

at the negative electrode. In VRLA batteries, the electrolyte is not in the liquid phase and therefore no spillage of electrolyte occurs in case of any break of the case or other accidents.

However, if the battery is incorrectly overcharged, more gas is generated than can recombine, so the gas must be able to leave the cell through the valve if an overpressure builds up. At the same time, the valve must prevent ambient air from entering the battery. As these batteries cannot be refilled with water, blowing off the gas from the cell must be reduced to a minimum to prevent the cell from drying out. As a rule of thumb, after more than 10% water loss the battery is at the end of its lifetime. The water loss can be estimated by the weighting of the battery.

To achieve low gassing rates in VRLA batteries, normally lead–calcium alloys are used for the grids. Flooded batteries use mainly lead–antimony alloys with less than 2.5% antimony (Sb). This is a good compromise among the beneficial effects of antimony grids (good grid conditions for casting and good contact of the active material to the grid result in low contact resistance) and the harmful effect of the reduction of the hydrogen overvoltage caused by the antimony. However, as gassing needs to be minimised in VRLA batteries, antimony grids are not an appropriate choice. Especially, in the early days of the VRLA batteries, the antimony-free grids caused a significant reduction in battery lifetime through the so-called antimony-free effect. This effect is described in the literature as premature capacity loss (PCL) [16].

While the rated capacity of a cell depends on the geometry and the number of parallel-connected electrodes, the rated voltage of a cell is 2.0 V. The open-circuit voltage U_0 of the cell depends on the electrolyte concentration as shown in Figure 18.14, but for practical purposes the open-circuit voltage can be determined by the following rule of thumb:

$$\frac{U_0}{\text{V}} = \frac{\rho}{\text{g/cm}^3} + 0.84 \dots 0.86 \quad (18.11)$$

where ρ is the density of the electrolyte. Electrolyte concentration and electrolyte density have an almost linear relation. As the electrolyte density can be easily measured, the electrolyte density is often used to express the electrolyte concentration. At 25°C, 30% H₂SO₄ in H₂O has a density of about 1.22 g/cm³ and 40% H₂SO₄ in H₂O has a density of 1.30 g/cm³. Typical electrolyte densities in fully charged batteries are between 1.22 and 1.32 g/cm³, depending on the application, the technological type and the climatic conditions. The acid density in the discharged state is between 1.18 and 1.05 g/cm³. According to equation 18.11, the open-circuit voltage also varies with the density. It is not a constant by any means.

Figure 18.14 shows the correlation between the electrode and cell potentials and the acid concentration. The acid concentration can be measured by means of the concentration in mol/l, the density in g/cm³ and the percentage of acid in the solution %_{weight}. This allows the translation of all values to one another.

According to equation (18.7), the electrolyte concentration decreases during discharge. According to equation (18.11) the open-circuit voltage decreases in a manner directly proportional to the acid concentration. VRLA (sealed) batteries have less electrolyte per ampere-hour capacity than flooded batteries. Therefore, the open-circuit voltage