batteries

Technology comparison:

	GEL	AGM
Total cost over life time	Lower related to AGM, due to higher life time (design life time and operational life time) and cycle stability	Higher related to GEL (especially tubular plate design) due to the danger of fast capacity decrease (PCL2 effect)
Design specialities	No cell's height restriction, cell design with positive tubular and flat/grid plates are possible with GEL	Plate thickness has to be in very low tolerance; AGM batteries are possible only with flat/grid plates Cells height not higher than nearly 350 mm, to prevent non uniform acid distribution obtained by low capillary power

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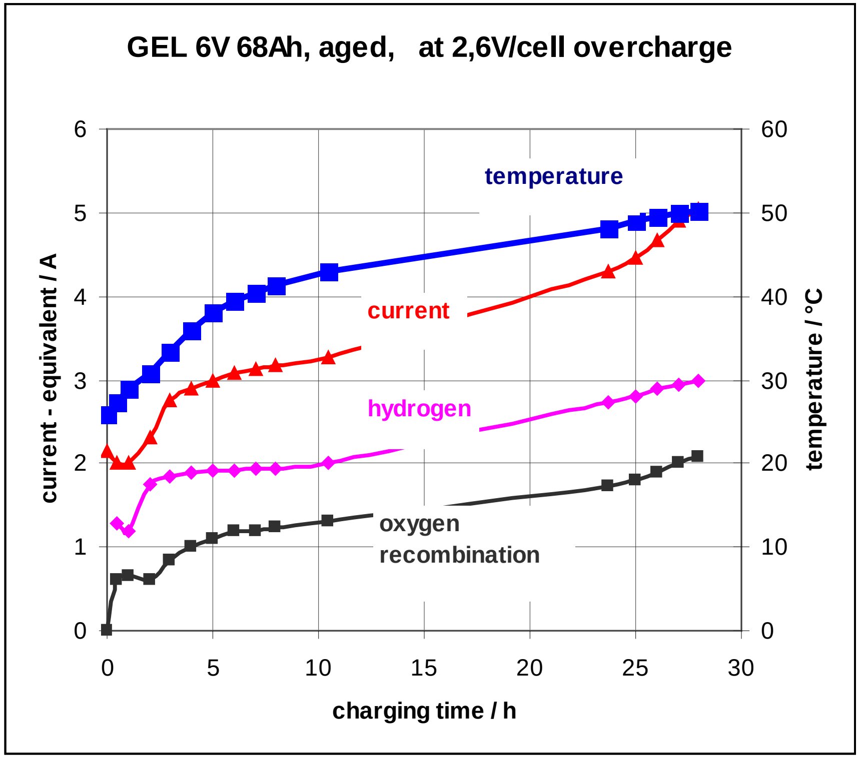
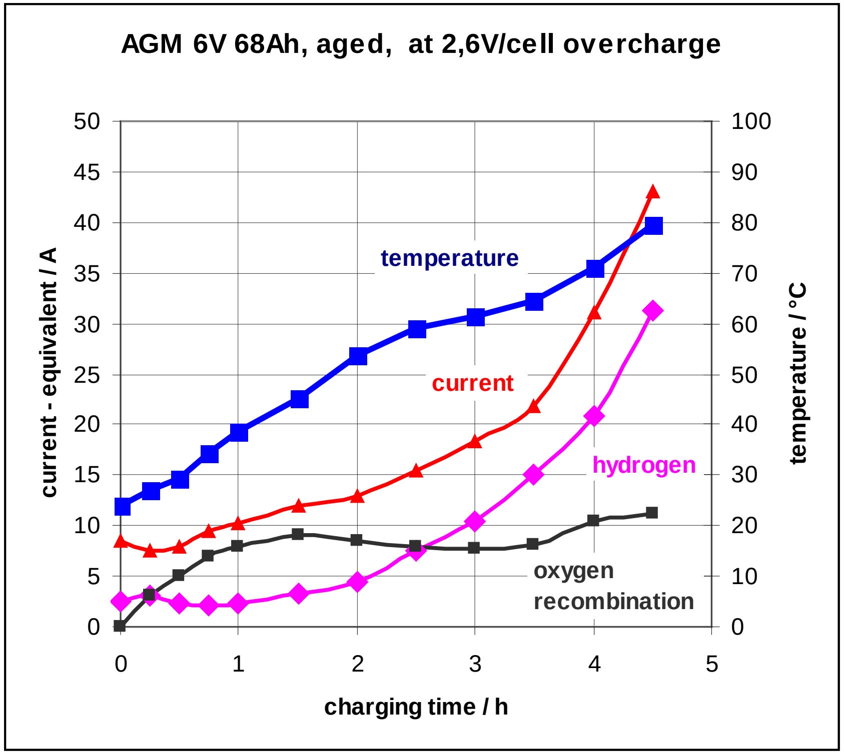
Comparison Gel and AGM Batteries

Technology comparison: Thermal runaway simulation





- Tmax = 50°C after 28 h
- Total current increases to 5A
- 6V 68Ah GEL

- Tmax = 80°C after 4,5 h
- Total current increases to 40A
- 6V 68Ah AGM

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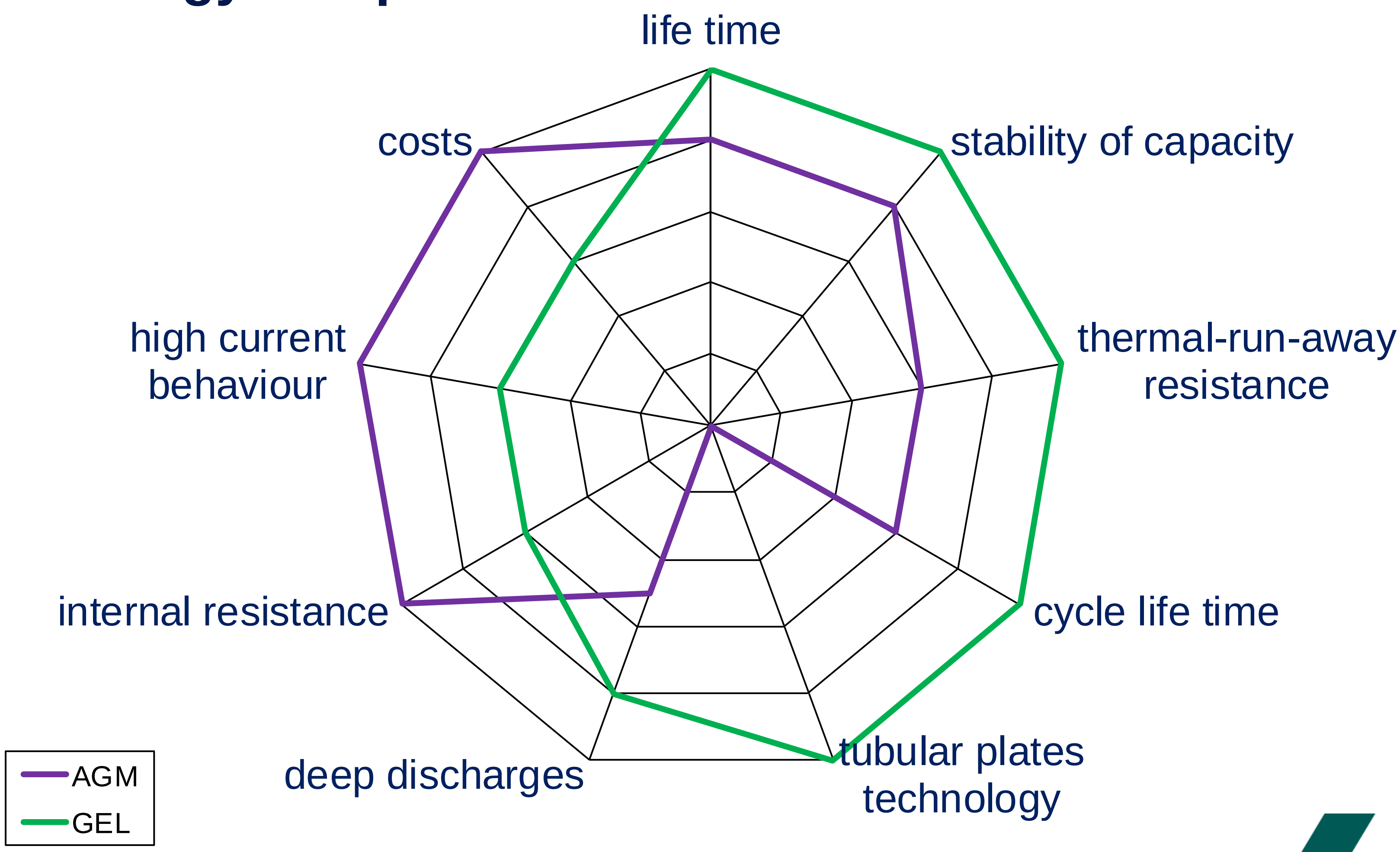
Comparison Gel and AGM Batteries

Technology comparison:



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BAE Gel Products - *SECURA* OPzV cell

Capacity range:	100 to 3250 Ah
Operational life:	20 years (stand-by)
IEC 60896-21 – cycles:	>1500
Float voltage:	2.25 V±1%
Acid density:	1.24 kg/l
Electrolyte fixed in:	GEL by fumed Silica
Valve:	120 mbar
Plate type:	tubular/flat
Alloy positive grid:	PbCaSn
Pole bushing:	100% tight
Container/lid:	high impact SAN UL-rating 94 HB; V-0 on request
Connectors:	bolted flexible or solid insulated copper connectors
Installation:	vertical, horizontal on request

BAE Gel Products - *SECURA* OPzV BLOCK

Capacity range:	50 to 900 Ah
Operational life:	18 years (stand-by)
IEC 60896-21 – cycles:	>1500
Acid density:	1.24 kg/l
Float voltage:	2.25 V±1%
Electrolyte fixed in:	GEL by fumed Silica
Valve:	120 mbar
Plate type:	tubular/flat
Alloy positive grid:	PbCaSn
Pole bushing:	100% tight
Container/lid:	high impact SAN UL-rating 94 HB; V-0 on request
Connectors:	bolted flexible or solid insulated copper connectors
Orientation:	vertical, horizontal on request

Energy from Batteries

Comparison OPzV Gel and AGM Batteries

Technology comparison:

BAE OPzV GEL	AGM
Positive plate – tubular plate	Negative plate – Flat plate/grid plate
Gauntlet encase and protect active mass • No mass softening (PCL2 effect) by counter pressure from gauntlet • High mass reserve, reduce mass stress during cyclic operation Centered lead road with high cross section • High corrosion life time • Homogeneous allocation and discharge of active mass	Mass pasted into grid Softening of active mass during cycling easier possible (PCL2 effect) Limited mass per plate • No cyclic stability • Limited capacity

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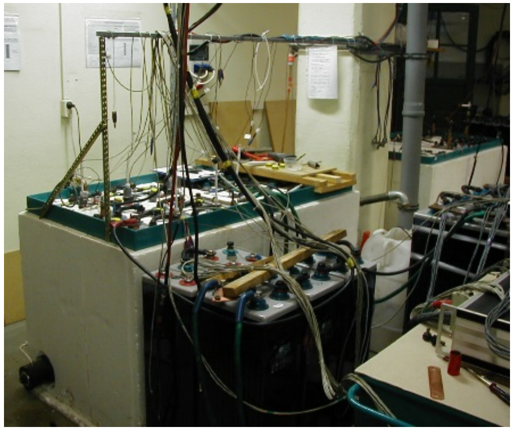
Test results accelerated aging test:

Initial requirements:

- 15 years at 23 °C → corresponding to 250 days at 62,8 °C
- (acc. to Arrhenius approach)
- At the end of temperature : Seismic test (simulation of earthquake and aircraft crash)

<u>Test procedure:</u>

- Every 50 days 3h capacity test to 1,75 V/cell at room temperature
- Float current, growth of poles were measured frequently
- Tear-down analysis at the end of the test



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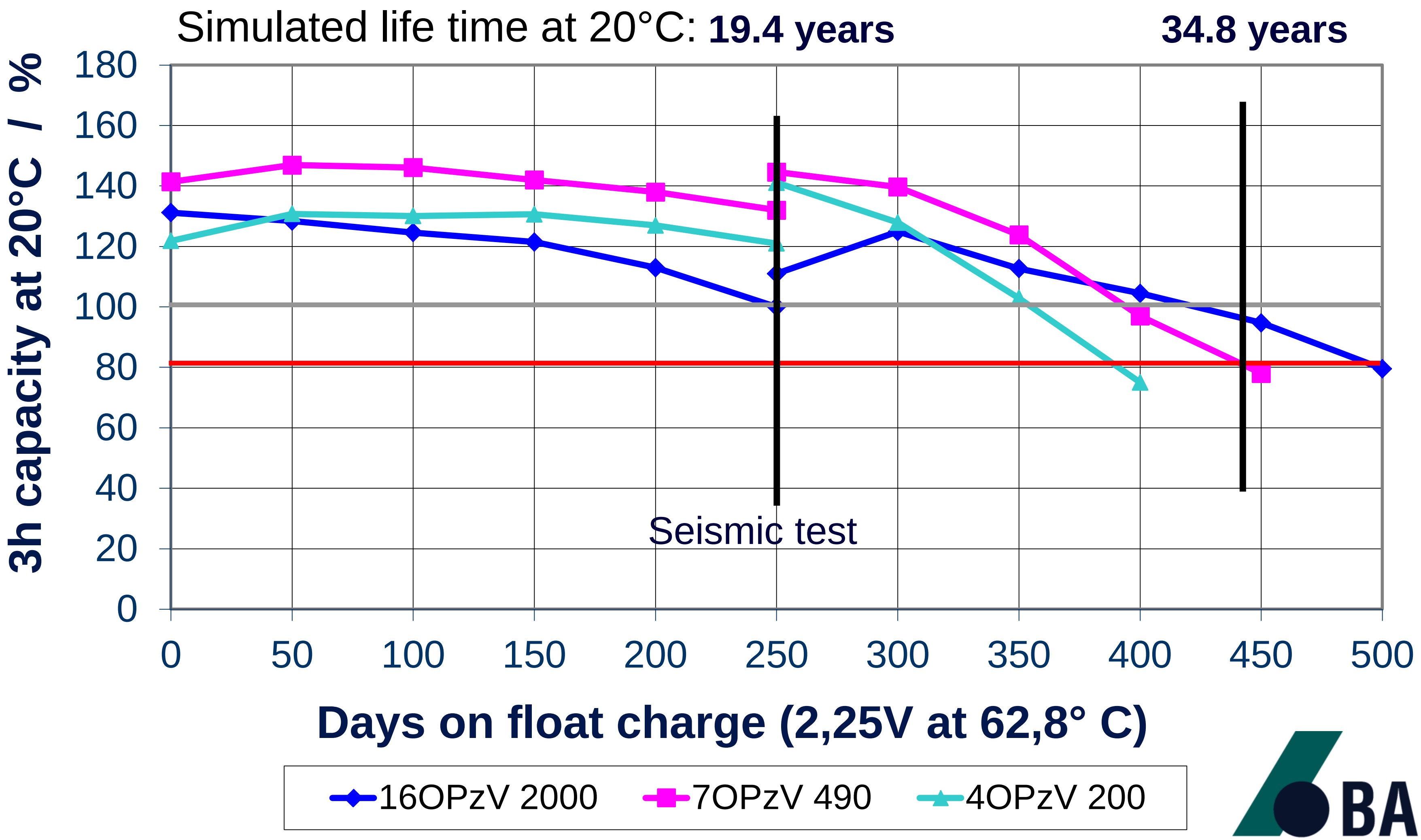
BAE Accelerated Life Time Test

Test results accelerated aging test:



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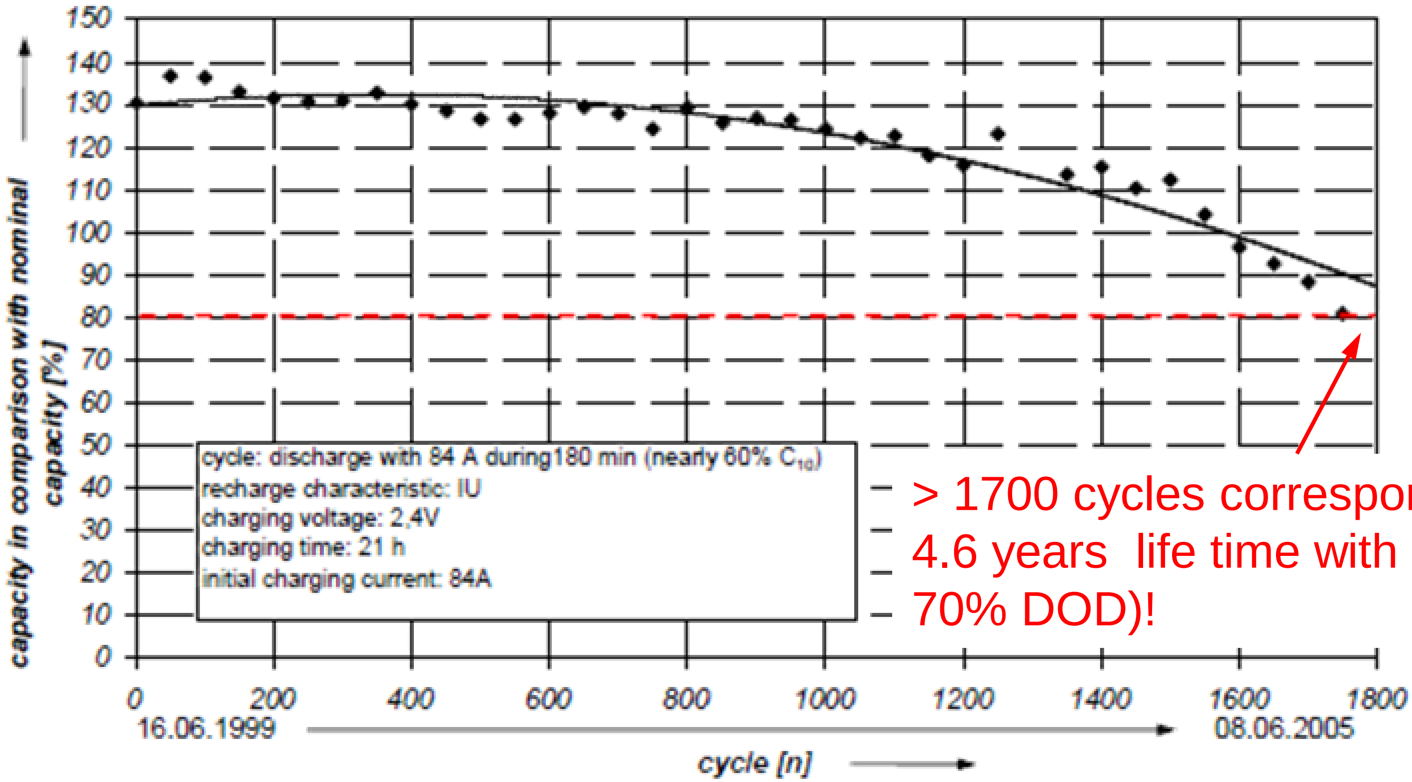
Full cycle test acc. to 60896-21 (IEC 896-2)

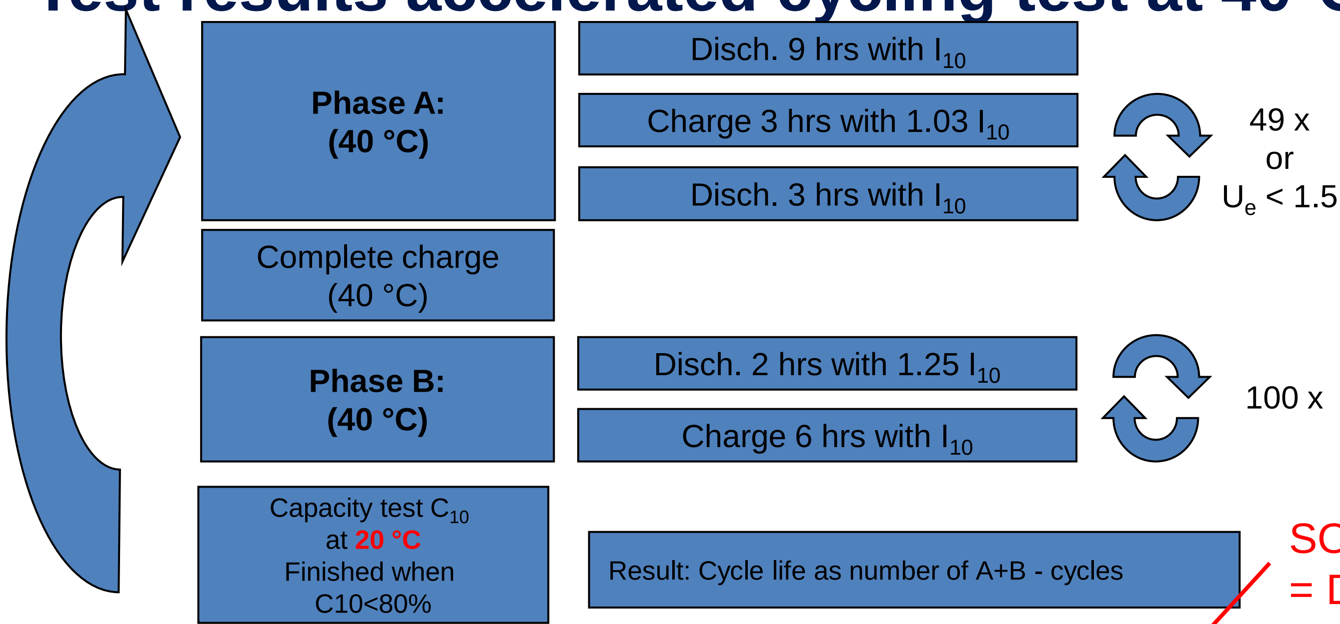
Test results accelerated cycling test:

- Procedure: 3 h discharge with 2 x I10 (here 86 A) □equals to 70 % DoD
- Full charging for 21 h at 2.40 V
- every 50th cycles □capacity test until Crt = 0.8 (EOL criteria)

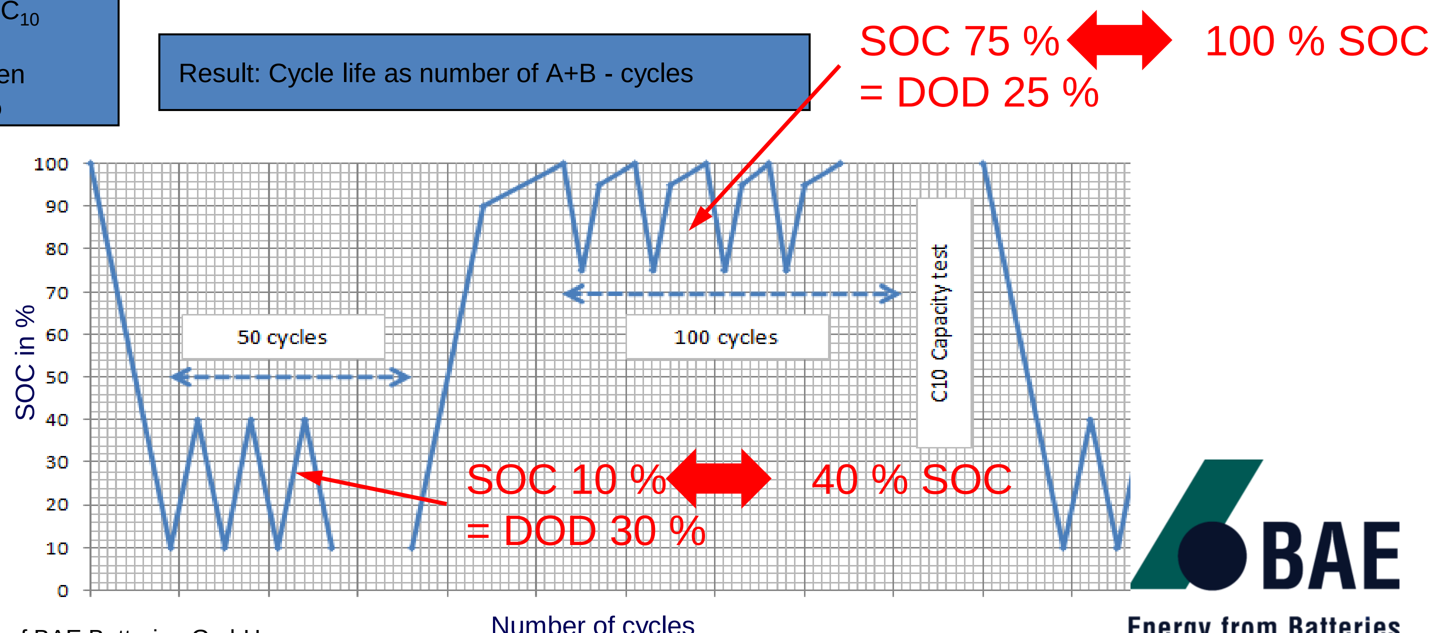


> 1700 cycles corresponds to 4.6 years life time with daily (at 70% DOD)!

Test results accelerated cycling test at 40°C/104 °F:



Phases A and B in scheme



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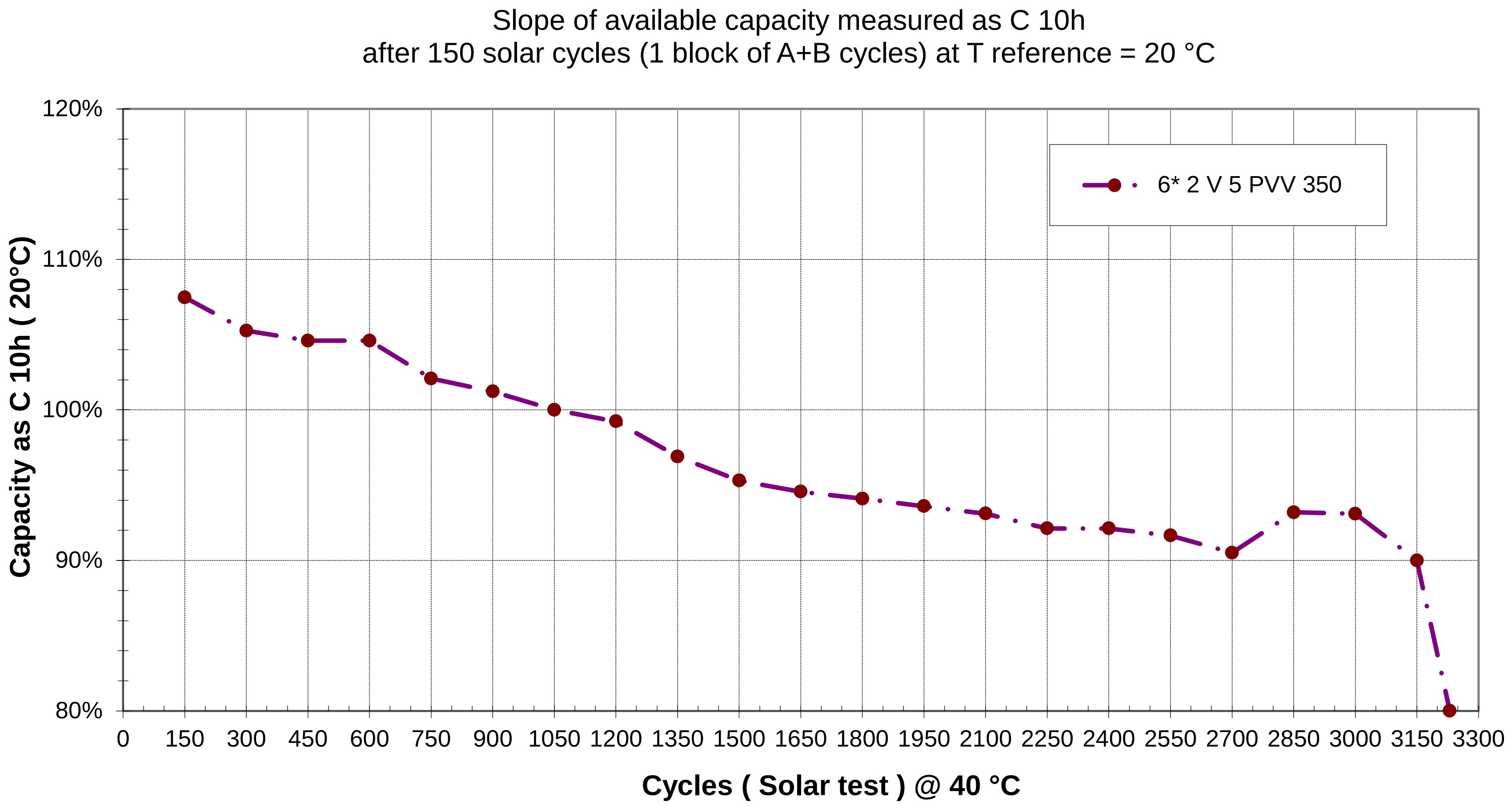
Test results accelerated cycling test at 40°C/104 °F:

Thermal chamber for the life time test

Solar cycle test acc. to IEC 61427:2002-04

Test results accelerated cycling test at 40°C/104 °F:



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Comparison Gel and AGM Batteries

Technology comparison:

	BAE OPzV GEL	AGM
IEC cycles	>1500 cycles	~700
Design Life	Cell: 20 years Block: 18 years	Ø 13 years
Float voltage per cell (driven by acid gravity)	2,23V	Ø 2,27 V
Needed installation space	Higher	Low
Weight (lead weight driven)	High	Low
Costs of acquisition	100 %	~ Ø 70 %

Thank you for your attention

Energy from Batteries