The sintered/plastic bonded plates do not contain graphite, therefore carbonation cannot come from oxidation, consequently with the sintered/plastic bonded products, the level of carbonate does not rise to a high enough level to impair the operation of the battery.

For this reason, it is not necessary to change the electrolyte from Sintered/PBE cells during their lifetime.

6.10. IRON MIGRATION

In the Pocket plate cells, iron is added to the negative mass to act as an expander and prevent agglomeration of cadmium particles. It is an essential part of the active mass.

In addition, all Nickel Cadmium products have a steel support structure for the electrode.

During use there is a slow, but inevitable, migration of iron particles from the negative active material to the positive plate. At the same time, there is also a migration from any exposed iron close to the active material. However, this latter effect has a much smaller magnitude than the iron in the mass and is generally eliminated by the nickel plating of contributing exposed iron surfaces.

These effects are part of the general aging of the battery and are taken into account in the general design of the battery system.

In the case of Sintered/PBE products, there is no iron added to the negative mass and the electrode substrate is nickel plated. Thus, there is no significant

iron migration to the positive plate and it is not necessary to take this into account when determining the life expectancy of the battery.

6.11. HEAT GENERATION

When charging and discharging a battery, a certain quantity of heat is generated. In general, this is relatively small and does not cause a significant increase in the battery temperature. However, in some cases there may be a significant short-term increase. The actual thermodynamics of this heat generation can be quite complex and the following subsection gives a simple method of calculation for the heat generated and also the temperature rise which would occur if there was heat loss.

In practice, the actual temperature rise will be less than calculated, or even zero, as the normal heat losses due to conduction, convection and radiation will easily dissipate the small level of heat generated when the battery is in a steady state condition. Thus, the only significant temperature rise occurs during discharge or if the battery has a severe overcharge.

6.11.1 DISCHARGE

The main data to take into account when dealing with heat generation in a Nickel Cadmium cell is the potential of zero heat generation.

This is a thermodynamic value (V°) depends on the electrochemical Nickel Cadmium couple that has a value equal to 1.44V.

During a discharge, the heat generation in a cell is directly related to the difference between the V° value and the discharge voltage (refer to Fig 6.17 below).

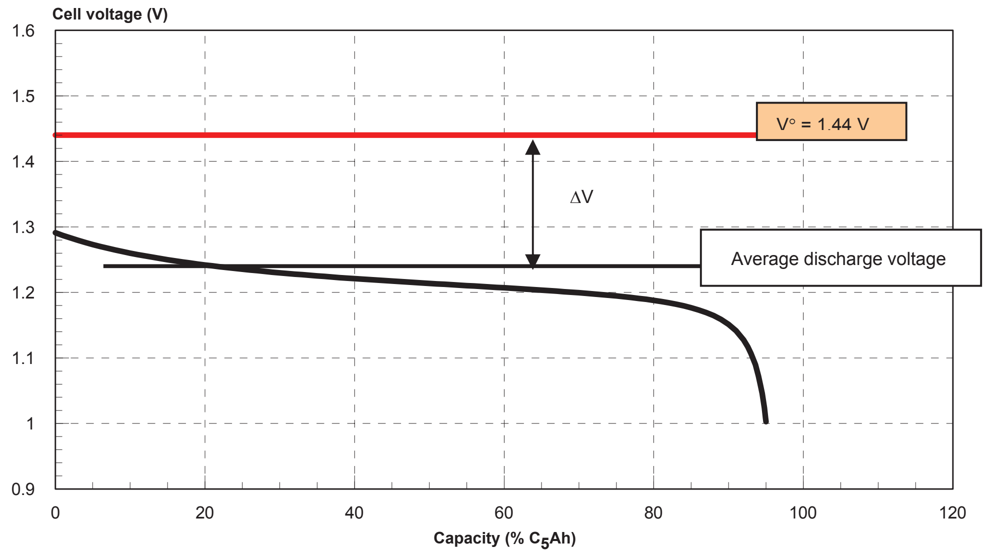

Fig 6.17 Comparison of average discharge voltage and thermodynamic voltage value

The instantaneous heat produced in the cell during the discharge is related to the voltage difference mentioned above and to the discharge current.

$$P_W = I_{Amp} \times (1.44 - Uv)$$

Where,

P_W is the power heat generated in W

I_{amp} is the average discharge current in A

Uv is the average discharge voltage in V

6.11.2 CHARGE

When a battery is charged, the energy produced by the charger is stored in the battery. During the first part of the charge, up to the gassing step, there is virtually no heat generation because during this phase the electrochemical charging process is endothermic. Therefore, all small heating effects due to resistance loss are masked by the cooling effect of the reaction.

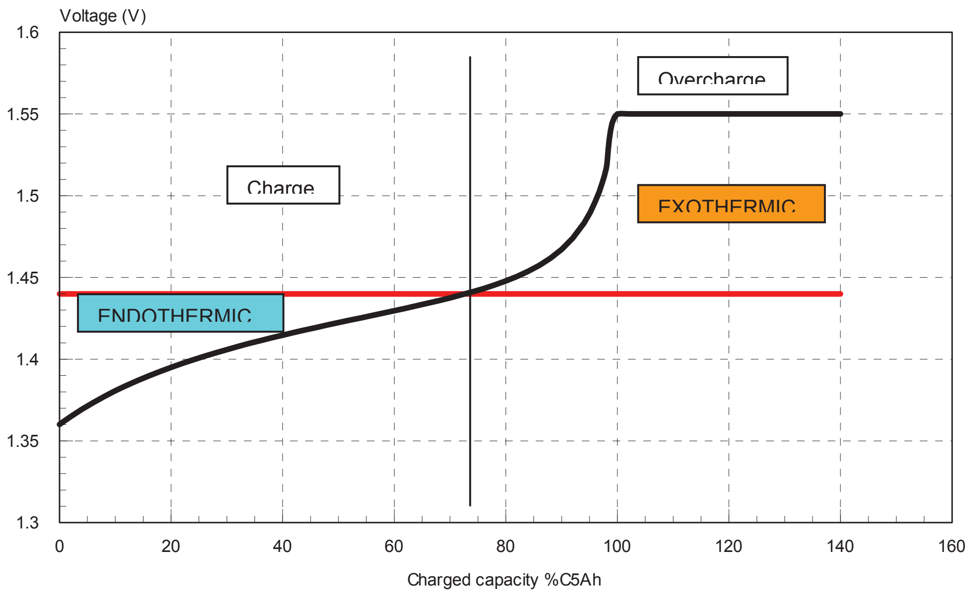

Fig 6.18 Heat generation during charge and overcharge.

While the first part of the charge is without gassing and all the energy introduced in the cell is converted to charged capacity, the charging efficiency decreases. Eventually the efficiency will fall to zero when a fully charged state is reached since only part of the excess energy, called overcharge is used to charge the battery while the remainder is used to decompose water, produce gas, and convert into heat (refer to Fig. 6.18 and 6.19).

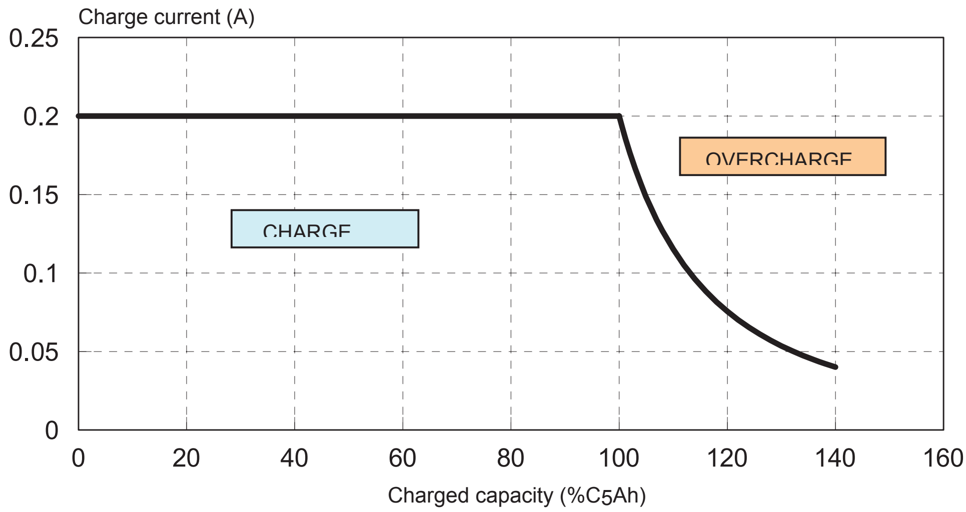

Fig 6.19 Charge and overcharge phases during complete charge at constant voltage

The voltage at which the charge converts from an endothermic to an exothermic reaction is 1.44V per cell (the ''zero heat'' voltage). To estimate the heat generated, the difference between the cell voltage and 1.44V per cell is used.

Thus, the power heat generated in Watts per cell is :

$$P_W = I_{amp} \times (Uv - 1.44)$$

Where,

P_W is the power heat generated in W
I_{Amp} is the average charge current in A
Uv is the average charge voltage in V

6.11.3 OVERCHARGE

In overcharge, the charge efficiency of the battery is close to zero, and since not all the energy introduced in the cell is used to charge the battery, but is used to decompose water, produce gas, and the rest converted into heat.

By experimentation, about 20% of the overcharged energy is used for gas recombination in Sintered/PBE cells, and about 30% in Pocket plate cells (refer to Section 4).

Therefore, the power heat generated in watts per cell in overcharge is :

$$P_W = R_v \times I_{amp} \times Uv$$

Where,

P_W is the power heat generated in W
I_{Amp} is the average charge current in A
Uv is the average charge voltage in V
Rv is the recombination ratio

6.11.4 TEMPERATURE ELEVATION IN DISCHARGE

In discharge, the theoretical temperature elevation inside the cell, not taking into account the external cooling, can be obtained by using the following formula :

$$\Delta°C = Qcal / (m \times Cp)$$

Where,

Qcal is the heat generated during the discharge in calories
m is the mass of the cell in grams
Cp is the specific heat of the cell in $cal.g^{-1}.°C^{-1}$

For Nickel cadmium cells, Sintered/PBE or Pocket plate, the average specific heat is close to 0.28 $cal.g^{-1}.°C^{-1}$.