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EXPERIENCE WITH 3 x 4500 TPD GAS SUSPENSION CALCINERS (GSC) FOR ALUMINA

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Abstract

In 2001, Queensland Alumina Limited, (QAL) of Australia, launched their environmentally driven expansion project of replacing nine rotary kilns by installing three Gas Suspension Calciners, (GSC), each with a capacity of 4500 tpd, representing the largest alumina calcination project ever undertaken.

This was the first alumina calcination project ever, in which stationary calciners were equipped with bag houses for gas cleaning. The commissioning and project experience of the world largest calcination plant for alumina and its impact on the environment will be presented.

Introduction

QAL operated nine 900 tpd rotary kilns and one 2200 tpd Circulating Fluid Bed calciner, all equipped with ElectroStatic Precipitators, (ESP), as the primary gas cleaning . The circulating fluid bed calciner was previously retrofitted with a bag house inline and after its ESP.

The three 4500 tpd units provide a peak capacity of 13,500 tpd, over the QAL operating requirement of 10,300 tpd to accommodate both scheduled maintenance shutdown of a calciner and a minor capacity expansion as well.

Project Background and Execution

The ESP's on the rotary kilns were old and relatively inefficient when compared with today's modern type ESP's, which can be designed to meet the allowed emission of 50 mg/Nm^3, dry gas.

However, in order to meet the allowed emission at all times, irrespective of process upsets or power failure, it was mandatory for QAL to introduce a constant barrier against dust emissions and hence Bag Houses were selected.

This degree of protection cannot be achieved with ESP's, which rely on power cut off to prevent explosion risks, if and when excessive levels of CO or other un-burnt combustibles are detected.

Before the decision to install stationary calciners was made several retrofit options were studied by QAL, including retrofitting the old rotary kilns with proven GSC technology [1] and converting the ESP's to bag houses. But in the final analysis these options were not attractive and it was decided to tender for a new Calcination Facility on full turn-key basis. Choosing stationary calciners would also result in benefits from lower emissions of "Green-house" gases.

QAL selected FFE Minerals as its Calcination Alliance partner [2] to supply its proven GSC technology for alumina, with Thiess's Process Engineering Division as main contractor.

The project schedule was phased into milestones for Mechanical Completion, Commissioning, Beneficial Operation and Final Acceptance Testing, with an overall duration from award in July 2001 to final acceptance in July 2005.

Flow sheet and Main Equipment Selection

In addition to Bag Houses supplied from FLS Airtech, the GSC units designed for QAL were the first units to be designed incorporating proven calcination technology for Smelter Grade Alumina from FFE Minerals and Alcoa. Some of those changes are described below.

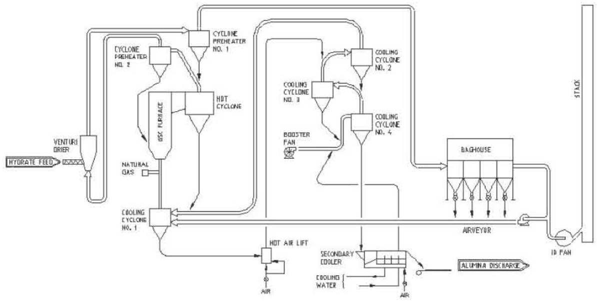

Fig. 1 Gas Suspension Calciner Flow - Sheet

Process Equipment Selection

FFE Mineral's cyclone design has been historically based on cement technology development and a new more cost effective cyclone design was adopted to take advantage of the physical differences between cement raw meal with D_{50} = 10 – 20 µm and alumina D_{50} = 90 – 100 µm.

The Alcoa hot air lift and Fluid Bed Cooler design was selected to obtain a more cost efficient lay-out.

Finally, a fixed speed ID-Fan combined with a variable speed FD-Fan were selected as prime gas movers to minimize power consumption and suction pressure into the bag house.

Air Pollution Control: Bag House versus ESP

The selection of a bag house was dictated by its absolute filter characteristics minimizing the sensitivity of emission towards process upsets and power failure. However, in situations without this requirement, the following pros and cons between a bag house and an ESP are valid [3]:

Table 1: ESP versus Bag House

Parameter	Bag House	ESP
Pressure Drop	1.50 kPa	0.25 kPa
Emissions (wet) - Possible	5 – 30 mg/Nm^3 < 5 mg/Nm^3	Sized to suit 5 mg/Nm^3
Explosion Risk	Low	High
CAPEX - Index	100%	~140%
OPEX - Index	~ 165%	100%
Maintenance - Possible	High On-line	Low Off – line only
Service intervals	1 – 5 years Varies with Bags	4 years Typical
Temperature, Max.	220 – 240 °C	< 400 - 450 °C
Fire Damage Risk	High	Low

The above comparison is sensitive to the size of the equipment and applies for a gas flow of ~ 11,000 Am^3/min.

The comparison indicates, that there is a breakeven point from a Net Present Value evaluation perspective, which depends on the quality of the bags selected for the particular application.

Major Scale up Issues

Equipment scale up was not extreme, I.e:

For the hot air lift and fluid bed cooler the scale up factor was ~ 1.5, and for the GSC technology the scale-up factor was ~ 2, which was based on experience from the cement industry.

However, we did encounter problems and while it may not be wholly obvious in the write up below, the scale up problems experienced were linked to the application difference between GSC technology for cement raw meal and hydrate/alumina.

Hydrate Feeding and Drying

The hydrate feed screw was sized too conservatively and had to be replaced with a smaller diameter unit to ensure minimization of false air into the Venturi Dryer section and proper suspension of wet hydrate into the gas stream.

The sizing of the Venturi throat itself was designed for a pick-up gas velocity of ~35 m/s, which was too low to prevent hydrate drop down at start of feeding and to ensure stable operating conditions at partial and full capacity.

These problems were solved by reducing the Venturi throat and modifying the start – up procedure.

Cyclone Efficiency and Gibbsite De-hydration

The new cyclone design incorporated a relatively short vortex finder as applied to cement raw meal, resulting in alumina by-passing into the cyclone overflow. This problem was solved by introducing longer vortex finders.

To solve the above problem solving took some time as the only initial indicator was higher overall dust flow to the bag house which exceeded the design capacity of the installed dust transportation system.

This restriction in the dust transport system made it impossible to reach steady–state operation at full production level with dust returned to cooling cyclone no. 1.

The restriction was overcome by directing the dust directly to the fluid bed cooler. However, initially this mode of operation resulted in an off-spec alumina product with respect to minimum acceptable gibbsite.

In the short term this problem was solved by a minor temporary modification of the flow sheet and a change in the operating conditions so that an alumina product was produced with less than 0.5 % gibbsite at 40 ~ 90% of rated production, corresponding to 1,800 – 4,000 tpd of alumina.

The temporary mode of operation suffered from the drawback of reduced thermal efficiency and increased gas velocities above the design values giving increased particle breakdown, needless to say, neither of these consequences was acceptable.

Several long term solutions were considered and it was decided to install a dust lift calciner to de-hydrate the gibbsite from the bag house dust before it was directed to the fluid bed cooler and mixed into the alumina product.

The dust lift calciner solved the problem so that the alumina with less than 0.5% gibbsite is produced in the full production capacity range of 1,800 – 4,500 tpd.

Process Control and Interlocks

The general philosophy of the process control system has been to keep it as simple as possible. To this end a layered approach to design has been used. The system is conceptually built in three control layers (CL1, CL2, CL3) that are characterized by their response to input:

CL 1 can start and stop drives and open and shut valves.
CL 2 can send positioning signals to equipment and valves.
CL 3 can send control set points to CL2

The background for the control layer approach is historically based in the relay technology of yesteryear. However, during the specification and design phases of the Burner Management System (BMS) and the control system it became clear that the concept had considerable merit as a structuring device in design of control systems for alumina calciners. The relative simplicity of the calciner design means that the actions that are needed to bring the plant to a safe state are simple and that they can be easily implemented in binary logic.

CL1 acts as a policeman. It protects people and equipment from the consequences of the process getting out of bounds. Ideally you will never want to invoke CL1 other than to start and stop drives and valves in response to operator input or input from CL2 and CL3. CL1 maintains the plant in a safe state at all times even if that safe state is that the plant is shut down.

With the safety aspects taken care of by CL1, the operator or CL2 and CL3 can now concentrate on operating the plant. Note that CL2 and CL3 exist solely to assist the operator in running the plant in the best way.

In order not to invoke CL1 all process conditions that would trigger CL1 have pre-alarms that alert the operator and may trigger actions in CL3 to bring the plant back on track again.

Burner Management System

The use of natural gas as a fuel means that a number of legislative requirements for combustion monitoring and control must be met. This is done by a dedicated burner management system (BMS). In the overall control architecture the BMS sits in CL1. This means that the BMS is relatively easy to verify as it has a countable number of states, and these states can all be described and thus verified. The only difference between the BMS and the rest of CL1 is the reliability of the BMS. The BMS will normally be required to be a SIL 2 (Safety and Integrity Level 2) system. Confining its functionality to CL1 will minimize the amount of hardware that has to be certified. It also makes the programs and thus the verification of the BMS simpler.

The temptation to move functionality into the BMS is very large, but it has been resisted. Examples have been seen where more or less the whole control system ends up in the BMS in an attempt to make things as safe as possible but that course leads inevitably to programs that are extremely difficult to prove correct. If you cannot prove the programs then the SIL of the whole system is indeterminate.

Protection of Bag House

The use of a bag house instead of an ESP for dedusting the offgases of the calciner made some form of over temperature protection necessary. The maximum allowable temperature of the air entering the bag house was 250 °C. After considering various options a simple cold air bleed valve was chosen. The bleed valve is an on/off device dedicated solely to the protection of the bag house. When the valve opens the plant shuts down. In keeping with the principle of simplicity this is the only function of the valve. To prevent unnecessary shutdowns the plant triggers a controlled partial shutdown to a lower temperature in order to minimize thermal shock to the refractory lining. This state of the plant is called “Hot Standby”.

Hot Standby Mode of Operation

The hot standby has the plant running at reduced draft, no feed and very low firing. The heat sink to prevent the baghouse from overheating is provided by the water spraying system in the downpipe from preheater cyclone no. 2 to the venturi dryer.

In older plants the operator drives the plant to hot standby manually when he needs to do so. This is the first plant where the control system can handle the job for the operator. A number of cases have been identified where the plant attempts to go to hot standby instead of letting CL1 shut the plant down. If the attempt does not succeed the plant shuts down anyway, so safety is maintained, but if the hot standby is attained then the operator can investigate the cause of the process upset with the plant in a safe state from which it is easy to resume production.

Operational Experience

Start – Up of Calciner

Pre-heating of the GSC is made over a period of 20 – 22 hours, where at the end of the period the GSC would be in hot standby and ready to receive hydrate. The pre-heating is done by using the start burner and the main calciner burner. The start burner is situated in the riser duct of cooling cyclone no. 2 and the main burner is at the inlet of the GSC furnace. The main burner is also supported by pilot burners.

The start burner will be used to pre-heat the air being drawn through cooler string by the ID Fan. The rate of temperature increase will be maintained at < 50 ^{o}C/h with a target temperature of 600 ^{o}C measured at the outlet of cooling cyclone no. 2. After a period of some 10 – 12 hours the main burner pilots will be ignited followed by ignition of the main burner, utilizing one of the eight burner nozzles to control the rate of increase in the main furnace temperature. On reaching the target temperature of 700 - 800 ^{o}C in the GSC furnace, the calciner is now ready for the introduction of hydrate.

This pre-feeding state known as hot standby can be maintained for a long period if required, the heat sink used at this time being atomized water.

Prior to the introduction of hydrate the air flow through the system will be increased to 75% of nominal air flow, in short this means that the airflow over the unit will be set for two scenarios.

Feed Rate	Airflow
50 – 75 %	75%
75 – 100 %	100%

Introduction of hydrate starts normally at a rate of 20 tph, (7 % of nominal feed). The production rate is increased to 150 tph (50 % of nominal feed) in a very short period, (~30 min) and thus the hydrate becomes the heat sink eliminating the need for atomized water.

With the furnace temperature selected for auto/cascade the remaining task left to the panel operator is to increase the hydrate feed.

If the plant has been put into hot standby the desired production for the unit can be achieved in a very short period of time, up to 75% of nominal feed in 1 hour and an additional 2-3 hours to reach 100 % of nominal feed.

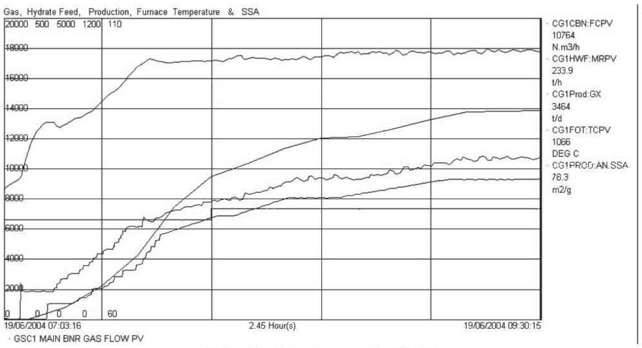

Fig 2. Start-up of GSC

Steady – State Operation

Operation of the plant between 40 – 100% CU requires different degrees of attention from the panel operator. The lower the production levels the more attention the GSC requires. As production is increased the GSC has proven to require fewer adjustments to be made. For the panel operator the GSC is simple to operate, and requires little or no attention when operating at desired production levels.

Figure 3 below shows steady state operation at 100% production.

The GSC was designed with a 50% turndown ratio; the target here is to maintain stability and quality. Operation experience has shown that lower levels of stable operation are indeed possible with a turndown ratio of 60%.

Operation levels of 25 – 30 % of nominal production have been achieved for long periods, but the operational downside is the introduction of atomized water as a secondary heat sink, and difficulty in maintaining quality, i.e. Specific Surface Area (SSA).

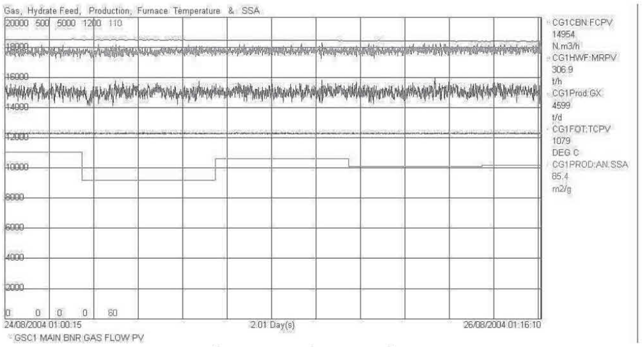

Fig. 3 Steady run of GSC

Emergency and Planned Shut – Down of Calciner

Shut down of the plant in an “Emergency State” would render the plant in one of two modes,

1) Hot Standby,
2) All Plant Equipment Stop.

An emergency stop of the unit would be activated by exceeding,

a) Interlock limits,
b) Cyclone blockages,
c) Mechanical failure.

Hot Standby is an automated function which simply means that air flow and fuel are reduced to minimum, hydrate feed is stopped, and atomized water is started as a heat sink.

All Plant Equipment Stop would only be generated by a stop of a major component, or a power failure. In this instance the GSC interlock system would systematically stop/close all equipment, dampers or valves.

As mentioned above the GSC is equipped with a bag house and thus requires protection from over heating. In hot standby the heat sink is the atomized water. If for other reasons water is not available or prevented by interlocks from operating, the cold air bleed valve placed in the gas duct leading to the bag house would be forced open and thus prevent over heating.

Planned stops of the unit have proved to be a simple task. This type of stop typically means the GSC would be required to cool down and access to vessels and other equipment made possible. The typical cooling down period for the GSC where entry to the main furnace is required would take 36 – 48 hours. Planned stops of the GSC has been relatively painless, the hydrate storage bin, hydrate weigh feeder, and hydrate screw conveyor are allowed to run empty. On running empty the hydrate weigh feeder will activate hot standby mode. All burners would be stopped, ID fan damper remains in operation with minimum opening of the ID Fan damper.

Preliminary Operational Data

Capacity & Alumina Quality

Preliminary data for alumina quality at different level of capacity are shown in Table 2 below.

Table 2: Capacity & Alumina Quality

Capacity	2250 tpd	3750 tpd	4500 tpd
Source	BO # 2	BO # 2	GSC#1 (PI)
SSA (m^2/g)	79.9	76.6	84.7
Alpha (%)	6.5	6.7	8.3
LOI (300-1000^oC)	0.99	0.91	1.09
Gibbsite (%)	0.34	0.29	0.08
% - 45 micron	6.6	8.8	9.0
% - 20 micron	nm	nm	1.2
SiO_2 (%)	0.012	0.012	0.010

The above data have been obtained through the commissioning period March to August’04 and before the optimization of GSC operation was finalized.

The data under BO#2 is from the Beneficial Operation Period of GSC # 2 in March’04, when it was operated under the temporary operation mode as mentioned above.

The data from GSC # 1 is with the dust lift calciner in operation and shows the effective de-hydration of Gibbsite.

The LOI is determined by the short time procedure used in the daily production.

The SSA versus Alpha content demonstrates that the final burner configuration is still to be optimized.

Energy Consumption

The preliminary results indicate [4] that the guaranteed specific heat consumption is achievable and that the specific power consumption excluding compressor power is less than 23 kWh/ton.

Dust Emission

The local Gladstone community has commented positively to QAL about the lower dust emissions as result of commissioning the project.

Typical average dust emission has been measured to 29.1 mg/Nm^3 (dry) and 41.1 mg/Nm^3 (dry) as 5 minutes and 1 day averages respectively [4].

Conclusion

In view of the above reported experience from scale-up and commissioning of three 4,500 tpd gas suspension calciners for alumina equipped with bag houses, it is reasonable to conclude that:

- Irrespective of scale-up, the GSC technology provides operationally flexibility while being exceedingly easy to operate.
- The environmental objective set out by QAL has been achieved using bag houses for gas cleaning.
- Subject to final performance testing, the indications are that all performance guarantees will be fulfilled.

At the paper submission deadline, the final performance testing of each GSC unit has yet to be undertaken. Testing will be conducted consecutively, as the resolved scale-up issues is introduced and the operating conditions trimmed on each GSC Unit.

References

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