Quantem

(Terminals Pty Ltd)

2^{nd} Thermal Oxidiser and Liquid Waste Burning

Port Botany, NSW, Australia

Technical Specification for the Supply of a VOC & Liquid Waste Thermal Oxidiser

Rev 3

Document Number: 180010DOC-002

Original CEC Project No. 180010

CEC Project No. 200003

November 2021

Prepared by CEC Engineers
Incorporating information supplied
by Quantem (Terminals Pty Ltd)

Document History

Date	Revision	Comments	Prepared by	Review	Authorised by
06/6/19	Rev 1	For Review	F. Sachinidis	A. Bialecki	
04/8/21	Rev 2	Updated to capture and incorporate additional requirements that were placed on TO vendor during tender and negotiation stage. – add worst case benzene scenario, gas flowmeter and OPSO pressure regulating valve.	F. Sachinidis		
09/11/21	Rev 3	Update operating Parameters (980oC and 2 sec residence time) and exclude benzene from liquid waste worst case.	F. Sachinidis		

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1 Introduction

This specification provides technical details for the design, supply, construction, installation and commissioning of a Thermal Oxidiser/Combustor unit for destruction of Volatile Organic Compounds (VOC's), Hazardous Air Pollutants (HAP's) and liquid waste generated at Terminals' Port Botany Terminal, in New South Wales, Australia. The scope and technical requirements are detailed in this specification.

The system will consist of one (1) thermal oxidiser/combustor destruction unit capable of treating three (3) separate streams:

- VOC-nitrogen inert vapour stream.
- Liquid waste stream.
- VOC- air dilute stream (future connection).

The thermal oxidiser unit will operate independently or in parallel with an existing thermal oxidiser, to treat the streams.

2 Scope of Works

2.1 General Scope

2.1.1 The scope of works includes:

a. Engineering and detailed process, mechanical electrical/instrumentation and control design.
b. Obtain all relevant authority permits and approvals and provision of associated fees.
c. Supply, fabrication and installation of all equipment, ancillary items, electrical items, wiring and control.
d. Supply of all labour and material to successfully complete the works.
e. Testing, commissioning and performance testing of the system.
f. Provision of associated documentation and training.
    - Operation and maintenance manuals
    - As constructed drawings
    - Operator training

2.1.2 Works not included:

a. All concrete and civil works (excluding any necessary grouting of equipment).
b. All building and demolition works.
c. The provision of gas, power and other services to the thermal oxidiser.
d. Ductwork, valves, fans, detonation arrestors and associated controls that relate to the VOC-nitrogen system and liquid waste system (unless specifically included).
e. Local area lighting.

2.2 Scope of Supply

The vendor shall design, manufacture, install and commission a thermal oxidiser suitable for the duties and performance listed.

The scope of supply shall include but is not limited to the following:

2.2.1 Design

1. Detail design of the thermal oxidiser and all associated equipment, including:
2. Design and selection of thermal oxidiser equipment suitable for the duties as detailed within.
3. Development of plant layout for the thermal oxidiser taking into account site restraints, requirements for access to equipment for operation and maintenance and need to be able to install the VOC-air dilute system in the future.
4. Development of a P&ID of the thermal oxidiser, to agreed termination points.
5. Development of a control system for the fully automated operation of the thermal oxidiser and provision of a functional specification detailing the operation.
6. Sizing and selection of all equipment.
7. Provision of process connection and location details and connection design loads for all equipment to allow design of civil, structural, electrical automation, utilities and piping by others.
8. Provision of all statutory design approvals and the payment of any associated fees.
9. Design in compliance with all relevant Australian standards and statutory requirements including AS 3000 and AS 5601.
10. Attendance at a HAZOP to be held in Sydney, Australia. (Allow 1 day for 1 person familiar with all aspects of the design)

2.2.2 Equipment

1. A natural gas fired burner system to combust VOC and HAP vapours and liquid waste.
2. Spray/atomising nozzle for the liquid waste

3. Thermal oxidiser stack- 17.3 meters height (TBC)
4. Combustion air and secondary/quench air fans.
5. EPA sample points and in stack gas analyser for testing emissions from stack
6. Access platform/s.
7. All equipment, as required between the agreed termination points as defined in this specification.
8. Supply of all pipework, fittings, valves and any other equipment required for operation of the thermal oxidiser.
9. Structures, frames, platforms and access ways complaint with Australian codes and standards.
10. Fencing, access restrictions and shielding as required for the system, including systems for Personnel Protective Equipment.
11. Supply of combustion management system in full compliance with AS 5601 and AS 3814.
12. Supply of motor control for all drives, junction boxes and field cabling to drives, as required. A power feeder cable to the MCC shall be provided by Terminals Pty Ltd for connection by the Vendor.
13. Provide a control system and supply and install all instruments required for the safe and effective operations of the thermal oxidiser.
14. Supply Emergency stops.

Note: An existing site PLC (by others) will control the operation of the VOC-nitrogen inerted vapour collection system including booster fans, stream isolation valves to oxidiser and divert system and the liquid waste feed system including stream isolation valves, instruments and pumps. An existing site safety PLC will control all safety related functions. The existing site PLC system/s and new thermal oxidiser control system must interface and work together as an integrated unit to ensure safe start-up, shut etc.

The tenderers shall confirm their preferred electrical and control interface with their tender.

2.2.3 Installation, Commissioning and Testing

1. Installation of the thermal oxidiser and all associated equipment in the nominated scope.
2. Commissioning and performance testing of the thermal oxidiser and all associated equipment
3. The training of Terminals staff in the safe operation and maintenance of the thermal oxidiser and associated equipment

3 Description

Terminals Pty Ltd operates a flammable liquid bulk storage facility at their Botany site. The terminal stores and handles a range of flammable liquids including Benzene, BTX, Hexene, ethanol and methanol. Volatile Organic Compound (VOC) vapours, Hazardous Air Pollutant (HAP) vapours, and odours are generated by the various operations at the terminal which include tank filling, ship filling, truck filling and diurnal breathing of tanks. These emissions are generally short term and sporadic in nature-not continuous. These vapours are collected in (two) separate streams (i) a VOC- nitrogen inert stream and (ii) a VOC-air dilute stream. The terminal also generates liquid waste from various cleaning and regenerative activities which are currently collected and disposed of site.

The VOC-nitrogen inert stream is directed to an existing thermal oxidiser where VOC's in the stream are oxidised before discharge to atmosphere. It is proposed that this stream will have the ability to feed the existing thermal oxidiser as well as the proposed new thermal oxidiser.

A VOC-air dilute stream directs vapours to an existing carbon adsorption plant -VECS. In the future it is proposed to direct the VOC- air dilute vapours to the existing thermal oxidiser as well as the proposed new thermal oxidiser.

It is proposed that the flammable liquid waste generated on site will be collected and pumped to the new thermal oxidiser for burning and disposal on site. The flammable liquid waste can vary in concentration from 100% flammable liquid to 100% water.

It is proposed that the new thermal oxidiser will be designed to treat the three (3) separate streams all operating together. It is proposed that the system will ultimately consist on a VOC-nitrogen inert stream, a VOC-air diluted stream and a flammable liquid waste stream feeding the new thermal oxidiser. The vapour streams will have the ability to feed both thermal oxidisers (existing and new), whilst the liquid feed stream will feed the new thermal oxidiser only. The thermal oxidiser units shall run in parallel at peak load.

3.1 Stream 1 (Nitrogen inerted rich VOC)

Refer to Section 4 for process details

VOC-nitrogen inerted emissions are generated in the following manner:

- The bulk storage tanks, which are nitrogen blanketed, generate emissions when tank filling occurs or when the vapours in the tank expand due to temperature increase during the day (diurnal breathing).
- During the filling of ships vapours are emitted which contain VOC's and air. These vapours are nitrogen inerted by injecting nitrogen into the vapour collection line so the oxygen concentration is below the Limiting Oxygen Concentration (LOC).
- In addition when tanks are cleaned they are purged with nitrogen gas until the VOC concentration is reduced.

The emissions from the various sources are collected in a dedicated nitrogen inerted rich VOC collection system (stream 1). The flowrate and concentration of the inert stream will vary significantly depending on the activities being undertaken at the terminal and the prevailing weather conditions. For the majority of the time the flowrate of this stream will be very low or negligible. A skid mounted booster fan is provided to assist the transfer of the vapours and to ensure a minimum suction pressure is maintained in the collection system. The skid mounted booster fan, and ancillary items are existing whilst the detonation arrestor and isolation valves to the thermal oxidiser will be provided by others (not part of thermal oxidiser tender).

The oxygen concentration in the stream is monitored via dual oxygen meters prior to entering the thermal oxidiser. If a high oxygen level is detected in the stream, the stream is put into an emergency diversion state. The stream shall be immediately isolated from the thermal oxidiser by closing isolation valves, the flowrate shall be reduced by reducing the speed of the fan and the stream shall be diverted to the emergency diversion duct by opening an isolation valve on the duct (the duct is connected to a stand-by carbon VECS).

Note: The skid mounted booster fan for stream 1 (inert stream) shall provide a discharge pressure of up to 3.0 kPag at the maximum design flowrate at the interface with the thermal oxidiser.

3.2 Stream 2 (VOC air –below 50% LEL)

Note: This stream will not be installed at this stage, however the oxidiser must be capable of handling the nominated stream and have provision for connection at a future date. Refer to Section 4 for process details.

Emissions are generated during truck filling, air sweep of sample tanks, hose cleaning, tank degassing. These emissions are collected in a dedicated VOC air collection system (stream 2). This streams concentration will be controlled to below 40% LEL and isolate flow to the thermal oxidiser if 50% LEL is reached. A negative pressure is maintained in the collection ducting by VSD controlled extraction fan. Additional dilution air is added to ensure the concentration of VOC's is below 50% LEL. The fan skid and isolation valves to the thermal oxidiser will be by others.

The LEL concentration of the VOC air stream will be monitored via dual LEL meters prior to entering the thermal oxidiser. If a high LEL level is detected in the VOC air stream, the stream is put into an emergency diversion state. The stream shall be immediately isolated from the thermal oxidiser by closing isolation valves, the air flowrate shall be reduced by reducing the speed of the fan and the stream shall be diverted to the emergency diversion duct by opening an isolation valve on the duct (the duct is to be connected to a stand-by carbon VECS).

Note: The skid mounted booster fan for stream 2 (dilute stream) shall provide a pressure of up to 1.0 kPa at the maximum design flowrate at the interface with the thermal oxidiser.

3.3 Stream 3 (Flammable liquid Waste)

The liquid waste feed rate to thermal oxidiser was determined to be 6.5 L/min. This would achieve a liquid waste throughput (based on 10 hrs/day 5 days/week 50 weeks/annum operation) of 972 tonnes/annum.

This throughput would be adequate to handle the nominated liquid waste to be generated on the terminal site of 900 tonnes/annum (as advised by TPL).

The liquid waste throughput could be increased by increasing operating hours. The maximum throughput (based on 20 hrs/day, 7 days/week 50 weeks/annum operation) could be 2722 tonnes/annum.

The thermal oxidiser shall be designed to thermal oxidise a liquid waste stream. The design shall consider the following:

- The liquid waste stream may contain both aqueous and/or flammable liquid waste.
- The burning of liquid waste shall occur at the same time as a peak thermal load from a rich VOC vapour stream -refer to section 4 and Appendix B for maximum thermal load requirements.
- Burning of the liquid waste stream shall not foul the burners and thermal oxidiser's critical components nor effect the long-term performance of the unit.
- The oxidiser shall be able to be easily inspected to ensure fouling is not occurring and also have the ability to be easily clean, should it occur.
- The tender shall allow for a dedicated spigot to be positioned on the thermal oxidiser and provide a liquid waste injection/spray nozzle. The injection/spray nozzle shall be a compressed air/liquid internal mix nozzle and shall be positioned as not to impact the performance of the flame detectors. The injection/spray nozzle should be positioned in a manner that permits cooling/supplementary air around to be added around the injection/spray nozzle when needed.

Even though the species and composition of the waste stream can vary the following will be excluded from the waste stream for burning/treatment in the thermal oxidiser. Assume the following will NOT be present in the liquid waste stream:

- No solid particles.
- No dissolved inorganic chemicals -which would form particulates and build up in the base of the thermal oxidiser or be carried out with the stack gases. The vertical thermal oxidiser design does not have provision for ash or solids removal at the base and has no flue gas filtering.
- No chlorinated or halogen species. These can form dioxins and furans when combusted.

3.4 Thermal Oxidiser

The thermal oxidiser shall be able to treat vapours from both vapour streams and the flammable liquid waste at the same time.

It is proposed that the existing thermal oxidiser shall provide redundancy for the new thermal oxidiser and both units shall be operated together to handle peak loads. The thermal oxidiser unit shall be designed to operate in parallel with the existing unit during high VOC stream flowrates.

The unit must be suited to frequent stop/starts and be capable of starting up and reaching operating temperature very quickly. The units must also be able to handle large and sudden changes in flowrate and VOC loading for both streams 1, 2 & 3.

4 Process Data

4.1 Preliminary Process and Instrumentation Diagrams

Preliminary Process and Instrumentation Diagrams (P&ID's) are included in Appendix A for information. (Note: The P&ID for the thermal oxidiser is conceptual only).

4.2 Inlet Stream Data

The 2nd thermal oxidiser will handle the following 3 streams:

- VOC-inert stream max thermal load at worst case flowrate (0 -1728 m^3/hr).
- VOC-air dilute stream max thermal load (0 - 4000m^3/hr).
- Liquid waste stream (0 - 6.5 L/min feed rate from 100% water - 100% flammable liquid).

4.2.1 VOC- Inert Stream – (stream 1)

The emission calculations (180010CAL-001) were based on the following set up.

Worst-case scenario for VOC-inert stream vapour flow to thermal oxidisers.

- All tanks listed are diurnally breathing simultaneously.
- Benzene being exported onto a ship at 200 m^3/hr. This will also require nitrogen injection of wharf vapour collection line.
- Hexene road tanker filling at 90 m^3/hr.

Maximum inert stream flow rate 1728 m^3/hr (actual at ambient conditions).

Maximum inert stream pressure at thermal oxidiser interface at maximum flowrate- 3 kPag.

Total inert stream thermal load 21,287 MJ/hr.

4.2.2 VOC -Air Stream – (stream 2)

The emission calculations (180010CAL-002) were based on the following set up

- Tanker truck filling (90m^3/hr) -hexene. This may require additional dilution air to maintain VOC conc below 25% LEL
- Tank truck filling (90m^3/hr) – acetone. This may require additional dilution air to maintain VOC conc below 25% LEL

- Hose cleaning x 2 (400 m^3/hr)
- Tank cleaning x 1 (200 m^3/hr).
- Total VOC-air stream flow rate 8000 m^3/hr to both thermal oxidiser – 4000 m3/hr max to each thermal oxidiser. With maximum dilution air if required to maintain 25% LEL.
- Maximum VOC- air stream pressure at thermal oxidiser interface at maximum flowrate- 1 kPag
- Total VOC-air stream thermal load 2,875 MJ/hr (energy in waste stream)

4.2.3 Liquid Waste Stream – (Stream 3)

A sample and analysis of existing liquid waste was undertaken by Terminals. The analysis indicated that the level of organics and flammables, within this sample, were relatively low however it is noted that flammable liquid species and concentration can vary significantly depending on the type of activities undertaken at the terminal.

As such, the design basis for the feed stream composition will vary from no flammables in the waste stream (assume 100% water) to maximum concentration of (100% flammables). CEC engineers has chosen benzene as the worst-case species due to its relatively high calorific value. The vendor shall design the thermal oxidiser to be able to treat all chemicals species listed in Appendix C of this report.

Liquid waste stream flow rate 6.5 L/min- normal. 7.8 L/min- peak design

Liquid waste stream max thermal load 11,771 MJ/hr (based on 100% hexene).

4.3 Sizing of Natural Gas Burner

The natural gas burner in the thermal oxidiser is to be sized to maintain the operating temperature whilst combusting the 3 streams together at maximum flowrate (assuming the streams have no calorific value).

- VOC-inert stream max thermal load at worst case flowrate (0 -1728 m^3/hr)-assume all nitrogen gas.
- VOC-air dilute stream max thermal load (0 - 4000m^3/hr)- assume all air.
- Liquid waste stream (0 - 6.5 L/min feed rate from 100% water - 100% hexene)- assume all water.

The estimated burner size for the natural gas for this duty was estimated as 22.7 GJ/hr. Refer to calculations 180010CAL-003. Vendor to size and confirm maximum burner size for the above listed duty.

Note: The thermal oxidiser would need to be sized to give the required minimum residence time based on the maximum thermal load of the gas burner and the waste streams (whichever is larger).

4.4 Worst-Case Thermal Load Waste Streams

The worst-case scenario for the max thermal load of the waste streams was assumed to occur as follows (2 thermal oxidisers together):

VOC/Inert Stream	**29712**	**MJ/hr**
Thermal load from the VOC/Inert stream - Total flowrate = 0-1346 m3/hr (worst case flow rate)		
VOC/Air Dilute Stream	**2834**	**MJ/hr**
Thermal load from the VOC/Air dilute stream – Flow rate 0-4000m3/hr -Refer to previous CEC calculation 110010Comcal 1		
Thermal Load Waste Burning (MJ/hr)	**4954**	**MJ/hr**
Max thermal load from liquid waste burning (6.5 l/min @ 48.4% (v/v) Hexene		
Total Thermal Load (MJ/hr)	37500	MJ/hr
VOC/Inert stream thermal load + VOC/Air dilute stream thermal load + Waste burning		
Total thermal load existing thermal Oxidiser (MJ/hr)	15000	MJ/hr
Total Thermal Load for new Oxidiser (MJ/hr)	**22500**	**MJ/hr**

The thermal oxidiser should nominally be sized as 22.8 GJ/hr for the incoming waste streams based on the above. This aligns with the capacity of the natural gas burner leading to a similar size thermal oxidiser when considering the maximum thermal capacity of the gas burner and incoming streams-thermal oxidiser tenderer to confirm. The stream flowrates, composition and calorific values can vary significantly. (from zero to maximum nominated). The thermal oxidiser should be designed to handle the full range. The various chemical species to be treated are as detailed in Appendix C.

The thermal oxidiser must be sized to handle the maximum flowrate and calorific value for each stream operating separately as listed above, as well as any combination of waste streams to a maximum of 22.8 GJ/hr. An example of a scenario approaching maximum thermal load for the 3 streams is listed below.

VOC/Inert Stream	18363	MJ/hr
Thermal load from the VOC/Inert stream - Total flowrate = 1658 m^3/hr		
VOC/Air Dilute Stream	2834	MJ/hr
Thermal load from the VOC/Air dilute stream - Flow rate 0-4000m3/hr -Refer to previous CEC calculation 180010CAL-002		
Thermal Load Waste Burning (MJ/hr)	1382	MJ/hr
Max thermal load from liquid waste burning (6.5 l/min @ 21.3% (v/v) Hexene		
Total Thermal Load (MJ/hr)	22579	MJ/hr

Note: It is most likely that the VECS unit will be accepting a “brew” of VOC’s that will be continually varying in concentration depending on what is happening at the terminal. There is no way of calculating what the concentration will be except to look at the averages and then to agree on a design figure that covers the expected extremes.

4.5 Worst-Case Benzene Waste Streams

The worst-case scenario for benzene emissions to the thermal oxidiser is benzene vapour in the VOC-Inert stream (stream 1). There will normally be negligible amount of benzene in the liquid waste and as such benzene in the liquid waste is not considered.

VOC-Inert Vapour (Stream 1) into thermal oxidiser summary - worst case Benzene & H2S

Component	*kg/hr*	% w/w
Benzene	146.2	9.4%
Hexene	0.0	0.0%
Acetone	0.0	0.0%
Ethanol	30.7	2.0%
Methanol	25.7	1.7%
Styrene	0.6	0.0%
Vinyl Acetate	40.1	2.6%
Methyl Methacrylate	0.0	0.0%
Butyl Acrylates	0.4	0.0%
Methyl Isobutyl Carbinol (MIBC)	0.0	0.0%
Hydrogen Sulphide (H_2S)	16.7	1.1%
Nitrogen Gas	1295.3	83.3%
Total	**1555.6**	**100.0%**

The TO should be sized to handle the worst-case scenario for benzene emissions with all streams operating together.

Supporting Process Calculations for the estimate of stream emissions and thermal load are include in Appendix B of this Technical Specification of information.

4.6 Chemical Species to be Treated

Refer to Appendix C for list of species to be treated.

5 Performance Requirements

5.1 Destruction Efficiency and Stack Limits

The thermal oxidiser VOC destruction performance shall be such, as to limit the mass rate of VOC's at the outlet to less than that detailed below under the range of operating conditions detailed in this specification:

- Minimum destruction efficiency of 99.99 % is required for all VOC/HAP input streams at maximum VOC/HAP load.
- Specific discharge limits for odour and toxic pollutants as detailed in Schedule 2 and 4 (Group 6) of the NSW Protection of the Environment Operations (Clean Air) Regulations 2010. Including discharge stack limits of:
  - Solid particles - 50 mg/m^3
  - Nitrogen dioxide (NO_2) or Nitric oxide (NO) - 350 mg/m^3
  - VOC compounds - 20 mg/m^3 VOC's
  - Hydrogen Sulphide (H_2S) - 5mg/m^3
  - Sulphuric acid mist or sulphur trioxide (SO_3) - 100 mg/m^3
  - Smoke - Ringelmann 1 or 20% opacity.

The thermal oxidiser shall be designed in accordance with the requirements of the NSW Protection of the Environment Operations (Clean Air) Regulations 2010 including the requirements of Division 4 Group 6 treatment plants:

- Minimum operating temperature –980^{o}C
- Minimum residence time - 2 sec

with the following exception:

- Minimum destruction efficiency – 99.99%

The vendor shall guarantee the thermal oxidiser supplied will destroy the incoming constituents to the degree required. Performance testing for adequate destruction efficiency shall be undertaken based on the nominate chemical constituents.

The vendor shall state the minimum guarantees offered.

5.2 Start-up/Shutdown

Due to the nature of operations at the terminal and the proposed configuration of the system, the thermal oxidiser shall be capable of:

- Reaching full operating temperature from a shutdown state in (10-15 min)
- Frequent startup -shutdowns (once everyday if shutdown at night)
- Suited to extended periods of shut down (typically up to 6 months)-future when second backup unit is installed

5.3 Hours of Operation

Shall be capable of operating continuously (approx. 8592 hrs)

5.4 Turndown and Transient Response

The VOC inert stream flowrate shall vary from 0 - 1728 m^3/hr. The thermal oxidiser shall be designed and sized to handle 0 - 1728 m^3/hr of VOC inert stream.

The VOC dilute air stream flowrate (with dilution air) shall normally vary from 0 - 8000 Nm^3/hr. The thermal oxidiser shall be designed and sized to handle 0 - 4000 Nm^3/hr maximum.

The liquid waste stream flowrate shall vary between 0-6.5 L/min. The thermal oxidiser shall be designed and sized to handle 0 – 7.8 L/min maximum flowrate.

The flow rate of the streams may vary suddenly. The thermal oxidiser shall be designed to handle the transient nature of operation of the flowrates.

The gas burner shall be designed and specified with a minimum 15:1 turndown.

The vendor shall specify the maximum turndown achievable with the system offered.

5.5 Operating Cost

The vendor shall specify the estimated stand-by gas usage (stream 1, 2 and 3 - no flowrate).

6 Mechanical Requirements

6.1 Materials of Construction

The vendor shall nominate the materials of construction to be used for all key components in the tender.

The following materials of construction are envisaged for the systems:

VOC-nitrogen inert duct: Any vapour ducting between the tie-in point and thermal oxidiser shall be minimum Sch 10 Stainless steel pipe.

Natural gas: Carbon Steel

Instrument Air: Galvanised iron pipe/Stainless Steel tube.

A pipe specification for the stainless steel vapour ducting will be provided to the successful tenderer by Terminals Pty Ltd after the award of the contract.

6.2 Painting

All pipes and components that are susceptible to corrosion shall be prepared and painted using a reputable paint manufacturer's painting system. The painting system and colours shall be approved by Terminals Pty Ltd prior to commencing work.

6.3 Earthing, Lightning Protection and Equipotential Bonding lugs

The vendor is to ensure that all equipment is appropriately earthed and bond at the same potential. The vendor shall provide lugs on the supplied equipment as required for the attachment of earthing, lightening protection and equipotential bonding systems.

6.4 Wind and Seismic Loading

The equipment shall be designed, fabricated and erected to resist wind and seismic forces in conformity with the relevant NSW and Australian and Legislation, Standards and Codes of Practice.

6.5 Equipment Layout

The vendor shall detail the required clearances around the thermal oxidiser for installation, operation and maintenance.

6.6 Installation

The vendor shall be responsible for the installation of the thermal oxidiser and all other associated equipment, etc. The oxidiser shall be installed on a flat concrete pad with appropriate foundations (provide by Terminals Pty Ltd). The vendor shall be responsible for the bolt down and grouting of all equipment.

6.7 Concrete Pad and Foundations

The size of the concrete pad/s required and details of the imposed loads etc shall be provided by the vendor to Terminals Pty Ltd. This will allow the detailed design of the concrete pad and foundations to be undertaken by others.

6.8 High Temperature Surfaces - Personnel Protection

All equipment items and surfaces running at temperatures in excess of 55ºC shall be provided with suitable access restriction, shielding or insulation and lagging for personnel protection.

7 Services

The following services will be available at the terminal:

a. Natural gas (supply pressure varying between 70-100 kPag)
b. Single phase (240 V) and 3 phase (415 V) AC Power
c. Compressed air-600 kPag min.

The vendor shall specify all services required.

8 Standard Specification

The thermal oxidiser shall comply with the requirements of applicable Terminals Pty Ltd standard specifications. If any Terminals Pty Ltd standard specifications are applicable, then they shall be nominated and detailed in the Appendix of this specification.

9 Applicable Standards and Regulations

The design and manufacture of the thermal oxidiser and all associated equipment and components shall comply with the requirements of applicable Australian Regulations, By-Laws, and latest Standards and Codes. These include but not limited to:

AS 1375-2013 - SAA Industrial Fuel - Fired Appliances Code.

AS 3814-2015 - Industrial and Commercial & Gas Fired Appliances.

AS/NZS 5601.1:2013 - Gas Installations Part 1: General installations.

AS 3000-SAA Wiring Rules.

AS 1675 - Code for fixed platforms, walkways, stairways and ladders.

NSW Protection of the Environment Operations (Clean Air) Regulations 2010.

Sydney Ports Corporation (SPC) Port Botany Development Code.

10 Statutory Requirements

Where the system comes under the jurisdiction of statutory authorities then all work shall comply with such requirements. All necessary applications, obtaining of approvals and payments of fees shall be by the vendor.

Note: The vendor shall provide details of all permits required with tender.

11 Preferred Equipment and Components

If Terminals Pty Ltd have preferred equipment and component suppliers, then they shall be detailed in the Appendix of this specification. If none are specified, then the vendor shall submit main components for approval.

12 Installation Location

The installation shall be located at Terminals Pty Ltd, Botany Facility. The following site conditions apply:

- Existing operational bulk storage terminal.
- Outdoors
- Non-Hazardous area
- Natural gas available
- Power available
- Refer to site layout for proposed location-Appendix D

13 Other Requirements

13.1 Exhaust Stack Height

The exhaust stack height shall be 19.3 m-based on preliminary design information from TO vendor.

13.2 Noise

The noise level shall not exceed 85 dBA at 1 m from any equipment item.

13.3 Low Nox Burners

The burners specified in the thermal oxidiser shall be of the low NOx producing type.

13.4 Flue Gas Oxygen Sensor

Dual redundant flue gas oxygen sensors shall be provided in the outlet stack of the thermal oxidiser.

These shall monitor and control the oxygen concentration in the exit stack gases to ensure excess oxygen is always present.

13.5 EPA Sample Points

Sample and test points shall be provided on the thermal oxidiser stack in line with EPA requirements, to permit measuring and sampling of the stack gases.

13.6 Access Platform and Ladder

Access platform/s and ladder/s shall be provided, where required, to ensure good access for maintenance, monitoring and operation of the thermal oxidiser. This includes good access to the sample points and oxygen sensor.

13.7 Visual

No flame or smoke shall be visible from any position at ground level when the thermal oxidiser is operational.

The system shall not produce any visible flame glow or glare. Shielding shall be specified and supplied by the vendor if flame glare is considered a problem.

13.8 Sulphuric Acid Corrosion

Hydrogen sulphide (H_2S) will be present in the vapour stream which will produce SO_2 and SO_3 during combustion. To prevent the chance of SO_3/sulphuric acid condensing and creating corrosion problems the flue gas temperature and thermal oxidiser skin temperature shall be maintained above the dew point.

13.9 Allowance for Future - Heat Recovery

The thermal oxidiser may be fitted with a recuperative heat recovery system at a later date to minimise energy use (pending economic and technical evaluation).

Allowance shall be made in the design of the thermal oxidiser for the future installation of a heat recovery system. It is envisaged that the thermal oxidiser will be vertical unit and heat recovery would be via a duct and extraction fan system to a heat exchanger. The vendor shall make allowance in the thermal oxidiser for this future heat recovery system by way of extraction and return duct tie-in point spigots.

It is estimated that the maximum practical recoverable heat load (TO operating at 870^{o}C) is 210 KW (756 MJ/hr), with an inlet flowrate to the heat recovery unit 4458 m3/hr of stack gases at 870^{o}C and exit temperature of 384^{o}C.

13.10 Smart Instrumentation

Smart instrumentation shall be provided where possible to assist with trouble shooting/feedback.

13.11 Data Trending

Data and trend tracking for historical analysis shall be provided. Note: this may be able to be incorporated into the existing site SCADA system. Vendor to advise and provide signals as required.

13.12 Redundancy

Critical instruments and components shall be provided with 100% redundancy. E.g. temperature sensors, oxygen sensors, flame sensors, etc. An appropriate FMEA and risk assessment to be provided by the successful vendor.

13.13 Natural Gas Flowmeter

A natural gas flowmeter shall be supplied and installed to measure flowrate of natural gas to TO2.

The flowmeter should have a mechanical volume counter on the unit. The flowmeter should provide a remote flow signal (pulse output/or other) to the TO PLC for determining flowrate and totalise flow. Include wiring, PLC programming, SCADA data exchange.

13.14 Natural Gas Pressure Regulator and OPSO

The natural gas supply pressure to the thermal oxidiser skid can vary (nominally between 70-100 kPag). The TO vendor shall supply a pressure regulator with OPSO to control the pressure to the requirements of the TO burner and shut off if excessive pressure occurs.

14 Quality Assurance/Test and Inspection

The vendor shall provide Terminals Pty Ltd with a proposed quality control plan ensuring both its works and work of sub-contractors comply with the requirements of this specification and that offered by the vendor.

The vendor shall maintain records of all documentation necessary to provide objective evidence which verifies achievement of the quality assurance requirements specified. Terminals Pty Ltd shall have full access to the documentation.

A detailed quality and test and inspection plan shall be submitted by the vendor no latter than 2 weeks after placement of order for review and approval by the client.

15 Design and Documentation

15.1 Engineering and Design

Documents and drawings shall be reviewed and approved by Terminals Pty Ltd or its representative prior to acceptance. No work is to be undertaken unless documents and drawings have been approved. Design approval by Terminals Pty Ltd does not in anyway relieve the vendor from their contractual responsibilities as detailed in this specification.

The vendor shall furnish to Terminals Pty Ltd Process and Instrumentation Diagrams, detail and working drawings, specifications, calculations, functional specification and other data of the system no latter than four (5) weeks after award of contract. This shall be required for the project HAZOP meeting.

15.2 Project Management

The vendor shall furnish to Terminals Pty Ltd within 2 weeks of placement of an order a program in CPM or Gantt chart format which identifies all design, procurement, construction and installation activities and key milestones, the sequence of events and timing. The progress shall be reported to Terminals Pty Ltd on a weekly basis.

15.3 As Built Drawings

The vendor shall maintain and provide accurate records of field changes or deviations from approved drawings. Prior to final payment the vendor shall provide as built drawings, documentation and Operation and Maintenance manuals.

15.4 Operation and Maintenance Manuals

The vendor shall provide three (3) hard copies of an operation and maintenance manual for the complete system.

The manual shall include:

a. Detail description of the system and key components.
b. Component specifications.
c. OEM manuals.
d. Drawings – as built
e. Detailed start-up, shut down and operating instructions and emergency procedures.
f. Electrical data and drawings.
g. Operator interface and PLC program print out and instructions.
h. Interlock and alarm list with final settings.
i. Maintenance procedures.
j. Schedules listing maintenance activities and checks.
k. Trouble shooting chart.

15.5 Softcopy

The vendor shall provide Terminals Pty Ltd a softcopy copy of all drawings and manuals.

Drawing shall be in AutoCAD format.

15.6 Labelling

All equipment, components, instruments, electrical cabling etc. shall be identified by a unique tag/id number. These tags shall be clearly labelled in the field and shall appear on all documentation.

Terminals Pty Ltd shall specify the tagging label system to be adopted. The vendor may use their own in-house system for tagging labelling if none is specified by the client.

15.7 Battery Limits

The battery limits for the scope of supply are as detailed on the preliminary P&ID's.

The provision and routing of services such as mains power, compressed air and natural gas shall be by others. The vendor shall nominate the connection point for services as required.

16 Spare Parts

The vendor shall provide a list of all recommended spare parts that should be maintained by Terminals Pty Ltd after commissioning of the system. The list shall nominate the type, details (model no. etc.) quantity and price of all the recommended spares.

17 Appendices

Appendix A P&ID's

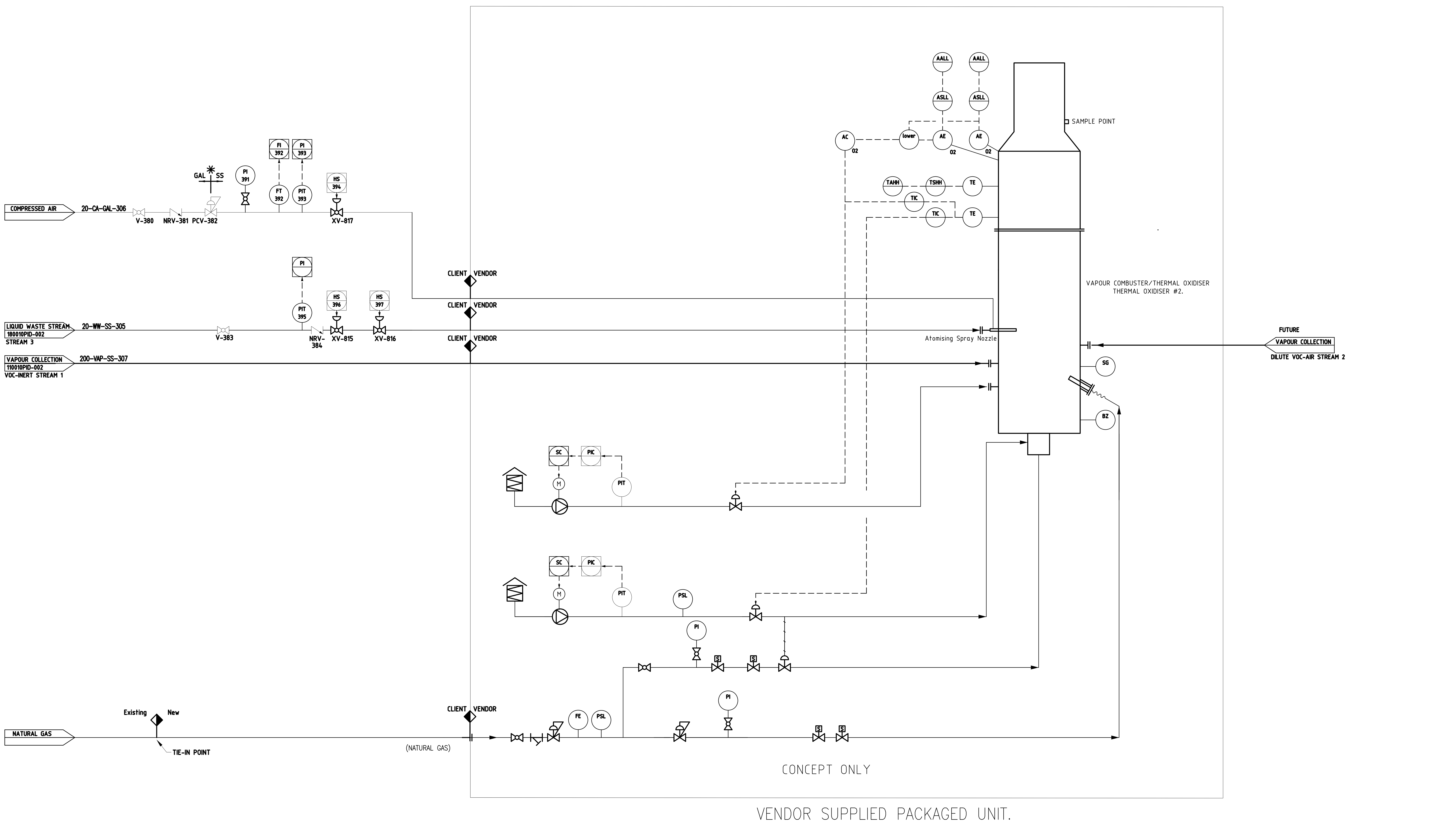
Appendix B Process Calculations

Appendix C Chemical species to be destroyed

Appendix D Site layout

Appendix A

P&ID's



NOTES:

1. ALL VAPOUR COLLECTION & LIQUID WASTE PIPING TO HAVE A MINIMUM DESIGN PRESSURE OF 1000 kPa.
2. ALL VAPOUR COLLECTION & LIQUID WASTE PIPING TO BE EARTHED AND EQUIPOTENTIALLY BONDED AS PER AS1020.
3. ALL VAPOUR COLLECTION & LIQUID WASTE PIPING TO BE DESIGNED AND CONSTRUCTED TO AS4041.
4. PROVIDE LOW POINT DRAINS AT LOW POINTS IN VAPOUR COLLECTION LINE.

EQUIPMENT & INSTRUMENT TAGS TO HAVE PREFIX "TO" UNLESS OTHERWISE INDICATED

REV	DESCRIPTION	DATE	APP.
A	INITIAL ISSUE	28/05/19	FS

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PROJECT
VAPOUR EMISSION COLLECTION AND THERMAL OXIDISER - BOTANY TERMINAL

TITLE
PID
PROPOSED 2ND COMBUSTOR
CONCEPT ONLY

SCALE	ORIGINAL SIZE
NTS	A1

STATUS: INITIAL ISSUE

DRAWN	DATE	DESIGN/CHK'D	DATE	APPROVED	DATE
AP	18/04/19	FS	18/04/19	FS	18/04/19

PROJECT NO.	DRAWING NO.	REVISION
180010	PID-001	A

Appendix B

Process Calculations- Maximum Inlet and Discharge Rates

Calculation Sheet Front Cover (Revision / Assumptions)

Client : **Terminals Pty Ltd**
Project No. : **180010**
Project : **2nd Thermal Oxidiser and Liquid Waste burning**

Calculation No: **180010CAL-001** **Rev 3**

Calculation Title: **VOC Emission and Thermal Load Estimate Calculations**

Calculation Summary

Calculation Objective:
Estimate total maximum VOC inert stream flowrate and thermal loading to thermal oxidiser/s for worst case scenario

Basis/Method:
Contents of tanks are based on data supplied by Terminals.
Tanks capacity, diameter and height data supplied by Terminals.
Connection of tanks to the existing VOC-nitrogen inert vapour collection system are based on data supplied by Terminals (refer to attachments).
All tanks that are connected to VOC-nitrogen inert vapour collection system are nitrogen blanketed
Thermal load from VOC/Air Dilute stream is based on previous CEC Engineers calculation 110010Comcal 1.
A single thermal oxidiser has currently been installed with a thermal capacity of 15,000 MJ/hr.
Previously CEC Engineers (refer to calculations 110010Comcal1 rev 2) estimated that the long term overall thermal capacity required for the thermal oxidiser was 30,000 MJ/hr. This would be met by installing 2 off thermal oxidisers (15,000 MJ/hr) operating in parallel.
It was decided to install only a single thermal oxidiser (15,000MJ/hr) initially for the relatively low thermal vapour loads when the system was first built and commissioned. The additional thermal oxidiser would be installed to operate in parallel when thermal loads increased.
A single fan on the VOC/Inert stream has been installed with a design flow of 1108 m3/hr @ 11.4 kPa differential.
A second fan with a capacity of 1728 m3/hr is currently being installed.

Assumptions:
Expansion factor for diurnal breathing is based on thermal expansion of vapours plus expansion due to vapour pressure.
Daily emissions are assumed to occur over a 3 hr period.
Tanks assumed to be 25% full.
Temperature of tank contents ranges between 15˚C and 30˚C.
All tanks listed are breathing diurnally to the VOC-nitrogen inerted vapour collection system.
Other assumptions are listed in the calculation sheet.
The maximum total thermal load calculation is based on the following scenario (with all loads occuring simultaneously):-
-All tanks diurnally breathing, tank 244 (Hexene) being filled at 200 m3/hr, hexene tanker being filled at 90 m3/hr.
-Thermal load from VOC-air stream
-Thermal load from liquid waste burning (6.5 l/min @ 48.4% (v/v) hexene or 2.74 L/min @ 100% (v/v) Hexene)
The maximum inert flow rate calculation is based on the following scenario (with all loads occuring simultaneously):-
-All tanks diurnally breathing, tanks 204 (BTX) exporting to ships at 200 m3/hr respectively with nitrogen inerting,
-Hexene tanker being filled at 90m3/hr
-Thermal load from VOC-air stream
-Thermal load from liquid waste buring (6.5 l/min @ 86.8% (v/v) hexene)
The maximum thermal load calculation for the 2nd thermal oxidiser is based on the following scenario (with all loads occuring simultaneously):-
-All tanks diurnally breathing, tanks 244 (Hexene) import from ship at 200 m3/hr,
-Hexene tanker being filled at 90m3/hr (temperature range from 15˚C to 27˚C)
-Thermal load from VOC-air stream
-Thermal load from liquid waste burning (6.5 l/min @ 21.3% (v/v) hexene)

Conclusions/Outcomes:
(1) The maximum total thermal load for 2 off thermal oxidiser was calculated to be 37500 MJ/hr
(2) The maximum flow rate in the VOC/Inert stream to the thermal oxidiser was calculated to be 2017 m3/hr
The 2nd thermal oxidser should be sized to handle this maximum flowrate (but not the max total thermal load)
(3) The Botany facility currently has one 15000 MJ/hr thermal oxidiser.
The 2nd thermal oxidser should have a thermal capacity of 22500 MJ/hr
(4) The existing single fan on the VOC/Inert stream does not have the flow capacity to meet the worst case calculated flow rate.
(5) The new second fan installed will have a capacity of 1728 m3/hr. This capacity will be less than the new calculated worst case volumetric flowrate requirment of 2017 m3/hr
The new fan may still have sufficient capacity pending detailed analysis of the flowcurve and calc of the DP of the detonation arrestor and thermal oxidiser during detailed design.

Design Verification Control

	Originator	Checked
Input Data Correct	FS	AB
Assumptions properly documented	FS	AB
Method of Calculation	FS	AB
Attachments included, clearly labelled and referenced	FS	AB
Results/conclusions clearly summarised	FS	AB

Rev	Issue Description	Date	Originated	Checked	Approved	Client
1	Initial Issue	15/5/2019	FS	AB		
2	Additional tanks added	2/9/2019	FS	AB		
3	No Benzene in LW. Replace with hexene	9/11/2021	FS			

Client :	Terminals Pty Ltd	Calc by	FS
Project No. :	180010	Date	2/9/2019
Project :	2nd Thermal Oxidiser and Liquid Waste burning	Checked	AB
Calculation No:	180010CAL-001	Rev	3

Emission Base Data-Botany Terminal

Scenario 1 - Worst Case Total Thermal Load

Temperature	30	°C
% Saturated vapour	100%	
% Tank vapour space	75%	
Diurnal breathing time/day	3	hrs

N2 inline inerting

Truck ship loading- O2 conc initial	21%
Truck ship loading- O2 conc final	5.5%

Product ID	
Benzene	A
Hexene	B
Acetone	C
Ethanol	D
Methanol	E

Product ID	
Styrene	F
Vinyl Acetate	G
Methyl Methacrylate	H
Butyl Acrylates	I
MIBC	J

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1							Note 3	Note 4		Note 5										
Existing Tank Number	Diameter m	Height m	Nominal Volume m^3	ERV Setting kPag	P Vent Setting kPag	N_2 Setting kPag	Actual Tank Filling Rate m^3/hr	Design Tank filling Rate m^3/hr	Actual Truck Loading Rate m^3/hr	Actual Ship Loading Rate m^3/hr	Design Truck Loading Rate m^3/hr	Design Ship Loading Rate m^3/hr	Calculation Truck/Ship Loading Rate m^3/hr	Product Nominated	Product ID	VOC Vapour Density kg/m^3	Mole Fraction	VOC Conc. at 100 % Sat. kg/m^3	% tank expansion Factor	Tank Diurnal Breathing m^3/hr	VOC mass rate (diurnal) (max) kg/hr	Maximum outflow to VCS from tank (CEC) m^3/hr	Breathing to TO Y/N	Tank fill Y/N	Truck/ Ship loading (VOC-nitrogen Y/N	Truck/ship vapours inline N2 inerted Y/N	Truck/ Ship loading (VOC-Air Y/N	Diurnal Breathing to VCS m^3/hr	Tank fill to VCS m^3/hr	Truck/ship loading vapours (VOC-nitrogen m^3/hr	Truck/ship loading N2 inerting m^3/hr	Truck/ship loading vapours (VOC-Air m^3/hr
Area 1																																
201	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	38.4	10.5	238	Y	N	N	N	N	38.4	0	0	0	0
202	8.6	14.64	850	2.5	1.25	0.25	60	200	-	160	-	200	200	Benzene	A	3.18	0.15	0.49	13.6%	29.0	14.1	229	Y	N	N	N	N	29.0	0	0	0	0
203	**8.6**	**14.64**	**850**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Styrene**	**F**	**4.24**	**0.01**	**0.05**	**5.9%**	**12.4**	**0.6**	**212**	**Y**	**N**	**N**	**N**	**N**	**12.4**	**0**	**0**	**0**	**0**
204	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	200	200	Benzene	A	3.18	0.15	0.49	13.6%	35.4	17.3	235	Y	N	N	N	N	35.4	0	0	0	0
205	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	200	200	Benzene	A	3.18	0.15	0.49	13.6%	35.4	17.3	235	Y	N	N	N	N	35.4	0	0	0	0
206	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	46.9	12.9	247	Y	N	N	N	N	46.9	0	0	0	0
207	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	46.9	12.9	247	Y	N	N	N	N	46.9	0	0	0	0
Sub total Area 1 cluster 1a			6702																	244	85							244.3	**0**	**0**	**0**	**0**
Cluster 1b																																
221	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**37.5**	**32.6**	**237**	**Y**	**N**	**N**	**N**	**N**	**37.5**	**0**	**0**	**0**	**0**
Sub total Area 1 cluster 1b			553																	37	32.6							37.5	0.0	0.0	0.0	0.0
Cluster 1c																																
223	**6.1**	**10.97**	**321**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**21.7**	**18.9**	**222**	**Y**	**N**	**N**	**N**	**N**	**21.7**	**0**	**0**	**0**	**0**
230	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**37.5**	**32.6**	**237**	**Y**	**N**	**N**	**N**	**N**	**37.5**	**0**	**0**	**0**	**0**
Sub total Area 1 cluster 1c			874																	59	51.4							59.2	0.0	0.0	0.0	0.0
Area 1 Total			**8130**																	**341**	**169.5**							**341.0**	**0.0**	**0.0**	**0.0**	**0.0**
Area 2																																
Cluster 1																																
cluster 1a																																
233	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
234	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
241	9.58	17.08	1231	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	35.3	6.7	235	Y	N	N	N	N	35	0	0	0	0
242	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
243	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
251	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
252	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
253	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**-**	**200**	**72**	**-**	**90**	**-**	**90**	**Butyl Acrylates**	**I**	**5.22**	**0.01**	**0.05**	**5.8%**	**8.0**	**0.4**	**208**	**Y**	**N**	**N**	**N**	**N**	**8.0**	**0**	**0**	**0**	**0**
254	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
259	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
260	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
Sub total Area 2 cluster 1a			**6765.6**																	**249.9**	**61.2**							**249.9**	**0.0**	**0.0**	**0.0**	**0.0**
Cluster 1b																																
235	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
240	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
245	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
250	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
255	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
258	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
Sub total Area 2 cluster 1b			**3321**																	**140.8**	**37.3**							**140.8**	**0.0**	**0.0**	**0.0**	**0.0**
Sub total Area 2 cluster 1			**10086**																	**390.7**	**98.6**							**390.7**	**0.0**	**0.0**	**0.0**	**0.0**
Area 2 cluster 2																																
237	10.7	17.08	1536	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	84.0	84.9	284	Y	N	Y	N	N	84	0	90	0	0
238	9.58	17.08	1231	2.5	1.25	0.25	-	200	60	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	67.3	68.1	267	Y	N	N	N	N	67	0	0	0	0
244	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	30.3	30.6	230	Y	Y	N	N	N	30	200	0	0	0
247	**8.74**	**17.08**	**1025**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**140**	**-**	**200**	**200**	**Vinyl Acetate**	**G**	**3.51**	**0.18**	**0.65**	**15.7%**	**40.2**	**26.0**	**240**	**Y**	**N**	**N**	**N**	**N**	**40.2**	**0**	**0**	**0**	**0**
248	8.74	17.08	1025	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	29.4	5.6	229	Y	N	N	N	N	29.4	0	0	0	0
249	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	24.4	4.6	224	Y	N	N	N	N	24.4	0	0	0	0
256	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**140**	**-**	**200**	**200**	**Vinyl Acetate**	**G**	**3.51**	**0.18**	**0.65**	**15.7%**	**21.7**	**14.1**	**222**	**Y**	**N**	**N**	**N**	**N**	**21.7**	**0**	**0**	**0**	**0**
257	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	24.4	4.6	224	Y	N	N	N	N	24.4	0	0	0	0
Subtotal Area 2 cluster 2			**7624**																	**321.6**	**238.5**							**321.6**	**200.0**	**90.0**	**0.0**	**0.0**
Area 2 Total			**17710**																	**712.3**	**337.1**							**712.3**	**200.0**	**90.0**	**0.0**	**0.0**
Total			**25840**																	**1053**	**507**							**1053**	**200**	**90**	**0**	**0**

Note 1: Information supplied by TPL

Note 2: Maximum tank filling 200 m3/hr from ship, 90 m3 from truck, maximum tank pump out 90 m3/hr to truck, 200 m3/hr to ship

Note 3 Estimated by CEC elsewhere based 15˚C temperature rise in liquid and vapour

Note 4 Estimated by CEC based on expansion factor and diurnal

Note 5 Summation of diurnal breathing and pump in rate

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
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Emission Estimate

Scenario 1 - Worst Case Total Thermal Load

All tanks listed are diurnally breathing simultaneously

Hexene tank filling, Hexene truck filling

Base Temperature 30 °C

VOC % saturated (VOC/Inert Stream) 100%

Stream ID	Input stream	Volumetric rate input stream @ inlet temp m3/hr	Base Temp °C	MW	VOC at 100% Saturation	VOC at XX% Saturation	VOC density kg/m3	100% VOC vol rate m3/hr	VOC conc. kg/m3	100% VOC mass rate Comb inlet kg/hr	Heat of Combustion of VOC net (LHV) MJ/kg	Energy MJ/hr
VOC/Inert Stream												
	Tank Diurnal Breathing											
A	Benzene	99.8	30	78	15.4%	15.4%	3.18	15.3	0.49	48.7	40.21	1956
B	Hexene	181.6	30	84	29.6%	29.6%	3.42	53.7	1.01	183.6	44.52	8171
C	Acetone	96.7	30	58	36.8%	36.8%	2.36	35.6	0.87	84.0	28.60	2402
D	Ethanol	160.9	30	46	10.2%	10.2%	1.87	16.4	0.19	30.7	26.85	824
E	Methanol	432.0	30	32	21.1%	21.1%	1.30	91.0	0.27	118.6	19.94	2366
F	Styrene	12.4	30	104	1.1%	1.1%	4.24	0.13	0.05	0.56	40.51	23
G	Vinyl Acetate	61.9	30	86	18.5%	18.5%	3.51	11.4	0.65	40.1	22.65	908
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.00	0.25	0.00	26.40	0
I	Butyl Acrylates	8.0	30	128	1.0%	1.0%	5.22	0.08	0.05	0.42	32.24	13
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.00	0.03	0.00	38.70	0
	Total Tank Diurnal Breathing	1053	30					223.6	0.48	506.5		16663
	Tank Filling											
A	Benzene	0.0	30	78	15.4%	15.4%	3.18	0.0	0.49	0.0	40.21	0
B	Hexene	200.0	30	84	29.6%	29.6%	3.42	59.1	1.01	202.2	44.52	9000
C	Acetone	0.0	30	58	36.8%	36.8%	2.36	0.0	0.87	0.0	28.60	0
D	Ethanol	0.0	30	46	10.2%	10.2%	1.87	0.0	0.19	0.0	26.85	0
E	Methanol	0.0	30	32	21.1%	21.1%	1.30	0.0	0.27	0.0	19.94	0
F	Styrene	0.0	30	104	1.1%	1.1%	4.24	0.0	0.05	0.0	40.51	0
G	Vinyl Acetate	0.0	30	86	18.5%	18.5%	3.51	0.0	0.65	0.0	22.65	0
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.0	0.25	0.0	26.40	0
I	Butyl Acrylates	0.0	30	128	1.0%	1.0%	5.22	0.0	0.05	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.0	0.03	0.0	38.70	0
	Total Tank Filling	200	30					59.1	1.01	202.2		9000
	Truck/Ship Filling											
A	Benzene	0.0	30	78	15.4%	15.4%	3.18	0.0	0.49	0.0	40.21	0
B	Hexene	90.0	30	84	29.6%	29.6%	3.42	26.6	1.01	91.0	44.52	4050
C	Acetone	0.0	30	58	36.8%	36.8%	2.36	0.0	0.87	0.0	28.60	0
D	Ethanol	0.0	30	46	10.2%	10.2%	1.87	0.0	0.19	0.0	26.85	0
E	Methanol	0.0	30	32	21.1%	21.1%	1.30	0.0	0.27	0.0	19.94	0
F	Styrene	0.0	30	104	1.1%	1.1%	4.24	0.0	0.05	0.0	40.51	0
G	Vinyl Acetate	0.0	30	86	18.5%	18.5%	3.51	0.0	0.65	0.0	22.65	0
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.0	0.25	0.0	26.40	0
I	Butyl Acrylates	0.0	30	128	1.0%	1.0%	5.22	0.0	0.05	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.0	0.03	0.0	38.70	0
	Supplementary N2 inerting	0.0	30									
	Total Truck/Ship Filling (incl. N2 inerting)	90	30					26.6	1.01	91.0		4050
	Total											
A	Benzene	99.8	30	78	15.4%	15.4%	3.18	15.3	0.49	48.7	40.21	1956
B	Hexene	471.6	30	84	29.6%	29.6%	3.42	139.4	1.01	476.7	44.52	21221
C	Acetone	96.7	30	58	36.8%	36.8%	2.36	35.6	0.87	84.0	28.60	2402
D	Ethanol	160.9	30	46	10.2%	10.2%	1.87	16.4	0.19	30.7	26.85	824
E	Methanol	432.0	30	32	21.1%	21.1%	1.30	91.0	0.27	118.6	19.94	2366
F	Styrene	12.4	30	104	1.1%	1.1%	4.24	0.13	0.05	0.56	40.51	23
G	Vinyl Acetate	61.9	30	86	18.5%	18.5%	3.51	11.4	0.65	40.1	22.65	908
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.00	0.25	0.00	26.40	0
I	Butyl Acrylates	8.0	30	128	1.0%	1.0%	5.22	0.08	0.05	0.42	32.24	13
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.00	0.03	0.00	38.70	0
	Supplementary N2 inerting	0	30									
	Total (incl. N2 inerting)	1343	30					309.3	0.60	799.7		29712

VOC/Inert Stream

Thermal load from the VOC/Inert stream - Total flowrate = 1346 m3/hr — 29712 MJ/hr

VOC/Air Dilute Stream

Thermal load from the VOC/Air dilute stream - Refer to previous CEC calculation 110010Comcal 1 — 2834 MJ/hr

Thermal Load Waste Burning (MJ/hr)

Max thermal load from liquid waste burning (6.5 l/min @ 48.4% (v/v) Hexene or 2.74 L/min @ 100% (v/v) Hexene) -Refer to CEC calculation 180010CAL-003 — 4954 MJ/hr

Total Thermal Load (MJ/hr)

VOC/Inert stream thermal load + VOC/Air dilute stream thermal load — 37500 MJ/hr

Total thermal load existing thermal Oxidser (MJ/hr) — **15000** MJ/hr

Total Thermal Load for 2nd Oxidiser (MJ/hr) — **22500** MJ/hr

Heat of combustion data (A-G): source: Perry Chemical Engineers Handbook 7th Ed., pg's 2-195 to 2-199, Cmpd No 67, 34, 123, 83, 82, 80, 155

Heat of combustion data (H-J): source: Cameo Chemicals data sheets

Ambient temperature is same as inlet temperature

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Vapour Density, Mole Fraction & Tank Expansion Factor

BENZENE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	83.918	-6517.7	-9.3453	7.1182E-06	2
Temperature			30	˚C	
			303	K	
Vapour Pressure			15747	Pa	
			15.7	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.154
Nitrogen Molecular Weight	28	Mole fraction	0.846
			1.00
Therefore Average Molecular Weight	35.7		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.45	kg/m3	Total Flow
Density =	3.18	kg/m3	Benzene vapour

BENZENE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	83.918	-6517.7	-9.3453	7.1182E-06	2
Temperature			15	˚C	
			288	K	
Vapour Pressure			7750	Pa	
			7.7	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.076
Nitrogen Molecular Weight	28	Mole fraction	0.924
			1.00
Therefore Average Molecular Weight	31.8		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.36	kg/m3	Total Flow
Density =	3.34	kg/m3	Benzene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.08	
initial mol fract N2	0.92	
Volume Act	56.66814	
Volume Vol	693.3319	
	750	
Final temp	30	
Final mol fract act	0.15	
Final mol fract N2	0.85	
Volume Act	115.1429	
Volume Vol	634.8571	
	750	
Vapour pressure expansion	8.4%	
Thermal gas expansion	5.2%	
expansion factor	13.6%	

HEXENE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	85.3	-6171.7	-9.702	8.9604E-06	2
Temperature			30	˚C	
			303	K	
Vapour Pressure			30314	Pa	
			30.3	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.296
Nitrogen Molecular Weight	28	Mole fraction	0.704
			1.00
Therefore Average Molecular Weight	44.6		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.81	kg/m3	Total Flow
Density =	3.42	kg/m3	Hexene vapour

HEXENE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	85.3	-6171.7	-9.702	8.9604E-06	2
Temperature			15	˚C	
			288	K	
Vapour Pressure			15862	Pa	
			15.9	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.155
Nitrogen Molecular Weight	28	Mole fraction	0.845
			1.00
Therefore Average Molecular Weight	36.7		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.57	kg/m3	Total Flow
Density =	3.60	kg/m3	Hexene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.15	
initial mol fract N2	0.85	
Volume Act	115.9806	
Volume Vol	634.0194	
	750	
Final temp	30	
Final mol fract act	0.30	
Final mol fract N2	0.70	
Volume Act	221.6568	
Volume Vol	528.3432	
	750	
Vapour pressure expansion	16.7%	
Thermal gas expansion	5.2%	
expansion factor	21.9%	

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Vapour Density, Mole Fraction & Tank Expansion Factor

ACETONE	From Perry 7th Ed Table 2-6					
	C1	C2	C3	C4	C5	
	69.006	-5599.6	-7.0985	6.2237E-06	2	
	Temperature		30	°C		
			303	K		
	Vapour Pressure		37719	Pa		
			37.7	kPa		
	Tank Pressure		5	"WC		
			1.25	kPag		
	System Total		102.6	kPa		
	Partial Pressure = Vapour Pressure at Saturation					
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction					
Tank Displacement						
	No Oxygen - All Nitrogen and Solvent Vapour					
	Acetone Molecular Weight		58	Mole fraction	0.368	
	Nitrogen Molecular Weight		28	Mole fraction	0.632	
					1	
Therefore Average Molecular Weight			39.0			
	PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole	
	Density =	1.59	kg/m3	Total Flow		
	Density =	2.36	kg/m3	Acetone vapour		

ACETONE	From Perry 7th Ed Table 2-6					
	C1	C2	C3	C4	C5	
	69.006	-5599.6	-7.0985	6.2237E-06	2	
	Temperature		15	°C		
			288	K		
	Vapour Pressure		19548	Pa		
			19.5	kPa		
	Tank Pressure		5	"WC		
			1.25	kPag		
	System Total		102.6	kPa		
	Partial Pressure = Vapour Pressure at Saturation					
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction					
Tank Displacement						
	No Oxygen - All Nitrogen and Solvent Vapour					
	Acetone Molecular Weight		58	Mole fraction	0.191	
	Nitrogen Molecular Weight		28	Mole fraction	0.809	
					1	
Therefore Average Molecular Weight			33.7			
	PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole	
	Density =	1.44	kg/m3	Total Flow		
	Density =	2.48	kg/m3	Acetone vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.19	
initial mol fract N2	0.81	
Volume Act	142.9372	
Volume Vol	607.0628	
	750	
Final temp	30	
Final mol fract act	0.37	
Final mol fract N2	0.63	
Volume Act	275.8063	
Volume Vol	474.1937	
	750	
Vapour pressure expansion	21.9%	
Thermal gas expansion	5.2%	
expansion factor	27.1%	

ETHANOL	From Perry 7th Ed Table 2-6					
	C1	C2	C3	C4	C5	
	74.475	-7164.3	-7.327	3.1340E-06	2	
	Temperature		30	°C		
			303	K		
	Vapour Pressure		10443	Pa		
			10.4	kPa		
	Tank Pressure		5	"WC		
			1.25	kPag		
	System Total		102.6	kPa		
	Partial Pressure = Vapour Pressure at Saturation					
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction					
Tank Displacement						
	No Oxygen - All Nitrogen and Solvent Vapour					
	Ethanol Molecular Weight		46	Mole fraction	0.102	
	Nitrogen Molecular Weight		28	Mole fraction	0.898	
					1	
Therefore Average Molecular Weight			29.8			
	PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole	
	Density =	1.21	kg/m3	Total Flow		
	Density =	1.87	kg/m3	Ethanol vapour		

ETHANOL	From Perry 7th Ed Table 2-6					
	C1	C2	C3	C4	C5	
	74.475	-7164.3	-7.327	3.1340E-06	2	
	Temperature		15	°C		
			288	K		
	Vapour Pressure		4300	Pa		
			4.3	kPa		
	Tank Pressure		5	"WC		
			1.25	kPag		
	System Total		102.6	kPa		
	Partial Pressure = Vapour Pressure at Saturation					
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction					
Tank Displacement						
	No Oxygen - All Nitrogen and Solvent Vapour					
	Ethanol Molecular Weight		46	Mole fraction	0.042	
	Nitrogen Molecular Weight		28	Mole fraction	0.958	
					1	
Therefore Average Molecular Weight			28.8			
	PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole	
	Density =	1.23	kg/m3	Total Flow		
	Density =	1.97	kg/m3	Ethanol vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.04	
initial mol fract N2	0.96	
Volume Act	31.44251	
Volume Vol	718.5575	
	750	
Final temp	30	
Final mol fract act	0.10	
Final mol fract N2	0.90	
Volume Act	76.35719	
Volume Vol	673.6428	
	750	
Vapour pressure expansion	6.3%	
Thermal gas expansion	5.2%	
expansion factor	11.5%	

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Vapour Density, Mole Fraction & Tank Expansion Factor

METHANOL (30 °C)

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2

- Temperature: 30 °C; 303 K
- Vapour Pressure: 21617 Pa; 21.6 kPa
- Tank Pressure: 5 "WC; 1.25 kPag
- System Total: 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

	Molecular Weight		Mole fraction
Methanol Molecular Weight	32	Mole fraction	0.211
Nitrogen Molecular Weight	28	Mole fraction	0.789
			1

Therefore Average Molecular Weight 28.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.17 kg/m3 Total Flow
Density = 1.30 kg/m3 Methanol vapour

METHANOL (15 °C)

From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2

- Temperature: 15 °C; 288 K
- Vapour Pressure: 9678 Pa; 9.7 kPa
- Tank Pressure: 5 "WC; 1.25 kPag
- System Total: 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

	Molecular Weight		Mole fraction
Methanol Molecular Weight	32	Mole fraction	0.094
Nitrogen Molecular Weight	28	Mole fraction	0.906
			1

Therefore Average Molecular Weight 28.4

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.22 kg/m3 Total Flow
Density = 1.37 kg/m3 Methanol vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	70.76916	
Volume Vol	679.2308	
	750	
Final temp	30	
Final mol fract act	0.21	
Final mol fract N2	0.79	
Volume Act	158.0642	
Volume Vol	591.9358	
	750	
Vapour pressure expansion	12.9%	
Thermal gas expansion	5.2%	
expansion factor	18.1%	

STYRENE (30 °C)

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2

- Temperature: 30 °C; 303 K
- Vapour Pressure: 1089 Pa; 1.1 kPa
- Tank Pressure: 5 "WC; 1.25 kPag
- System Total: 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

	Molecular Weight		Mole fraction
Styrene Molecular Weight	104.15	Mole fraction	0.011
Nitrogen Molecular Weight	28	Mole fraction	0.989
			1

Therefore Average Molecular Weight 28.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.17 kg/m3 Total Flow
Density = 4.24 kg/m3 Styrene vapour

STYRENE (15 °C)

From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2

- Temperature: 15 °C; 288 K
- Vapour Pressure: 430 Pa; 0.4 kPa
- Tank Pressure: 5 "WC; 1.25 kPag
- System Total: 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

	Molecular Weight		Mole fraction
Styrene Molecular Weight	104.15	Mole fraction	0.004
Nitrogen Molecular Weight	28	Mole fraction	0.996
			1

Therefore Average Molecular Weight 28.3

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.21 kg/m3 Total Flow
Density = 4.46 kg/m3 Styrene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.143507	
Volume Vol	746.8565	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	7.96287	
Volume Vol	742.0371	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.9%	

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Vapour Density, Mole Fraction & Tank Expansion Factor

VINYL ACETATE

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6
Temperature	30	°C			
	303	K			
Vapour Pressure	18946	Pa			
	18.9	kPa			
Tank Pressure	5	"WC			
	1.25	kPag			
System Total	102.6	kPa			

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.185		
Nitrogen Molecular Weight	28	Mole fraction	0.815		
			1		
Therefore Average Molecular Weight	38.7				
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole		
Density =	1.58	kg/m3	Total Flow		
Density =	3.51	kg/m3	Vinyl acetate vapour		

VINYL ACETATE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6
Temperature	15	°C			
	288	K			
Vapour Pressure	9157	Pa			
	9.2	kPa			
Tank Pressure	5	"WC			
	1.25	kPag			
System Total	102.6	kPa			

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.089		
Nitrogen Molecular Weight	28	Mole fraction	0.911		
			1		
Therefore Average Molecular Weight	33.2				
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole		
Density =	1.42	kg/m3	Total Flow		
Density =	3.69	kg/m3	Vinyl acetate vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	66.95524	
Volume Vol	683.0448	
	750	
Final temp	30	
Final mol fract act	0.18	
Final mol fract N2	0.82	
Volume Act	138.5338	
Volume Vol	611.4662	
	750	
Vapour pressure expansion	10.5%	
Thermal gas expansion	5.2%	
expansion factor	15.7%	

METHYL METHACRYLATE

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2
Temperature	30	°C			
	303	K			
Vapour Pressure	6387	Pa			
	6.4	kPa			
Tank Pressure	5	"WC			
	1.25	kPag			
System Total	102.6	kPa			

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.062		
Nitrogen Molecular Weight	28	Mole fraction	0.938		
			1		
Therefore Average Molecular Weight	32.5				
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole		
Density =	1.32	kg/m3	Total Flow		
Density =	4.08	kg/m3	Metylmetacrylate vapour		

METHYL METHACRYLATE From BOC data (Same method as Perry 7th Ed Table 2-6)

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2
Temperature	15	°C			
	288	K			
Vapour Pressure	2819	Pa			
	2.8	kPa			
Tank Pressure	5	"WC			
	1.25	kPag			
System Total	102.6	kPa			

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.027		
Nitrogen Molecular Weight	28	Mole fraction	0.973		
			1		
Therefore Average Molecular Weight	30.0				
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole		
Density =	1.28	kg/m3	Total Flow		
Density =	4.29	kg/m3	Metylmetacrylate vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.03	
initial mol fract N2	0.97	
Volume Act	20.61324	
Volume Vol	729.3868	
	750	
Final temp	30	
Final mol fract act	0.06	
Final mol fract N2	0.94	
Volume Act	46.70079	
Volume Vol	703.2992	
	750	
Vapour pressure expansion	3.6%	
Thermal gas expansion	5.2%	
expansion factor	8.8%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
Calculation No:	**180010CAL-001**	**Rev**	**3**

Vapour Density, Mole Fraction & Tank Expansion Factor

BUTYL ACRYLATE

A	B	C
8.141759	2199.925	273.16

Temperature 30 ˚C
303 K
Vapour Pressure 7.68 mmHg
1023 Pa
1.0 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight 128.17 Mole fraction 0.010
Nitrogen Molecular Weight 28 Mole fraction 0.990
1
Therefore Average Molecular Weight 29.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.18 kg/m3 Total Flow
Density = 5.22 kg/m3 Butyl acrylate vapour

BUTYL ACRYLATE From Odor and VOC Control Handbook - H.J Rafson)

A	B	C
8.141759	2199.925	273.16

Temperature 15 ˚C
288 K
Vapour Pressure 3.22 mmHg
429 Pa
0.4 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight 128.17 Mole fraction 0.004
Nitrogen Molecular Weight 28 Mole fraction 0.996
1
Therefore Average Molecular Weight 28.4

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.22 kg/m3 Total Flow
Density = 5.49 kg/m3 Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.135541	
Volume Vol	746.8645	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	7.482607	
Volume Vol	742.5174	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.8%	

METHYL ISOBUTYL CARBINOL (MIBC)

A	B	C
6.63977	1521.88	196.767

Temperature 30 ˚C
303 K
Vapour Pressure 0.85 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight 102.174 Mole fraction 0.008
Nitrogen Molecular Weight 28 Mole fraction 0.992
1
Therefore Average Molecular Weight 28.6

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.17 kg/m3 Total Flow
Density = 4.16 kg/m3 Butyl acrylate vapour

METHYL ISOBUTYL CARBINOL (MIBC) From Shell Chemicals Data Sheet

A	B	C
6.63977	1521.88	196.767

Temperature 15 ˚C
288 K
Vapour Pressure 0.28 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight 102.174 Mole fraction 0.003
Nitrogen Molecular Weight 28 Mole fraction 0.997
1
Therefore Average Molecular Weight 28.2

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.21 kg/m3 Total Flow
Density = 4.38 kg/m3 Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	2.076018	
Volume Vol	747.924	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	6.203018	
Volume Vol	743.797	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.8%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
Calculation No:	**180010CAL-001**	**Rev**	**3**

Emission Base Data-Botany Terminal

Scenario 2 - Worst Case Total Volumetric Load

Temperature	**30**	**'C**
% Saturated vapour	**100%**	
% Tank vapour space	**75%**	
Diurnal breathing time/day	**3**	**hrs**

N2 inline inerting	
Truck ship loading- O2 conc initial	**21%**
Truck ship loading- O2 conc final	**5.5%**

Product ID	
Benzene	A
Hexene	B
Acetone	C
Ethanol	D
Methanol	E

Product ID	
Styrene	F
Vinyl Acetate	G
Methyl Methacrylate	H
Butyl Acrylates	I
MIBC	J

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1							Note 3	Note 4		Note 5										
Existing Tank Number	Diameter	Height	Nominal Volume	ERV Setting	P Vent Setting	N_2 Setting	Actual Tank Filling Rate	Design Tank filling Rate	Actual Truck Loading Rate	Actual Ship Loading Rate	Design Truck Loading Rate	Design Ship Loading Rate	Calculation Truck/Ship Loading Rate	Product Nominated	Product ID	VOC Vapour Density	Mole Fraction	VOC Conc. at 100 % Sat.	% tank expansion Factor	Tank Diurnal Breathing	VOC mass rate (diurnal) (max)	Maximum outflow to VCS from tank (CEC)	Breathing to TO Y/N	Tank fill Y/N	Truck/ Ship loading (VOC-nitrogen Y/N	Truck/ship vapours inline N2 inerted Y/N	Truck/ Ship loading (VOC-Air Y/N	Diurnal Breathing to VCS	Tank fill to VCS	Truck/ship loading vapours (VOC-nitrogen	Truck/ship loading N2 inerting	Truck/ship loading vapours (VOC-Air
	m	m	m^3	kPag	kPag	kPag	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr			kg/m^3		kg/m^3		m^3/hr	kg/hr	m^3/hr						m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr
Area 1																																
Cluster 1a																																
201	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	38.4	10.5	238	Y	N	N	N	N	38.4	0	0	0	0
202	8.6	14.64	850	2.5	1.25	0.25	60	200	-	160	-	200	200	Benzene	A	3.18	0.15	0.49	13.6%	29.0	14.1	229	Y	Y	N	N	N	29.0	200	0	0	0
203	**8.6**	**14.64**	**850**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Styrene**	**F**	**4.24**	**0.01**	**0.05**	**5.9%**	**12.4**	**0.6**	**212**	**Y**	**N**	**N**	**N**	**N**	**12.4**	**0**	**0**	**0**	**0**
204	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	160	200	Benzene	A	3.18	0.15	0.49	13.6%	35.4	17.3	235	Y	N	Y	Y	N	35.4	0	200	564	0
205	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	90	200	Benzene	A	3.18	0.15	0.49	13.6%	35.4	17.3	235	Y	N	N	N	N	35.4	0	0	0	0
206	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	46.9	12.9	247	Y	N	N	N	N	46.9	0	0	0	0
207	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	46.9	12.9	247	Y	N	N	N	N	46.9	0	0	0	0
Sub total Area 1 cluster 1a			6702																	244	85							244.3	**200**	**200**	**564**	**0**
Cluster 1b																																
221	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**37.5**	**32.6**	**237**	**Y**	**N**	**N**	**N**	**N**	**37.5**	**0**	**0**	**0**	**0**
Sub total Area 1 cluster 1b			553																	37	32.6							37.5	0.0	0.0	0.0	0.0
Cluster 1c																																
223	**6.1**	**10.97**	**321**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**21.7**	**18.9**	**222**	**Y**	**N**	**N**	**N**	**N**	**21.7**	**0**	**0**	**0**	**0**
230	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**160**	**-**	**200**	**200**	**Acetone**	**C**	**2.36**	**0.37**	**0.87**	**27.1%**	**37.5**	**32.6**	**237**	**Y**	**N**	**N**	**N**	**N**	**37.5**	**0**	**0**	**0**	**0**
Sub total Area 1 cluster 1c			874																	59	51.4							59.2	0.0	0.0	0.0	0.0
Area 1 Total			**8130**																	**341**	**169.5**							**341.0**	**200.0**	**200.0**	**563.6**	**0.0**
Area 2																																
Cluster 1																																
cluster 1a																																
233	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
234	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
241	9.58	17.08	1231	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	35.3	6.7	235	Y	N	N	N	N	35	0	0	0	0
242	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
243	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
251	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
252	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
253	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**-**	**200**	**72**	**-**	**90**	**-**	**90**	**Butyl Acrylates**	**I**	**5.22**	**0.01**	**0.05**	**5.8%**	**8.0**	**0.4**	**208**	**Y**	**N**	**N**	**N**	**N**	**8.0**	**0**	**0**	**0**	**0**
254	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
259	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
260	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
Sub total Area 2 cluster 1a			**6765.6**																	**249.9**	**61.2**							**249.9**	**0.0**	**0.0**	**0.0**	**0.0**
Cluster 1b																																
235	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
240	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
245	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
250	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
255	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	15.9	3.0	216	Y	N	N	N	N	15.9	0	0	0	0
258	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.30	0.21	0.27	18.1%	25.0	6.9	225	Y	N	N	N	N	25.0	0	0	0	0
Sub total Area 2 cluster 1b			**3321**																	**140.8**	**37.3**							**140.8**	**0.0**	**0.0**	**0.0**	**0.0**
Sub total Area 2 cluster 1			**10086**																	**390.7**	**98.6**							**390.7**	**0.0**	**0.0**	**0.0**	**0.0**
Area 2 cluster 2																																
237	10.7	17.08	1536	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	84.0	84.9	284	Y	N	N	N	N	84	0	0	0	0
238	9.58	17.08	1231	2.5	1.25	0.25	-	200	60	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	67.3	68.1	267	Y	N	N	N	N	67	0	0	0	0
244	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.42	0.30	1.01	21.9%	30.3	30.6	230	Y	N	N	N	N	30	0	0	0	0
247	**8.74**	**17.08**	**1025**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**140**	**-**	**200**	**200**	**Vinyl Acetate**	**G**	**3.51**	**0.18**	**0.65**	**15.7%**	**40.2**	**26.0**	**240**	**Y**	**N**	**N**	**N**	**N**	**40.2**	**0**	**0**	**0**	**0**
248	8.74	17.08	1025	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	29.4	5.6	229	Y	N	N	N	N	29.4	0	0	0	0
249	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	24.4	4.6	224	Y	N	N	N	N	24.4	0	0	0	0
256	**7.6**	**12.2**	**553**	**2.5**	**1.25**	**0.25**	**60**	**200**	**-**	**140**	**-**	**200**	**200**	**Vinyl Acetate**	**G**	**3.51**	**0.18**	**0.65**	**15.7%**	**21.7**	**14.1**	**222**	**Y**	**N**	**N**	**N**	**N**	**21.7**	**0**	**0**	**0**	**0**
257	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.87	0.10	0.19	11.5%	24.4	4.6	224	Y	N	N	N	N	24.4	0	0	0	0
Subtotal Area 2 cluster 2			**7624**																	**321.6**	**238.5**							**321.6**	**0.0**	**0.0**	**0.0**	**0.0**
Area 2 Total			**17710**																	**712.3**	**337.1**							**712.3**	**0.0**	**0.0**	**0.0**	**0.0**
Total			**25840**																	**1053**	**507**							**1053**	**200**	**200**	**564**	**0**

Note 1:	Information supplied by TPL
Note 2:	Maximum tank filling 200 m3/hr from ship, 90 m3 from truck, maximum tank pump out 90 m3/hr to truck, 200 m3/hr to ship
Note 3	Estimated by CEC elsewhere based 15˚C temperature rise in liquid and vapour
Note 4	Estimated by CEC based on expansion factor and diurnal
Note 5	Summation of diurnal breathing and pump in rate

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
Calculation No:	**180010CAL-001**	**Rev**	**3**

Emission Estimate

Scenario 2 - Worst Case Total Volumetric Load
All tanks listed are diurnally breathing simultaneously
Hexene tanker filling, BTX ship export + nitrogen inerting

Base Temperature 30 °C
VOC % saturated (VOC/Inert Stream) 100%

Stream ID	Input stream	Volumetric rate input stream @ inlet temp m3/hr	Base Temp °C	MW	VOC at 100% Saturation	VOC at XX% Saturation	VOC density kg/m3	100% VOC vol rate m3/hr	VOC conc. kg/m3	100% VOC mass rate Comb inlet kg/hr	Heat of Combustion of VOC net (LHV) MJ/kg	Energy MJ/hr
VOC/Inert Stream												
	Tank Diurnal Breathing											
A	Benzene	99.8	30	78	15.4%	15.4%	3.18	15.3	0.49	48.7	40.21	1956
B	Hexene	181.6	30	84	29.6%	29.6%	3.42	53.7	1.01	183.6	44.52	8171
C	Acetone	96.7	30	58	36.8%	36.8%	2.36	35.6	0.87	84.0	28.60	2402
D	Ethanol	160.9	30	46	10.2%	10.2%	1.87	16.4	0.19	30.7	26.85	824
E	Methanol	432.0	30	32	21.1%	21.1%	1.30	91.0	0.27	118.6	19.94	2366
F	Styrene	12.4	30	104	1.1%	1.1%	4.24	0.13	0.05	0.56	40.51	23
G	Vinyl Acetate	61.9	30	86	18.5%	18.5%	3.51	11.4	0.65	40.1	22.65	908
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.00	0.25	0.00	26.40	0
I	Butyl Acrylates	8.0	30	128	1.0%	1.0%	5.22	0.08	0.05	0.42	32.24	13
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.00	0.03	0.00	38.70	0
	Total Tank Diurnal Breathing	1053	30					223.6	0.48	506.5		16663
	Tank Filling											
A	Benzene	200.0	30	78	15.4%	15.4%	3.18	30.7	0.49	97.5	40.21	3921
B	Hexene	0.0	30	84	29.6%	29.6%	3.42	0.0	1.01	0.0	44.52	0
C	Acetone	0.0	30	58	36.8%	36.8%	2.36	0.0	0.87	0.0	28.60	0
D	Ethanol	0.0	30	46	10.2%	10.2%	1.87	0.0	0.19	0.0	26.85	0
E	Methanol	0.0	30	32	21.1%	21.1%	1.30	0.0	0.27	0.0	19.94	0
F	Styrene	0.0	30	104	1.1%	1.1%	4.24	0.0	0.05	0.0	40.51	0
G	Vinyl Acetate	0.0	30	86	18.5%	18.5%	3.51	0.0	0.65	0.0	22.65	0
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.0	0.25	0.0	26.40	0
I	Butyl Acrylates	0.0	30	128	1.0%	1.0%	5.22	0.0	0.05	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.0	0.03	0.0	38.70	0
	Total Tank Filling	200	30					30.7	0.49	97.5		3921
	Truck/Ship Filling											
A	Benzene	200.0	30	78	15.4%	15.4%	3.18	30.7	0.49	97.5	40.21	3921
B	Hexene	0.0	30	84	29.6%	29.6%	3.42	0.0	1.01	0.0	44.52	0
C	Acetone	0.0	30	58	36.8%	36.8%	2.36	0.0	0.87	0.0	28.60	0
D	Ethanol	0.0	30	46	10.2%	10.2%	1.87	0.0	0.19	0.0	26.85	0
E	Methanol	0.0	30	32	21.1%	21.1%	1.30	0.0	0.27	0.0	19.94	0
F	Styrene	0.0	30	104	1.1%	1.1%	4.24	0.0	0.05	0.0	40.51	0
G	Vinyl Acetate	0.0	30	86	18.5%	18.5%	3.51	0.0	0.65	0.0	22.65	0
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.0	0.25	0.0	26.40	0
I	Butyl Acrylates	0.0	30	128	1.0%	1.0%	5.22	0.0	0.05	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.0	0.03	0.0	38.70	0
	Supplementary N2 inerting	563.6	30									
	Total Truck/Ship Filling (incl. N2 inerting)	764	30					30.7	0.13	97.5		3921
	Total											
A	Benzene	499.8	30	78	15.4%	15.4%	3.18	76.7	0.49	243.7	40.21	9797
B	Hexene	181.6	30	84	29.6%	29.6%	3.42	53.7	1.01	183.6	44.52	8171
C	Acetone	96.7	30	58	36.8%	36.8%	2.36	35.6	0.87	84.0	28.60	2402
D	Ethanol	160.9	30	46	10.2%	10.2%	1.87	16.4	0.19	30.7	26.85	824
E	Methanol	432.0	30	32	21.1%	21.1%	1.30	91.0	0.27	118.6	19.94	2366
F	Styrene	12.4	30	104	1.1%	1.1%	4.24	0.13	0.05	0.56	40.51	23
G	Vinyl Acetate	61.9	30	86	18.5%	18.5%	3.51	11.4	0.65	40.1	22.65	908
H	Methyl Methacrylate	0.0	30	100	6.2%	6.2%	4.08	0.00	0.25	0.00	26.40	0
I	Butyl Acrylates	8.0	30	128	1.0%	1.0%	5.22	0.08	0.05	0.42	32.24	13
J	Methyl Isobutyl Carbinol (MIBC)	0.0	30	102	0.8%	0.8%	4.16	0.00	0.03	0.00	38.70	0
	Supplementary N2 inerting	563.6	30									
	Total (incl. N2 inerting)	2017	30					285.0	0.35	701.6		24504

VOC/Air Dilute Stream (MJ/hr)
Thermal load from the VOC/Air dilute stream - Refer to previous CEC calculation 110010Comcal 1 — 2834

Thermal Load Waste Burning (MJ/hr)
Max thermal load from liquid waste burning (6.5 l/min @ 86.8% (v/v) hexene) -Refer to CEC calculation 180010CAL-003 — 10033

Total Thermal Load (MJ/hr)
VOC/Inert stream thermal load + VOC/Air dilute stream thermal load — 37371

Total thermal load existing thermal Oxidser (MJ/hr) — **15000**

Total Thermal Load for 2nd Oxidiser (MJ/hr) — **22371**

Heat of combustion data (A-G): source: Perry Chemical Engineers Handbook 7th Ed., pg's 2-195 to 2-199, Cmpd No 67, 34, 123, 83, 82, 80, 155
Heat of combustion data (H-J): source: Cameo Chemicals data sheets
Ambient temperature is same as inlet temperature

Client :	**Terminals Pty Ltd**		**Calc by**	**FS**
Project No. :	**180010**		**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**		**Checked**	**AB**
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Vapour Density, Mole Fraction & Tank Expansion Factor

BENZENE (30 °C)

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
83.918	-6517.7	-9.3453	7.1182E-06	2

Temperature	30	˚C
	303	K
Vapour Pressure	15747	Pa
	15.7	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.154
Nitrogen Molecular Weight	28	Mole fraction	0.846
			1.00
Therefore Average Molecular Weight	35.7		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density =	1.45	kg/m3	Total Flow
Density =	3.18	kg/m3	Benzene vapour

BENZENE (15 °C)

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
83.918	-6517.7	-9.3453	7.1182E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	7750	Pa
	7.7	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.076
Nitrogen Molecular Weight	28	Mole fraction	0.924
			1.00
Therefore Average Molecular Weight	31.8		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density =	1.36	kg/m3	Total Flow
Density =	3.34	kg/m3	Benzene vapour

Benzene tank expansion

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.08	
initial mol fract N2	0.92	
Volume Act	56.66814	
Volume Vol	693.3319	
	750	
Final temp	30	
Final mol fract act	0.15	
Final mol fract N2	0.85	
Volume Act	115.1429	
Volume Vol	634.8571	
	750	
Vapour pressure expansion	8.4%	
Thermal gas expansion	5.2%	
expansion factor	13.6%	

HEXENE (30 °C)

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
85.3	-6171.7	-9.702	8.9604E-06	2

Temperature	30	˚C
	303	K
Vapour Pressure	30314	Pa
	30.3	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.296
Nitrogen Molecular Weight	28	Mole fraction	0.704
			1.00
Therefore Average Molecular Weight	44.6		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density =	1.81	kg/m3	Total Flow
Density =	3.42	kg/m3	Hexene vapour

HEXENE (15 °C)

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
85.3	-6171.7	-9.702	8.9604E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	15862	Pa
	15.9	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.155
Nitrogen Molecular Weight	28	Mole fraction	0.845
			1.00
Therefore Average Molecular Weight	36.7		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density =	1.57	kg/m3	Total Flow
Density =	3.60	kg/m3	Hexene vapour

Hexene tank expansion

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.15	
initial mol fract N2	0.85	
Volume Act	115.9806	
Volume Vol	634.0194	
	750	
Final temp	30	
Final mol fract act	0.30	
Final mol fract N2	0.70	
Volume Act	221.6568	
Volume Vol	528.3432	
	750	
Vapour pressure expansion	16.7%	
Thermal gas expansion	5.2%	
expansion factor	21.9%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
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Vapour Density, Mole Fraction & Tank Expansion Factor

ACETONE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
69.006	-5599.6	-7.0985	6.2237E-06	2

Temperature	30	˚C
	303	K
Vapour Pressure	37719	Pa
	37.7	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Acetone Molecular Weight	58	Mole fraction	0.368
Nitrogen Molecular Weight	28	Mole fraction	0.632
			1
Therefore Average Molecular Weight	39.0		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.59	kg/m3	Total Flow
Density =	2.36	kg/m3	Acetone vapour

ACETONE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
69.006	-5599.6	-7.0985	6.2237E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	19548	Pa
	19.5	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Acetone Molecular Weight	58	Mole fraction	0.191
Nitrogen Molecular Weight	28	Mole fraction	0.809
			1
Therefore Average Molecular Weight	33.7		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.44	kg/m3	Total Flow
Density =	2.48	kg/m3	Acetone vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.19	
initial mol fract N2	0.81	
Volume Act	142.9372	
Volume Vol	607.0628	
	750	
Final temp	30	
Final mol fract act	0.37	
Final mol fract N2	0.63	
Volume Act	275.8063	
Volume Vol	474.1937	
	750	
Vapour pressure expansion	21.9%	
Thermal gas expansion	5.2%	
expansion factor	27.1%	

ETHANOL From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
74.475	-7164.3	-7.327	3.1340E-06	2

Temperature	30	˚C
	303	K
Vapour Pressure	10443	Pa
	10.4	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Ethanol Molecular Weight	46	Mole fraction	0.102
Nitrogen Molecular Weight	28	Mole fraction	0.898
			1
Therefore Average Molecular Weight	29.8		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.21	kg/m3	Total Flow
Density =	1.87	kg/m3	Ethanol vapour

ETHANOL From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
74.475	-7164.3	-7.327	3.1340E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	4300	Pa
	4.3	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Ethanol Molecular Weight	46	Mole fraction	0.042
Nitrogen Molecular Weight	28	Mole fraction	0.958
			1
Therefore Average Molecular Weight	28.8		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.23	kg/m3	Total Flow
Density =	1.97	kg/m3	Ethanol vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.04	
initial mol fract N2	0.96	
Volume Act	31.44251	
Volume Vol	718.5575	
	750	
Final temp	30	
Final mol fract act	0.10	
Final mol fract N2	0.90	
Volume Act	76.35719	
Volume Vol	673.6428	
	750	
Vapour pressure expansion	6.3%	
Thermal gas expansion	5.2%	
expansion factor	11.5%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
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Vapour Density, Mole Fraction & Tank Expansion Factor

METHANOL

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2

Temperature 30 ˚C
303 K
Vapour Pressure 21617 Pa
21.6 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Methanol Molecular Weight	32	Mole fraction	0.211
Nitrogen Molecular Weight	28	Mole fraction	0.789
			1

Therefore Average Molecular Weight 28.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.17 kg/m3 Total Flow
Density = 1.30 kg/m3 Methanol vapour

METHANOL

From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2

Temperature 15 ˚C
288 K
Vapour Pressure 9678 Pa
9.7 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Methanol Molecular Weight	32	Mole fraction	0.094
Nitrogen Molecular Weight	28	Mole fraction	0.906
			1

Therefore Average Molecular Weight 28.4

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.22 kg/m3 Total Flow
Density = 1.37 kg/m3 Methanol vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	70.76916	
Volume Vol	679.2308	
	750	
Final temp	30	
Final mol fract act	0.21	
Final mol fract N2	0.79	
Volume Act	158.0642	
Volume Vol	591.9358	
	750	
Vapour pressure expansion	12.9%	
Thermal gas expansion	5.2%	
expansion factor	18.1%	

STYRENE

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2

Temperature 30 ˚C
303 K
Vapour Pressure 1089 Pa
1.1 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Styrene Molecular Weight	104.15	Mole fraction	0.011
Nitrogen Molecular Weight	28	Mole fraction	0.989
			1

Therefore Average Molecular Weight 28.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.17 kg/m3 Total Flow
Density = 4.24 kg/m3 Styrene vapour

STYRENE

From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2

Temperature 15 ˚C
288 K
Vapour Pressure 430 Pa
0.4 kPa

Tank Pressure 5 "WC
1.25 kPag
System Total 102.6 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Styrene Molecular Weight	104.15	Mole fraction	0.004
Nitrogen Molecular Weight	28	Mole fraction	0.996
			1

Therefore Average Molecular Weight 28.3

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.21 kg/m3 Total Flow
Density = 4.46 kg/m3 Styrene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.143507	
Volume Vol	746.8565	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	7.96287	
Volume Vol	742.0371	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.9%	

Client :	**Terminals Pty Ltd**		**Calc by**	**FS**
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Vapour Density, Mole Fraction & Tank Expansion Factor

VINYL ACETATE

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6

Temperature	30	˚C
	303	K
Vapour Pressure	18946	Pa
	18.9	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.185
Nitrogen Molecular Weight	28	Mole fraction	0.815
			1
Therefore Average Molecular Weight	38.7		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density =	1.58	kg/m3	Total Flow
Density =	3.51	kg/m3	Vinyl acetate vapour

VINYL ACETATE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6

Temperature	15	˚C
	288	K
Vapour Pressure	9157	Pa
	9.2	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.089
Nitrogen Molecular Weight	28	Mole fraction	0.911
			1
Therefore Average Molecular Weight	33.2		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density =	1.42	kg/m3	Total Flow
Density =	3.69	kg/m3	Vinyl acetate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	66.95524	
Volume Vol	683.0448	
	750	
Final temp	30	
Final mol fract act	0.18	
Final mol fract N2	0.82	
Volume Act	138.5338	
Volume Vol	611.4662	
	750	
Vapour pressure expansion	10.5%	
Thermal gas expansion	5.2%	
expansion factor	15.7%	

METHYL METHACRYLATE

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2

Temperature	30	˚C
	303	K
Vapour Pressure	6387	Pa
	6.4	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.062
Nitrogen Molecular Weight	28	Mole fraction	0.938
			1
Therefore Average Molecular Weight	32.5		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density =	1.32	kg/m3	Total Flow
Density =	4.08	kg/m3	Metylmetacrylate vapour

METHYL METHACRYLATE From BOC data (Same method as Perry 7th Ed Table 2-6)

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	2819	Pa
	2.8	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.027
Nitrogen Molecular Weight	28	Mole fraction	0.973
			1
Therefore Average Molecular Weight	30.0		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density =	1.28	kg/m3	Total Flow
Density =	4.29	kg/m3	Metylmetacrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.03	
initial mol fract N2	0.97	
Volume Act	20.61324	
Volume Vol	729.3868	
	750	
Final temp	30	
Final mol fract act	0.06	
Final mol fract N2	0.94	
Volume Act	46.70079	
Volume Vol	703.2992	
	750	
Vapour pressure expansion	3.6%	
Thermal gas expansion	5.2%	
expansion factor	8.8%	

Client :	**Terminals Pty Ltd**		**Calc by**	**FS**
Project No. :	**180010**		**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**		**Checked**	**AB**
Calculation No:	**180010CAL-001**		**Rev**	**3**

Vapour Density, Mole Fraction & Tank Expansion Factor

BUTYL ACRYLATE

	A	B	C	
	8.141759	2199.925	273.16	
Temperature			30	˚C
			303	K
Vapour Pressure			7.68	mmHg
			1023	Pa
			1.0	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight	128.17	Mole fraction	0.010
Nitrogen Molecular Weight	28	Mole fraction	0.990
			1
Therefore Average Molecular Weight	29.0		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.18	kg/m3	Total Flow
Density =	5.22	kg/m3	Butyl acrylate vapour

BUTYL ACRYLATE From Odor and VOC Control Handbook - H.J Rafson)

	A	B	C	
	8.141759	2199.925	273.16	
Temperature			15	˚C
			288	K
Vapour Pressure			3.22	mmHg
			429	Pa
			0.4	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight	128.17	Mole fraction	0.004
Nitrogen Molecular Weight	28	Mole fraction	0.996
			1
Therefore Average Molecular Weight	28.4		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.22	kg/m3	Total Flow
Density =	5.49	kg/m3	Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.135541	
Volume Vol	746.8645	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	7.482607	
Volume Vol	742.5174	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.8%	

METHYL ISOBUTYL CARBINOL (MIBC)

	A	B	C	
	6.63977	1521.88	196.767	
Temperature			30	˚C
			303	K
Vapour Pressure			0.85	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight	102.174	Mole fraction	0.008
Nitrogen Molecular Weight	28	Mole fraction	0.992
			1
Therefore Average Molecular Weight	28.6		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.17	kg/m3	Total Flow
Density =	4.16	kg/m3	Butyl acrylate vapour

METHYL ISOBUTYL CARBINOL (MIBC) From Shell Chemicals Data Sheet

	A	B	C	
	6.63977	1521.88	196.767	
Temperature			15	˚C
			288	K
Vapour Pressure			0.28	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight	102.174	Mole fraction	0.003
Nitrogen Molecular Weight	28	Mole fraction	0.997
			1
Therefore Average Molecular Weight	28.2		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.21	kg/m3	Total Flow
Density =	4.38	kg/m3	Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	2.076018	
Volume Vol	747.924	
	750	
Final temp	30	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	6.203018	
Volume Vol	743.797	
	750	
Vapour pressure expansion	0.6%	
Thermal gas expansion	5.2%	
expansion factor	5.8%	

Client : Terminals Pty Ltd
Project No. : 180010
Project : 2nd Thermal Oxidiser and Liquid Waste burning

Calculation No: 180010CAL-001

Calc by FS
Date 2/9/2019
Checked AB

Rev 3

Emission Base Data-Botany Terminal

Scenario 3 - Worst Case Thermal Load for Single 2nd Oxidiser

Temperature	27	˚C
% Saturated vapour	100%	
% Tank vapour space	75%	
Diurnal breathing time/day	3	hrs

N2 inline inerting

Truck ship loading- O2 conc initial	21%
Truck ship loading- O2 conc final	5.5%

Product ID

Benzene	A
Hexene	B
Acetone	C
Ethanol	D
Methanol	E

Product ID

Styrene	F
Vinyl Acetate	G
Methyl Methacrylate	H
Butyl Acrylates	I
MIBC	J

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1	Note 1							Note 3	Note 4		Note 5										
Existing Tank Number	Diameter	Height	Nominal Volume	ERV Setting	P Vent Setting	N_2 Setting	Actual Tank Filling Rate	Design Tank filling Rate	Actual Truck Loading Rate	Actual Ship Loading Rate	Design Truck Loading Rate	Design Ship Loading Rate	Calculation Truck/Ship Loading Rate	Product Nominated	Product ID	VOC Vapour Density	Mole Fraction	VOC Conc. at 100 % Sat.	% tank expansion Factor	Tank Diurnal Breathing	VOC mass rate (diurnal) (max)	Maximum outflow to VCS from tank (CEC)	Breathing to TO	Tank fill	Truck/ Ship loading (VOC-nitrogen	Truck/ship vapours inline N2 inerted	Truck/ Ship loading (VOC-Air	Diurnal Breathing to VCS	Tank fill to VCS	Truck/ship loading vapours (VOC-nitrogen	Truck/ship loading N2 inerting	Truck/ship loading vapours (VOC-Air
	m	m	m^3	kPag	kPag	kPag	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr			kg/m^3		kg/m^3		m^3/hr	kg/hr	m^3/hr	Y/N	Y/N	Y/N	Y/N	Y/N	m^3/hr	m^3/hr	m^3/hr	m^3/hr	m^3/hr
Area 1																																
201	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.32	0.18	0.24	13.7%	29.2	6.9	229	Y	N	N	N	N	29.2	0	0	0	0
202	8.6	14.64	850	2.5	1.25	0.25	60	200	-	160	-	200	200	Benzene	A	3.21	0.13	0.43	10.5%	22.3	9.6	222	Y	N	N	N	N	22.3	0	0	0	0
203	8.6	14.64	850	2.5	1.25	0.25	60	200	-	160	-	200	200	Styrene	F	4.28	0.01	0.04	4.6%	9.9	0.4	210	Y	N	N	N	N	9.9	0	0	0	0
204	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	160	200	Benzene	A	3.21	0.13	0.43	10.5%	27.2	11.7	227	Y	N	Y	Y	N	27.2	0	200	564	0
205	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	160	-	90	200	Benzene	A	3.21	0.13	0.43	10.5%	27.2	11.7	227	Y	N	N	N	N	27.2	0	0	0	0
206	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.32	0.18	0.24	13.7%	35.6	8.5	236	Y	N	N	N	N	35.6	0	0	0	0
207	9.5	14.64	1038	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.32	0.18	0.24	13.7%	35.6	8.5	236	Y	N	N	N	N	35.6	0	0	0	0
Sub total Area 1 cluster 1a			6702																	187	57							187.0	0	200	564	0
Cluster 1b																																
221	7.6	12.2	553	2.5	1.25	0.25	60	200	-	160	-	200	200	Acetone	C	2.39	0.32	0.77	20.7%	28.6	22.2	229	Y	N	N	N	N	28.6	0	0	0	0
Sub total Area 1 cluster 1b			553																	29	22.2							28.6	0.0	0.0	0.0	0.0
Cluster 1c																																
223	6.1	10.97	321	2.5	1.25	0.25	60	200	-	160	-	200	200	Acetone	C	2.39	0.32	0.77	20.7%	16.6	12.8	217	Y	N	N	N	N	16.6	0	0	0	0
230	7.6	12.2	553	2.5	1.25	0.25	60	200	-	160	-	200	200	Acetone	C	2.39	0.32	0.77	20.7%	28.6	22.2	229	Y	N	N	N	N	28.6	0	0	0	0
Sub total Area 1 cluster 1c			874																	45	35.0							45.2	0.0	0.0	0.0	0.0
Area 1 Total			8130																	261	114.4							260.8	0.0	200.0	563.6	0.0
Area 2																																
Cluster 1																																
cluster 1a																																
233	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
234	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
241	9.58	17.08	1231	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	27.0	4.4	227	Y	N	N	N	N	27	0	0	0	0
242	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
243	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
251	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	12.1	2.0	212	Y	N	N	N	N	12.1	0	0	0	0
252	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
253	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Butyl Acrylates	I	5.27	0.01	0.04	4.6%	6.4	0.3	206	Y	N	N	N	N	6.4	0	0	0	0
254	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
259	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
260	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	12.1	2.0	212	Y	N	N	N	N	12.1	0	0	0	0
Sub total Area 2 cluster 1a			6765.6																	190.4	40.2							190.4	0.0	0.0	0.0	0.0
Cluster 1b																																
235	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
240	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
245	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
250	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
255	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	12.1	2.0	212	Y	N	N	N	N	12.1	0	0	0	0
258	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Methanol	E	1.32	0.18	0.24	13.7%	19.0	4.5	219	Y	N	N	N	N	19.0	0	0	0	0
Sub total Area 2 cluster 1b			3321																	107.0	24.5							107.0	0.0	0.0	0.0	0.0
Sub total Area 2 cluster 1			10086																	297.4	64.7							297.4	0.0	0.0	0.0	0.0
Area 2 cluster 2																																
237	10.7	17.08	1536	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.45	0.26	0.90	16.8%	64.4	58.1	264	Y	N	Y	N	N	64	0	90	0	0
238	9.58	17.08	1231	2.5	1.25	0.25	-	200	60	-	90	-	90	Hexene	B	3.45	0.26	0.90	16.8%	51.6	46.6	252	Y	N	N	N	N	52	0	0	0	0
244	7.6	12.2	553	2.5	1.25	0.25	-	200	72	-	90	-	90	Hexene	B	3.45	0.26	0.90	16.8%	23.2	20.9	223	Y	N	N	N	N	23	0	0	0	0
247	8.74	17.08	1025	2.5	1.25	0.25	60	200	-	140	-	200	200	Vinyl Acetate	G	3.54	0.16	0.57	12.0%	30.8	17.5	231	Y	N	N	N	N	30.8	0	0	0	0
248	8.74	17.08	1025	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	22.4	3.7	222	Y	N	N	N	N	22.4	0	0	0	0
249	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	18.6	3.0	219	Y	N	N	N	N	18.6	0	0	0	0
256	7.6	12.2	553	2.5	1.25	0.25	60	200	-	140	-	200	200	Vinyl Acetate	G	3.54	0.16	0.57	12.0%	16.6	9.5	217	Y	N	N	N	N	16.6	0	0	0	0
257	8.6	14.64	850	2.5	1.25	0.25	60	200	-	140	-	200	200	Ethanol	D	1.89	0.09	0.16	8.8%	18.6	3.0	219	Y	N	N	N	N	18.6	0	0	0	0
Subtotal Area 2 cluster 2			7624																	246.4	162.4							246.4	0.0	90.0	0.0	0.0
Area 2 Total			17710																	543.8	227.1							543.8	0.0	90.0	0.0	0.0
Total			25840																	805	342							805	0	290	564	0

Note 1: Information supplied by TPL
Note 2: Maximum tank filling 200 m3/hr from ship, 90 m3 from truck, maximum tank pump out 90 m3/hr to truck, 200 m3/hr to ship
Note 3 Estimated by CEC elsewhere based 15˚C temperature rise in liquid and vapour
Note 4 Estimated by CEC based on expansion factor and diurnal
Note 5 Summation of diurnal breathing and pump in rate

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
Calculation No:	**180010CAL-001**	**Rev**	**3**

Emission Estimate

Scenario 3 - Worst Case Thermal Load for Single 2nd Oxidiser
All tanks listed are diurnally breathing simultaneously
Hexene tanker filling, BTX ship export + nitrogen inerting

Base Temperature 27 °C
VOC % saturated (VOC/Inert Stream) 100%

Stream ID	Input stream	Volumetric rate input stream @ inlet temp m3/hr	Base Temp °C	MW	VOC at 100% Saturation	VOC at XX% Saturation	VOC density kg/m3	100% VOC vol rate m3/hr	VOC conc. kg/m3	100% VOC mass rate Comb inlet kg/hr	Heat of Combustion of VOC net (LHV) MJ/kg	Energy MJ/hr
VOC/Inert Stream												
	Tank Diurnal Breathing											
A	Benzene	76.8	27	78	13.4%	13.4%	3.21	10.3	0.43	33.1	40.21	1329
B	Hexene	139.3	27	84	26.1%	26.1%	3.45	36.4	0.90	125.7	44.52	5595
C	Acetone	73.9	27	58	32.4%	32.4%	2.39	24.0	0.77	57.2	28.60	1635
D	Ethanol	123.1	27	46	8.6%	8.6%	1.89	10.6	0.16	20.0	26.85	537
E	Methanol	327.9	27	32	18.1%	18.1%	1.32	59.3	0.24	78.0	19.94	1556
F	Styrene	9.9	27	104	0.9%	0.9%	4.28	0.09	0.04	0.38	40.51	15
G	Vinyl Acetate	47.4	27	86	16.1%	16.1%	3.54	7.6	0.57	27.0	22.65	612
H	Methyl Methacrylate	0.0	27	100	5.3%	5.3%	4.12	0.00	0.22	0.00	26.40	0
I	Butyl Acrylates	6.4	27	128	0.8%	0.8%	5.27	0.05	0.04	0.28	32.24	9
J	Methyl Isobutyl Carbinol (MIBC)	0.0	27	102	0.7%	0.7%	4.20	0.00	0.03	0.00	38.70	0
	Total Tank Diurnal Breathing	805	27					148.3	0.42	341.6		11288
	Tank Filling											
A	Benzene	0.0	27	78	13.4%	13.4%	3.21	0.0	0.43	0.0	40.21	0
B	Hexene	0.0	27	84	26.1%	26.1%	3.45	0.0	0.90	0.0	44.52	0
C	Acetone	0.0	27	58	32.4%	32.4%	2.39	0.0	0.77	0.0	28.60	0
D	Ethanol	0.0	27	46	8.6%	8.6%	1.89	0.0	0.16	0.0	26.85	0
E	Methanol	0.0	27	32	18.1%	18.1%	1.32	0.0	0.24	0.0	19.94	0
F	Styrene	0.0	27	104	0.9%	0.9%	4.28	0.0	0.04	0.0	40.51	0
G	Vinyl Acetate	0.0	27	86	16.1%	16.1%	3.54	0.0	0.57	0.0	22.65	0
H	Methyl Methacrylate	0.0	27	100	5.3%	5.3%	4.12	0.0	0.22	0.0	26.40	0
I	Butyl Acrylates	0.0	27	128	0.8%	0.8%	5.27	0.0	0.04	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	27	102	0.7%	0.7%	4.20	0.0	0.03	0.0	38.70	0
	Total Tank Filling	0	27					0.0	#DIV/0!	0.0		0
	Truck/Ship Filling											
A	Benzene	200.0	27	78	13.4%	13.4%	3.21	26.8	0.43	86.1	40.21	3460
B	Hexene	90.0	27	84	26.1%	26.1%	3.45	23.5	0.90	81.2	44.52	3616
C	Acetone	0.0	27	58	32.4%	32.4%	2.39	0.0	0.77	0.0	28.60	0
D	Ethanol	0.0	27	46	8.6%	8.6%	1.89	0.0	0.16	0.0	26.85	0
E	Methanol	0.0	27	32	18.1%	18.1%	1.32	0.0	0.24	0.0	19.94	0
F	Styrene	0.0	27	104	0.9%	0.9%	4.28	0.0	0.04	0.0	40.51	0
G	Vinyl Acetate	0.0	27	86	16.1%	16.1%	3.54	0.0	0.57	0.0	22.65	0
H	Methyl Methacrylate	0.0	27	100	5.3%	5.3%	4.12	0.0	0.22	0.0	26.40	0
I	Butyl Acrylates	0.0	27	128	0.8%	0.8%	5.27	0.0	0.04	0.0	32.24	0
J	Methyl Isobutyl Carbinol (MIBC)	0.0	27	102	0.7%	0.7%	4.20	0.0	0.03	0.0	38.70	0
	Supplementary N2 inerting	563.6	27									
	Total Truck/Ship Filling (incl. N2 inerting)	854	27					50.3	0.20	167.3		7075
	Total											
A	Benzene	276.8	27	78	13.4%	13.4%	3.21	37.1	0.43	119.1	40.21	4789
B	Hexene	229.3	27	84	26.1%	26.1%	3.45	59.9	0.90	206.9	44.52	9210
C	Acetone	73.9	27	58	32.4%	32.4%	2.39	24.0	0.77	57.2	28.60	1635
D	Ethanol	123.1	27	46	8.6%	8.6%	1.89	10.6	0.16	20.0	26.85	537
E	Methanol	327.9	27	32	18.1%	18.1%	1.32	59.3	0.24	78.0	19.94	1556
F	Styrene	9.9	27	104	0.9%	0.9%	4.28	0.09	0.04	0.38	40.51	15
G	Vinyl Acetate	47.4	27	86	16.1%	16.1%	3.54	7.6	0.57	27.0	22.65	612
H	Methyl Methacrylate	0.0	27	100	5.3%	5.3%	4.12	0.00	0.22	0.00	26.40	0
I	Butyl Acrylates	6.4	27	128	0.8%	0.8%	5.27	0.05	0.04	0.28	32.24	9
J	Methyl Isobutyl Carbinol (MIBC)	0.0	27	102	0.7%	0.7%	4.20	0.00	0.03	0.00	38.70	0
	Supplementary N2 inerting	563.6	27									
	Total (incl. N2 inerting)	1658	27					198.6	0.31	508.9		18363

VOC/Air Dilute Stream (MJ/hr)
Thermal load from the VOC/Air dilute stream - Refer to previous CEC calculation 110010Comcal 1 — 2834

Thermal Load Waste Burning (MJ/hr)
Max thermal load from liquid waste burning (6.5 l/min @ 21.3% (v/v) hexene) -Refer to CEC calculation 180010CAL-003 — 1382

Total Thermal Load (MJ/hr)- 2nd Thermal Oxidiser
VOC/Inert stream thermal load + VOC/Air dilute stream thermal load + liquid Waste — 22579

Heat of combustion data (A-G): source: Perry Chemical Engineers Handbook 7th Ed., pg's 2-195 to 2-199, Cmpd No 67, 34, 123, 83, 82, 80, 155
Heat of combustion data (H-J): source: Cameo Chemicals data sheets
Ambient temperature is same as inlet temperature

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
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Vapour Density, Mole Fraction & Tank Expansion Factor

BENZENE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
83.918	-6517.7	-9.3453	7.1182E-06	2

Temperature	27	˚C
	300	K
Vapour Pressure	13759	Pa
	13.8	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.134
Nitrogen Molecular Weight	28	Mole fraction	0.866
			1.00

Therefore Average Molecular Weight 34.7

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.43	kg/m3	Total Flow
Density =	3.21	kg/m3	Benzene vapour

BENZENE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
83.918	-6517.7	-9.3453	7.1182E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	7750	Pa
	7.7	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.076
Nitrogen Molecular Weight	28	Mole fraction	0.924
			1.00

Therefore Average Molecular Weight 31.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.36	kg/m3	Total Flow
Density =	3.34	kg/m3	Benzene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.08	
initial mol fract N2	0.92	
Volume Act	56.66814	
Volume Vol	693.3319	
	750	
Final temp	27	
Final mol fract act	0.13	
Final mol fract N2	0.87	
Volume Act	100.6028	
Volume Vol	649.3972	
	750	
Vapour pressure expansion	6.3%	
Thermal gas expansion	4.2%	
expansion factor	10.5%	

HEXENE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
85.3	-6171.7	-9.702	8.9604E-06	2

Temperature	27	˚C
	300	K
Vapour Pressure	26796	Pa
	26.8	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.261
Nitrogen Molecular Weight	28	Mole fraction	0.739
			1.00

Therefore Average Molecular Weight 42.6

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.75	kg/m3	Total Flow
Density =	3.45	kg/m3	Hexene vapour

HEXENE From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
85.3	-6171.7	-9.702	8.9604E-06	2

Temperature	15	˚C
	288	K
Vapour Pressure	15862	Pa
	15.9	kPa
Tank Pressure	5	"WC
	1.25	kPag
System Total	102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Hexene Molecular Weight	84	Mole fraction	0.155
Nitrogen Molecular Weight	28	Mole fraction	0.845
			1.00

Therefore Average Molecular Weight 36.7

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.57	kg/m3	Total Flow
Density =	3.60	kg/m3	Hexene vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.15	
initial mol fract N2	0.85	
Volume Act	115.9806	
Volume Vol	634.0194	
	750	
Final temp	27	
Final mol fract act	0.26	
Final mol fract N2	0.74	
Volume Act	195.933	
Volume Vol	554.067	
	750	
Vapour pressure expansion	12.6%	
Thermal gas expansion	4.2%	
expansion factor	16.8%	

Client :	**Terminals Pty Ltd**		**Calc by**	**FS**
Project No. :	**180010**		**Date**	**2/9/2019**
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Vapour Density, Mole Fraction & Tank Expansion Factor

ACETONE	From Perry 7th Ed Table 2-6					**ACETONE**	From Perry 7th Ed Table 2-6						tank vol	1000	m3
	C1	C2	C3	C4	C5		C1	C2	C3	C4	C5		tank empty	0.75	
	69.006	-5599.6	-7.0985	6.2237E-06	2		69.006	-5599.6	-7.0985	6.2237E-06	2		vap vol	750	m3
	Temperature		27	˚C			Temperature		15	˚C					
			300	K					288	K			initial temp	15	
	Vapour Pressure		33273	Pa			Vapour Pressure		19548	Pa			initial mol fract act	0.19	
			33.3	kPa					19.5	kPa			initial mol fract N2	0.81	
													Volume Act	142.9372	
	Tank Pressure		5	"WC			Tank Pressure		5	"WC			Volume Vol	607.0628	
			1.25	kPag					1.25	kPag				750	
	System Total		102.6	kPa			System Total		102.6	kPa					
	Partial Pressure = Vapour Pressure at Saturation						Partial Pressure = Vapour Pressure at Saturation						Final temp	27	
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction						Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction						Final mol fract act	0.32	
													Final mol fract N2	0.68	
Tank Displacement						**Tank Displacement**							Volume Act	243.2932	
No Oxygen - All Nitrogen and Solvent Vapour						No Oxygen - All Nitrogen and Solvent Vapour							Volume Vol	506.7068	
														750	
Acetone Molecular Weight			58	Mole fraction	0.324	Acetone Molecular Weight			58	Mole fraction	0.191				
Nitrogen Molecular Weight			28	Mole fraction	0.676	Nitrogen Molecular Weight			28	Mole fraction	0.809		Vapour pressure expansion	16.5%	
					1						1				
Therefore Average Molecular Weight			37.7			Therefore Average Molecular Weight			33.7				Thermal gas expansion	4.2%	
PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole		PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole			expansion factor	20.7%	
Density =	1.55	kg/m3	Total Flow			Density =	1.44	kg/m3	Total Flow						
Density =	2.39	kg/m3	Acetone vapour			Density =	2.48	kg/m3	Acetone vapour						

ETHANOL	From Perry 7th Ed Table 2-6					**ETHANOL**	From Perry 7th Ed Table 2-6						tank vol	1000	m3
	C1	C2	C3	C4	C5		C1	C2	C3	C4	C5		tank empty	0.75	
	74.475	-7164.3	-7.327	3.1340E-06	2		74.475	-7164.3	-7.327	3.1340E-06	2		vap vol	750	m3
	Temperature		27	˚C			Temperature		15	˚C					
			300	K					288	K			initial temp	15	
	Vapour Pressure		8817	Pa			Vapour Pressure		4300	Pa			initial mol fract act	0.04	
			8.8	kPa					4.3	kPa			initial mol fract N2	0.96	
													Volume Act	31.44251	
	Tank Pressure		5	"WC			Tank Pressure		5	"WC			Volume Vol	718.5575	
			1.25	kPag					1.25	kPag				750	
	System Total		102.6	kPa			System Total		102.6	kPa					
	Partial Pressure = Vapour Pressure at Saturation						Partial Pressure = Vapour Pressure at Saturation						Final temp	27	
	Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction						Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction						Final mol fract act	0.09	
													Final mol fract N2	0.91	
Tank Displacement						**Tank Displacement**							Volume Act	64.47086	
No Oxygen - All Nitrogen and Solvent Vapour						No Oxygen - All Nitrogen and Solvent Vapour							Volume Vol	685.5291	
														750	
Ethanol Molecular Weight			46	Mole fraction	0.086	Ethanol Molecular Weight			46	Mole fraction	0.042				
Nitrogen Molecular Weight			28	Mole fraction	0.914	Nitrogen Molecular Weight			28	Mole fraction	0.958		Vapour pressure expansion	4.6%	
					1						1				
Therefore Average Molecular Weight			29.5			Therefore Average Molecular Weight			28.8				Thermal gas expansion	4.2%	
PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole		PV =nRT, Density = MW x P/RT		R =	8314	J/Kelvin.kmole			expansion factor	8.8%	
Density =	1.22	kg/m3	Total Flow			Density =	1.23	kg/m3	Total Flow						
Density =	1.89	kg/m3	Ethanol vapour			Density =	1.97	kg/m3	Ethanol vapour						

Client :	**Terminals Pty Ltd**		**Calc by**	**FS**
Project No. :	**180010**		**Date**	**2/9/2019**
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Vapour Density, Mole Fraction & Tank Expansion Factor

METHANOL

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2
Temperature			27	°C	
			300	K	
Vapour Pressure			18545	Pa	
			18.5	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Methanol Molecular Weight	32	Mole fraction	0.181
Nitrogen Molecular Weight	28	Mole fraction	0.819
			1
Therefore Average Molecular Weight	28.7		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.18 kg/m3	Total Flow		
Density = 1.32 kg/m3	Methanol vapour		

METHANOL From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	81.768	-6876	-8.7078	7.1926E-06	2
Temperature			15	°C	
			288	K	
Vapour Pressure			9678	Pa	
			9.7	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Methanol Molecular Weight	32	Mole fraction	0.094
Nitrogen Molecular Weight	28	Mole fraction	0.906
			1
Therefore Average Molecular Weight	28.4		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.22 kg/m3	Total Flow		
Density = 1.37 kg/m3	Methanol vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	70.76916	
Volume Vol	679.2308	
	750	
Final temp	27	
Final mol fract act	0.18	
Final mol fract N2	0.82	
Volume Act	135.5993	
Volume Vol	614.4007	
	750	
Vapour pressure expansion	9.5%	
Thermal gas expansion	4.2%	
expansion factor	13.7%	

STYRENE

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2
Temperature			27	°C	
			300	K	
Vapour Pressure			913	Pa	
			0.9	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Styrene Molecular Weight	104.15	Mole fraction	0.009
Nitrogen Molecular Weight	28	Mole fraction	0.991
			1
Therefore Average Molecular Weight	28.7		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.18 kg/m3	Total Flow		
Density = 4.28 kg/m3	Styrene vapour		

STYRENE From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	105.93	-8685.9	-12.42	7.5583E-06	2
Temperature			15	°C	
			288	K	
Vapour Pressure			430	Pa	
			0.4	kPa	
Tank Pressure			5	"WC	
			1.25	kPag	
System Total			102.6	kPa	

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Styrene Molecular Weight	104.15	Mole fraction	0.004
Nitrogen Molecular Weight	28	Mole fraction	0.996
			1
Therefore Average Molecular Weight	28.3		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.21 kg/m3	Total Flow		
Density = 4.46 kg/m3	Styrene vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.143507	
Volume Vol	746.8565	
	750	
Final temp	27	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	6.672778	
Volume Vol	743.3272	
	750	
Vapour pressure expansion	0.5%	
Thermal gas expansion	4.2%	
expansion factor	4.6%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
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Vapour Density, Mole Fraction & Tank Expansion Factor

VINYL ACETATE

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6
Temperature			27 °C		
			300 K		
Vapour Pressure			16493 Pa		
			16.5 kPa		
Tank Pressure			5 "WC		
			1.25 kPag		
System Total			102.6 kPa		

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.161
Nitrogen Molecular Weight	28	Mole fraction	0.839
			1
Therefore Average Molecular Weight	37.3		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.54 kg/m3	Total Flow		
Density = 3.54 kg/m3	Vinyl acetate vapour		

VINYL ACETATE

From Perry 7th Ed Table 2-6

	C1	C2	C3	C4	C5
	57.406	-5702.8	-5.0307	1.1042E-17	6
Temperature			15 °C		
			288 K		
Vapour Pressure			9157 Pa		
			9.2 kPa		
Tank Pressure			5 "WC		
			1.25 kPag		
System Total			102.6 kPa		

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

Vinyl Acetate Molecular Weight	86.09	Mole fraction	0.089
Nitrogen Molecular Weight	28	Mole fraction	0.911
			1
Therefore Average Molecular Weight	33.2		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.42 kg/m3	Total Flow		
Density = 3.69 kg/m3	Vinyl acetate vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.09	
initial mol fract N2	0.91	
Volume Act	66.95524	
Volume Vol	683.0448	
	750	
Final temp	27	
Final mol fract act	0.16	
Final mol fract N2	0.84	
Volume Act	120.5983	
Volume Vol	629.4017	
	750	
Vapour pressure expansion	7.9%	
Thermal gas expansion	4.2%	
expansion factor	12.0%	

METHYL METHACRYLATE

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2
Temperature			27 °C		
			300 K		
Vapour Pressure			5468 Pa		
			5.5 kPa		
Tank Pressure			5 "WC		
			1.25 kPag		
System Total			102.6 kPa		

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.053
Nitrogen Molecular Weight	28	Mole fraction	0.947
			1
Therefore Average Molecular Weight	31.8		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.31 kg/m3	Total Flow		
Density = 4.12 kg/m3	Metylmetacrylate vapour		

METHYL METHACRYLATE

From BOC data (Same method as Perry 7th Ed Table 2-6)

	C1	C2	C3	C4	C5
	107.36	-8085.3	-12.72	8.3307E-06	2
Temperature			15 °C		
			288 K		
Vapour Pressure			2819 Pa		
			2.8 kPa		
Tank Pressure			5 "WC		
			1.25 kPag		
System Total			102.6 kPa		

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MMA Molecular Weight	100.12	Mole fraction	0.027
Nitrogen Molecular Weight	28	Mole fraction	0.973
			1
Therefore Average Molecular Weight	30.0		
PV =nRT, Density = MW x P/RT	R =	8314	J/Kelvin.kmole
Density = 1.28 kg/m3	Total Flow		
Density = 4.29 kg/m3	Metylmetacrylate vapour		

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.03	
initial mol fract N2	0.97	
Volume Act	20.61324	
Volume Vol	729.3868	
	750	
Final temp	27	
Final mol fract act	0.05	
Final mol fract N2	0.95	
Volume Act	39.98153	
Volume Vol	710.0185	
	750	
Vapour pressure expansion	2.7%	
Thermal gas expansion	4.2%	
expansion factor	6.8%	

Client :	**Terminals Pty Ltd**	**Calc by**	**FS**
Project No. :	**180010**	**Date**	**2/9/2019**
Project :	**2nd Thermal Oxidiser and Liquid Waste burning**	**Checked**	**AB**
Calculation No:	**180010CAL-001**	**Rev**	**3**

Vapour Density, Mole Fraction & Tank Expansion Factor

BUTYL ACRYLATE

	A	B	C	
	8.141759	2199.925	273.16	
Temperature			27	˚C
			300	K
Vapour Pressure			6.50	mmHg
			866	Pa
			0.9	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight	128.17	Mole fraction	0.008
Nitrogen Molecular Weight	28	Mole fraction	0.992
			1
Therefore Average Molecular Weight	28.8		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.19	kg/m3	Total Flow
Density =	5.27	kg/m3	Butyl acrylate vapour

BUTYL ACRYLATE From Odor and VOC Control Handbook - H.J Rafson)

	A	B	C	
	8.141759	2199.925	273.16	
Temperature			15	˚C
			288	K
Vapour Pressure			3.22	mmHg
			429	Pa
			0.4	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

BA Molecular Weight	128.17	Mole fraction	0.004
Nitrogen Molecular Weight	28	Mole fraction	0.996
			1
Therefore Average Molecular Weight	28.4		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.22	kg/m3	Total Flow
Density =	5.49	kg/m3	Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	3.135541	
Volume Vol	746.8645	
	750	
Final temp	27	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	6.331771	
Volume Vol	743.6682	
	750	
Vapour pressure expansion	0.4%	
Thermal gas expansion	4.2%	
expansion factor	4.6%	

METHYL ISOBUTYL CARBINOL (MIBC)

	A	B	C	
	6.63977	1521.88	196.767	
Temperature			27	˚C
			300	K
Vapour Pressure			0.69	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight	102.174	Mole fraction	0.007
Nitrogen Molecular Weight	28	Mole fraction	0.993
			1
Therefore Average Molecular Weight	28.5		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.17	kg/m3	Total Flow
Density =	4.20	kg/m3	Butyl acrylate vapour

METHYL ISOBUTYL CARBINOL (MIBC) From Shell Chemicals Data Sheet

	A	B	C	
	6.63977	1521.88	196.767	
Temperature			15	˚C
			288	K
Vapour Pressure			0.28	kPa
Tank Pressure			5	"WC
			1.25	kPag
System Total			102.6	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement
No Oxygen - All Nitrogen and Solvent Vapour

MIBC Molecular Weight	102.174	Mole fraction	0.003
Nitrogen Molecular Weight	28	Mole fraction	0.997
			1
Therefore Average Molecular Weight	28.2		

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density =	1.21	kg/m3	Total Flow
Density =	4.38	kg/m3	Butyl acrylate vapour

tank vol	1000	m3
tank empty	0.75	
vap vol	750	m3
initial temp	15	
initial mol fract act	0.00	
initial mol fract N2	1.00	
Volume Act	2.076018	
Volume Vol	747.924	
	750	
Final temp	27	
Final mol fract act	0.01	
Final mol fract N2	0.99	
Volume Act	5.042283	
Volume Vol	744.9577	
	750	
Vapour pressure expansion	0.4%	
Thermal gas expansion	4.2%	
expansion factor	4.6%	

VOC/Air Stream 2
Calculation Basis

Calculation No:	180010CAL-002	Rev 1

Calculation Title: VOC Emission Estimate Calculations
For air diluted stream to thermal oxidiser - based on dilution of vapours to minimum of 25% LEL.

System Description: The existing vapour collection and VECS system to be upgraded to reduce VOC emissions at Terminals Pty Ltd (Botany).
VOC emissions are generated during transfer to tanker trucks (2 off) - air sweep of manholes, tank cleaning, hose cleaning, air sweep on sample tanks
Two smaller thermal oxidisers units will be installed to provide redundancy, however both thermal oxidisers will run together at maximum load.
Each thermal oxidiser is sized for only partial full stream 2 flowrate.

Aim of Calculations: The calculations are based on a selected worst case scenario for sizing collection ductwork, estimating thermal loading and assessing emissions - note other snap shots exist.
Estimate emissions from various sources and total air diluted stream to combustion system.
Estimate emissions from combustion system to allow environmental assessment to occur.
Estimate maximum VOC mass loading in dilute stream to thermal oxidiser.

Basis Data: Refer to CEC calculation 180010CAL-001

Assumptions:

1. Worst case chemicals assumed to be hexane and acetone.
2. Maximum temperature of VOC vapour will be 30°C.
3. Tank cleaning/degassing will initially occur using nitrogen and vented through the inert collection system until the VOC concentration is below 25% LEL.
4. A VSD suction fan, appropriate pressure sensing, LEL measuring and controls and interlocks will be installed at the thermal oxidiser.
   This will maintain a negative pressure in the dilute vapour collection duct work and facilitate transfer of vapour to the thermal oxidiser.
5. Vapour from trucks assumed to be 50% saturated - worst case.

Calculation Notes:

Basis data: Inputs the various source and stream process data and assumptions.
Calculates the various mass rates of VOC, dilution required for 25% LEL and maximum total flowrate

Input data: Calculates input stream data to thermal oxidiser
Calculates output data from thermal oxidiser
Esimates outlet volumetric rate, velocity and concentration.

Design Verification Control						
			Originator		Checked	
Input Data Correct						
Assumptions properly documented						
Method of Calculation						
Attachments included, clearly labeled and referenced						
Results/conclusions clearly summarised						
Rev	**Issue Description**	**Date**	**Originated**	**Checked**	**Approved**	**Client**
2	Client issue	17/04/2019	FS	AB	FS	

VOC/Air Stream 2
Summary

Selected worst case scenario

Calculation No.	180010CAL-002	Rev 1

0

Source: Truck and drum filling (air sweep), tank cleaning, hose cleaning, sample tank air sweep and dilution air

	Input to Thermal Oxidiser (TO)/Combustor				Output from Thermal Oxidiser (TO)/combustor				
VOC Note 3	Mass rate VOC into TO kg/hr	Mass rate VOC into TO g/min	Total vap rate to TO m3/hr	VOC conc. into TO total g/m3	VOC mass rate kg/hr	VOC mass rate g/min	VOC outlet conc. per stream at max flow outlet temp Note 4 mg/m3	VOC outlet conc. per stream at max flow normal temp Note 5 mg/m3	Outlet Velocity m/sec
Benzene	0.00	0	0	0.00	0.000	0.000	0.000	0.000	
Hexane	38.28	638	3966	5.31	0.004	0.064	0.131	0.590	
Acetone	40.53	675	2841	5.62	0.004	0.068	0.138	0.624	
Ethanol	0.00	0	0	0.00	0.000	0.000	0.000	0.000	
MMA	0.00	0	0	0.00	0.000	0.000	0.000	0.000	
Other air utilities	0.00	0	400	0.00	0.000	0.000	0.000	0.000	
Total	78.81	1313	7207	10.93	0.008	0.131	0.269	1.214	10.377

Volumetric flowrate: 0- 7207 m3/hr
Stream Inlet temperature 5-30 °C

Notes:

Stream 2- VOC air diluted to maximum of 25% of LEL.
The above presents a selected worst case scenario as an input stream to the Thermal oxidiser.
The flowrate and the VOC concentration of the input stream will vary significantly depending on the activities undertaken at the terminal and the prevailing weather conditions.

Other chemical species must also be treated. Refer to the full list of species to be treated by the TO.
The input stream (Acetone, Hexane) can be any combination of up to 6 chemicals from the list of chemical species up to the maximum mass and volumetric flowrate nominate above.

VOC/Air Stream 2
Basis Data-VOC/Air stream

Calculation No. 180010CAL-002 Rev 1

Combustor eff	99.99%	VOC inlet stream	30.0	°C	Tank cleaning dilution factor	60
		Air temp	30.0	°C	1 = undiluted (saturate vapour)	
% VOC saturation	50%	Comb Temp	960.0	°C		
		Outlet dia	1.0	m	assumed-TBC	

VOC/Air ancillary air stream

Description	Design basis tank contents Input stream	Vapour rate m3/hr	Vapour Density kg/m3	VOC % at saturation	VOC % at 50% saturation	VOC Conc. kg/m3	VOC mass rate into VECS kg/hr	LEL %	UEL %	Vapour dilution factor dilution to 25% LEL	Air sweep to achieve 25% LEL m3/hr	Total vapour rate incl air sweep for dil to x % LEL m3/hr	Estimate min rate (air) for air sweep capture excluding dil to x% LEL m3/hr
Tank cleaning (note 1)	Acetone	200	2.37	0.6%	0.3%	0.01	1.4	2.5%	13.0%	0	0	200	200
Truck filling	Benzene	0	3.18	15.3%	7.7%	0.24	0.0	1.3%	7.9%	23.6	0	0	0
Truck filling	Flammable (Hexane)	90	3.51	24.2%	12.1%	0.43	38.3	1.1%	7.5%	44.1	3876	3966	350
Truck filling	Flammable (Acetone)	90	2.37	36.7%	18.3%	0.43	39.1	2.5%	13.0%	29.3	2551	2641	350
Truck filling	Flammable (Ethanol)	0	1.88	10.2%	5.1%	0.10	0.0	1.1%	7.5%	18.5	0	0	0
Truck filling	Flammable (MMA)	0	4.08	6.4%	3.2%	0.13	0.0	1.7%	8.2%	7.5	0	0	0
Drum filling	Acetone	0	2.37	36.7%	18.3%	0.43	0.0	2.5%	13.0%	29.3	0	0	0
Hose cleaning	Utility air	200									0	200	200
Hose cleaning	Utility air	200									0	200	200
Total		**780**									**6427**	**7207**	**1300**
Supplementary dilution air													5727

Maximum rate (with dil to x% LEL)=	**7207**	**m3/hr**
Maximum rate for air sweep/capture -excluding dil to x% LEL=	1300	m3/hr
Minimum based load rate for air sweep (note 3)=	400	m3/hr
Assume 50-50 split per combustor		
Assume Max flowrate per combustor /Thermal Oxidiser	**3603**	m3/hr

Worst case scenario is 6
Design basis for oxidiser
1500 m3/hr of air no VOC's
4000 m3/hr of Air-VOC at 25% LEL

Other Data:

Substance	Sat. Vap. Mol. Fraction	Vapour Density	Temp °C
Benzene	15.3%	3.18	30.0
Hexane	24.2%	3.51	30.0
MMA	6.4%	4.08	30.0
Acetone	36.7%	2.37	30.0
Ethanol	10.2%	1.88	30.0
Air		1.2	15.0

Note 1 Conc of Acetone after dilution to be below 25% LEL. First purge with with nitrogen to inert stream before air dilutic

Note 3 Base load assumes sample tank, hose clean operate continuously

VOC/Air Stream 2
Input Data

Selected worst case scenario

Calculation No. 180010CAL-002 | Rev 1

Emission reduction eff. 99.99%

	Input to Thermal Oxidiser (TO)/Combustor				Output from Thermal Oxidiser (TO)/combustor							
VOC Note 3	Mass rate VOC into TO kg/hr	Mass rate VOC into TO g/min	Total vap rate to TO m3/hr	VOC conc. into TO total g/m3	VOC mass rate kg/hr	VOC mass rate g/min	Approx. vol rate of outle gases at 960 °C m3/hr	VOC outlet conc. per stream at max flow outlet temp Note 4 mg/m3	VOC outlet conc. per stream at max flow normal temp Note 5 mg/m3	Outlet Velocity m/sec	Heat of Comb of VOC net (LHV) MJ/kg	Energy of VOC MJ/hr
Benzene	0.00	0	0.00	0.00	0.0000	0.0000	0	0.00	0.00		40.21	0
Hexane	38.28	638	3966	5.31	0.0038	0.0638	16137	0.13	0.59		44.83	1716
Acetone	40.53	675	2841	5.62	0.0041	0.0675	11562	0.14	0.62		28.60	1159
Ethanol	0.00	0	0.00	0.00	0.0000	0.0000	0	0.00	0.00		26.85	0
MMA	0.00	0	0	0.00	0.0000	0.0000	0	0.00	0.00		26.22	0
Other air utilities			400									
Total	78.81	1313	7207	10.93	0.01	0.13	29327	0.27	1.21	10.4		2875

Total

Assume min air rate to TO/Comb. as combustion air 1300 assumed TBC by TO vendor during detailed design.

Note 1- Approximation- based on total flowrate for each stream only at outlet temp. (minimum flowrate =combustion air at outlet condition)

Note 3-VOC can be any species in the list of VOC's to be treated at the terminal -this represents worst case VOC & air load.
Note 4- Approximation- based on total flowrate at outlet temp
Note 5- Approximation- based on total flowrate at normal temp
Note 6- Assumes that part of the process air stream is feed into TO as combustion air.

BENZENE

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
83.918	-6517.7	-9.3453	7.1182E-06	2

Temperature	30	Deg C
	303	Deg K
Vapour Pressure	15747	Pa
	15.7	kPa
Tank Pressure	6	"WC
	1.5	kPag
System Total	102.8	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Benzene Molecular Weight	78	Mole fraction	0.15
Nitrogen Molecular Weight	28	Mole fraction	0.85
			1.00
Therefore Average Molecular Weight	35.7		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density = 1.46 Kg/m3 Of Total Flow
Density = 3.18 Kg/m3 Of Benzene vapour

Hexane

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
104.65	-6995.5	-12.702	1.238E-05	2

Temperature	30	Deg C
	303	Deg K
Vapour Pressure	24917	Pa
	24.9	kPa
Tank Pressure	6	"WC
	1.5	kPag
System Total	102.8	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Hexane Molecular Weight	86	Mole fraction	0.24
Nitrogen Molecular Weight	28	Mole fraction	0.76
			1.00
Therefore Average Molecular Weight	42.1		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density = 1.72 Kg/m3 Of Total Flow
Density = 3.51 Kg/m3 Of hexane vapour

ACETONE

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
69.006	-5599.6	-7.0985	6.2237E-06	2

Temperature	30	Deg C
	303	Deg K
Vapour Pressure	37719	Pa
	37.7	kPa
Tank Pressure	6	"WC
	1.5	kPag
System Total	102.8	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Acetone Molecular Weight	58	Mole fraction	0.37
Nitrogen Molecular Weight	28	Mole fraction	0.63
			1.00
Therefore Average Molecular Weight	39.0		

PV =nRT, Density = MW x P/RT   R = 8314 J/Kelvin.kmole

Density = 1.59 Kg/m3 Of Total Flow
Density = 2.37 Kg/m3 Of Acetone vapour

Temp 30 C

ETHANOL

From Perry 7th Ed Table 2-6

C1	C2	C3	C4	C5
74.475	-7164.3	-7.327	3.1340E-06	2

Temperature 30 Deg C
303 Deg K
Vapour Pressure 10443 Pa
10.4 kPa

Tank Pressure 6 "WC
1.5 kPag
System Total 102.8 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Ethanol Molecular Weight	46	Mole fraction	0.10
Nitrogen Molecular Weight	28	Mole fraction	0.90
			1.00

Therefore Average Molecular Weight 29.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.22 Kg/m3 Of Total Flow
Density = 1.88 Kg/m3 Of Ethanol vapour

Methyl Methacrylate

From Rafson, 1998, VOC and Odour handbook, McGraw Hill

Validated against VP data for EA table 2-8 page 68 Perry's 7th Ed
FS 22-4-01

A	B	C
6.5168	1052.176	188.37

Temperature 30 Deg C
303 Deg K
Vapour Pressure 49.94 mmHg
6.5716 kPa

Tank Pressure 6 "WC
1.5 kPag
System Total 102.8 kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

Tank Displacement

No Oxygen - All Nitrogen and Solvent Vapour

Acrylate Molecular Weight	100	Mole fraction	0.064
Nitrogen Molecular Weight	28	Mole fraction	0.94
			1.00

Therefore Average Molecular Weight 32.6

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.33 Kg/m3 Of Total Flow
Density = 4.08 Kg/m3 Of MMA vapour

Gas Density

Air

Temperature 15 Deg C
288 Deg K
Pressure 0.0 kPag
System Total 101.3 kPa abs

N_2	MW	28
	%vol	0.79
O_2	MW	32
	%vol	0.21

Therefore Average Molecular Weight 28.8

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.22 Kg/m3 Of Total Flow

Nitrogen

Temperature 15 Deg C
288 Deg K
Pressure 0.0 kPag
System Total 101.3 kPa abs

Molecular Weight 28.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.18 Kg/m3 Of Total Flow

Oxygen	Temperature	15	Deg C		
		288	Deg K		
	Pressure	0.0	kPag		
	System Total	101.3	kPa abs		

Molecular Weight 32.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.35 Kg/m3 Of Total Flow

Carbon dioxide	Temperature	15	Deg C
		288	Deg K
	Pressure	0.0	kPag
	System Total	101.3	kPa abs

Molecular Weight 44.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 1.86 Kg/m3 Of Total Flow

Water vapour	Temperature	15	Deg C
		288	Deg K
	Pressure	0.0	kPag
	System Total	101.3	kPa abs

Molecular Weight 18.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 0.76 Kg/m3 Of Total Flow

Suphur dioxide	Temperature	15	Deg C
		288	Deg K
	Pressure	0.0	kPag
	System Total	101.3	kPa abs

Molecular Weight 64.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 2.71 Kg/m3 Of Total Flow

Methane

Temperature	15	Deg C
	288	Deg K
Pressure	0	"WC
	0.0	kPag
System Total	101.3	kPa

Partial Pressure = Vapour Pressure at Saturation
Partial Pressure / Total Pressure = Mole Fraction = Volume Fraction

CH4 Molecular Weight 16 Mole fraction 1.00

Therefore Average Molecular Weight 16.0

PV =nRT, Density = MW x P/RT R = 8314 J/Kelvin.kmole

Density = 0.68 Kg/m3

Appendix C

Chemical Species to be Treated by Thermal Oxidiser

Appendix C

Chemical species to be treated by thermal oxidiser (dated: 27-5-19)

Chemical Species	Estimated maximum rate into inert stream per chemical species m^3/hr (tank filling & breathing) - note 1,2	Estimated maximum rate into dilute air stream per chemical species m^3/hr (truck filling) - note 3
Acetone	442	90
Benzene/BTX	415	-
Butyl Acrylate	300	90
Butyl Acetate	300	90
Cumene	300	90
Cyclohexane	300	90
2-Ethyl Hexyl Acrylate	300	90
Ester	300	90
Ethanol	300	90
Ethyl Acetate	300	90
Ethyl Benzene	300	90
Ethyl Hexyl Acrylate	300	90
Exxsol D 30	300	90
Heptenes	300	90
Hexane	331	90
Iso Butyl Alcohol	300	90
Iso Propyl Alcohol	300	90
Isopar G	300	90
Methanol	300	90
Methyl Ethyl Ketone	300	90
Methyl Iso-Butyl Ketone	300	90
Methyl Methacrylate Monomer	300	90
Methyl Styrene	300	90
Mineral Turps	300	90
Naptha	300	90
n-Butanol	300	90
n-Propanol	300	90
Propyl Acetate	300	90
Styrene Monomer	300	90
Toluene	300	90
Vinyl Acetate Monomer	300	90
White Spirit	300	90
Xylene	300	90

Refer to notes next page

Notes:

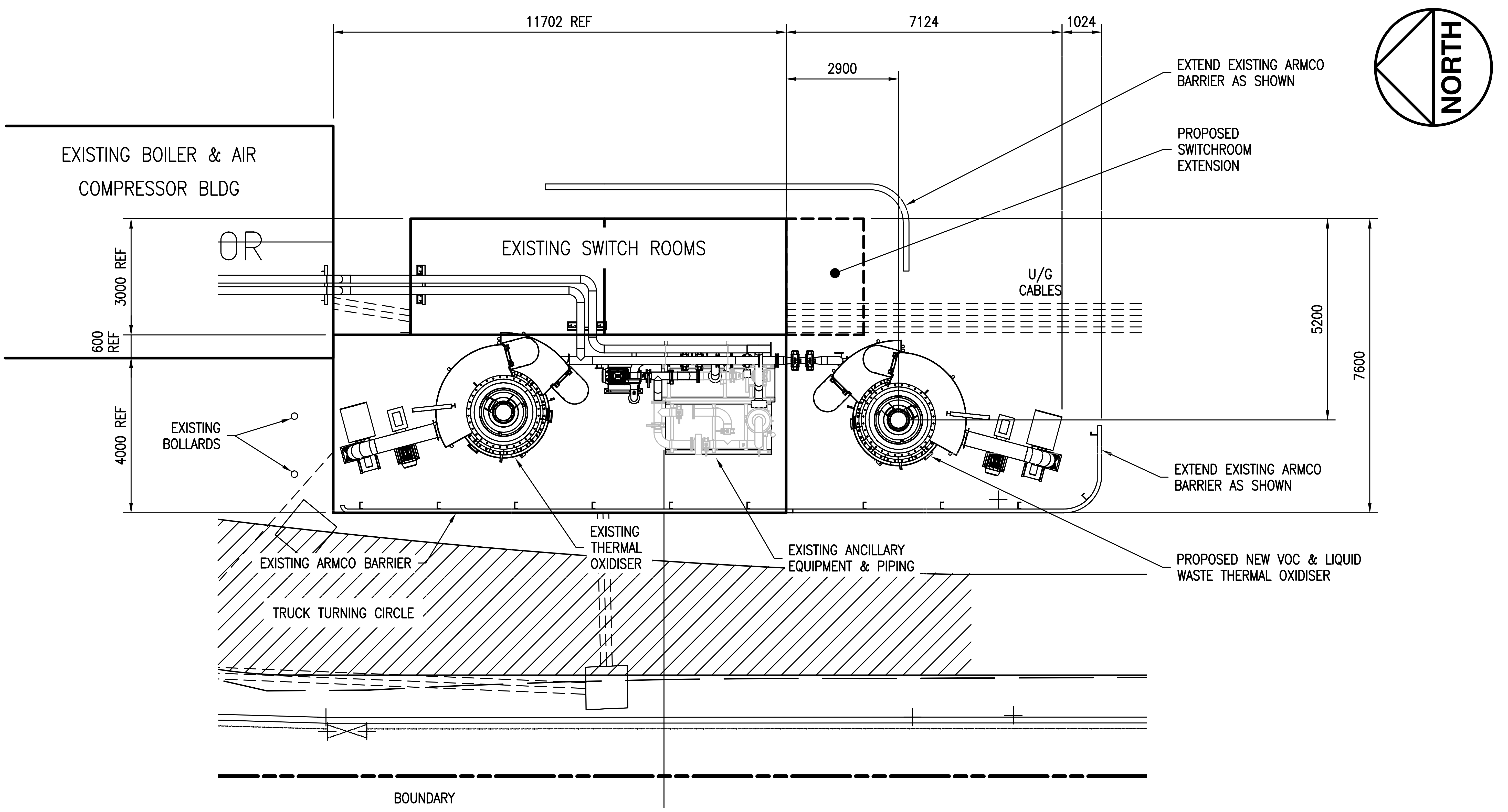
Note 1
Assume worst case 100% saturated VOC vapour @ 30^{o}C inerted with nitrogen (0% to 8% max. oxygen)
VOC conc. can vary between 0 -100% saturation between 10-30^{o}C.

Note 2
Worst case flowrate into inert stream is any combination up to 1728 m3/hr and to the maximum thermal load.

Note 3
Assume worst case 50% saturated VOC vapour @ 30^{o}C in air
VOC conc. can vary between 0 -100% saturation between 10- 30^{o}C.
Maximum rate for each VOC assumed (1 x 90 m3/hr truck filling)-worst case is 2 trucks filling at same time

Appendix D

Site Layout



REV	DESCRIPTION	DATE	APP.
A	INITIAL ISSUE	13/06/19	FS

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PROJECT
2ND THERMAL OXIDISER & LIQUID WASTE BURNING BOTANY TERMINAL

TITLE
LAYOUT
NEW THERMAL OXIDISER
PROPOSED LOCATION

SCALE	ORIGINAL SIZE
1:100	A3

STATUS: ISSUED FOR INFORMATION

DRAWN	DATE	DESIGN/CHK'D	DATE	APPROVED	DATE
SDeL	13/06/19	FS	13/06/19	FS	13/06/19

PROJECT NO.	DRAWING NO.	REVISION
180010	LAY-001	A