



Figure 18.21 Freezing point of diluted sulphuric acid as a function of the acid concentration

as the voltage does not break down until very late in the process. Batteries that are subjected to temperatures below the freezing point should be dimensioned such that after withdrawing $1.3 \times C_{100}$ or $1.7 \times C_{10}$, the acid density is still so high that freezing is not expected, according to Figure 18.21.

18.4.7.5 Battery peripherals

For proper battery operation, several battery peripherals must be used. The following gives a brief description of the most important devices.

Charge controller: Charge controllers are responsible for the charging strategies and the deep-discharge protection. They limit the power from the PV generator if necessary. More details on the operation strategies are given in Section 18.4.7.6 and on the hardware in Chapter 19.

Chargers: Chargers are AC/DC converters that use the power from motor generators to recharge the battery. They need a charge control as well to avoid overcharging of the battery. The charging regime should be the same as for charge controllers.

Charge equaliser: In long strings of series-connected cells, problems with individual cells like overcharging and reverse charging can occur owing to differences in the ageing processes or tolerances in the production. Charge equalisers avoid the detrimental effects by individual treatment of the cells. More details are given in [13] and in Chapter 19.

Monitoring: To get actual information of the state of the battery, monitoring systems can be used. A wide range of commercial products is available. They range from simple voltage monitoring of the complete battery to complete monitoring of temperature, current and voltage of individual blocks and cells as well as impedance of the battery.

State-of-charge meters: For proper battery operation (Section 18.4.7.6) and for the orientation of the user, it is helpful to have proper information on the actual state of charge of the battery. Several devices and algorithms are available, but only very few are really suited to autonomous power supply systems [26].