Experience Driven Design Improvements of Gas Suspension Calciners

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Abstract

FLSmidth has experience with Gas Suspension Calciners (GSC) over the past 40 years from different hydrate sources calcined in both pilot and full scale Gas Suspension Calciners of various design and capacity. This paper outlines the design changes in cyclone dimensions to lower the gas velocity to reduce pressure drop & wear on vortex finder and to minimize the risk of particle breakdown; redesign of riser ducts to reduce the peak velocites to minimize the Particle Break down, Pressure drop & wear; improved refractory design to minimize radiation loss, thereby reduction in thermal energy consumption and other improvements in calciner such as optimized holding vessel, start-up burner relocation etc.

Keywords: Alumina, Calciners, Thermal, Energy, Consumption.

1. Introduction to Gas Suspension Calciner with 4 Direct Heat Recovery Stages

Calcination is the final step of the Bayer process where alumina is produced from aluminum trihydroxide (Hydrate, Gibbsite). After calcination, alumina is sent to a smelter where pure aluminum is produced.

In 1976 FLS had commissioned the first industrial Gas Suspension Calciner (GSC) technology for the pre-calcination raw meal (~70% limestone fines) in a new 4600 tpd Cement clinker production line in Japan. The pre-calciner operating temperature was about 950^{o} C with few seconds of solid retention time.

Since the basic research and development work and prototyping of the gas suspension calcination technology was developed and done for cement raw meal it was relatively straight forward in 1976 for FLS to adopt this calcination furnace/reactor technology for alumina production.

2. Gas Suspension Calcination

The timing of this technology spin-off was very fortunate as FLS had lost its dominating world market position for supply of rotary kilns for production of sandy or floury alumina when the last rotary kiln for alumina was contracted in 1974.

Ten years after FLS started the development with pilot plant testing in 1976, the first GSC unit with a calcining capacity of 1000 TPD and calcination furnace temperature around 1050^{o}C for Smelter Grade Alumina (SGA) was commissioned at Hindalco [1]., India in 1986, replacing three old FLS rotary kilns.

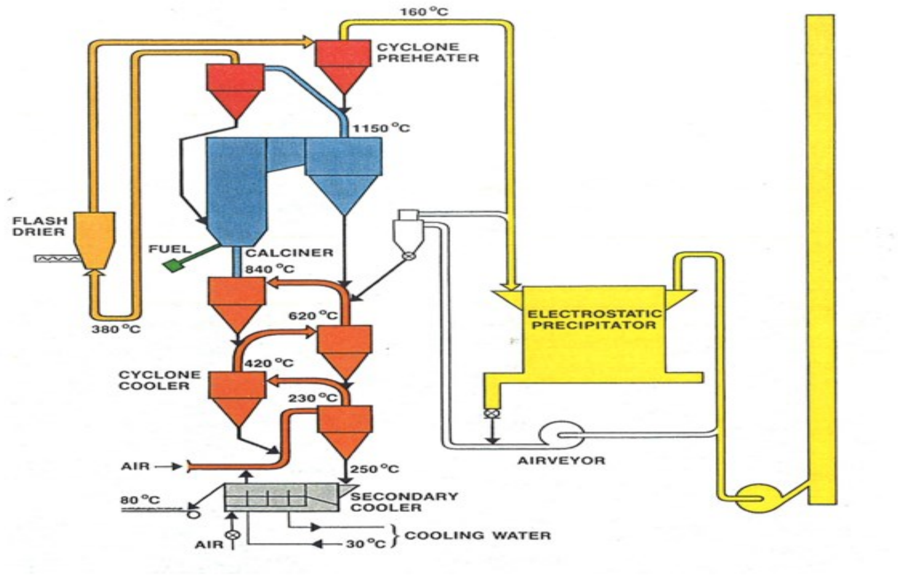


Figure 1: Gas Suspension Calciner Vertical arrangement.

The First GSC technology is a vertical arrangement comprises (Figure 1) of:

- Drying and Pre-heating/Pre-Calcination (PO1, PO2) of Feed material
- Calcination Furnace (P04) and Furnace Cyclone (P03)
- Direct Heat Recovery from alumina by cooling with Air in Four (4) stage Cyclone cooler;
- Indirect alumina cooling with water in a Fluxo Cooler.

In 1986, Eurallumina, Italy, decided to retrofit one of three Ø3.95 x 107 m long rotary kilns producing 900 tpd sandy alumina with an oil fired GSC unit to produce 1550 tpd SGA. The specific energy consumption was reduced to 3100 kJ(LHV) per kg SGA from about 4100 kJ(LHV) per kg sandy alumina. The alpha-phase content was reduced from about 18% in the sandy alumina to 2-5% in SGA for the same SSA and the LOI (300-1000 °C) was reduced from 0.8% to 0.55-0.65 wt %.

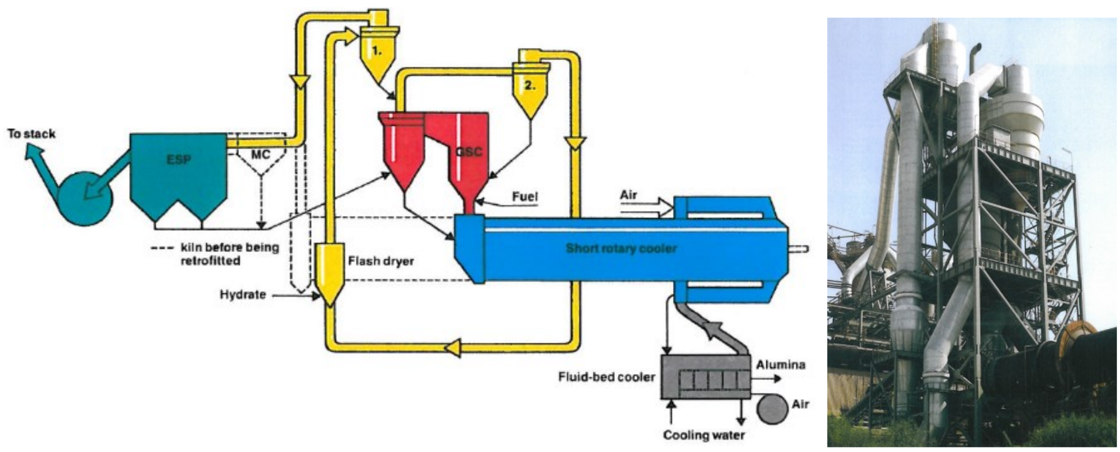


Figure 2a. GSC Retrofit converting rotary kiln to rotary cooler, Eurallumina, Italy.

In the global alumina market rotary kilns were replaced with new stationary calciners, but some were retrofitted to more energy efficient operation and higher production capacities Figure 2a.

In 1989, Integrated GSC & filtration arrangement was developed and supplied to Sherwin Alumina, USA with reduced height of GSC structure.

Figure 2b. Integrated GSC with reduced tower height, Sherwin alumina.

In 2001, FLSmidth collaborating with Alcoa further developed a semi vertical GSC arrangement using Hot air Lift (HAL) and introduced Fluid bed cooler (FBC) replacing fluxo cooler. With this technology, FLSmidth supplied world's largest Stationary calciners 3×4500 tpd GSC units to QAL, Australia.

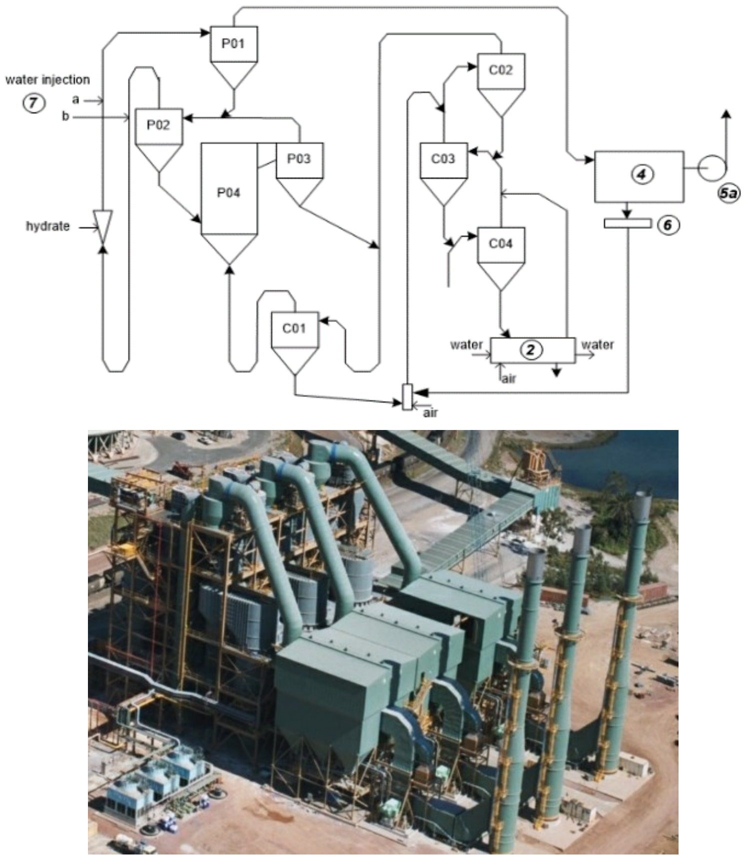


Figure 3. GSC with HAL and FBC, without HV QAL, Australia- 3 X 4500 TPD GSC Unit.

The modern GSC design, which was implemented in Yarwun, Australia in 2007, has four main process stages [2] [6]:

- Drying and pre-heating/pre-calcination (PO1/PO2)
- Calcination furnace (PO4), furnace cyclone (PO3) and holding vessel (HV)
- Direct heat recovery (by direct air cooling, CO1-CO4)
- Indirect heat recovery (by water cooling in a fluidized bed cooler, FBC)

Holding vessel (HV) increases the retention time and ensure that the reactions have time to proceed to a desired degree in order to meet product specifications and provides significant energy savings as the temperature in the furnace reduced and the reaction time is prolonged in this process stage. As Wind et al. remark, higher temperature is substituted by longer retention times [3].

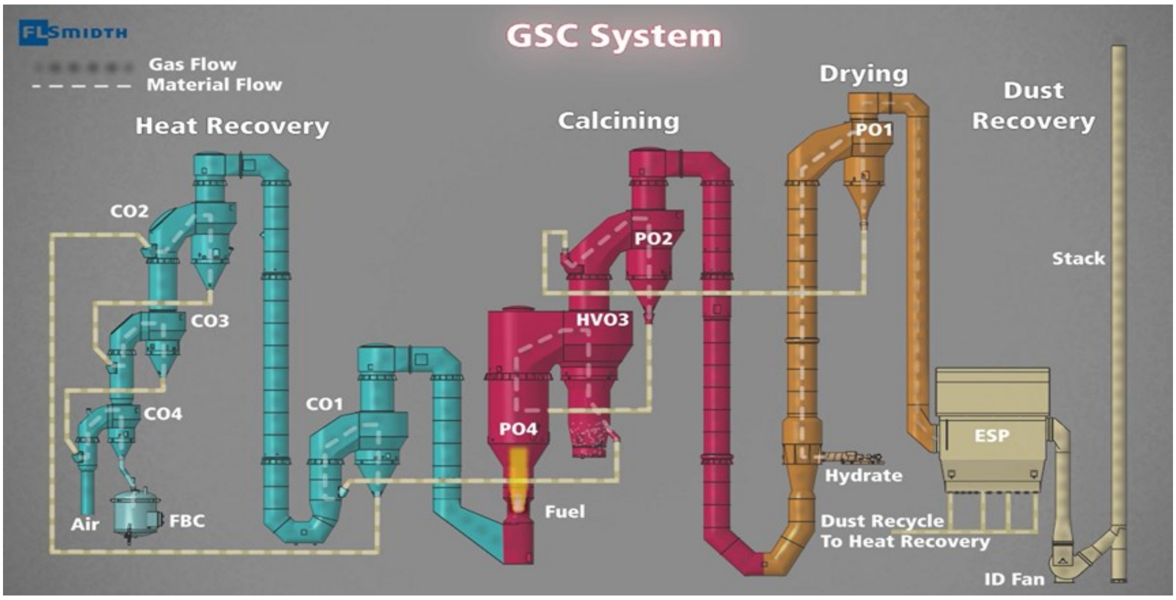


Figure 4. Gas Suspension Calciner with Holding vessel.

3. Recent Developments in Gas Suspension Calciner

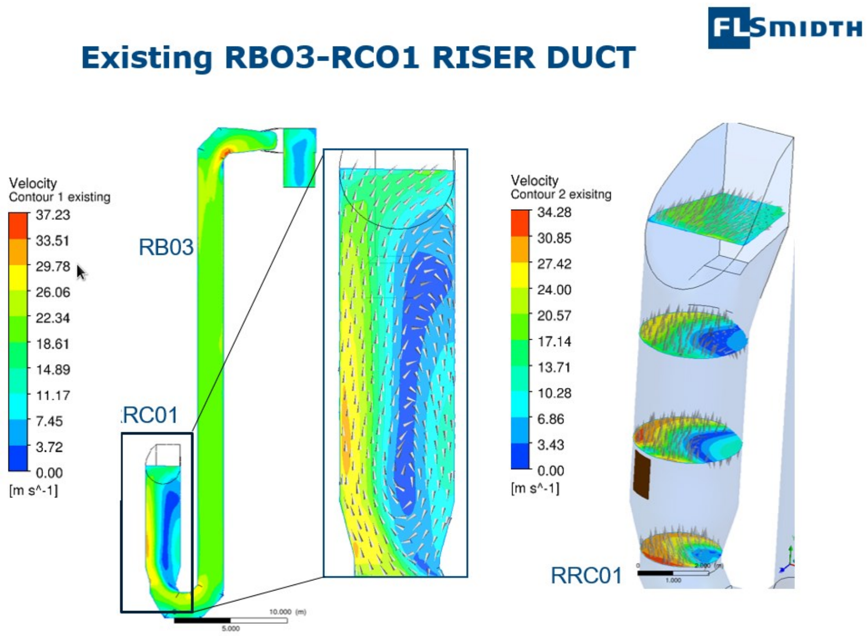
Based on the vast experiences from FLSmidth supplied calciners from 2009-2013 with different hydrate sources and from different precipitation technologies, the following improvements/design changes are adopted in latest GSC.

a. Optimization of Cyclone design

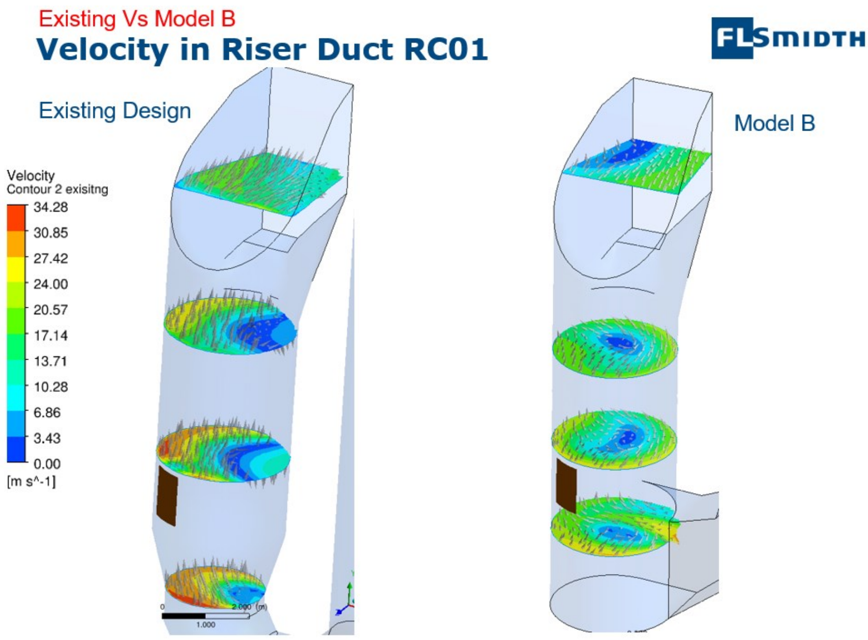
The cyclone dimensions are adjusted to lower the gas velocity, to reduce the pressure drop & wear on vortex finder and to minimize the risk of particle breakdown.

b. Redesign of riser ducts in GSC

FLSmidth R&D work shows that PBD happens due to internal and external thermomechanical forces acting on the alumina particles during cool down. High degree of turbulence is observed in the existing riser duct RBO3-RCO1 to the CO1 cooler cyclone from CFD modeling and it has a potential of particle break down.



a)



b)

Figure 5. RCO1 Riser Duct Existing (a). New design Model B (b).

Comparative CFD analysis of the existing RCO1 Riser duct and the Model B redesign as shown in figure clearly indicates a reduction in peak velocities and thus Particle Break down. The re-design of RCO1 has potential of reducing the estimated Particle Break down, Pressure drop & wear.

By implementing a & b design changes, It is possible to achieve particle break down less than 4% in -45 microns for weaker hydrates with higher alumina attrition index.[5]

c. Improved Refractory design

Refractory engineering is done with a primary design objective to keep the condition of calciner stable throughout its operation and give a long life. In consideration of energy saving, ideally all the heat added to the calciner system should be used to heat the hydrate but in practice, a lot of heat is lost in several ways: energy losses through the cyclone wall at steady state operating condition and heat storage loss during transient condition. Heat loss through refractory wall during steady state condition depends on thermal conductivity "K" of refractory materials, wind velocity, ambient air temperature, surface temperature, emissivity factor and the operating temperature. High porosity, low thermal conductive materials due to lower strength and lower resistance towards chemical attack reduce life of the furnace and in contrast high density refractory materials needs multilayer backup to save potential energy loss through the refractory wall.

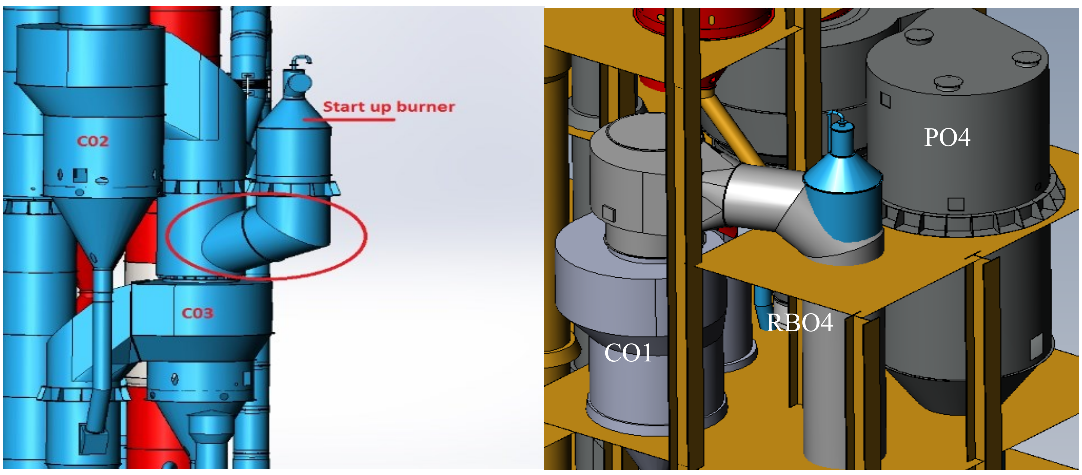
A multi-layer lining with optimized performance of layers with the operating environment and proper installation improves the energy efficiency of a furnace and can contribute to potential energy saving.

In the existing alumina calciners, refractory design is of two layers i.e., one insulation layer and a hot face refractory layer. During operation of the calciners, it was observed that the radiation losses through the walls of cyclone was high resulting in higher specific thermal energy consumption.

A detailed study was done on the lining materials and their thickness. Thermal calculations were done to optimize the refractory thickness so as to improve the energy efficiency. Based on the detailed calculations, the insulation thickness and materials were changed. Instead of two-layer lining, multi-layer lining was introduced.

Due to this, it has been found that the heat loss was reduced by about 45% and thereby achieving specific thermal energy consumption less than to 2650 kJ/kg of Alumina . As stated by Benny [7] improved refractory design shall significantly reduce the specific thermal energy consumption in the GSC units.

d. Start/Preheat burner location change



Existing Location New Location
Figure 6. Change of Start/Preheat burner location.

In GSC, Start burner is located at cooling stage three outlet and has few disadvantages:

- Higher thermal load to Cooling cyclone (CO2) second stage and its riser duct (RCO2) which leads to damage in RCO2 refractory lining.
- Refractory failure in start burner combustion chamber.
- Since the start burner is located in RCO2, Preheating of PO4 is not possible above 750 °C.

In latest GSC, FLSmidth has addressed the above issues by relocating the start burner location to RBO4 (inlet to PO4):

- This new design location will reduce the risk of refractory failure in start burner combustion chamber, because the RBO4 duct volume is used as burning chamber.
- Faster ramp up – Preheating of PO4.
- PO4 inlet temperature can be preheated above 750 °C.
- Reduced thermal load on Cooling cyclone (CO2) second stage and its riser duct (RCO2)

e. Optimization of Holding Vessel

Existing Holding vessel design provides higher residence in HV which leads to over calcination, creates dead zones in Holding vessel.

To overcome the above issues, HV design has been optimized to provide:

- More reliable fluidization
- Less risk of dead zones in HV
- Less risk of over calcination
- Lower thermal impact to HV refractory

f. Redesign of Distribution box

RPO2 distribution/spreader/feeder box function is to evenly distribute dried hydrate in to the gas stream of RPO2 to maximize the heat transfer between gas and material. The existing conventional spreader box in some of the GSC's were experiencing Hydrate bypass. This is a phenomenon that occurs when the dried hydrate that discharges from the spreader box splits in to two streams, one that is transported to PO2 cyclone and the other known as "Hydrate Bypass" passes through the gas stream down in PO3/HVO3 (Cyclone / Holding Vessel). This results in un-Calcined material mixing with the final product and could have a detrimental impact on the quality of the product. Based on R&D results to address this issue, an aeration type RPO2 spreader box is designed to provide uniform distribution of dried hydrate into the gas stream of RPO2 and to minimize the hydrate bypass.

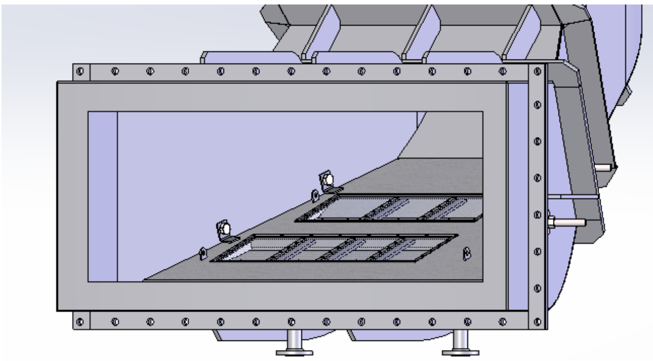


Figure 7. RPO2 Aeration Spreader box.

4. Conclusions

With the improved design changes of:

- Cyclone design optimization
- Redesign of riser ducts in GSC
- Improved refractory design
- Optimization of holding vessel
- Redesign of distribution box

the specific energy consumption shall be reduced less than 2650 kcal/kg and particle break down of -45 micron less than 4%.

5. References

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