3rd Thai-German Community-based Renewable Energy Conference 2018

8th February 2018, Eastin Grande Hotel Sathorn,
Surasak Ballroom, Bangkok

Table of Contents

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Table of Contents

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Site Storage Requirement

- Storage Requirements

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- The battery have to be fully charge
- The storage room must be dry and frost-free.
- Variations in the ambient temperature should be avoided in the battery storage room. In any circumstances the temperatures must be below 40°C (104°F).
- Water condensation in the cells must be avoided.
- Direct sunlight must be avoided.
- Detergents, solvent material or its vapours as well as other chemicals are to be kept well apart from the cells / blocks
- Cells / blocks are not to be stacked, to avoid mechanical damages
- For dry uncharged VLA cells / blocks: the plugs on the cell lid have to be removed only short time before filling of the cells

Site Storage Requirement

- Maximum Storage Time and Recharge Requirements

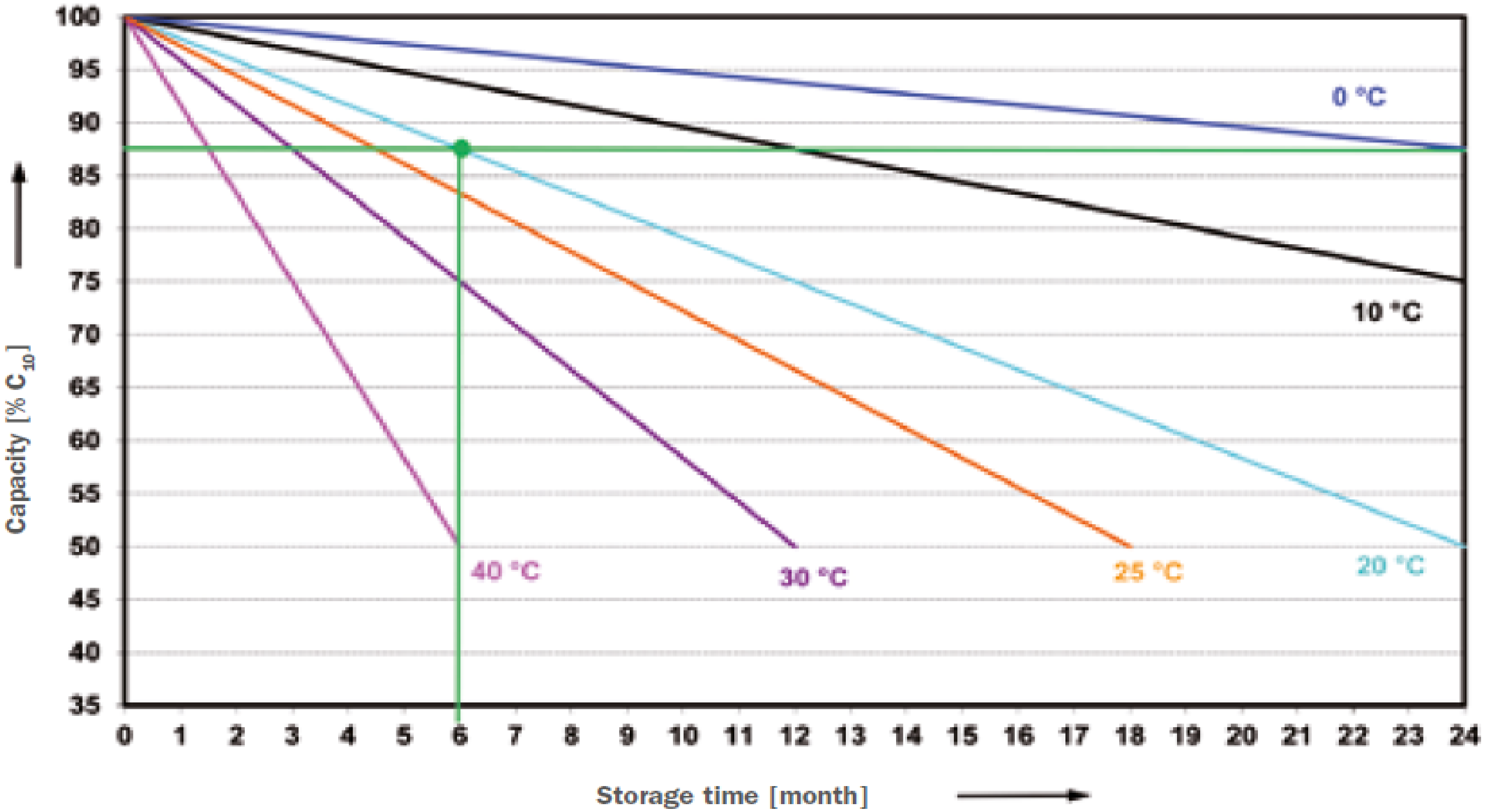
- **Dry uncharged VLA cells / blocks:**
  - ✓ Maximum storage time in dry condition should not exceed 24 months after delivery.
- **Filled VLA cells / blocks:**
  - ✓ Maximum storage time should not exceed 3 months at 20°C after commissioning date at manufacturing site.
- **VRLA cells / blocks:**
  - ✓ Maximum storage time should not exceed 6 months at 20°C after commissioning date at manufacturing site.

Note:

Recharge of the blocks / cells should be performed max. 2 times during storage time! Thereafter the batteries must be connected to continuous float charge.

Site Storage Requirement

- VRLA @ Available Capacity vs Storage Time



Site Storage Requirement

- VLA @ Available Capacity vs Storage Time

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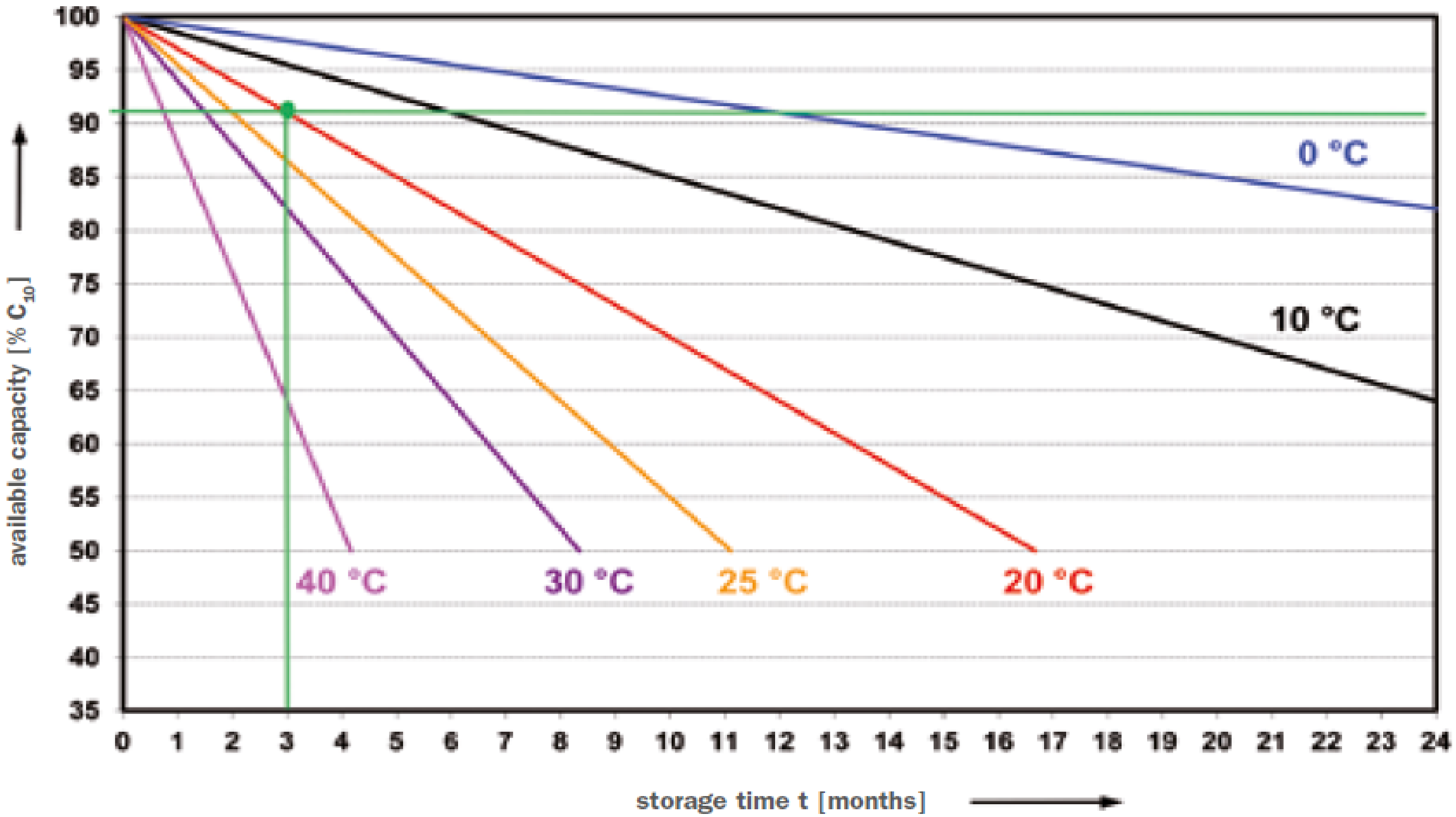

Site Storage Requirement

- Improper storage will avoid manufacturer warranty

Site Storage Requirement

- Storage Warehouse without Air-conditioning System

Spacious area with high roof and air ventilation

Rectifier System – Battery Charging Station

Table of contents

Parameters for battery sizing

- Temperature influence on battery capacity ?

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- Capacity is smaller at low temperatures.
  This effect is caused by an increase of acid viscosity (stickiness) and thus a slower diffusion of acid into the plates.

- A low temperature increases acid viscosity. If acid viscosity increases, conductivity reduces.

- A low temperature leads to a slower exchange of interior & exterior sulphuric acid – the cell voltage reduces earlier – the available current is smaller.

- Dependance of battery capacity on basis of 20°C:

at discharges below 3 h	1 % per 1 °C
at discharges above 3 h	0.6 % per 1 °C

Example: 250 Ah nominal capacity at 20°C is 250Ah / 80% = 312 Ah at 0°C

Parameters for battery sizing

- Temperature influence – on capacity

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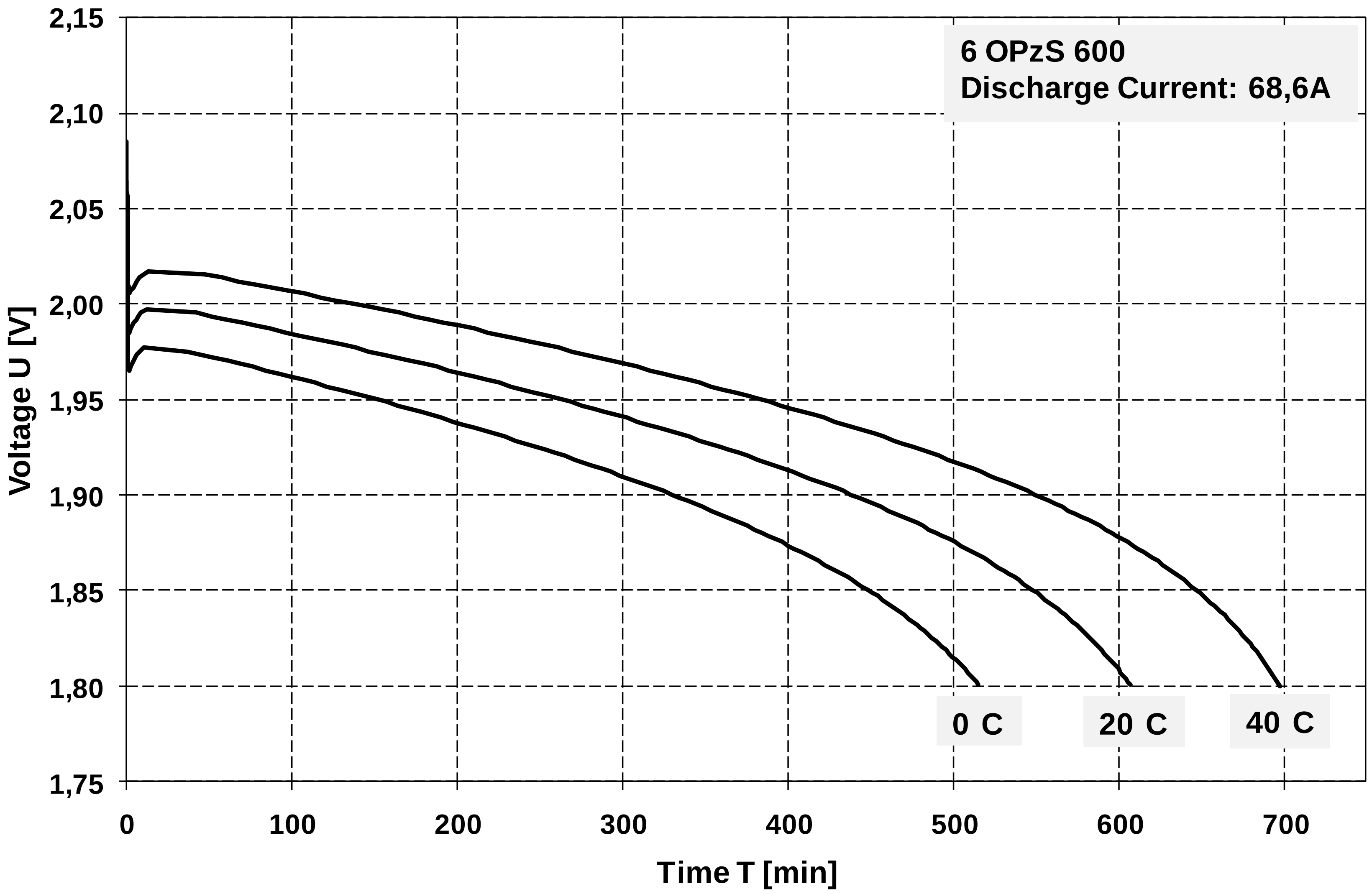

Parameters for battery sizing
- Temperature influence – on capacity

Temperature range for OPzV solar.power batteries:

Possible temperature range : -20°C to 45°C
Recommend temperature range: 15°C to 35°C

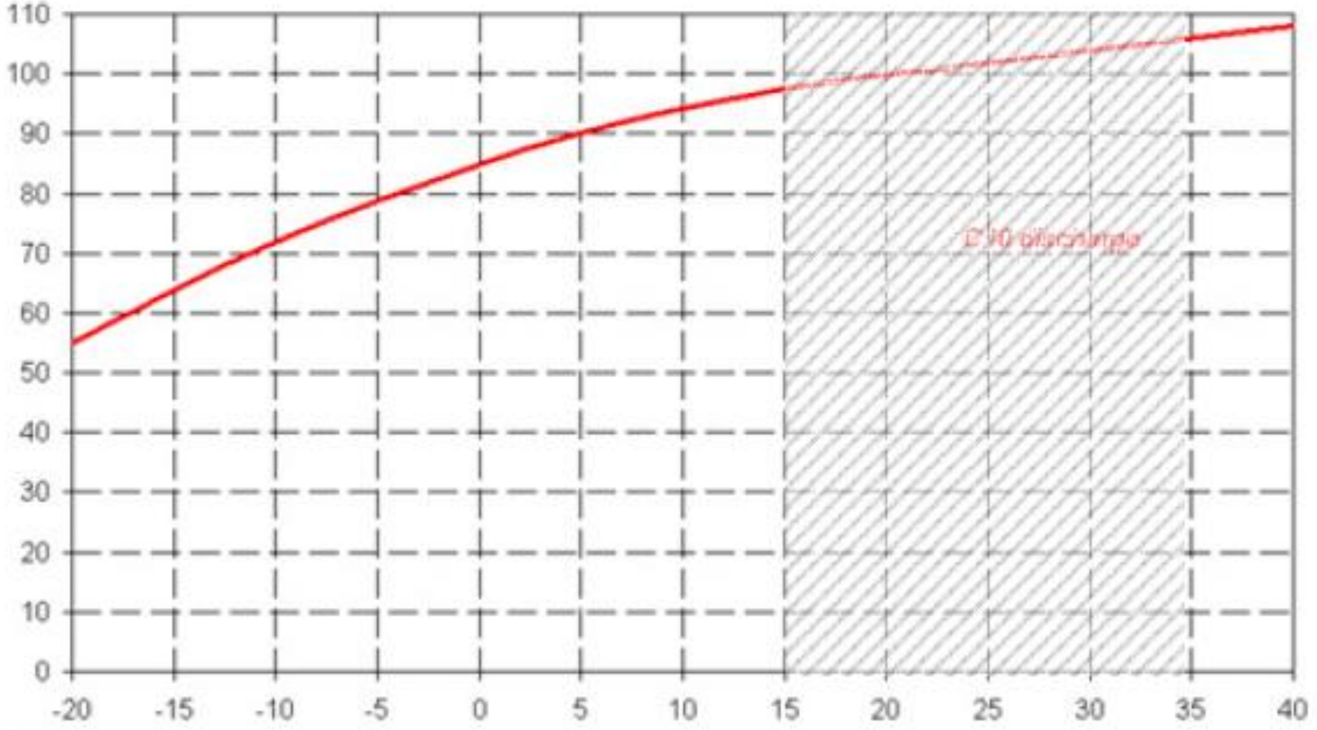

Figure 6: OPzV solar.power: Dependency of battery capacity on temperature

Parameters for battery sizing
- Temperature influence on self discharge and corrosion life time ?

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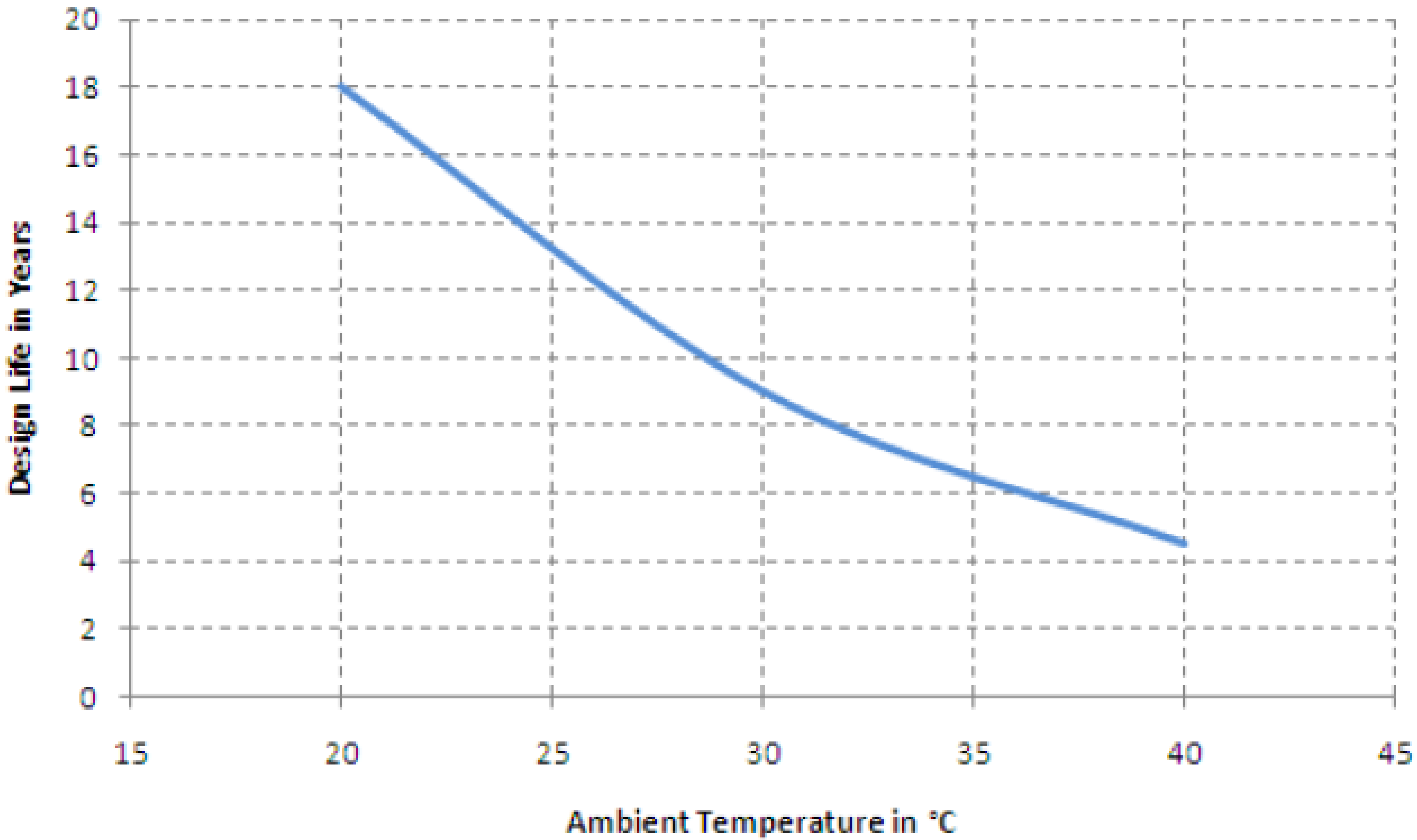
- Self discharge is a continuous side effect. This is due to the decomposition of water.
- A monthly self discharge of 2 – 3 % is usual, based on nominal capacity.
- Chemical reactions depend on ambient temperature. A temperature increase of approximately 10 K (10 °C), increases the speed of chemical reaction by factor 2.
- An increase of ambient temperature by 10°C doubles the self-discharge rate, i.e. shortens the shelf life of the battery and reduces its operational life by 50%, if no other aging effects, such as drying out (sealed LA batteries) or mass softening due to under charge in cycle application show up.
- Also ambient temperature has an adverse effect on the corrosion life of the positive plate and limits its operational battery life, because plate corrosion can never be stopped.

Parameters for battery sizing
- Temperature influence – on battery aging

Aging (of OPZV in standby application) as a function of ambient temperature



Parameters for battery sizing

- Temperature influence – on cycle life

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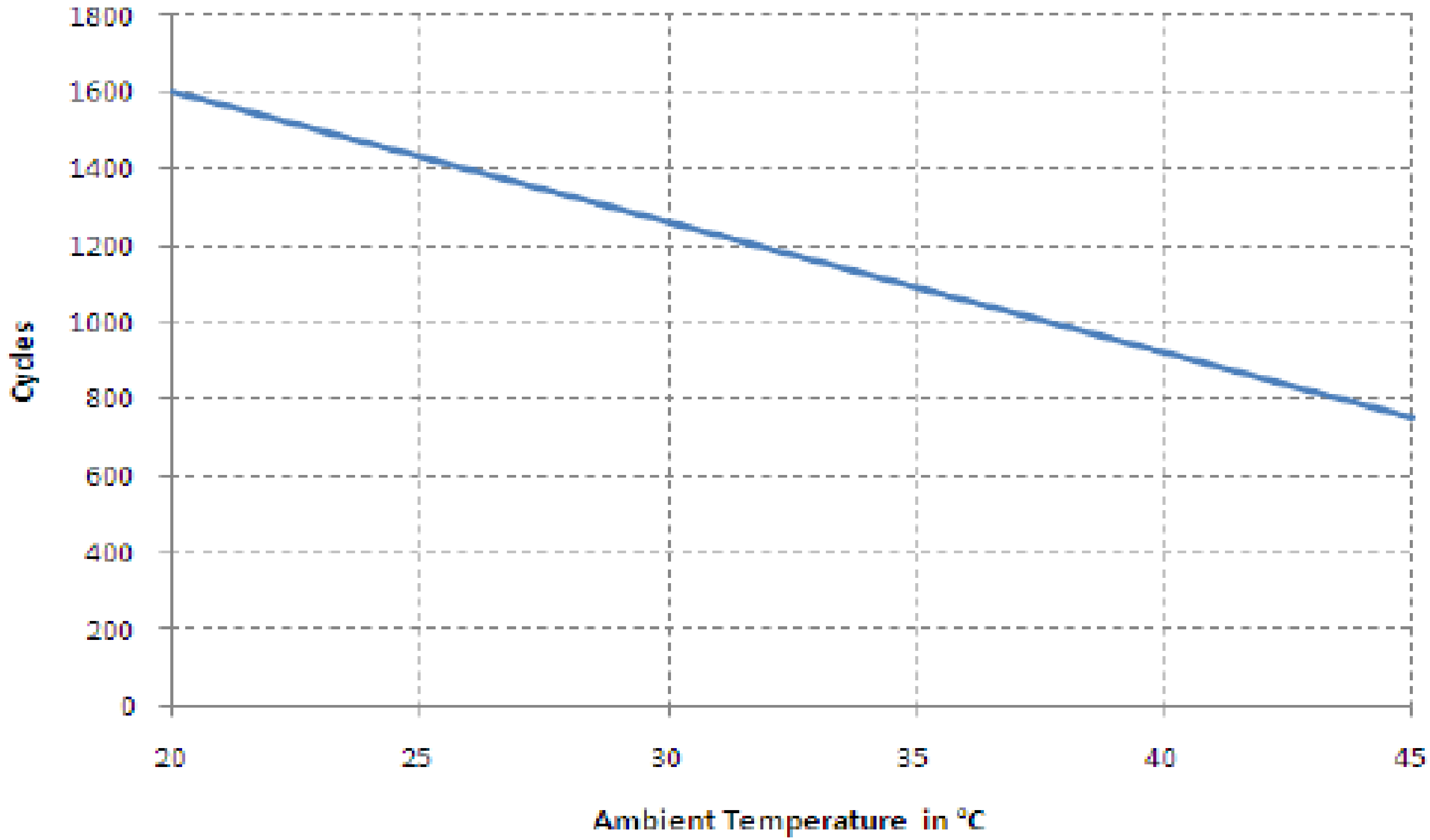
Cycle life time (of OPZV at 80% dod) as a function of ambient temperature



Parameters for battery sizing

Temperature influence – freezing point

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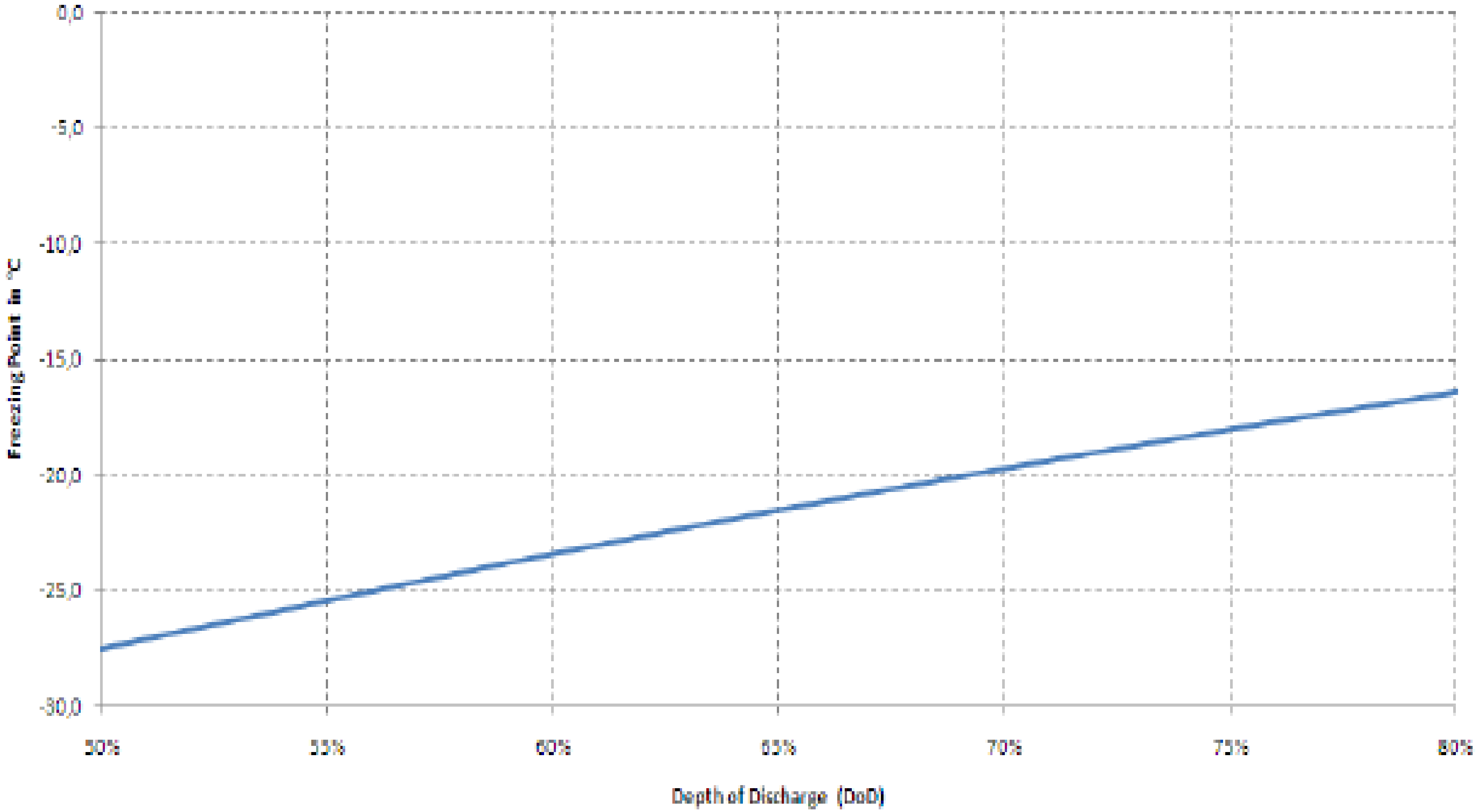
If a battery is discharged at 60% (dod), the ambient temperature must not fall below -23,4°C



Parameters for battery sizing

- Important Info for Battery Sizing

When considering the battery sizing, the following parameters need to be considered:

i) Load – ampere / kilowatt (kW) / kilowatt hour (kWh)

ii) Back-up time – hours (hrs)

iii) Autonomy time – day(s)

iv) Battery system voltage - Vdc

v) Maximum Depth of Discharge - % DOD

vi) Minimum ambient temperature

vii) Inverter Efficiency

Parameters for battery sizing

- Equations to determine battery capacity (Ah)

i) Battery capacity (Ah) **(DC Load in Ampere)**

$$\text{Battery capacity (Ah)} = \frac{\text{Total Ampere (A)} \times \text{Back-up time (hrs)}}{\text{DOD} \times \text{temp. correction (minimum)}} \times \text{Autonomy days}$$

ii) Battery capacity (Ah) **(AC Load in Wh))**

$$\text{Battery capacity (Ah)} = \frac{\text{Total Daily Energy Consumption (Wh)} \times \text{Autonomy days}}{\text{Inv. Efficiency} \times \text{Nom. Batt. Volt.} \times \text{temp. correction (minimum)} \times \text{DOD}}$$

Notes:

- ***Aging Factor*** *- battery performance is relatively stable through out its life, dropping of rapidly towards the end. To ensure the battery can meet the design requirements throughout its life the standard suggestions the initial capacity should be 125% of the design capacity.*
- ***Design Margin*** *- to cater for unexpected circumstances (increased loads, poor maintenance, recent discharge, etc.) it is common to allow a design margin of 10% to 15%.*

Parameters for battery sizing

- Example 1: Battery sizing in stand alone system (PV only without Genset)

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Environment conditions:

- ***Current*** consumption 2 A for 5 hours over night
- Maximum period without any recharge: 4 days autonomy
- Maximum depth of discharge under extreme conditions: 50%
- **Minimum ambient temperature: 10°C**

Sizing Calculation:

- 2 Ampere x 5 hours = 10Ah
- 4 days x 10 Ah = 40Ah (extreme condition)
- 40Ah / 50% dod = 80Ah nominal capacity
- 80Ah / 0.9 = 89Ah (**temperature correction 1% per 1K below 20°C**)
- Result 89Ah C_{100} = 4 days
- Choose battery type from product brochure which can provide minimum capacity of 89Ah@C_{100}
- Selected battery type: sun|power VRM 12-90

Parameters for battery sizing

- Example 2: load profile of the customer: 499,77 kWh daily battery capacity

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Caractéristiques de la charge et besoins énergétiques

Designation	Quantite	Puissance Unitaire (W)	Puissance Totale(KW)	Temps de fonctionnent en heure/jour	Consommation d'énergie (KWh/J)
Ventilateurs	35	85	2,975	3	8,925
Climatiseur 2CV	22	1472	32,384	8	259,072
Climatiseur 1,5CV	5	1104	5,52	8	44,16
Ordinateurs + Ecran	44	250	11	8	88
Ampoules 1,20m	162	40	6,48	8	51,84
Imprimante laser jet	16	295	4,72	0,25	1,18
imprimante laserjet HP9050dn	6	1000	6	0,5	3
Imprimante Genre M 603h	5	920	4,6	2	9,2
imprimante laserjet HP 2035	5	550	2,75	8	22
Photocopieuse	1		0	2	0
Refrigérateur	3	150	0,45	24	10,8
Téléviseur LCD	2	100	0,2	8	1,6
Puissance Installée (KW)			77,079		0
Consommation journalière moyenne (KWh/J)					499,777
Consommation mensuelle moyenne					

Parameters for battery sizing

- Example 2: load profile of the customer: 499,77 kWh daily battery capacity

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Environment conditions:

- ***Energy*** consumption: 500 kWh over night
- Battery System Voltage: 48 Vdc
- Maximum period without any recharge: 1 day autonomy
- Maximum depth of discharge under extreme conditions: 50%
- Minimum ambient temperature: 20°C

Sizing Calculation:

- 500 kWh / 0,9 (compensation efficiency losses) = 555.55 kWh
- (555.55 kWh x 1000) / 48V = 11,574 Ah dischargeable capacity on daily basis
- 11.574Ah / 50% dod = 23,148 Ah required nominal capacity C_{10}
- Decide number of battery strings: e.g. 8 string
- Battery capacity Ah/string = 23,148 Ah / 8 ; minimum = 2,894 Ah @ C_{10}
- Choose battery type from product brochure which can provide minimum capacity of 2,894Ah@C_{10}
- 8 strings of 24 cells x sun|power VL 2-3980 (2,952Ah@C_{10})

Parameters for battery sizing

Battery selection from manufacturer brochure / discharge data sheet

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Battery datasheet for example 1

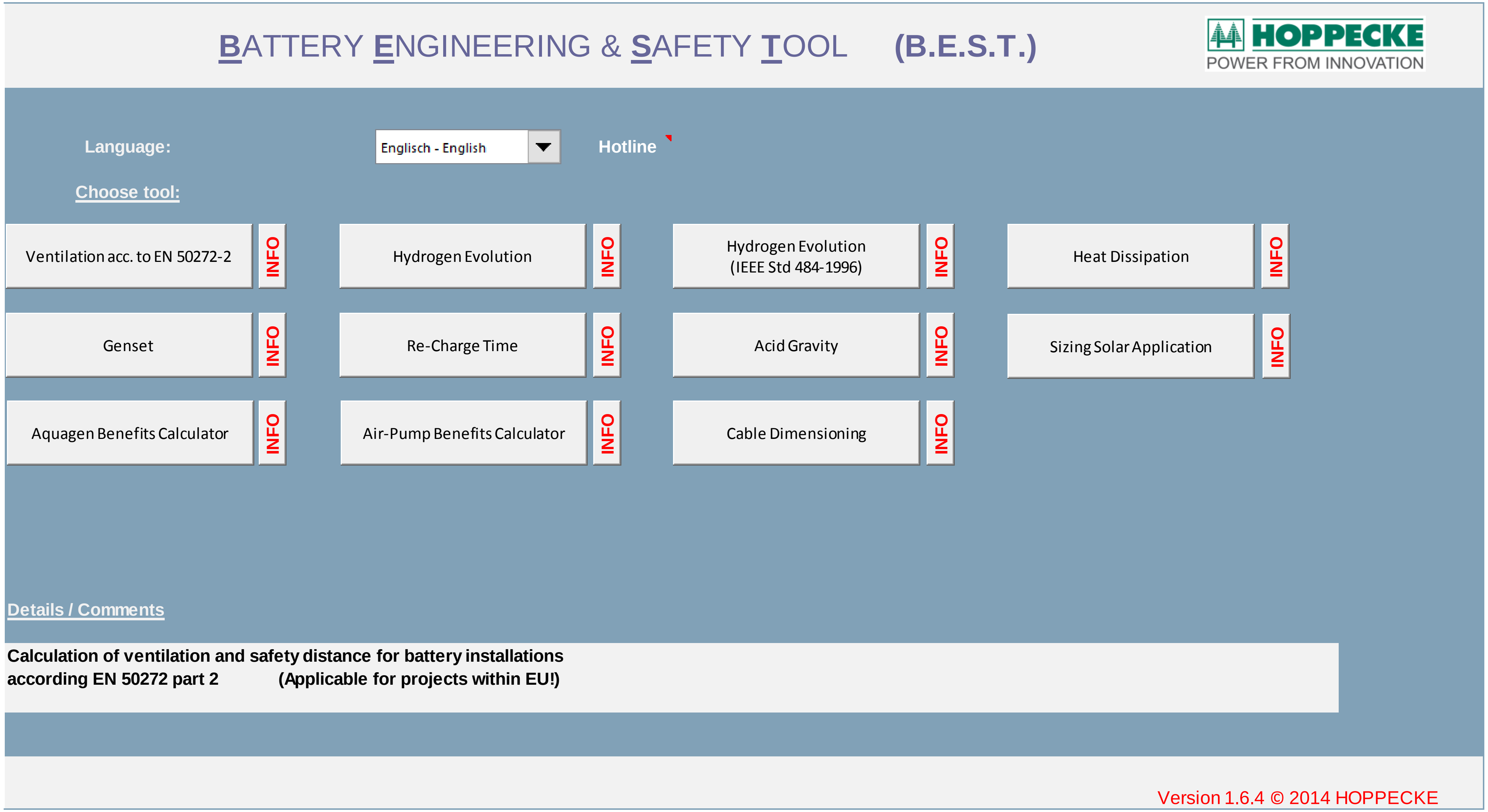
Type	Nominal Voltage V	C_{100}/1.85 V Ah	C_{50}/1.80 V Ah	C_{24}/1.80 V Ah	C_{10}/1.80 V Ah
sun | power VR M 12-58	12	56	58	56	48
sun | power VR M 12-70	12	69	71	68	58
sun | power VR M 12-80	12	76	78	74	66
sun | power VR M 12-90	12	88	89	85	76
sun | power VR M 12-105	12	101	103	98	87
sun | power VR M 12-135	12	125	128	122	111
sun | power VR M 12-150	12	146	151	146	133
sun | power VR M 6-200	6	186	190	183	167
sun | power VR M 6-250	6	247	253	243	229

Battery datasheet for example 2

Series OPzS	C_{100}/1.85 V Ah	C_{50}/1.80 V Ah	C_{24}/1.83 V Ah	C_{10}/1.80 V Ah	C_{8}/1.77 V Ah
18 sun | power VL 3250	3250	3015	2765	2412	2097
20 sun | power VL 3610	3610	3350	3072	2680	2330
22 sun | power VL 3980	3980	3685	3382	2952	2562
24 sun | power VL 4340	4340	4020	3696	3220	2795
26 sun | power VL 4700	4700	4355	4004	3488	3028

Parameters for battery sizing

- Hoppecke Battery Engineering & Safety Tools (B.E.S.T)



Parameters for battery sizing

- B.E.S.T Chart – Battery sizing with constant load (Amps)

INPUT REQUIREMENT

Input 1: choose batt type (VLA / VRLA)

Input 2: choose batt model (OPzS, OPzV & blocs battery)

Input 3: Nom. Sys. Volt (12, 24, 36, 48V)

Input 4: Nom. Final Disc. Volt (1.80 – 1.95)

Input 5: Number of parallel strings

Input 6: Operating Temperature

Input 7: Ageing factor - optional

Input 8: Lifetime factor (Temp.= 35°C, DOD < 20%) - optional

Input 9: Targeted Depth of Discharge (DOD)

Input 10: Load profile (amp. / watt., constant or variable load) – ampere & constant load

INPUT

Parameters

Battery Type ○ Vented ◉ VRLA

Model: OPzV solar.power

Nominal system voltage: 48 V

Final discharge voltage: 1.80 V / Cell 1.)

Number of parallel battery strings: ☐ Yes / No 1 2.)

Compensation factor "Capacity vs Temperature" 3.): 30 / 86 °C / °F

Compensation factor "Ageing": ☐ Yes / No 4.)

Compensation factor "Lifetime (T≥35°C (95°F) and DOD < 20% per day: ☐ Yes / No 5.)

Utilization of the available capacity: 50 % 6.)

Loadprofile ☐ Ampere / Watt 7.)

Step	Current [A]	Discharge Time	
1	100.0	10.0	Hours
2			Hours
3			Hours
4			Hours
5			Hours
6			Hours
7			Hours
8			Hours
9			Hours
10			Hours

8.)

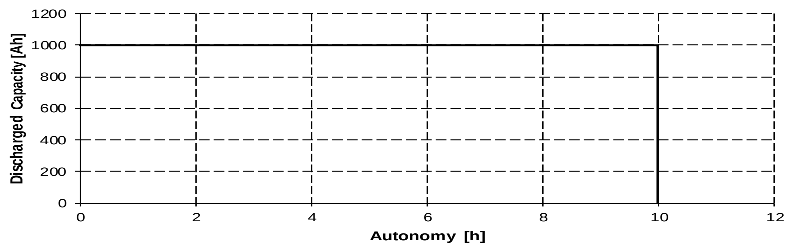
Footnote

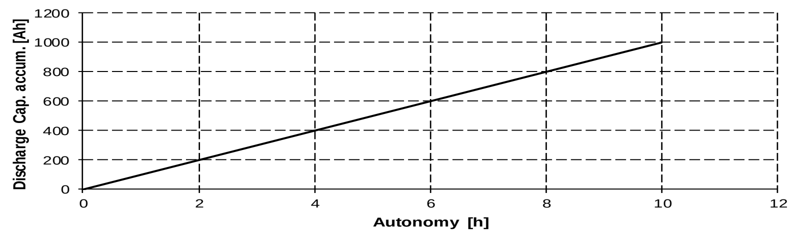
Comments "Footnote"

1.) Due to the long discharge times in solar application the final discharge voltages should be set like follows:
Autonomy ≤ 20h - 1,8 V/Cell
Autonomy ≤ 100h - 1,85 V/Cell
Autonomy > 100h - 1,9 V/Cell
2.) Selection only if number of strings are prescribed!
3.) Compensation factor for capacity loss or benefit depending on the ambient temperature.
4.) Compensationfactor 1,25 for ageing up to 80% of the nominal capacity.
5.) Compensation factor for accelerated ageing at ambient temperature > 35°C and a max. depth of discharge (DOD) of less than 20% per day.
6.) To optimize the cycling performance within a certain autonomy the max available battery capacity can be adjusted in a range between 0 - 80%.
7.) The loadprofile can be given in current [A] or power [W] values.
8.) The time frame for each load step can be adjusted individually!

RESULTS

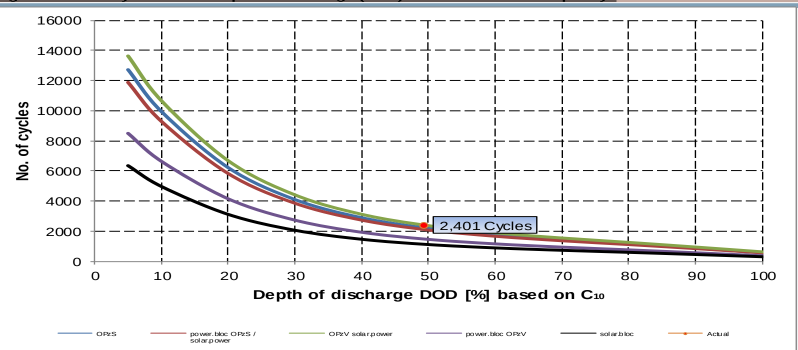
Diagram " Discharged capacity and accumulated capacity depending on discharge time"





Discharged Capacity	1,000.0	Ah
Total discharge time:	10.00	h
Power consumption (average):	4,800.00	Wh
Recommended Battery:	1 x 24 cells	16 OPzV 2300 solar.power

Diagram: "No. of cyles versus depth of discharge (DOD) based on the C10 capacity"



OUTPUT / RESULT

Load graph at constant load profile (ampere) input for 10 hours

Calculated capacity (Ah) @ constant ampere input for 10 hours

Propose number of battery strings and battery type / model

Calculated % Depth of Discharge (%DOD) and possible number of life cycles before battery capacity has drop 20% from nominal capacity (Remaining capacity = 80%)

Hours

Bac

Parameters for battery sizing

- B.E.S.T Chart – Battery sizing with variable load (watt)

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INPUT REQUIREMENT

Input 1: choose batt type (VLA / VRLA)

Input 2: choose batt model (OPzS, OPzV & blocs battery)

Input 3: Nom. Sys. Volt (12, 24, 36, 48V)

Input 4: Nom. Final Disc. Volt (1.80 – 1.95)

Input 5: Number of parallel strings

Input 6: Operating Temperature

Input 7: Ageing factor - optional

Input 8: Lifetime factor (Temp.= 35°C, DOD < 20%) - optional

Input 9: Targeted Depth of Discharge (DOD)

Input 10: Load profile (amp. / watt., constant or variable load) – watt & variable load

INPUT

Parameters

Battery Type — Vented / VRLA

Model — OPzV solar.power

Nominal system voltage — 48 V

Final discharge voltage — 1.80 V / Cell — 1.)

Number of parallel battery strings — Yes / No — 1 — 2.)

Compensation factor "Capacity vs Temperature" — 30 / 86 °C / °F — 3.)

Compensation factor "Ageing" — Yes / No — 4.)

Compensation factor "Lifetime (T≥35°C (95°F) and DOD < 20% per day — Yes / No — 5.)

Utilization of the available capacity — 50 % — 6.)

Loadprofile — Ampere / Watt — 7.)

Step	Power [W]	Discharge Time	
1	5000.0	2.0	Hours
2	3500.0	1.0	Hours
3	7000.0	3.0	Hours
4	1200.0	1.5	Hours
5	3500.0	1.5	Hours
6	1250.0	1.0	Hours
7			Hours
8			Hours
9			Hours
10			Hours

8.)

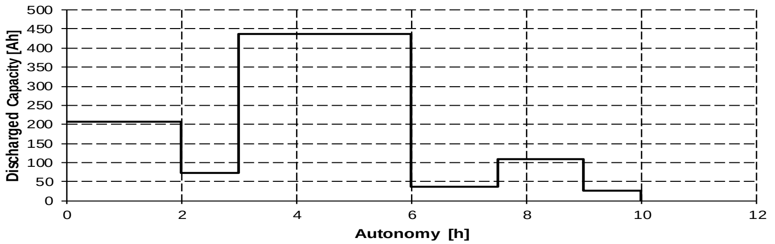
Footnote

Comments "Footnote"

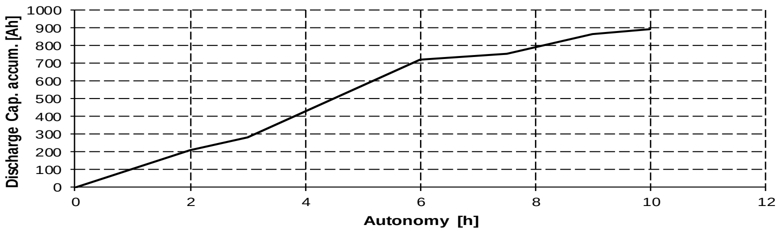
1.) Due to the long discharge times in solar application the final discharge voltages should be set like follows:
Autonomy ≤ 20h - 1,8 V/Cell
Autonomy ≤ 100h - 1,85 V/Cell
Autonomy > 100h - 1,9 V/Cell
2.) Selection only if number of strings are prescribed!
3.) Compensation factor for capacity loss or benefit depending on the ambient temperature.
4.) Compensationfactor 1,25 for ageing up to 80% of the nominal capacity.
5.) Compensation factor for accelerated ageing at ambient temperature > 35°C and a max. depth of discharge (DOD) of less than 20% per day.
6.) To optimize the cycling performance within a certain autonomy the max available battery capacity can be adjusted in a range between 0 - 80%.
7.) The loadprofile can be given in current [A] or power [W] values.
8.) The time frame for each load step can be adjusted individually!

RESULTS

Diagram " Discharged capacity and accumulated capacity depending on discharge time"



Load graph at variable load profile (watt) input for 10 hours

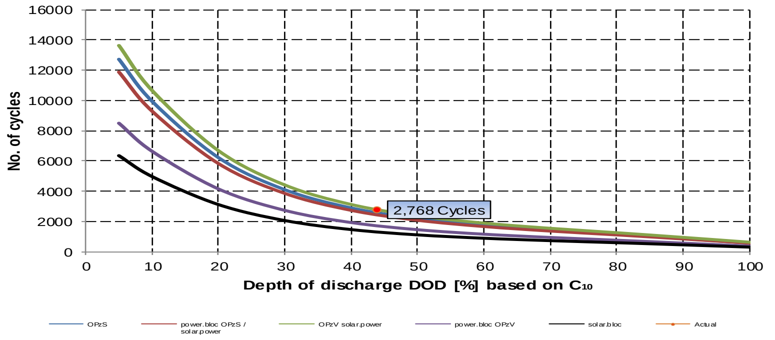


Calculated capacity (Ah) @ variable load (watt) input for 10 hours

Discharged Capacity	891.7	Ah
Total discharge time:	10.00	h
Power consumption (average):	4,280.00	Wh
Recommended Battery:	**1 x 24 cells**	**16 OPzV 2300 solar.power**

Propose number of battery strings and battery type / model

Diagram: "No. of cyles versus depth of discharge (DOD) based on the C10 capacity"



Calculated % Depth of Discharge (%DOD) and possible number of life cycles before battery capacity has drop 20% from nominal capacity (Remaining capacity = 80%)

Parameters for battery sizing

- B.E.S.T Chart – Charging at float voltage @ 2.25 Vpc

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INPUT REQUIREMENT

Input 1: Choose battery type

Input 2: battery nominal capacity

Input 3 : discharge capacity

Calculated battery DOD

Calculated remaining capacity

Calculated battery SOC

Input 4: Charging Voltage

Input 5: Target SOC

Input 6: Charging Currents

INPUT

Parameters

Battery Type

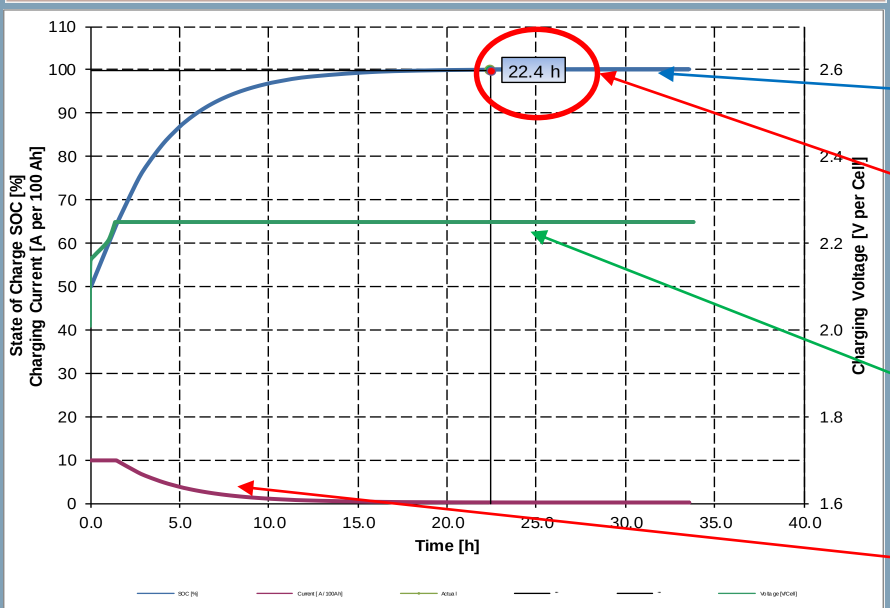
Vented (Density: 1,22 - 1,24 kg/ltr.)	○		
Vented (Density: > 1,24 kg/ltr.)	○		1.)
VRLA	◉		

Nominal Capacity (C10)	**2000**	Ah	2.)
Discharged Capacity	**1000**	Ah	3.)
Depth of Discharge [DOD]	50.00	%	
Remaining Capacity	1,000	Ah	
State of Charge [SOC]	50.00	%	
Charging voltage	2.25	V	4.)
Requested SOC	100	%	5.)
Charging Current	10	A per 100 Ah	6.)
	200	A	
Charging Factor	1		7.)

Footnote

RESULTS

Diagram "Charging Curve Depending on Charging Voltage, Charging Current and Time"



OUTPUT / RESULT

SOC Level (blue curve)

Charging time required from 50% SOC to 100% SOC with normal float charge @ 2.25 Vpc

Charging Voltage (green curve)

Charging Current (red curve)

Comments "Footnote"

1.) Battery type influences the acid density, the open circuit voltage as well as the available voltage window!
2.) Nominal capacity: Pb: C10 at 1,8 V/C; NiCd: C5 at 1,0 V/C, 20°C (68°F)
3.) Discharged capacity due to the load profile (Current x Time = Ah)
4.) Available charging voltage.
5.) Required state of charging during recharging (State of charge [SOC] and the appropriate time will be shown in the diagram!)
Causion: By using the charging factor please set the state of charge [SOC] to 100%!
The time frame for each load step can be adjusted individually!
6.) Available charging current in [A per 100 Ah]
7.) The required charging factor is depending on the depth of discharge [DOD], cell height, the electrolyte temperature and the charging voltage. For low charging voltages and low depth of discharges increase the charging factor!

Details / Comments

High charging voltages benefits the mixture of the electrolyte and is therefore generally recommended at deep discharges!

Typical charging factors are like follows:

Vented batteries:	1.20
VRLA batteries due to the capillar effect of the AGM /Gel:	1,05 - 1,10

Parameters for battery sizing

- B.E.S.T Chart – Charging at boost/equalize voltage @ 2.40 Vpc

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INPUT

Parameters

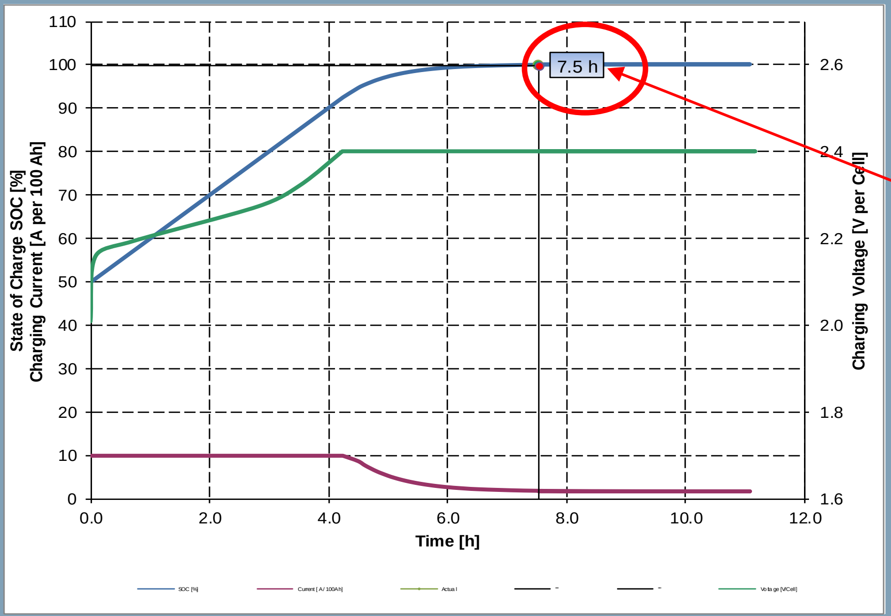
Battery Type

Vented (Density: 1,22 - 1,24 kg/ltr.)	○		
Vented (Density: > 1,24 kg/ltr.)	○		1.)
VRLA	◉		
Nominal Capacity (C10)	**2000**	Ah	2.)
Discharged Capacity	**1000**	Ah	3.)
Depth of Discharge [DOD]	50.00	%	
Remaining Capacity	1,000	Ah	
State of Charge [SOC]	50.00	%	
Charging voltage	2.4	V	4.)
Requested SOC	100	%	5.)
Charging Current	10	A per 100 Ah	6.)
	200	A	
Charging Factor	1		7.)

Footnote

RESULTS

Diagram "Charging Curve Depending on Charging Voltage, Charging Current and Time"



Charging time required from 50% SOC to 100% SOC with charge (boost) voltage of 2.40 Vpc

Comments "Footnote"

1.) Battery type influences the acid density, the open circuit voltage as well as the available voltage window!
2.) Nominal capacity: Pb: C10 at 1,8 V/C; NiCd: C5 at 1,0 V/C, 20°C (68°F)
3.) Discharged capacity due to the load profile (Current x Time = Ah)
4.) Available charging voltage.
5.) Required state of charging during recharging (State of charge [SOC] and the appropriate time will be shown in the diagram!)
Causion: By using the charging factor please set the state of charge [SOC] to 100%!
The time frame for each load step can be adjusted individually!
6.) Available charging current in [A per 100 Ah]
7.) The required charging factor is depending on the depth of discharge [DOD], cell height, the electrolyte temperature and the charging voltage. For low charging voltages and low depth of discharges increase the charging factor!

Details / Comments

High charging voltages benefits the mixture of the electrolyte and is therefore generally recommended at deep discharges!

Typical charging factors are like follows:

Vented batteries:	1.20
VRLA batteries due to the capillar effect of the AGM /Gel:	1,05 - 1,10

Table of contents

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- Site Storage Requirement
- Parameters for Battery Sizing
- Battery Depth of Discharge (DOD) & Life Cycles
- Charging Parameters for Solar Application
- Battery Maintenance
- Optimized Battery System (AquaGen & ECS)

Battery Depth of Discharge (DOD) & Life Cycles

Battery Terminology

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- ***State of Charge (SOC)(%)*** – An expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time.
- ***Depth of Discharge (DOD) (%)*** – The percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity. A discharge to at least 80 % DOD is referred to as a deep discharge.
- ***Terminal Voltage (V)*** – The voltage between the battery terminals with load applied. Terminal voltage varies with SOC and discharge/charge current.
- ***Open-circuit voltage (V)*** – The voltage between the battery terminals with no load applied. The open-circuit voltage depends on the battery state of charge, increasing with state of charge.
- ***Internal Resistance*** – The resistance within the battery, generally different for charging and discharging, also dependent on the battery state of charge. As internal resistance increases, the battery efficiency decreases and thermal stability is reduced as more of the charging energy is converted into heat.
- ***Nominal Voltage (V)*** – The reported or reference voltage of the battery, also sometimes thought of as the “normal” voltage of the battery.
- ***Cut-off Voltage*** – The minimum allowable voltage. It is this voltage that generally defines the “empty” state of the battery.

Battery Depth of Discharge (DOD) & Life Cycles

Battery Terminology

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- ***Charge Voltage*** – The voltage that the battery is charged to when charged to full capacity. Charging schemes generally consist of a constant current charging until the battery voltage reaching the charge voltage, then constant voltage charging, allowing the charge current to taper until it is very small.

- ***Float Voltage*** – The voltage at which the battery is maintained after being charge to 100 percent SOC to maintain that capacity by compensating for self-discharge of the battery.

- ***(Recommended) Charge Current*** – The ideal current at which the battery is initially charged (to roughly 70 percent SOC) under constant charging scheme before transitioning into constant voltage charging.

- ***Capacity or Nominal Capacity (Ah for a specific C-rate)*** – The coulometric capacity, the total Amp-hours available when the battery is discharged at a certain discharge current (specified as a C-rate) from 100 percent state-of-charge to the cut-off voltage. Capacity is calculated by multiplying the discharge current (in Amps) by the discharge time (in hours) and decreases with increasing C-rate.

- ***Cycle Life (number for a specific DOD)*** – The number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria. Cycle life is estimated for specific charge and discharge conditions. The actual operating life of the battery is affected by the rate and depth of cycles and by other conditions such as temperature and humidity. The higher the DOD, the lower the cycle life.

Battery Depth of Discharge (DOD) & Life Cycles

- solar.bloc: Cycle life vs Depth of Discharge and Temperature

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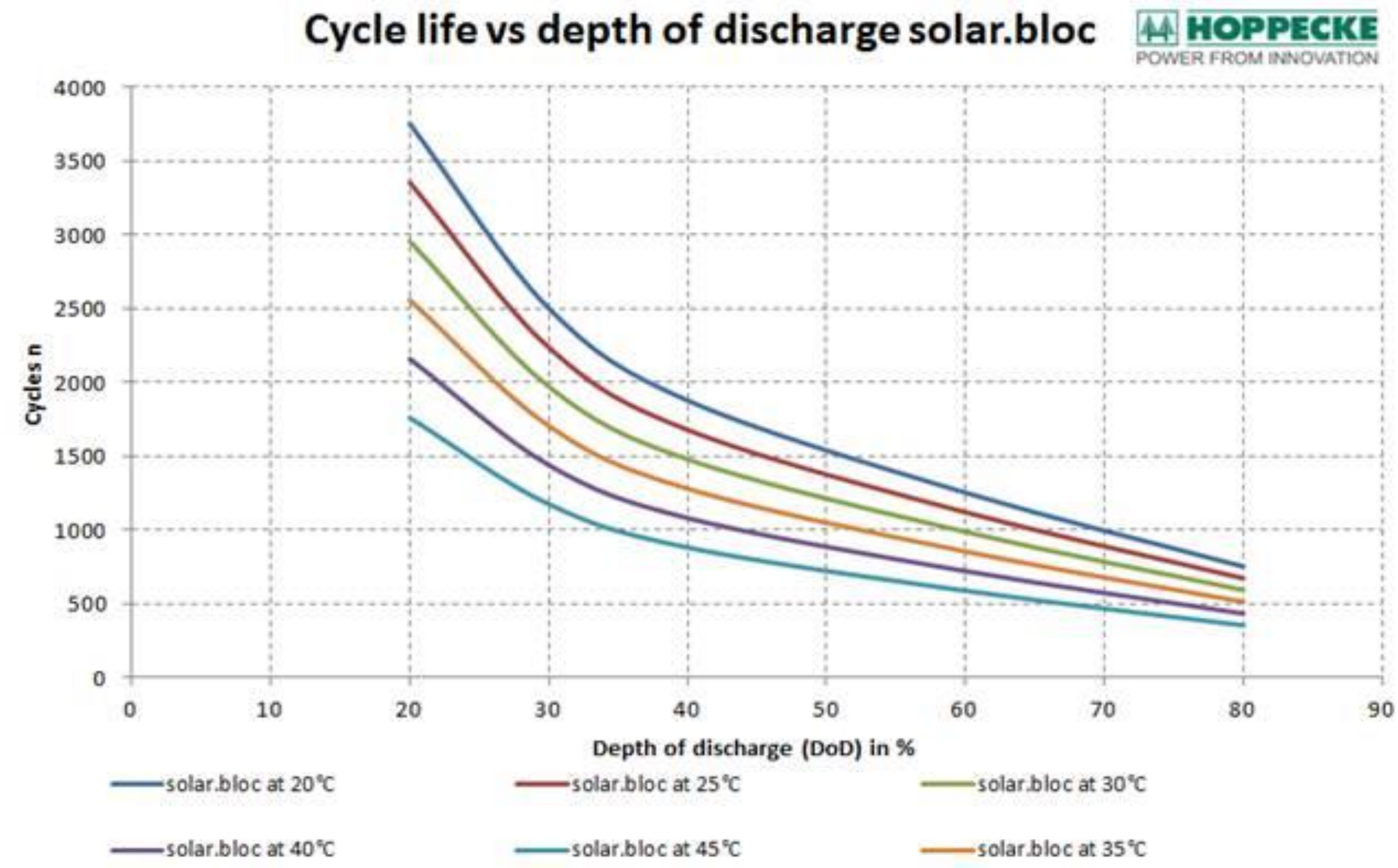

Battery Depth of Discharge (DOD) & Life Cycles

- OPzV solar.power: Cycle life vs Depth of Discharge and Temperature

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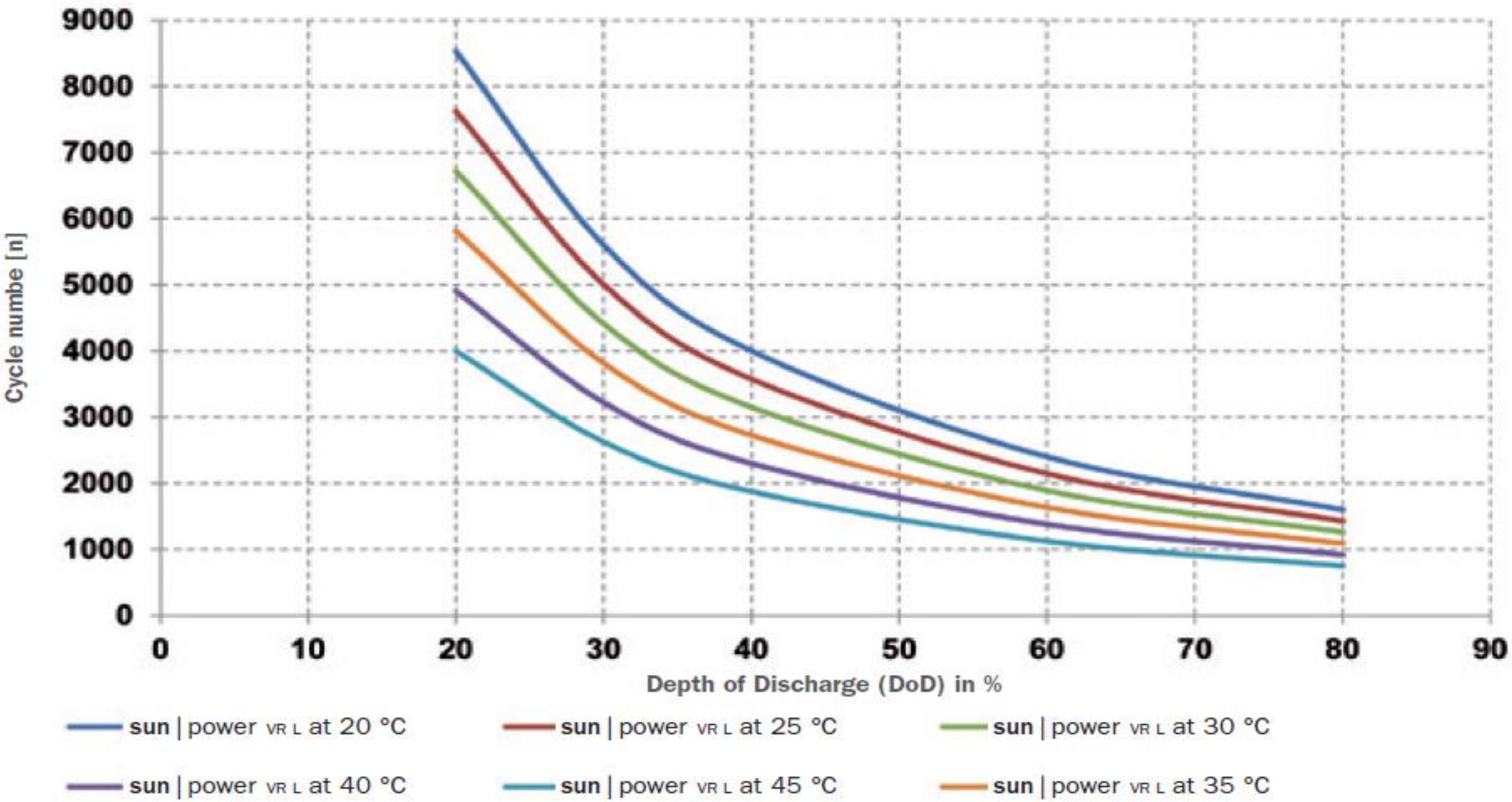
The following figure depicts dependency of the endurance in cycles on depth of discharge and temperature.



Battery Depth of Discharge (DOD) & Life Cycles

- OPzS solar.power: Cycle life vs Depth of Discharge and Temperature

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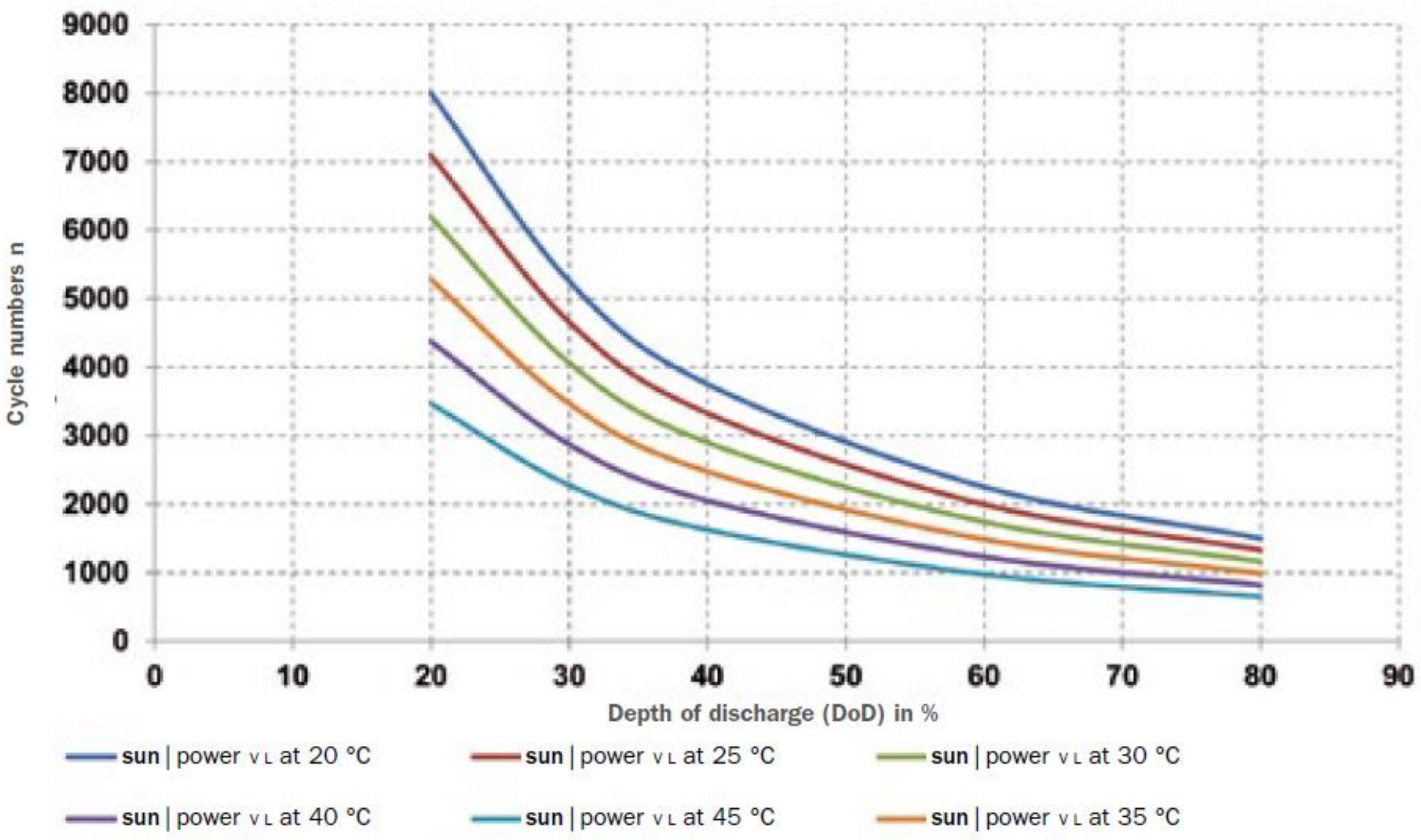

Table of contents

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Charging Parameters for Solar Application

- Charging Stage/Phase in Solar Application

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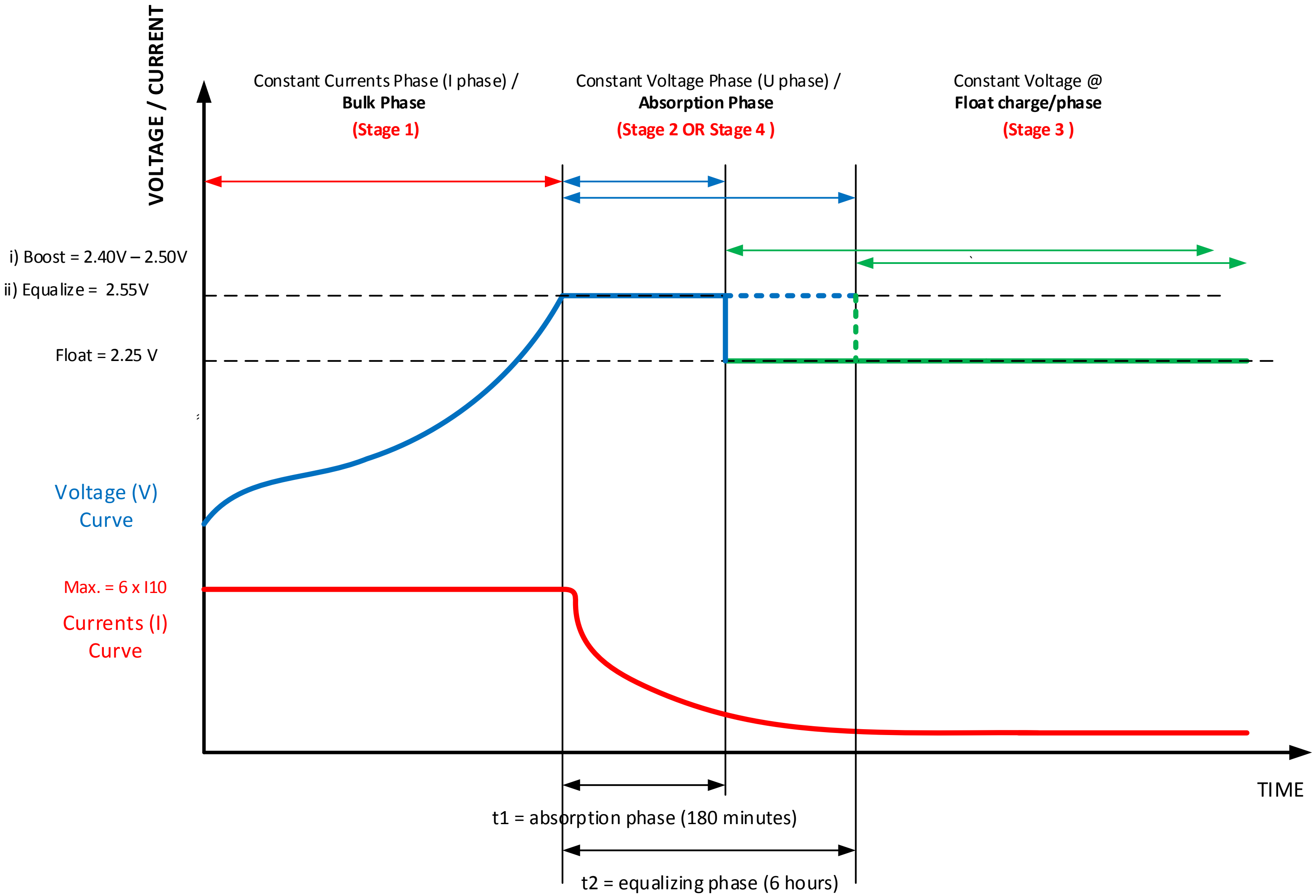
- **Stage 1 – boost/bulk charge phase**: this is a period of constant current and increased voltage that provides most of the charge. Charging voltage runs up to the full-rated output of the battery charger for faster charging. Limiting of charging voltage and charging currents required to protect the battery from overcharge.
- **Stage 2** – **absorption phase**: also called the soak stage or topping stage. The charging currents drops during this stage while the charging voltage remain at the same boost charge value. It is held for a controlled period so the electrolyte solution has the opportunity to absorb the charge fully and completely. If a battery is left at this charge stage, it will overcharge.
- **Stage 3** – **Float phase**: A lower voltage “trickle” charge is delivered to maintain the battery’s fully charge while not overcharging. In the float stage, the battery is at full charge (almost full charge) and ready for next discharge.
- **Stage 4** – **Equalization phase**: A battery bank consists of many individual battery cells connected in series which all behave slightly different. Over time, this results in different charge levels in individual cells. This can lead to premature failure, initially of individual cells, and finally to failure of the entire bank. Equalization charge will bring up individual cell voltage at same levels.

Charging Parameters for Solar Application

- Charging with IU Characteristics (constant currents & constant voltage)



Charging Parameters for Solar Application

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- Recommended Charging Parameters for VRLA, OPzV solar.power & solar.bloc

Parameter	sun | power VR L OPzV solar.power	sun | power VR M solar.bloc
battery charge		
max. charging current	6 x I10	6 x I10
standard charge (regular operating cycles)		
characteristic	IU (with subsequent switchover to float)	IU (with subsequent switchover to float)
max. current (consider the fuses and cable lengths)	6 x I10	6 x I10
max. voltage absorption phase	2.4 - 2.5 V/cell	2.4 V/cell
recommended absorption time	180 min	180 min
float charge	No change-over due to a current threshold!	No change-over due to a current threshold!
voltage	2.25 V/cell +/- 1%	2.25 V/cell +/- 1%
temperature correction	<20 °C: -3 mV/K >=20 °C: 0 mV/K	<20 °C: -3 mV/K >=20 °C: 0 mV/K
equalization charge (frequency depending on which of the following two criteria occurs first)		
frequency/cycle, based on capacity throughput	10 x Cn	10 x Cn
frequency/cycle, based on time period	40 days	40 days
characteristic	IU/IUIa (with subsequent switchover to float)	IU/IUIa (with subsequent switchover to float)
comment to the characteristic	At IUIa characteristic: current in Ia phase max. 0.8 A/100 Ah C_{10} for 2 to 4 h	At IUIa characteristic: current in Ia phase max. 5 A/100 Ah C_{10} für 2 bis 4 h
max. current (note the fuses and cable lengths)	6 x I10	6 x I10
max. voltage absorption phase	2.55 V/c at IU-characteristic 2.4 V/c at IUIa-characteristic	2.5 V/c
absorption time	6 h	4 h

Charging Parameters for Solar Application

- Recommended Charging Parameters for VLA, OPzS solar.power

Parameter	sun | power VL OPzS solar.power without electrolyte circulation pump	sun | power VL OPzS solar.power with electrolyte circulation pump
battery charge		
max. charging current	6 x I10	6 x I10
standard charge (regular operating cycles)		
characteristic	IU (with subsequent switchover to float)	IU (with subsequent switchover to float)
max. current (consider the fuses and cable lengths)	6 x I10	6 x I10
max. voltage absorption phase	2.55 V/c	2.4 V/c
recommended absorption time	180 min	180 min
float charge	No change-over due to a current threshold!	No change-over due to a current threshold!
voltage	2.23 V/cell +/- 1%	2.23 V/cell +/- 1%
temperature correction	<20°C: -3mV/K >=20°C: 0mV/K	<20°C: -3mV/K >=20°C: 0mV/K
equalization charge (frequency depending on which of the following two criteria occurs first)		
frequency/cycle, based on capacity throughput	10 x Cn	10 x Cn
frequency/cycle, based on time period	40 days	40 days
characteristic	IU/IUIa (with subsequent switchover to float)	IU/IUIa (with subsequent switchover to float)
comment to the characteristic	At IUIa characteristic: current in Ia phase max. 5A/100Ah C10 for 2 to 4h	At IUIa characteristic: current in Ia phase max. 5A/100Ah C10 for 2 to 4h
max. current (note the fuses and cable lengths)	6 x I10	6 x I10
max. voltage absorption phase	2.55 V/c at IU-characteristic 2.4 V/c at IUIa-characteristic	2.55 V/c at IU-characteristic 2.4 V/c at IUIa-characteristic
absorption time	8h	6h

Table of contents

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Battery Maintenance

Why battery maintenance and surveillance ?

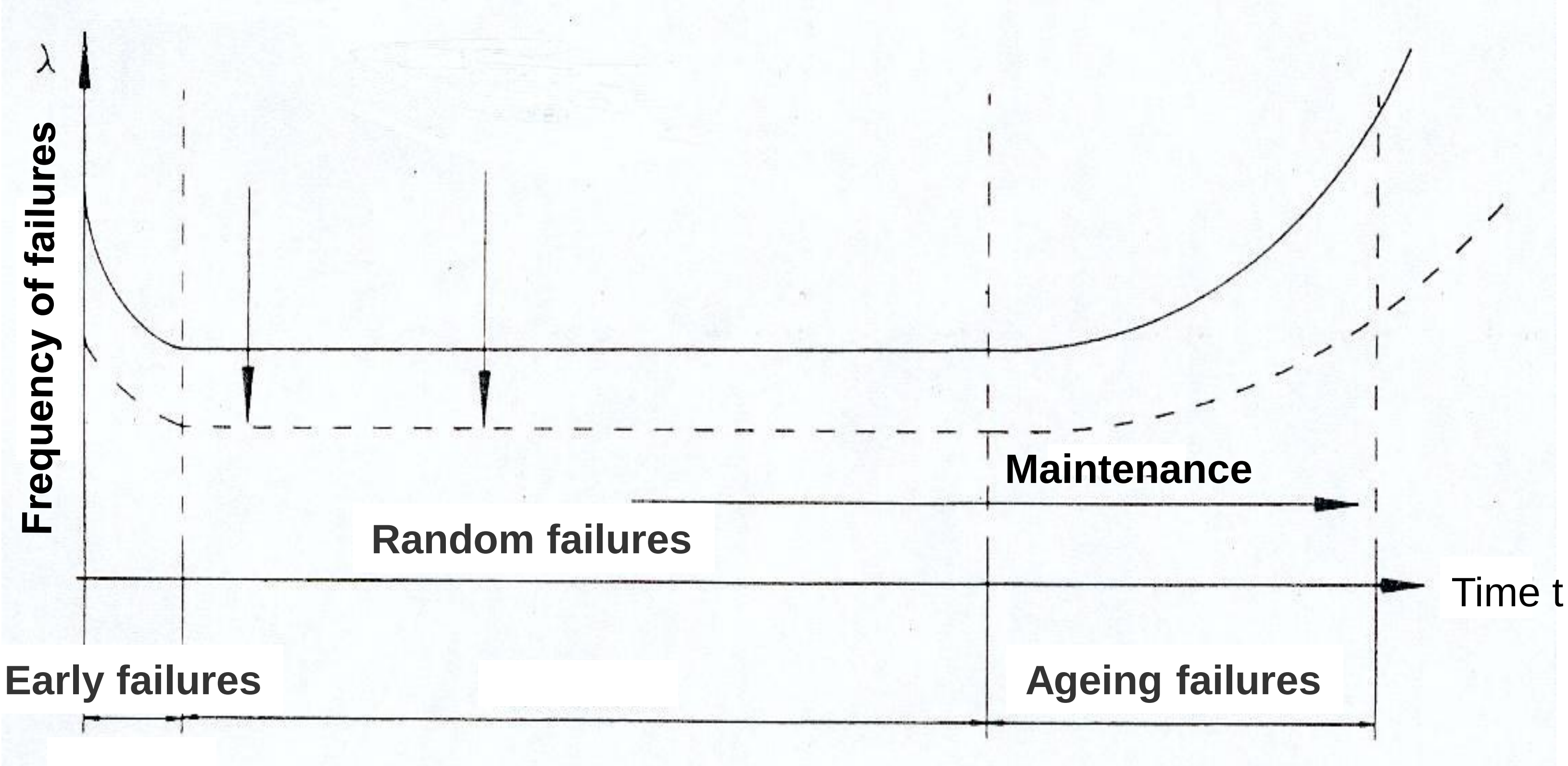
It ensures maintaining the operation

It supports the extension of service life

Battery Maintenance

Battery maintenance / monitoring and life time

Battery maintenance / monitoring and life time



- Early failures : manufacturing quality and commission (Supplier)
- Random failures : operating conditions/ Stress-Factors (Customer)
- Ageing failures : dependant on care and maintenance (Customer)

Maintenance

Take records of the type and scope of maintenance works performed, (reference chapter 8 of maintenance handbooks Vented or VRLA). This is helpful for

- troubleshooting
- claiming defects

1.Measure the room temperature (recommended between 10°C to 30°C)

2.Measure the surface temperature of each individual cell or monobloc (if VRLA batteries are concerned) or the electrolyte temperature and density (if Vented batteries are concerned). There must be a maximum deviation of +/-5 K between individual cell or monobloc temperatures.

3.Do a visual inspection of the battery rack and battery cells (clean impression, no dried particles, no deformation of poles).

Battery Maintenance

Measurement of Voltage (during float operation)

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half-yearly:
Measure system voltage (Check the rectifier)
Tolerance of voltage: +/- 1 %

every year:
Measure single cell or bloc voltages

Range refers to the mean value of the average of measured total system voltage

Vented/flooded batteries				
Voltage of the cell / bloc battery	2 V	4V	6V	12V
Maximum allowed voltage tolerances on float operation	-0,05 V +0,10 V	-0,07 V +0,14 V	-0,09 V +0,17 V	-0,12 V +0,25 V

Sealed/valve-regulated batteries				
Voltage of the cell / bloc battery	2 V	4V	6V	12V
Maximum allowed voltage tolerances on float operation	-0,10 V +0,20 V	-0,14 V +0,28 V	-0,17 V +0,35 V	-0,25 V +0,50 V

Battery Maintenance

Measurement of acid density (during float operation)

half-yearly:
Measuring the density on pilot cells
Tolerance of density: +/- 0,01 kg/l

every year:
Measuring of individual cell densities

Tolerance:	Lead, vented	+/- 0,01 kg/l
	Lead, valve-regulated	not applicable

Each value with reference to the nominal acid density and room temperature of the product

Battery Maintenance

Measurement of acid density (during float operation)

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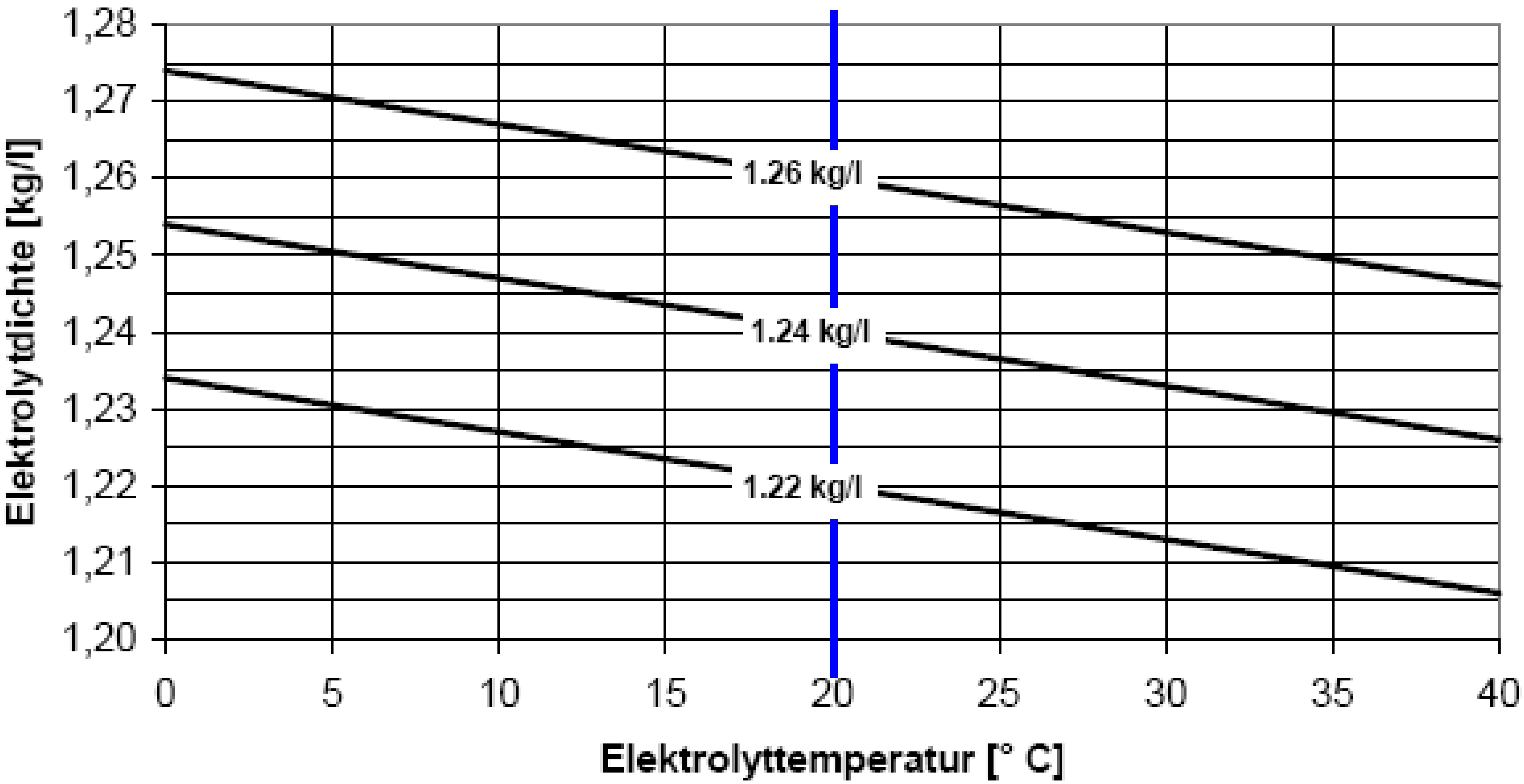
Influence of temperature on the acid density



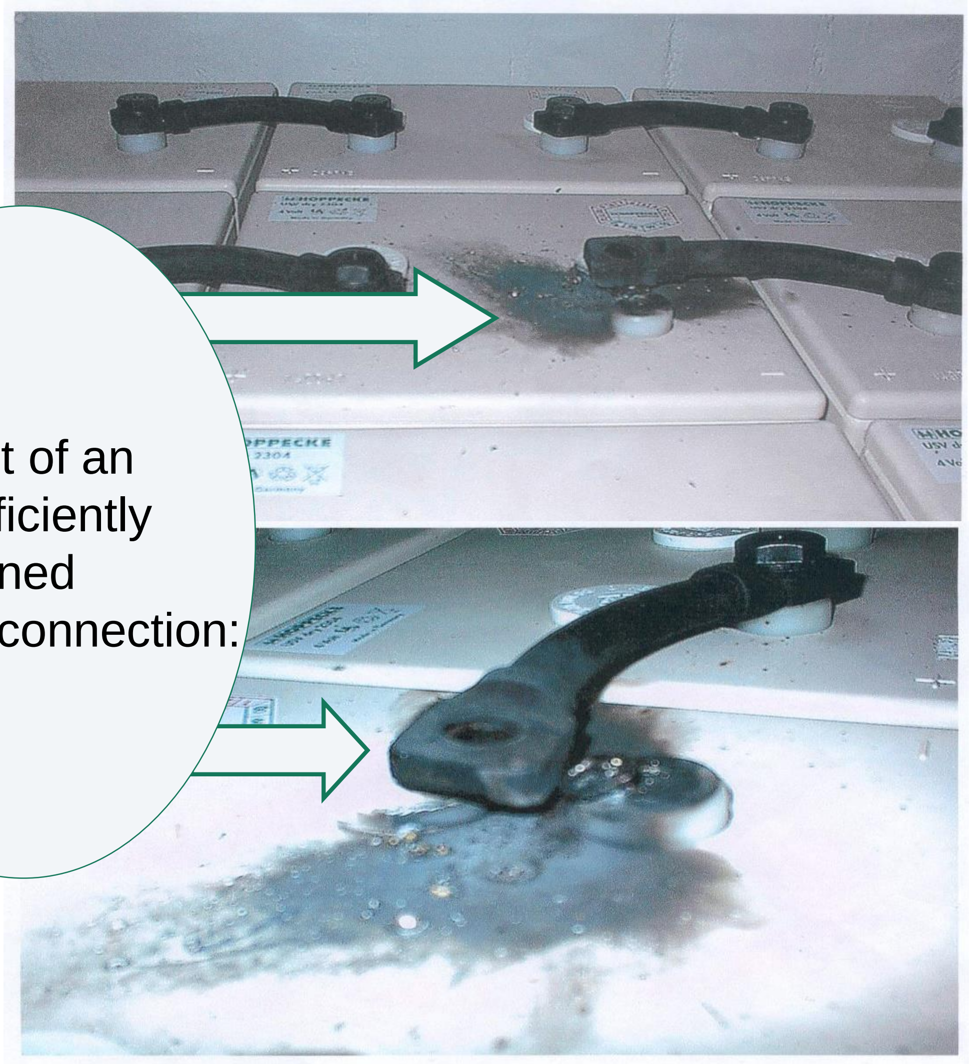
Battery Maintenance

- Examination of tight connectors

- Check tight position of pole screw

Not correctly tightened screw connections cause overheating of materials and can cause fire.

Result of an insufficiently tightened pole connection:



Battery Maintenance

- Examination of tight connectors

- Screws are fixed with a torque of 20 Nm
- All screws have a protection against self-loosening (thread with lock-tight)
- Protection against self-loosening disappears with repeated installation

Protection against self-loosening

Battery Maintenance

- Keeping the battery surface clean

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- Attention, electrostatic charge !!!

For cleaning of batteries only use **absorbent cleaning cloths,** which are moisted **with water.**

Other cleaning detergents can lead to **electrostatic charge** or damage the battery container.

Part EN 50272-2:2001

Battery Maintenance

- Keeping the battery surface clean

- Example of grossly negligence !!!

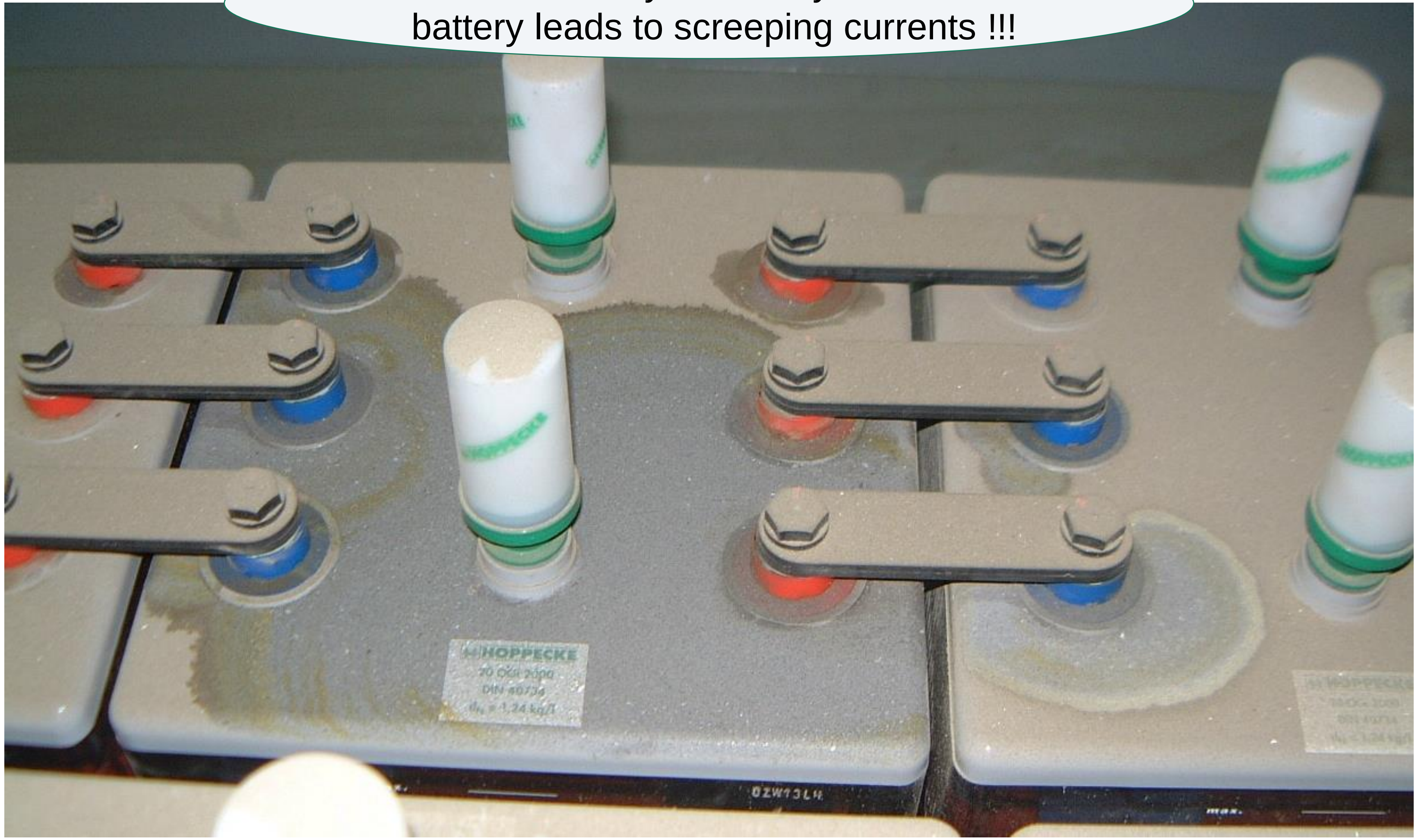
Dangerous example from the field …

Battery Maintenance

- Keeping the battery surface clean

- Example of insufficient care !!!

With humidity a dust layor on the battery leads to screeping currents !!!



Battery Maintenance

- Keeping the battery surface clean

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In order to avoid screeping currents, which cause a diversion of the potentional or even evolve short circuits in an extreme situation.

Attention:

Clean the battery only

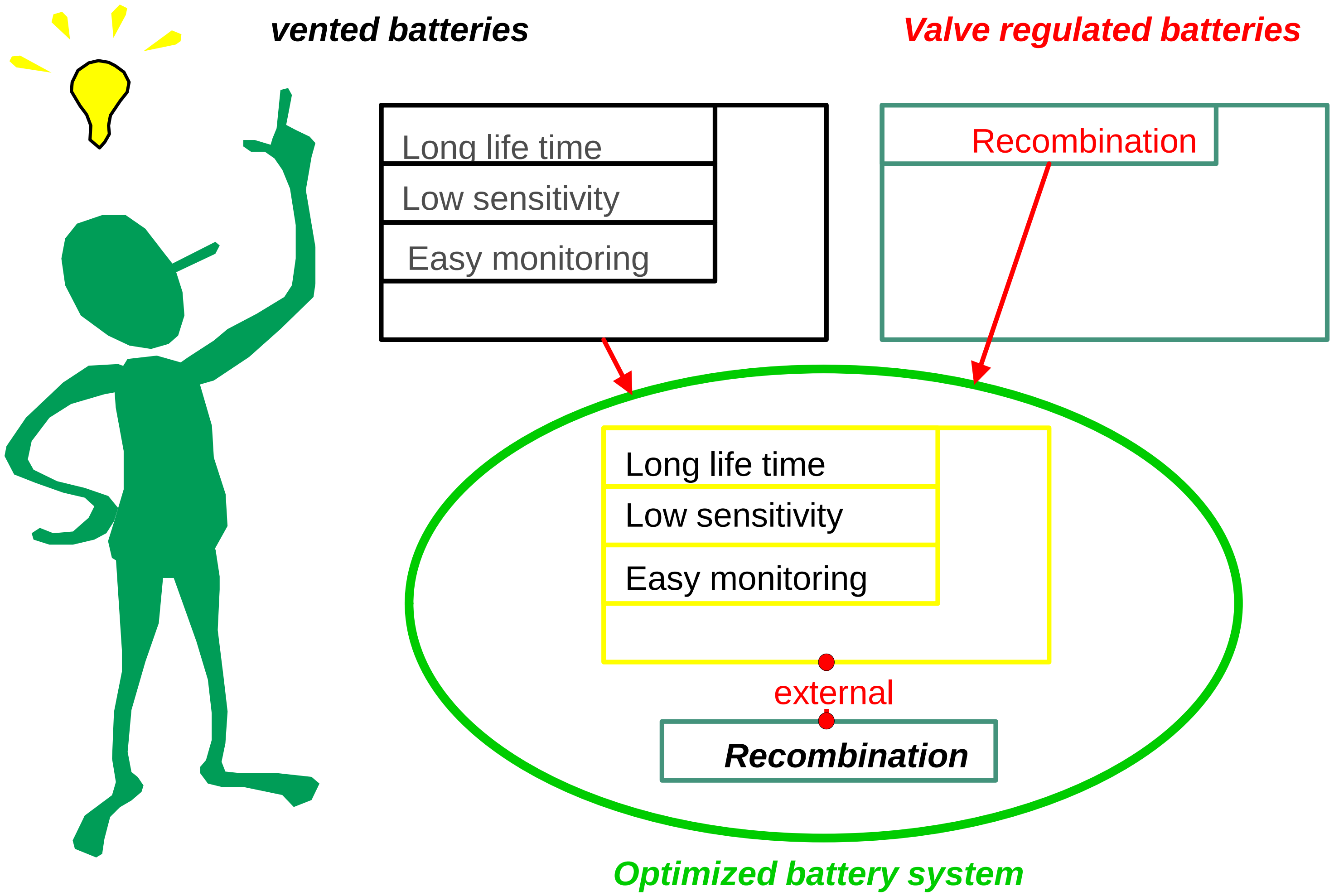
- With humid cloth
- Without cleaning detergents

Table of contents

HOPPECKE
POWER FROM INNOVATION

Optimized Battery System

1) Benefit of AquaGen



Optimized Battery System

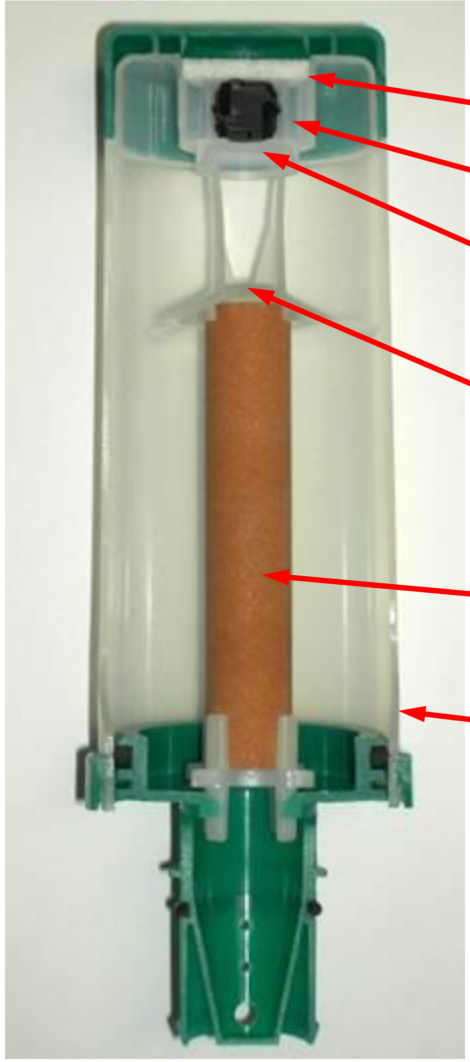
1) Benefit of AquaGen

POWER FROM INNOVATION

Installation of AquaGen premium.top H possible for batteries up to 350 Ah for higher capacities AquaGen premium.top V have to be used

Optimized Battery System

1) Benefit of AquaGen



flash back protection

valve

opening permits escaping gas when overloading

cover (roof) for the protection against falling down drops

ceramic protection for the catalyst

dome for the condensation of the water vapor

Optimized Battery System

1) Benefit of AquaGen

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- ***Operation:***

  - **Inside the batteries takes part as secondary reaction - water decomposition of liquid electrolyte**
  - **during the operation of the AquaGen® premium.top-recombination systems the developed oxygen and hydrogen gas is moving to the AquaGen® plug**
  - **by the integrated catalyst these gases recombined to the water vapour**
  - **the water vapour condenses at walls of the dome of the AquaGen® premium.top-plug**
  - **water drops flow themselves downward back into the battery**

Optimized Battery System

1) Benefit of AquaGen

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POWER FROM INNOVATION

- ***Customer benefits:***

  - **maintenance intervals are fully extended with even total freedom from maintenance (up to 98 % recombination rate)**

  - **no damage of the battery by refill of contaminated water**

  - **Reduction of the ventilation requirements by 50 % small costs of room air engineering**

  - **Prevention of a danger of explosion by outside flaming/spark effect with integration of a backfire protection**

  - **No significant escape of gas or of electrolyte fumes**

  - **Decrease of maintenance and installation costs with increased safety**

  - ***high operational battery life time at low maintenance costs (topping up with water)***

Optimized Battery System

1) Benefit of AquaGen

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POWER FROM INNOVATION

16 OPzS solar.power 2900

Depth of Discharge = 50%

Number of Cell = 24 (48V system)

Number of cycles per year = 365

Temperature - 30°C

Charging Voltage = 2.4 V

Number of refilling interval
Without AquaGen = 96
With AquaGen = 4

Calculation of the water consumption / maintenance costs at vented lead acid batteries

HOPPECKE POWER FROM INNOVATION

INPUT

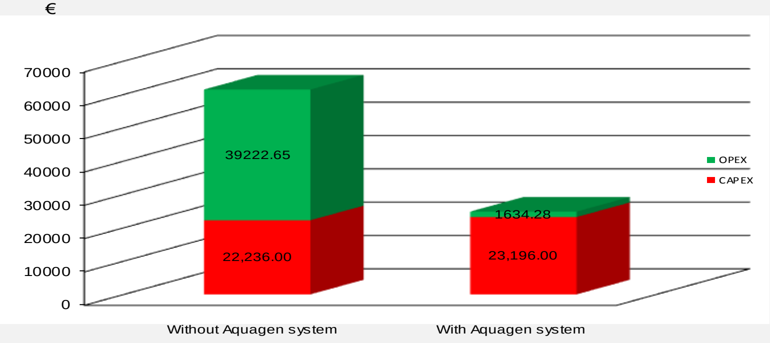
Parameters

Currency	€		
Battery Type	16 OPzS solar.power 2900		
Real Capacity (C10 at Uf=1,8 V/Cell)	2146	Ah	
Design Life	20	Years	
Type Aquagen premium.top	48	PTV	1.)
Aquagen recombination efficiency	**95**	%	2.)
Depth of Discharge [DOD]	**50**	%	3.)
No. of cells	**24**		
Actual Age of the Battery System	**0**	Years	4.)
Expected Service Life of the Battery	**10.0**	Years	5.)
Number of cycles per year	365		6.)
Temperature	30 / 86	°C / °F	7.)
Charging voltage	2.4	V	8.)
Raising of the Water Consumption over Battery Life Time	4		9.)
Price Aquagen premium.top PTH or PTV	**20.00**	€	
Price for Destilled Water or Preparation of Water per Litre	**1.50**	€	
Price Arrival / Departure / Provide Water Overal	**40.00**	€	
Price per hour Service Stuff	**50.00**	€	
Time to Refill one Battery String	**5.40**	h	10.)
Price of battery without Aquagen premium.top	**22,236.00**	€	
Price of battery with Aquagen premium.top	23,196.00	€	

Footnote

RESULTS

Comparison of CAPEX and OPEX with and without Aquagen ® premium.top



Difference over the complete observed time (cost reduction potential)	36628.37	€
Accumulated cost reduction over the complete battery life time	59.60	%

	Without Aquagen	With Aquagen	
Number of refilling intervals	96	4	
Amount of refilled water during the complete time	6,308.43	262.85	ltr.
Service cost including refilling + working time + arrival + water	39,222.65	1,634.28	€
System price	22,236.00	23,196.00	€
System price including maintenance costs	61,458.65	24,830.28	€

Comments "Footnote"

1.) Aquagen classification will be done automatically depending on battery capacity
2.) Aquagen recombinations rate - Default value 95%
3.) Discharge depth according load profile (Σ Discharge Current x Time)
4.) PbSb batteries increases their water consumption over life time due to the antimony poisioning effect of the negative electrode. The consequence will be higher costs savings at aged PbSb batteries by using the Aquagen recombiners.

5.) Item 4.) and 5.) correlates with the time frame for sizing of the OPEX costs. The expected service life of a battery is depending on the design life or cycling ability, which means that both values have to be correlated to each other!
6.) Discharge and charge cycles increase the water consumption due to the needed overcharge capacity to prevent acid stratification. (Charge factor: 1,20)

7.) Operating temperatures above 20°C leads to a higher water consumption if the charging voltage is not temperature regulated! (Arrhenius)
8.) Charging voltage which is mainly used at the battery system. This will be for batteries in standby operation generally 2,23 V/Cell, whereas cyclic application uses 2,40 V/Cell.

9.) Recommended ageing factor: PbSb = 4, PbCa = 1, NiCd = 1
10.) Investment- and operation- costs, which have to be adapted individually based on customers respectively countries to calculate the appropriate costs savings.

Details / Comments

The water consumption of a lead acid battery can differ really much depending on the application. Batteries in standby operation will be kept in fully charged condition by a certain float charge current, which is going into the battery. This overcharging is the main reason for the water consumption of the battery.
Batteries in cyclic applications have quite often discharge and charge cycles every day followed by a switch off. To eliminate the phenomenon of acid stratification or to compensate charge losses it is necessary to put a certain overcharge capacity inside the battery. This means for vented lead acid generally a charge factor of 1,20 at each fully recharge.

During overcharging 1 Ah decompose 0,3361g H2O und generates 0,449 ltr. hydrogen at 20°C /68°F

Optimized Battery System

1) Benefit of AquaGen

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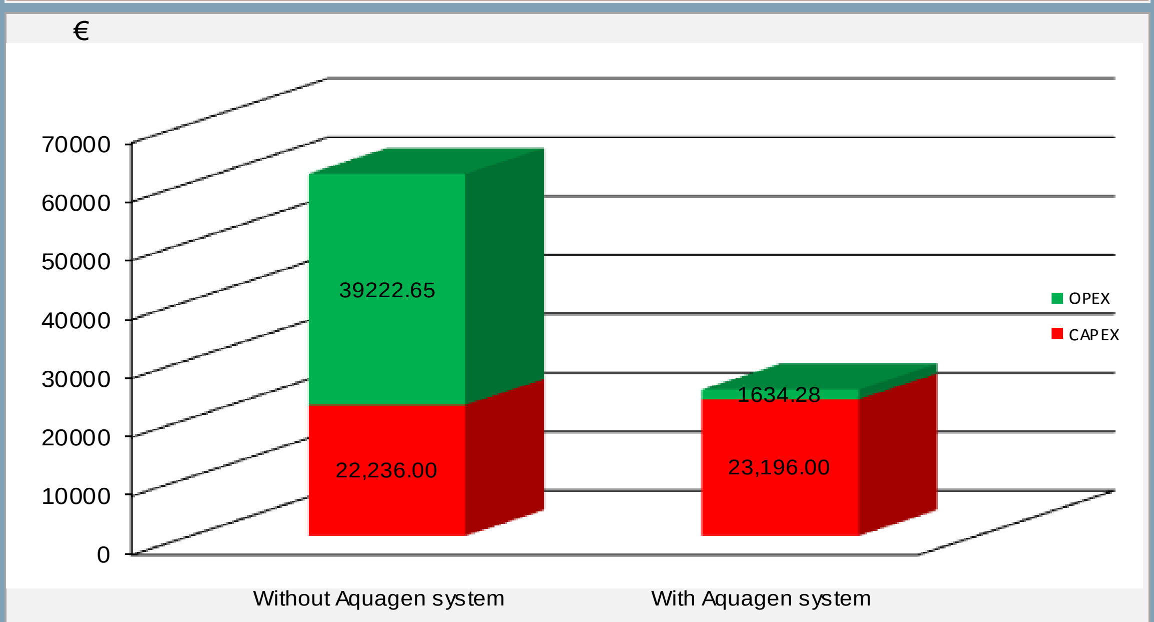
R E S U L T S

Comparison of CAPEX and OPEX with and without Aquagen ® premium.top



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Without AquaGen = 96
With AquaGen = 4

Details / Comments

Optimized Battery System

1) Benefit of AquaGen

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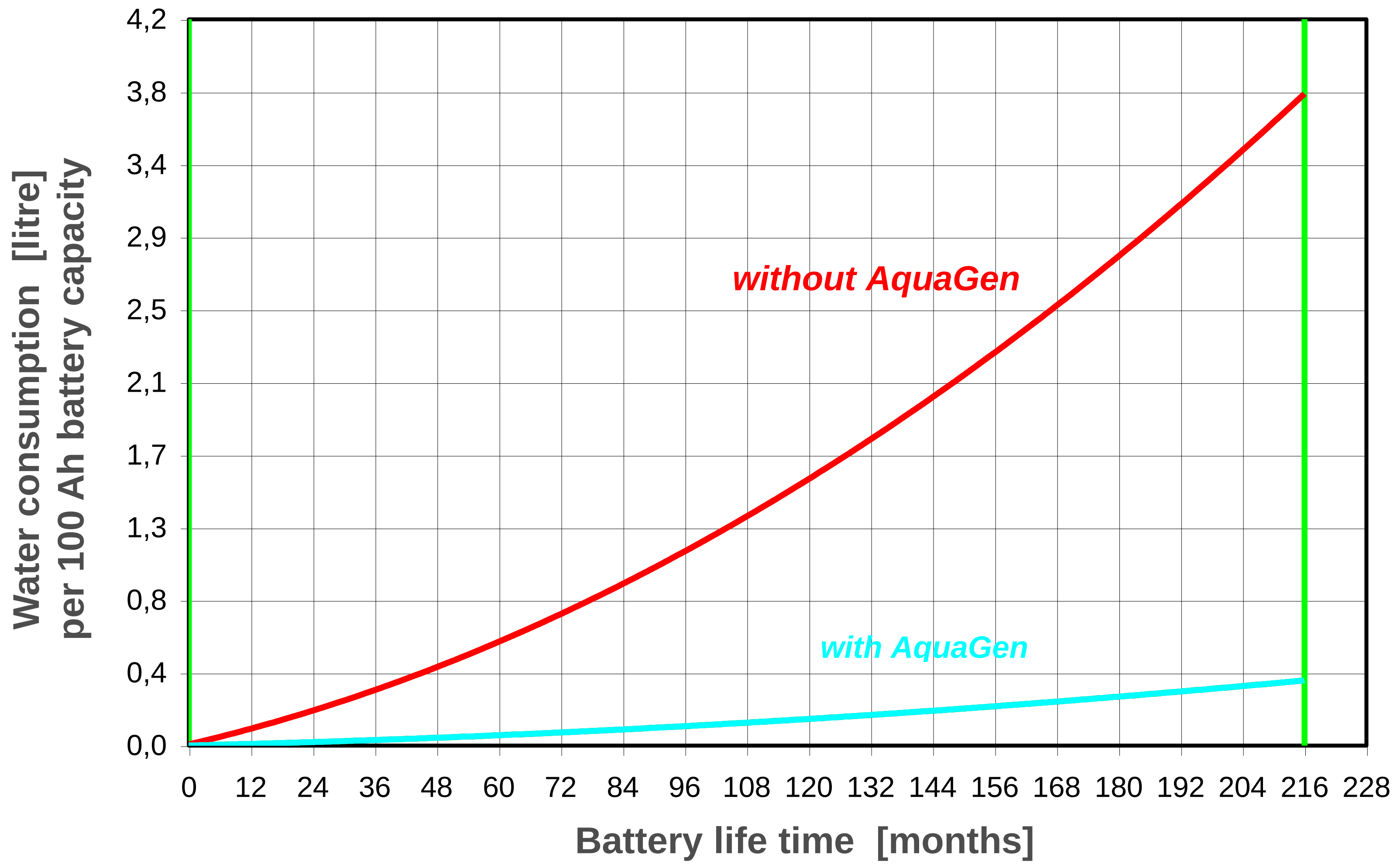
- ***Comparison water consumption during battery life time – standby operation***



Optimized Battery System

Installation with AquaGen

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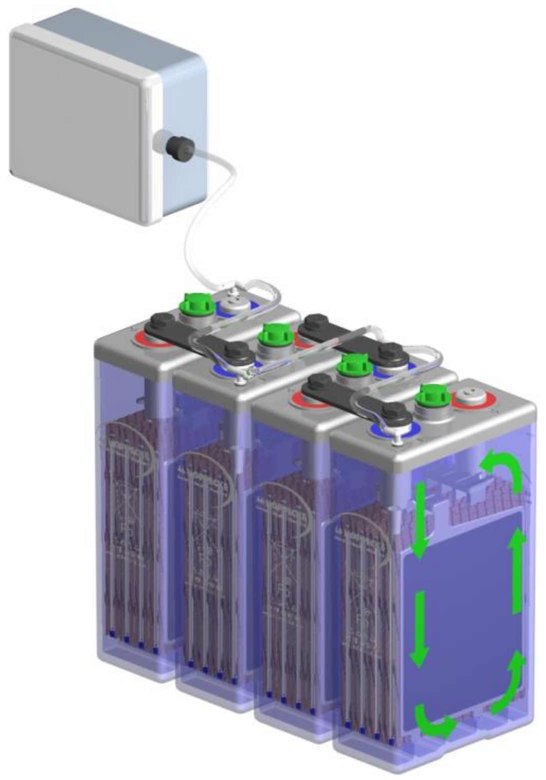
HOPPECKE Electrolyte Circulation System – Applications



Typical Applications:

Solar-/Off-grid applications
Power supply for remote off-grid applications and isolated power networks, drinking water supply systems, healthcare facilities

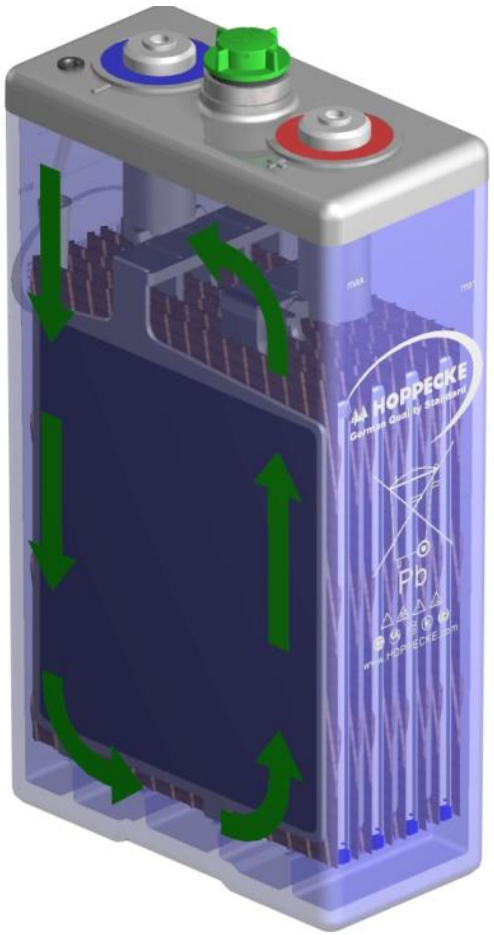
Telecommunications
Mobile phone stations, BTS stations, Off-grid/on-grid solutions

Traffic Systems
Signaling systems, Lighting

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

HOPPECKE Electrolyte Circulation System – Benefits



Your benefits with the HOPPECKE Electrolyte Circulation System:

Economic Recharge – cost reduction through increased charging efficiency, significant reduced recharge time

Environmental-friendly – reduced runtime of additional (Diesel) generators and cost savings

Extended battery service life – no acid stratification

Minimum maintenance costs – maintenance free pump system (automatically controlled)

Reduced battery service costs – reduced water loss for longer refill intervals

HOPPECKE Electrolyte Circulation System – Features

Operation Concept:
The HOPPECKE Electrolyte Circulations System pumps ambient air to the bottom of each battery cell. Emerging air bubbles rise through the electrolyte, ensuring a homogeneous electrolyte density distribution in each cell. The system is switched on and off automatically and virtually maintenance free.

Features:

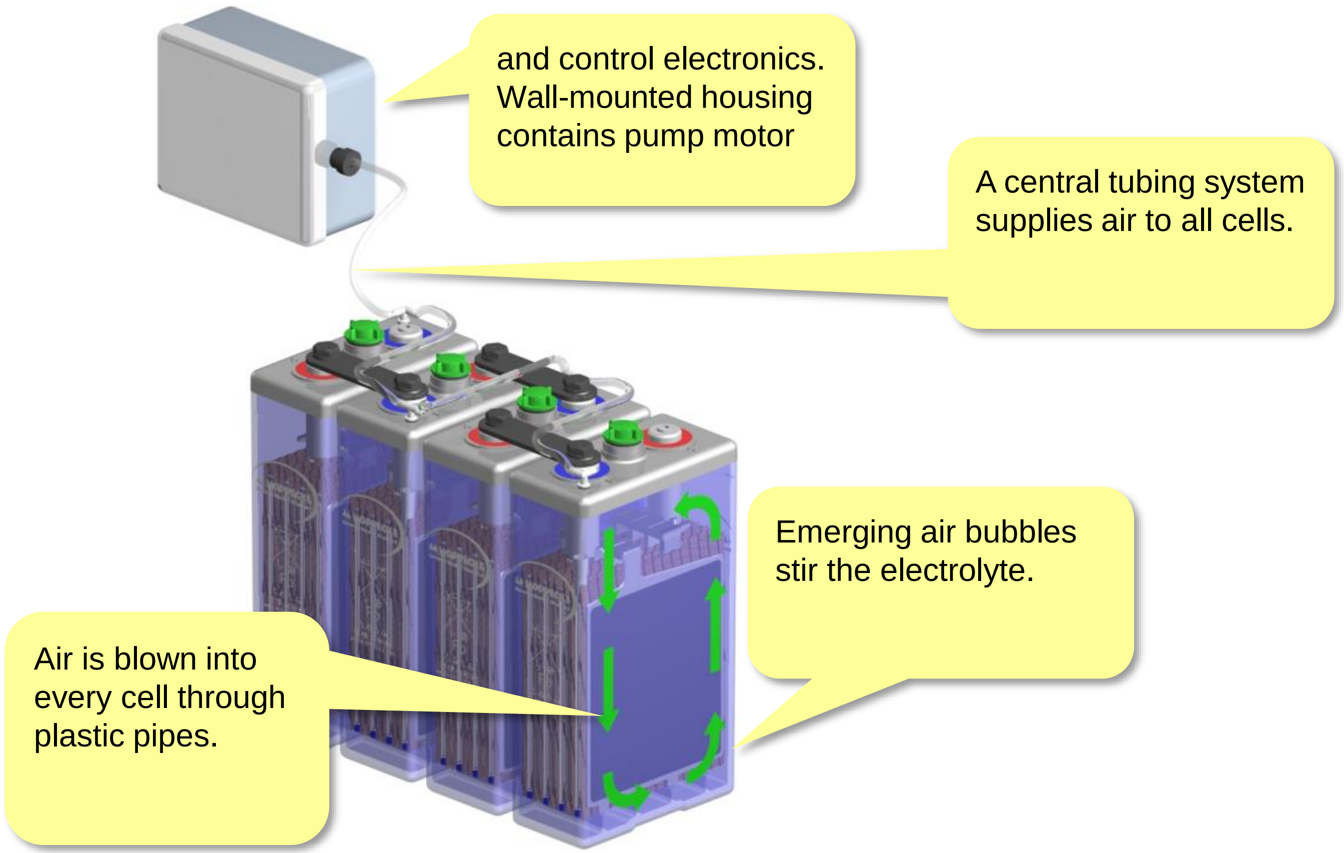
- Easy to install system components (plug & play).
- Pump is switched by µ-controller and works automatically.
- System can be retrofit.
- Maintenance free pump motor.
- Filter for air intake.
- Backpressure valve for protection of pump motor and control unit.

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

HOPPECKE POWER FROM INNOVATION

➢ HOPPECKE Electrolyte Circulation System – functional principle



Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

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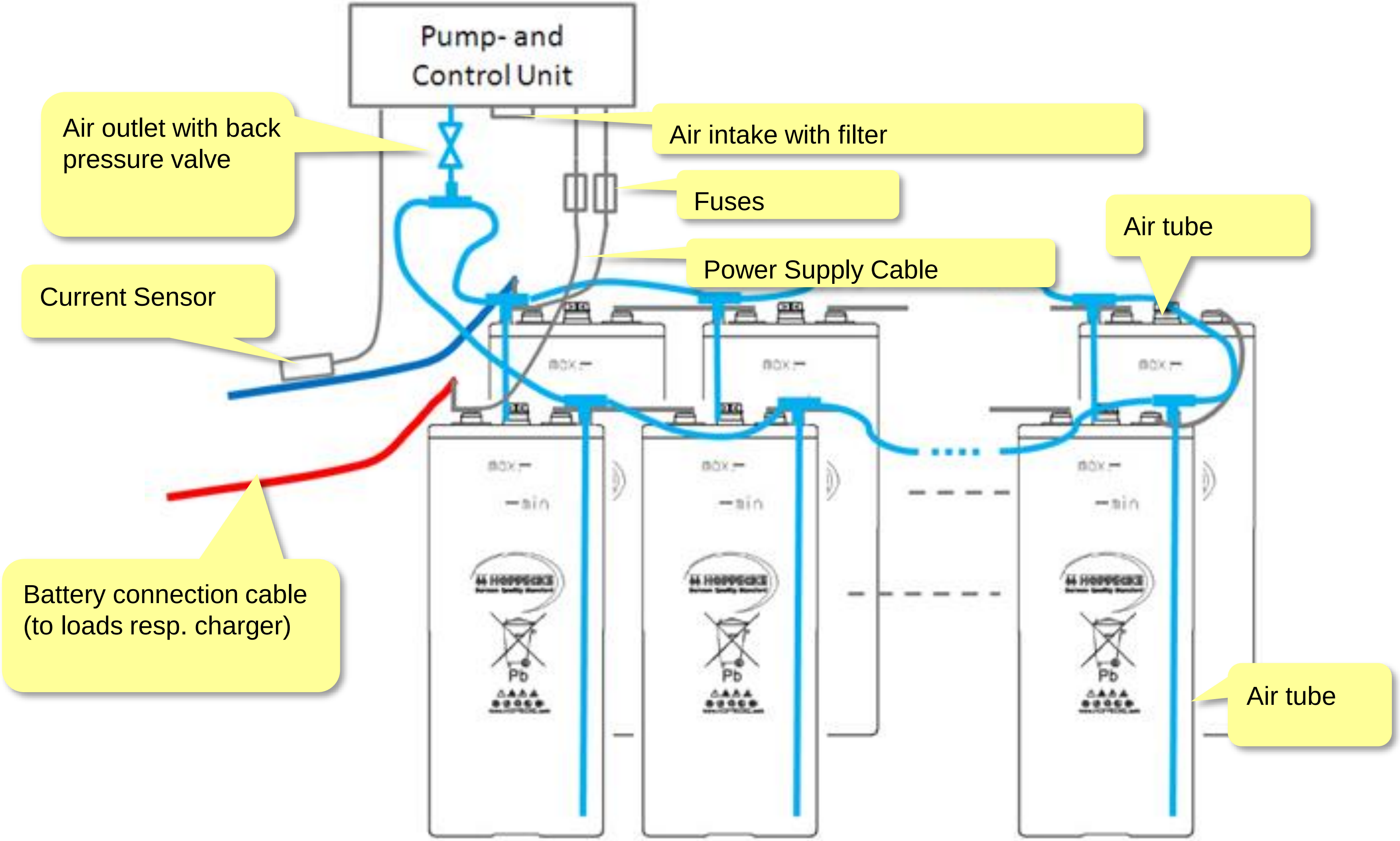
- HOPPECKE Electrolyte Circulation System – Overview Components



Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

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➢ HOPPECKE Electrolyte Circulation System – Advantages

Increase of efficiency and cost savings:

Typically up to 120% of discharged energy need to be recharged in order to reach the initial state of charge (vented lead acid battery types). This charging factor includes the elimination of acid stratification.

Application of the HOPPECKE electrolyte circulation system reduces the required charging factor significantly. **Increase of efficiency is up to 15%** compared to charging without electrolyte circulation system.

Therefore **less time and energy** is required to recharge the battery and to achieve a homogeneous electrolyte distribution.

The electrolyte circulation system **reduces also service costs** because of **reduced water loss compared** to conventional charging.

Moreover the HOPPECKE electrolyte circulation system **increases service life** of the battery and provides environmental and economical benefits for the entire battery system.

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

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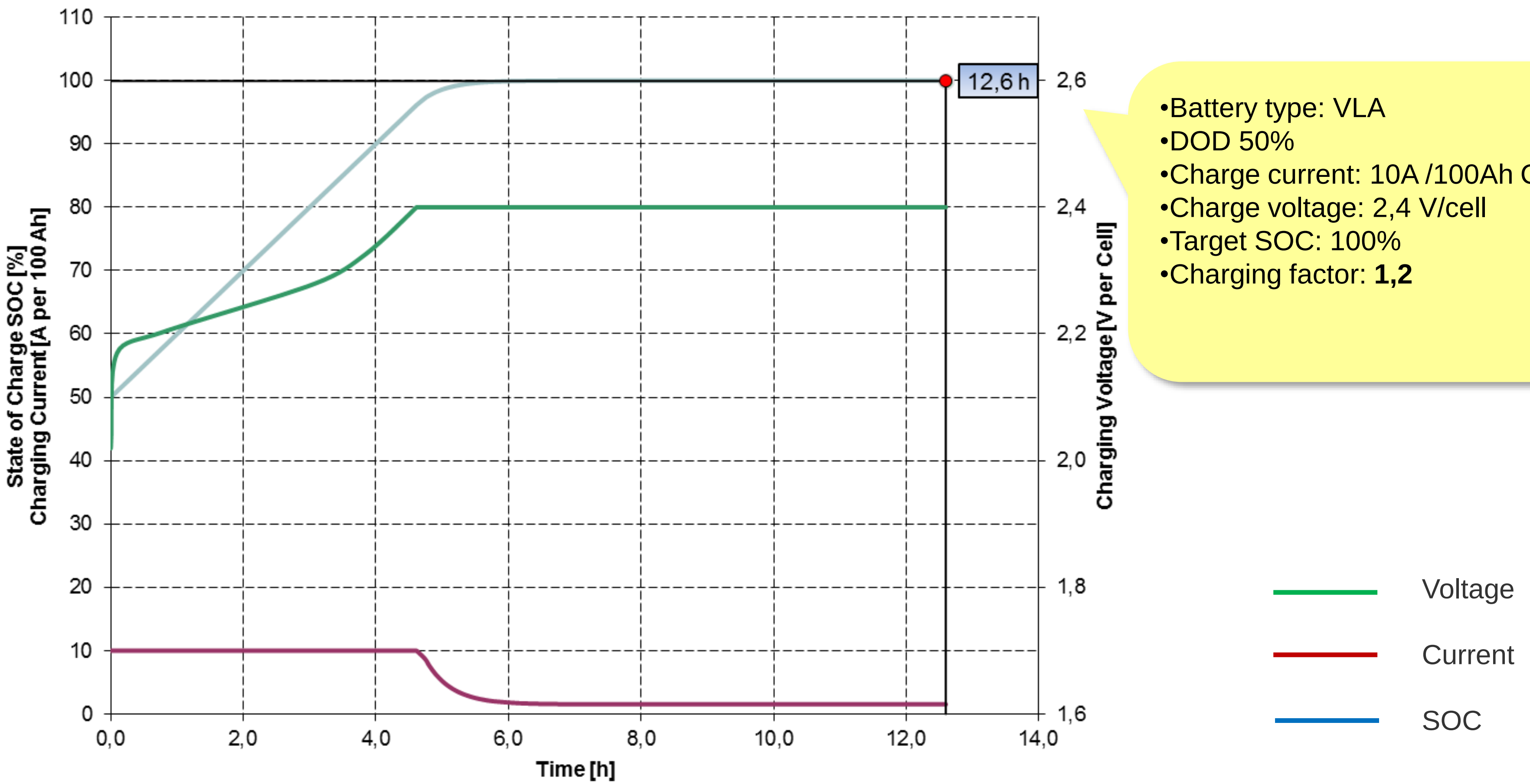
- Example for equalization recharge time without electrolyte pump



- •Battery type: VLA
- •DOD 50%
- •Charge current: 10A /100Ah C10
- •Charge voltage: 2,4 V/cell
- •Target SOC: 100%
- •Charging factor: **1,2**

Best Version 1.6.3. 2014

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

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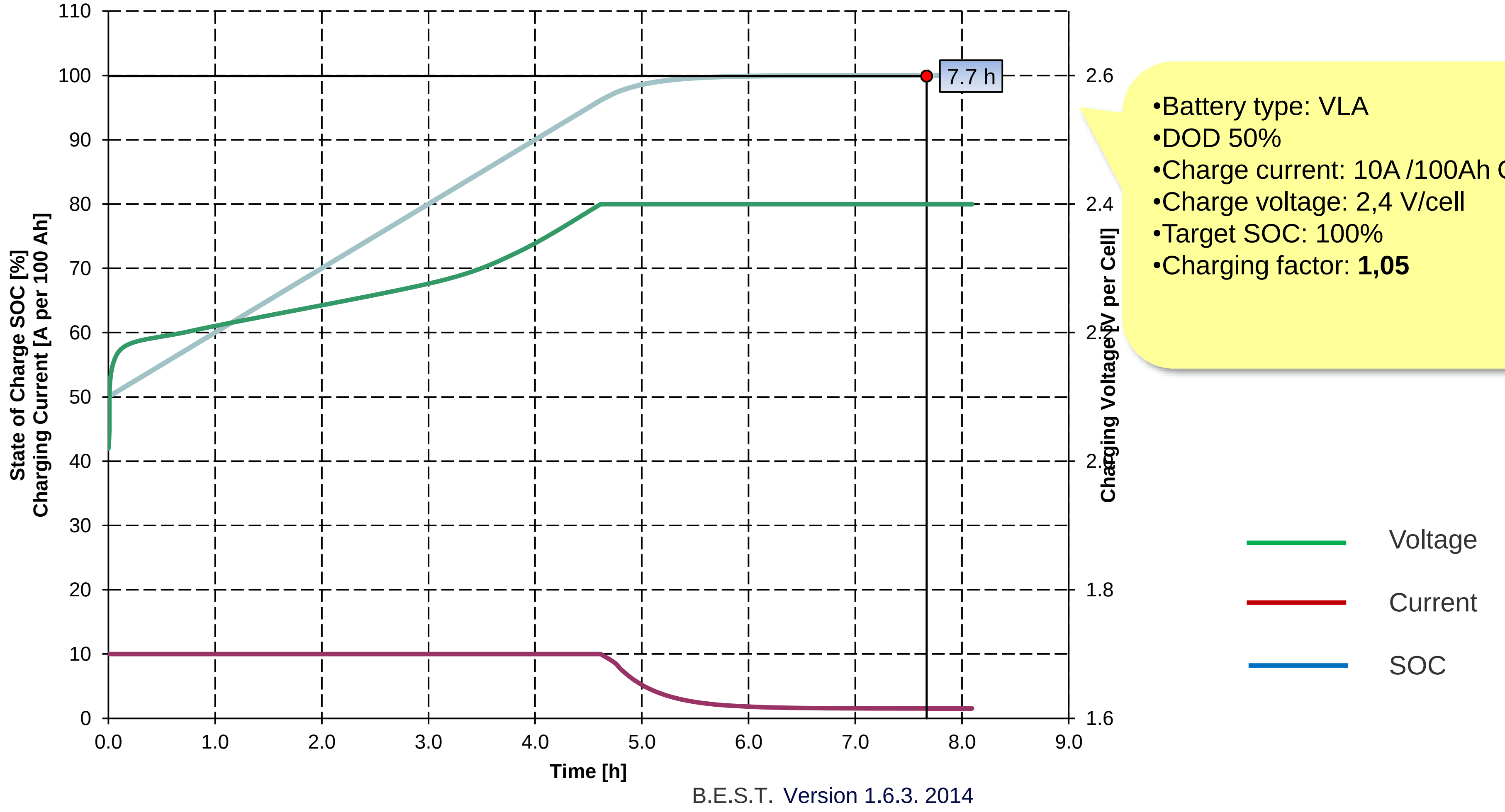
- Example for equalization recharge time with electrolyte pump



- Battery type: VLA
- DOD 50%
- Charge current: 10A /100Ah C10
- Charge voltage: 2,4 V/cell
- Target SOC: 100%
- Charging factor: **1,05**

Optimized Battery System

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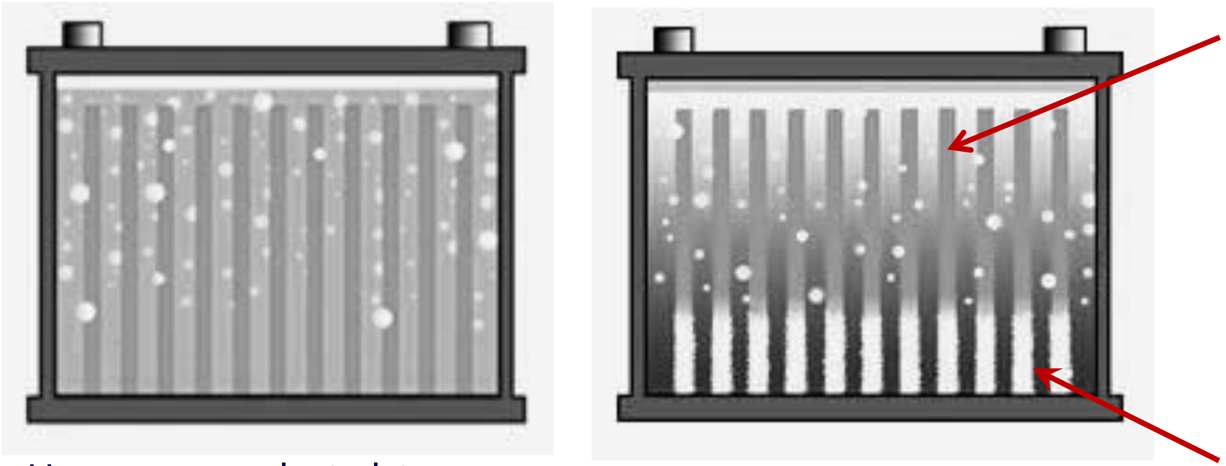
2) Benefit of Electrolyte Circulation System (ECS)

- Acid Stratification

Standby application

Cycling application



At the Top:
Lower Specific Gravity
- corrosion
- overcharged

At the Bottom: Higher Specific Gravity
- sulfation
- undercharged

Homogenous electrolyte
- distributed over time

Key effects of electrolyte stratification:
1. Corrosion at the top lead due to low specific gravity
2. Electrode overcharge at the top of the cell
3. Undercharge in the lower part of the cell
4. Sulfation in the bottom of the cell due to high specific gravity
5. Premature capacity loss
6. Shortened cell life

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

- Acid Stratification

electrolyte distribution → homogeneous

electrolyte distribution → stratified

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)

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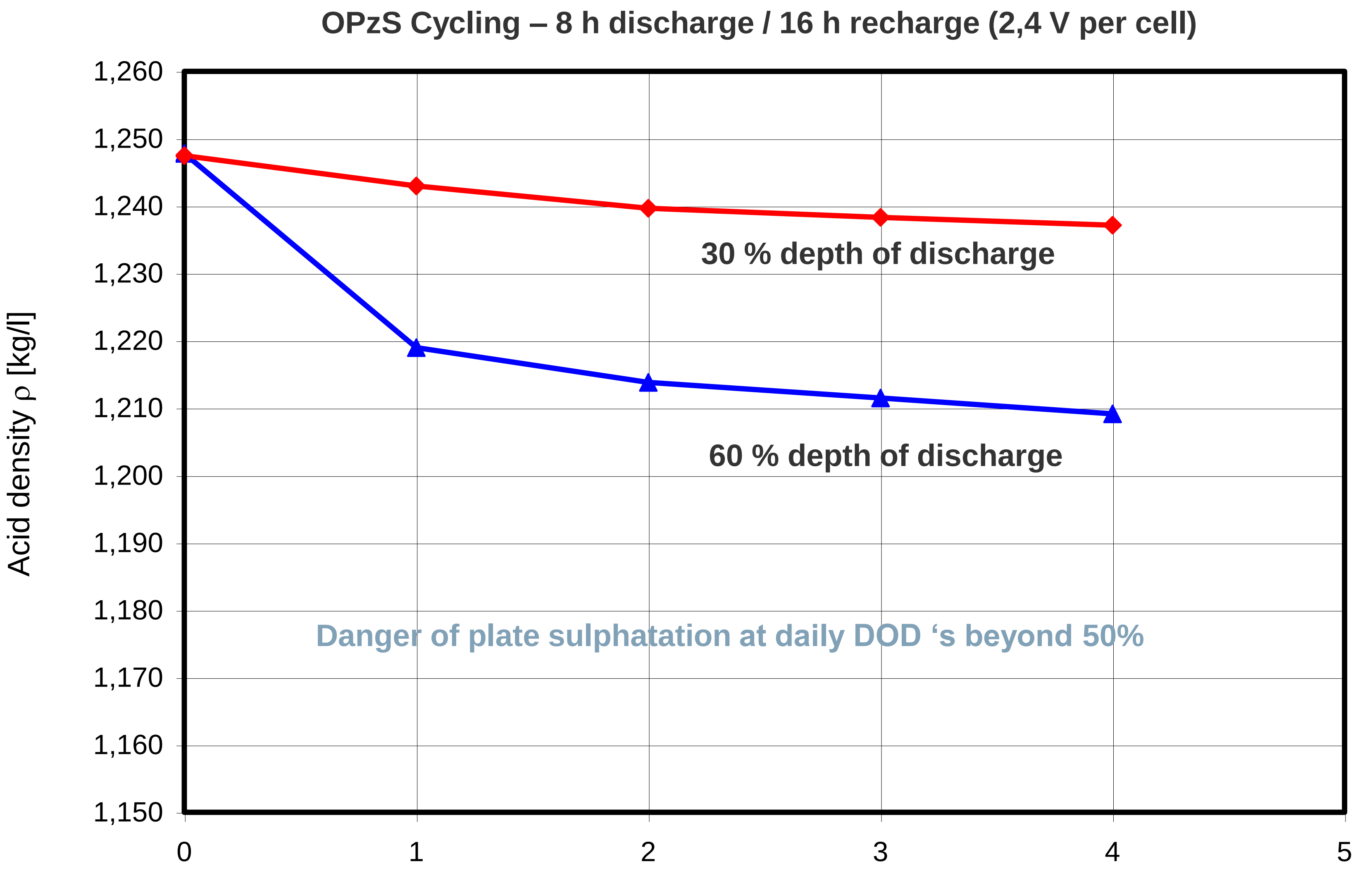
➢ Problem of acid stratification

- Excessive acid concentration causes sulphatation on the lower half of the plates.
- Light acid restricts plate activation and supports corrosion which reduces performance.
- A non-uniform acid-distribution causes an uneven depth of discharge of the plates which leads to additional mass shedding.
- Differences in the electrical potential within the plates increase the self-discharge of the cells.

Optimized Battery System

2) Benefit of Electrolyte Circulation System (ECS)



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