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Temperature-controlled formation

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Abstract

The development of a multi-step procedure for the container formation of automotive batteries is discussed. This involves the simultaneous measurement of electrolyte temperature, battery voltage, formation current and total charge passed as control parameters. The process enables batteries to be formed within 24 h in an efficient, safe and economic manner.

During tank formation, lead/acid battery manufacturers do not experience serious problems with high temperatures. In the container formation of automotive and industrial batteries there are, however, certain difficulties. These arise because there is a lower heat capacity per plate (small electrolyte volume), a covering of all sides by the heat-insulating container, and a smaller cooling effect by water evaporation from the surface through the exhaust. With the introduction of maintenance-free batteries and the continuously increasing need for longer shelf-life, the more cost-effective container formation is being used in an increasing percentage of automotive batteries, both for the original equipment and replacement markets.

The initial evolution of heat originates from the reaction of lead oxide and basic lead sulphates in the cured active material with the filling electrolyte. It is possible for the temperature to reach easily 65 to 70 °C (Fig. 1). Thus, a rest period is required to allow the battery to cool down. The data in Fig. 1 show the initial temperature rise and the following cooling phase for a 72 A h automotive battery. Assuming that the reaction is virtually finished after the temperature maximum (T_{max}), the exponential decrease leads to a time constant τ given by:

$$T_{obs} = T_{max} \times e(-t/\tau)$$

where T_{obs} is the observed temperature. For the battery in question, τ has a value of 5.1 h. The τ value will differ for various battery types and sizes, but provides a time base for the design of a temperature-controlled formation procedure.

In the initial stage of plate formation, the charge current will create heat both through resistive losses in the low conductivity conditions of the electrolyte and through further conversion of the active material to lead sulphate.

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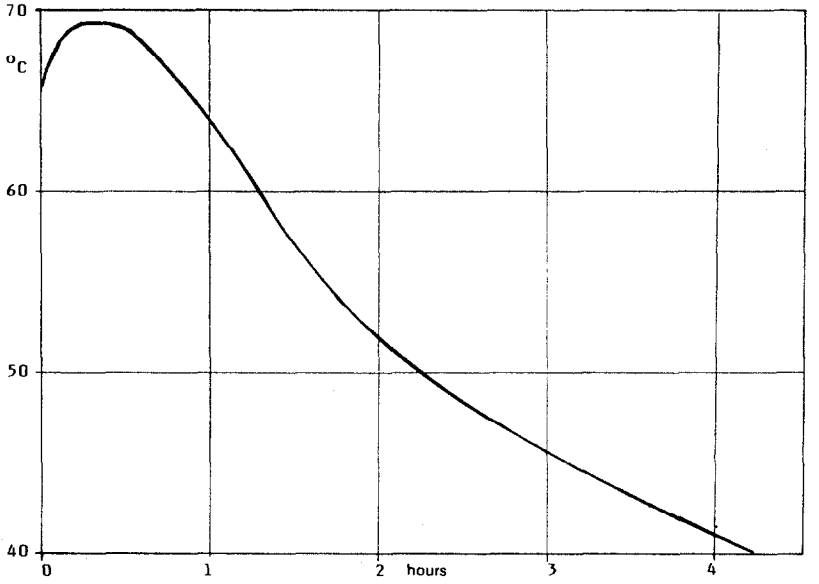

Fig. 1. Temperature of automotive battery after filling with electrolyte.

The electrolyte specific gravity increases significantly only after approximately half of the active material in the positive and negative plates is converted electrochemically into PbO_2 and Pb, respectively. This is equivalent to the passage of charge equivalent to the nominal 20-h capacity. High polarization and gas evolution then become the main sources of heat.

A general scheme for container formation of automotive batteries should therefore include:

- control of acid temperature to avoid damage
- maximum allowable current level to keep total formation time short
- low acid pollution of the environment
- low energy consumption

Such aspects are difficult to realize with electro-mechanical controls but offer no problems when using computer- and microprocessor-controlled systems. The latter allow electrolyte temperature, battery voltage, formation current, and total charge (A h) to be used simultaneously as process-control parameters in multi-step formation programmes.

The first 2 h of a formation procedure are shown in Fig. 2. The maximum current was set at 25 A and the electrolyte temperature was limited to 53 °C. With the high current, the temperature rise is quite steep. At a stage 3 °C below the maximum temperature, the current was reduced in order to avoid exceeding the limit. After some 45 min, the heat evolution obviously became smaller and so allowed a current increase to be made. A further period of 40 min was possible at this rate before the current had to be reduced

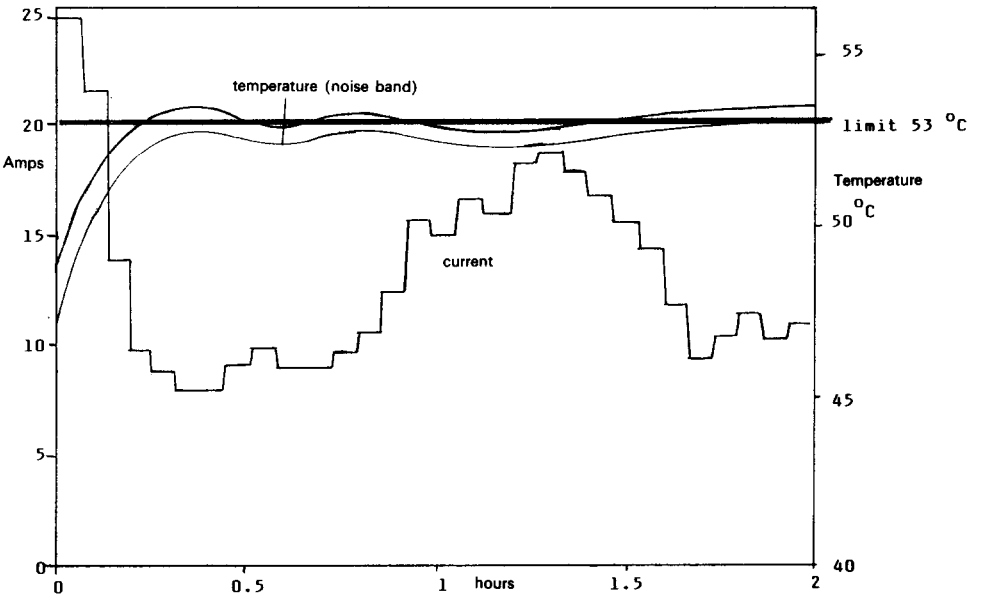

Fig. 2. Initial stage of temperature-controlled formation of automotive batteries.

again. Quite a low temperature limit was used in order to demonstate operation of the control.

A more realistic, but still a demonstration-type scheme for a container formation of automotive batteries, is given in Table 1 for a 72 A h battery. The results of this formation are presented in Fig. 3.

The initial pause (PAU) allows for a cooling down to 50 °C before a maximum charge (CHA) current of 25 A is applied. Following this, a temperature of 60 °C and a voltage of 16 V should not be exceeded. After a total charge of 155 A h, further charging is limited to a voltage of 15.6 V until the current is reduced to 3.6 A. Then, the battery normally is fully charged. In

TABLE 1

Programme for temperature-controlled formation with a maximum temperature of 60 °C; 72 A h automotive battery

Operator	Nominal value	Switch (to next line)
PAU		50 °C
CHA	25 A	155 A h
	60 °C	
	16 V	
CHA	15.6 V	3.6 A
CHA	3.6 A	180 A h
STO		

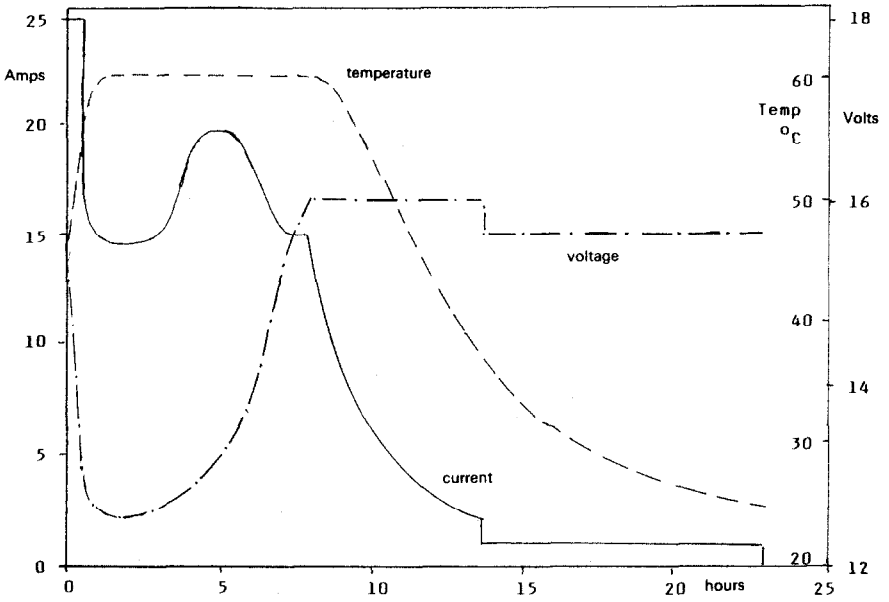

Fig. 3. Temperature-controlled formation at maximum temperature of 60 °C; 72 A h automotive battery.

the event of a problem, such as a bad inter-battery connection creating a significant voltage drop, a third step ensures that, with a constant current, the battery is charged up to the necessary 180 A h, i.e., 2.5 times the nominal capacity.

According to Fig. 3 the high initial current can be maintained for only 30 min before the increased temperature demands a reduction in current. This information could be used to open a cooling water valve. After 3.5 h, the current is increased from 15 to 20 A. From then on, both the voltage and the ohmic losses increase and, after a total of 7 h, the current has to be reduced again. The maximum voltage of 16 V (2.67 V/cell) is reached after 8 h and the current is tapered down until, after 13.5 h, 155 A h have been passed. At this point, there commences a constant-voltage charge at 15.6 V. This step lasts to 23 h with almost constant current. As the total charge reached 185 A h, the third step was not used in this case.

Both, hardware and software for such a process control are commercially available. The above example demonstrates that with standard automotive batteries from normal production it is possible to complete a container formation within 24 h using a current of only $2.5 \times C/20$, or some 120% of the theoretical value. This procedure results in low energy consumption, little evolution of acid fumes, and a higher charger output rate. Furthermore, there are additional benefits in the form of less floor space and reduced corrosion problems in the formation area.