THE APPLICATION OF CERAFIL® CERAMIC FILTER ELEMENTS FOR PARTICULATE REMOVAL ON A LIQUOR BURNING APPLICATION FOR WORSLEY ALUMINA PTY LTD

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Abstract

Worsley Alumina commenced commissioning of a Liquor Burner at their site near Collie in Western Australia in 2000. The Liquor Burner process removes organic contaminants in the caustic soda liquor used in the refining process, and involves a number of key process stages, including a gas treatment train. To achieve the particulate removal efficiencies required, the gas treatment stage incorporated a baghouse. This was commissioned containing both Cerafil ceramic elements and fabric bags. Emissions were expected to be less than 10 mg/Nm^3.

During commissioning it was evident that the emission target could not be achieved with the fabric media. In February 2001 the filter was completely refitted with Cerafil filter elements. Emissions within the expected levels were immediately achieved and subsequent refinements have allowed the Liquor Burner to run at up to 80% design capacity. The bag-house in its current form comprises 4 modules, each containing 420 Cerafil XS-3000 filter elements and is the largest installation of its type in the world. Madison Filter, a leading supplier of filtration solutions, worked closely with Worsley to develop, trial and implement the use of Cerafil in this application.

This paper discusses the liquor burning process itself, a history of modifications which were made to the gas cleaning stages and its subsequent performance. Detailed information on the performance of the filter plant is included, illustrating the successful application of ceramic gas cleaning on this process by reducing particulate emissions well below regulation.

1. Introduction

The Worsley Alumina refinery is situated 20km north-west of the coal mining town of Collie in the southwest of Western Australia. Bauxite mining takes place near Boddington where the bauxite is crushed and transported 51 km by a cable belt conveyor system to the refinery site. Alumina product is shipped through the port of Bunbury, which is situated 45 km to the southwest of the Worsley refinery.

The Alumina refining process is divided into four major areas. These areas consist of Digestion, Clarification, Precipitation and Calcination.

A recent expansion of the Worsley refinery saw the alumina production increase from 1.7 to 3.1 Mtpa. This expansion was based on two principles:

- a flow increase through installation of additional equipment,
- an increase in alumina yield in the precipitation circuit.

The increase in yield accounts for a significant proportion of the production increase. To achieve & maintain this yield increase, implementation of a Liquor Burning plant was necessary.

The Liquor Burner plant treats a small side stream of spent liquor, out of which the inert dissolved organic compounds are burned off. The cleaned liquor is returned to the main refining process.

Before implementation of Liquor Burning the concentration of organic compounds in process liquor was approximately 24 g/l. After the expansion and without Liquor Burning, this level was predicted to rise as high as 40 g/l. By implementing a Liquor Burning facility the level could be maintained at 16 g/l. The Worsley Liquor Burner process is unique in that it incorporates an integral Sulphate removal process.

2. The Liquor Burner Process

A small side stream of 40 m^3/hr spent-liquor is pumped to a Niro Kestner deep evaporator. In the evaporator the liquor is concentrated from 310 to 560 g/l caustic. The working of the evaporator is based on three effects: backward feed, forced circulation evaporation and one climbing-falling film deep evaporator.

After the evaporator the concentrated stream is mixed in a pug mixer with fine hydrate/alumina from the calcination area. A slight excess of hydrate/alumina is added to ensure no free caustic is present and thus preventing caustic attack of the kiln refractory liner downstream. This slurry is fed to a paddle mixer where the slurry is mixed with dried product from the downstream process. This mixture, with approximately 5 % moisture, is released into the 800°C off gases coming from the downstream rotary kiln. The mixture is entrained with the gas stream through a rotor (cage mill) and dried while going up a vertical drying duct. The temperature in the drier is controlled at 260°C. The cage mill is located under the drier in the gas stream and its function is to break up the bigger lumps that fall back from the vertical drier duct.

The dried solids are separated from the gas through a primary cyclone, a multiclone and a 4 cell bag house. The gas stream is released to atmosphere through a fan and a 60-meter high stack. The concentration of solids in the gas to atmosphere had to adhere to statutory requirements.

The solids from the underflows of the multiclone, bag house and part of the primary cyclone are directed to the paddle mixer to be mixed with the slurry coming from the pug mixer. The remainder of the primary cyclone underflow is the actual product stream that is fed to the rotary kiln.

The 58 m long, 3.75 m diameter Krupp-Polysius rotary kiln is fired with natural gas and calcines the solids at 850°C. In the kiln the following reaction takes place:

KEY WORDS: cerafil, emission, baghouse

$Na_2O + Al_2O_3$ (@850°C) = $2NaAlO_2$

The hot solids are cooled in a fluidized bed cooler with air. The air is used as secondary air in the kiln firing. After cooling, the solids (300 °C) overflow into a partially below ground leach tank and are mixed with spent liquor from the refinery. The Worsley liquor stream contains a high sodium sulphate concentration, and this reports as solid sodium sulphate in the Liquor Burner kiln discharge. The conditions in the leach tank are such that the solid sodium sulphate does not dissolve. The slurry, containing both sodium sulphate solids and the excess alumina/hydrate solids, is fed to the leach filters.

The solids are separated from the liquor in four automatic chamber and membrane leach filter presses. The filter cake discharges to a dissolver tank. The liquor filtrate, which is the actual cleaned product stream, is returned to the refinery. In the dissolver tank the filter cake is slurried with water and sodium sulphate is dissolved. The resulting slurry that still contains the excess alumina/hydrate solids is pumped to the two alumina-filters where the alumina/hydrate is separated from the dissolved sodium sulphate. The liquor is pumped to the residue disposal area and the alumina/hydrate solids are mixed with spent liquor and pumped as evaporator feed to the evaporator. The above process is summarized in Figure 1 below.

3. Baghouse

Low stack particulate emissions were seen as critical due to the nature of sodium aluminate dust. A decision was made to make use of a baghouse instead of the traditional use of an electrostatic precipitator (ESP). Combinations of media were selected for the baghouse. Fabric was chosen for three cells with the fourth cell fitted with ceramic elements (Cerafil XS-3000) as a trial for potential future use.

Cerafil XS-3000 elements are rigid, low density ceramic filter elements. The elements are tubular with a 150 mm outer diameter, and a total length of 3000 mm, and are manufactured as a single piece. One end of the filter element is closed and the other is flanged to locate into the filter plant tubesheet, sealing with a ceramic felt gasket. Particulates to be filtered are captured on the element's outer surface and removed periodically by a reverse pulse system, much as with fabric bags.

The filter elements are made from an aluminosilicate fibre, bonded with silica and alumina. This combination of materials makes them resistant to attack by most acids and allows them to operate at temperatures of up to 900ºC. The fine fibre structure allows very high efficiencies to be achieved and emissions are frequently less than 5 mg/Nm^3. The temperature resistance and high particulate removal efficiency were seen as the key properties for the liquor burning application, given the potential for temperature excursions in the baghouse.

3.1 *High particulate emissions*

The plant was commissioned during the second half of 2000. High particulate emissions were experienced due to failure of the fabric media during start-up of the plant. Exhaustive, but unsuccessful efforts were made by Worsley and the vendor to solve the problem. By contrast, the Cerafil elements appeared to perform to specification. Table 1 below describes the conditions of the plant at start up.

Table 1 — Commissioning conditions of baghouse with combination of fabric and ceramic media.

Face velocity (m/min)	Temperature (°C)	Pressure Drop (kPa)	Emissions (mg/Nm3)
0.9	230	1.8	> 100

A decision was made at the end of 2000 to substitute the fabric media with Cerafil. One concern of changing to Cerafil was the potential for higher pressure-drop due to the nature of the media in comparison to bags. On line tests were performed to simulate the baghouse with Cerafil media by increasing the baghouse differential pressure. The tests indicated that the baghouse would run at a higher DP but would still achieve design capacity.

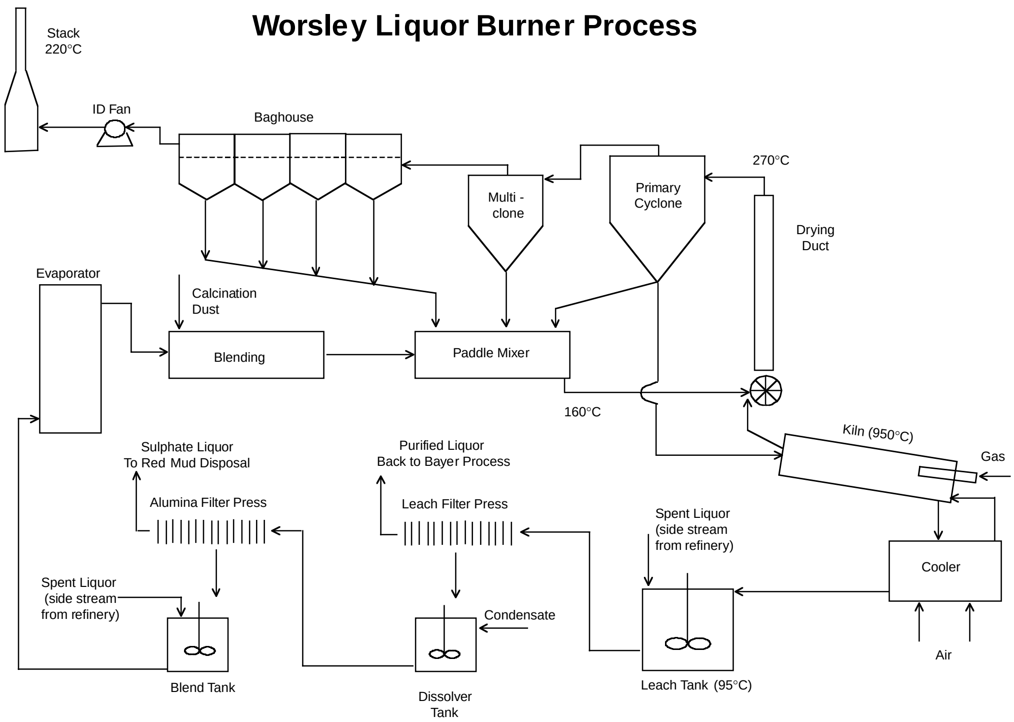

Figure 1 — Liquor Burner Flowsheet.

3.2 *High pressure drop*

During the 1st quarter of 2001 the three fabric compartments of the baghouse were refitted with Cerafil elements. During this refit the clamping arrangement was modified to improve the Cerafil element fixing to the cell plate. The elements were preconditioned with alumina product from the calcination area. The preconditioning was performed during the pre-heat phase of start-up. Table 2 describes the conditions at the time of commissioning in March 2001.

Table 2 — Start up conditions of baghouse with ceramic media.

Face velocity (m/min)	Temperature (°C)	Pressure Drop (kPa)	Plant Capacity (%)	Emissions (mg/Nm3)
1.02	230	>3 to 6	50	<30

Soon after commissioning it was found that the baghouse differential pressure was increasing as per Figure 2. The break at approximately 100 hours was due to a plant shutdown for offline pulsing of the elements. This interruption would also cause other problems like kiln refractory damage etc. The drift in differential pressure was not identified during the trial of a full-scale cerafil baghouse due to the high particulate emissions, which limited the duration of the test.

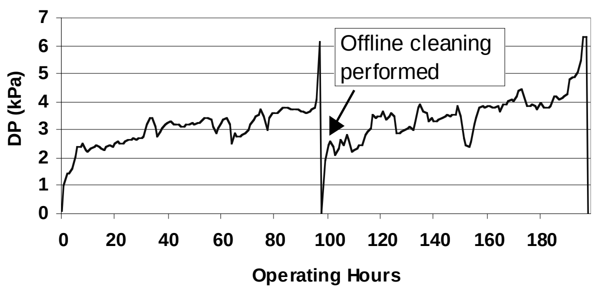

Figure 2 — Baghouse Differential Pressure drift.

3.2.1 *Dust characteristics*

Data was collected to measure the exact conditions of the filter plant. The dust loading was measured and was found to be similar to the design dust loading — this meant that the upstream processes (cyclone & multiclone) were operating as per design. The dust was sampled and the size analysis of the dust is summarized in Figure 3.

The particle size of the baghouse feed material was relatively fine which would cause cleaning difficulties of the cake on the elements and thus a higher differential pressure.

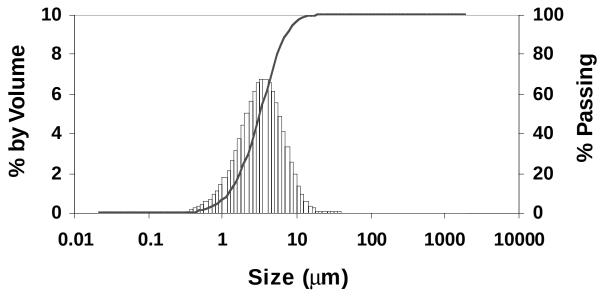

Figure 3 — Typical Dust Size Analysis of Baghouse Feed.

3.2.2 *Cleaning system*

A third party was approached to assess the cleaning ability of the Cerafil elements. It was initially believed that the entire length of the element was not being cleaned which may have contributed to the high differential pressure. Figure 4 illustrates that this was not the case. The cleaning pressure was maintained through the length of the element. The peak cleaning pressure 1 meter down in the element was very similar to the pressure achieved at the bottom of the element — approximately 4kPa. This number of 4 kPa is significant in the sence that the baghouse became unstable at this pressure drop (as was seen in Figure 2). The cleaning methodology is different for a rigid Cerafil candle compared to a fabric bag. The rigid element relies on sufficient backpressure from the pulse to allow the cake to be discharged where-as a fabric bag physically flexes and causes the cake to drop off. At this stage it became clear that the pulse cleaning was not efficient. This was then further pursued.

Laboratory testwork was performed to measure the impact of venturis on the peak cleaning pressure. Figure 5 indicates the impact of venturis on the peak pulse pressure experienced in an element during a pulse. It is quite clear from this chart that the cleaning pressure of approximately 4kPa was insufficient after the Cerafil refit. This would be the reason why the liquor burner plant required a shutdown when the differential pressure approached this value. The addition of a venturi or straightening nozzle to the blow tube would increase the pulse pressure to approximately 7 kPa. A combination of the venturi & straightening nozzle would lift the peak pressure to approximately 16 kPa — this high pulse pressure would potentially impact on filter media life as in this particular application it is expected that an element would experience approximately 7.5 million pulses.

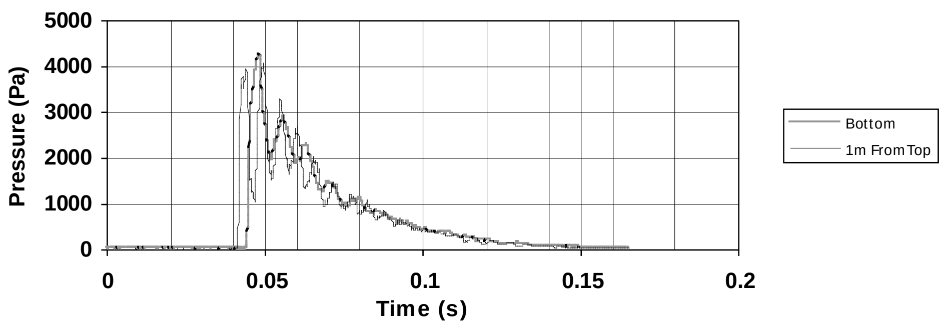

Figure 4 — Cleaning pressure profile achieved on element.

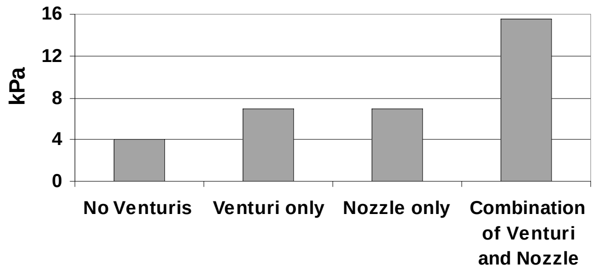

Figure 5 — Impact of venturis and straightener nozzles on peak cleaning pressure from laboratory tests.

Worsley proceeded to install the venturis in the following combinations:

Cell #1 — Internal venturis added (pulse header pressure of 650 kPa).

Cell #2 — No venturis. Reference cell (pulse header pressure of 650 kPa).

Cell #3 — Straightening nozzle and internal venturi added (pulse header pressure of 350 kPa).

Cell #4 — Straightening nozzle added to blowpipe (pulse header pressure of 650 kPa).

The above installations were trialled online to measure the impact of the different cleaning combinations. The individual cell airflows were also measured to indicate the cell with the path of least resistance. Figure 6 describes the results. The air supply pressure to the header of Cell #3 was regulated at 350 kPa to reduce potential element failures.

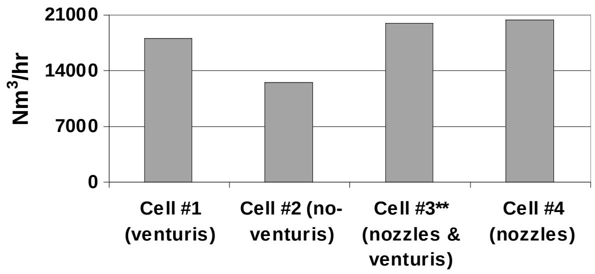

Figure 6 — Gas flows achieved through each cell with different cleaning system in each cell of the baghouse
(** 350 kPa air supply pressure with other cells at 650kPa).

nozzles. The gas flowrates achieved through the modified cells (Cell #1,3&4) were up 160% when compared to Cell #2, which had no modification to the cleaning system. Cell #2 was modified soon after the test results by adding straightening nozzles to the blowtubes on this cell, as this was the quickest installation to perform. The best results were achieved with the combination of the venturi & straightening nozzle — an added benefit to this is that the compressed air supply system only needs to generate approximately 50% of the supply pressure.

4. The Solution

The plant has not required a shutdown due to high DP since the modification of the cleaning system. Table 3 describes the conditions of the baghouse in its current form.

Table 3 — Current operating conditions on baghouse since all modifications complete.

Temperature (°C)	Pressure Drop (kPa)	Plant Capacity (%)	Emissions (mg/Nm^3)
230	3 to 4	80	<10

The throughput of the plant has increased to 80% — other issues are impacting the balance of the capacity. It is planned to increase the baghouse to six cells in order to make provision for back-up capacity. Particulate emissions have been well below the legal limits. It is important to ensure the pulsing system is fully operational at all times to prevent buildup on the elements (beehive effect) to eliminate potential element failures.

5. Conclusions

In a Liquor Burner type application the Cerafil XS-3000 elements have made it possible to achieve particulate emissions far below regulated requirements. The Cerafil elements do require a suitable cleaning system in this specific application. At this stage there is no reason to believe that the 3m elements will cause problems in future.

Acknowledgements

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