

ODOUR DESTRUCTION FOR DIGESTION VENT GASES

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Abstract

Odour emissions from alumina refineries are an increasingly sensitive environmental issue. One source of odour is the organic matter in bauxite, which reacts with caustic liquor under elevated temperature and pressure at the digestion step.

Odour surveys at QAL have identified digestion heater vent gases as a major source of emissions. Means to combat these emissions were reviewed. The relatively low volume and easy capture of vent gases makes thermal oxidation a suitable technology for this stream.

This paper will describe the odour analysis and technology selection process, and present the results obtained from a pilot thermal oxidation unit at QAL.

1. Introduction

Queensland Alumina Limited (QAL) operates a 3.7 million tonnes per annum alumina refinery at Gladstone in Central Queensland. The refining of bauxite to produce alumina using the Bayer process results a characteristic odour associated with alumina plants around the world. The odours from various plants are not identical, due to the bauxite feed and other process factors.

QAL is located upwind (for the prevailing wind direction) of the city of Gladstone, with the nearest residences being about 1.5km from the refinery.

At QAL, Weipa bauxite is ground in spent liquor, pre-desilicated at 100°C in holding tanks, and then injected into digesters operating at 250°C. Slurry from digesters is flashed through ten flash tanks with final flash to atmospheric pressure in the blow-off tank. Vapour from flash tanks passes to the shell side of spent liquor heat exchangers. Flash tank slurry is diluted with mud washer overflow liquor at the blow-off tank and pumped to settlers.

2. Refinery Odour Survey

A comprehensive odour survey was conducted on the refinery. Every potential odour emission point was identified, and the flow rate of odour emitting gas from each of these points was measured or estimated. A representative cross section of the potential odour emitting points was sampled and analysed by dynamic olfactometry and gas chromatography / mass spectrometry (GCMS).

It was found that the digestion area accounted 82% of the total odour emission from the plant. A plant wide breakdown of odour emission rate is shown in Figure 1.

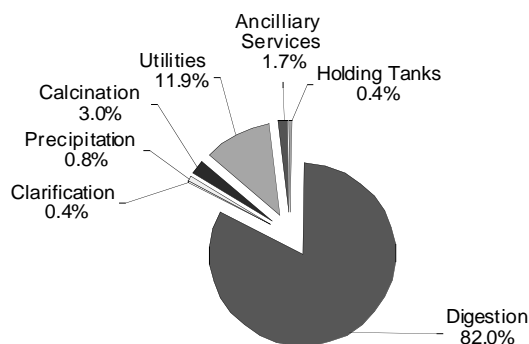


Figure 1 — Total Odour Emission by Plant Section

The cross section of compounds found were similar to those identified in earlier studies by Forster & Grocott, 1996.

3. Digestion Plant Odours

With the larger portion of odour identified as coming from digestion, further surveys were conducted to quantify the specific sources in that area. A substantial portion of digestion odour emission was found to come from the heat exchanger vents, with the balance being released in the final flash to the blow off vent.

On the three digestion units, the highest-pressure flash tank (position 10) passes steam to a direct injection heater. Steam from the other nine flash tanks condenses in shell and tube heat exchangers, which require continuous venting to prevent build-up of non-condensable gas. The vent stream is typically 2% gas in steam. As seen in Figure 2 the non-condensable gases are predominantly hydrogen, with odorous hydrocarbons forming a small fraction.

The high pressure heat exchangers are the major odour emitters. A typical distribution can be seen in Figure 3.

Note: All data presented in Figures 3, 5 and 6 is shown as normalised and relative to the highest individual emission point — 9th position heat exchanger: 100 units.

4. Odour Control Options

Two broad approaches could be made to odour control — elimination of root cause or treatment at “end-of-pipe”.

“Root cause” treatment would involve elimination of organics in the bauxite, or modification of the Bayer process to prevent organic conversion to odorous species. No economically viable technologies are available in that area.

Some of the “end-of-pipe” treatment options considered were:

- Ozone destruction
- Absorption and adsorption techniques
- Biological oxidation
- Thermal oxidation

Ozone could be an effective reactant, but there are likely to be health and safety issues with the generation of large quantities of ozone in a closed environment. Absorption and adsorption techniques will leave a liquid or solid saturated with odorous material to be subsequently treated. Biological oxidation requires operation at near ambient temperatures, and is at risk from temperature excursion and chemical poisoning.

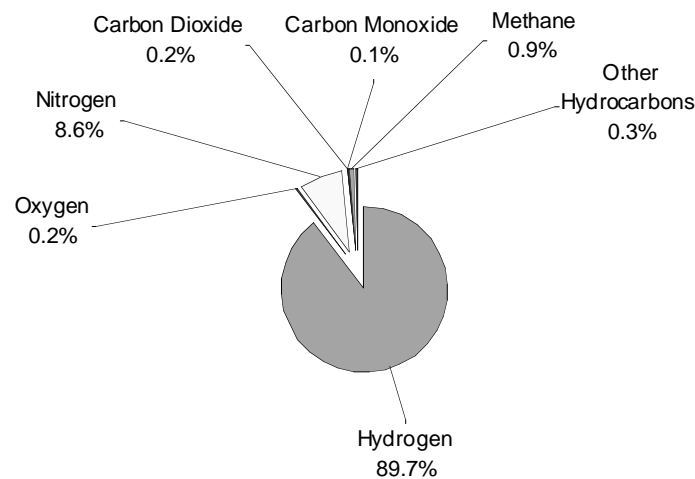
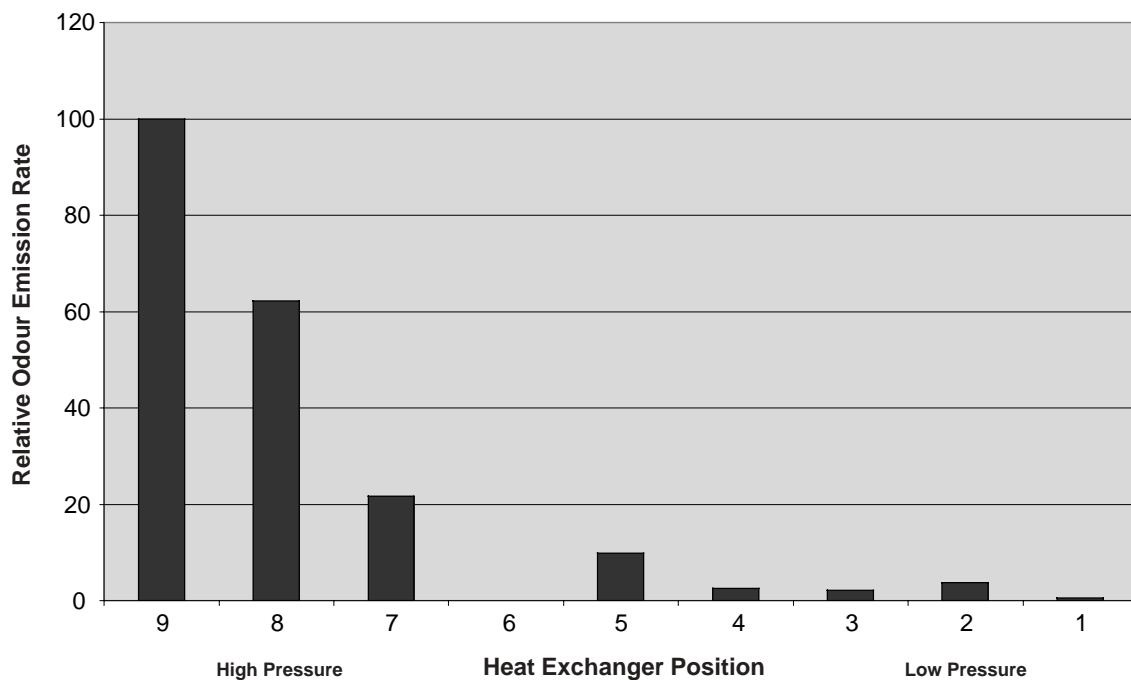


Figure 2 — Typical Analysis of Digestion Heat Exchanger Vent Gas

Figure 3 — Typical Profile of Digestion Heat Exchanger Odour Emission Rates (6th position flash tank out of service).

Whilst not rejecting any of these options absolutely, QAL has chosen thermal oxidation as the preferred path for at least the first major odour reduction project. The main basis for this choice was simplicity and robustness.

5. Pilot Thermal Oxidation Trials

A pilot thermal oxidiser (PTO) was constructed, with the following objectives:

- Demonstrate the efficiency of thermal destruction as a technology for odour reduction on the heater vent gas stream.
- Determine the effect of destruction time and temperature on odour reduction.
- Specify the operating conditions necessary for effective thermal destruction of odours, and the technologies capable of fulfilling the specification.
- Identify any secondary emission or odour problems expected from the gas handling and thermal destruction.

The PTO, depicted in Figure 4, comprised the following essential components:

- Combustion chamber with tangential inlet of process gas and burner

- Residence chamber with sampling and measurement points at 25%, 50%, 75% and 100% of treatment time
- Stack with flow measurement point
- LPG gas supply, burner control and modulation
- Fume fan with explosion vent, flashback protection and flow measurement
- Inlet fume ducting with shut off valve and flow measurement
- Bleed air ducting with flow control and flow measurement
- Control panel with fume flow and destruction temperature control

The system was designed so that the specified flow of heater vent gas could be presented to the PTO in either a condensed or uncondensed state. Safety margins were built into the PTO design to ensure that the hydrogen level in the combustion chamber was maintained at or below 25% of the lower explosive limit (LEL).

The test program was intended to define an operating envelope for effective odour destruction from a time and temperature perspective. The difference between heating condensed and uncondensed fume was also to be investigated.

6. Test Results

The Pilot Thermal Oxidiser was operated at a range of temperatures up to 900°C, on uncondensed and condensed fume. Samples were taken from four points along the residence chamber, representing a range of residence times.

The uncondensed fume comprised approximately 98% water vapour. The high water content required additional energy to raise the fume temperature, resulting in higher flow of products of combustion through the PTO.

The fume, after condensing out water vapour, comprised about 50% non condensables and 50% water vapour — dependent on temperature. This stream was diluted with bleed air, thus the PTO received air as the major gas constituent. This resulted in lower energy being required for heating to the operating temperature.

Tests on uncondensed and condensed fume showed quite similar results with respect to temperature and residence time requirements. At 400°C approximately 80% of the odour has been destroyed. Total odour destruction capability is 99% or greater at 700°C. A trend of typical outlet odour against destruction temperature is presented in Figure 5.

This data demonstrates the following:

Inadequate odour destruction at temperatures of 400–500°C.

Effective odour destruction from 600°C and above.

700°C as an optimum destruction temperature.

The effect of residence time on odour destruction is shown in Figure 6, at a temperature of 700°C.

This data confirms that a treatment time in the range of 1–1.5 seconds is adequate, with no evidence that additional treatment time will improve odour destruction.

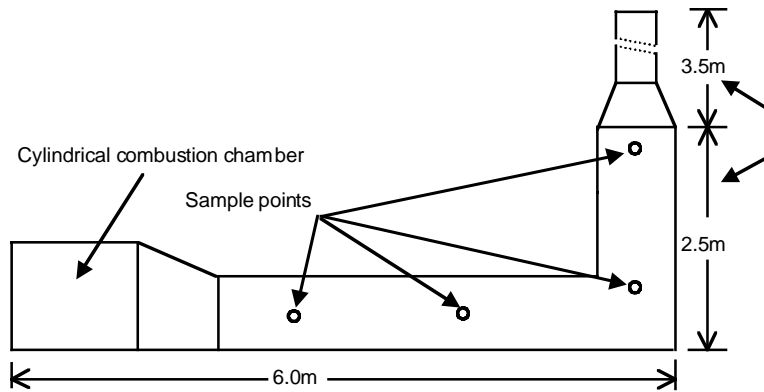


Figure 4 — Pilot Thermal Oxidiser

Temperature Effect

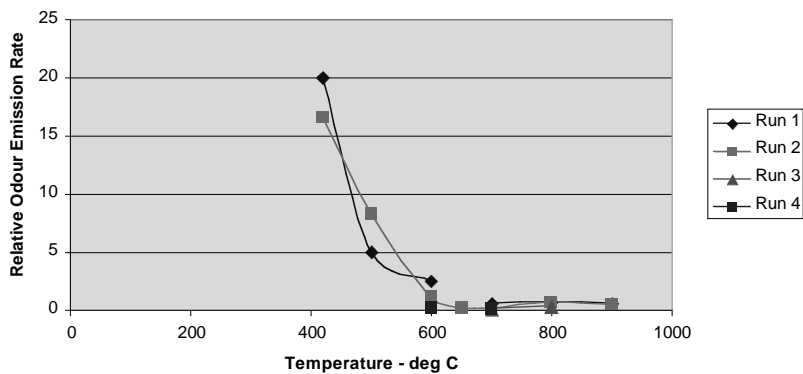


Figure 5 — Relative Odour Destruction with Temperature

Residence Time Effect

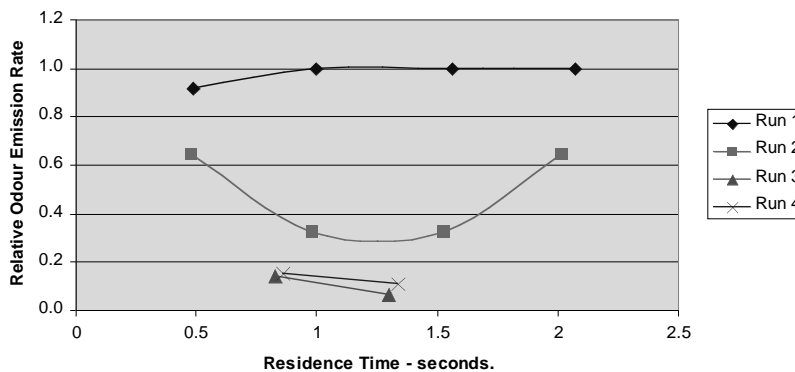


Figure 6 — Relative Odour Destruction with Residence Time at 700°C.

7. Future Direction

A feasibility study considered existing coal fired boilers, existing gas fired lime kilns and a new stand-alone thermal oxidiser as potential combustion sources.

QAL operates seven coal-fired boilers. Condensed fume would have been admitted through a new penetration in the combustion chamber wall, requiring expensive rearrangement of water wall tubes. Uncondensed fume would have been introduced to the secondary air system. The system would have been set up to three boilers, with two receiving odorous gas at any time. Operating and safety interlocks with boiler controls would be required, as well as adequate physical isolations. The boiler option was rejected on the grounds of complexity of control and that even slight leakage to the closed boilerhouse building during maintenance or normal operation would be unacceptable. The introduction of uncondensed fume may also introduce a small boiler capacity penalty.

QAL operates two natural gas fired rotary lime kilns. Condensed fume was the only option considered in this case, as the water vapour in uncondensed fume would put combustion stability at risk. Comparable interlocks and safety measures to the boiler option would be required. The lime kiln option was also rejected.

The option of a stand alone thermal oxidiser operating on condensed fume was chosen. The stand-alone oxidiser

is not linked to the operation of other critical equipment and as such requires a simpler control and safety interlock system. It also allows the opportunity to directly assess the degree of odour destruction without having to make allowance for background combustion processes or dilution by other combustion products. Hydrogen in the condensed fume will be the source of fuel, and a supplementary LPG flame will be provided to ensure stability.

Each of 93 digestion heat exchangers will be fitted with a vent flow restrictor, to allow adequate (but not excessive) venting of non-condensable gases. Vents will be manifolded together and passed through an air-cooled condenser to minimise the water vapour content. Condensate will be returned to the plant condensate system. The condensed fume will be piped to a stand-alone thermal oxidiser, fitted with the appropriate combustion and safety controls.

8. Conclusion

Thermal oxidation will provide at least 99% destruction of odour in digestion heat exchanger vent gases at a temperature of 700°C and residence time of 1 to 1.5 seconds. A stand-alone oxidiser will require relatively simple combustion controls, and health and safety issues will be manageable. Operating cost will be low. Source fume and destruction equipment will have the advantage of being located within the same operating section of the refinery.

Reference

Forster, P. and Grocott, C., Alumina Refinery Odour, *Fourth International Alumina Quality Workshop*, 1996.