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Application of Circulating Fluid Bed Calciners in Large-size Alumina Plants

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Abstract

Using circulating fluid bed calciners for the calcining step in alumina production, considerable heat savings can be achieved. After successful operation of the first 560 sh. t. p. d. unit at VAW's Lünen plant more fluid bed calciners with maximum capacities of 725 sh. t. p. d. for a single unit are being built. For future alumina plant projects 900 and 1100 sh. t. p. d. units are under discussion. Design studies have shown that the circulating fluid bed system can be applied for such large capacities. A high degree of automation of the process, a floorspace-saving arrangement for multiple units avoiding high buildings and a simplified process flowsheet are important design criteria.

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Application of Circulating Fluid Bed Calciners in Large-size Alumina Plants

Principle of the circulating bed technique

As described in more detail at the 1971 Annual AIME Meeting in New York, Lurgi and VAW jointly have developed the circulating fluid bed technique for calcining alumina to an industrial scale (1). The calcination of aluminiumtrihydrate to metal grade alumina is carried out in a highly expanded fluid bed, allowing for fluidization velocities of well over 10 ft./sec. The entrained alumina (Fig. 1) is precipitated in a recycling cyclone and fed back to the fluid bed via a fluidized bed immersion seal (2).

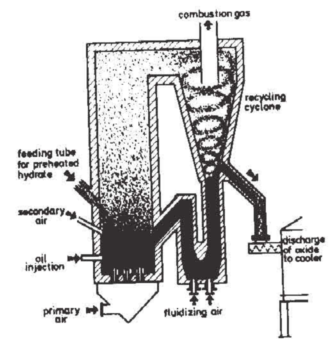

Fig. 1 Principle of the circulating fluid bed calciner

Firing is achieved by direct oil injection into the lower furnace section, in which a zone of increased solids concentrations is formed by dividing the fluidizing air into primary and secondary streams. The combustion of heavy fuel oil takes place under conditions which are below stoichiometric, in the lower furnace section and is completed by the secondary air stream under an excess of 5 to 10% above stoichiometric in the upper part of the furnace. By preheating primary and secondary airstreams in a multistage counter-current fluidized bed cooler to technically allowable temperatures, high theoretical combustion temperatures of about 4500° F can be adjusted giving an excellent thermal efficiency of the calcining system. Due to gas/gas and gas/solids mixing behavior of the fluid bed, these temperatures hardly ever occur and the bricklining of the furnace is ideally exposed to the uniform calcining temperature, normally ranging from 1800 to 2200° F, depending on the required degree of conversion from γ-alumina to α-alumina. The mean retention time of the alumina to be calcined in the circulating bed can be adjusted between 20 and 60 minutes if necessary. Thus, in a given plant, a wide variation of the calcining conditions is possible. By recovering the sensitive heat in the off-gas by means of a two-stage Venturi fluid bed heat exchanger and by recovering the sensitive

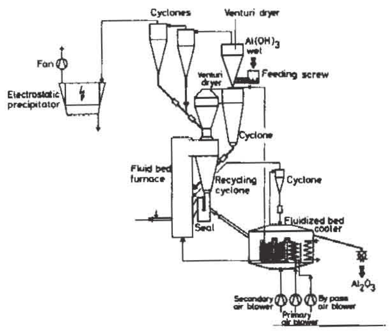

Fig. 2 Flowsheet of the first 560 sh. t. p. d. fluid bed calcining plant.

heat of the discharged alumina in a multistage fluidized bed cooler (Fig. 2), the daily average heat consumption of the whole calcining step, starting from an aluminiumtrihydrate with 14% filter moisture, could easily be brought below 1400 BTU/lb. Al_2O_3. The first industrial unit of 560 sh. t. p. d. Al_2O_3 at VAW Lippewerk Lünen has been in operation since April, 1970 with improving performance data, producing a product with an angle of repose of 40° to 41°, an α-alumina content of 50 - 60% (measured by X-ray) and half-year average heat consumption figures of 1450 BTU/lb. Al_2O_3, including start-up losses and losses due to operation with partial load. The capacity of the plant was raised to 620 sh. t. p. d. by minor changes. The whole calcining plant is arranged in a tower of 64 ft. by 64 ft. floorspace requirement and a height of 204 ft., allowing an ideal gravitational flow of the solids through the whold calcining system.

New plants using the tower arrangement

For Western European conditions, where industrial estates are high-priced and where the techniques for erection of high industrial buildings are quite highly developed, the tower arrangement of calcining plants has advantages despite a slightly higher capital investment. A cost estimate for a turnkey 2250 sh. t. p. d. calcining plant, comparing two 1125 sh. t. p. d. units in a tower arrangement and alternatively in a more spread out version with considerably reduced top height (as described later), gave a difference of less than 5% in capital cost in favor of the spread out version.

In a new alumina plant in Northern Germany, where the whole complex is being built on reclaimed soil, the tower arrangement of 4 units, each with 725 sh. t. p. d. rated capacity, was chosen.

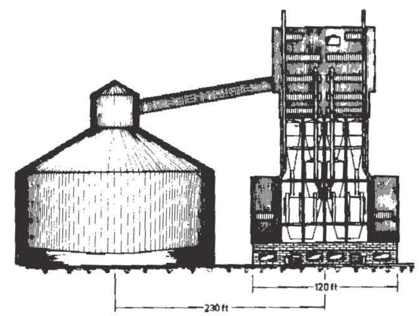

Fig. 3 Tower arrangement of 4 circulating fluid bed calcining units with a total capacity of 2900 sh. t. p. d. Al_2O_3.

Fig. 3 shows a sketch of this plant in connection with the alumina silo. The alumina produced is conveyed by airlifts up to the top of the tower from where the hydrate slides down via an airslide directly into the nearby silo. The floorspace for the 2900 sh. t. p. d. Al_2O_3 calcining plant is 120 ft. by 120 ft., the top height of the calcining plant reaches 230 ft. Three of four units are now under erection. The flowsheet of the single unit is similar to that of the first plant at Lünen (Fig. 2). Due to higher plant capacity the expected specific consumption figures will be slightly lower.

In August, 1972 the second 560 sh. t. p. d. calcining unit at VAW Nabwerk, Schwandorf, Germany, was successfully started up. This plant, also built in a tower arrangement, with regard to a simplified operation, shows some important features for future large-size plants.

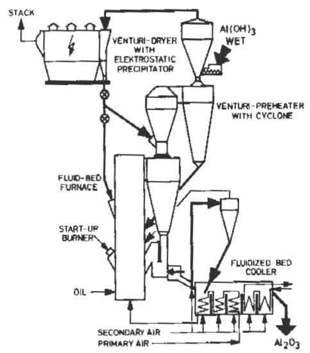

Fig. 4 Flowsheet of simplified circulating fluid bed calcining plant.

Two cyclones of the Venturi drying step are completely eliminated by using an electrostatic precipitator especially designed and proven in cement mills for handling gas streams with high solids concentrations (3). By lifting the electrostatic precipitator to the top of the tower, Venturi drier and electrostatic precipitator were combined into an operational unit forming the upper preheating stage in the off-gas system. No separate fine dust appears and no extra dust handling system is needed, all dried solids pass on by gravitational flow, the heat radiating surface of the system becomes considerably less and the stack is reduced remarkably in length. By giving a controlled flow of solids from the Venturi drier directly into the calcining furnace the waste gas temperature behind the electrostatic precipitator can easily be controlled and kept on a low level for all load conditions. Improving the cross-counter current flow in the fluidized bed cooler of the secondary air stream, its preheating temperatures were considerably raised to 1400° F, enabling us to eliminate the former bypass air stream completely and to cut the cooler down in size. The plant, which is shown in Fig. 5, easily produces 560 sh. t. p. d. of a fine-grained alumina with α-contents of 70%, at least equal specific consumption figures as the Lünen plant.

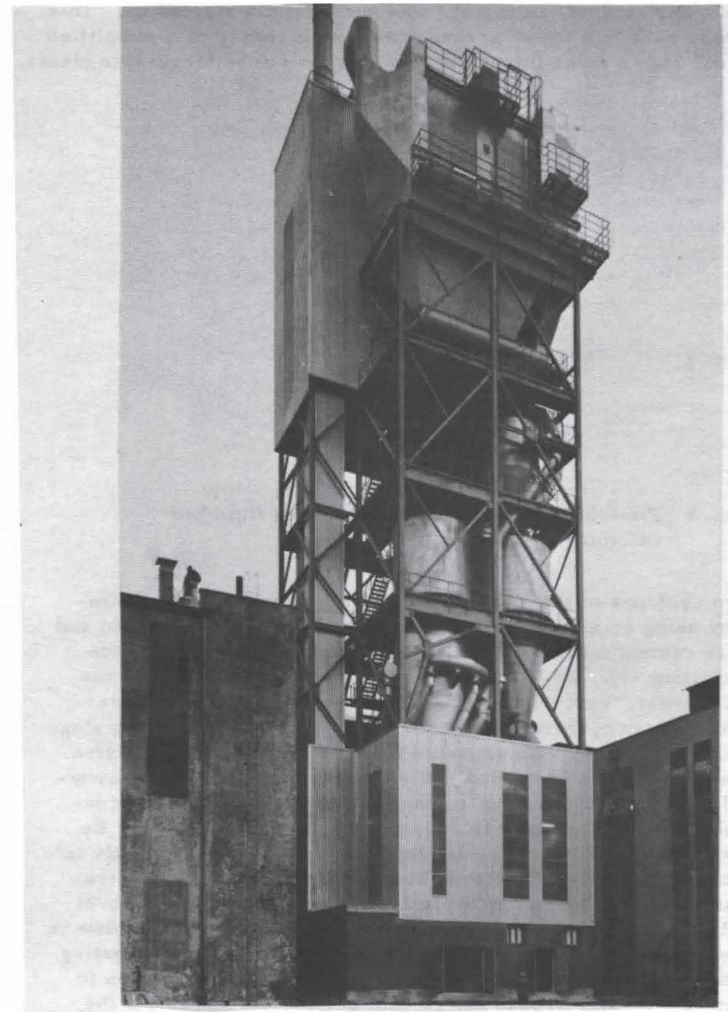

Fig. 5 View of 560 sh.t.p.d. calcining plant at VAW Nabwerk, Schwandorf, Germany.
The floorspace requirement of this plant is 49 ft. by 59 ft. and makes this type favorable for enlarging capacities of existing plants. The top height of the roof is 175 ft.

Design studies for plants with 900 or 1100 sh. t. p. d. units

Alumina plants with yearly capacities over 1 million tons are becoming more and more the rule, especially when they are built close to bauxite mines. Here, mostly in tropical and remote areas, quite different requirements have to be fulfilled. Besides good specific consumption figures, a safe and easy operation of the plant must be guaranteed, erection of the plant must be easily possible with mobile cranes and the plant has to be able to stand up to hurricane windloads and earthquakes. The need for a high availability of the plant and for a minimum number of trained operational personnel calls for a simply and to a large extent automatically controlled operation.

Considering these requirements a spread out arrangement of the calcining units was studied which, similarly to rotary kiln calcining plants, allows an easy side-by-side erection of the different units. The principle of these units is shown in Fig. 6.

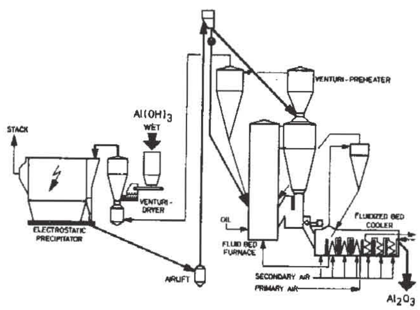

Fig. 6 Principal flowsheet of circulating fluid bed calciners with spread out arrangement.

In order to achieve a high security of operation, the simplified gas and solids flow system of the Schwandorf plant was chosen, with the only difference that the operational unit Venturi drier/electrostatic precipitator was moved to the ground. The dried hydrate leaving the electrostatic precipitator is conveyed by an airlift to the Venturi preheater section, which is still arranged on top of the circulating fluid bed calciner.

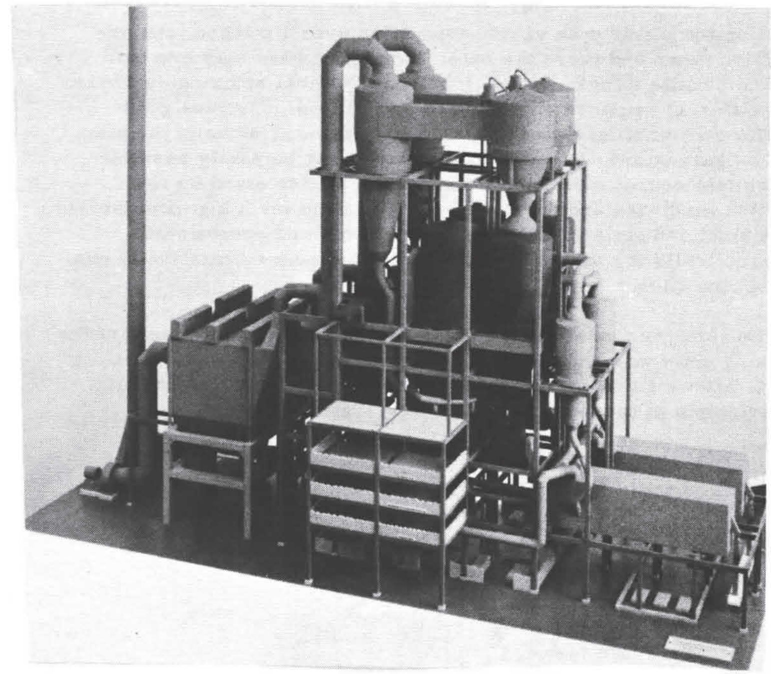

Fig. 7 Lay-out model of two parallel 1100 sh. t. p. d. Al_2O_3 calcining units.

The lay-out model of two parallel 1100 sh. t. p. d. units shows clearly the advantages of this step:

1) The feeding point of the hydrate to the Venturi drier, the discharge of the hot calcined alumina to the fluidized bed cooler and the oil lances of the fluid bed furnaces being the most important places for operation of the plant are arranged at one level. The distance from the control room at the same level to all these points is less than 65 ft.

2) The feeding point for incoming hydrate to the plant is at a level of approximately 75 ft.

3) No moving parts, except an automatic control device, operate above this level. All blowers, compressors, pumps and high voltage equipment are located on the ground floor.

4) During power failure no heat from the calcining step can be transported by convectional flow into the drying stage, constructed from mild steel.

5) There is a good accessibility to all parts of the plant for a mobile crane.

For larger size plants two more units may be added, still using the same control room with power distribution in the floors below. Therefore, a large calcining capacity may be handled by one trained operator with the aid of auxiliary personnel watching the incoming and outgoing material flows. All other functions of the plant are automatically controlled or can be supervised by instrumentation in the control room.

With increasing plant capacities specific heat consumption figures have a declining trend caused by an improving volume to surface ratio, the heat losses by convection and radiation decrease. As previously shown, a decreasing specific heat consumption, by reasons of the mass and energy balance of a calcining plant has to be followed by a decreasing air volume and an increasing air preheating temperature, otherwise heat is withdrawn from the cooling system. As a minimum heat consumption, figures around 1200 BTU/lb. Al_2O_3 could be expected if air preheating temperatures up to 1600° F were allowed for. These high temperatures are critical for a safe long-time operation, at least for preheating the primary air stream passing the cooling bundles and the grate of the fluid bed furnace.

Therefore the primary air preheating temperature is limited to about 1000° F, resulting in a specific heat consumption figure of 1400 BTU/lb Al_2O_3 for a 900 or 1000 sh. t. p. d. unit.

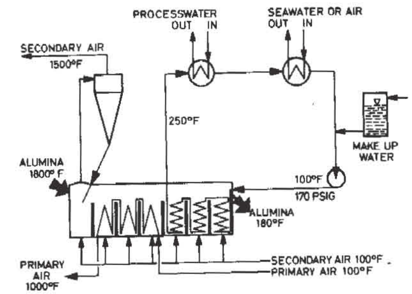

Fig. 8 Fluidized bed cooler with 3-stage counter-current water cooling.

The remaining heat to cool the alumina down to conveying temperatures of about 180° F is preferably withdrawn by water cooling (Fig. 8) (4). Using a pressurised cooling circuit of condensate the circulating water can easily be heated up to 250° F, high enough to heat process water, such as filter wash water, in a separate heat exchanger. The heat not used here can be withdrawn by a seawater cooler or air cooler. Heat amounting to 150 BTU/lb. Al_2O_3 can be re-used.

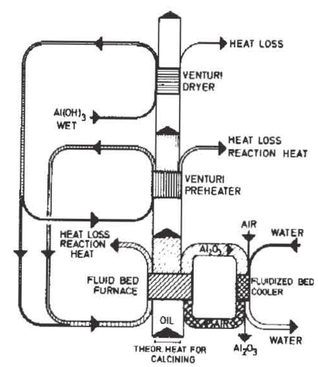

Fig. 9 Heat flow diagram for a 900 sh. t. p. d. Al_2O_3 calcining plant (related to 1 lb. of produced Al_2O_3).

The heat flow diagram again shows the high thermal efficiency of the system compared with theoretical heat consumptions of the calcining reaction from 1020 to 1120 BTU/lb. Al_2O_3. By combustion of oil 1400 BTU/lb. Al_2O_3 are spent. From this amount of heat for heating of process water 100 BTU/lb. Al_2O_3 can be regained, equivalent to an oil consumption of 39 barrels per day for a 900 sh. t. p. d. unit (Fig. 9).

In Table I actual figures for an operating 560 sh. t. p. d. fluid bed calcining plant are compared with projected data for a 2200 sh. t. p. d. plant. Major savings for large-size plants can be expected in capital investment costs, minor savings are possible by heat credit for process water by lower power consumption and by operational personnel. Repair costs cannot yet be fixed accurately because the operational experience of a two-year period with the first industrial plant is too short to give an average figure. No bricklining failure has been observed in the past two years, nor is it expected in the next few years. Therefore normal repair cost figures for continually operating plants seem to be feasible.

Table I. Comparison of main specific cost figures for different plant capacities.

Plant capacity sh. t. p. d. Al_2O_3	560	2,200
Number of units	1	2
Arrangement	Tower	spread out
Annual rated capacity (calculated for 330 operating days) sh. t. Al_2O_3	185,000	725,000
Specific investment for turnkey plant (including licence fees based on early 1972 German prices converted into US \$) US \$/annual sh. t. Al_2O_3	14.50	10.00
Specific oil consumption as daily average (Bunker C oil, 2% S) US gall. /sh. t. Al_2O_3	19.6	19.6
Credit for heating process water Heat equivalent to combustion of US gall. /sh. t. Al_2O_3	-	1.5
Specific power consumption KWh/ sh. t. Al_2O_3	24,5	22

Table I. (contd.)

Operational personnel per shift		
Operators	1	1
Auxiliary personnel	1	2

The absence of longlasting brick repair work allows the minimisation of the number of units in large-size alumina plants and the avoidance of spare units because most of the repair work in a fluid bed calcining plant can be done while keeping the system hot. The plants have proven to be very flexible in capacity and normal operation from 40% of rated capacity upward is possible under automatic control. Heating up periods are short and shutting down the plant does not need extended care apart from stopping the blowers and moving the oil injection lances into shut-down position. The system can be started up after 2 - 3 days simply by bringing the blowers and oil lances into operation again.

Table II. Distribution of capital investment costs for different items of a 2200 sh. t. p. d. circulating fluid bed calcining plant (projected for erection in Germany).

		Percentage of total investment
Deliveries (including licence fees, freight)	Machinery (including brick-lining material)	46.1%
	Electrical equipment (including cables, light inside battery limits)	14.0%
	Control instruments	2.6%
Erection	Machinery, electrical equipment and instrumentation	22.0%
Foundations (normal soil conditions)		4.5%

Table II. (contd.)	
Buildings (walls, roofs, rain protection)	1.7%
Structural steel (incl. erection)	9.1%

Table II shows the distribution of investment costs to different items. These cost relations may vary considerably for locations in overseas areas, but give at least a good impression of the cost structure of the new fluid bed calcining system.

The projected unit sizes do not yet represent the maximum possible capacities but seem to be an optimum size for current large-size alumina plants. It is hoped that the given figures may be proven in the not too distant future.

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