

Vacuum- and air-cooled mixing of lead/acid battery paste: a comparison of the production results

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Received 27 August 1994; accepted 10 September 1994

Abstract

The duty and performance of the vacuum mixing and reacting technology for the preparation of lead/acid battery paste is reported. The production results achieved under vacuum are compared with those of conventional, air-cooled plants. Due to the more effective cooling and the use of a closed system, improvements such as reduced burned-lead portion, control of paste composition and formulation accuracy, and independence of climatic conditions are achieved. The capacity and mechanical resistance of the plates, as well as the cold-start properties and service life of batteries are improved and production costs are reduced.

Keywords: Lead/acid battery paste; Production; Vacuum mixing

1. Introduction

In 1985, the author's company introduced a new technology for the preparation of lead/acid battery paste, namely, mixing and reacting technology under vacuum [1]. Since then, about 30 vacuum plants have been put into operation successfully. The work reported here answers the following questions.

- What is the purpose of mixing and reacting under vacuum?
- How does the system work?
- What are the differences in production results in comparison with air-cooling technology?

2. Process description

The mixing and reacting technology under vacuum for lead/acid battery paste provides for intensive mixing of the raw materials (water, leady oxide, additives, fibres, and sulphuric acid) and for removal of the heat that is generated by the reaction between leady oxide and sulfuric acid.

When cooling the paste by air or under vacuum, the reaction heat is consumed by evaporation of part of the water contained in the paste. Thus, the average paste temperature cannot exceed the boiling point of water. In the vacuum system the boiling point of water

and, consequently, the paste temperature is determined by the depression (e.g., 60 °C at 200 mbar) inside the mixing reactor according to the vapour-pressure diagram (Fig. 1). At the end of the batch time, the paste can be cooled down very quickly to a defined temperature.

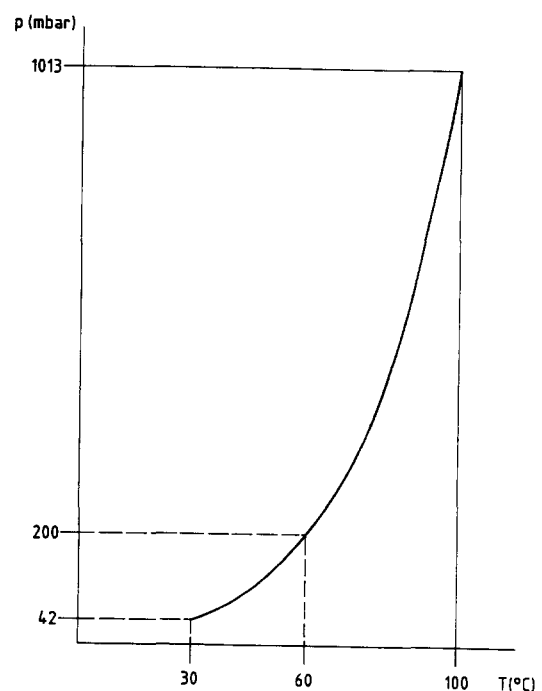


Fig. 1. Boiling point of water as a function of pressure.

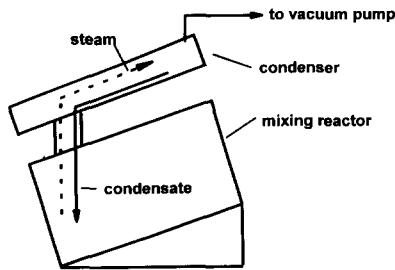


Fig. 2. Principle of vacuum cooling.

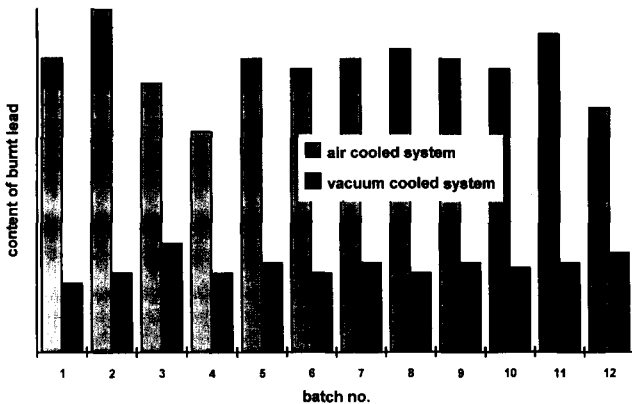


Fig. 3. Dependence of burned-lead content on cooling system.

Again, this only depends upon the adjusted depression (e.g., 30 °C at 42 mbar).

The vacuum system is a closed system mainly consisting of mixing reactor, condenser and vacuum pump. The evaporated water is entirely condensed by the condenser and refed to the paste (Fig. 2). Compared with an air-cooled plant, the reaction heat is carried off more effectively. This ensures an optimal control of both the paste temperature and the chemical reactions. These facts result in the following benefits:

- a reduced portion of burned lead
- more precise control of paste composition
- higher formulation accuracy
- independence from climatic conditions

3. Production results

3.1. Burned lead

Fig. 3 compares the production of burned lead (monobasic lead sulfate) in an air-cooled system with the production results of a vacuum system that replaced the conventional plant.

The proportion of burned lead, thus the proportion of inactive material, was reduced to about one-third. As a result, higher plate capacities and better cold-start properties of the batteries could be achieved because of the more effective action of vacuum cooling.

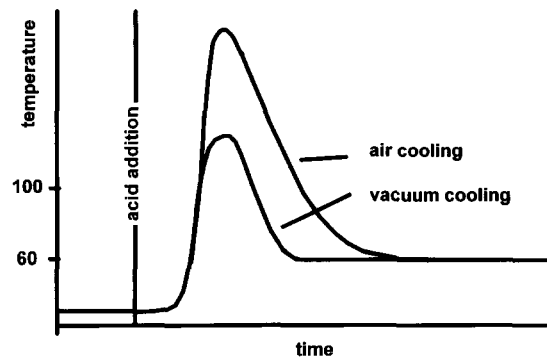


Fig. 4. Temperature course in a partial paste volume during the reaction of acid and oxide.

Explanation. Temperature peaks that lead to the production of burned lead come from points where the acid impacts on the lead oxide (Fig. 4). At these points, the temperature rises to the boiling point of water. Consequently, there is an intense removal of heat through the evaporation of large amounts of water. However, at these points the temperature at the oxide particles increases further and exceeds the boiling point of water, i.e. burned lead is produced. In an air-cooled plant, which means operation under atmospheric pressure, the intensive evaporation of water starts at 100 °C, whereas in a vacuum system it starts at the adjusted temperature according to the vapour pressure diagram, for instance, at 60 °C.

The cooling in the vacuum system, which is faster and commences at a lower temperature, reduces the maximum peak-temperature, as well as the duration of the heat effect. Consequently, the amount of burned lead is also reduced.

3.2. Control of phase composition

Another interesting aspect is the control of the paste properties via the composition of the constituent phases. Controlling the relative proportions of tribasic (3BS) and tetrabasic (4BS) lead sulfate is of particular importance in this connection. For example, an increasing amount of 4BS prolongs the service life of batteries. Moreover, since 4BS imparts mechanical strength to pasted plates, there are fewer rejects during battery formation and assembly. By contrast, 3BS leads to a higher initial capacity and better cold-start properties.

The exact control of the phase proportions allows an optimization of these properties. The two basic sulfates partly exclude each other since 4BS is generated from 3BS at temperatures higher than 70 °C. Consequently, it is necessary to interrupt the reaction by a sudden cooling as soon as the desired amounts of the phases are reached, i.e., the required 3BS/4BS ratio. The vacuum technology allows such control within

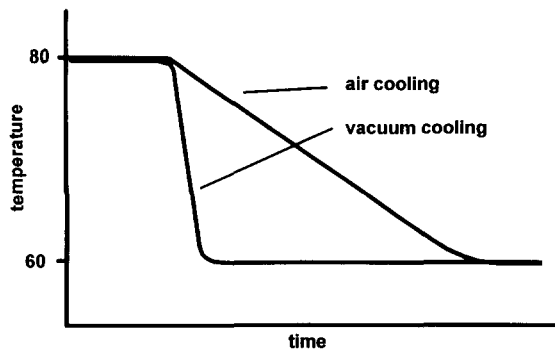


Fig. 5. Cooling capability of vacuum cooling vs. air cooling.

seconds, simply by lowering the pressure to, e.g., 200 mbar which corresponds to 60 °C. An example of such control is given in Fig. 5.

3.3. Formulation accuracy

The vacuum system provides for a better formulation accuracy. As a result, variations of water content and, consequently, of porosity and density are minimized. This leads to very consistent paste and battery properties, e.g., paste penetration, capacity, conductivity and service life. Consequently, there are savings from less rejects throughout all the production process, from pasting up to the final battery.

The reasons are again to be found in the design of the vacuum system as a closed system. The amounts of water and other components (fibres and additives) in the final product correspond exactly to the formulation fed to the mixer previously. The water that evaporates to cool the paste is entirely condensed and returned to the paste. Fibre and lightweight additives are not extracted from the mix due to the low flow velocities in the mixing reactor.

In air-cooled systems, lightweight components or fibres tend to be extracted because of the air flow. To provide for the evaporative cooling, the formulation contains always an excess of water that evaporates

during the course of the process. Determination and adjustment of the water content by weighing the paste-filled mixer, or by measuring the penetration, cannot reach the accuracy that can be obtained with a vacuum system.

3.4. Independence from climatic conditions

The vacuum system is absolutely independent of climatic conditions. The result is, above all, a very constant paste density. This, in turn, gives improvements in properties such as service life and capacity and, consequently, a very constant battery quality and minimization of rejects.

The reason is that an air-cooled system is subject to changing climatic conditions with the result that cooling times and excess water proportions (for which the formulations must allow) have to be adjusted according to the time of day and year as dictated by air humidity and air temperature. By contrast, a vacuum system always creates one and the same climate.

4. Summary

The above comparison presents the most important advantages of the vacuum mixing and reacting technology in terms of battery production. These lead to:

- higher initial capacity of the plates
 - better cold-start properties of the battery
 - better mechanical resistance of the plates
 - longer service life of the battery
- and, ultimately, to
- constant and superior quality of both paste and battery
 - minimization of reject-related costs

Reference

- [1] H.-J. Vogel, *J. Power Sources*, 48 (1994) 71–76.