Gasco Pty Ltd
ABN 55 869 575 588
ACN 051 824 741

20 May 2021

Attention: Trent Gearside
Email: trent.gearside@quantem.com.au
Re: NSW EPA Letter - DOC21-318981. 28/04/2021

Dear Trent,

Please see below additional information requested pertaining to the GASCO Thermal Oxidiser and specific matters to be addressed as noted in the above-reference letter from NSW EPA.

EPA Letter Ref. 1 b)

Gasco provide the below advice and justification that the thermal oxidiser is designed to maintain the required temperature and destruction efficiency when treating liquid waste.

Details of Thermal Oxidizer

This is an afterburner type TO as shown in preliminary GA Drawing attached. It has a maximum design heat release of 24.6 GJ/h and is capable of handling all operating scenarios as per Quantem specification. More details of the TO are presented in "Technical Details of TO" and preliminary GA Drawing attached.

We are able to guarantee 99.99% destruction efficiency for BTEX and other VOC's by ensuring (Ref. "Design of Thermal Oxidation Systems for Volatile Organic Compounds" by D. A. Lewandowski, Lewis Publishers, New York):

- Operating temperature of 980 degC,
- Residence time of minimum 2s,
- Good mixing of air and waste streams, and
- Minimum 3% free O2 (dry) in the exhaust gas.

Temperature

The TO will be operated at 980 degC, which is auto-controlled through a burner management system (BMS). Method for maintaining temperature setpoint in simple terms:

- If chamber temperature is too low, BMS will call for increase in burner output, and
- If chamber temperature is too high, BMS will call for decreased burner output and then more secondary air (cooling air).

Heat and mass balance (HMB) for the following extreme cases are attached for illustration:

- HMB 1: Inert waste gas + 100% water, where required burner heat release is 18 GJ/h in order to maintain chamber temperature at 980 deg C.
- HMB 2: Waste gas of maximum Benzene content + 100% liquid Benzene. This is the sizing/design case for the TO where the burner is operated at minimum firing (for combustion stabilization). In this case, highest amount of cooling air (19,250 kg/h) is required for maintaining 980 degC chamber temperature.

Comparisons of operating parameters for the above cases are tabulated below:

Operating Parameter	**Inert Waste Gas + 100% Water (HMB 1)**	**Waste Gas of Max Benzene + 100% Liquid Benzene (HMB 2)**
Chamber Temperature, degC	980	980
Heat Release of TO, GJ/h	18	24.6
Heat Release of Burner, GJ/h	18	1.2
Primary Air, kg/h	5,593	372
Secondary (Cooling) Air, kg/h	4,639	19,250
Exhaust Gas Free O2, % (dry)	8.4	12.2
Exhaust Gas Volume, Am3/s	13.4	21.2

Residence time

Residence time of 2s minimum is achieved by ensuring that volume of the mixing chamber is greater than 42.4 m3. The Gasco thermal oxidiser mixing chamber will have an internal volume of approximately 56 m3 (TBC during detail design).

Mixing

The mixing chamber design is formed by a concentric series of gas nozzles around the central up-fired gas burner. The inner nozzles are for VOC gas stream, and the outer nozzles are for secondary/cooling air. This configuration (see photo below) forces rapid mixing in the swirling gas streams and leads to high destruction efficiency.

Free O2 in Exhaust Gas

To achieve a high destruction efficiency, free O2 in exhaust gas is usually required to be minimum 3% for TO's. We note that free O2 will be greater than 6% (dry) for all operating scenarios under consideration.

Liquid Handling Capability

The TO is designed to handle, by way of atomization, liquid waste of 0 – 6.5 L/min. The required liquid handling capability is similar to those for a number of TO's that Gasco supplied in recent years including TO's for

- Queensland Alumina Ltd,
- APA Group (Orbost Gas Plant),
- Leigh Creek Energy, and
- Northern Oil Refinery.

The atomization system is characterized by fine droplet generation and uniform droplet distribution. More details of the atomization nozzle are shown in the following documents (see attached):

- Spraying System Nozzle
- Photos of TO with Spray Nozzle

EPA Letter Ref. 2 c)

Gasco provide the below comments on alternative oxidisation methods to demonstrate that Thermal Oxidisation is appropriate and justification why the afterburner type thermal oxidiser has been selected over alternatives.

Catalytic Oxidation

Catalytic oxidizers are usually not used unless the waste stream LHV is less than approximately 0.75 MJ/Sm3. This is because catalytic oxidation of higher LHV gases can lead to high temperature rise over the catalyst, which will cause damage to the catalyst in the form of masking and sintering.

The Max Benzene stream has an LHV of 7.2 MJ/Sm3, so catalytic oxidation cannot be considered in this application.

In addition, there is danger of catalyst poisoning due to variable waste gas/liquid properties.

Other Types of Thermal Oxidisation

1. Regenerative Thermal Oxidizer (RTO)

RTO's are oxidizers of highest thermal efficiency, typically 90% to 95%; they are ideally suited for waste gases of very low calorific value (CV), e.g., <0.1 MJ/kg in higher heating value (HHV). To accommodate small spikes in waste gas CV, a hot bypass is required in the design.

In a recent joint study between Gasco and KBR Houston, we found that the waste gas HHV shall not exceed approximately 0.4 MJ/kg for an existing RTO, even if up to 25% of the hot gas bypasses the regenerative beds.

Therefore, an RTO would not be suitable for the present application.

2. Recuperative Thermal Oxidizer

A recuperative TO achieves reduction in fuel gas consumption by preheating combustion air and/or waste gas. This option cannot be considered due to

- Possible reliability issues,
- Higher construction cost, and
- Requirement of a larger plot area.

If you have any further questions, please don't hesitate to contact me.

Yours sincerely,

Shan Wang

Dr Shan Wang
Manager - Combustion Engineering S&M
Email: shan.wang@gasco.net.au

Attachments:

- Technical Details of Thermal Oxidiser document
- Thermal Oxidiser General Arrangement - Q12803-G001A
- Heat & Mass Balance - HMB 1 (Inert waste gas + 100% water)
- Heat & Mass Balance - HMB 2 (Waste gas of maximum Benzene content + 100% liquid Benzene)
- Spraying System Nozzle
- Photos of TO with Spray Nozzle

TECHNICAL DETAILS OF THERMAL OXIDIZER

Customer: Quantem

Project Location: Botany Bay, NSW

Design Overview

The thermal oxidizer is sized to handle combined, as well as individual, waste streams as per package specification including:

- VOC-N2 stream: 0 – 1,642 Sm3/h (ambient conditions, 3 kPag). We note that the VOC-N2 stream contains up to 1.07% w/w H2S in a new Max Benzene H2S case.
- VOC-air stream (for future): 0 – 3,802 Sm3/h (ambient conditions, 1 kPag)
- Liquid waste: 0 – 6.5 L/min (ambient conditions, 400 kPag). We note that the liquid waste contains up to 0.2% w/w H2S in a new Max Benzene H2S case.

Package specification calls for the following burner sizing criteria:

a) VOC-N2 stream: 0 – 1,642 Sm3/h assuming all N2
b) VOC-air stream: 0 – 3,802 Sm3/h assuming all air
c) Liquid waste stream: 0 – 468 kg/h water

The thermal oxidizer is designed to handle all possible operating scenarios while meeting performance requirements per package specification.

Thermal Oxidizer Chamber and Stack

(1) Overall height of thermal oxidizer: 17,300 mm

(2) Sampling port elevation: 12,820 mm

(4) Combustion chamber: 2,860 mm shell od, 10mm wall thickness, CS construction

(5) Stack: 1,250 mm shell od, 10mm wall thickness, CS construction

(6) Rain cowl, uninsulated: 1,350 mm diameter & 3,000 mm length

Insulations for Oxidizer Chamber and Stack

(a) Lower combustion chamber: 150mm castable refractory (TBC)

(b) Upper combustion chamber: 100mm thick ceramic fibre modules

(c) Stack: 100mm thick ceramic fibre modules

Combustion Air Fan

Drive Type: Direct driven arrangement 4

Design Capacity: 19,622 kg/h

Outlet Pressure: 3 kPag

Fan Speed: 2,900 rpm

Motor: WEG W21; 30 kW; 2 pole; D200L frame

Construction Materials: 304SS casing / pedestal; 304SS impeller

Gas Burner

Make/Type: Bloom Engineering / 1020-120 burner

Max. Heat Duty: 18.0 GJ/hr (Gross)

Turndown Capability: 15:1 (through use of a high turndown centre lance)

Flame Dimensions: Appr. 3.73 m long x 1.38m diameter at stoichiometric air

Fuel: Natural gas

Flame Monitor: UV Scanner

Atomization Nozzle (Referring to Photos of QAL TO with Spray Nozzle)

Make/Type: Spraying Systems / FloMax FM3A

Material of Construction: 310SS

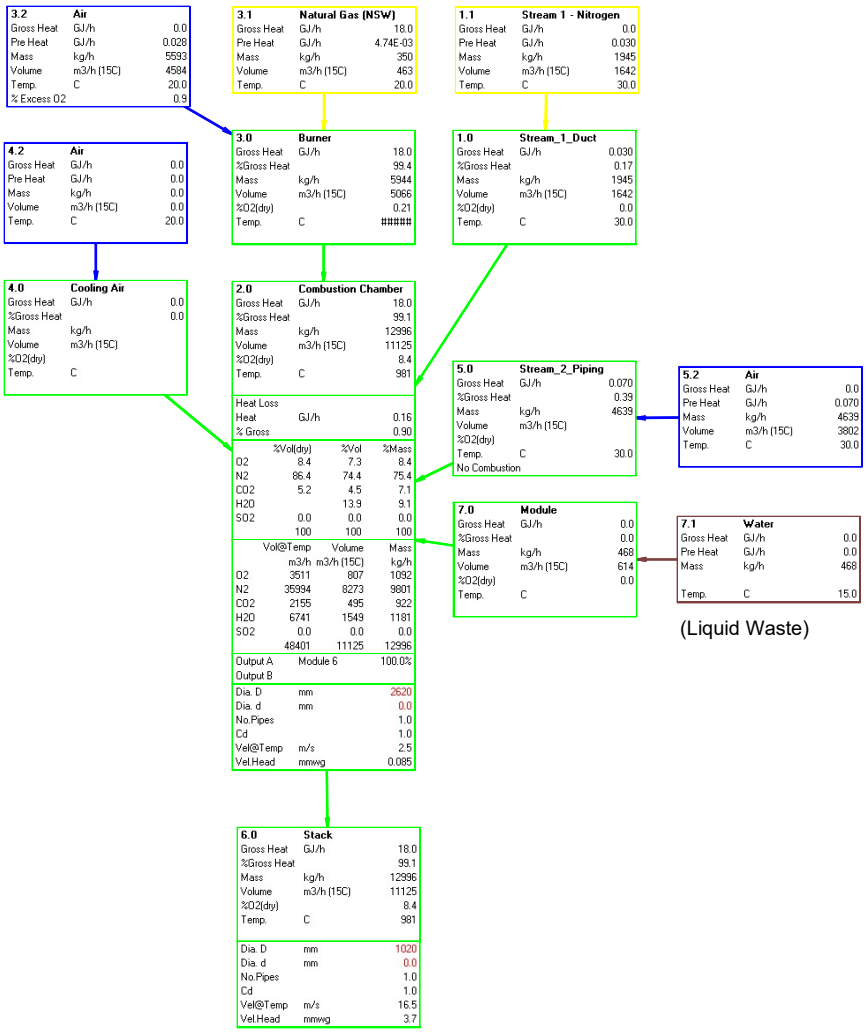
Liquid Orifice Size: 6.35 mm

Liquid Pressure Range: 50 to 160 kPag

Atomization Air Pressure: 200 to 400 kPag

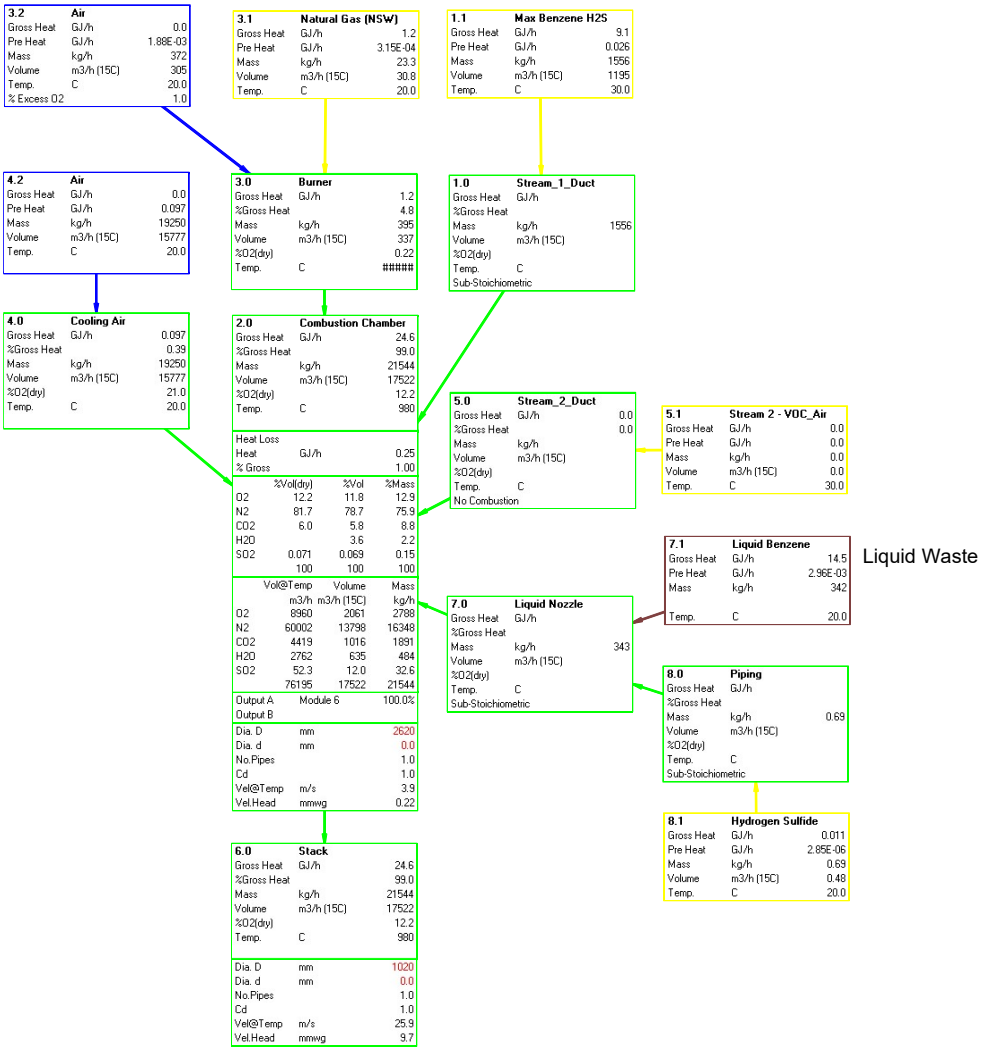
Atomization Air Consumption: Approx. 48 Nm3/h at fluid flowrate of 7.8 L/min

HMB 1



GASCO engineering with flare	Gasco Project	Q12803	Notes:For temperatures >1500C,dissociation must be accounted for
	By	SW	TO for Port Botany (Terminals Pty Ltd / Quantem)
	Checked/Approved		
	Date	24 June, 2020	HMB 1
	Amb.Temp.C	15.0	Heat and Mass Balance Ver. 1.0.3

HMB 2



GASCO engineering with flare

Gasco Project	Q12803	Notes:For temperatures >1500C,dissociation must be accounted for
By	SW	TO for Port Botany (Terminals Pty Ltd / Quantem)
Checked/Approved		
Date	23 Nov, 2020	HMB 2
Amb.Temp.C	15.0	Heat and Mass Balance Ver. 1.0.3

For Applications Demanding Precision and Efficiency, FloMax® Nozzles Outperform All Others

If your application requires a finely atomized, controlled spray, you won't find a more effective solution than our high-efficiency FloMax air atomizing nozzles.

FloMax nozzles are not traditional air atomizing nozzles. Using patented multi-stage atomization processes, FloMax nozzles produce very small drops with exceptional efficiency. Compressed air use and energy consumption are low. The nozzles also offer significantly higher turndown ratios than standard air atomizing nozzles for maximum operating flexibility.

There are many other features that result in better spray performance and lower operating costs than competitive nozzles. In the sections that follow, you'll find more detailed information on the FloMax A Series, the FloMax Anti-Bearding Series, the smaller capacity FloMax X Series and how these nozzles can help you optimize the performance of your spray system.

Typical applications and industries

FloMax A Series:

- Gas cooling and conditioning
  - Cooling prior to baghouse, ESP, heat exchanger, kilns
  - Cooling towers
  - Induct cooling
  - NO_x control
  - SO_2 removal

FloMax Anti-Bearding Series:

- Gas cooling and conditioning
  - High concentration of dust particulates
  - Slurry spraying

FloMax X Series:

- Gas cooling and conditioning
  - Induct cooling
  - NO_x control
- Chemical injection

Industries:

- Aluminum
- Cement
- Chemical
- Lime
- Petrochemical
- Power generation
- Pulp and paper
- Refinery
- Steel
- Waste incineration

Overview of the FloMax air atomizing nozzle line

FloMax A and FloMax Anti-Bearding Series

FM3A and FM3A-AB: 0.03 to 3 gpm (1.13 to 11.3 l/min)
55° spray angle standard, 20° spray angle optional*

FM5A and FM5A-AB: 0.7 to 7.0 gpm (2.6 to 26.5 l/min)
55° spray angle standard, 20° spray angle optional*

FM10A and FM10A-AB: 1.3 to 13.0 gpm (4.9 to 49.2 l/min)
55° spray angle standard, 20° spray angle optional*

FM25A and FM25A-AB: 10.0 to 30.0 gpm (37.8 to 114 l/min)
55° spray angle standard, 20° spray angle optional*

FloMax X Series

FMX015: 0.03 to 0.25 gpm (0.11 to 0.94 l/min)
20° spray angle

FMX030: 0.05 to 0.5 gpm (0.19 to 1.89 l/min)
20° spray angle

FMX090: 0.5 to 1.5 gpm (1.89 to 5.67 l/min)
20° and 55° spray angles

Options

Standard and custom spray lances available in a wide range of materials and configurations.

Compatible with AutoJet® Gas Conditioning System for a fully automated, turnkey solution.

Pre-assembled Valve Regulation Packages to save engineering and installation time.

*FloMax Anti-Bearding Series only available in 55° spray angle.

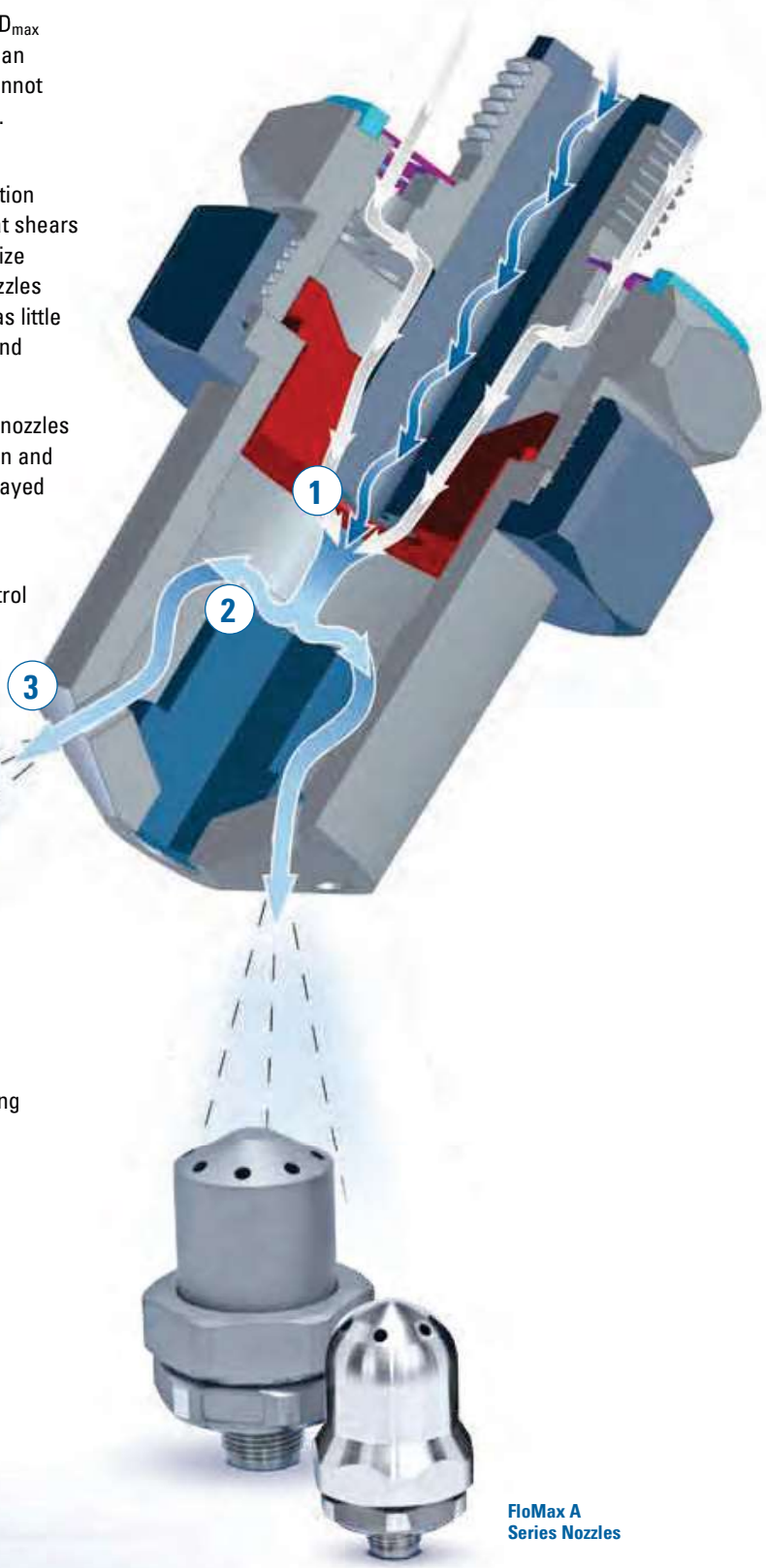
FloMax® A Series: Produces Smaller Drops, Uses Less Air. Here's How:

When it comes to drop size, the goal is to minimize D_{max} and achieve a finely atomized spray with D_{32} less than 100 microns at 10 gpm (37.8 l/min). This drop size cannot be achieved with a single-step atomization process. A multi-stage process is required.

FloMax nozzles use a patented three-stage atomization principle to produce a highly focused air stream that shears the liquid with minimal air. The result is a D_{32} drop size 34% smaller using 20% less air than competitive nozzles (flow rate of 10 gpm [37.8 l/min]). Each nozzle uses as little as 45 scfm (76 Nm^3/hr). Energy costs are lowered and compressor life extended.

The very small drops produced by FloMax A Series nozzles reduce dwell time required for complete evaporation and reduce the risk of wetting. Plus, the liquid being sprayed generates more surface area per gallon (liter).

The uniformity of drop size distribution produced by FloMax A Series nozzles ensures precise, tight control of drop size. This is another unique attribute – FloMax nozzles provide a narrower Relative Span Factor (RSF) than many other air atomizing nozzles at most air pressures.



FloMax A Series Nozzles

FloMax A Series: principle of operation

1. **Stage One: Primary Fluid Breakup**
   Air and liquid converge at the annulus allowing high velocity air to shear the liquid column.

2. **Stage Two: Secondary Fluid Breakup**
   Focused stream impacts the target bolt forcing additional mechanical breakup.

3. **Stage Three: Final Mixing**
   Air cap acts as a final mixing chamber. As liquid crosses multiple orifices, an additional pressure drop provides the final atomization.

Photos of Thermal Oxidizer with Spray Nozzle

Customer: Queensland Alumina Ltd

Project: Thermal Oxidizer for Waste Gas and Condensate