VOC COLLECTION AND TREATMENT FACILITY IN AN EFFLUENT TREATMENT PLANT

By
YOGESH BHATT

College of Engineering
University of Petroleum & Energy Studies
Dehradun
May, 2008

VOC COLLECTION AND TREATMENT FACILITY IN AN EFFLUENT TREATMENT PLANT

A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
(Refining & Petrochemical Engineering)

By
YOGESH BHATT

Under the guidance of

Mr. J. K. Joshi
(Assistant General Manager)
Environment Department
Engineers India Limited
New Delhi

Approved

Dr. B.P. Pandey
Dean

College of Engineering
University of Petroleum & Energy Studies
Dehradun
May, 2008

UNIVERSITY OF PETROLEUM & ENERGY STUDIES
(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled "***VOC Collection and Treatment Facility in an Effluent Treatment Plant***" has been carried out by Mr. Yogesh Bhatt under the supervision of Mr. J.K. Joshi and myself and has not been submitted elsewhere for a degree.

DNSaraf

Dr. D.N. Saraf
Professor of Chemical Engineering
U.P.E.S, Dehradun
Date: 23.05.08

orporate Office:
ydrocarbons Education & Research Society
rd Floor, PHD House,
/2 Siri Institutional Area
ugust Kranti Marg, New Delhi - 110 016 India
h.: +91-11-41730151-53 Fax : +91-11-41730154

Main Campus:
Energy Acres,
PO Bidholi Via Prem Nagar,
Dehradun - 248 007 (Uttarakhand), India
Ph.: +91-135-2102690-91, 2694201/ 203/ 208
Fax: +91-135-2694204

Regional Centre (NCR) :
SCO, 9-12, Sector-14,
Gurgaon 122 007
(Haryana), India.
Ph: +91-124-4540 300
Fax: +91-124-4540 330

Regional Centre (Rajahmundry):
GIET, NH 5, Velugubanda,
Rajahmundry - 533 294,
East Godavari Dist., (Andhra Pradesh), India
Tel: +91-883-2484811/ 855
Fax: +91-883-2484822

Email: info@upes.ac.in URL : www.upes.ac.in

इंजीनियर्स इंडिया लिमिटेड
ENGINEERS INDIA LIMITED
पंजीकृत कार्यालय: इंजीनियर्स इंडिया भवन, 1, भीकाएजी कामा प्लेस, नई दिल्ली-110066
Regd. Office: Engineers India Bhawan, 1, Bhikaiji Cama Place, New Delhi-110066

TRG/VT/2007-08 (W)/28

May 02, 2008

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. Yogesh Bhatt,** a student of M.Tech (Refining & Petrochemical Engineering) from University of Petroleum & Energy Studies, Dehradun, completed his Practical Training in **Environment Division** of our organization from March 10, 2008 to May 02, 2008. He has undertaken his training assignment on **"VOC Collection & Treatment Facility in an Effluent Treatment Plant."**

During the course of training, **Mr. Yogesh Bhatt** has been regular and punctual. He has shown interest in his assignment and his performance on evaluation has been found to be **"Excellent."**

(R.P. Goswami)
Asst. General Manager – Human Resource

सर्व · शिक्षा अभियान
उत्कृष्टता का आधार - हमारे कर्मी
DELIVERING EXCELLENCE THROUGH PEOPLE
ISO 9001
फोन : 26102121 (EPABX)
Phone : 26101419 (DISA)
फैक्स/Fax: 91-11-26186245
Visit us at http://www.engineersindia.com
हिन्दी देश की एकता की कड़ी है।

CERTIFICATE

This is to certify that the work contained in this thesis titled "***VOC Collection and Treatment Facility in an Effluent Treatment Plant***" has been carried out by Mr. Yogesh Bhatt under my supervision and has not been submitted elsewhere for a degree.

Joshi

Mr. J. K. Joshi
(Assistant General Manager)
Environment Department
Engineers India Limited
New Delhi
01.05.2008

ABSTRACT

Petroleum industries emit gaseous and liquid Volatile Organic Compounds (VOCs). Since the environmental rules are becoming more and more stringent, reduction of VOC emissions is now made mandatory under the Environmental Pollution Act and all the new facilities are being asked to adopt VOC control and treatment measures.

The major sources for VOC emissions in a Waste Water Treatment Plant have been broken into two Groups. Major polluting source like Oily Water Sump (OWS) sump, American Petroleum Institute (API), Tilted Plate Interceptor (TPI) and slop oil sump are grouped together. And other less polluting source like Dissolved Air Floatation (DAF), Flash mixing tank and Flocculation Tank are grouped separately.

Total VOC emissions from the Effluent Treatment Plant of a typical refinery are estimated to be 1.31 x 10^5 kg/yr based on the USEPA model. Summary (unit-wise and component-wise) of these emissions along with emission details of each component from each of the unit are incorporated in this report. These calculations are made by means of WATER 9 (Version 3) software.

Flow rate and vent sizing calculations have been done based on the breathing losses or displacement losses accounting for the volume entering the VOC control system.

Flame arrestors are provided in the main header to help protect the upstream equipment in case of detonation.

Process and Instrumentation Diagrams for the complete Effluent Treatment Plant is prepared showing all the relevant controls.

ACKNOWLEDGEMENTS

I take this opportunity to express my deep sense of gratitude to:

Mr. J.K. Joshi, Asst. General Manager (Mentor), for his invaluable guidance, constant encouragement, inspiring criticism and keen interest throughout the course of this project. His benevolent advice, guidance and dedication to the work has always been a source of inspiration to me;

Mr. M.K. Joshi, Director, Engineers India Limited, for his kind permission to make use of the facilities of the company for carrying out my project work;

Mr. A. Haldar, Head - Environment Division for encouraging me throughout my training period and providing me with all possible help.

Mr. Susheel Sadh and Mr. P.K. Goel for encouraging me throughout my training period and providing me with all possible help.

HR Department of Engineers India Limited for their cooperation.

I am thankful to Dr. D.N. Saraf, Course Coordinator - Refining & Petrochemical Engineering and the Faculty at UPES, Dehradun for arranging eight weeks training at this esteemed organization.

(Yogesh Bhatt)

Final Year M. Tech, Refining & Petrochemical Engineering
University of Petroleum & Energy Studies
Dehradun

CONTENTS

LIST OF FIGURES

FIGURE

PAGE

1.0 INTRODUCTION

Reduction of Volatile Organic Compounds (VOCs) is becoming more and more important for the chemical industry. There are all kinds of reasons for VOC reduction: toxicity, typical or unpleasant odor, the environmental impact (smog, greenhouse gases), but also because of the commercial value of the volatiles involved. Besides the public awareness has changed and environmental regulations have become more stringent and as a result control of VOC's emissions is a major concern of the industries' commitment towards the environment.

There are many different techniques available to control VOC emissions [1].

Basically these techniques can be divided into two groups:

- Process and equipment modification
- Add-on control techniques

The first group is the inherent technique and controls emissions by change of equipment and or process (what is not there cannot be emitted, equipment that does not leak will not emit).

Unfortunately it is difficult to modify existing plants and processes so destruction or recoveries are added to reduce the emissions. More and more VOC treatment units are installed after an economic analysis.

1.1 EMISSION CONTROL TECHNIQUES FOR VOC REDUCTION

Emissions of VOC's originate from breathing and loading losses from storage tanks, venting of process vessels, leaks from piping, flanges or valves and equipment (pumps), waste water streams and heat exchange systems. In order to treat the VOC emissions the streams are collected and contained in treatment units. While collecting VOC's almost always flammable mixtures will be formed, which can react or ignite under conditions that were not predicted during the design stage.

For large continuous plants VOC treatment systems are easier to design than for plants in the fine and specialty chemicals industry. The former with large continuous plants has more defined gas emissions and a more continuous flow. The latter uses more batch processes, which generate discontinuous VOC streams of fluctuating composition. The greater the variability of substances to be controlled, the greater the limitations placed upon the type of treatment process.

The selection of the treatment type is often based on economic analysis only for one plant. Once a choice has been made it is easy to use the same solution for other problems or connect other emission points to the same treatment unit. The influence on the total risk is difficult to assess [2].

1.2 DESTRUCTION TECHNIQUES [3]

INCINERATORS

VOC's can be destroyed by oxidation. This can be done with thermal oxidation or by catalytic oxidation. Thermal oxidizers (TO's) are sophisticated systems designed to destroy 95-99% of the VOC's emitted. They are reliable and cost effective. TO's can be used for VOC emissions from 100 to 2000 ppm. However, it is not advised to exceed concentrations in excess of 25% of the Lower Explosive Limit (LEL). The larger the streams, the more expensive and complicated the design will be.

Precautions must be taken to prevent flash backs of incinerator flames into the inlet vapor streams. The connecting piping between process vessels or process operations and a thermal oxidizer act as a swift conduit for flame propagation and could thus cause a fire or explosion in the vapor lines, storage vessels or connective piping. Modern TO burner-heads are designed to prevent flame entry. Also water seals, detonation or flame arrestors are used to prevent fire and explosion. In addition, protective piping can be equipped with fast acting valves, which close in a fraction of a second in response to a deflagration in a process vessel.

Catalytic oxidizers are virtually the same but because a catalyst is used in the oxidation they operate at lower temperatures e.g. 600-900 ^{0}F instead of 1400-2000 ^{0}F. The catalytic systems are reported to be more suited for low concentration operations [1]. A disadvantage of catalytic oxidizers is that the catalyst can be sensitive to poisoning by material like sulfur, chlorides and silicon. The spent catalyst can require disposal as hazardous waste.

1.3 VOC SEPARATION SYSTEMS FOR AQUEOUS WASTES

Several technologies exist that can be used for recovery & treatment of VOC's from aqueous wastes. The most widely used technologies are air stripping, steam stripping and activated carbon adsorption; however, several emerging membrane-based technologies, such as reverse osmosis and pervaporation, have also shown potential for use in recovering VOC's from wastewater. The following is a summary of these technologies, a description of the technology, and some advantages and disadvantages of these technologies. Additional information and modeling equations of these mass transfer operations can be found in literature such as McCabe et al. (1993), Perry and Green (1984), Geankoplis (1983), Henley and Seader (1981), King (1980), and Treybal (1980).

VOC Recovery Technologies for Aqueous Wastes

Air Stripping

Description

- Wastewater flows into the top of a packed column and is distributed throughout the packing.
- Air flows into the bottom of the column and the VOC is transferred from the wastewater to the air via direct contact.
- The VOC-laiden air exits the top of the column and the VOC is subsequently condensed from this gas stream prior to emitting the stream to the environment.
- "VOC-free" waste water exits the bottom of the column.

Advantages

- Operating temperatures are lower than steam stripping which may protect sensitive column internals or reduce compound degradation from these high temperatures.
- More effective for VOC's with higher volatility (lower boiling point).
- Preventive maintenance costs are typically low.
- System can usually be easily upgraded to strip greater amounts of VOC's with relatively small increases in capital costs.

Disadvantages

- Maximum allowable concentration of VOC in the air exiting the stripper is limited by the Lower Flammability Limit (LFL) of the VOC in exit air stream.

- Exceeding the LFL in the exit air stream may lead to fires and/or explosions in the stripper or the subsequent air handling equipment/condenser.

Steam Stripping

Description

- Wastewater flows into the top of a packed or tray column and is distributed throughout the column.
- Steam flows into the bottom of the column and the VOC is transferred from the wastewater to the steam via direct contact.
- The VOC-laden steam exits the top of the column and the VOC is subsequently condensed with the steam. If the VOC is immiscible in water, the condensate will form an aqueous layer and a solvent layer that can be separated using a decanter. If the VOC is miscible in water, additional distillation can be used to further separate the VOC and water.
- "VOC-free" wastewater exits the bottom of the column.

Advantages

- A widely used technology with well known operating characteristics.
- Operating temperatures are higher than air stripping, which presents a generally more favorable equilibrium relationship.
- More effective for VOC's with lower volatility (higher boiling point).
- Can remove a wider range of VOC's.
- Allows a wider range of removal levels.

Disadvantages

- Higher operating temperatures than air stripping may accelerate equipment and/or compound degradation.
- Some steam will condense and add to the hydraulic load of the system.

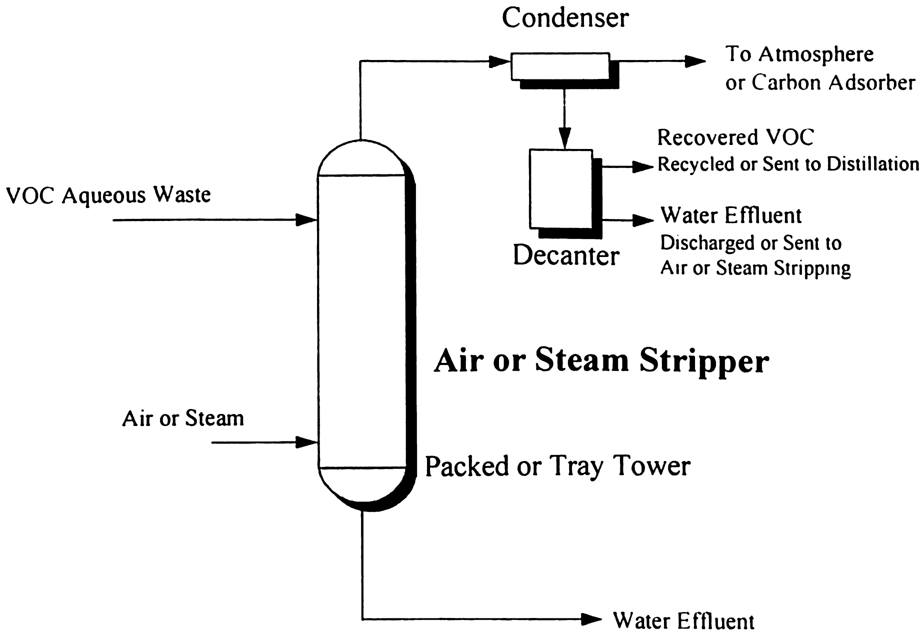


Figure 1.1
A Schematic Representation of an Air or Steam Stripping Process for VOC Aqueous Wastes

Activated Carbon Adsorption

Description

- Wastewater flows into the top or bottom of an adsorption column, filled with porous activated carbon, and is distributed throughout the carbon bed.
- Carbon adsorption beds can be fixed or moving, with respect to the carbon. For moving beds, the flow of activated carbon is countercurrent to the flow of the wastewater; however, fixed beds are more common in industry.
- The VOC is adsorbed onto the surface of the activated carbon and onto the surface of the pores. At some point the carbon becomes saturated with VOC and loses its capacity for additional adsorption. When this occurs the carbon must be regenerated for re-use or replaced with virgin carbon.
- Multiple fixed beds are generally employed so that as one or more beds are adsorbing at least one bed can be regenerating. Regenerating a bed of activated carbon typically involves the direct injection of steam, hot nitrogen or hot air to the bed which causes the VOC to release from the carbon and exit the bed via a vapor or steam condensate stream. The regenerated stream, containing a higher concentration of the VOC than the original wastewater stream, is subsequently condensed. If the VOC is immiscible in water, the condensate will form an

aqueous layer and a solvent layer that can be separated using a decanter. If the VOC is miscible in water, additional distillation can be used to further separate the VOC and water.

- "VOC-free" wastewater exits the adsorber after the contact with the activated carbon.

__Advantages__

- A widely used technology with well established performance levels.
- Can be used for low concentration inlet streams.
- Can achieve high removal efficiencies.
- Can efficiently handle fluctuations in wastewater flow rates and VOC concentrations.

__Disadvantages__

- Higher complexity of operation than other technologies.
- Larger space requirements than other technologies.
- Water adsorption lowers the VOC adsorption capacity.
- Exceeding the Lower Flammability Limit (LFL) in the exit regeneration stream (when using air regeneration) may lead to fires and/or explosions in the adsorber or the subsequent air handling equipment/condenser.

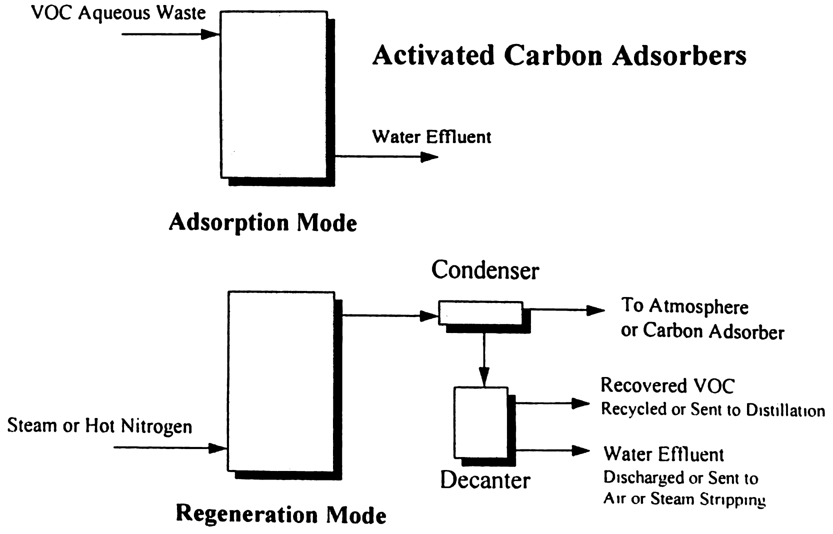


Figure 1.2
A Schematic Representation of a Carbon Adsorption Process for VOC Aqueous Wastes

__Liquid-Liquid Extraction__

__Description__

- Liquid-liquid extraction involves the separation of VOC's by contact with another liquid (solvent) in which the VOC's are more soluble.

- Extraction solvent selection is based on:
    - selectivity (ability of the solvent to extract much of the VOC but very little of the water)
    - ease of regeneration (ability to separate the VOC from the extraction solvent, typically using distillation)
    - low miscibility with the feed solution (the extraction solvent should not transfer to the exiting wastewater stream)
    - significant density difference between the extraction solvent and the wastewater feed (aqueous and organic phases are generally separated by settling)
    - moderate interfacial tension (impacts mixing capabilities)
    - low viscosity (<10 cps minimizes resistance to mass transfer)
    - low flammability and toxicity
    - low cost and ready availability
- Separation of the solvent-VOC waste can be handled via air stripping, steam stripping, distillation, or additional liquid-liquid extraction.
- Separation of the exiting wastewater stream can occur via air stripping, steam stripping, activated carbon adsorption or biological treatment.
- Process efficiency can be increased by increasing the flowrate of solvent to wastewater or by increasing the number of extraction stages.

Advantages

- Generally, liquid-liquid extraction is easy to operate.
- Capital costs are relatively low; however, if additional separation (distillation) of exiting streams is required capital cost generally increases by a factor of 8-10 and operating costs increase by a factor of 20.
- Can be used for heat sensitive materials.
- Can be used to separate close-boiling mixtures, such as isomers.

Disadvantages

- VOC gaseous emissions may occur from the extraction unit.
- Energy costs are high.
- Additional treatment (distillation) of streams leaving the extraction unit is generally required.

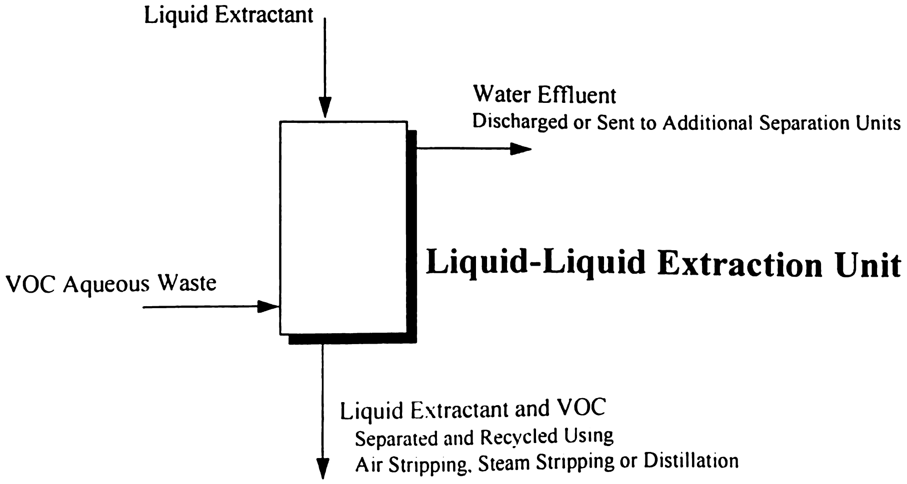


Figure 1.3
Schematic Representation of a Liquid-Liquid Extraction Process for VOC Aqueous Wastes

Pervaporation

Description

- Pervaporation (a technology that combines permeation and evaporation) is a membrane-based process that operates on the principle of selective permeation of a VOC through the membrane.
- For VOC removal from wastewater, a hydrophobic (organophilic) membrane (typically a rubbery polymer) is required.
- Feed streams to pervaporation membranes are typically preheated. The warm wastewater feed enters the membrane housing at a high pressure and the VOC (and some water) preferentially permeates to the low pressure side of the membrane. As the VOC (referred to as the permeate) goes from high pressure to low pressure it flashes to the vapor state and a condensation process (typically using chilled water) is used to condense the VOC.
- "VOC-free" wastewater (referred to as the retentate) exits the high pressure side of the membrane.

Advantages

- Organics can be concentrated 10 to 50 times higher than in the original wastewater stream.
- Systems are modular and compact.
- Efficient at low VOC inlet concentrations (100-5000 ppm).
- Less energy intensive than reverse osmosis.

- Can be used to separate close-boiling or azeotropic compounds.

Disadvantages

- Restricted to smaller flow rates (<15 gpm).
- Membrane fouling may occur.
- Although a proven technology, no large scale industrial uses currently exist.

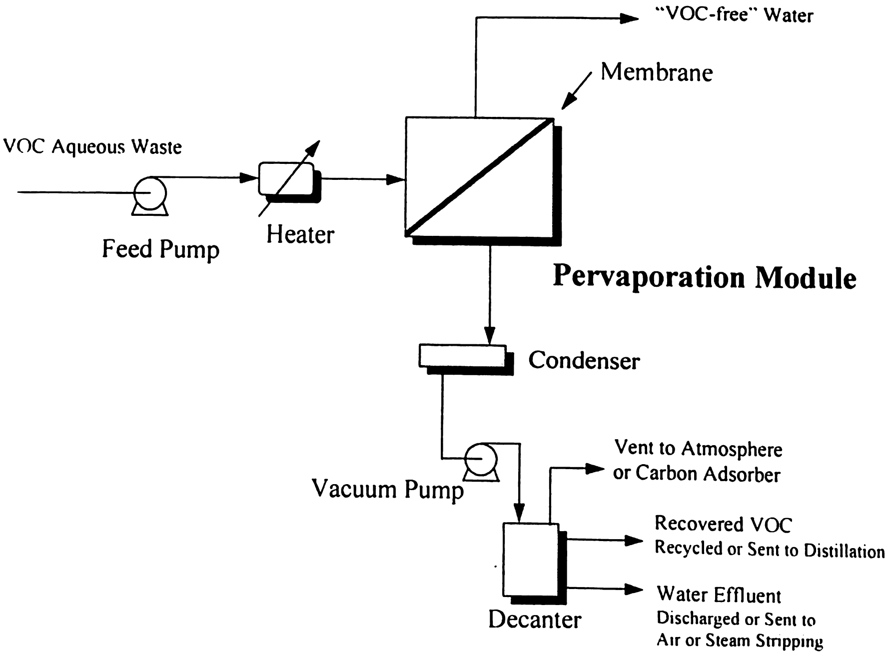


Figure 1.4
A Schematic Representation of a Pervaporation Process for VOC Aqueous Wastes

Reverse Osmosis *Description*

- Reverse Osmosis is a membrane-based process that operates on the principle of selective permeation of a VOC through the membrane. Unlike pervaporation, no phase change occurs across the membrane and the water permeates from the feed side of the membrane to the permeate side of the membrane.
- Wastewater streams fed to reverse osmosis membranes enter the

membrane housing at a high pressure and the water (and some VOC) preferentially permeates to the low pressure side of the membrane.

- "VOC-free" wastewater (referred to as the permeate) exits the low pressure side of the membrane.
- The "reject" stream exits the high pressure side of the module and contains a higher concentration of VOC than the initial wastewater stream. This stream can be disposed of or distilled for further VOC recovery.

Advantages

- Generally compact in size; therefore, a reverse osmosis system can be easily added to existing plant operations.
- Flexibility of adding modules or bypassing modules can accommodate surges in wastewater loads and/or concentrations.

Disadvantages

- Fouling of membranes may occur.
- Can not be used on streams with a high osmotic pressure.
- May require additional treatment of the reject stream to purify the VOC to levels acceptable for reuse in the plant.

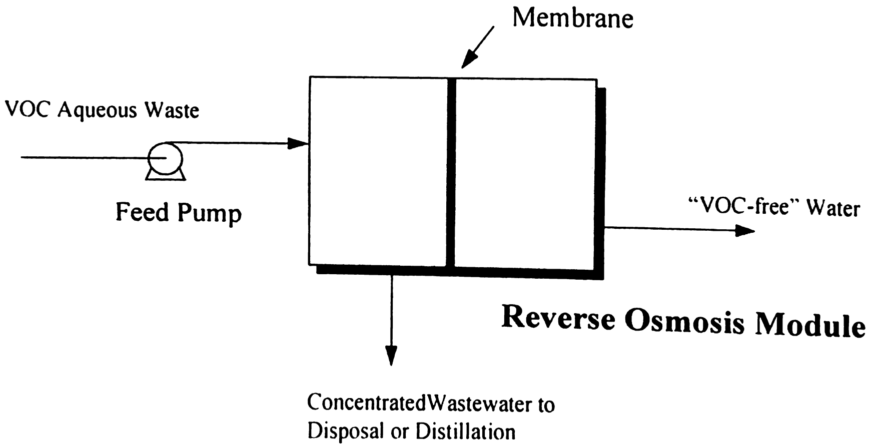


Figure 1.5
A Schematic Representation of a Reverse Osmosis Process for VOC Aqueous Wastes

1.4 VOC SEPARATION SYSTEMS FOR GASEOUS WASTES

Similar to the recovery of aqueous VOC wastes, several technologies exist that can be used for recovering VOC's from gaseous wastes. The most widely used technologies for recovering VOC's from gaseous wastes are liquid absorption using heavy oils/hydrocarbons, activated carbon adsorption, and condensation using coolants/refrigerants. In addition, recently developed membrane-based technologies can be used in conjunction with one of the above technologies to improve system efficiency and/or overall operating. The following is a summary of these technologies, a description of the technology, and some advantages and disadvantages of these technologies. Additional information and modeling equations of these mass transfer operations can be found in literature such as McCabe et al. (1993), Perry and Green (1984), Geankoplis (1983), Henley and Seader (1981), King (1980), and Treybal (1980).

VOC Recovery Technologies for Gaseous Wastes

Absorption

Description

- VOC gaseous emissions flow into the bottom of a packed or tray column and is distributed throughout the absorption column.
- A heavy oil/hydrocarbon flows into the top of the column and the VOC is transferred (an amount based on solubility levels) from the gas to the oil via direct contact, thus, the airstream is "scrubbed".
- The VOC/oil mixture exits the bottom of the column and is subsequently distilled to allow separation of the VOC and the oil.
- "VOC-free" gas exits the top of the column.

Advantages

- Can achieve high recovery efficiencies (95-98%).
- Can be used for a wide range of gas flow rates (2,000-100,000 cfm).
- Can handle a wide range of inlet VOC concentrations (500-5,000 ppm).
- Good for high humidity (>50% r.h.) air streams.

Disadvantages

- May result in the generation of a wastewater stream.
- May result in column packing plugging or fouling if particulates are present in the gaseous waste stream.
- Some of the liquid absorbent may be transferred to the exit gas stream, thus creating a new pollution concern.

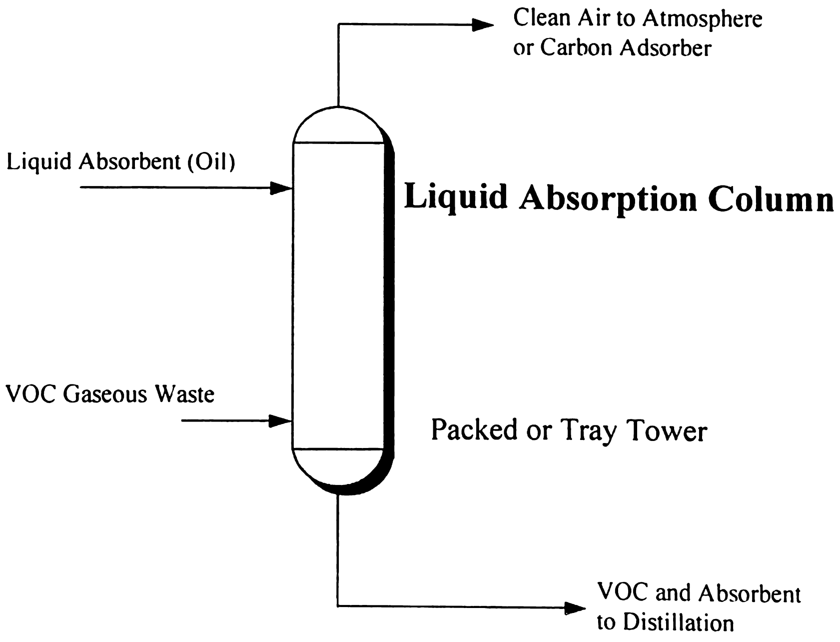


Figure 1.6
A Schematic Representation of an Absorption Process for VOC Gaseous Wastes

Activated Carbon Adsorption

Description

- VOC gaseous emissions flow into the top or bottom of an adsorption column, filled with porous activated carbon, & is distributed throughout the carbon bed.
- Two adsorption processes exist, temperature-swing adsorption (TSA) and pressure-swing adsorption (PSA). Temperature-swing adsorption is the approach commonly used for VOC recovery and the process description, advantages, and disadvantages listed in this section correspond to the temperature-swing adsorption process.
- Carbon adsorption beds can be fixed or moving, with respect to the carbon. For moving beds, the flow of activated carbon is countercurrent to the flow of the gas; however, fixed beds are more common in industry.
- The VOC is adsorbed onto the surface of the activated carbon and onto the surface of the pores. At some point the carbon becomes saturated with VOC and loses its capacity for additional adsorption. This results in the concept of "breakthrough" where significant quantities of VOC become apparent in the gas stream exiting the adsorption process. When this occurs the carbon must be regenerated for re-use or replaced with virgin carbon.
- Multiple fixed beds are generally employed so that as one or more beds are adsorbing at least one bed can be regenerating. Regenerating a bed of activated carbon typically involves the direct injection of steam, hot nitrogen or hot air to

the bed which causes VOC to release from the carbon & exit the bed via a vapor or condensate stream. The regenerated stream, containing a higher concentration of the VOC than the original wastewater stream, is subsequently condensed. If the VOC is immiscible in water, the condensate will form an aqueous layer & a solvent layer that can be separated using a decanter. If the VOC is miscible in water, additional distillation can be used to further separate the VOC & water.

- "VOC-free" gas exits the adsorber after contacting the activated carbon.

Advantages

- A widely used technology with well established performance levels.
- Can achieve high recovery efficiencies (90-98%).
- Can be used for a wide range of gas flow rates (100-60,000 cfm).
- Can handle a wide range of inlet VOC concentrations (20-5,000 ppm).
- Can efficiently handle fluctuations in gas flow rates and VOC concentration.

Disadvantages

- VOC having high adsorption heats (typically ketone) can cause carbon bed fires.
- Carbon attrition properties (permanent bonding of small quantities of VOC through each adsorption cycle) require the periodic replacement of carbon with virgin or reactivated carbon. Spent carbon may need to be disposed of as a hazardous waste depending on the VOC(s) adsorbed.
- Carbon efficiency decreases for high humidity (>50% r.h.) air streams.

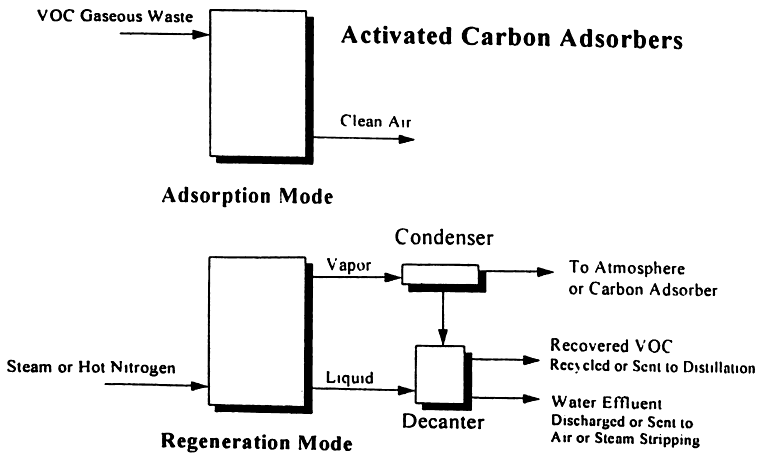


Figure 1.7
A Schematic Representation of a Carbon Adsorption Process for VOC Gaseous Wastes

Condensation

Description

- VOC gaseous emissions are cooled below the stream dew point to condense the stream VOC.
- Cooling occurs in indirect-contact heat transfer equipment (i.e. shell and tube heat exchangers, finned heat exchangers, etc.)
- Cooling mediums are usually cooling water, chilled water, and refrigerants.
- The cooling medium is recycled, re-cooled, and reused for additional VOC condensation.
- "VOC-free" gas exits the condenser.

Advantages

- Can achieve moderate recovery efficiencies (50-90%).
- Simple process that does not require contacting the VOC gas stream with other streams (i.e. oils, activated carbon), thus, minimizing contamination concerns.
- Efficiency improves as VOC concentration in inlet gas increases.
- Good for low volatility (high boiling point) VOC's.

Disadvantages

- May result in the generation of a wastewater stream.
- May require inert gas blanketing if inlet gas exceed the UEL to eliminate explosion hazards.
- The liquid produced via condensation may require treatment for water removal or may require additional separation (typically distillation) if multiple VOC are recovered.
- Cryogenic temperatures may be necessary and special equipment designs for these temperatures will be required.
- Condensation is typically used for low- to moderate inlet gas flow rates (<20,000 cfm).
- Extensive cooling is required for low concentration VOC gaseous streams.
- Ice formation in heat transfer equipment may occur.

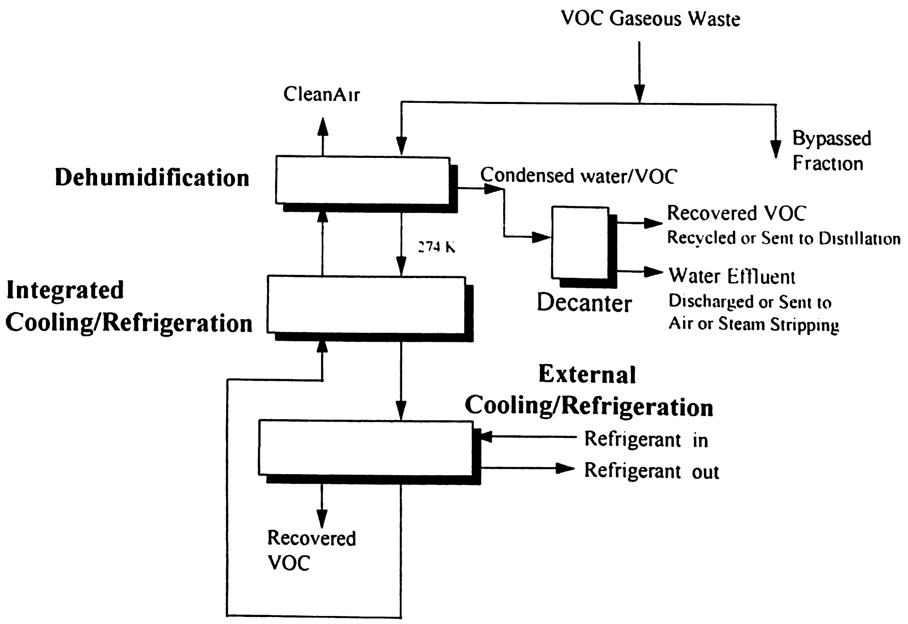


Figure 1.8
A Schematic Representation of a Condensation Process for VOC Gaseous Wastes

Condensation-Hybrid

Description

- Pressurization of the gaseous VOC stream is used to enhance condensation effectiveness.
- De-Pressurization is used for energy recovery.
- VOC gaseous emissions are cooled below the stream dew point to condense the stream VOC.
- Cooling occurs in indirect-contact heat transfer equipment (i.e. shell and tube heat exchangers, finned heat exchangers, etc.)
- Cooling mediums are usually cooling water, chilled water, and refrigerants.
- The cooling medium is recycled, re-cooled, and reused for additional VOC condensation.
- “VOC-free” gas exits the condenser.

Advantages

- Can achieve higher recovery efficiencies (>90%) than conventional condensation processes.
- Simple process that does not require contacting the VOC gas stream with other streams (i.e. oils, activated carbon), thus, minimizing contamination concerns.
- Efficiency improves as VOC concentration in inlet gas increases.

- Efficiency improves as inlet gas pressure increases.
- Good for low volatility (high boiling point) VOC's.
- Improves effectiveness for high volatility (low boiling point) VOC's.
- Cryogenic temperatures may not be necessary.

Disadvantages

- May result in the generation of a wastewater stream.
- May require inert gas blanketing if inlet gas exceed the UEL to eliminate explosion hazards.
- The liquid produced via condensation may require treatment for water removal or may require additional separation (typically distillation) if multiple VOC are recovered.
- Condensation is typically used for low to moderate inlet gas flow rates (<20,000 cfm).
- Extensive cooling or high pressurization is required for low concentration VOC gaseous streams.

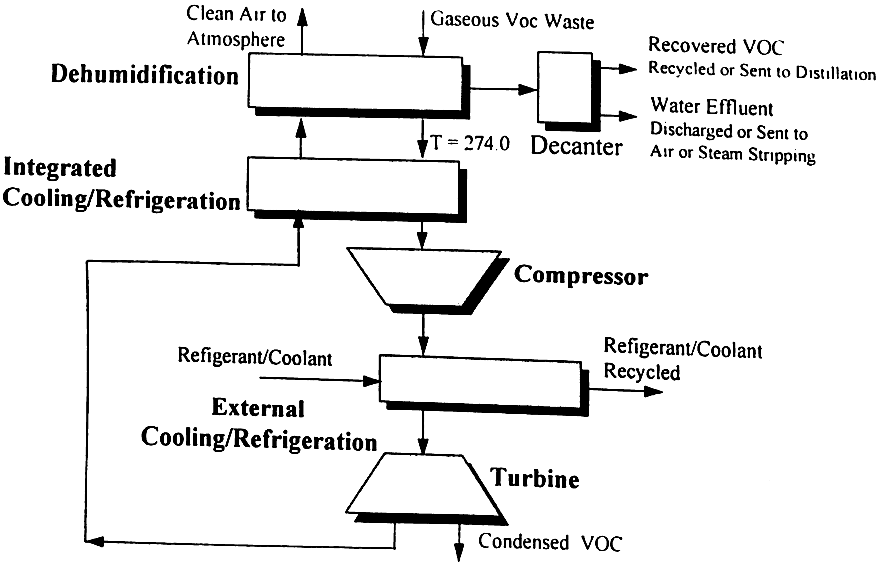


Figure 1.9
A Schematic Representation of a Condensation-Hybrid Process for VOC Gaseous Wastes

Membrane Separation

Description

- VOC gaseous emissions are concentrated using organic selective (VOC permeable) membranes.
- Air and VOC's permeate through the membrane at rates determined by their relative permeabilities and the pressure difference across the membrane.

- Membranes are typically 10 to 100 times more permeable to VOC's than air, depending on the specific VOC's under evaluation
- Based on the system design, the exit membrane stream VOC concentration can be increased five to fifty times the inlet membrane stream concentration.
- Concentrated gas streams are then compressed (typically to pressures between 45 and 200 psig) followed by the use of conventional condensation technology.

Advantages

- Can achieve high recovery efficiencies when combined with condensation (>90%) without operating at cryogenic temperatures.
- Can allow efficient recovery of high volatility (low boiling point) VOC's.
- Can efficiently handle low concentration gaseous emission streams.

Disadvantages

- Membranes may require annual replacement due to fouling.
- Typically used on high concentration (>10,000 ppm) inlet gas streams.
- Generally not cost effective for high flow rate gas streams.
- New technology with little industrial implementation knowledge.

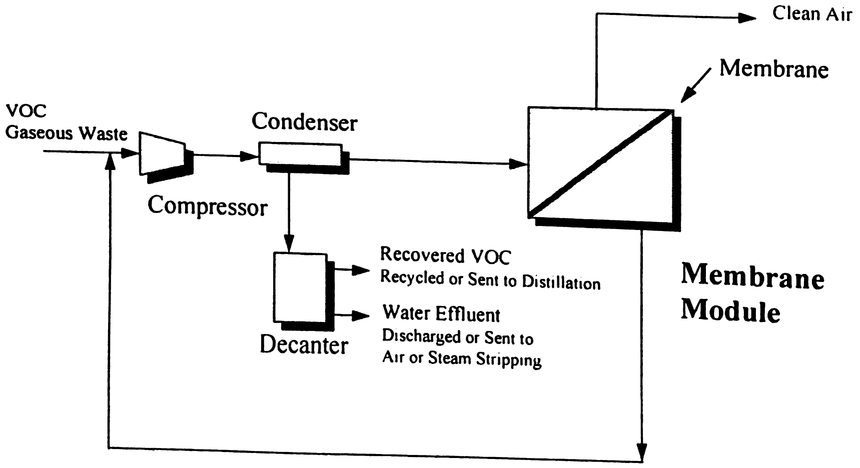


Figure 1.10
A Schematic Representation of a Membrane-Hybrid Process for VOC Gaseous Wastes

1.5 FLAME ARRESTORS

1.5.1 FLASHBACK PREVENTION METHODS

Enrichment –

By adding natural gas or other hydrocarbon, the mixture can be brought above the UEL, preventing combustion.

Dilution –

By adding inert such as N_2 or CO_2, the mixture can be brought to a nonflammable state.

DESIGN CRITERIA

Velocity –

Flames progress at a defined rate through a flammable mixture. For instance, the "maximum flame velocity" of a methane/air mixture is 1.48 ft/sec under lab conditions. If this mixture flows through a pipe at 1.5 ft/sec, any flame will be unable to propagate against the flow [4]. This fact is used in designing flame arrestors – by designing for gas velocity above the flame velocity, the flame can be prevented from moving upstream from the point of ignition. NOTE: as a flame front moves through a vessel or pipe, the flame velocity increases. With long enough piping the velocity can increase to detonation levels, which are supersonic.

1.5.2 FLASHBACK INTERRUPTION METHODS

Many methods to stop flashbacks have been devised. "Active" methods require maintenance of certain parameters, such as liquid level or gas velocity. "Passive" methods require only routine inspection and typically have no moving parts or instrument requirements.

Venturi Type Flame Arrestors (active) –

Venturi flame arrestors simply create a restriction in the hydrocarbon/air mixture delivery pipe so that the gas velocity is faster than the flame speed, preventing progression of a flashback upstream. Flashbacks in the direction of flow can still happen. Even a partly closed valve can create a high velocity for flashback prevention, but a venturi shape creates much lower pressure drop. If gas flow stops, the venturi is no longer effective, so methods to measure flow and add makeup gas (nitrogen, for instance) are often included. A venturi arrestor must be located close to the point of ignition to avoid problems.

Inline flame arrestors (passive) –

Mechanical flame arrestors are filled with metal or ceramic, which absorbs heat from a flashback, quenching it to a temperature below what is needed for ignition. This stops the flame. With a low enough hydrocarbon/air mixture flow rate, if a flame travels to the face of the arrestor, it can become stable at that point. Heating of the arrestor body and internals results. Once the arrestor temperatures increase enough, ignition temperature can be reached on the upstream side of the arrestor and the flashback can proceed. For this reason, a temperature switch is often installed on the flame side of each arrestor (adding an "active" element). If an elevated temperature is detected, an alarm sounds and steps can be taken to stop flow completely [5].

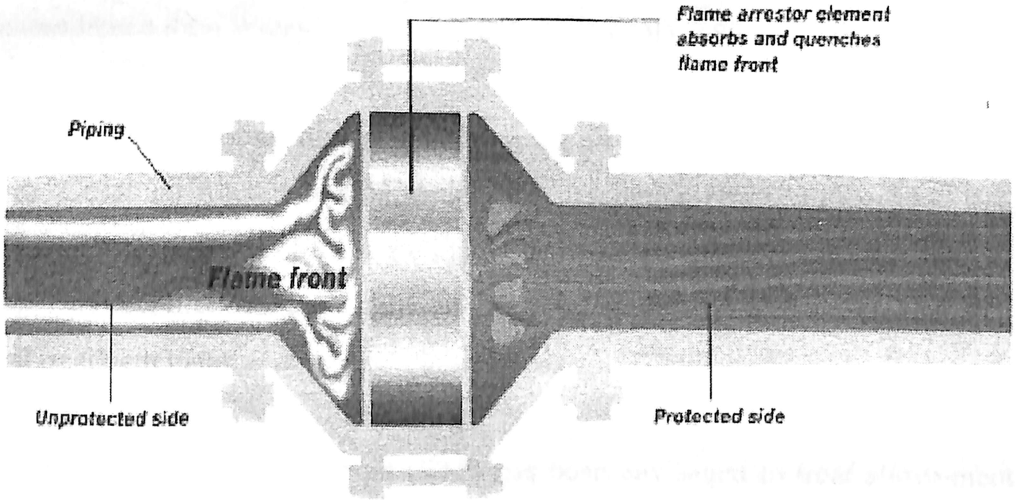


Figure 1.11
A Mechanical Flame Arrestor

2.0 PROCESS DESCRIPTION / TREATMENT PHILOSOPHY

Volatile Organic Compounds "VOC's" are among the most important chemicals used in and emitted from the process industries. Due to the significant economic and environmental implications of disposing of VOC's, much attention has been recently directed towards pollution-prevention techniques aimed at reducing VOC emissions from industrial facilities in a cost-effective manner. This report addresses VOC pollution prevention and control methodologies, which should be adopted in a refinery in Indian context. This report is prepared by considering the type of crude our refinery processes and VOC emissions occur from an effluent treatment plant.

2.1 VOCs GENERATED FROM REFINERY's EFFLUENT TREATMENT PLANT

Refining of crude is a complex process, which involves physical separation of products on the basis of difference in their boiling points. The principal contaminants in different effluent streams include the following:

Stream Description	Principal Contaminants
Process (Oily) Effluents	Oil, BOD/COD, TSS, Phenols, Sulfides
Spent Caustic	Sulfides, Phenols, BOD/COD, Oil
Contaminated Rain Water	Oil, BOD/COD, TSS

Out of the above-mentioned contaminants, oil is one of the major sources of VOC emission. Crude oil when subjected to different distillation processes produces ranges of organic compounds. Some of them are lighter and volatile and others are heavier and non-volatile. This report concentrates only on Volatile compounds which are emanating from Effluent treatment plant.

An Effluent Treatment Plant (ETP) has been envisaged to treat above-mentioned effluent streams. The ETP shall broadly consist of the following sections/treatment units:

- Oil Removal Section consisting of API, TPI & DAF

- Biological Treatment Section consisting of SBR & MBR
- Oily & Chemical Sludge Handling System
- Recovered slop oil handling system

Units which are expected to generate VOCs in the Effluent Treatment Plant include the following:

- Inlet collection system (Closed Drains & OWS Sump)
- API Separators
- TPI Separators
- Flash Mixing Tanks
- Flocculation Tanks
- Dissolved Air Flotation Tanks
- Slop Oil Sump

Typical VOCs which are expected to be generated from these units include the following:

- Propanone (acetone)
- Ammonia
- Benzene
- Benzotrichloride
- Hexane (-n)
- Heptane(-n)
- Octane(-n)
- Hydrogen Sulfide
- Methanethiol (methyl mercaptan)
- Butanone (methyl ethyl ketone, MEK)
- Oil (decane as surrogate)
- Phenol
- Toluene
- Xylene
- Ethanethiol (ethyl mercaptan)

2.2 DESCRIPTION OF THE UNITS IN THE EFFLUENT TREATMENT PLANT

OWS INFLUENT SUMP

PURPOSE: Collection of influent waste water.

API SEPARATORS

Separators designed to API standards, commonly known as API separators, are considered to be the optimum means for simple gravity oil/water separation. The design principles involved (avoidance of short-circuiting, avoidance of turbulence, provision of adequate separation time, and optimized skimming) are applicable to all gravity separators, but the term is usually reserved for large in–ground or above-ground field-constructed units and is more common in facilities such as refineries which have high wastewater flow rates.

TILTED PLATE INTERCEPTOR (TPI)

Parallel plate separators, or Corrugated Plate interceptors / Tilted Plate interceptors (commonly known as CPI & TPI respectively), are made of inclined stacks of corrugated metal or plastic sheets. In addition to providing stiffening, the corrugations are claimed to promote oil coalescence and channelling in the upwardly convex sections of the plates. The Efficiency of an oil water separator is inversely proportional to the ratio of its discharge rate to the unit's surface area.

FLOCCULATION TANK

PURPOSE: Flocculation / Mixing of chemicals.

DISSOLVED AIR FLOTATION (DAF)

Dissolved Air Floatation, commonly called DAF, is based on the principle that gases dissolved in a liquid at high pressure will come out of solution as microscopic gas bubbles when the pressure is released; the principle can be seen when carbonated beverages are opened. In a DAF, water is saturated with compressed air at about 40-50 psi in a saturation chamber, and then sent through a letdown valve into the separation chamber.

There are two types of DAF; in the first type, the entire water stream is saturated with air and passed through the unit. In the second type, a portion (15/20 percent) of the de-oiled effluent water is recycled back through the air saturation chamber, and mixed with the main water stream after the pressure release.

2.3 STATUTORY STANDARDS FOR VOC EMISSIONS FROM WASTEWATER COLLECTION AND TREATMENT

- All contaminated and odorous wastewater streams should be handled in closed systems from the source to the primary treatment stages (oil-water separator and equalization tanks).

- The collection system should be covered with water seals (traps) on sewers and drains and gas tight covers on junction boxes.

- Oil-water separators and equalization tanks should be provided with floating/fixed covers. The off-gas generated should be treated to remove at least 90% of VOC and eliminate odor. The system design should ensure safety (prevention of formation of explosive mixture, possible detonation and reduce the impact) by dilution with air/inert gas, installing LEL detector including control devices, seal drums, detonation arrestors, etc. The system should be designed and operated for safe maintenance of the collection and primary treatment systems.

- Wastewater from aromatics plants (benzene and xylene plants) should be treated to remove benzene/aromatics to a level of 10/20 ppm before discharge to effluent treatment system without dilution.

2.4 PROCESS DESCRIPTION / TREATMENT PHILOSOPHY

Facilities are provided for Handling of Volatile Organic Compounds (VOC) in terms of their collection from oil-handling units, routing to centralized VOC handling facilities and treatment in Package units to meet the VOC emission norms as per statutory standards

In order to design a system for VOC control using any of the previously described technologies, it is necessary to determine equilibrium data for the technology considered. Accurate experimental results provide the most reliable source for equilibrium data. If not available, empirical correlations for predicting equilibrium data may be invoked. These correlations are particularly useful at the conceptual-design stage. Several literature sources provide compilations of equilibrium data and correlations. Examples of these sources include Lo et al. (1983) as well as Francis (1964) for solvent extraction, Reid et al. (1977) for vapor-liquid and liquid-liquid systems, Breton et al. (1988) for liquid extraction, carbon adsorption and air stripping, Hwang et al. (1992) for steam stripping, Mackay and Shiu (1981), Fleming (1989), Clark et al. (1990) and Yaws (1992) for air stripping, US EPA (1980), Perrich (1981), Valenzuela (1989), Stenzel and Merz (1989) and Stenzel (1993) for adsorption.

For the present case carbon adsorption system is considered for the control and treatment of VOC based on the merit of the system and techno-economic superiority on other systems as narrated in previous sections. The VOC has been estimated based on the USEPA model for estimation of VOCs. System design / sizing calculations have been done based on the VOCs estimated from the USEPA model and the breathing losses or displacement losses account for the volume entering the VOC control system or due to volatility of the compound.

The VOC Control System consists of vents, carrying pipes, valves, ID fans, flame arrestors, carbon filters and a vent to take out harmless air from the system. System is designed for compactness & minimization of operation cost by putting up in the vicinity where VOC emissions are generated.

The system is designed to accommodate the estimated flow rates and concentrations of the system, meet the emission requirement of minimum 90% capture rate, and minimize pressure drop. The quantity of carbon use may vary based on actual operating conditions.

Carbon use rate is estimated based on the compounds present as identified. It is very difficult to estimate the concentrations of various compounds that may appear at a particular time as refinery operations are diversified in nature. Their concentrations may not necessarily be able to be specified in the incoming stream and the same are estimated using chemical formulas and EPA guidelines/programs/model. As a precautionary note, it is emphasized that this data is estimated only and actual operation will vary and may require operational adjustments.

Another area of concern of the carbon adsorption system is that a high concentration level of some VOCs may cause the carbon to generate heat on the bed since the adsorption is an exothermic reaction. This heat may eventually build into a fire. Thus, the quantities of VOC's need to remain below the Lower Explosive Limit (LEL) for the VOC compounds. It may be necessary to use a LEL monitor or other device as suggested to meter the level of VOC's and add dilution air as necessary. As a design precaution, water quenching and temperature measurement at the adsorption system are envisaged.

The presence of higher concentrations of VOCs that may be present will shorten the life of the carbon beds. Carbon needs replenished when the adsorption level drops below 90%. The main unit that is considered to be the largest source of VOC is API separators and inlet sumps beside slop oil recovery system. It has been estimated that in a waste water treatment plant recovery and treatment of VOC emanating from API accounts for minimum 80% of total VOC losses. The design of the system uses the oil as the primary air borne VOC since the oil is taken as 100% on the liquid phase on top of the water. The balance of VOCs is minor concentrations in comparison and consumes low levels of carbon.

For better safety, thermocouple connections are provided in the carbon bed and in the duct or pipe. The pipe length are optimized for best plant layout and system is distributed in such a way that a balanced flow achieved in each of the sub-system. The diameter is sized to maintain a good design velocity at full flow.

The VOC control system design provides the following benefits:

- The system is designed to meet emission control requirements.
- Low air pressure drop thus low operating cost

- ID fans are designed to keep the flow rate in the pipe as required for the estimated concentration of VOC and well below of LEL to improve safety of the system.

- System flexibility to handle normal and minimum flows, pressures and temperatures. Field adjustment may be required.

3.0 VOC EMISSION CALCULATIONS & TREATMENT

- The VOC has been estimated based on the USEPA model for estimation of VOCs. Total VOC emissions from the Effluent Treatment Plant are estimated to be 1.31×10^5 kg/yr. Summary (unit-wise and component-wise) of these emissions along with emission details of each component from each of the unit are incorporated in this report.

- Flow rate & vent sizing calculations have been done based on the breathing losses or displacement losses accounting for the volume entering the VOC control system.

- The fixed Bed Carbon Adsorption for VOC control is designed as per the process requirements. Two (2) Nos. of carbon filters are provided. Each of the carbon beds shall be sized to handle normal flow of Total VOC emissions from the Plant. However, as a safeguard to meet statutory requirements for VOC treatment, one of the filters shall operate as Primary filter. The second filter shall be a standby and brought to service when the other filter gets exhausted. The expected cycle time for replacement of bed is 4-6 months.

- Fixed bed is used to control the VOCs due to the low concentration of VOCs. Easy replacement of carbon makes the fixed bed easy to maintain, especially for lower VOC flow rates. It should be noted that concentrations may vary and if they require more than anticipated carbon use, the carbon may need replaced more often than anticipated. This is dependent on the actual operating conditions.

- Carbon Adsorption is designed to handle the normal flow rate through series and parallel operation based on the VOC concentration. The system may be alternated for longer life of each column simultaneously.

- The major sources for VOC emissions sources have been broken into two Groups. Major polluting source like OWS sump, API, TPI and slop oil sump are grouped together. And other less polluting source like DAF, Flash mixing tank and Flocculation Tank are grouped separately. More over selection of groups have been done to avoid fluctuations in VOC emissions from each source.

- The VOC concentration is estimated and the amount of air added subsequently calculated. The mixture of air and VOC are introduced at the specified temperature. The liquid concentrations of each compound have been used and the partial pressures of each used to develop the concentrations in each gas in the collected air. All soluble compounds have concentrations far below that of oil used at 100% since oil will form a film on the surface. The life of carbon is also directly dependent on the oil presence and resulting concentration of organic carbon in air.

- Sufficient primary air for operation is introduced in the VOC collection system. While the temperature is monitored for safety. the excess air rate shall be field adjusted for best operating cost conservation.

- The airflow rate is calculated based upon the compounds present in the VOC streams. The airflow rate is adjusted in such a way that is never between LEL and HEL. This measurement may be a one time test at start up by which the air is fixed and the point that it is needed the most.

- The carbon beds after 4-6 months are expected to be exhausted and shall be replaced with a fresh one. The supplier of canister system shall be responsible to take back the exhausted carbon.

- As the VOC gas flow rate fluctuates, the controls continue to modulate to maintain the operating condition for improved safety. Pressure transmitters are used to control the pressure by controlling the ID fans.

- There will be occasional requirement of service water @ 15 m^3/hr/canister, in case the temperature of the carbon bed increases. This is provided to control the temperature of carbon bed through sprinkling system.

- The vent pipe of 200 mm diameter shall be made Carbon Steel (CS). The minimum vent length is considered to be 10 m.

FLOW RATE AND LINE SIZING CALCULATIONS

UNIT	OWS SUMP	API	TPI	FLASH MIXER	FLOCULATION	DAF	COVERED DRAIN	
Instantaneous flow from the unit (m3/h)	187.200	300.000	150.000	75.000	75.000	150.000	34.000	
Velocity of fumes (m/s)	5.000	5.000	5.000	5.000	5.000	5.000	5.000	
Calculated vent size (m)	0.115	0.145	0.103	0.073	0.073	0.103	0.049	
Vent size provided (m)	0.150	0.150	0.100	0.100	0.100	0.100	0.100	
Size of slip fit (m)	0.200	0.200	0.150	0.150	0.150	0.150	0.150	
Area for air flow thru slip fit (m2)	0.014	0.014	0.010	0.010	0.010	0.010	0.010	
Velocity of air thru slip fit (m/s)	2.000	2.000	2.000	2.000	2.000	2.000	2.000	
Fresh air flow (m3/h)	98.910	98.910	70.650	70.650	70.650	70.650	70.650	
Total flow of air and H/C (m3/h)	286.110	398.910	220.650	145.650	145.650	228.150	104.650	1529.770
ID FAN CAPACITY PROVIDED								2000
COMMON HEADER SIZE	8	8	6	6	6	6	6	
Blower HP								3.9

4.0 CONTROL PHILOSOPHY

4.1 The VOC from individual units along with the fresh air are collected by a piping network which bring them to the main header. The VOC emissions sources have been broken into two groups. Less polluting sources like DAF, Flash mixing tank and Flocculation Tank are grouped separately. The Major polluting sources like OWS sump, API, TPI and slop oil sump are connected to the main VOC collection header through a separate ID fan (VOC-B-01). VOC emissions from the DAF, Flocculation Tank and Flash mixers are collected separately and connected to the main header. The discharge of the ID fan (VOC-B-01) is also connected to the Main Header.

4.2 Dampener is provided at the discharge header of the ID Fan (VOC-B-02) to control the Draft in the main collection header and the temperature in canisters. Flow indication is also provided in the discharge header of the ID Fan (VOC-B-02).

4.3 The gas collected travels through the pipes, which is designed with pressure drop and velocities as per design requirements. Each of the ID fans is sized accordingly with 20% additional capacity.

4.4 Flame arrestors are provided in the Main header to help protect the upstream equipment in case of detonation.

4.5 Two (2) Nos. of carbon filters are provided. Each of the carbon beds shall be sized to handle normal flow of Total VOC emissions from the Plant. However, as a safeguard to meet statutory requirements for VOC treatment, one of the filters shall operate as Primary. The second filter shall be a standby and brought to service when the other filter gets exhausted.

4.6 The carbon filters are equipped with temperature sensors with associated high and high-high alarms to sense overheating of the Carbon beds and help the operator to take corrective actions. The dampener valve is provided with limit switches and the standby ID Fan shall autostart if the dampener valve is at full open condition. Interlocks have also been provided to initiate the fire suppression system in case the bed temperature exceeds the High-High set value. This condition is one of the rare conditions which may occur due to high level of acetones in the incoming VOC streams. On actuation of the High-High temperature alarm, the quenching valve (SOV) shall open to spray water in the carbon bed to arrest the rise in temperature.

4.7 Precaution shall be taken to avoid any liquid overflow into the collection piping. Low point drains are provided to drain out water from the collection header.

4.8 Differential Pressure transmitter with low and high alarms is provided in the flame arrestor to measure the pressure drop. If the pressure drop becomes significantly high, the flame arrestor's element shall be cleaned / replaced. A bypass across the flame arrestor is provided to facilitate cleaning/ replacement of the flame arrestor.

4.9 Differential Pressure transmitters are also provided in the carbon beds with low and high alarms. If the pressure drop in a bed becomes significantly high, the filter shall be isolated and the standby filter shall be taken in line.

4.10 Hydrocarbon Analyzer is provided in the common header upstream of the carbon beds to measure the VOC entering the beds.

4.11 Hydrocarbon Analyser and CO analyzer is provided in the downstream of the ID Fan to monitor the carbon monoxide (CO) levels before the air is vented out.

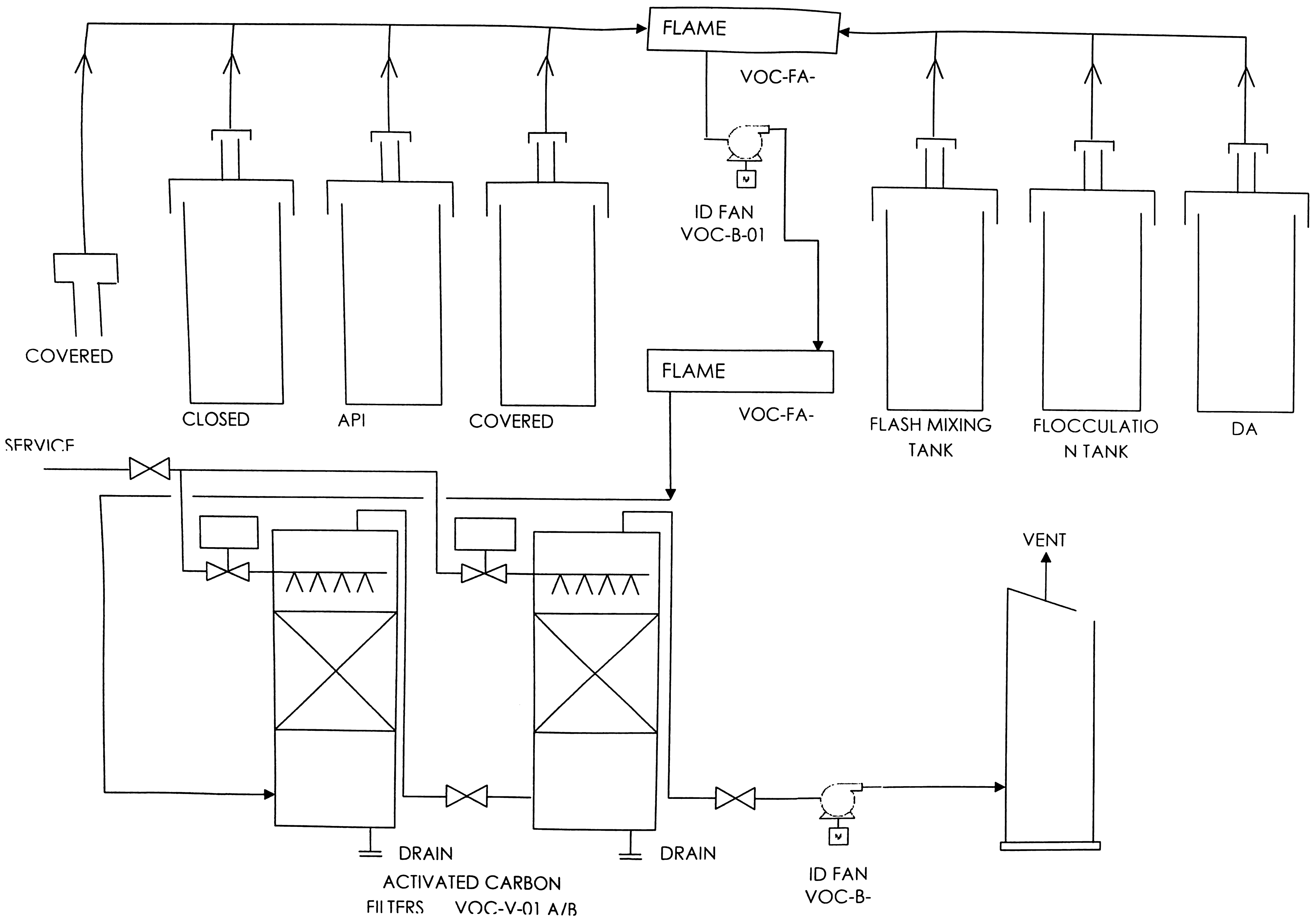
5.0 DATASHEETS

ITEM NO	VOC-FA-01	SERVICE	FLAME ARRESTOR
1	ITEM NO	:	VOC-FA-01
2	LOCATION	:	MAIN HEADER OF OFF GAS FROM OILY UNITS
3	SERVICE	:	TO CHECK BACK FLAME DUE TO H/C IGNITION
4	FLUID	:	HYDROCARBON
5	CONTINUOUS/INTERMITTENT	:	CONTINUOUS
6	MOUNTING	:	HORIZONTAL
7	DISCHARGE TO	:	CANISTER POOL
8	OPERATING TEMPERATURE, DEG C	:	25
9	OPERATING PRESSURE mmWC	:	200
10	DESIGN TEMPERATURE, DEG C	:	65
11	DESIGN PRESSURE(kg/cm2 g)	:	1
12	FLOW RATE, m^3/hr	:	2000
14	ALLOWABLE DIFFERENTIAL PRESSURE	:	25 mmWC
15	MOC		
	SHELL	:	CS + 3mm CA
	BANK	:	SS 304 L

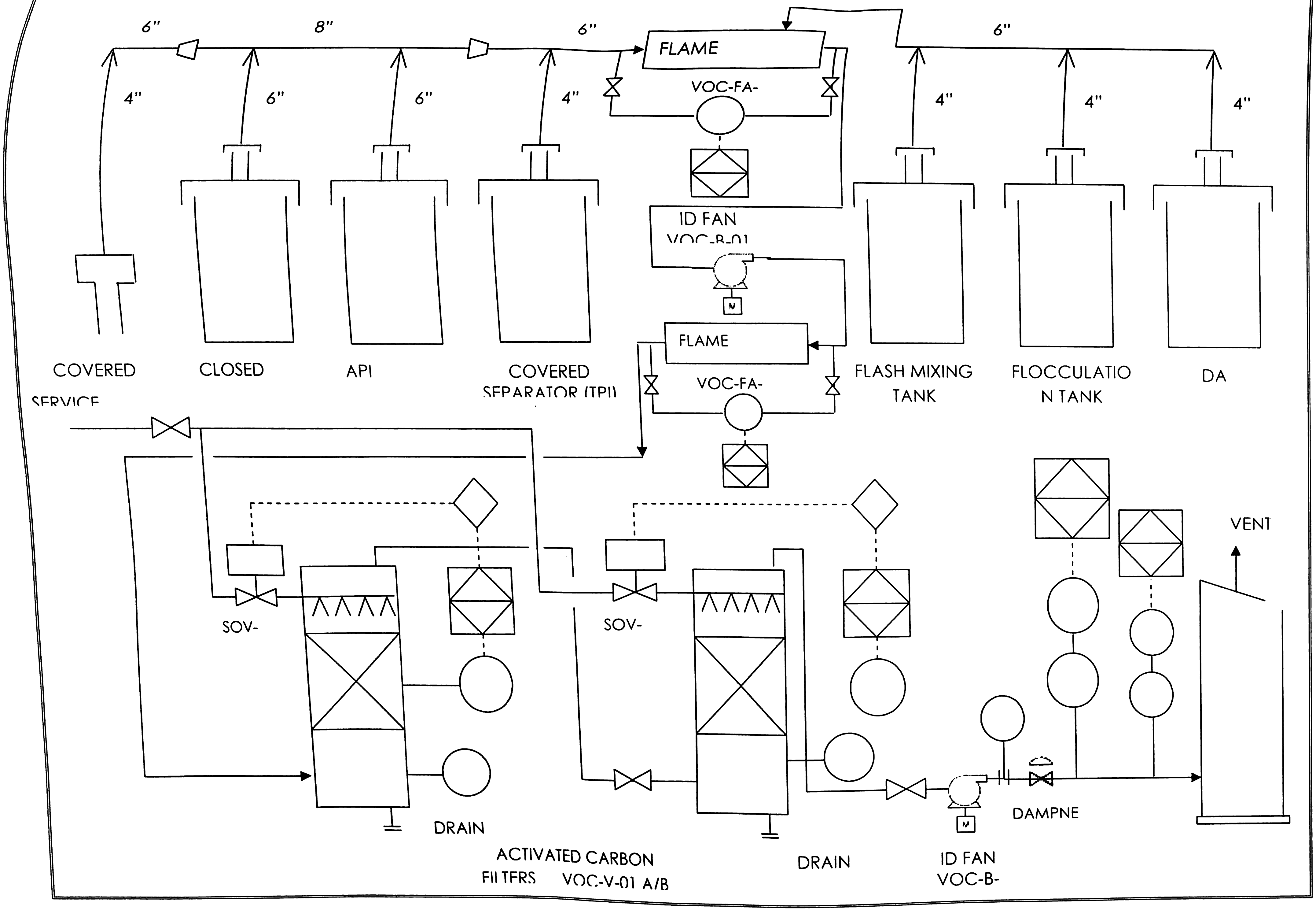
ITEM NO	**ID FAN**	**SERVICE**	**TO CARRY HC VAPORS TO ACF**
1	ITEM NO	:	VOC-B-01, VOC-B-02
2	LOCATION	:	MAIN HEADER OF OFF GAS FROM OILY UNITS AND DOWNSTREAM OF ACF
3	SERVICE	:	TO CARRY HC VAPORS TO ACF
4	FLUID	:	AIR + HYDROCARBON
5	CONTINUOUS/INTERMITTENT	:	CONTINUOUS
6	FLOW RATE m^3/hr	:	2000
7	DENSITY kg/m^3	:	1.3
8	SUCTION TEMPERATURE, DEG C	:	AMBIENT
9	SUCTION PRESSURE mmWC	:	150
10	DUST LOADING, IF ANY	:	NO
11	DISCHARGE PRESSURE	:	200
12	DISCHARGE HEAD mmWC	:	350
13	COMPRESSION RATIO	:	NA
14	NO OF FANS	:	2
15	DESIGN PRESSURE(kg/cm^2 abs)	:	2.5
16	DESIGN TEMPERATURE, DEG C	:	65
17	MOC		
	CASING	:	CI
	FAN	:	SS316
18	DRIVER	:	ELECTRIC MOTOR
19	MOTOR HP	:	4

6.0 DRAWINGS

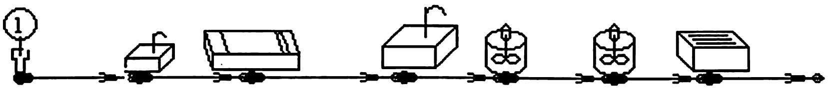
PROCESS FLOW DIAGRAM OF VOC CONTROL SYSTEM



PROCESS AND INSTRUMENTATION DIAGRAM OF VOC CONTROL



7.0 RESULTS AND DISCUSSIONS

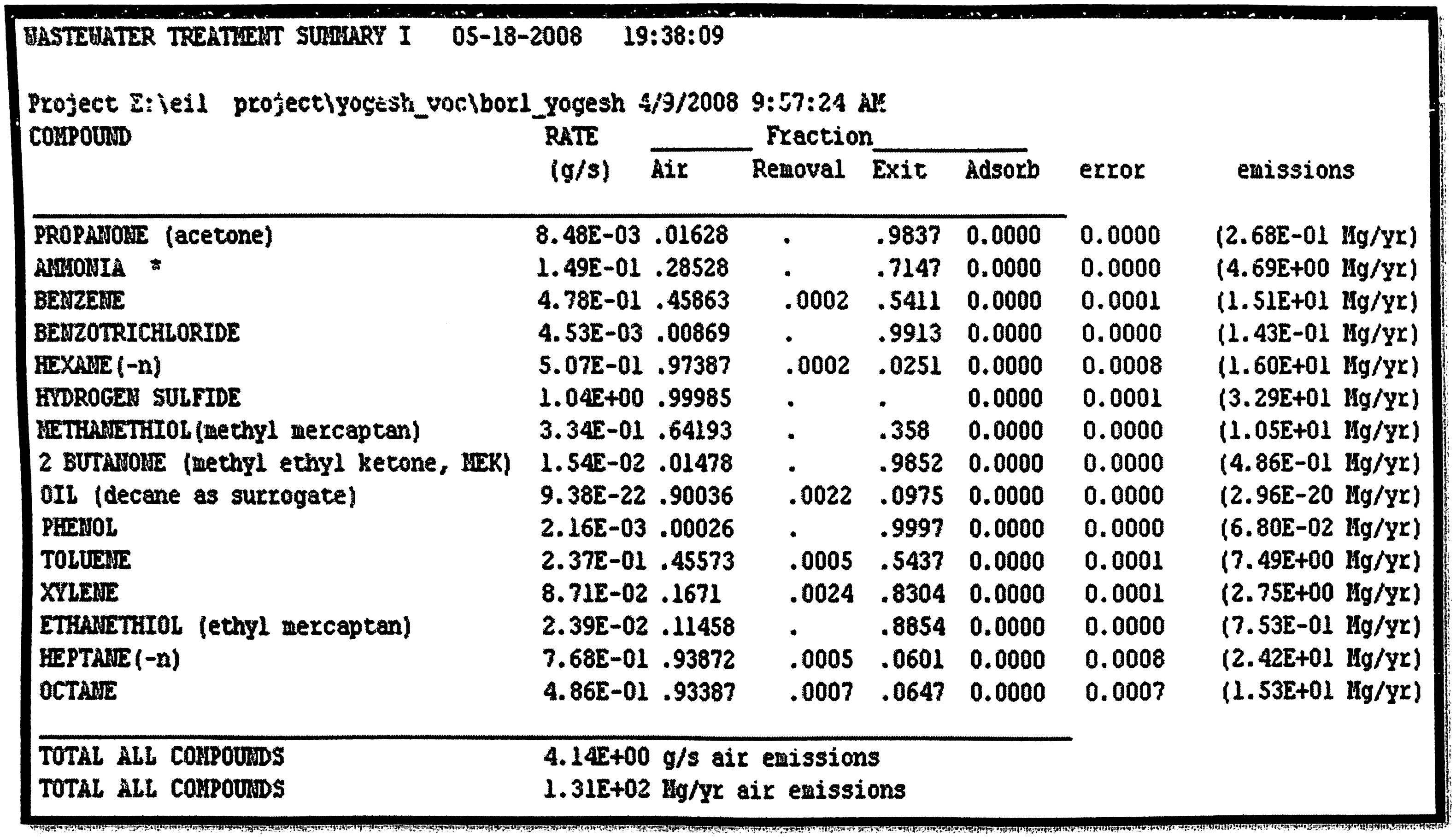


As this report concentrates only on the Volatile compounds which are emanating from Effluent Treatment Plant, the Process Flow Diagram (PFD) in the previous section shows only the VOCs collection in the main header from each unit and its treatment in the activated carbon beds.

Summary (unit-wise and component-wise) of these emissions along with emission details of each component from each of the unit are incorporated in the Annexure.

Input concentrations of compounds in the first unit (covered drain) have been assumed based on the personal experience. Flow rate of influent is assumed to be 104.2 L/s. Properties of each unit involved are set by-default in WATER9 on the basis of which it calculates the emission rate of VOCs. Emission of VOCs depends upon the various physical properties viz. temperature, vapor pressure, solubility of the component in the effluent. More VOCs are emitted from the units involving stirring/agitation.. Emissions from each unit are summed up to get the overall emissions from the whole system.

OVERALL SUMMARY

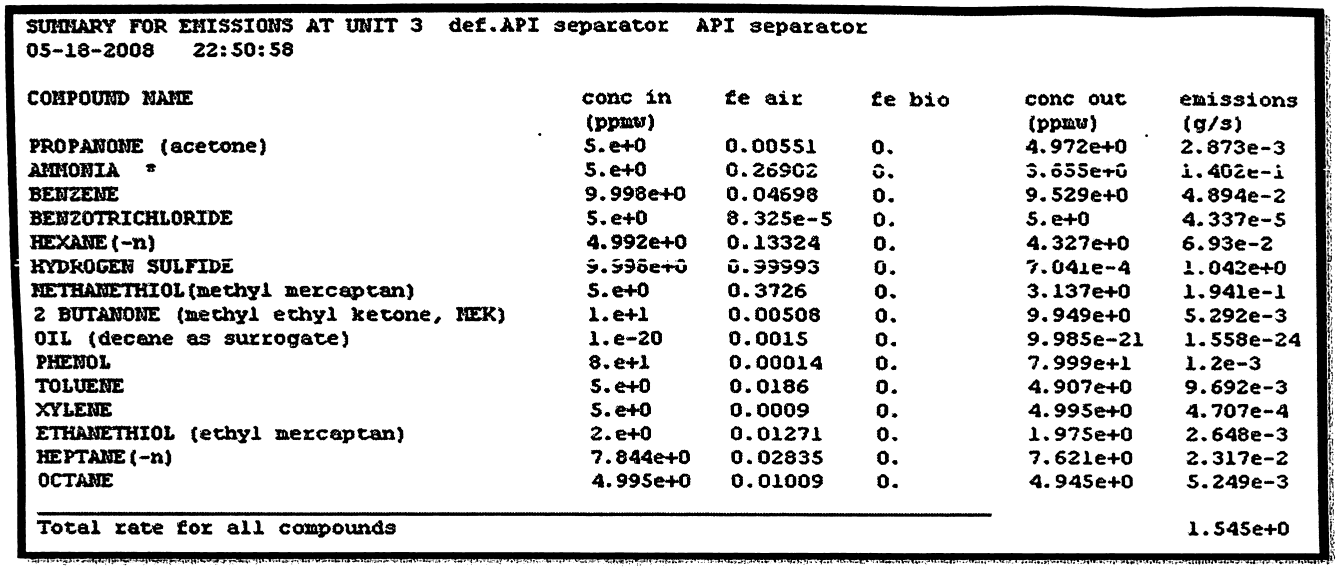


```
WASTEWATER TREATMENT SUMMARY I    05-18-2008    19:38:09

Project E:\eil  project\yogesh_voc\borl_yogesh 4/9/2008 9:57:24 AM
COMPOUND                                RATE    ________ Fraction___________
                                        (g/s)    Air     Removal  Exit   Adsorb    error       emissions
_____________________________________________________________________________
PROPANONE (acetone)                    8.48E-03 .01628     .     .9837  0.0000   0.0000    (2.68E-01 Mg/yr)
AMMONIA  *                             1.49E-01 .28528     .     .7147  0.0000   0.0000    (4.69E+00 Mg/yr)
BENZENE                                4.78E-01 .45863   .0002  .5411  0.0000   0.0001    (1.51E+01 Mg/yr)
BENZOTRICHLORIDE                       4.53E-03 .00869     .     .9913  0.0000   0.0000    (1.43E-01 Mg/yr)
HEXANE(-n)                             5.07E-01 .97387   .0002  .0251  0.0000   0.0008    (1.60E+01 Mg/yr)
HYDROGEN SULFIDE                       1.04E+00 .99985     .       .    0.0000   0.0001    (3.29E+01 Mg/yr)
METHANETHIOL(methyl mercaptan)         3.34E-01 .64193     .     .358   0.0000   0.0000    (1.05E+01 Mg/yr)
2 BUTANONE (methyl ethyl ketone, MEK)  1.54E-02 .01478     .     .9852  0.0000   0.0000    (4.86E-01 Mg/yr)
OIL (decane as surrogate)              9.38E-22 .90036   .0022  .0975  0.0000   0.0000    (2.96E-20 Mg/yr)
PHENOL                                 2.16E-03 .00026     .     .9997  0.0000   0.0000    (6.80E-02 Mg/yr)
TOLUENE                                2.37E-01 .45573   .0005  .5437  0.0000   0.0001    (7.49E+00 Mg/yr)
XYLENE                                 8.71E-02 .1671    .0024  .8304  0.0000   0.0001    (2.75E+00 Mg/yr)
ETHANETHIOL (ethyl mercaptan)          2.39E-02 .11458     .     .8854  0.0000   0.0000    (7.53E-01 Mg/yr)
HEPTANE(-n)                            7.68E-01 .93872   .0005  .0601  0.0000   0.0008    (2.42E+01 Mg/yr)
OCTANE                                 4.86E-01 .93387   .0007  .0647  0.0000   0.0007    (1.53E+01 Mg/yr)
_____________________________________________________________________________
TOTAL ALL COMPOUNDS                    4.14E+00 g/s air emissions
TOTAL ALL COMPOUNDS                    1.31E+02 Mg/yr air emissions
```

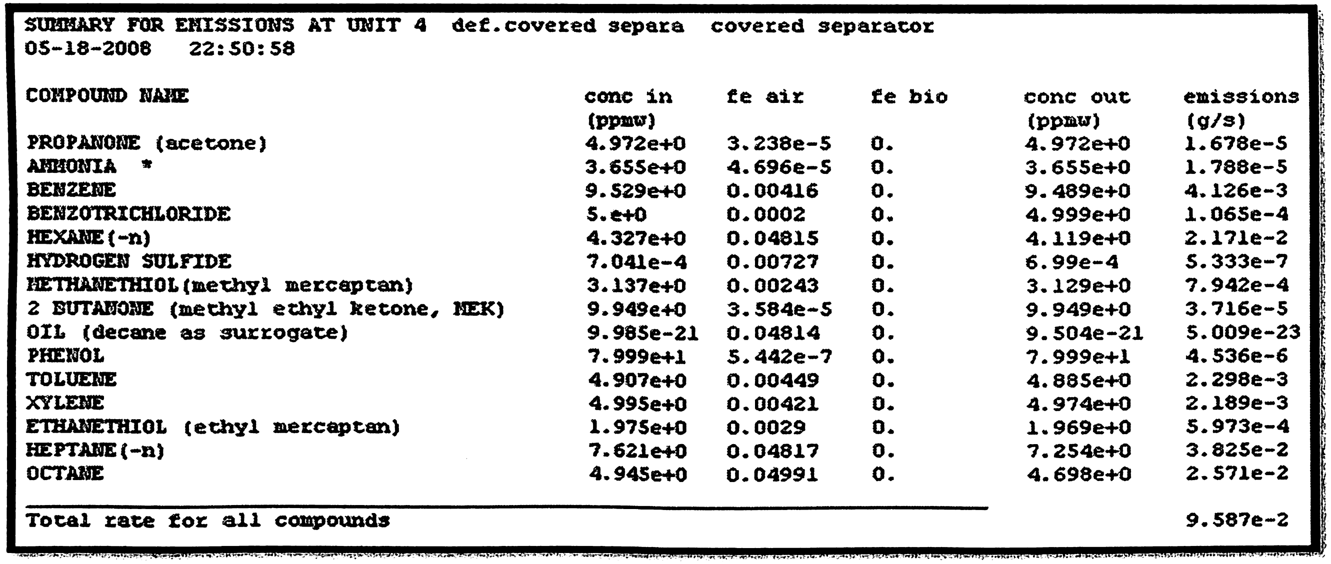
ANNEXURE

VOC EMISSION CALCULATIONS BASED ON USEPA MODEL

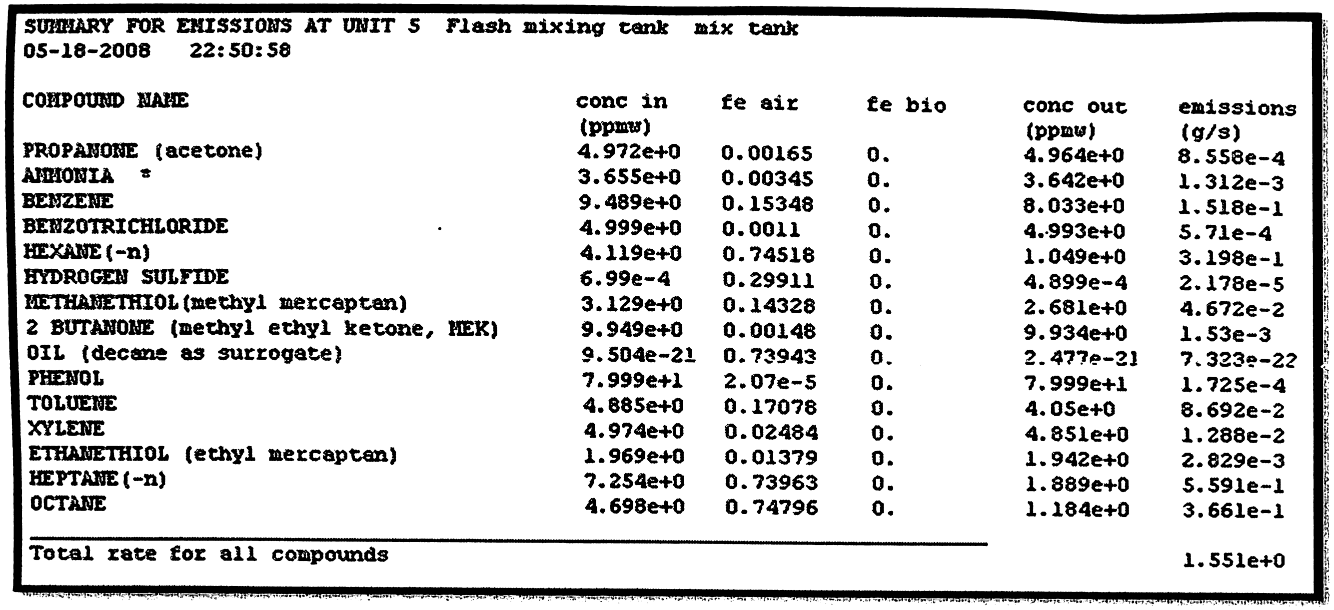
UNIT-WISE SUMMARY



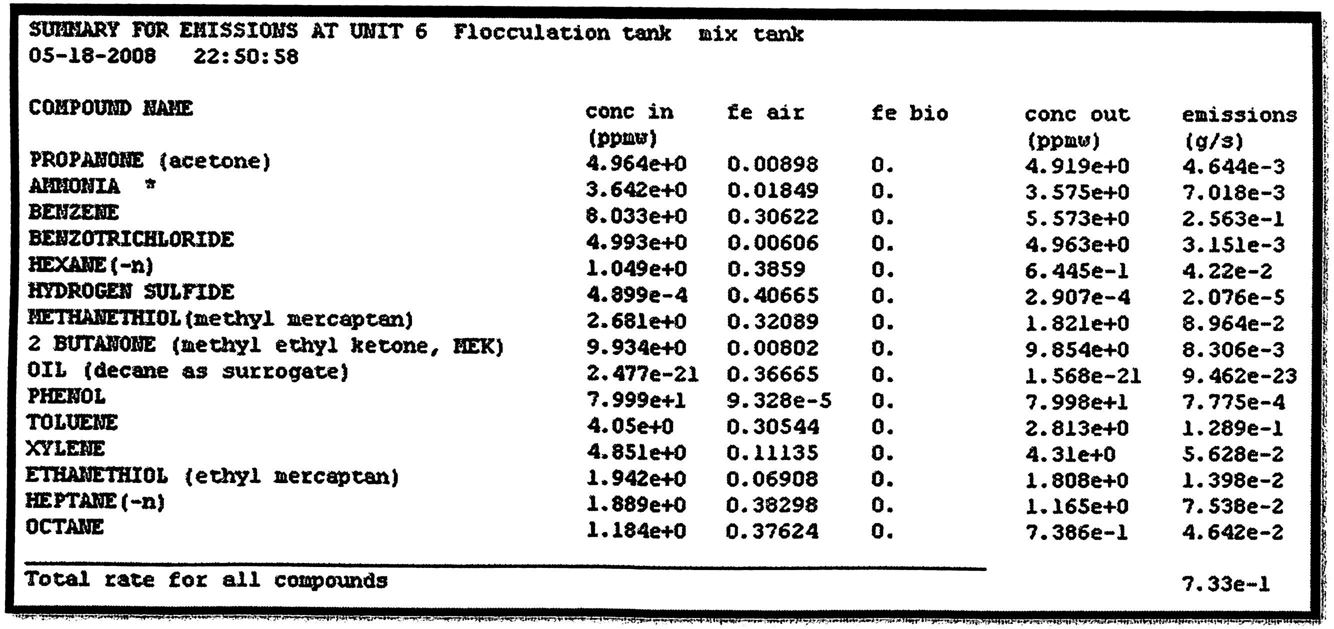
```
SUMMARY FOR EMISSIONS AT UNIT 3  def.API separator  API separator
05-18-2008   22:50:58

COMPOUND NAME                                conc in    fe air     fe bio      conc out    emissions
                                             (ppmw)                            (ppmw)      (g/s)
PROPANONE (acetone)                          5.e+0      0.00551    0.          4.972e+0    2.873e-3
AMMONIA  *                                   5.e+0      0.26902    0.          3.655e+0    1.402e-1
BENZENE                                      9.998e+0   0.04698    0.          9.529e+0    4.894e-2
BENZOTRICHLORIDE                             5.e+0      8.325e-5   0.          5.e+0       4.337e-5
HEXANE(-n)                                   4.992e+0   0.13324    0.          4.327e+0    6.93e-2
HYDROGEN SULFIDE                             9.998e+0   0.99993    0.          7.041e-4    1.042e+0
METHANETHIOL(methyl mercaptan)               5.e+0      0.3726     0.          3.137e+0    1.941e-1
2 BUTANONE (methyl ethyl ketone, MEK)        1.e+1      0.00508    0.          9.949e+0    5.292e-3
OIL (decane as surrogate)                    1.e-20     0.0015     0.          9.985e-21   1.558e-24
PHENOL                                       8.e+1      0.00014    0.          7.999e+1    1.2e-3
TOLUENE                                      5.e+0      0.0186     0.          4.907e+0    9.692e-3
XYLENE                                       5.e+0      0.0009     0.          4.995e+0    4.707e-4
ETHANETHIOL (ethyl mercaptan)                2.e+0      0.01271    0.          1.975e+0    2.648e-3
HEPTANE(-n)                                  7.844e+0   0.02835    0.          7.621e+0    2.317e-2
OCTANE                                       4.995e+0   0.01009    0.          4.945e+0    5.249e-3
__________________________________________________________________________________
Total rate for all compounds                                                               1.545e+0
```



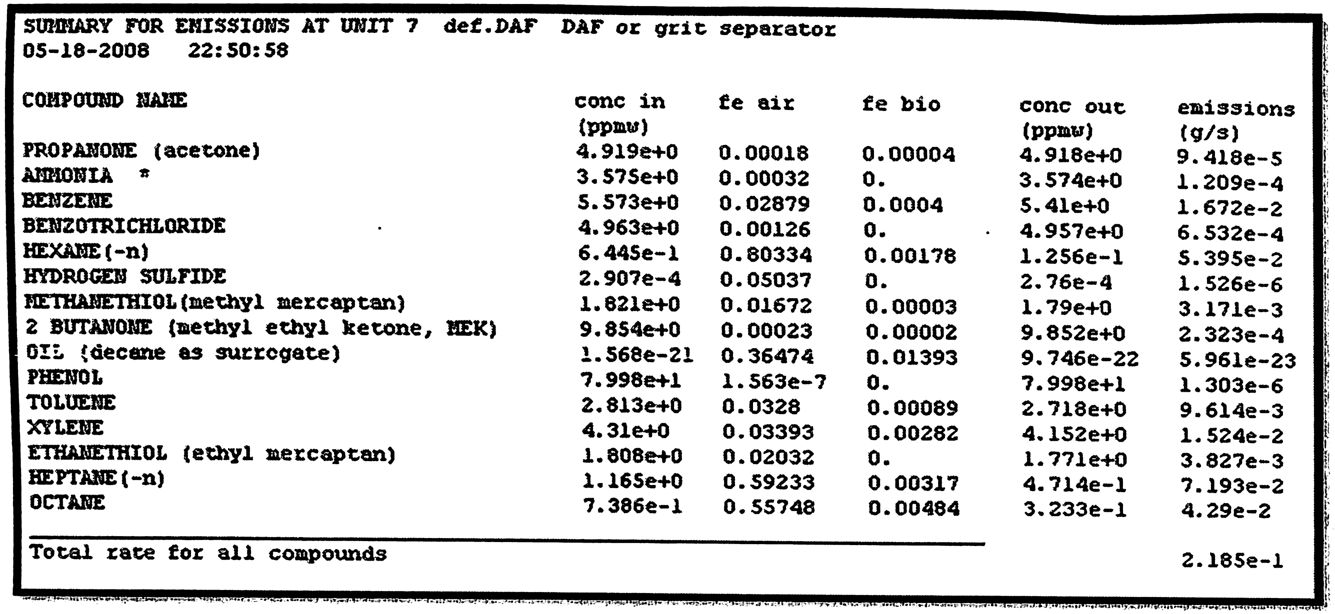
```
SUMMARY FOR EMISSIONS AT UNIT 4  def.covered separa  covered separator
05-18-2008   22:50:58

COMPOUND NAME                                conc in    fe air     fe bio      conc out    emissions
                                             (ppmw)                            (ppmw)      (g/s)
PROPANONE (acetone)                          4.972e+0   3.238e-5   0.          4.972e+0    1.678e-5
AMMONIA  *                                   3.655e+0   4.696e-5   0.          3.655e+0    1.788e-5
BENZENE                                      9.529e+0   0.00416    0.          9.489e+0    4.126e-3
BENZOTRICHLORIDE                             5.e+0      0.0002     0.          4.999e+0    1.065e-4
HEXANE(-n)                                   4.327e+0   0.04815    0.          4.119e+0    2.171e-2
HYDROGEN SULFIDE                             7.041e-4   0.00727    0.          6.99e-4     5.333e-7
METHANETHIOL(methyl mercaptan)               3.137e+0   0.00243    0.          3.129e+0    7.942e-4
2 BUTANONE (methyl ethyl ketone, MEK)        9.949e+0   3.584e-5   0.          9.949e+0    3.716e-5
OIL (decane as surrogate)                    9.985e-21  0.04814    0.          9.504e-21   5.009e-23
PHENOL                                       7.999e+1   5.442e-7   0.          7.999e+1    4.536e-6
TOLUENE                                      4.907e+0   0.00449    0.          4.885e+0    2.298e-3
XYLENE                                       4.995e+0   0.00421    0.          4.974e+0    2.189e-3
ETHANETHIOL (ethyl mercaptan)                1.975e+0   0.0029     0.          1.969e+0    5.973e-4
HEPTANE(-n)                                  7.621e+0   0.04817    0.          7.254e+0    3.825e-2
OCTANE                                       4.945e+0   0.04991    0.          4.698e+0    2.571e-2
__________________________________________________________________________________
Total rate for all compounds                                                               9.587e-2
```



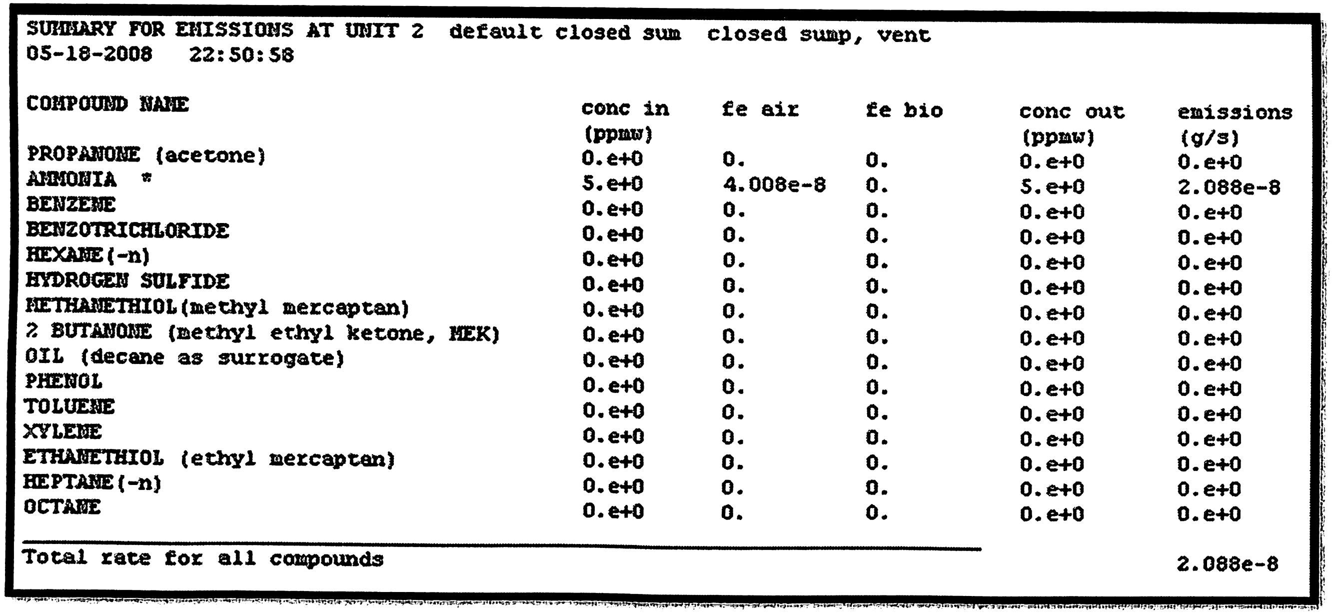
```
SUMMARY FOR EMISSIONS AT UNIT 5  Flash mixing tank  mix tank
05-18-2008    22:50:58

COMPOUND NAME                                 conc in     fe air     fe bio     conc out    emissions
                                              (ppmw)                            (ppmw)      (g/s)
PROPANONE (acetone)                           4.972e+0    0.00165    0.         4.964e+0    8.558e-4
AMMONIA  *                                    3.655e+0    0.00345    0.         3.642e+0    1.312e-3
BENZENE                                       9.489e+0    0.15348    0.         8.033e+0    1.518e-1
BENZOTRICHLORIDE                              4.999e+0    0.0011     0.         4.993e+0    5.71e-4
HEXANE(-n)                                    4.119e+0    0.74518    0.         1.049e+0    3.198e-1
HYDROGEN SULFIDE                              6.99e-4     0.29911    0.         4.899e-4    2.178e-5
METHANETHIOL(methyl mercaptan)                3.129e+0    0.14328    0.         2.681e+0    4.672e-2
2 BUTANONE (methyl ethyl ketone, MEK)         9.949e+0    0.00148    0.         9.934e+0    1.53e-3
OIL (decane as surrogate)                     9.504e-21   0.73943    0.         2.477e-21   7.323e-22
PHENOL                                        7.999e+1    2.07e-5    0.         7.999e+1    1.725e-4
TOLUENE                                       4.885e+0    0.17078    0.         4.05e+0     8.692e-2
XYLENE                                        4.974e+0    0.02484    0.         4.851e+0    1.288e-2
ETHANETHIOL (ethyl mercaptan)                 1.969e+0    0.01379    0.         1.942e+0    2.829e-3
HEPTANE(-n)                                   7.254e+0    0.73963    0.         1.889e+0    5.591e-1
OCTANE                                        4.698e+0    0.74796    0.         1.184e+0    3.661e-1
__________________________________________________________________________________
Total rate for all compounds                                                                1.551e+0
```



```
SUMMARY FOR EMISSIONS AT UNIT 6  Flocculation tank  mix tank
05-18-2008    22:50:58

COMPOUND NAME                                 conc in     fe air     fe bio     conc out    emissions
                                              (ppmw)                            (ppmw)      (g/s)
PROPANONE (acetone)                           4.964e+0    0.00898    0.         4.919e+0    4.644e-3
AMMONIA  *                                    3.642e+0    0.01849    0.         3.575e+0    7.018e-3
BENZENE                                       8.033e+0    0.30622    0.         5.573e+0    2.563e-1
BENZOTRICHLORIDE                              4.993e+0    0.00606    0.         4.963e+0    3.151e-3
HEXANE(-n)                                    1.049e+0    0.3859     0.         6.445e-1    4.22e-2
HYDROGEN SULFIDE                              4.899e-4    0.40665    0.         2.907e-4    2.076e-5
METHANETHIOL(methyl mercaptan)                2.681e+0    0.32089    0.         1.821e+0    8.964e-2
2 BUTANONE (methyl ethyl ketone, MEK)         9.934e+0    0.00802    0.         9.854e+0    8.306e-3
OIL (decane as surrogate)                     2.477e-21   0.36665    0.         1.568e-21   9.462e-23
PHENOL                                        7.999e+1    9.328e-5   0.         7.998e+1    7.775e-4
TOLUENE                                       4.05e+0     0.30544    0.         2.813e+0    1.289e-1
XYLENE                                        4.851e+0    0.11135    0.         4.31e+0     5.628e-2
ETHANETHIOL (ethyl mercaptan)                 1.942e+0    0.06908    0.         1.808e+0    1.398e-2
HEPTANE(-n)                                   1.889e+0    0.38298    0.         1.165e+0    7.538e-2
OCTANE                                        1.184e+0    0.37624    0.         7.386e-1    4.642e-2
__________________________________________________________________________________
Total rate for all compounds                                                                7.33e-1
```

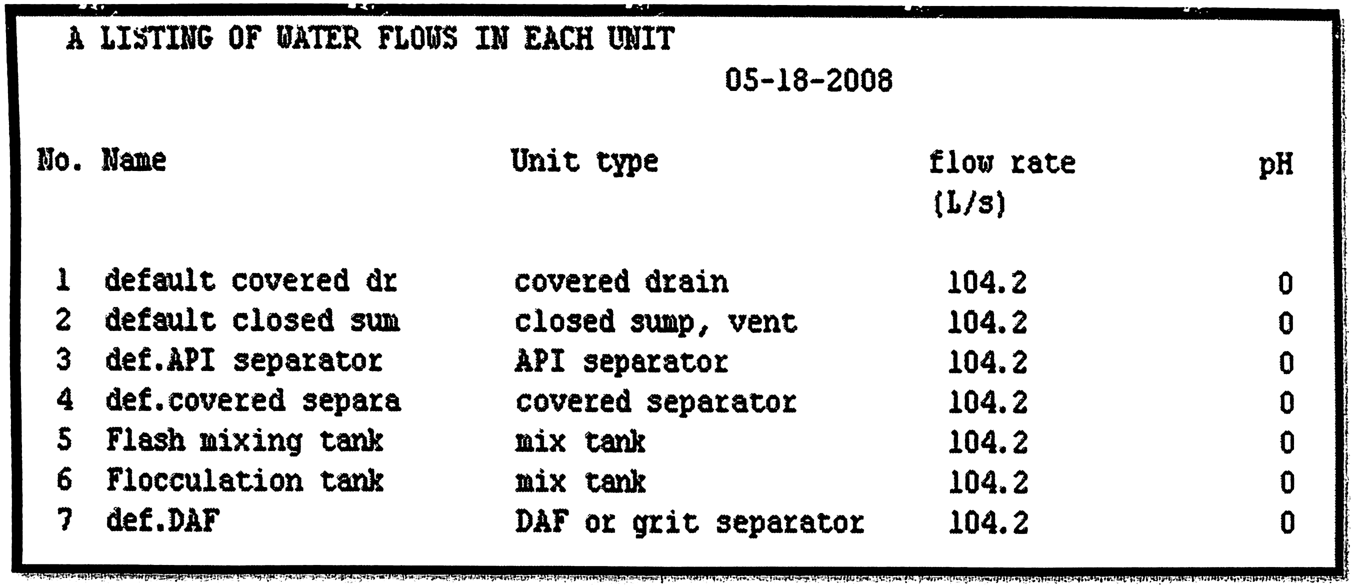


```
SUMMARY FOR EMISSIONS AT UNIT 7  def.DAF  DAF or grit separator
05-18-2008    22:50:58

COMPOUND NAME                                  conc in    fe air     fe bio     conc out    emissions
                                               (ppmw)                           (ppmw)      (g/s)
PROPANONE (acetone)                            4.919e+0   0.00018    0.00004    4.918e+0    9.418e-5
AMMONIA  *                                     3.575e+0   0.00032    0.         3.574e+0    1.209e-4
BENZENE                                        5.573e+0   0.02879    0.0004     5.41e+0     1.672e-2
BENZOTRICHLORIDE                               4.963e+0   0.00126    0.         4.957e+0    6.532e-4
HEXANE(-n)                                     6.445e-1   0.80334    0.00178    1.256e-1    5.395e-2
HYDROGEN SULFIDE                               2.907e-4   0.05037    0.         2.76e-4     1.526e-6
METHANETHIOL(methyl mercaptan)                 1.821e+0   0.01672    0.00003    1.79e+0     3.171e-3
2 BUTANONE (methyl ethyl ketone, MEK)          9.854e+0   0.00023    0.00002    9.852e+0    2.323e-4
OIL (decane as surrogate)                      1.568e-21  0.36474    0.01393    9.746e-22   5.961e-23
PHENOL                                         7.998e+1   1.563e-7   0.         7.998e+1    1.303e-6
TOLUENE                                        2.813e+0   0.0328     0.00089    2.718e+0    9.614e-3
XYLENE                                         4.31e+0    0.03393    0.00282    4.152e+0    1.524e-2
ETHANETHIOL (ethyl mercaptan)                  1.808e+0   0.02032    0.         1.771e+0    3.827e-3
HEPTANE(-n)                                    1.165e+0   0.59233    0.00317    4.714e-1    7.193e-2
OCTANE                                         7.386e-1   0.55748    0.00484    3.233e-1    4.29e-2
_________________________________________________________________________________
Total rate for all compounds                                                                2.185e-1
```



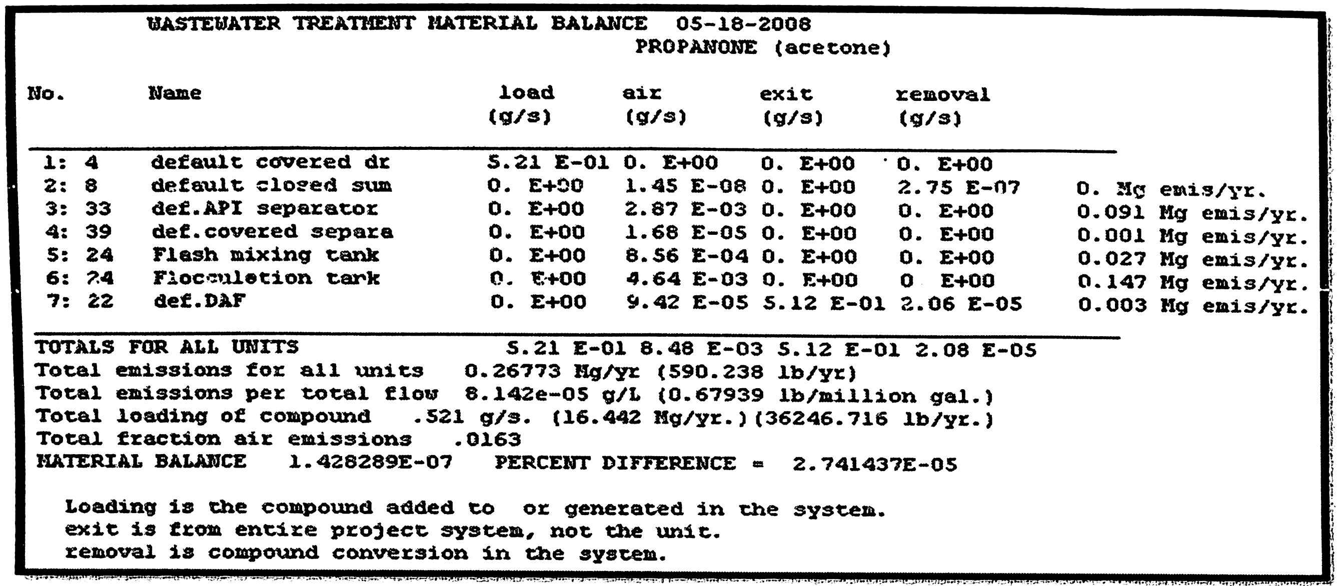
```
SUMMARY FOR EMISSIONS AT UNIT 2  default closed sum  closed sump, vent
05-18-2008    22:50:58

COMPOUND NAME                                  conc in    fe air     fe bio     conc out    emissions
                                               (ppmw)                           (ppmw)      (g/s)
PROPANONE (acetone)                            0.e+0      0.         0.         0.e+0       0.e+0
AMMONIA  *                                     5.e+0      4.008e-8   0.         5.e+0       2.088e-8
BENZENE                                        0.e+0      0.         0.         0.e+0       0.e+0
BENZOTRICHLORIDE                               0.e+0      0.         0.         0.e+0       0.e+0
HEXANE(-n)                                     0.e+0      0.         0.         0.e+0       0.e+0
HYDROGEN SULFIDE                               0.e+0      0.         0.         0.e+0       0.e+0
METHANETHIOL(methyl mercaptan)                 0.e+0      0.         0.         0.e+0       0.e+0
2 BUTANONE (methyl ethyl ketone, MEK)          0.e+0      0.         0.         0.e+0       0.e+0
OIL (decane as surrogate)                      0.e+0      0.         0.         0.e+0       0.e+0
PHENOL                                         0.e+0      0.         0.         0.e+0       0.e+0
TOLUENE                                        0.e+0      0.         0.         0.e+0       0.e+0
XYLENE                                         0.e+0      0.         0.         0.e+0       0.e+0
ETHANETHIOL (ethyl mercaptan)                  0.e+0      0.         0.         0.e+0       0.e+0
HEPTANE(-n)                                    0.e+0      0.         0.         0.e+0       0.e+0
OCTANE                                         0.e+0      0.         0.         0.e+0       0.e+0
_________________________________________________________________________________
Total rate for all compounds                                                                2.088e-8
```

UNIT WASTEWATER FLOWS

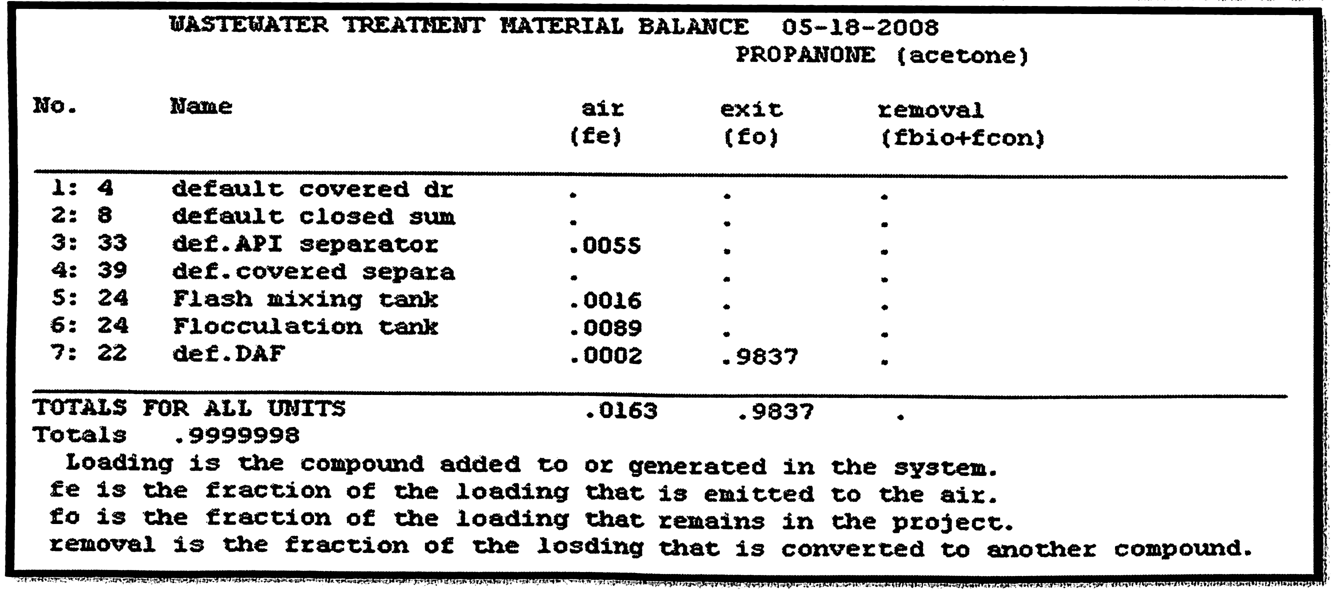


```
 A LISTING OF WATER FLOWS IN EACH UNIT
                                              05-18-2008

No. Name                   Unit type                 flow rate         pH
                                                     (L/s)

 1  default covered dr     covered drain              104.2             0
 2  default closed sum     closed sump, vent          104.2             0
 3  def.API separator      API separator              104.2             0
 4  def.covered separa     covered separator          104.2             0
 5  Flash mixing tank      mix tank                   104.2             0
 6  Flocculation tank      mix tank                   104.2             0
 7  def.DAF                DAF or grit separator      104.2             0
```

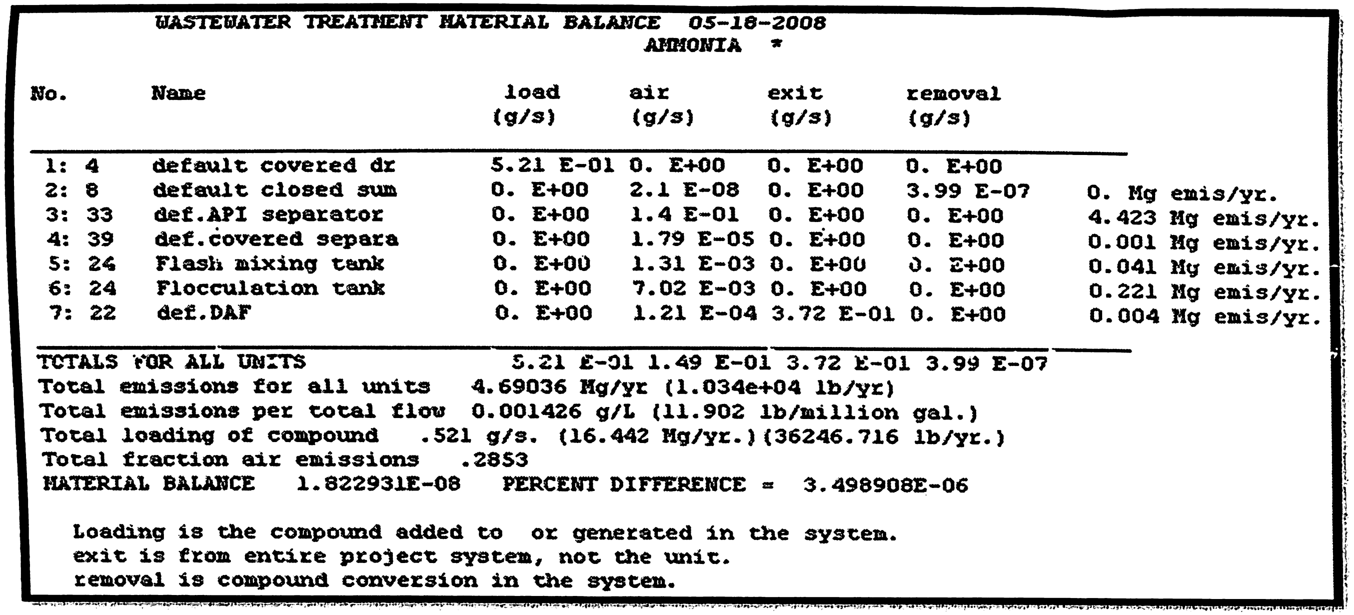
MATERIAL BALANCE



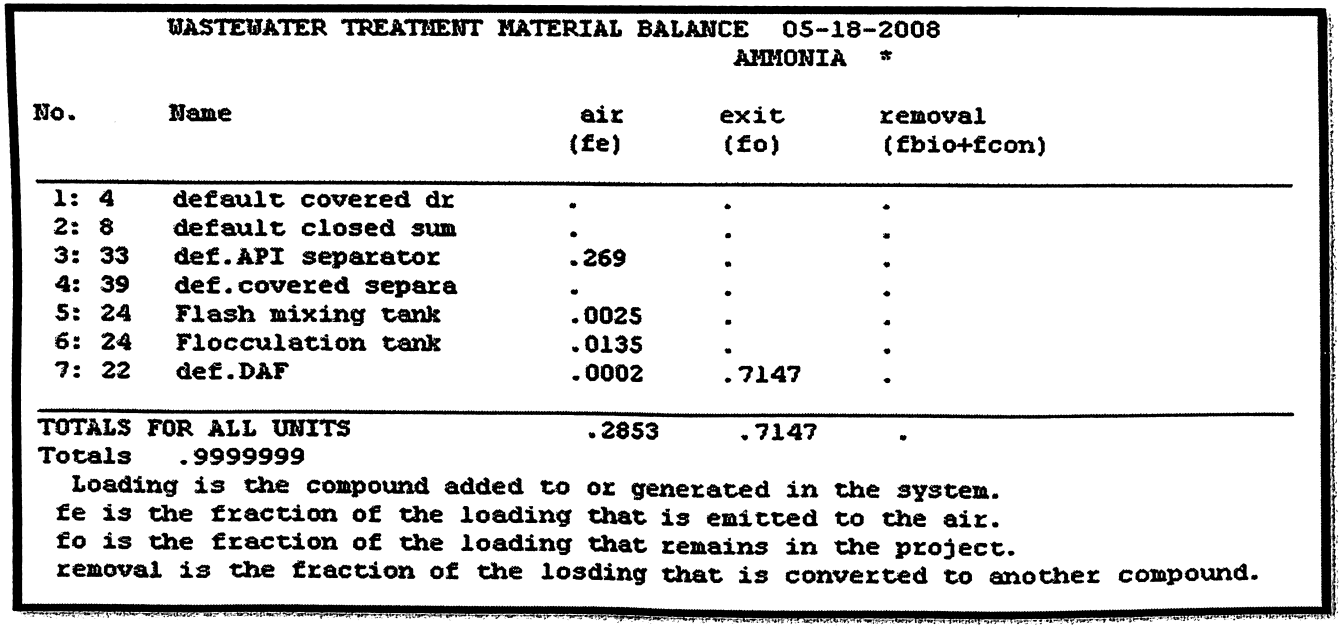
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-18-2008
                                              PROPANONE (acetone)

No.     Name                       load      air       exit      removal
                                   (g/s)     (g/s)     (g/s)     (g/s)
 ------------------------------------------------------------------------
 1: 4    default covered dr        5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum        0. E+00   1.45 E-08 0. E+00   2.75 E-07    0. Mg emis/yr.
 3: 33   def.API separator         0. E+00   2.87 E-03 0. E+00   0. E+00      0.091 Mg emis/yr.
 4: 39   def.covered separa        0. E+00   1.68 E-05 0. E+00   0. E+00      0.001 Mg emis/yr.
 5: 24   Flash mixing tank         0. E+00   8.56 E-04 0. E+00   0. E+00      0.027 Mg emis/yr.
 6: 24   Flocculation tank         0. E+00   4.64 E-03 0. E+00   0. E+00      0.147 Mg emis/yr.
 7: 22   def.DAF                   0. E+00   9.42 E-05 5.12 E-01 2.06 E-05    0.003 Mg emis/yr.
 ------------------------------------------------------------------------
TOTALS FOR ALL UNITS                5.21 E-01 8.48 E-03 5.12 E-01 2.08 E-05
Total emissions for all units    0.26773 Mg/yr (590.238 lb/yr)
Total emissions per total flow   8.142e-05 g/L (0.67939 lb/million gal.)
Total loading of compound    .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions    .0163
MATERIAL BALANCE    1.428289E-07    PERCENT DIFFERENCE =  2.741437E-05

   Loading is the compound added to  or generated in the system.
   exit is from entire project system, not the unit.
   removal is compound conversion in the system.
```



```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-18-2008
                                          PROPANONE (acetone)

No.      Name                       air       exit      removal
                                   (fe)      (fo)      (fbio+fcon)
 ----------------------------------------------------------------
 1: 4    default covered dr         .         .         .
 2: 8    default closed sum         .         .         .
 3: 33   def.API separator         .0055      .         .
 4: 39   def.covered separa         .         .         .
 5: 24   Flash mixing tank         .0016      .         .
 6: 24   Flocculation tank         .0089      .         .
 7: 22   def.DAF                   .0002     .9837      .
 ----------------------------------------------------------------
TOTALS FOR ALL UNITS               .0163     .9837      .
Totals   .9999998
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-18-2008
                                              AMMONIA  *

No.      Name                     load      air       exit      removal
                                  (g/s)     (g/s)     (g/s)     (g/s)
_________________________________________________________________________
 1: 4    default covered dr       5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum       0. E+00   2.1 E-08  0. E+00   3.99 E-07   0. Mg emis/yr.
 3: 33   def.API separator        0. E+00   1.4 E-01  0. E+00   0. E+00     4.423 Mg emis/yr.
 4: 39   def.covered separa       0. E+00   1.79 E-05 0. E+00   0. E+00     0.001 Mg emis/yr.
 5: 24   Flash mixing tank        0. E+00   1.31 E-03 0. E+00   0. E+00     0.041 Mg emis/yr.
 6: 24   Flocculation tank        0. E+00   7.02 E-03 0. E+00   0. E+00     0.221 Mg emis/yr.
 7: 22   def.DAF                  0. E+00   1.21 E-04 3.72 E-01 0. E+00     0.004 Mg emis/yr.
_________________________________________________________________________
TOTALS FOR ALL UNITS              5.21 E-01 1.49 E-01 3.72 E-01 3.99 E-07
Total emissions for all units   4.69036 Mg/yr (1.034e+04 lb/yr)
Total emissions per total flow  0.001426 g/L (11.902 lb/million gal.)
Total loading of compound     .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions    .2853
MATERIAL BALANCE    1.822931E-08   PERCENT DIFFERENCE =  3.498908E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



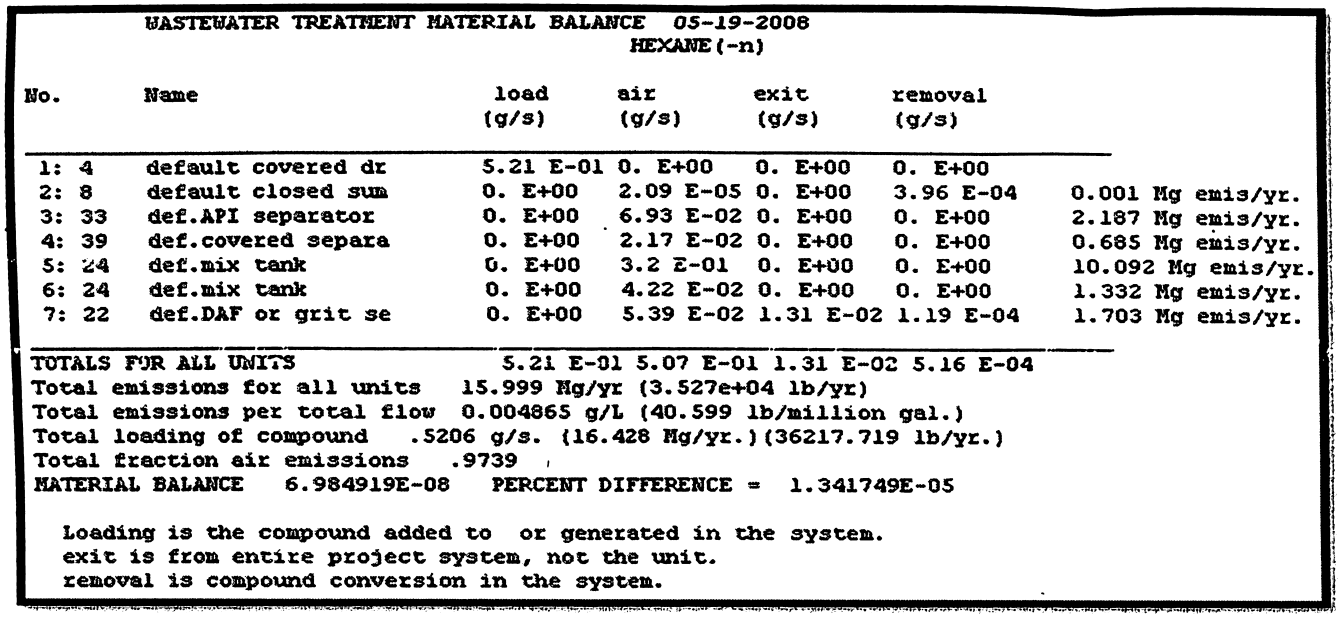
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-18-2008
                                              AMMONIA  *

No.      Name                        air       exit      removal
                                     (fe)      (fo)      (fbio+fcon)
____________________________________________________________________
 1: 4    default covered dr          .         .         .
 2: 8    default closed sum          .         .         .
 3: 33   def.API separator           .269      .         .
 4: 39   def.covered separa          .         .         .
 5: 24   Flash mixing tank           .0025     .         .
 6: 24   Flocculation tank           .0135     .         .
 7: 22   def.DAF                     .0002     .7147     .
____________________________________________________________________
TOTALS FOR ALL UNITS                 .2853     .7147     .
Totals   .9999999
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```

```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                                 BENZENE

No.     Name                         load      air       exit      removal
                                     (g/s)     (g/s)     (g/s)     (g/s)
----------------------------------------------------------------------------
 1: 4   default covered dr          1.04 E+00 0. E+00   0. E+00   0. E+00
 2: 8   default closed sum          0. E+00   3.81 E-06 0. E+00   7.24 E-05    0. Mg emis/yr.
 3: 33  def.API separator           0. E+00   4.89 E-02 0. E+00   0. E+00      1.544 Mg emis/yr.
 4: 39  def.covered separa          0. E+00   4.13 E-03 0. E+00   0. E+00      0.13 Mg emis/yr.
 5: 24  def.mix tank                0. E+00   1.52 E-01 0. E+00   0. E+00      4.789 Mg emis/yr.
 6: 24  def.mix tank                0. E+00   2.56 E-01 0. E+00   0. E+00      8.088 Mg emis/yr.
 7: 22  def.DAF or grit se          0. E+00   1.67 E-02 5.64 E-01 2.31 E-04    0.528 Mg emis/yr.
----------------------------------------------------------------------------
TOTALS FOR ALL UNITS                1.04 E+00 4.78 E-01 5.64 E-01 3.04 E-04
Total emissions for all units    15.08 Mg/yr (3.324e+04 lb/yr)
Total emissions per total flow  0.004586 g/L (38.266 lb/million gal.)
Total loading of compound    1.0419 g/s. (32.88 Mg/yr.)(72486.179 lb/yr.)
Total fraction air emissions    .4586
MATERIAL BALANCE    1.207518E-07   PERCENT DIFFERENCE =  1.158962E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```

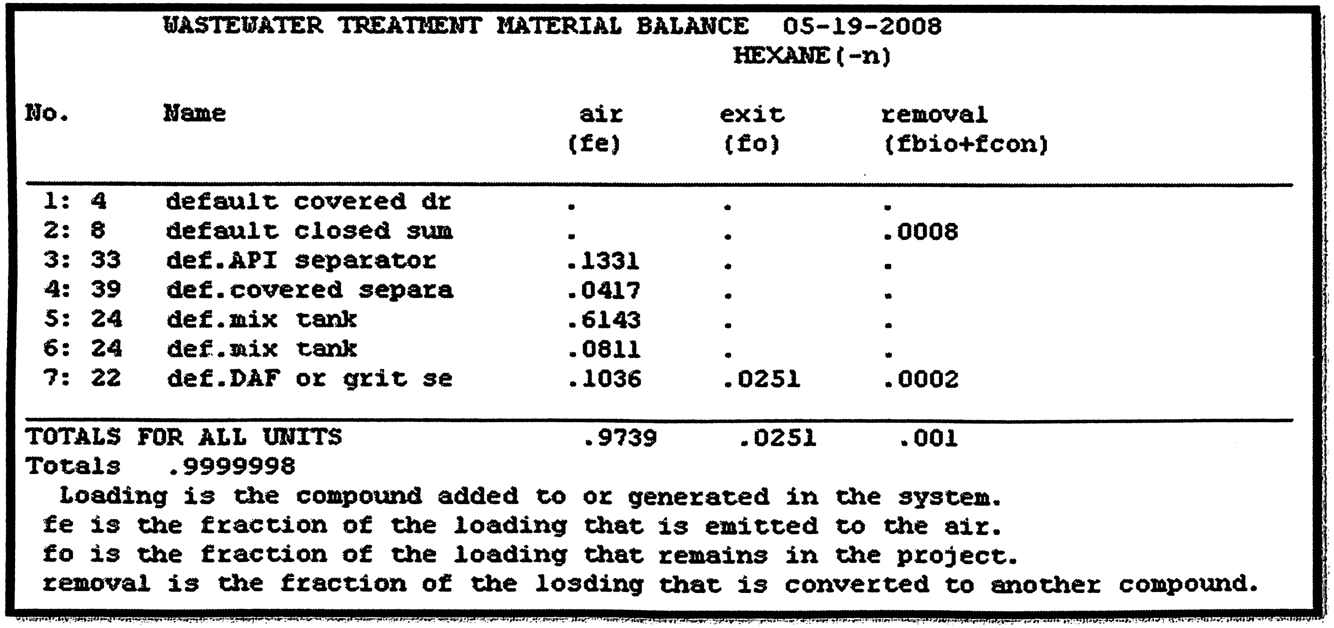
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                               BENZENE

No.      Name                      air       exit      removal
                                   (fe)      (fo)      (fbio+fcon)
-------------------------------------------------------------------
 1: 4    default covered dr        .         .         .
 2: 8    default closed sum        .         .         .0001
 3: 33   def.API separator         .047      .         .
 4: 39   def.covered separa        .004      .         .
 5: 24   def.mix tank              .1457     .         .
 6: 24   def.mix tank              .246      .         .
 7: 22   def.DAF or grit se        .016      .5411     .0002
-------------------------------------------------------------------
TOTALS FOR ALL UNITS                .4586     .5411     .0003
Totals   .9999999
 Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```

```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                                 BENZOTRICHLORIDE

No.       Name                        load      air       exit      removal
                                     (g/s)     (g/s)     (g/s)     (g/s)
 1: 4     default covered dr        5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8     default closed sum        0. E+00   8.18 E-08 0. E+00   1.55 E-06   0. Mg emis/yr.
 3: 33    def.API separator         0. E+00   4.34 E-05 0. E+00   0. E+00     0.001 Mg emis/yr.
 4: 39    def.covered separa        0. E+00   1.06 E-04 0. E+00   0. E+00     0.003 Mg emis/yr.
 5: 24    def.mix tank              0. E+00   5.71 E-04 0. E+00   0. E+00     0.018 Mg emis/yr.
 6: 24    def.mix tank              0. E+00   3.15 E-03 0. E+00   0. E+00     0.099 Mg emis/yr.
 7: 22    def.DAF or grit se        0. E+00   6.53 E-04 5.16 E-01 0. E+00     0.021 Mg emis/yr.

TOTALS FOR ALL UNITS                 5.21 E-01 4.53 E-03 5.16 E-01 1.55 E-06
Total emissions for all units   0.14281 Mg/yr (314.836 lb/yr)
Total emissions per total flow  4.343e-05 g/L (0.36239 lb/million gal.)
Total loading of compound    .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions   .0087
MATERIAL BALANCE    1.149164E-07   PERCENT DIFFERENCE =  2.205688E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```

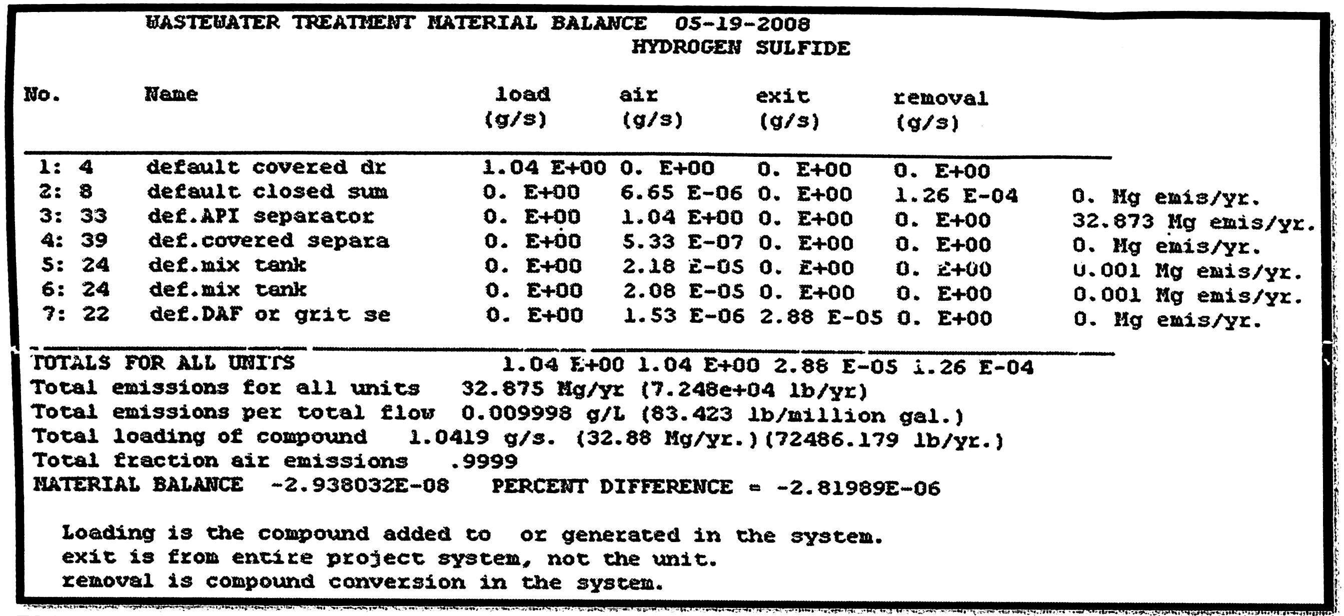
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                               BENZOTRICHLORIDE

No.     Name                       air       exit      removal
                                  (fe)      (fo)      (fbio+fcon)
 1: 4   default covered dr        .         .         .
 2: 8   default closed sum        .         .         .
 3: 33  def.API separator        .0001      .         .
 4: 39  def.covered separa       .0002      .         .
 5: 24  def.mix tank             .0011      .         .
 6: 24  def.mix tank             .006       .         .
 7: 22  def.DAF or grit se       .0013     .9913      .

TOTALS FOR ALL UNITS              .0087     .9913     .
Totals   .9999998
 Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



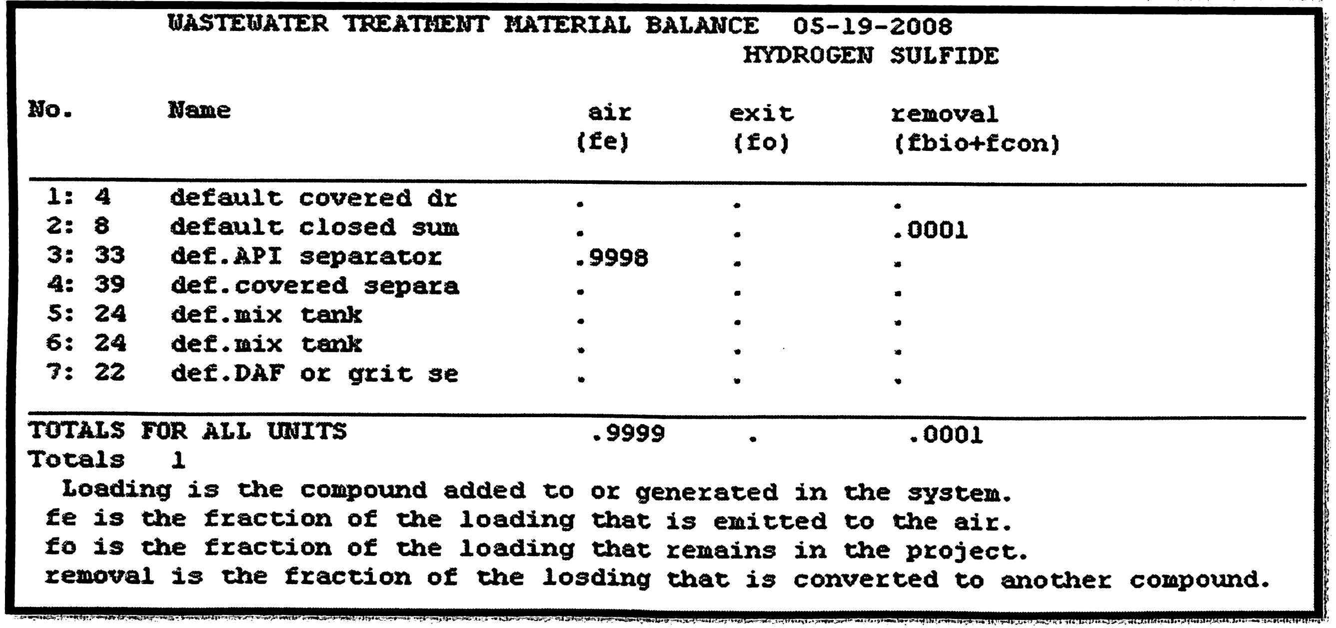
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                   HEXANE(-n)

No.      Name                       load      air       exit      removal
                                    (g/s)     (g/s)     (g/s)     (g/s)
-------------------------------------------------------------------------
 1: 4    default covered dr       5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum       0. E+00   2.09 E-05 0. E+00   3.96 E-04    0.001 Mg emis/yr.
 3: 33   def.API separator        0. E+00   6.93 E-02 0. E+00   0. E+00      2.187 Mg emis/yr.
 4: 39   def.covered separa       0. E+00   2.17 E-02 0. E+00   0. E+00      0.685 Mg emis/yr.
 5: 24   def.mix tank             0. E+00   3.2 E-01  0. E+00   0. E+00     10.092 Mg emis/yr.
 6: 24   def.mix tank             0. E+00   4.22 E-02 0. E+00   0. E+00      1.332 Mg emis/yr.
 7: 22   def.DAF or grit se       0. E+00   5.39 E-02 1.31 E-02 1.19 E-04    1.703 Mg emis/yr.
-------------------------------------------------------------------------
TOTALS FOR ALL UNITS               5.21 E-01 5.07 E-01 1.31 E-02 5.16 E-04
Total emissions for all units    15.999 Mg/yr (3.527e+04 lb/yr)
Total emissions per total flow   0.004865 g/L (40.599 lb/million gal.)
Total loading of compound     .5206 g/s. (16.428 Mg/yr.)(36217.719 lb/yr.)
Total fraction air emissions    .9739
MATERIAL BALANCE     6.984919E-08    PERCENT DIFFERENCE =  1.341749E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



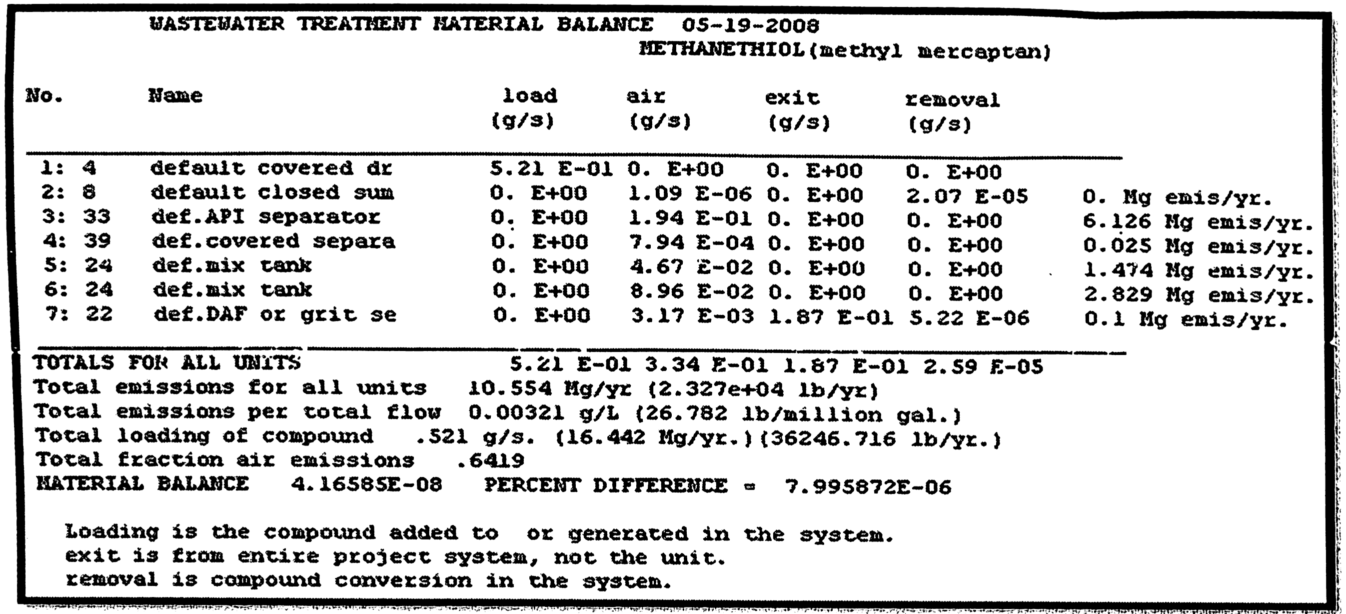
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                   HEXANE(-n)

No.      Name                    air       exit      removal
                                 (fe)      (fo)      (fbio+fcon)
----------------------------------------------------------------
 1: 4    default covered dr      .         .         .
 2: 8    default closed sum      .         .         .0008
 3: 33   def.API separator       .1331     .         .
 4: 39   def.covered separa      .0417     .         .
 5: 24   def.mix tank            .6143     .         .
 6: 24   def.mix tank            .0811     .         .
 7: 22   def.DAF or grit se      .1036     .0251     .0002
----------------------------------------------------------------
TOTALS FOR ALL UNITS              .9739     .0251     .001
Totals   .9999998
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



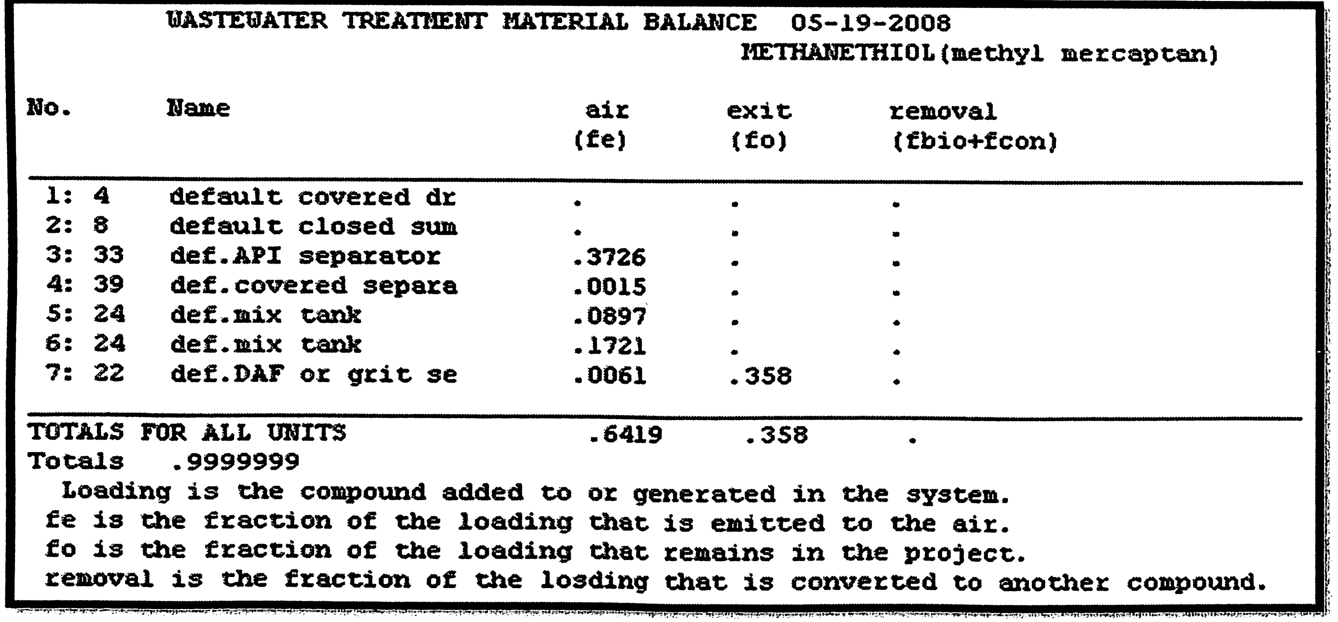
```
         WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                        HYDROGEN SULFIDE

No.      Name                          load      air       exit      removal
                                       (g/s)     (g/s)     (g/s)     (g/s)
------------------------------------------------------------------------------
 1: 4    default covered dr            1.04 E+00 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum            0. E+00   6.65 E-06 0. E+00   1.26 E-04     0. Mg emis/yr.
 3: 33   def.API separator             0. E+00   1.04 E+00 0. E+00   0. E+00       32.873 Mg emis/yr.
 4: 39   def.covered separa            0. E+00   5.33 E-07 0. E+00   0. E+00       0. Mg emis/yr.
 5: 24   def.mix tank                  0. E+00   2.18 E-05 0. E+00   0. E+00       0.001 Mg emis/yr.
 6: 24   def.mix tank                  0. E+00   2.08 E-05 0. E+00   0. E+00       0.001 Mg emis/yr.
 7: 22   def.DAF or grit se            0. E+00   1.53 E-06 2.88 E-05 0. E+00       0. Mg emis/yr.
------------------------------------------------------------------------------
TOTALS FOR ALL UNITS                   1.04 E+00 1.04 E+00 2.88 E-05 1.26 E-04
Total emissions for all units    32.875 Mg/yr (7.248e+04 lb/yr)
Total emissions per total flow   0.009998 g/L (83.423 lb/million gal.)
Total loading of compound    1.0419 g/s. (32.88 Mg/yr.)(72486.179 lb/yr.)
Total fraction air emissions    .9999
MATERIAL BALANCE   -2.938032E-08    PERCENT DIFFERENCE = -2.81989E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



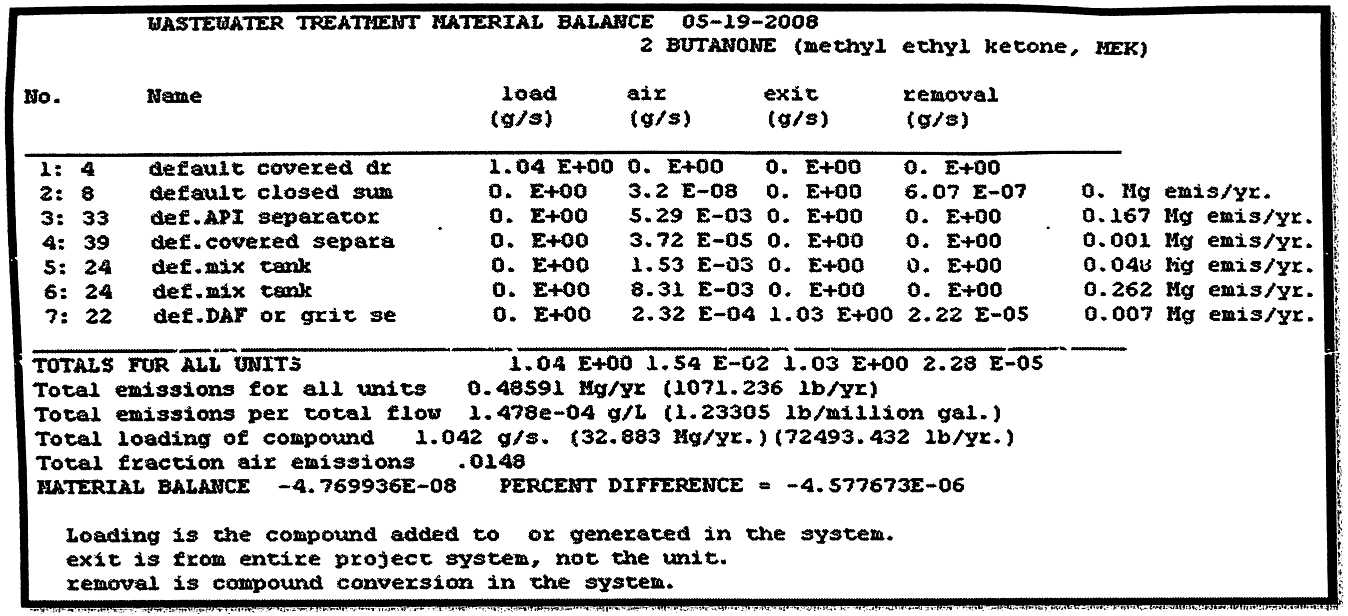
```
         WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                     HYDROGEN SULFIDE

No.      Name                      air       exit      removal
                                   (fe)      (fo)      (fbio+fcon)
-------------------------------------------------------------------
 1: 4    default covered dr        .         .         .
 2: 8    default closed sum        .         .         .0001
 3: 33   def.API separator         .9998     .         .
 4: 39   def.covered separa        .         .         .
 5: 24   def.mix tank              .         .         .
 6: 24   def.mix tank              .         .         .
 7: 22   def.DAF or grit se        .         .         .
-------------------------------------------------------------------
TOTALS FOR ALL UNITS                .9999     .         .0001
Totals   1
 Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



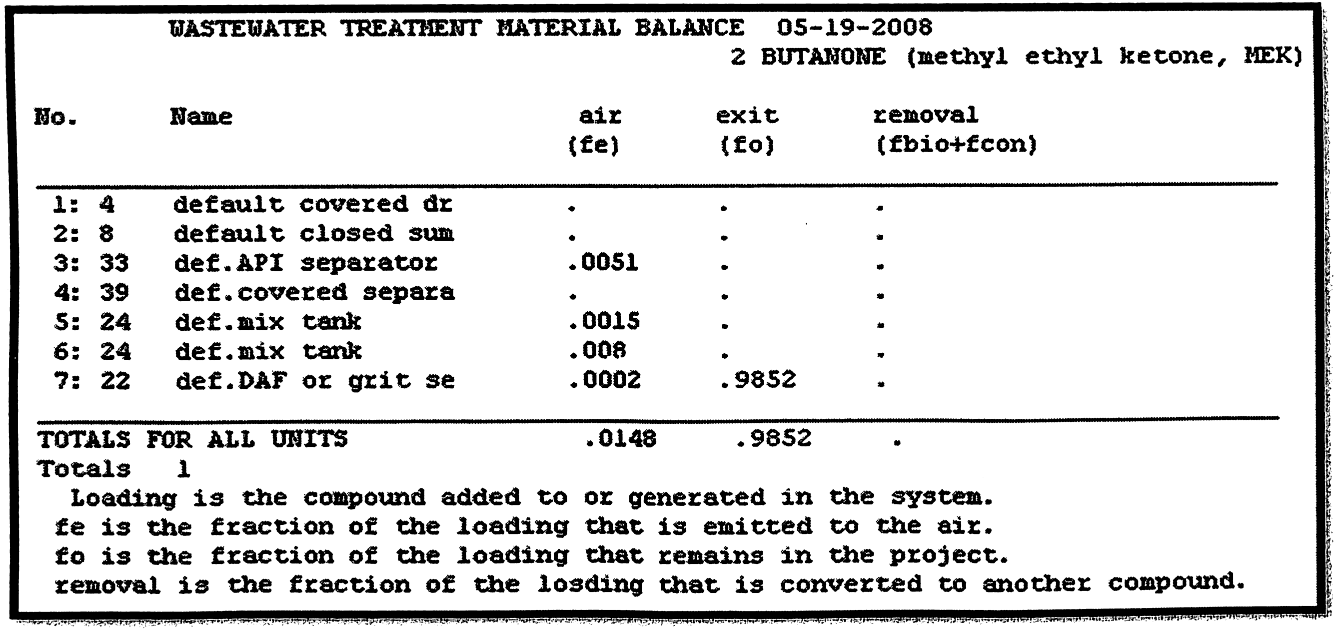
```
         WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                          METHANETHIOL(methyl mercaptan)

No.      Name                          load      air        exit       removal
                                       (g/s)     (g/s)      (g/s)      (g/s)
---------------------------------------------------------------------------------
 1: 4    default covered dr          5.21 E-01 0. E+00    0. E+00    0. E+00
 2: 8    default closed sum          0. E+00   1.09 E-06 0. E+00    2.07 E-05    0. Mg emis/yr.
 3: 33   def.API separator           0. E+00   1.94 E-01 0. E+00    0. E+00      6.126 Mg emis/yr.
 4: 39   def.covered separa          0. E+00   7.94 E-04 0. E+00    0. E+00      0.025 Mg emis/yr.
 5: 24   def.mix tank                0. E+00   4.67 E-02 0. E+00    0. E+00      1.474 Mg emis/yr.
 6: 24   def.mix tank                0. E+00   8.96 E-02 0. E+00    0. E+00      2.829 Mg emis/yr.
 7: 22   def.DAF or grit se          0. E+00   3.17 E-03 1.87 E-01 5.22 E-06    0.1 Mg emis/yr.
---------------------------------------------------------------------------------
TOTALS FOR ALL UNITS                 5.21 E-01 3.34 E-01 1.87 E-01 2.59 E-05
Total emissions for all units    10.554 Mg/yr (2.327e+04 lb/yr)
Total emissions per total flow   0.00321 g/L (26.782 lb/million gal.)
Total loading of compound     .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions    .6419
MATERIAL BALANCE    4.16585E-08    PERCENT DIFFERENCE =  7.995872E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



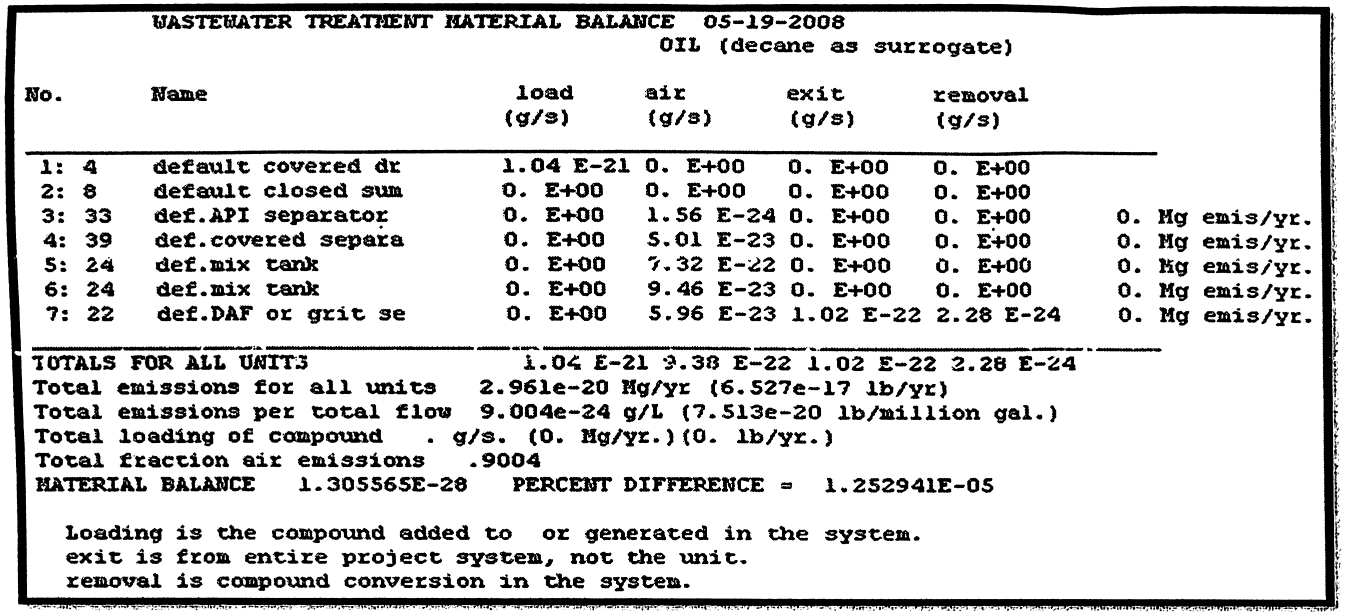
```
      WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                     METHANETHIOL(methyl mercaptan)

No.      Name                       air       exit      removal
                                    (fe)      (fo)      (fbio+fcon)
-------------------------------------------------------------------
 1: 4    default covered dr         .         .         .
 2: 8    default closed sum         .         .         .
 3: 33   def.API separator          .3726     .         .
 4: 39   def.covered separa         .0015     .         .
 5: 24   def.mix tank               .0897     .         .
 6: 24   def.mix tank               .1721     .         .
 7: 22   def.DAF or grit se         .0061     .358      .
-------------------------------------------------------------------
TOTALS FOR ALL UNITS                 .6419     .358      .
Totals   .9999999
 Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



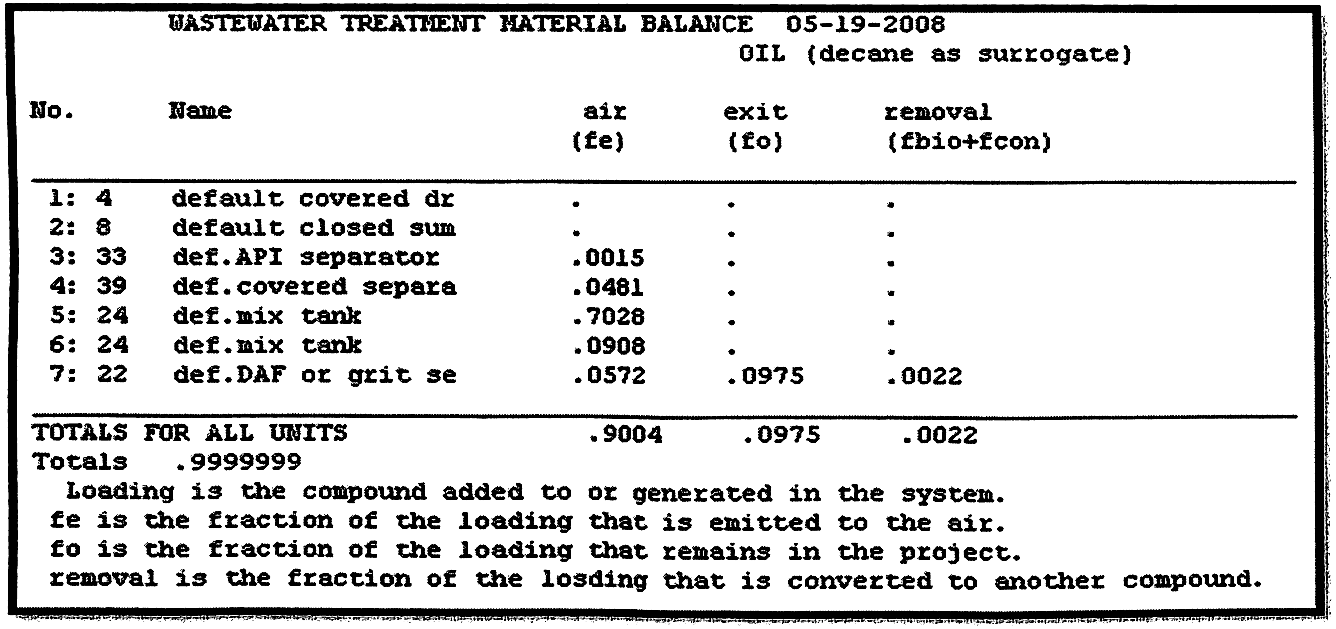
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                              2 BUTANONE (methyl ethyl ketone, MEK)

No.     Name                       load      air       exit      removal
                                   (g/s)     (g/s)     (g/s)     (g/s)
 ------------------------------------------------------------------------------
 1: 4    default covered dr        1.04 E+00 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum        0. E+00   3.2 E-08  0. E+00   6.07 E-07    0. Mg emis/yr.
 3: 33   def.API separator         0. E+00   5.29 E-03 0. E+00   0. E+00      0.167 Mg emis/yr.
 4: 39   def.covered separa        0. E+00   3.72 E-05 0. E+00   0. E+00      0.001 Mg emis/yr.
 5: 24   def.mix tank              0. E+00   1.53 E-03 0. E+00   0. E+00      0.048 Mg emis/yr.
 6: 24   def.mix tank              0. E+00   8.31 E-03 0. E+00   0. E+00      0.262 Mg emis/yr.
 7: 22   def.DAF or grit se        0. E+00   2.32 E-04 1.03 E+00 2.22 E-05    0.007 Mg emis/yr.
 ------------------------------------------------------------------------------
TOTALS FOR ALL UNITS                1.04 E+00 1.54 E-02 1.03 E+00 2.28 E-05
Total emissions for all units   0.48591 Mg/yr (1071.236 lb/yr)
Total emissions per total flow  1.478e-04 g/L (1.23305 lb/million gal.)
Total loading of compound   1.042 g/s. (32.883 Mg/yr.)(72493.432 lb/yr.)
Total fraction air emissions   .0148
MATERIAL BALANCE  -4.769936E-08    PERCENT DIFFERENCE = -4.577673E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



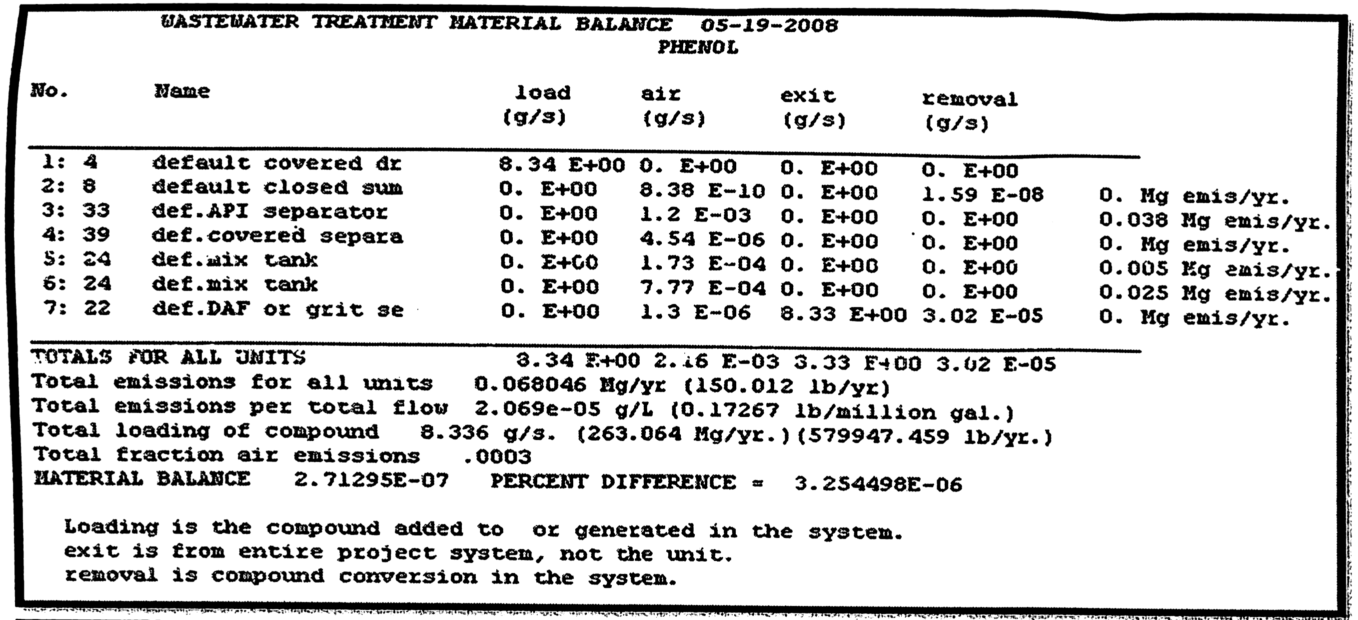
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                       2 BUTANONE (methyl ethyl ketone, MEK)

No.     Name                       air       exit      removal
                                   (fe)      (fo)      (fbio+fcon)
 -------------------------------------------------------------------
 1: 4    default covered dr        .         .         .
 2: 8    default closed sum        .         .         .
 3: 33   def.API separator         .0051     .         .
 4: 39   def.covered separa        .         .         .
 5: 24   def.mix tank              .0015     .         .
 6: 24   def.mix tank              .008      .         .
 7: 22   def.DAF or grit se        .0002     .9852     .
 -------------------------------------------------------------------
TOTALS FOR ALL UNITS                .0148     .9852     .
Totals   1
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



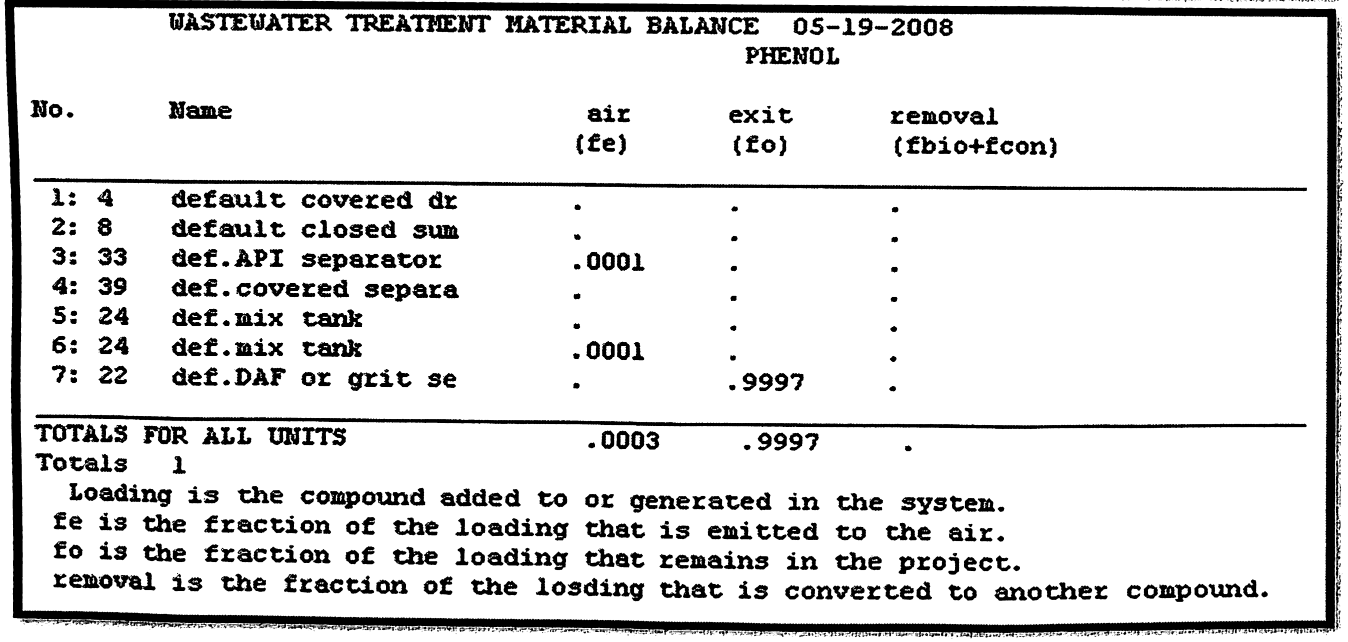
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                            OIL (decane as surrogate)

No.      Name                      load      air       exit      removal
                                  (g/s)     (g/s)     (g/s)     (g/s)
 ---------------------------------------------------------------------------
 1: 4    default covered dr       1.04 E-21 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum       0. E+00   0. E+00   0. E+00   0. E+00
 3: 33   def.API separator        0. E+00   1.56 E-24 0. E+00   0. E+00     0. Mg emis/yr.
 4: 39   def.covered separa       0. E+00   5.01 E-23 0. E+00   0. E+00     0. Mg emis/yr.
 5: 24   def.mix tank             0. E+00   7.32 E-22 0. E+00   0. E+00     0. Mg emis/yr.
 6: 24   def.mix tank             0. E+00   9.46 E-23 0. E+00   0. E+00     0. Mg emis/yr.
 7: 22   def.DAF or grit se       0. E+00   5.96 E-23 1.02 E-22 2.28 E-24   0. Mg emis/yr.
 ---------------------------------------------------------------------------
TOTALS FOR ALL UNITS                1.04 E-21 9.38 E-22 1.02 E-22 2.28 E-24
Total emissions for all units   2.961e-20 Mg/yr (6.527e-17 lb/yr)
Total emissions per total flow  9.004e-24 g/L (7.513e-20 lb/million gal.)
Total loading of compound    . g/s. (0. Mg/yr.)(0. lb/yr.)
Total fraction air emissions   .9004
MATERIAL BALANCE   1.305565E-28   PERCENT DIFFERENCE =  1.252941E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



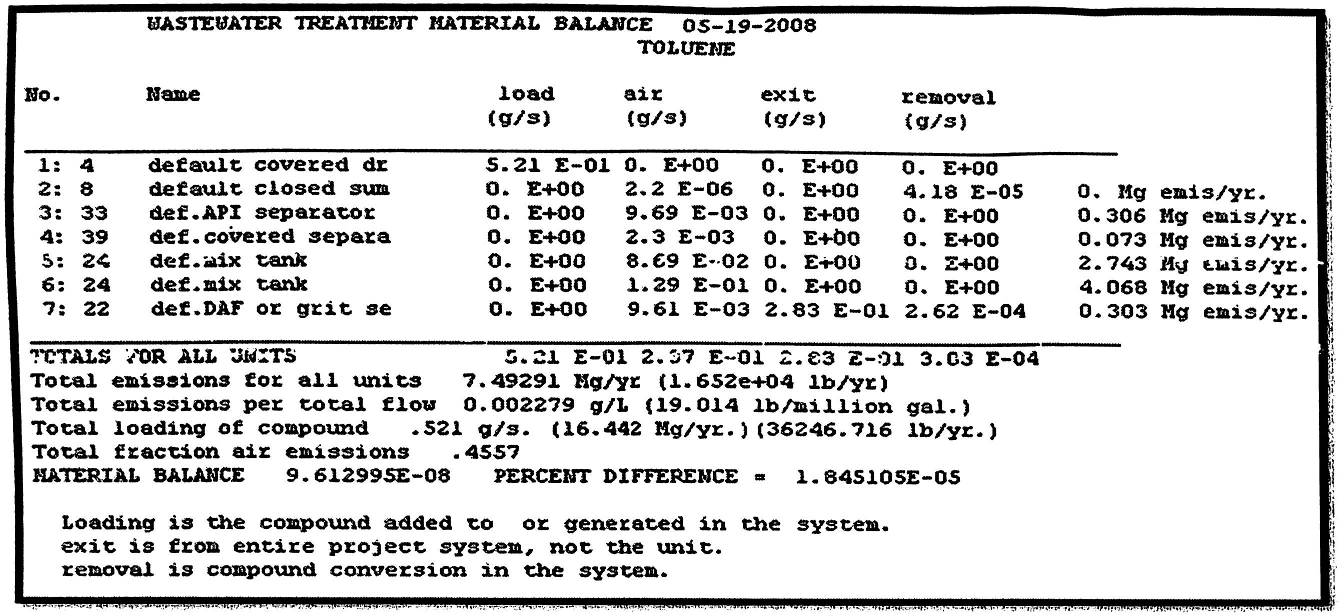
```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                      OIL (decane as surrogate)

No.      Name                     air       exit      removal
                                 (fe)      (fo)      (fbio+fcon)
 ---------------------------------------------------------------
 1: 4    default covered dr       .         .         .
 2: 8    default closed sum       .         .         .
 3: 33   def.API separator        .0015     .         .
 4: 39   def.covered separa       .0481     .         .
 5: 24   def.mix tank             .7028     .         .
 6: 24   def.mix tank             .0908     .         .
 7: 22   def.DAF or grit se       .0572     .0975     .0022
 ---------------------------------------------------------------
TOTALS FOR ALL UNITS              .9004     .0975     .0022
Totals   .9999999
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



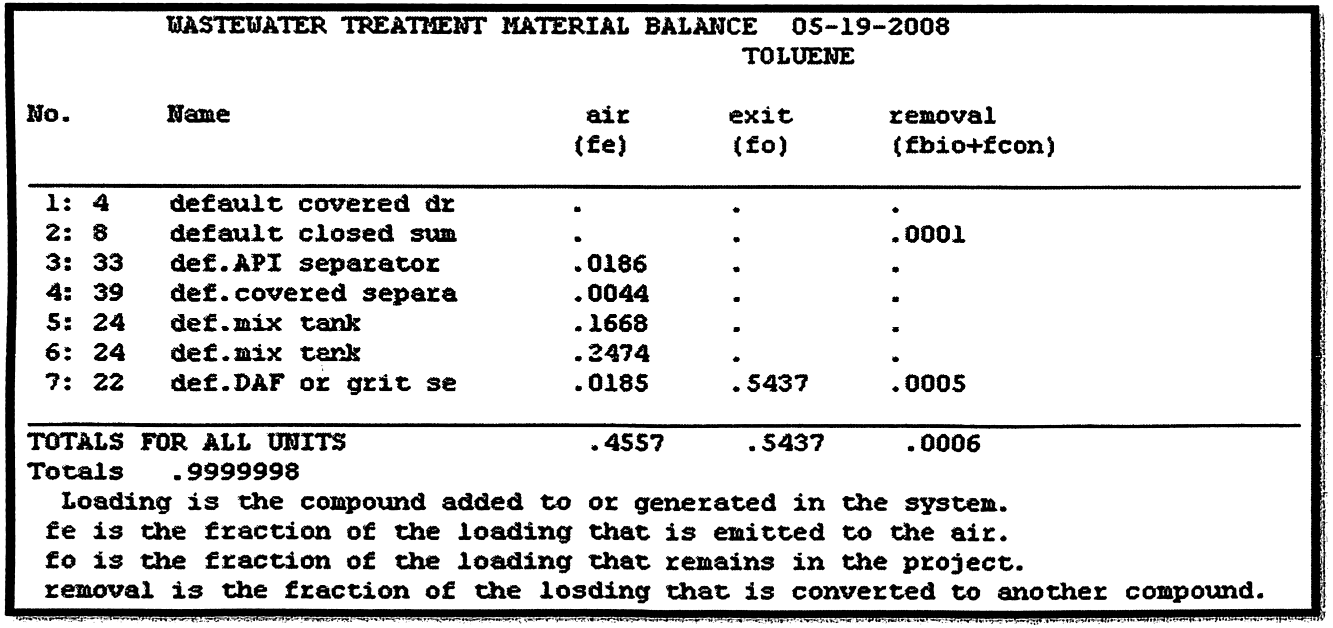
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                                PHENOL
No.       Name                          load      air       exit      removal
                                       (g/s)     (g/s)     (g/s)     (g/s)
1: 4      default covered dr         8.34 E+00 0. E+00   0. E+00   0. E+00
2: 8      default closed sum         0. E+00   8.38 E-10 0. E+00   1.59 E-08    0. Mg emis/yr.
3: 33     def.API separator          0. E+00   1.2 E-03  0. E+00   0. E+00      0.038 Mg emis/yr.
4: 39     def.covered separa         0. E+00   4.54 E-06 0. E+00   0. E+00      0. Mg emis/yr.
5: 24     def.mix tank               0. E+00   1.73 E-04 0. E+00   0. E+00      0.005 Mg emis/yr.
6: 24     def.mix tank               0. E+00   7.77 E-04 0. E+00   0. E+00      0.025 Mg emis/yr.
7: 22     def.DAF or grit se         0. E+00   1.3 E-06  8.33 E+00 3.02 E-05    0. Mg emis/yr.
TOTALS FOR ALL UNITS                  8.34 E+00 2.16 E-03 3.33 E+00 3.02 E-05
Total emissions for all units   0.068046 Mg/yr (150.012 lb/yr)
Total emissions per total flow  2.069e-05 g/L (0.17267 lb/million gal.)
Total loading of compound   8.336 g/s. (263.064 Mg/yr.)(579947.459 lb/yr.)
Total fraction air emissions   .0003
MATERIAL BALANCE   2.71295E-07   PERCENT DIFFERENCE =  3.254498E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



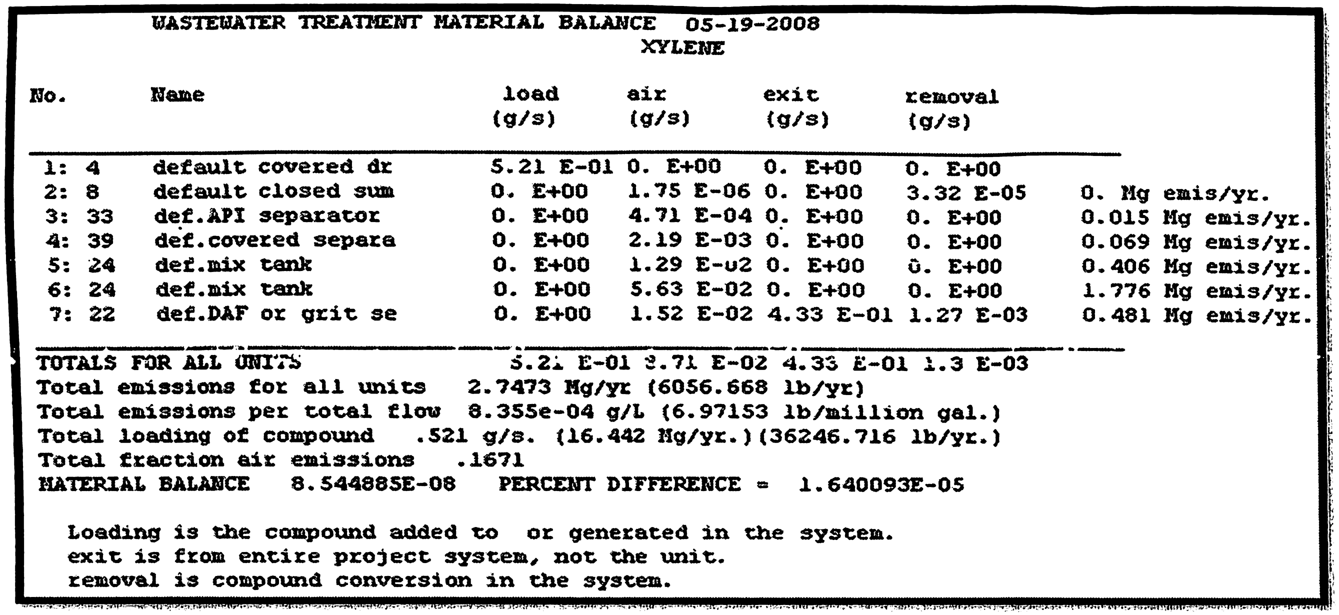
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                               PHENOL

No.       Name                          air        exit       removal
                                        (fe)       (fo)       (fbio+fcon)

1: 4      default covered dr            .          .          .
2: 8      default closed sum            .          .          .
3: 33     def.API separator             .0001      .          .
4: 39     def.covered separa            .          .          .
5: 24     def.mix tank                  .          .          .
6: 24     def.mix tank                  .0001      .          .
7: 22     def.DAF or grit se            .          .9997      .

TOTALS FOR ALL UNITS                    .0003      .9997      .
Totals   1
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



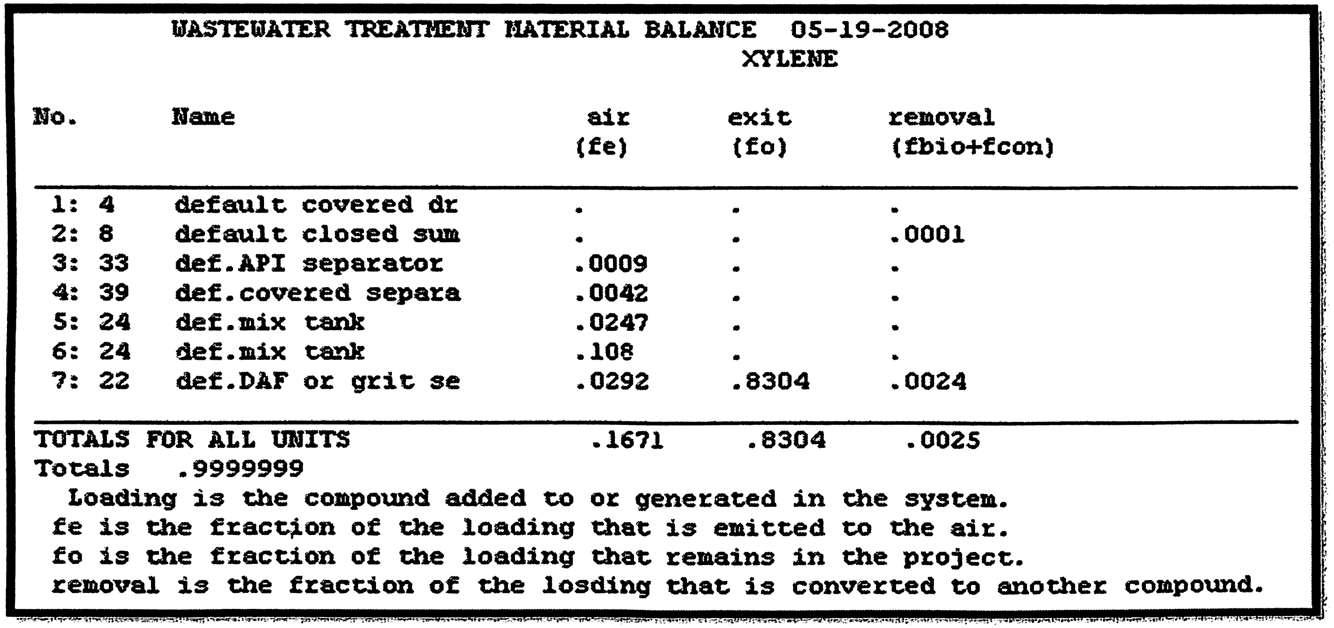
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                           TOLUENE

No.       Name                      load       air        exit       removal
                                    (g/s)      (g/s)      (g/s)      (g/s)

 1: 4     default covered dr        5.21 E-01 0.  E+00   0.  E+00   0.  E+00
 2: 8     default closed sum        0.  E+00   2.2 E-06  0.  E+00   4.18 E-05    0. Mg emis/yr.
 3: 33    def.API separator         0.  E+00   9.69 E-03 0.  E+00   0.  E+00     0.306 Mg emis/yr.
 4: 39    def.covered separa        0.  E+00   2.3 E-03  0.  E+00   0.  E+00     0.073 Mg emis/yr.
 5: 24    def.mix tank              0.  E+00   8.69 E-02 0.  E+00   0.  E+00     2.743 Mg emis/yr.
 6: 24    def.mix tank              0.  E+00   1.29 E-01 0.  E+00   0.  E+00     4.068 Mg emis/yr.
 7: 22    def.DAF or grit se        0.  E+00   9.61 E-03 2.83 E-01 2.62 E-04     0.303 Mg emis/yr.

TOTALS FOR ALL UNITS                 5.21 E-01 2.37 E-01 2.83 E-01 3.03 E-04
Total emissions for all units   7.49291 Mg/yr (1.652e+04 lb/yr)
Total emissions per total flow  0.002279 g/L (19.014 lb/million gal.)
Total loading of compound   .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions    .4557
MATERIAL BALANCE   9.612995E-08   PERCENT DIFFERENCE =  1.845105E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                            TOLUENE

No.       Name                      air        exit       removal
                                    (fe)       (fo)       (fbio+fcon)

 1: 4     default covered dr        .          .          .
 2: 8     default closed sum        .          .          .0001
 3: 33    def.API separator         .0186      .          .
 4: 39    def.covered separa        .0044      .          .
 5: 24    def.mix tank              .1668      .          .
 6: 24    def.mix tank              .2474      .          .
 7: 22    def.DAF or grit se        .0185      .5437      .0005

TOTALS FOR ALL UNITS                 .4557      .5437      .0006
Totals    .9999998
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



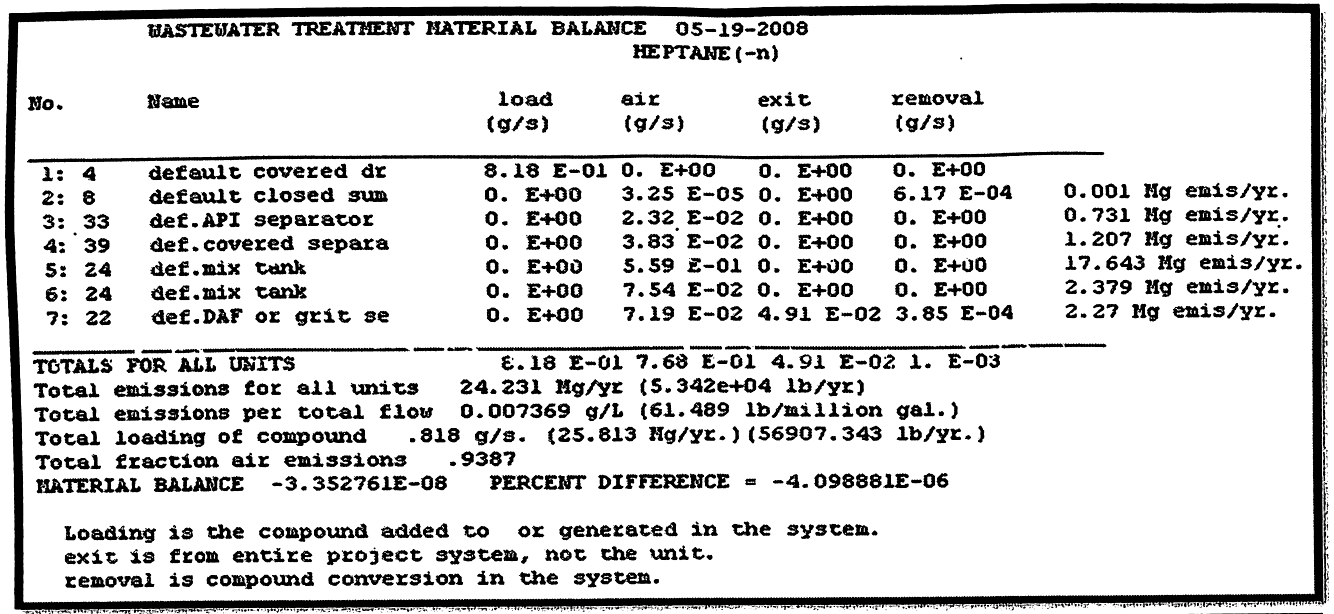
```
         WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                        XYLENE

No.      Name                       load      air       exit      removal
                                   (g/s)     (g/s)     (g/s)     (g/s)
-------------------------------------------------------------------------
 1: 4    default covered dr      5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum      0. E+00   1.75 E-06 0. E+00   3.32 E-05     0. Mg emis/yr.
 3: 33   def.API separator       0. E+00   4.71 E-04 0. E+00   0. E+00     0.015 Mg emis/yr.
 4: 39   def.covered separa      0. E+00   2.19 E-03 0. E+00   0. E+00     0.069 Mg emis/yr.
 5: 24   def.mix tank            0. E+00   1.29 E-02 0. E+00   0. E+00     0.406 Mg emis/yr.
 6: 24   def.mix tank            0. E+00   5.63 E-02 0. E+00   0. E+00     1.776 Mg emis/yr.
 7: 22   def.DAF or grit se      0. E+00   1.52 E-02 4.33 E-01 1.27 E-03     0.481 Mg emis/yr.
-------------------------------------------------------------------------
TOTALS FOR ALL UNITS             5.21 E-01 3.71 E-02 4.33 E-01 1.3 E-03
Total emissions for all units   2.7473 Mg/yr (6056.668 lb/yr)
Total emissions per total flow  8.355e-04 g/L (6.97153 lb/million gal.)
Total loading of compound    .521 g/s. (16.442 Mg/yr.)(36246.716 lb/yr.)
Total fraction air emissions    .1671
MATERIAL BALANCE    8.544885E-08    PERCENT DIFFERENCE =  1.640093E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



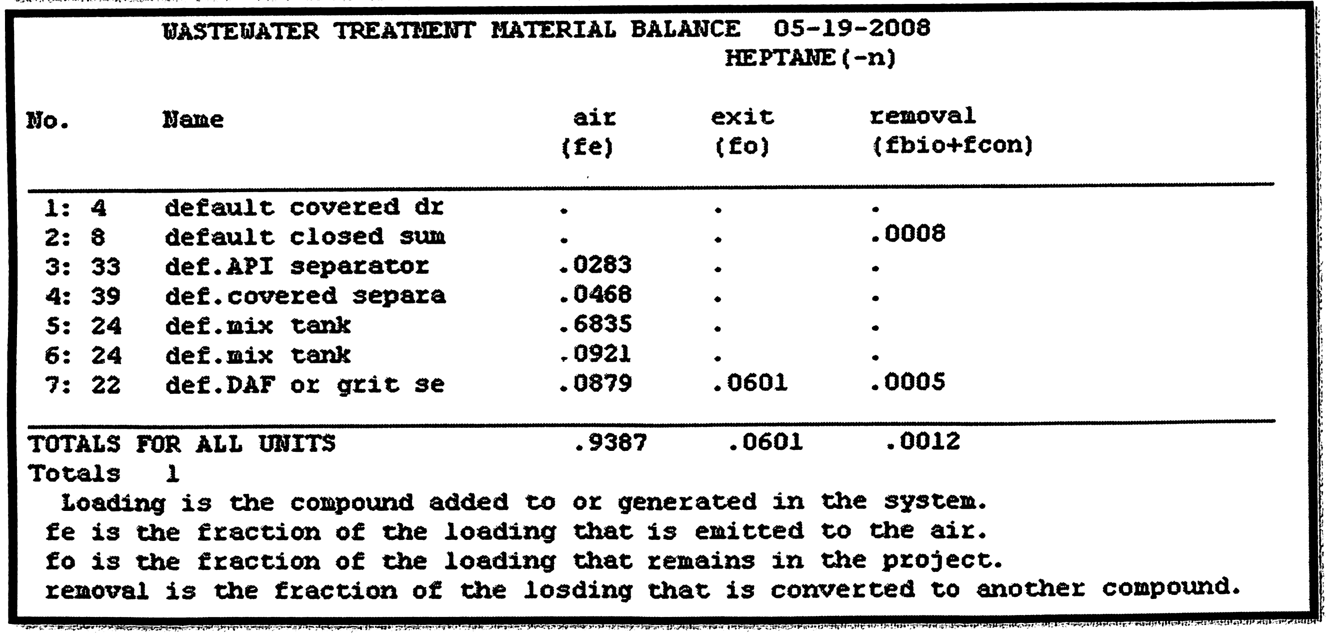
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                         XYLENE

No.       Name                     air        exit       removal
                                  (fe)       (fo)       (fbio+fcon)
--------------------------------------------------------------------
 1: 4     default covered dr      .          .          .
 2: 8     default closed sum      .          .          .0001
 3: 33    def.API separator       .0009      .          .
 4: 39    def.covered separa      .0042      .          .
 5: 24    def.mix tank            .0247      .          .
 6: 24    def.mix tank            .108       .          .
 7: 22    def.DAF or grit se      .0292      .8304      .0024
--------------------------------------------------------------------
TOTALS FOR ALL UNITS               .1671      .8304      .0025
Totals   .9999999
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```

```
           WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                                 ETHANETHIOL (ethyl mercaptan)

No.      Name                          load      air         exit       removal
                                       (g/s)     (g/s)       (g/s)      (g/s)
 ------------------------------------------------------------------------------
 1: 4     default covered dr          2.08 E-01 0. E+00    0. E+00    0. E+00
 2: 8     default closed sum          0. E+00   3.94 E-07 0. E+00    7.48 E-06     0. Mg emis/yr.
 3: 33    def.API separator           0. E+00   2.65 E-03 0. E+00    0. E+00       0.084 Mg emis/yr.
 4: 39    def.covered separa          0. E+00   5.97 E-04 0. E+00    0. E+00       0.019 Mg emis/yr.
 5: 24    def.mix tank                0. E+00   2.83 E-03 0. E+00    0. E+00       0.089 Mg emis/yr.
 6: 24    def.mix tank                0. E+00   1.4 E-02  0. E+00    0. E+00       0.441 Mg emis/yr.
 7: 22    def.DAF or grit se          0. E+00   3.83 E-03 1.85 E-01 0. E+00       0.121 Mg emis/yr.
 ------------------------------------------------------------------------------
TOTALS FOR ALL UNITS                 2.00 E-01 2.39 E-02 1.85 E-01 7.48 E-06
Total emissions for all units   0.75353 Mg/yr (1661.216 lb/yr)
Total emissions per total flow  2.292e-04 g/L (1.91214 lb/million gal.)
Total loading of compound   .2084 g/s. (6.577 Mg/yr.)(14498.686 lb/yr.)
Total fraction air emissions   .1146
MATERIAL BALANCE    1.402577E-08    PERCENT DIFFERENCE =   6.730218E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```

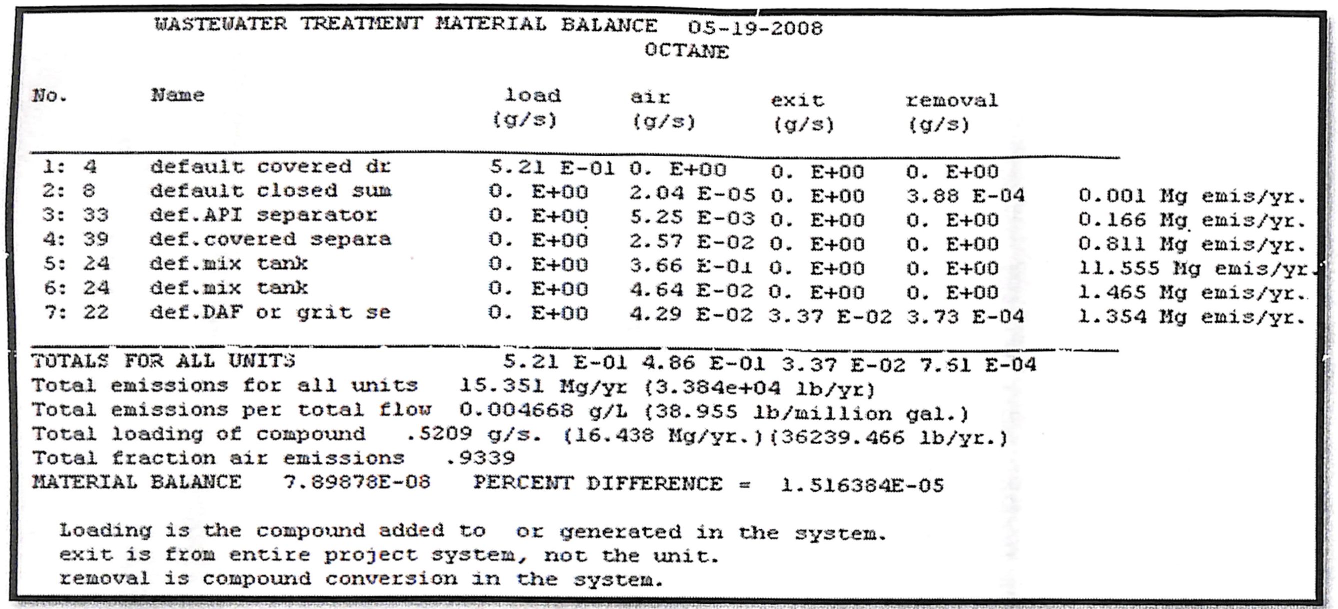
```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                            ETHANETHIOL (ethyl mercaptan)

No.      Name                      air       exit       removal
                                   (fe)      (fo)       (fbio+fcon)
 ----------------------------------------------------------------------
 1: 4     default covered dr       .         .          .
 2: 8     default closed sum       .         .          .
 3: 33    def.API separator        .0127     .          .
 4: 39    def.covered separa       .0029     .          .
 5: 24    def.mix tank             .0136     .          .
 6: 24    def.mix tank             .0671     .          .
 7: 22    def.DAF or grit se       .0184     .8854      .
 ----------------------------------------------------------------------
TOTALS FOR ALL UNITS               .1146     .8854      .
Totals   1
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



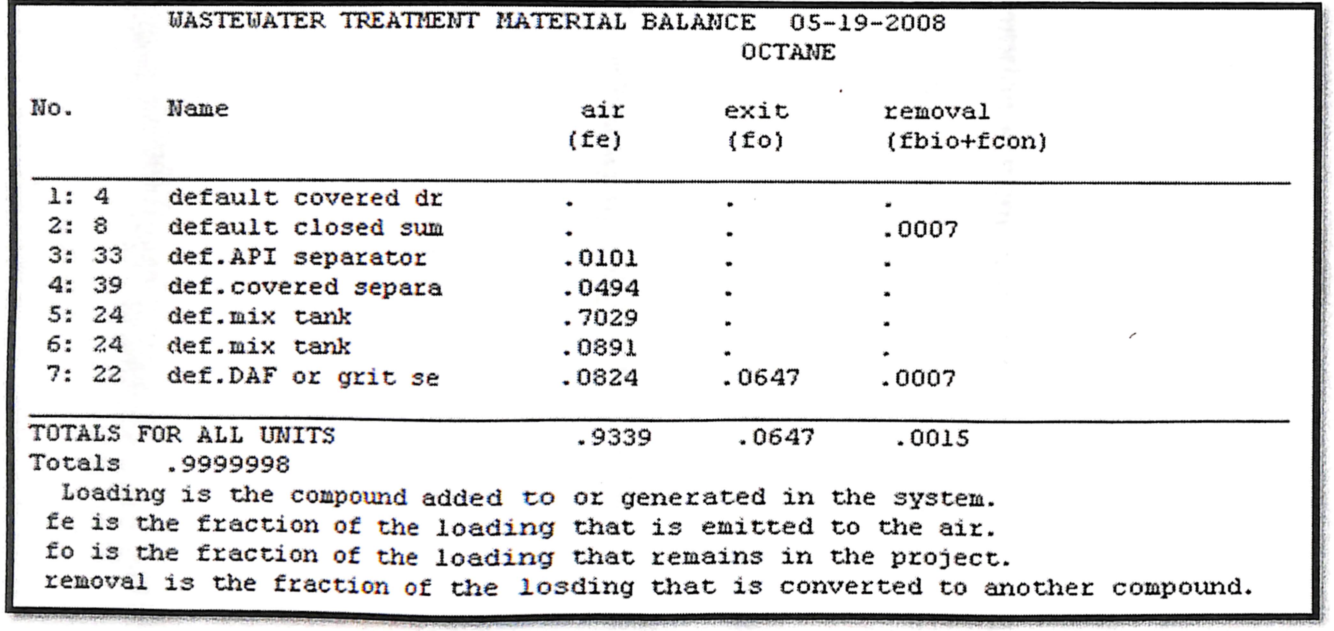
```
            WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                                 HEPTANE(-n)

No.     Name                      load      air       exit      removal
                                  (g/s)     (g/s)     (g/s)     (g/s)
------------------------------------------------------------------------
 1: 4   default covered dr        8.18 E-01 0. E+00   0. E+00   0. E+00
 2: 8   default closed sum        0. E+00   3.25 E-05 0. E+00   6.17 E-04    0.001 Mg emis/yr.
 3: 33  def.API separator         0. E+00   2.32 E-02 0. E+00   0. E+00      0.731 Mg emis/yr.
 4: 39  def.covered separa        0. E+00   3.83 E-02 0. E+00   0. E+00      1.207 Mg emis/yr.
 5: 24  def.mix tank              0. E+00   5.59 E-01 0. E+00   0. E+00      17.643 Mg emis/yr.
 6: 24  def.mix tank              0. E+00   7.54 E-02 0. E+00   0. E+00      2.379 Mg emis/yr.
 7: 22  def.DAF or grit se        0. E+00   7.19 E-02 4.91 E-02 3.85 E-04    2.27 Mg emis/yr.
------------------------------------------------------------------------
TOTALS FOR ALL UNITS              8.18 E-01 7.68 E-01 4.91 E-02 1. E-03
Total emissions for all units   24.231 Mg/yr (5.342e+04 lb/yr)
Total emissions per total flow  0.007369 g/L (61.489 lb/million gal.)
Total loading of compound    .818 g/s. (25.813 Mg/yr.)(56907.343 lb/yr.)
Total fraction air emissions   .9387
MATERIAL BALANCE  -3.352761E-08    PERCENT DIFFERENCE = -4.098881E-06

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



```
        WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                          HEPTANE(-n)

No.     Name                   air      exit     removal
                               (fe)     (fo)     (fbio+fcon)
-----------------------------------------------------------
 1: 4   default covered dr     .        .        .
 2: 8   default closed sum     .        .        .0008
 3: 33  def.API separator      .0283    .        .
 4: 39  def.covered separa     .0468    .        .
 5: 24  def.mix tank           .6835    .        .
 6: 24  def.mix tank           .0921    .        .
 7: 22  def.DAF or grit se     .0879    .0601    .0005
-----------------------------------------------------------
TOTALS FOR ALL UNITS            .9387    .0601    .0012
Totals   1
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```



```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                          OCTANE
No.      Name                        load      air       exit      removal
                                    (g/s)     (g/s)     (g/s)     (g/s)
-------------------------------------------------------------------------
 1: 4    default covered dr        5.21 E-01 0. E+00   0. E+00   0. E+00
 2: 8    default closed sum        0. E+00   2.04 E-05 0. E+00   3.88 E-04   0.001 Mg emis/yr.
 3: 33   def.API separator         0. E+00   5.25 E-03 0. E+00   0. E+00     0.166 Mg emis/yr.
 4: 39   def.covered separa        0. E+00   2.57 E-02 0. E+00   0. E+00     0.811 Mg emis/yr.
 5: 24   def.mix tank              0. E+00   3.66 E-01 0. E+00   0. E+00     11.555 Mg emis/yr.
 6: 24   def.mix tank              0. E+00   4.64 E-02 0. E+00   0. E+00     1.465 Mg emis/yr.
 7: 22   def.DAF or grit se        0. E+00   4.29 E-02 3.37 E-02 3.73 E-04   1.354 Mg emis/yr.
-------------------------------------------------------------------------
TOTALS FOR ALL UNITS                5.21 E-01 4.86 E-01 3.37 E-02 7.61 E-04
Total emissions for all units    15.351 Mg/yr (3.384e+04 lb/yr)
Total emissions per total flow  0.004668 g/L (38.955 lb/million gal.)
Total loading of compound    .5209 g/s. (16.438 Mg/yr.)(36239.466 lb/yr.)
Total fraction air emissions    .9339
MATERIAL BALANCE    7.89878E-08    PERCENT DIFFERENCE =  1.516384E-05

  Loading is the compound added to  or generated in the system.
  exit is from entire project system, not the unit.
  removal is compound conversion in the system.
```



```
          WASTEWATER TREATMENT MATERIAL BALANCE  05-19-2008
                                            OCTANE

No.      Name                        air         exit        removal
                                     (fe)        (fo)        (fbio+fcon)
------------------------------------------------------------------------
 1: 4    default covered dr          .           .           .
 2: 8    default closed sum          .           .           .0007
 3: 33   def.API separator           .0101       .           .
 4: 39   def.covered separa          .0494       .           .
 5: 24   def.mix tank                .7029       .           .
 6: 24   def.mix tank                .0891       .           .
 7: 22   def.DAF or grit se          .0824       .0647       .0007
------------------------------------------------------------------------
TOTALS FOR ALL UNITS                  .9339       .0647       .0015
Totals    .9999998
  Loading is the compound added to or generated in the system.
 fe is the fraction of the loading that is emitted to the air.
 fo is the fraction of the loading that remains in the project.
 removal is the fraction of the losding that is converted to another compound.
```

CONCLUSION

Petroleum industries emit gaseous and liquid Volatile Organic Compounds (VOCs) which have to be reduced as per the new Environmental Pollution Act. In purview of the stringent environmental rules, all the units have to adopt VOC control and treatment measures. In the present case, all the units in an Effluent Treatment Plant of a typical refinery are closed (previously used to be open) and provided with the vent connecting the main header.

For the present case carbon adsorption system is considered for the control and treatment of VOC based on the merit of the system and techno-economic superiority on the other systems.

Activated carbon adsorption technique can be compared with the condensation technique and a cost analysis can be done in future.

REFERENCES

1. J. Loss Prev Proc. Ind. 13 (2000), 527-545; Khan, F.I., Ghoshal, A.Kr.
2. Proc. Ann. Loss Prevention Symp (1999), 33rd, 5d/1-5d/17, Ozog H., Erny W.J.
3. Environmental Engineering World (1995), 1995, 1(4), 18-23; Straitz, J.F. III
4. North American Combustion Handbook, Second Edition.
5. http://www.enardo.com
6. Water9 (version 3.0)