ODOUR EMISSION REDUCTION CASE STUDY AT ALCOA'S WAGERUP ALUMINA REFINERY

Cox S. J.
Alcoa World Alumina Australia

Abstract

Alcoa World Alumina Australia's Wagerup Alumina Refinery is located 130 km south of Perth in Western Australia. The refinery has received a high degree of community, government and media focus on emissions, particularly odours, since the installation of a liquor burning process in 1996. Significant reductions have been made to the refinery's odour emissions since 1997 and by July 2002 we will have achieved a source odour reduction of approximately 50% at a cost of over $40M. This paper is an overview of the technical program to measure, identify and reduce odour emissions from the Wagerup Alumina Refinery.

1. Introduction

Alcoa World Alumina Australia (Alcoa) operates three alumina refineries in Western Australia located at Kwinana, Pinjarra and Wagerup. The Wagerup Alumina Refinery, located 130 km south of Perth, commenced operation in 1984.

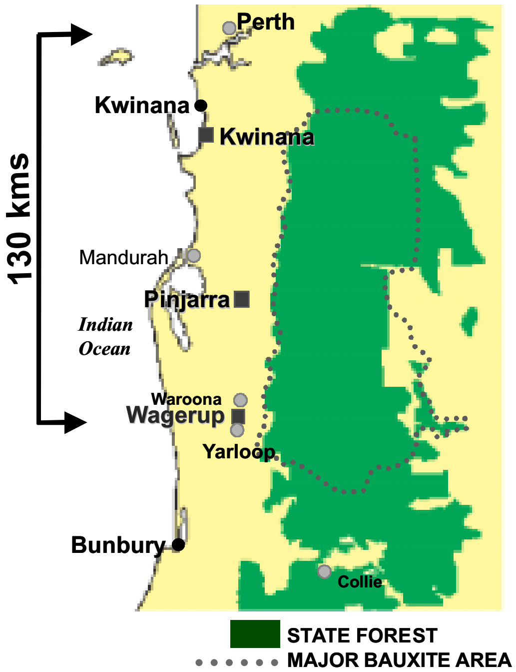

Figure 1 — Location of the Western Australian, Alcoa Alumina Refineries

The Wagerup refinery is located near the three local communities of Waroona (~10 km), Hamel (~5km) and Yarloop (~4 km). The nearest neighbours in northern Yarloop are approximately 1.5 km from the refinery however the population density has increased over the last 18 years, due to extension of the township.

Odorous emissions are caused by the breakdown of fossilised organic material from the bauxite in the liquor stream and by-products of combustion processes. Scrutiny of such emissions, particularly odours, by the workforce, community, government and media has significantly increased since the installation of a liquor burning process in 1996.

An aggressive program to reduce odorous emissions, initially focussing on the liquor burning facility, has been in progress since 1998 culminating in a significant capital works program in 2002.

2. Wagerup Refinery History

The Wagerup Alumina Refinery utilises low pressure digestion for alumina extraction, and impurities removal facilities for sodium oxalate and total organic carbon (TOC). The refinery commenced single unit operation in 1984, producing 0.6 Mtpa, with a second unit commissioned in late 1992. A further incremental upgrade was completed in 1999, enabling the current licence production levels of 2.35 Mtpa.

A liquor burning facility was installed in 1996 to improve liquor productivity and ensure the future of the refinery with high levels of organics in the bauxite. The resulting stack emissions from liquor burning were significant in noise and odour levels. Initial engineering focus was placed on reducing noise levels below acceptable limits. During this period a significant number of noise and odour complaints were received from the community. The noise problem was reduced, however odour complaints were still received and increased in number.

The liquor burning unit was shut down for installation of additional emission control equipment in the beginning of 1998. A high technology catalytic thermal oxidiser (CTO) was installed and commissioned in mid 1998 after a comprehensive selection process. The CTO reduced odorous emissions from the liquor burning stack by approximately 90% (measured by VOC reduction).

3. Wagerup Refinery Complaints History

Before installation of the liquor burning unit in 1996, approximately 10 community complaints to the refinery were received per year. Most of these complaints were due to dust from the residue disposal area. This increased significantly after the liquor burning facility was installed with the majority of complaints pertaining to noise and odour. The installation of the CTO in liquor burning reduced the number of complaints in 1998, but further increases were recorded in 1999 and 2000 with the community apparently becoming sensitised to plant odours. In 2001 the number of complaints again jumped significantly, with increased community and media focus on emissions from Wagerup. For 2001, 72% of the complaints were due to odour, with 19% due to noise, 9% due to health issues and less than 1% due to dust from the residue area.

KEY WORDS: odour, emissions, odour dispersion, Wagerup, Alcoa

The nature of the complaints are cyclic with most complaints received in the winter months when atmospheric inversions are present and prevailing winds blow emissions from the refinery towards the local community of Yarloop.

4. Odour Emission Measurement

Two comprehensive odour surveys were conducted in October 1999 (CH2M Hill, 1999) and September 2000 (The Odour Unit, 2001) to determine the source odour emission rate from the Wagerup Refinery before and after various odour reduction activities. The refinery odour sources were measured using the Draft Australian Standard technique of Dynamic Olfactometry to determine the odour concentration, reported as odour units per cubic metre (OU/m3). This was multiplied by the emission flow rate (m^3/s) to determine the odour emission rate (OU/s). All practicable odour sources from the refinery were measured to determine the total refinery odour emission. These included emissions from vents, stacks, liquor and water surfaces within liquor burning, calcination, digestion, desilication, clarification and precipitation and many other minor sources.

The odour surveys conducted in 1999 and 2000 were snapshots of the refinery during those periods. Refinery emission conditions vary due to process variability, and process and equipment maintenance. Further examination of these periods identified the refinery was not running under ‘normal’ operating conditions. Analysis of both odour and process emission rates for the 1999 and 2000 operating periods were therefore revised in 2002. The emission rates discussed are a general guide and not absolute numbers.

4.1 *1999 and 2000 Wagerup Refinery Odour Survey Results*

The overall refinery odour emission rate from the 1999 survey shows the refinery released approximately 2.55 million odour units (MOU/s). This was used as a basis for the reduction activities in 2000. The 2000 odour survey calculated a refinery emission rate of 1.26 MOU/s. (Note: both these values were later revised to better represent normal operating conditions.)

Since the 2000 odour survey, a continuing monitoring program of major refinery odour sources has been in progress to achieve a more robust estimate of the average refinery odour emission rate. A total of over 850 individual odour measurements have been taken from the refinery.

5. 2000 and 2001 Odour Reduction Projects

The program to reduce odorous emissions from Wagerup commenced in 1998 with the installation of the CTO after adverse reactions to odours from the liquor burning facility. Since that time, the management response to emission issues has moved from reactive to proactive. The emissions reduction program was initiated following workforce and community concerns over odours despite every analysis carried out showing that emissions were significantly lower than appropriate occupational and ambient requirements. As the program evolved through more detailed analysis and understanding of the nature and type of emissions, Alcoa has become more proactive on emissions issues. We now have very open communication with all stakeholders (workforce, community, government and industry) on the emissions reduction program in accordance with Alcoa’s best practise vision.

5.1 *2000 Emission Reduction Activities*

Upon completion of the odour survey in 1999 a program was put in place to reduce emissions where practicably possible. The first wave of emission reduction projects, completed in 2000, targeted the easily completed, low cost emission sources in the top 5 areas from the 1999 odour survey. The following areas were targeted:

- Calciner odour reductions,
- Desilication tank vapour emission reductions,
- Clarification tank vapour emission reductions,
- Oxalate kiln stack emission elimination

Odour reduction from the calciner area focussed on reduction of soluble soda levels in the washed hydrate through increased washing efficiency. The soluble soda levels are directly related to the organic material within the hydrate contributing to odour emission.

The reduction in odorous emissions from the desilication and clarification areas was achieved through installing vent covers on the desilication tanks, thickeners and first stage washers. The vent covers control the release of vapour associated with these previously open vents thereby reducing the emission source flow rate.

Removing the requirement to burn sodium oxalate eliminated the odour from the oxalate kiln stack. This was achieved by suppling sodium oxalate to Vanadium Australia Pty Ltd as a feedstock for their vanadium reduction process. The oxalate kiln has not been operated since July 2000.

These projects contributed to an odour reduction of approximately 20% over the 2000 period, despite refinery production increasing by 14% during the same period.

5.2 *2001 Odour Reduction Activities*

Following the 2000 odour survey, further emission reduction projects were implemented at the Wagerup Refinery concentrating in the calcination, liquor burning, desilication and digestion areas. Calcination was the major focus area as the calciner odours made up approximately 50% of the refinery odour emissions.

Two further source reductions were achieved in calcination through changing to a lower odour condensate for hydrate washing and optimising calciner conditions for lower odour production. The evaporation condensate was substituted for hydrate washing once the odour impacts of the previous condensate supply, digestion condensate, were realised. A system was installed for alternate disposal of the digestion condensate (discussed in Section 6.1.5).

The calciner operating conditions were optimised after a design trial was completed on calciner odour generation. The trial indicated odour from Alcoa Fluid Bed Calciners could be minimised by promoting combustion conditions (oxygen, temperature and turbulence) within the calciners. Odour measurements and online flue gas component analysis was used to evaluate the trial. Changes have been made to the operating conditions of the calciners to minimise odour production while maintaining product quality targets.

In November 2001, a new three-stage high efficiency gas scrubber was installed in the liquor burning facility, replacing the old single stage scrubber as the final emissions control element. This significantly reduced odour, noise and dust emissions from the liquor burning stack. The combination of the CTO and the new gas scrubber removed approximately 97% of the initial liquor burning flue gas odour.

Reductions in odour emissions were achieved in the desilication and digestion areas by improved operating and maintenance practices. Focus was placed on minimising vapour emissions during equipment maintenance and improving control of the digestion and evaporation energy balance. Control and operating practices were improved on the desilication tanks to maximise the flash vapour condensed in the contact heaters and minimise the variability of slurry feed from the mills.

From the initial identification of odorous emissions in 1999 to the end of 2001, the Wagerup Refinery reduced odour emissions by approximately 35%. This was achieved in conjunction with a 20% increase in production output for the same period. Figure 2 below, outlines the reduction in source odour emissions from the Wagerup Refinery from 1999 to the end of 2001.

6. 2002 Odour Reduction Activities

During the fourth quarter of 2001, further major reductions in refinery emissions were identified as being required to minimise nuisance odours from the refinery, particularly during the winter months. An aggressive odour reduction strategy was implemented to develop further emissions reductions technology and implement engineering solutions before the winter of 2002. A specialised team was developed to look at all facets of the emissions reduction program to meet the high expectations of Alcoa, the community and Western Australian government.

The multidisciplinary team consisted of Alcoa experts and specialised consultants and the team focussed primarily on emissions reductions from all areas of the Wagerup Refinery, including:

- Assessing new emission reduction technology
- Development and implementation of engineering solutions
- Optimising existing plant performance for odour reductions
- Development of existing and new emissions measurement techniques
- Development and co-ordination of source and ambient emissions monitoring programs
- Guiding an extensive research and development program.

This paper concentrates on the development and implementation of the engineering solutions for the above strategy with a small reference to measurement techniques and monitoring programs.

6.1 *2002 Engineering Solutions for Emissions Reduction*

A $25 million major capital works program was undertaken in 2002 to further reduce odorous emissions in the calcination, digestion, evaporation and clarification areas. The major emission reductions projects were:

- Calciner odour dispersion,
- Digestion vapour condensers,
- Non-condensable gas destruction,
- Powerhouse NOx reduction, and
- Bio-destruction of digestion condensate odours.

6.1.1 *Calciner Odour Dispersion*

Figure 3 — Calciner Multifluke Stacks

Evaluation of source odour emission data showed that calcination was the major emission source from the refinery. The concentration of the calciner odour emissions

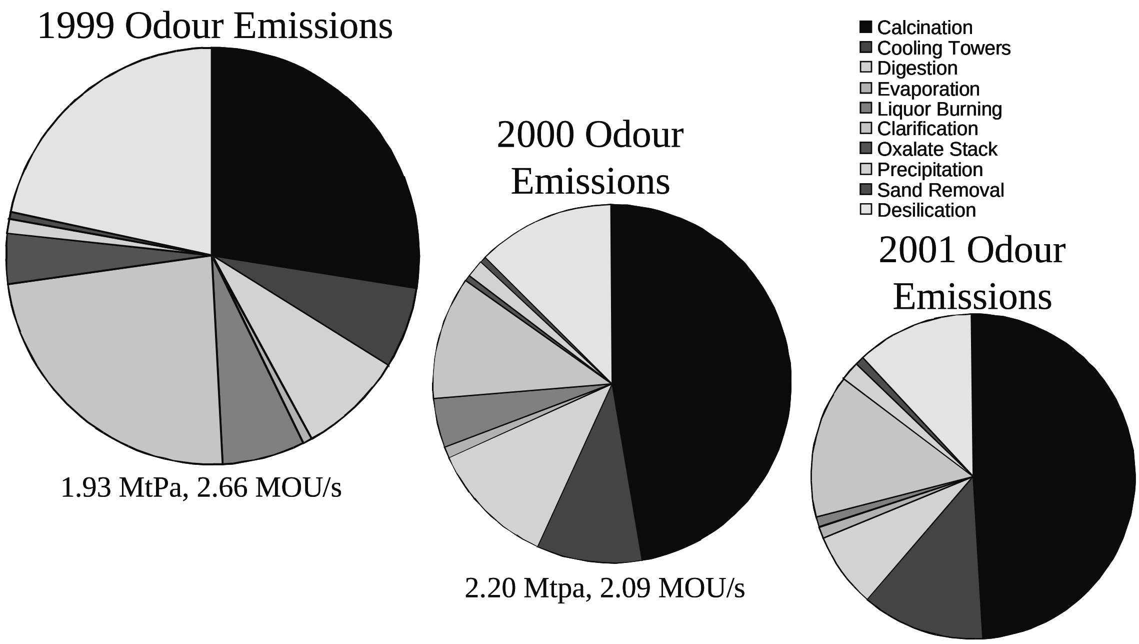

Figure 2 — Wagerup Refinery odour emission and production history — 1999 to 2001

are low, however the high exhaust flow rates result in calcination contributing to approximately 50% of the refinery odour. Although, odour reduction activities in 2000/2001 have reduced calcination odour, a significant reduction is still required to minimise impact of these odours.

Atmospheric dispersion modelling was undertaken at Wagerup in late 2001 to determine the effect of installing taller stacks for increased odour dispersion from calcination. Three separate dispersion models (Ausplume 5, Calpuff 4.1, and TAPM) and a Computational Fluid Dynamics (CFD) model were employed. These were validated using field odour surveys and ground level nitrogen oxides measurements. Local surface meteorological data was collected at the Wagerup Refinery weather monitoring stations and campaigns were run over winter 2001 to characterise the vertical temperature and wind profiles. This was done over a series of days with high ground odour levels in the community as determined by field odour surveys and community complaints. The validation of the dispersion models is detailed in the paper "Assessing odour impacts of an alumina refinery by source measurement, dispersion modelling and field odour surveying", (Coffey, 2002).

The dispersion modelling initially used various discharge heights for combining three calciner stacks into a single multiflue arrangement. The TAPM model was determined to be the most representative dispersion model for evaluating impacts of elevated stacks, as Calpuff and Ausplume tend to under predict contributions from those sources (Sinclair Knight Merz, 2002). As shown in Figure 4, the TAPM model predicted a peak odour reduction at 1500m of approximately 50% for 60m stacks and 70% for 100m stacks compared to the existing installation.

To further validate that a 100m multiflue stack would significantly reduce downwind odour and confirm that taller stacks will not 'touch down' further than the existing installation, CFD modelling of the various arrangements was conducted. The CFD modelling was performed by Alcoa's process modelling department and external expert Dr D Fletcher (University of Sydney). As shown in Figure 5, the odour level is decreased at all points downwind of the current installation and the plume will not 'touch down' further from the source. This confirms the conclusions of the dispersion modelling.

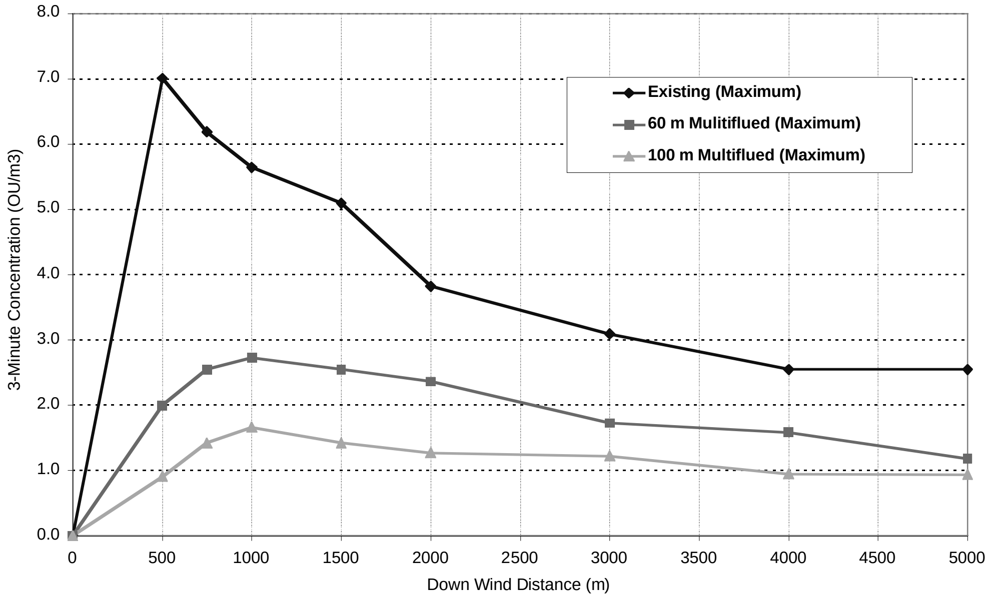

Figure 4 — Peak TAPM predicted 3-minute odour concentrations downwind from calcination.

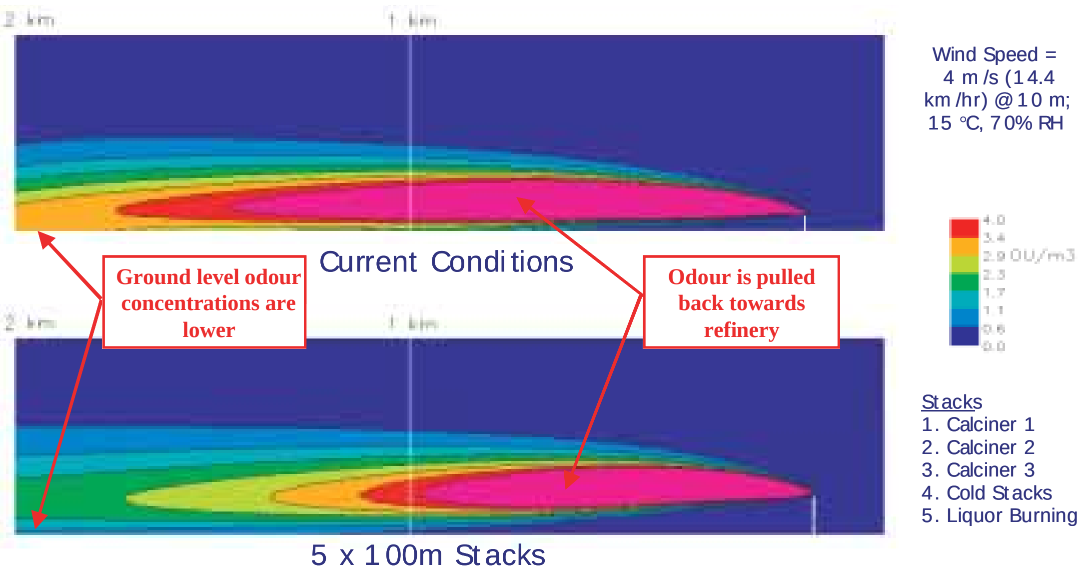

Figure 5 — CFD Model Results for Calciner Odour Dispersion from Multiflue Stacks

The installation of a multiflue stack (Figure 3) was commenced in January 2002 for three calciners and one combined low level source stack from calcination and the liquor burning stack. Hatch Associates Pty completed the engineering in conjunction with stack construction experts Steelcon (Denmark). The stacks were fabricated by Western Construction in Kwinana, WA, and erected in only three weeks by Monadelphous. They will be tied into the process by the start of July 2002. Tracer trials are planned for June and July 2002 to validate the stack dispersion.

6.1.2 *Digestion Vapour Condensers*

The digestion vapour condenser project targets the odorous blow off vapour emissions exiting the Wagerup containment tanks. The emissions are highly variable due largely to process and equipment maintenance. Under normal operating conditions (when the energy balance is at optimum) no vapour is emitted from the blow off tanks. During bypass of digestion flash stages for maintenance requirements, approximately 55t/hr of steam is emitted to atmosphere. The field odour survey (Sinclair Knight Merz, 2002) conducted in September 2001 indicated the digestion odour was very noticeable at the refinery boundary during flash tank bypass conditions. This, along with measured odour emission data and refinery dispersion modelling established digestion blow off vapour as a significant odour source.

Figure 6 — Digestion Vapour Condensers

The digestion vapour condenser project condenses the blow off vapour from the containment tank vents. The initial design incorporated direct contact condensers however this did not enable the odorous condensate to be disposed of separately, so two shell and tube condensers were installed. The wash water supply to the washers was diverted though the condensers to supply the tube side condensing medium. The digestion non-condensable gases were combined through the vapour condensers and vacuum system into a single stream for further processing. The condensate from the condensers is combined with the existing digestion flash condensate stream for further odour reduction treatment.

6.1.3 *Non-Condensable Gas Destruction*

A comprehensive program to determine the best solution to eliminate non-condensable gases was investigated through a technology risk assessment. The options considered included afterburners, flameless thermal oxidisers, biological filters and activated carbon scrubbing with the lowest total risk solution concluded to be a piping system to direct the gases to the powerhouse for thermal oxidation within the boilers.

This project collects non-condensable gases under negative pressure from digestion, evaporation, heat interchange, causticisation and the green liquor tanks and directs them to the powerhouse boilers through a light weight stainless steel piping system for odour destruction. Dilution air is added to the system to ensure the gas components are well below their lower explosion limits and moisture is removed through a series of knock out pots to ensure a clean gas stream is presented to the powerhouse.

Assessment of the non-condensable gases indicates all odorous volatile organic carbon species present will be easily destroyed within the powerhouse boilers. The fuel source in the non-condensable gases is less than 0.1% of the boiler fuel and does not provide any energy benefits to the powerhouse. Boiler safety systems were upgraded to incorporate this new fuel source by installing combustion gas analysers on the boiler stacks.

Gas composition of the boiler exhaust has been measured before project commissioning to confirm full thermal oxidisation of the non-condensable gases in the boilers. At the time of writing this paper the construction of the project is still underway and due for completion at the end of June 2002.

6.1.4 *Powerhouse NOx Reduction*

Following a review of the Wagerup refinery in late 2001, former EPA chief Barry Carbon suggested that NOx emissions may breakdown organics components in the atmosphere (not necessarily from refinery sources) and produce an irritant to the community. Alcoa also has corporate targets to reduce NOx emission by 30% by the year 2007. For these reasons, the powerhouse NOx reduction project was accelerated.

The powerhouse at Wagerup has three boilers and one Gas Turbine/Heat Recovery Steam Generator (GT/HRSG). One of the boilers already has low NOx producing technology installed. The project is installing low NOx producing burners on the other 2 boilers and the GT/HRSG to achieve a 40% reduction in powerhouse NOx emissions. The project is due to be completed in July 2002. The Wagerup powerhouse already operates on low polluting natural gas fuel.

6.1.5 *Bio-Destruction Of Digestion Condensate Odours*

Digestion condensate has been identified as the most odorous liquid stream of the refinery. Various water-soluble odorous components are condensed within the flash evaporation digestion train. These components, although low in concentration and highly odorous, give digestion its characteristic smell. Historically the digestion condensate was used for washing hydrate feed to calcination and used in the process water balance. The odorous condensate built up odour levels within the liquor stream, and, apart from calcination, no method of removing odour from the process was available.

In late 2001 an intensive research and development program looking at alternate methods for destroying the odour from digestion condensate was instigated. Options investigated included scrubbing with various absorbers (carbon, natural sponges, etc), ozonation, in-pipe UV oxidisation and oxidising reagent addition. The conclusion of the work was that in-pipe solutions were extremely difficult to achieve on the digestion condensate stream. Further laboratory testing indicated that natural oxidisation would occur at extended holding times in the presence of dissolved oxygen and UV light. This combined with biological destruction of odorous compounds would reduce the odour in the condensate stream.

A plant trial commenced in October 2001 to divert the digestion condensate to the condensate dam at Wagerup.

An extensive monitoring program was established to monitor any changes occurring in the water quality from the dam. Initially the trial proceeded as planned, with odour levels dropping in the refinery liquor and lake circuits, however after a few months the workforce noticed the odour characteristics of the dam had changed. Review of the dynamic olfactometry analysis could not discern a difference in the dam odour, however individual "sniff" analysis of the saved samples picked up a noticeable odour change.

A program was implemented to minimise the odour to the dam while alternate approaches for odour destruction were investigated. The condensate dam still destroyed approximately 90% of the odorous emissions. Further laboratory testing indicated that increasing the bio-destruction rate would remove the odour from the dam. A project was approved to install "Living Barrier Technology" developed by Clean TeQ. This system consists of floating pontoons filled with "BioBlocks" that encourage the reproduction of large populations of native bacteria, enhancing the existing bio-treatment. The "Living Barrier Technology" is due to be installed in June 2002.

6.2 *Emissions Measurement Development and Monitoring Programs*

Various attempts have been made to determine the odour concentration in stack emissions from the component concentrations. Although no empirical correlation has yet to be determined, current information indicates the odorous materials consist mainly of aldehydes and ketones. Testing and monitoring programs routinely target these chemicals using USEPA approved sampling methods.

The Wagerup Refinery has a number of current monitoring programs for emissions. These include:

- bimonthly licence sampling of 11 emission sources for a wide range of compounds;
- "emissions Inventory Survey" looking for trace levels in source emissions of over 500 chemical compounds; and
- a winter ambient monitoring program around the refinery and in the local community.

Online measurement trials of source and ambient VOCs have been conducted using both infra red and ultraviolet technology. Both technologies have their limitations and no instrument can meet the current emissions monitoring requirements at Wagerup.

7. 2002 Odour Emission Reductions

The implementation of the 2002 emissions reduction program will significantly reduce the impact of odour from the Wagerup Refinery upon its workforce and surrounding community. Source odour emissions will reduce by a further 35%, totally eliminating odour emissions from a number of areas. As shown in figures 7 and 8, the impact of the total refinery odour, as measured by Calpuff dispersion modelling, shows a reduction of approximately 50% from 2001 at Boundary Road in the community of Yarloop for the 99.5 percentile, or near worst-case conditions. The 2002 program will have reduced the refinery source emissions by 56% since 1999.

Predicted 3-minute, 99.5 percentile ground level concentration from the Wagerup Refinery.

Figure 9 shows that the calcination building will account for 65% of the total refinery odour, however the impacts have been significantly reduced due to the calciner dispersion project. The cooling towers are the next highest odour emission, accounting for 19% of the refinery emissions. A technical program is underway to identify options for further source odour reductions from calcination and the cooling towers.

8. Discussions and Conclusions

Alcoa has progressively reduced odour emissions from the Wagerup refinery since 1998, with the total cost of the program being approximately $40 million. By July 2002 we will have achieved an odour reduction of approximately

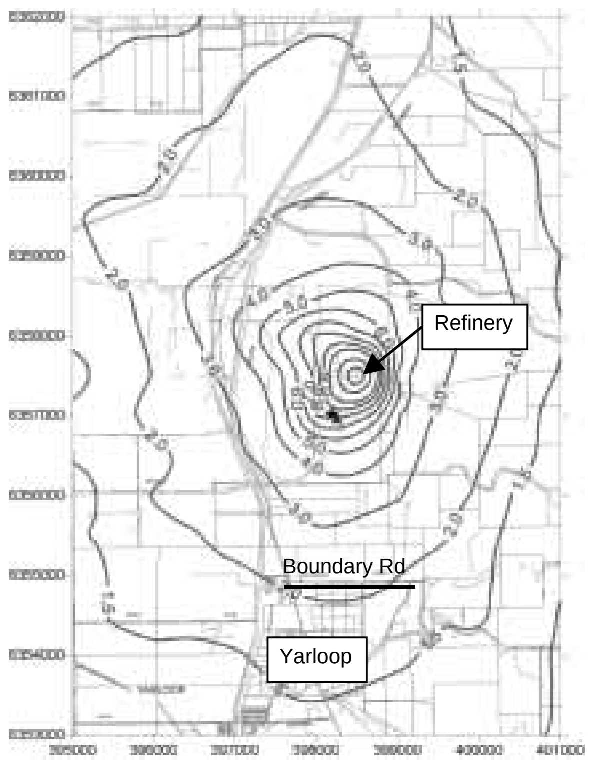

Figure 7 — Odour before 2002 projects

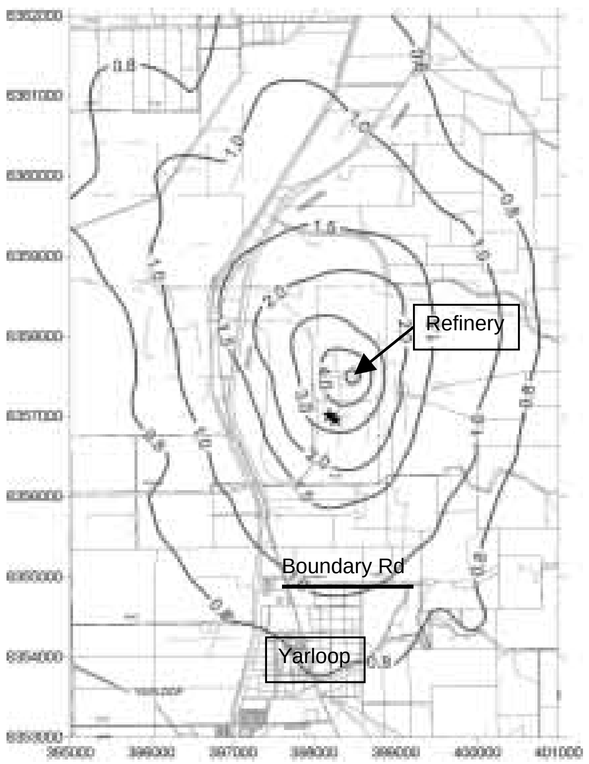

Figure 8 — Odour after 2002 reduction projects

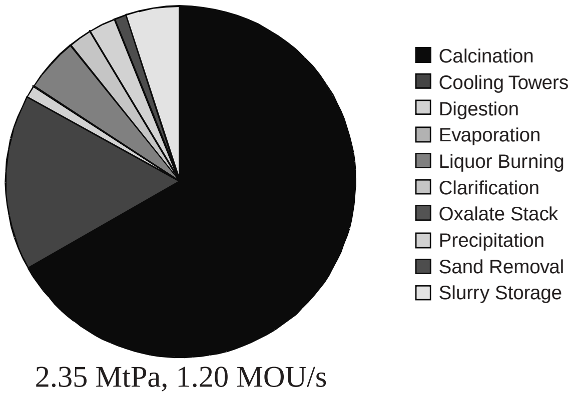

Figure 9 — 2002 Predicted Odour Emission Breakdown

50% despite a production increase of 20% over the last four years. The program was initially developed following workforce and community concerns. The program now has the structure and science to enable proactive response to odour emission problems, before escalation by external pressures. Alcoa is now expanding the learnings from the Wagerup Refinery to the ongoing management of our refinery air emissions and odours.

The 2002 emissions reduction program is the result of a very quick response to a large problem by a diverse and talented team. They had to go beyond the usual practice of designing to current standards and try and predict future conditions set by the community and government legislators.

The items discussed in this paper are only a portion of the total work carried out in identifying, measuring and reducing total refinery emissions in general.

A major part of the program not discussed in this paper was the communication strategy to ensure the correct information is sent to the workforce, community, and local and state governments. This needs to be included as part of the overall strategy. We have learnt many things along the way, most importantly that people's perception is reality, and the requirement for prompt response to emission concerns.

Acknowledgments

The work described in this paper is the culmination of a diverse and broad ranging investigation undertaken by Alcoa staff resources as well as external consultants. Alcoa personnel contributing to this work include B Maley, E Chedid, P Coffey, G Brown, L Myers, Dr C Armanios, Dr S Eyer, A Logiudice, P Edwards, P Males, the author and numerous other contributors. Odour analysis was undertaken largely at the laboratories of The Odour Unit Pty Ltd and Dr O Pitts at Sinclair Knight Merz primarily undertook the odour dispersion modelling.

References

Coffey, P. (2002). Assessing odour impacts of an alumina refinery by source measurement, dispersion modelling and field odour surveying, Paper in Alumina Quality Workshop — 2002.

CH2M Hill, (1999). Wagerup Refinery Odour Emissions Study, Dec 1999 consultant's report to Alcoa, CH2M Hill, Sydney.

Sinclair Knight Merz, (2002). Wagerup Refinery Odour Assessment, final consultant's report to Alcoa, Feb 2002.

The Odour Unit Pty Ltd, (2001). Odour Survey — Oct 2000 Wagerup Refinery, consultant's report to Alcoa, Sydney.