Journal of Power Sources, *31* (1990) 263 - 269

IMPROVEMENTS IN THE MANUFACTURING OF LEAD/ACID BATTERIES WITH TUBULAR POSITIVE PLATES

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Introduction

Lead/acid batteries with tubular positive plates (Fig. 1) are increasingly being used for traction, stationary, and railcar applications. This is mainly due to their lower lead consumption and higher specific energy when compared with Planté-plate designs. Other reasons include more effective production technology and more efficient lead recycling.

The advantages of tubular-plate batteries encouraged the Polish battery industry to market them. Production started in the Bielsko-Biała Battery Factory in 1964. The history of this lead/acid battery manufacturer dates back to 1923.

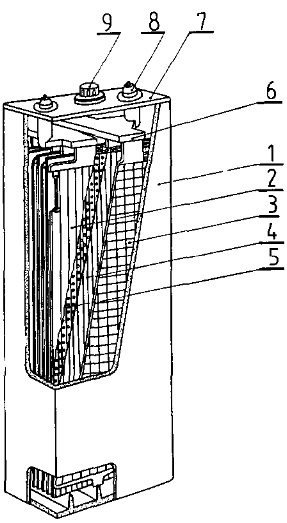

Fig. 1. Traction cells with positive tubular plates: 1, container; 2, positive tubular plate; 3, negative grid plate; 4, microporous separator; 5, perforated and corrugated PVC spacer; 6, strap; 7, cover; 8, screw terminal post; 9, vent plug.

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0378-7753/90/$3.50

The present paper describes the manufacturing technology involved in the production of tubular plates, with special reference to dry- and wet-fill methods. The production process for negative pasted plates is similar to that for automotive batteries, and therefore it will not be discussed here.

Materials and technology

The more sophisticated design of a tubular plate, as compared with the pasted type, requires a different production technology from the spine-casting operation onwards (Fig. 2). Tubular-plate spines are made with semi-automatic or automatic pressure die casters. These machines ensure correct mould filling for the long spines of tall plates — this is not possible with gravity-casting equipment. Some small-scale manufacturers, however, use

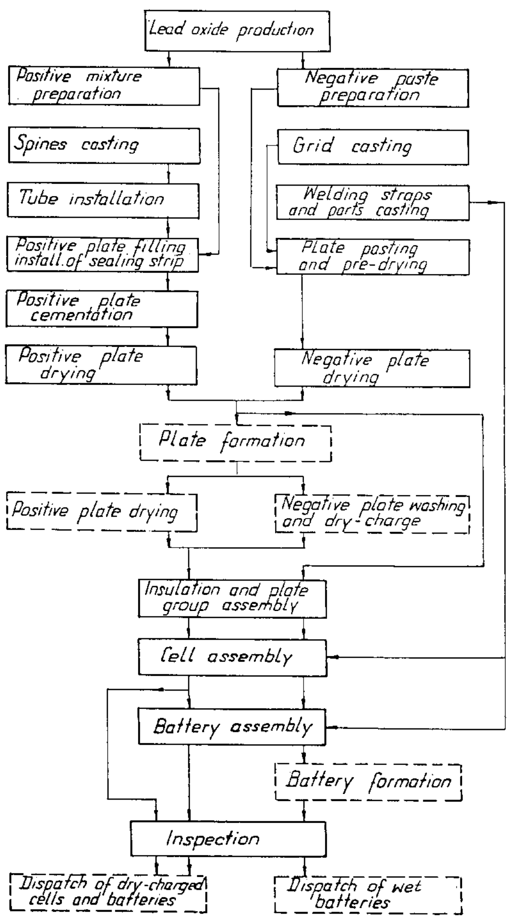

Fig. 2. Flow chart for positive tubular-plate production.

semi-automatic gravity casters or even manual spine casting. The length of gravity-cast spines is up to 300 mm. Pressure die casters, on the other hand, can produce spines of 650 mm or longer; their average production capacity is 3 castings per minute.

The spines are made from lead alloys containing 1.5 - 8 wt.% Sb or even 11 wt.% Sb. There is a tendency towards pressure die casters that can operate with low antimonial or lead–calcium alloys. Lead–antimony alloys with 3 - 5 wt.% Sb content are not recommended.

Automation of auxiliary processes includes feeding of lead pigs to the melting pot, as well as collection and transport of cast spines to the next operation using industrial robots. In the next manufacturing step, the lower part of the spine is cut using a cutter or is manually removed, and the tube sleeves are then installed. These operations can be carried out on individual stations or on an automatic line.

Both single- and multi-tubes are used. Single tubes are made from perforated, hard PVC foil with an inner lining of fibre-glass fabrics. Single tubes have been used by Tudor of Sweden for more than 40 years.

Multi-tubes are mainly made from woven synthetic fibres, *e.g.*, polyester. They are shaped on metal rods followed by additional treatment. Woven tubes with the addition of heat-hardened fibres (*e.g.*, PVC) are stiffened by a thermal process, while tubes without such fibres are impregnated with resin solutions (*e.g.*, phenolic, acrylic, etc.) prior to thermal treatment.

In addition to woven tubes, needled cloth tubes are used. Their size is usually 5 - 9 mm, and their shape can be round, oval or square, depending on battery design.

Leady oxide for tubular plates is produced either in a ball mill or in a Barton-pot system. Usually, a mixture of leady oxide and 10 - 30 wt.% of red lead is used, since the latter is considered to have a beneficial effect on both the formation process and the initial battery performance. The proportions of these two oxide components also influence the weight of the filled plates.

It is claimed [1] that the use of granular oxide material instead of powder shortens the tube-filling time, reduces the content of undersized grains, ensures optimum pickling and formation, and improves the electrical parameters of the plate. For example, granular material of 3.3 - 3.8 g cm^{-3} density ‘flows’ easily and is non-dusting. As a result, tube filling time can be reduced five-fold.

Dry filling

Dry filling requires the use of vibratory-type equipment that can operate either in cycles or as an automatic line to give continuous plate filling, cleaning, and closing. The filling machine contains a chamber in which plates are installed with the lugs down. The chamber is then closed and the oxide pouring and vibratory mechanism activated. After a pre-determined time, the filled plates are removed and weighed. Finally, the plates are cleaned and transported to a second station for manual or mechanical installation of the bottom bars.

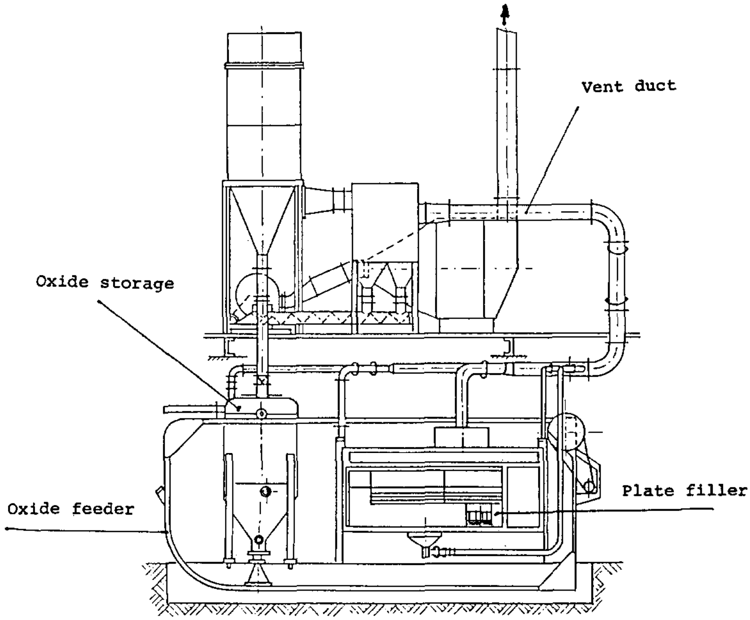

Fig. 3. Schematic diagram of oxide-filling system for tubular plates.

Figure 3 shows details of a dry-fill machine, type UNP-4, that has been developed in the authors' laboratories [2]. The machine consists of the following components:

- filling system with chain conveyor for filling containers
- scraper conveyor for leady oxide circulation
- leady oxide silos with batcher
- filtration and vent system.

On one stand, single plates are individually inserted into 26 vertical filling containers mounted on a chain conveyor. The containers are moved under a charging hopper and the plates are continuously filled with leady oxide powder. A vibration system installed under the conveyor vibrates the containers. These are then passed between rotary brushes and a stream of air to clean the filled plates. On a second stand, the bottom bars (or 'feet') are installed. The capacity of the filling machine depends on the plate size and is 3 - 5 plates per minute.

The mixture of leady oxide and red lead is transported to the silos by a pneumatic system. From there, it is released through a batch feeder onto a scrap conveyor and transported to a charging hopper. The scrap conveyer also collects the excess of powdered material from the filling and cleaning chamber. The filtration and vent system generates a sub-pressure inside the machine and provides three-step dedusting through a cyclone, a bag filter and a final filter.

Filled plates are subject to a pickling/drying treatment to achieve plate sulphation. The drying process oxidizes any free lead remaining in the plate mixture.

Wet filling

The wet-fill method consists of either pumping a mixed slurry of leady oxide and red lead into a tubular plate (filtration–fill method) or pressing a dense, paste-like material into the plate.

The so-called filtration–fill method has been introduced by Chloride [3]. During pumping of the slurry into the tube the oxide is retained by the sleeves while the water passes out through its pores. The flow rate is 10 - 20 l per min and the fill time is 5 - 10 s. The filling head operates at a pre-determined pressure range (usually 1.4 - 2.1 kg cm^{-2}) to ensure precise weight control. The output of the individual filling station is 200 - 400 plates per hour, depending on plate length. The design of the filling station is given in Fig. 4.

Oxide is mixed with water to form a slurry of a given density, normally in the range 2.0 - 2.5 g cm^{-3}. The addition of oxide and water to the mixer is carried out automatically. The slurry is then pumped to individual filling stations. Lead slurry effluents from the transportation system and the filling stations are reprocessed (*i.e.*, filtration, water recovery, correction of density) and re-introduced into the distribution system. A dry-packed density of 3.6 - 5.0 g cm^{-3} can be achieved using the filtration method.

The wet-fill process and necessary equipment have also been developed by HOPPECKE and HADI, both in the F.R.G. The HADI tubular-plate filling machine [4] operates with paste material similar to that used in automotive batteries. The specific density of the paste is 3.8 - 4.2 g cm^{-3} and the penetra-

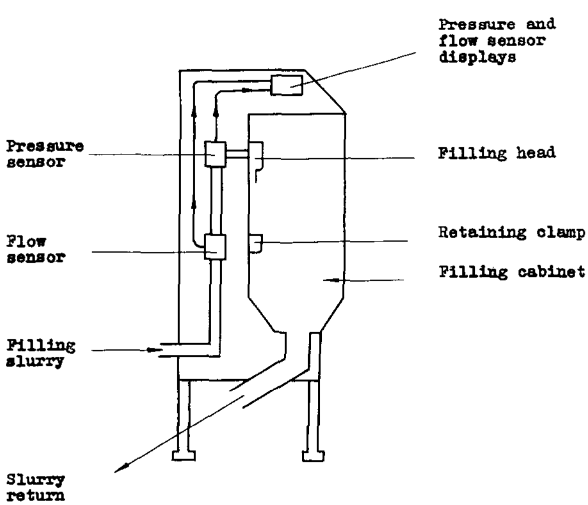

Fig. 4. Chloride oxide-filling machine for tubular plates.

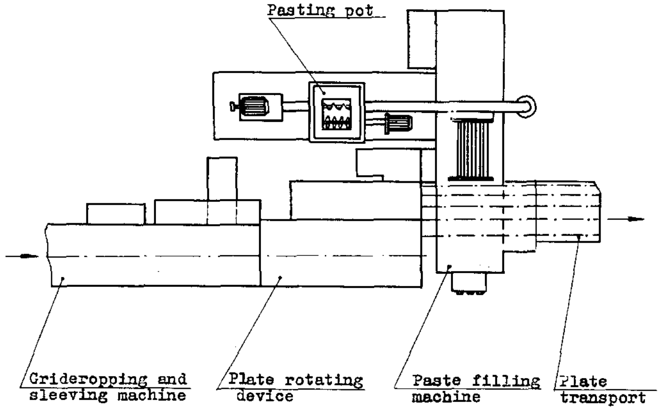

Fig. 5. HADI oxide-filling machine for tubular plates.

tion is 20 - 22. The grid and its tubular sleeve are passed to the feedpipes of a filling machine that fills the electrode automatically with the paste (not slurry). The machine operates with multi-tube systems. During the filling process, the plate is drawn off the pipes so that the paste is evenly distributed inside the tubular sleeve. The machine output is about 3 plates per minute for 600 mm-long plates (Fig. 5).

The next manufacturing step involves continuous welding of the plastic bottom bar. Plates are then washed and weighed automatically. Paste effluents and water are recycled.

The wet-filling installation developed by HOPPECKE (Fig. 6) comprises

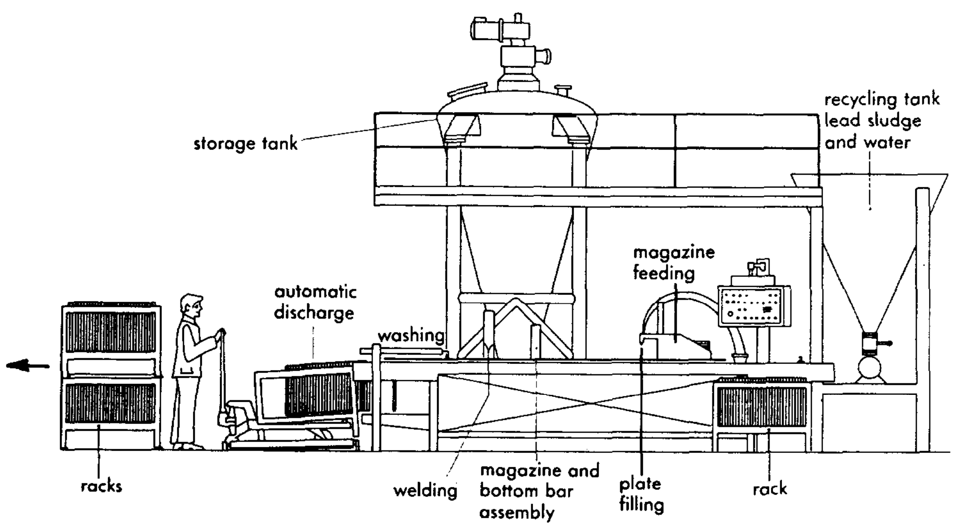

Fig. 6. HOPPECKE oxide-filling machine for tubular plates.

an automatic tubular-plate filling machine, a paste hopper, a washing and weighing station, and equipment for water and paste recovery [5]. The paste-filling technology is similar to that used by HADI. Plates filled with paste do not require pickling before formation.

Conclusions

Stringent regulations concerning the lead-in-air content imposed on battery manufacturers has resulted in the development of more efficient and environmentally-safe processes. Both the dry- and wet-fill methods for tubular-plate production have their advantages and disadvantages.

Dry-fill processes involve the use of more efficient filtration and vent systems, while the use of granular oxide instead of powder increases the filling capacity and reduces dusting. On the other hand, wet-fill technology uses a special recirculation system consisting of pumps, tanks, and filtration screens. Long-term industrial trials are necessary for a final evaluation of these two methods.

References

1 M. J. Weighall, D. W. H. Lambert, D. A. J. Rand and W. G. A. Baldsing, in T. Keily and B. W. Baxter (eds.), *Power Sources 12*, International Power Sources Symposium Committee, Leatherhead, U.K., 1988, pp. 77 - 91.

2 J. Kwaśnik and H. Krysiak, *B. Electrochem.*, *4* (1988) 35.

3 J. M. Stevenson and A. Battery, *Int. Symp. Mech. Autom. in Chem. Power Sources Production, Poznań, 1988*, Paper No. 7.

4 P. Faber, *Int. Symp. Mech. Autom. in Chem. Power Sources Production, Poznań 1988*, Paper No. 15.

5 W. E. Fetzer, *Int. Symp. Mech. Autom. in Chem. Power Sources Production, Poznań, 1988*, Paper No. 8.