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ADVANCES IN MANUFACTURING SYSTEMS FOR TUBULAR POSITIVE PLATES FOR STATIONARY AND TRACTION LEAD/ACID BATTERIES

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Introduction

HOPPECKE is one of the leaders in lead/acid battery manufacture and technology in the Federal Republic of Germany. The family-owned company has been developing and manufacturing storage batteries for a wide variety of applications since 1927. HOPPECKE operates three factories in Germany and one in France. More than 1100 employees are engaged in the production of automotive batteries, traction batteries, stationary batteries, nickel/cadmium batteries, charging systems, and lithium cells.

The development of reliable production machinery has opened up new market opportunities for HOPPECKE's engineering department. HOPPECKE's wet-filling system for tubular plates provides maximum reliability during production. Long-term trials with different battery manufacturers have shown that this process possesses a number of important benefits compared with conventional dry-fill methods using oxide or granular oxide. These benefits include:

- no dusting properties, resulting in safer working conditions, and improved hygiene (no filtering, exhausting or masks required)
- high-pressure flow properties that enable a significant reduction in plate-filling times
- constant weights by control of filling and, thereby, improved quality
- no pickling/dipping of plates in H_2SO_4 required after tube filling
- paste/suspension preparation can be conducted in customer's existing mixer
- water and paste can be fully recycled
- more than 2000 plates can be processed per 8 h shift, even for lengths of 600 mm, with one operator only
- electricity consumption is ~10 kW compared with conventional systems that usually consume 80 - 100 kW through the need for heavy exhausting, etc.

Tubular plates

In Europe, nearly all stationary and traction lead/acid batteries use the tubular positive-plate design. This results in a number of advantages

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compared with other designs, namely:

- improved gravimetric energy density ($W\,h\,kg^{-1}$)
- improved volumetric energy density ($W\,h\,l^{-1}$)
- more positive active material
- more acid
- higher active material/grid weight ratio.

The positive active material is kept in place by a gauntlet made from polyester fibre. Improved active material utilization is achieved because of closer proximity of the active material to the grid spines, more uniform access of the acid to the active material, and greater exposed surface area. The tubular design also has greater mechanical stability and thereby reduces shedding of plate material.

The disadvantages of tubular-plate manufacture relate mainly to the machinery and process requirements. For example:

- the dusty nature of the filling oxide requires stringent environmental controls
- the oxide is not free-flowing and speed of production is inhibited by the difficulty met with in filling the annular space between the gauntlet and the grid spine with oxide and achieving the desired oxide density; voids may occur and these will result in poor formation and significant variations in plate capacity
- if the oxide contains a high percentage of fines, the resultant blocking of the gauntlet may prevent, or inhibit, the ingress of acid; increased shedding of active material may also occur, thus reducing cycle life
- overall manufacturing costs are higher for the equivalent flat-plate design; this fact enables flat-plate cells to be marketed at a lower price than tubular-plate cells (for a given cell size) in many countries and markets.

Oxide properties — conventional oxides

Some battery manufacturers use 100 wt.% red lead to fill tubular positive plates, but it is more common for the red lead to be blended with leady oxide and/or litharge. A certain amount of red lead is considered desirable as it facilitates plate formation and improves the initial energy efficiency. Each manufacturer has developed proprietary blends to give the required flow properties, filling density, cell performance, and raw materials' costs. The PbO_2 content of the blend is typically 10 - 30 wt.% and the 'tamped', or 'vibrated', oxide density is normally in the range 3.3 - 3.8 $g\,ml^{-1}$. The required density is achieved by clamping the plates upside down in a jig and vibrating, or bumping, the jig after the oxide is loaded in from above. A similar density range can be achieved without difficulty, and with faster filling times, when the paste/suspension technique is used.

The free-lead content of the conventional oxide blend can vary between 0 wt.% (for 100 wt.% red lead) and approximately 15 wt.% for blends containing leady oxide.

After filling, the tubular plates are subjected to a pickling/seasoning process before formation. The details of this process are usually proprietary to each manufacturer. The purpose is to sulphate the plates and produce a hard plate that does not shed oxide during the subsequent assembly and formation processes, and that enables the formation stage to proceed in a uniform manner. Any free lead in the oxide is also oxidised during this seasoning process.

Environmental and production benefits

There is increasing pressure on battery manufacturers to reduce the amount of airborne lead dust in their factories, and further reductions in permitted lead-in-air levels are anticipated. Currently, the tubular-plate filling area is one of the most hazardous areas within a battery factory for airborne lead dust. HOPPECKE has succeeded in overcoming this by using a new wet-paste fill technique.

The free-flowing suspension provides an alternative solution to the environmental problem. It is a lead slurry that is easy to handle, much cleaner in use, does not spread around the workplace, and results in significantly lower lead-in-air values. No masks, exhausting and filtering equipment are required. Because of its free-flowing nature, the suspension fills the tubes significantly faster than conventional oxide or granular oxide blends and this also contributes to improved hygiene around the working area. It has been found that filling times can be reduced from 150 s for leady oxide or 30 s for granular oxide to ~13 s for suspensions. This includes all working and checking steps for a ready-made tubular plate.

User trials to date indicate that lead-in-air values can be reduced by 95 - 99%, at least, and filling times reduced by a factor of 8 or 10 (for oxide) and 2 or 3 (for granular oxide) using the new wet-filling system. This reduction in filling times and streamlining of plate processing should offer the manufacturer significant reductions in production costs.

Tubular-plate wet-filling system

The HOPPECKE tubular-plate installation is the first, and currently the only fully-automatic wet-filling system, with a proven record of production for more than a decade. It comprises the following elements: tubular-plate automatic filling machine, paste hopper, and equipment for water and paste recovery. The technical design of the plant makes it possible to combine high productivity with very low manpower requirements. Water and paste are almost 100% recycled. The system has a number of advantages over dry-filling installations. The plates produced are uniform, and plate weights are within close tolerances. All emission problems caused by production are contained by the water in HOPPECKE's wet-filling system; this gives environmental protection directly at the working place.

The HOPPECKE tubular-plate automatic plant comprises the following:

- suspension storage tank
- reciprocating metering pump
- magazine for unfilled plates
- filling station
- automatic bottom-bar assembly station
- ultrasonic welding station for bottom bars
- washing station
- weighing station
- magazine for filled plates.

It is operated automatically through a fully-programmable control unit.

Approximately five tubular plates (up to an effective length of 600 mm = 125 or 150 A h plate) are filled per minute. The precise metering of the paste by a reciprocating metering pump with variable stroke/filling capacity makes it possible to keep the weight of the filled plates within very close tolerances. The machine's linear conveyance system transfers the plates in timed sequence from one workstation to the next. Final checking of the filled weight is by a computer-controlled weighing station. The machine can be reset to deal with various plate widths and lengths.

Paste preparation takes place in a conical suspension-stabilizer with a rotating screw. This ensures that the consistency of the paste supplied is kept constant. The paste is produced in a conical mixer upstream of, and similar to, the suspension-stabilizer. This can also be carried out, however, in the customer's existing mixing equipment.

The water- and paste-recovery unit comprises:

- thickener
- storage tank
- four spiral pumps
- pipework
- high-pressure water unit.

The process water gathered in the collection tank is transferred by a spiral pump to the thickener. The excess lead paste is returned to the storage tank. The concentrated paste from the supply tank and the thickener is re-used at the start of a new mixing operation. In other words, recycling is achieved during production. The pre-clarified water is returned to the filling machine as washing water by a high-pressure water unit.

HOPPECKE sell the system together with a know-how package. On purchase of the tubular-plate system with know-how package, and provided that the material specifications are adhered to, the full HOPPECKE production and performance guarantee becomes effective. The know-how package comprises:

- adaptation of customer materials (tubular gauntlets, grids, moulds, bottom bars, lead oxide, additives) to the system, at HOPPECKE's works

- advice at the customer's premises on layout, paste-mixing, formulations, etc.

After delivery, the customer will enjoy five years' participation in further development of the HOPPECKE filling system.

Cell performance

An industrial traction cell traditionally has a capacity of only 85% on its first discharge and gradually builds to full capacity after about 10 cycles. It is often not economic or practical for the manufacturer to cycle the battery before dispatch and the customer may receive a battery that does not achieve its rated capacity until several duty cycles have been completed.

By contrast, batteries with the new, wet-filling process have achieved full rated capacity after the first cycle and 105 - 110% of rated capacity after 10 cycles. The capacity after 10 cycles is typically 5 - 10% better than that for the standard product at an equivalent oxide weight and density. This is probably due to the better access provided to the acid by virtue of the open porous structure of the paste/suspension material and the balanced particle size range. Also, the capacity from cell-to-cell is more consistent.

The battery manufacturer who uses the new wet-filling process will be manufacturing a more consistent product which will achieve full rated capacity after the first cycle. There may also be scope for reduction in plate weight for an equivalent performance — or a higher performance from the equivalent weight and volume.

Filling trials have confirmed that more consistent filling can be achieved using the wet-filling process. For example, if filling weights are currently controlled to $\pm 5\%$, with the new system, control to $\pm 1.5\%$ is achievable, with obvious benefits in terms of lower raw materials' costs and improved product quality (Fig. 1).

Applications

In a number of markets (*e.g.*, in the U.S.A.) fears of the environmental hazards associated with tubular-plate filling have inhibited some manufacturers from designing and manufacturing tubular-plate batteries. This is in spite of marketplace demands for more reliable batteries with higher performance and longer cycle life; needs that can be met by tubular-plate designs (Figs. 2 - 4). The availability of a hygienic, free-flowing, wet-filling system should encourage battery manufacturers to reconsider using tubular-plate designs (Figs. 5, 6).

For motive power applications, the ability to achieve full rated capacity from cycle 1, and the improved active material utilization using the new wet-filling system, will be of particular benefit. The potential saving in manufacturing costs, and improved product quality and consistency, are also expected to widen the market for tubular-plate batteries.

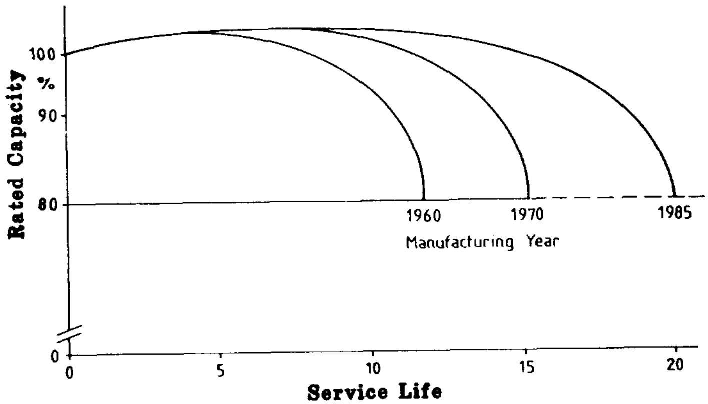

Fig. 1. Progress in the service life of stationary/traction lead/acid batteries.

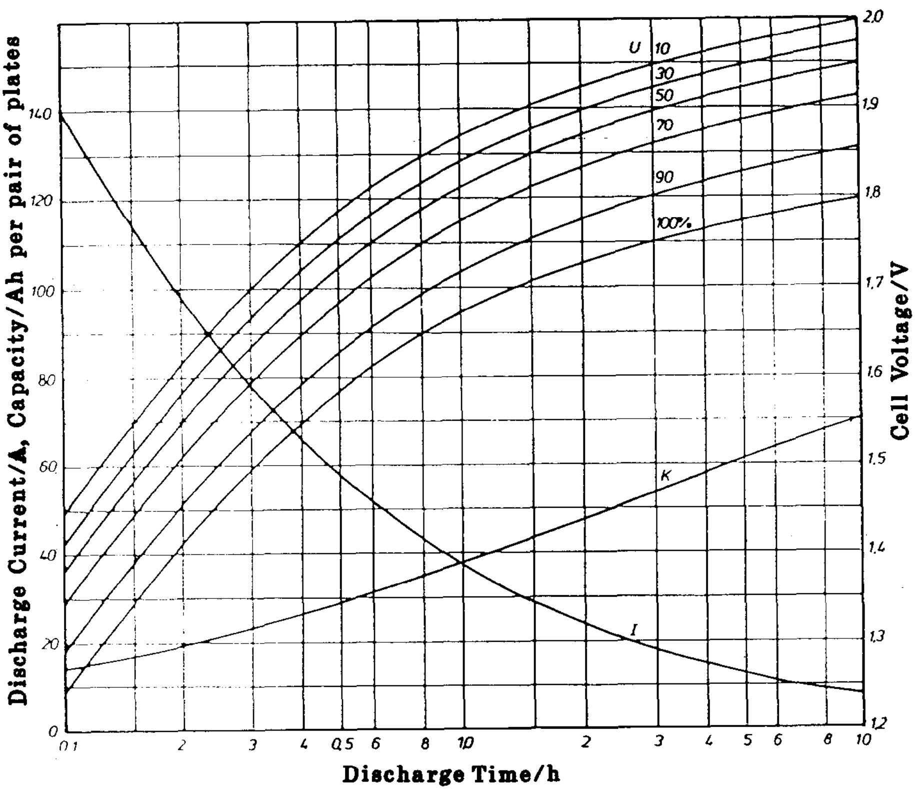

Fig. 2. Discharge characteristics of OPz S 70 (PO/315) tubular-plate batteries of 70 A h capacity and 5 - 7 positive plates.

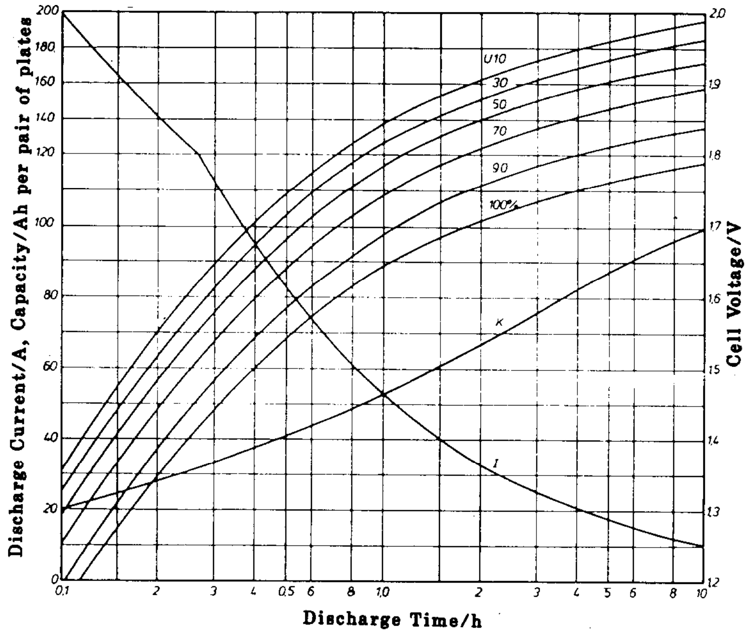

Fig. 3. Discharge characteristics of OPz S 100 (PO/445) tubular-plate batteries of 100 A h capacity and 6 - 12 positive plates.

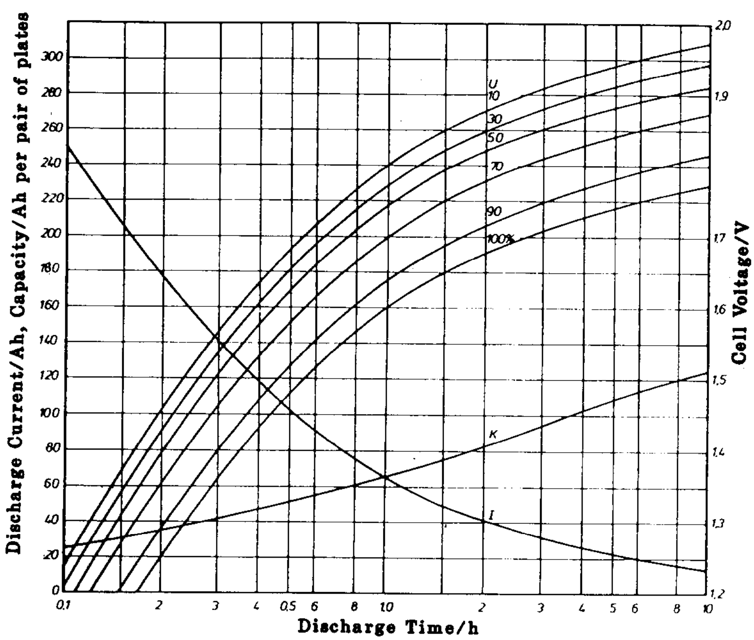

Fig. 4. Discharge characteristics of OPz S 125 (PO 555/19) tubular-plate batteries of 125 A h capacity and 12 positive plates.

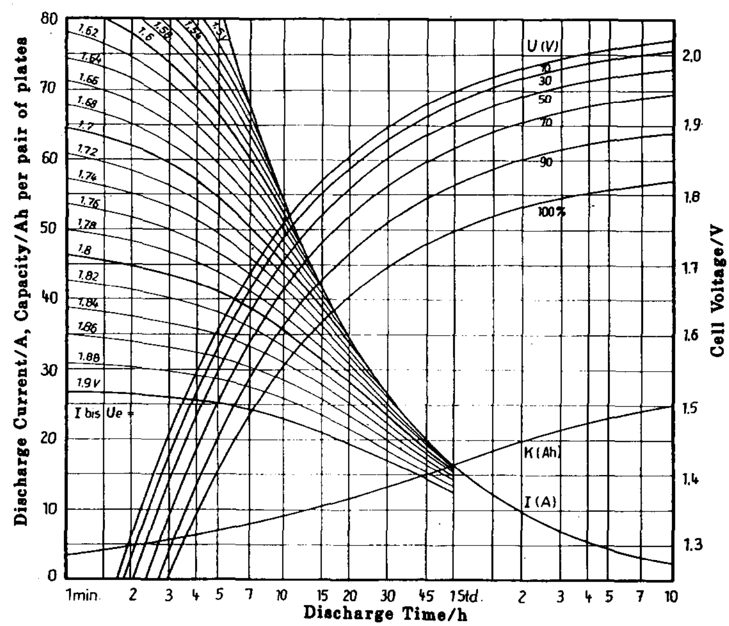

Fig. 5. Discharge characteristics of OGi 25 flat-plate batteries of 25 A h capacity with 6 - 20 positive plates.

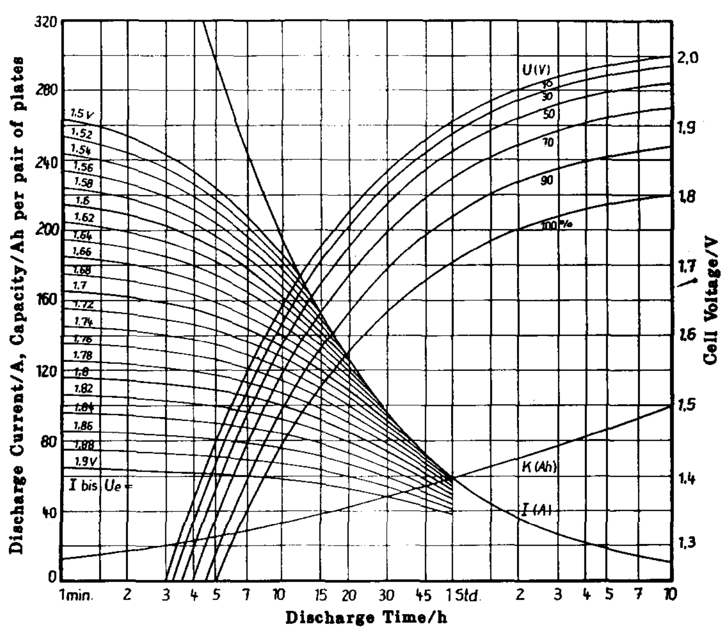

Fig. 6. Discharge characteristics of OGi 100 flat-plate batteries of 100 A h capacity with 6 - 20 positive plates.