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Information Leaflet

Dependencies and rules for operating PzS- and PzV-traction batteries at low temperatures (cold storage house applications)

1 Introduction

For the usage of traction batteries in areas with low temperatures, e.g. cold storage houses, some important temperature dependencies for the battery projection and operation must be considered.

The batteries are cooling down during the operation and becoming warm while recharging them. The available capacities that can be used are basically linked to the average temperature. The nominal capacity of traction batteries are valid for a temperature of 30 ˚C. For lower temperatures the available capacity is significantly reduced.

The final voltage also decreases with lower temperatures, therefore less power is available.

Lower temperatures are decreasing the conductivity of the electrolyte and aggravate the current acceptance, whereby the charging of the battery is negatively influenced.

Charger with settings for standard applications with a cut-off criterion based on data of the main charge period (time or Ah-balance) result, in combination with low battery temperatures, in lack of charge or acid stratification. The overall effect will be that the battery fails very early. As a consequence more time is needed for charging the battery.

With regulated chargers (thyristor controlled or switch mode) a temperature-controlled or manual adjustment of the charge voltage (gassing voltage) is possible.

For measurements of the electrolyte density it is important to take in account, that the electrolyte density is temperature-dependent. Low temperatures increase the measured density of the electrolyte (values are listed in the operation manual for PzS-traction batteries). A worst case scenario would be, that the electrolyte of a deep discharged and cold battery will freeze, which results in an irreversible damage of the cells.

For optional battery accessories like water refill systems, air agitation systems and electronic devices, limit temperatures have to be considered.

2 Rules for operating batteries at low temperatures

The following instructions describe the influence of temperature and provide application hints for an optimal operation at low temperatures.

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- To compensate the lack of capacity at low temperatures, the utilization of batteries with the maximum nominal capacity for the respective dimensions is recommended.
- Electric vehicles must not be parked for a long time at places with low temperatures. This rule has also to be followed for the storage of batteries.
- The place for the charging station and parking the vehicles, as well as the batteries should have room temperature (not below 10 ˚C). Charging at low temperatures will take a long time. Furthermore, with standard charge parameters, a full recharge at temperatures lower than 10 ˚C is not possible.
- Only chargers with regulated IUI-charging characteristic and a temperature-controlled charge voltage are convenient to prevent lack of charge.
- Before starting an operating shift a full recharge has to be accomplished.
- Purified water (refill water) has always to be refilled during the gassing phase, to ensure the mixing with the acid and to prevent the freezing of the refill water.
- Water refill systems are not allowed to be used at temperatures lower than 0 ˚C, because the water in the hose line and the system might freeze.
- Short time charge (5 – 6 hours) supported by a air agitation system or pulse charge at temperatures lower than 10 ˚C and fully discharged batteries can not be realized.
- To operate electronic devices, like battery controllers, state of filling controllers the respective limit temperatures have to be regarded.

3 Influence of the temperature on the capacity

The nominal capacity of a traction battery is valid for the nominal temperature of + 30 ˚C. For temperatures lower than + 30 ˚C the available capacity is decreasing (figure 1).

The viscosity of sulphuric acid becomes 3 times higher going from + 30 ˚C to – 10 ˚C. In addition to that, its agility is significantly lowered. This results in a decreased conductivity. The acid diffusion is also constrained during charging or discharging due to the fact, that the exchange barrier between the bulk acid and the acid in the electrodes has become very high. Therefore, at low temperatures, the voltage of a battery is generally lower and the final discharge voltage is reached earlier. This means that the capacity is reduced.

A percentage increase or decrease of the capacity by changing the temperature at 1 ˚C, is represented by the temperature coefficient, which proceeds linear only in a small temperature range. The coefficient depends not only on the temperature, but on the construction of the cell and the height of the discharge current. The temperature coefficient increases with the discharge current. For practical experiences a value for the coefficient around 0.6 % per 1 ˚C based on average discharge currents and differences of the temperature between + 10 ˚C and + 30 ˚C is common.

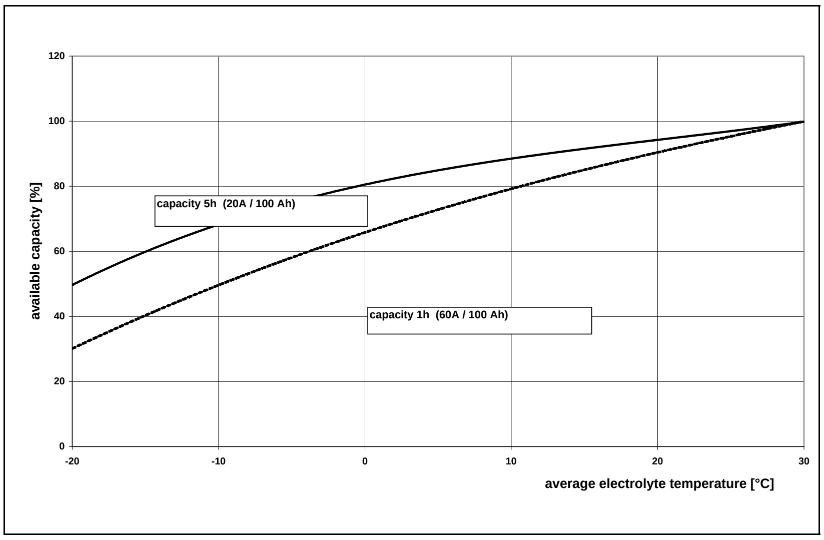


Figure 1: Dependencies of the capacity in relation to the average electrolyte temperature

The capacity K_t for the temperature ϑ_t can be calculated by the equation:

$$K_t = K_E\,[1 + 0{,}006\,(\vartheta_t - 30\,^{\circ}C)]$$

K_E: capacity for the nominal temperature of 30 ˚C

ϑ_t: measured temperature

4 Influence of the temperature on the measured acid density

The nominal acid density for PzS-traction batteries is 1,29 kg/L at + 30 ˚C. In order to measure of the acid density, its temperature dependency has to be noted. The density decreases with the increase of the temperature and the density increases with the decrease of the temperature (figure 2). A difference in temperature of 1 ˚C means a change of the electrolyte density value at 0,0007 kg/L. The temperature corrected value of an electrolyte density of 1,28 kg/L (ϑ = 15 ˚C) is 1,27 kg/L for the temperature of 30 ˚C.

The electrolyte density for operation d_B with the nominal temperature of 30 ˚C can be calculated using the equation:

$$d_B = d_t - 0{,}0007\,(30\,^\circ C - \vartheta_t)$$

d_t: measured density [kg/L]

ϑ_t: measured temperature

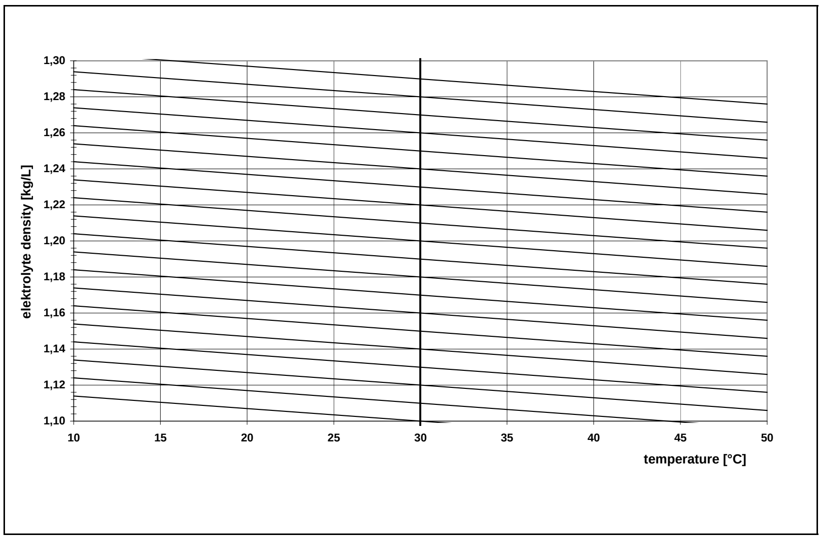


Figure 2: Electrolyte density in relation to the temperature

5 Freezing point of sulphuric acid

The freezing point of sulphuric acid with a nominal density of 1,29 kg/L (referred to +30 ˚C) is lower than –70 ˚C, while a discharged battery with an acid density of 1,15 kg/L could freeze at a temperature of –15 ˚C (figure 3).

At low temperatures the purified water has to be refilled just before the end of recharging, during the gassing period, to ensure the mixing with the acid. Otherwise the refilled water could freeze.

Attention: Operating automatic water refill systems is not allowed in areas with an ambient temperature constantly below 0 ˚C.

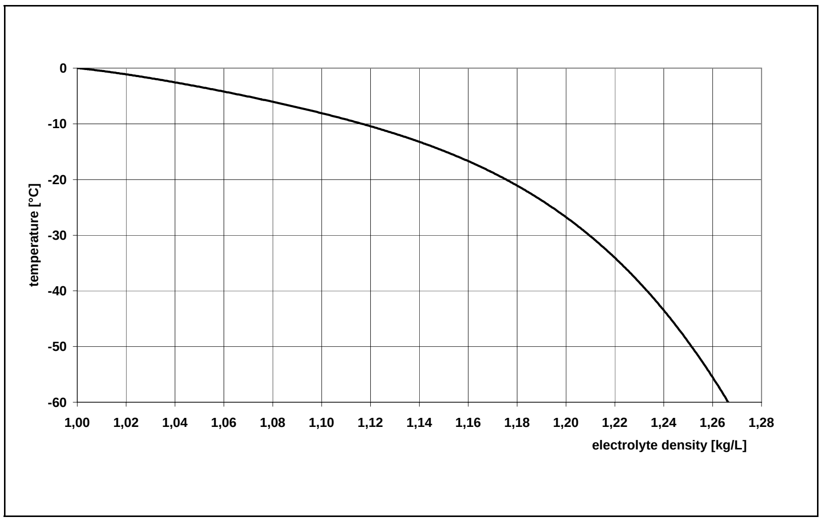


Figure 3: Freezing points of the electrolyte [˚C]

6 Influence of the temperature on recharging the battery

The influence of the acid temperature on the capacity is similar to the influence on the recharge of a battery.

Low temperatures are resulting in the immobilization of the acid and in a significant decrease of the conductivity, which leads to a higher charge voltage. Furthermore the temperature dependency of the gassing voltage has to be considered (see also chapter 7).

The standard value of the voltage calibration point for switching from main charge to residual charge will be reached too early. Therefore the amount of recharged ampere-hours during the main charge period is lower and the charging time is shorter.

The residual charge period of standard chargers is determined on the basis of the main recharge time or the main recharge amount in ampere-hour (reaching the gassing phase).

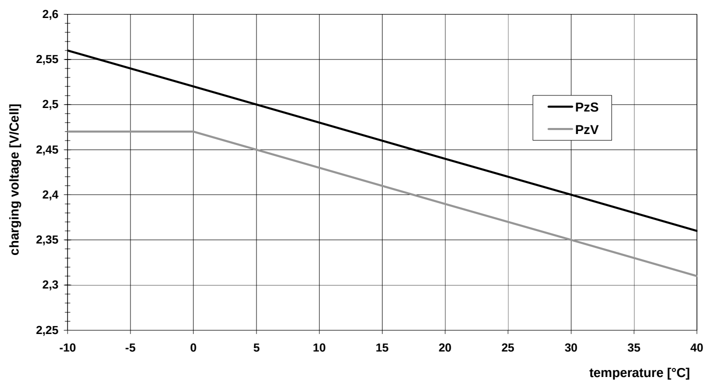
Due to this fact the switch off criterion is reached too early.

For the optimized fitting of the recharge parameters based on the electrolyte temperature, the value for the gassing voltage has to be increased, whereby the charge factor is increasing accordingly. The consequence is, the switch-off criterion is reached later and the charging time is extended compared to the uncompensated case.

Therefore regulated IUI-charging methods with a temperature depended adjustment of the charging voltage avoids a lack of charge.

The usage of unregulated W(s)a- / W0Wa-charging methods at low temperatures causes problems, because adjusting of the gassing voltage as well as the charge parameters is necessary. Moreover the required charge voltage and charge current possibly cannot be provided by the transformer.

Figure 4: Temperature depended charging voltage (U-charging characteristic)



7 Recharging with constant voltage (IU- / IUI-characteristic) and temperature correction factor for the charging voltage

The gassing voltage of a battery is depended on temperature and increases with low temperatures (figure 4). Therefore the temperature corrector factor – 0,004 V/cell per 1 K difference in temperature is recommended in the temperature range from 0 ˚C up to 40 ˚C (IUI-charging characteristic).

The temperature corrected charging voltage U_{LK} can be calculated using the following equations.

For PzS-batteries:

U_{LK} = 2,40 V + [– 0,004 (ϑ_t – 30 ˚C)]

For PzV-batteries:

U_{LK} = 2,35 V + [– 0,004 (ϑ_t – 30 ˚C)]

(0 ˚C to –10 ˚C constant 2,47 V/cell)

ϑ_t: measured temperature

Advice: A winter- / summer-switch for not temperature depended regulated charging voltage in not tempered charging areas is recommended. An example can be, a PzS-battery which is charged while the winter season in an area with a temperature of +10 ˚C and the proper charge voltage of 2,48 V/Z, which causes an overcharge in summer, resulting in a damage of the battery.

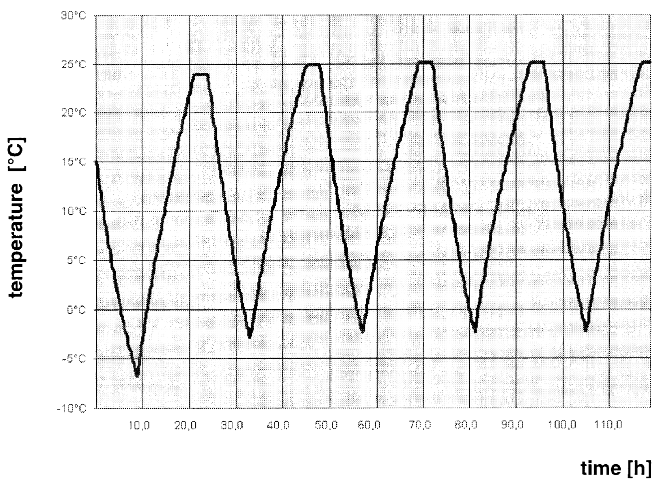


Figure 5: Temperature profile of a battery in cold storage house applications

8 Temperature depended behaviour of PzS-traction batteries in cold storage house applications

In common applications in cold storage houses a forklift truck periodically moves in and out and is recharged outside. While this temporally limited operation of traction batteries in cold storage houses, the batteries are cooling down during the discharge process and becoming warm in the recharge process.

The typical temperature profile of a PzS-traction battery observed in a one-week operation in a cold storage house is shown in figure 5.

Starting from a battery temperature of + 15 ˚C (24V / 340 Ah battery) the battery was operated in a cold storage house at – 28 ˚C and recharged at room temperature (+ 20 ˚C). This results in an average battery temperature of + 10 ˚C and an available capacity of 90 %.

Advice: With a thermal isolated battery tray a higher temperature level can be achieved and therefore the available capacity is also higher.

9 The cooling down times of PzS-traction batteries at low temperatures

Usually a PzS-traction battery is cooled thoroughly in dependency on the dimensions of the battery in 12 h up to 24 h. In consequence PzS-traction batteries can be used, with regard to the previous rules, at low ambient temperatures.

Equation for calculating an approximated battery temperature for different standing times (without charging and discharging intervals):

$$\vartheta_t = \vartheta_u + (\vartheta_0 - \vartheta_u) \cdot \exp\frac{-18 \cdot A_B \cdot t_s}{m_B}$$

ϑ_u: ambient temperature (˚C)

ϑ_0: starting battery temperature [˚C]

A_B: overall battery surface [m^2]

m_B: battery mass [kg]

t_s: storage time of the battery at the temperature ϑ_u [h]

Calculation examples for some PzS-traction battery types are listed in table 1. It is important to note, that the calculations were performed without regard of any charging and discharging intervals!

battery type	dimensions L x W x H [m]	[m]	[m]	A_B [m^2]	m_B [kg]	t_s [h]	ϑ_0 [˚C]	ϑ_u [˚C]	ϑ_t **[˚C]**	T_{diff} **[K]**
24V 3 PzS 375	0,624	0,284	0,612	1,47	299	8	10	– 30	**– 10**	**20**
	0,624	0,284	0,612	1,47	299	16	10	– 30	**– 20**	**30**
	0,624	0,284	0,612	1,47	299	24	10	– 30	**– 25**	**35**
48V 5 PzS 625	1,03	0,529	0,612	3,00	906	8	10	– 30	**– 5**	**15**
	1,03	0,529	0,612	3,00	906	16	10	– 30	**– 15**	**25**
	1,03	0,529	0,612	3,00	906	24	10	– 30	**– 20**	**30**
80V 5 PzS 700	1,03	0,852	0,769	4,65	1863	8	10	– 30	**– 2**	**12**
	1,03	0,852	0,769	4,65	1863	16	10	– 30	**– 11**	**21**
	1,03	0,852	0,769	4,65	1863	24	10	– 30	**– 16**	**26**

Table 1: Calculation of the cooling down behaviour of some PzS-traction batteries