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A COMPARISON OF BARTON-POT AND BALL-MILL PROCESSES FOR MAKING LEADY OXIDE

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Introduction

There are two principal methods of making leady oxide for lead/acid batteries. These are. (i) the Barton-pot process, which utilizes the oxidation of molten lead; (ii) the ball-mill process, which employs the oxidation of solid lead Several conflicting claims have been made for the advantages of the one process over the other, and vice versa (for a review see ref 1)

It has been estimated that about 80% of the cost of making battery plates involves that of the raw materials, direct and indirect labour costs account for the remaining 20%. Cost analysis emphasizes the importance of accurately and efficiently controlling and producing the raw materials One such material is leady oxide. Thus, the importance of carefully analyzing the two methods of producing battery oxide, both from a process and from a product standpoint, is obvious Such a comparison is made here by using information obtained from the Linklater type of Barton pot and a European type of ball-mill.

Process operation

In the Barton-pot method of making leady oxide, high-purity lead is first melted in a separate vessel and then pumped to a reaction pot. There, the lead is rapidly stirred with a paddle under a forced flow of air. The lead droplets formed by the agitation are partially oxidized to lead monoxide (PbO) which is carried by the air stream to a collecting system. The oxide so produced is primarily a mixture of tetragonal (α-PbO) and orthorhombic (β-PbO) lead monoxide together with some unreacted ("free") lead. By changing the lead processing parameters, the proportion of lead monoxide can be made to vary between 65 and 80 wt.%.

In the ball-mill process, high-purity lead in various size configurations is allowed to tumble in a rotating mill. This motion produces heat which, in turn, causes the lead to oxidize. The oxidation reaction is exothermic and thus provides more heat to accelerate the process further. (Note, to prevent the charge from melting, the mill must be kept cool during operation.) The oxide usually consists of 60 - 65 wt.% of α-PbO, with the remainder being free lead

0378-7753/87/$3 50

Process variables

For a given process, several variables usually exist which affect the production rate as well as the quality of the product. The Barton-pot and ball-mill processes are no exceptions to the rule in both instances, a number of variables must be carefully regulated to ensure a consistent, high-quality product The importance of oxide consistency cannot be over-emphasized as it allows the battery plate-making process to be standardized

There are two important process variables associated with the Barton-pot, namely, temperature and water addition. Temperature is particularly critical as it determines both the phase composition (structure) and the overall production rate of the leady oxide As noted above, there are two types of lead monoxide The β polymorph is formed at temperatures above 488 °C and is considered undesirable in the final product [2] Below 488 °C, α-PbO is the stable form and therefore it is important to operate the process below this temperature. Water injection is used in some instances to increase the rate of oxide production. The presence of water lowers the pot temperature, results in a greater demand for lead, and thus causes an increase in oxide formation

In a ball mill, the air supply that enters either through the loading port or through several vents in the drum casing can be varied to influence both the oxidation rate and the lead monoxide/free-lead ratio This ratio can also be determined by the amount and temperature of the charge The weight of the charge must be kept as constant as possible in order to ensure a consistent product. The temperature must be held below the melting point of lead, *e g*, by water or air cooling The size configuration of the raw lead feed does not affect the quality of the oxide product The only limiting factor is the dimension of the loading port. Finally, ball-mill capacity has been found to be directly proportional to the speed of rotation The energy required to produce a tonne of oxide remains fairly constant when the mill is operated at about 55 - 90% of its critical speed. The latter is the speed at which the content of the mill ceases to tumble because it is held against the walls by centrifugal force

Process flexibility

A process should be flexible and responsive to variable changes The more flexible and responsive a system is, the easier it is to control, and the easier it is for the customer to obtain the desired product

The temperature of the reactor in a Barton-pot system is controlled by the rate of feeding-in the lead. In the Linklater type, the air–oxide temperature is controlled by the water flow into the reactor and by regulating the air flow through the reactor These two parameters determine both the production rate and the density of the leady oxide

As discussed above, the ball mill has several controllable variables, but the process does not respond very quickly to change The volume of air passing through the mill, and the weight and temperature of the charge are adjusted to produce a given leady oxide composition. The capacity and particle size of the oxide is determined by the speed of rotation.

Operating and maintenance problems

Operational problems encountered with leady oxide production are usually associated with the level of control of the process parameters that most affect the rate of production and the quality of the product. The accurate monitoring and fixing of these parameters is obviously the key to efficient production

One problem with the Barton-pot system is that of controlling the pot temperature If the temperature is excessive, *i e.*, above 488 °C, a large amount of β-PbO can be formed, which some manufacturers maintain is undesirable [2]. Normally, Barton oxide contains less than 15 wt.% of this polymorph. The Linklater system regulates the air, water, and lead flows in order to prevent high temperatures

Fixing the temperature of a ball mill has always been difficult. This is due to the fact that the temperatures of the drum, the charge and the air are all different. A further problem is that of controlling the amount of lead in the drum. These factors give rise to difficulties in classification and recycling of the oxide product

Product comparison

Barton pots normally produce an oxide having 70 - 80 wt.% of PbO, an apparent density of between 1.2 and 1.8 g cm^{-3} and an acid absorption of 160 - 190 mg H_2SO_4 per gram of oxide. The oxide particles are usually round or spherical in shape, and are all less than 60 μm in size with a mean diameter of 3 - 4 μm

By contrast, ball mills yield an oxide with 60 - 70 wt.% PbO, an apparent density of 1.2 - 1.5 g cm^{-3} and an acid absorption of around 200 mg H_2SO_4 per gram of oxide. The oxide particles are flat and non-uniform in shape. A comparison of the properties of the oxide formed by the Barton-pot and ball-mill processes is given in Table 1.

Economic considerations

The operating cost of a Barton-pot system amounts to 0.5 H per day maintenance. This figure varies with the skill of the operators and the maintenance programme in force. Horsepower per tonne of oxide produced in the 500 - 900 kg h^{-1} systems requires approximately 60 kW. By contrast, a 900 - 1000 kg h^{-1} ball mill requires about 215 kW

TABLE 1

Properties of Barton-pot and ball-mill processes and the respective oxides

Parameter	Barton pot	Ball mill
Process		
Production (kg h^{-1})	850	650
Power required (kW)	30	40
Water flow (l h^{-1})	—	200
Air flow (m^3 min^{-1})	0 43	0 28
Natural gas (BTU h^{-1})	0 25 × 10^6	—
Dimensions		
length (m)	7 5	10 5
width (m)	3 6	5 0
height (m)	6 3	5 2
Operation	*Start/stop as required*	*Continuous*
Oxide		
Total PbO (wt %)	70 - 80	55 - 65
α-PbO (wt %)	70 - 100	100
β-PbO (wt %)	0 - 30	0
Apparent density (g cm^{-3})	1 2 - 1 8	1 2 - 1 5
Acid absorption (mg H_2SO_4/g oxide)	160 - 190	180 - 240
Maximum particle size (μm)	< 60	< 150
Particle shape	round	flat

The start-up to normal running condition of a preheated Barton pot takes about 0.5 h, the system can be stopped at any time and shut-down requires 0 25 h

Compared with the ball-mill system, the Barton pot has a lower cost per tonne per space required (Note, a ball mill occupies 1.5 - 2 times more area) Labour and supervising costs are virtually the same for both systems and involve less than 0.5 h per day

Considering capital expenditure, an automatic Barton-pot system capable of producing about 900 kg h^{-1} of oxide would cost approximately US$175000, a 1000 kg h^{-1} ball mill would cost US$280000. Both prices do not include storage, weighing or conveying equipment, and the lead ingot caster is excluded from the figure for the ball mill

Conclusions

A comparison of the Barton-pot and ball-mill processes is given in Table 2 [1] It is concluded that the Barton-pot method is easier to adjust and quicker to respond to changes in the process parameters The ball mill usually operates with less fluctuation in the product, but must be run continuously in order to keep both quantity and quality within specification

Various reports in the literature maintain that

(i) Barton-pot oxide will produce a battery that will give very good life and high capacity,

TABLE 2

Comparison of Barton-pot (unground) and ball-mill processes for leady oxide production*

Parameter	Barton pot	Ball mill
Economics	Initial cost lower More energy efficient	— —
Operation	Oxide easier to handle, less prone to aggregation Process easier to control Higher production rate per unit space Higher conversion of lead to lead oxide	Higher production rate per weight (more lead under process)
Oxide	Oxide and lead particles more equidimensional Greater apparent bulk density Higher β-PbO content Longer shelf life	Lead particles flatter and thinner Oxide particles smaller (lower median particle diameter) and more reactive Higher free-lead content
Paste	Paste mixing and pasting easier	Higher acid absorption Better paste consistency at very low densities
Plate characteristics		
Curing	—	Process faster Stronger active material
Formation	—	Greater surface area Higher initial capacity

*Taken from ref 1, page 143

(ii) ball-mill oxide will produce a battery with good capacity and good life.

References

1 G L Corino, R J Hill, A M Jessel, D A J Rand and J A Wunderlich, *J Power Sources*, *16* (1985) 141

2 M. Barak, in M Barak (ed), *Electrochemical Power Sources Primary and Secondary Batteries*, Peter Peregrinus, Stevenage, U K , 1980, p. 223