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RECOVERY OF PETROL VAPOUR AT A BULK STORAGE FACILITY

By

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DECLARATION BY STUDENT

I, CORNELIA VENTER, hereby declare that the work as contained in this document was compiled and set out by myself and it has not been submitted to any other university.

SIGNED ON THE 24th DAY OF NOVEMBER 2003.

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CORNELIA VENTER

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RECOVERY OF PETROL AT A BULK STORAGE FACILITY

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SYNOPSIS

VOC emissions are emitted during the various storage and distribution stages of petrol. These emissions contribute to the formation of smog and the control of these emissions has been applied internationally for some years. Vapour recovery is the preferred control technology after prevention and minimisation. The application of vapour recovery of petrol in South Africa has been limited and the first vapour recovery unit in the country was installed at the Engen-Wentworth storage and loading facility in 2001. Petrol loading data and vapour analyses data were used to determine the theoretical and experimental filling emissions from the Engen bulk storage facility. The average filling emission at the Engen facility was 0,08% compared to a value of 0,05% in Europe. It is recommended that further research be conducted to determine the vapour collection efficiency at the Engen facility, and to assess VOC emissions from the other stages in the overall petrol storage and distribution system.

KEYWORDS: volatile organic compounds, carbon vacuum adsorption process, petrol, vapour, vapour recovery systems, bulk storage facility

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ABBREVIATIONS

BAT	Best Available Technology/Technique
CAA	Clean Air Act
CAPCO	Chief Air Pollution Control Officer
CFR	Code of Federal Regulations
CVA	Carbon Vacuum Adsorption
EMCAs	Environmental Management Co-operation Agreements
EPA	Environmental Protection Agency
EU	European Union
GLO	Groundlevel Ozone
GNAs	Good Neighbour Agreements
IPPC	Integrated Pollution Prevention and Control
NAAQSs	National Ambient Air Quality Standards
ORVR	Onboard Refuelling Vapour Recovery
PLV	Preloading Vapour
POCP	Photochemical Ozone Creation Potential
RVP	Reid Vapour Pressure
TOMA	Tropospheric Ozone Management Area
VOC/s	Volatile Organic Compound/s
VRU	Vapour Recovery Unit
UNECE	United Nations Economic Commission for Europe

CHAPTER 1

Introduction

Volatile organic compounds (VOCs) are among the most common air pollutants emitted by chemical process industries, and include hydrocarbons such as olefins, paraffins and aromatics. VOCs adversely affect air quality as it is one of the precursors of groundlevel ozone (GLO), the primary component of smog. It can also have a negative impact on human health due to its toxicity. During petrol storage and distribution, VOCs are emitted due to evaporation, where the rate of evaporation depends on factors such as the vapour pressure of the liquid, temperature and turbulence.

Vapour recovery of petrol is used extensively in Europe and the United States of America, with legislation to enforce its use. In South Africa little attention has been given to VOC control in general, and the use of vapour recovery systems in particular. There are also no South African legislation regarding the use of vapour recovery systems for the control of VOC emissions originating from petrol storage and distribution systems.

The Engen-Wentworth refinery and loading facility is situated in Durban's South Basin where poor planning has left a legacy of environmental and social problems. A vapour recovery unit (VRU), the first of its kind in South Africa, was installed at the Engen bulk storage and loading facility to recover vapour originating from road tanker filling. However, little is known locally about the use of vapour recovery generally, the available technologies, as well as the operational setup at bulk storage facilities.

The objectives of this dissertation are to:

- evaluate vapour recovery systems used in first world countries for the control of VOC emissions from petrol,
- determine evaporative losses from the filling of road tankers at a bulk storage facility, and
- assess South African present and future legislation with regard to VOC emission control.

In this dissertation the evaluation of vapour recovery systems and related terminology was conducted *via* a literature survey and is presented in Chapter 2. The complete vapour recovery system at the Engen Wentworth bulk storage and loading facility and the methodology for experimental work is set out in Chapter 3, followed by a discussion of the results in Chapter 4. Conclusions and recommendations are presented in Chapter 5.

CHAPTER 2
Literature survey

2.1 INTRODUCTION

Petrol is a commodity used worldwide. During its use, carbon dioxide, nitrous oxides and hydrocarbons are emitted as a result of combustion processes taking place in a vehicle. Further emissions, consisting of hydrocarbons, take place during the storage and distribution of petrol due to evaporation.

The hydrocarbons emitted during petrol storage and distribution can be broadly classified as volatile organic compounds (VOCs). VOCs make up a major class of air pollutants and is a broad collective term for different organic compounds. These include pure hydrocarbons, partially oxidized hydrocarbons and organics containing chlorine, sulphur and nitrogen; with most VOCs being toxic and/or carcinogenic (Jo and Song, 2001).

According to Jeffery (1998), there is some discrepancy in the definition of VOCs used in international legislation. In the United States of America a VOC is defined as any compound of carbon that participates in atmospheric photochemical reactions, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates and ammonium carbonate. The United Nations Economic Commission for Europe (UNECE) classifies VOCs based on their photochemical ozone creation potential (POCP). POCP is defined as the change in photochemical ozone production due to a change in emission of a particular VOC and can be determined by photochemical model calculations or laboratory experiments (Jeffery, 1998).

In the presence of sunlight, VOCs react with nitrogen oxides forming photochemical oxidants such as ozone. Groundlevel ozone (GLO) is a major component in the formation of smog, can migrate great distances and is a known greenhouse gas. Smog also adversely affects human health, vegetation and materials. Although VOCs and nitrogen oxides occur naturally, anthropogenic sources have greatly increased the concentration in the atmosphere. According to Sangster (1991), VOC emissions originate from:

- industrial and domestic solvents (40%);
- exhaust gases from motor vehicles (25%);
- evaporative and running losses from motor vehicles (10%);
- petrol distribution (3%);
- vehicle refuelling (2%);
- oil refining (3%); and
- 17% from other sources.

Although petrol distribution and vehicle refuelling contributes to only 5% of the total VOC emissions, these emissions are concentrated at petrol bulk storage facilities and service stations, highly frequented by people.

A typical petrol distribution system is shown in Figure 2.1. In South Africa, rail cars and pipelines are mainly used for the transportation of petrol from product storage facilities at refineries to bulk storage tanks at marketing depots, with marine vessels also used in other countries. From the marketing depots road tankers are used to transport the petrol to the service stations.

The control of emissions that occur during the transportation of petrol from bulk storage facilities to the ultimate consumer is represented by three stages, namely (Figure 2.2):

- Stage Ia involves the control of emissions that occur at facilities when road tankers are loaded;

- Stage Ib involves the control of emissions that occur when road tankers unload into service station storage tanks; and
- Stage II involves the control of emissions that are formed during vehicle refuelling.

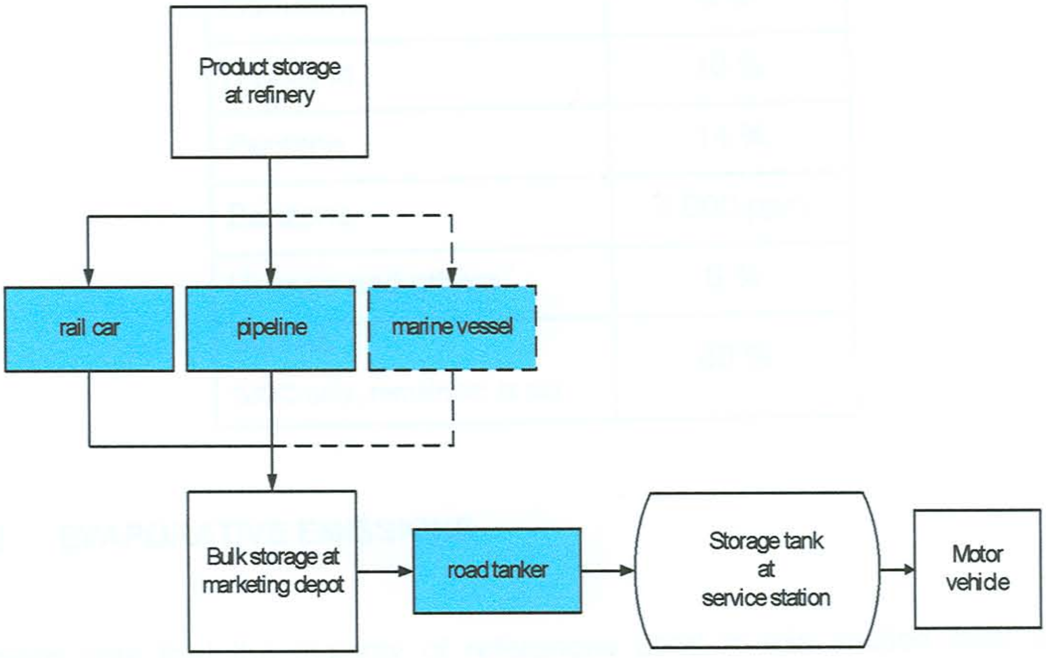

Figure 2.1 Typical petrol distribution system.

During each of these stages evaporation losses occur, as shown in Figure 2.2. Evaporation occurs whenever petrol is introduced into a tank that has a vapour space (Hadley *et al.*, 1978:13). Unless the resultant vapour (a VOC/air mixture) is contained or suppressed by some means, a loss of product results. The VOC composition of petrol vapour; petrol being a mixture of compounds with different boiling points with the tendency of the lower molecular weight compounds to evaporate; is shown in Table 2.1 (Hansen, 1996).

Table 2.1 Typical petrol vapour composition (only VOC).

Compound	Volume
Ethane	Traces
Propane	1,5 %
Isobutane	8 %
n-Butane	10 %
Pentane	14 %
Benzene	5 000 ppm
Hexane and others	6 %
TOTAL (VOC only, remainder is air)	**40 %**

2.2 EVAPORATIVE EMISSIONS

Please note that the majority of references used in this section refer to the publication of Hadley *et al.* (1978). Although other sources were consulted and are available on this particular subject, for example EPA (1995), most of them where found to either refer back to the study conducted by Hadley *et al.* (1978), or do not provide the same in depth coverage of the Hadley study.

According to Hadley *et al.* (1978:8), the average emission from a typical European petrol storage and distribution system, as shown in Figure 2.2, is 0,56 volume % of the petrol distributed. Therefore, for every 1 000 litres of petrol distributed (that is, petrol from the bulk storage facilities to the remainder of the distribution system); 5,6 litres are lost to the atmosphere through evaporative emissions. These emissions can be divided into four types, namely displacement, breathing and withdrawal, filling and refuelling emissions.

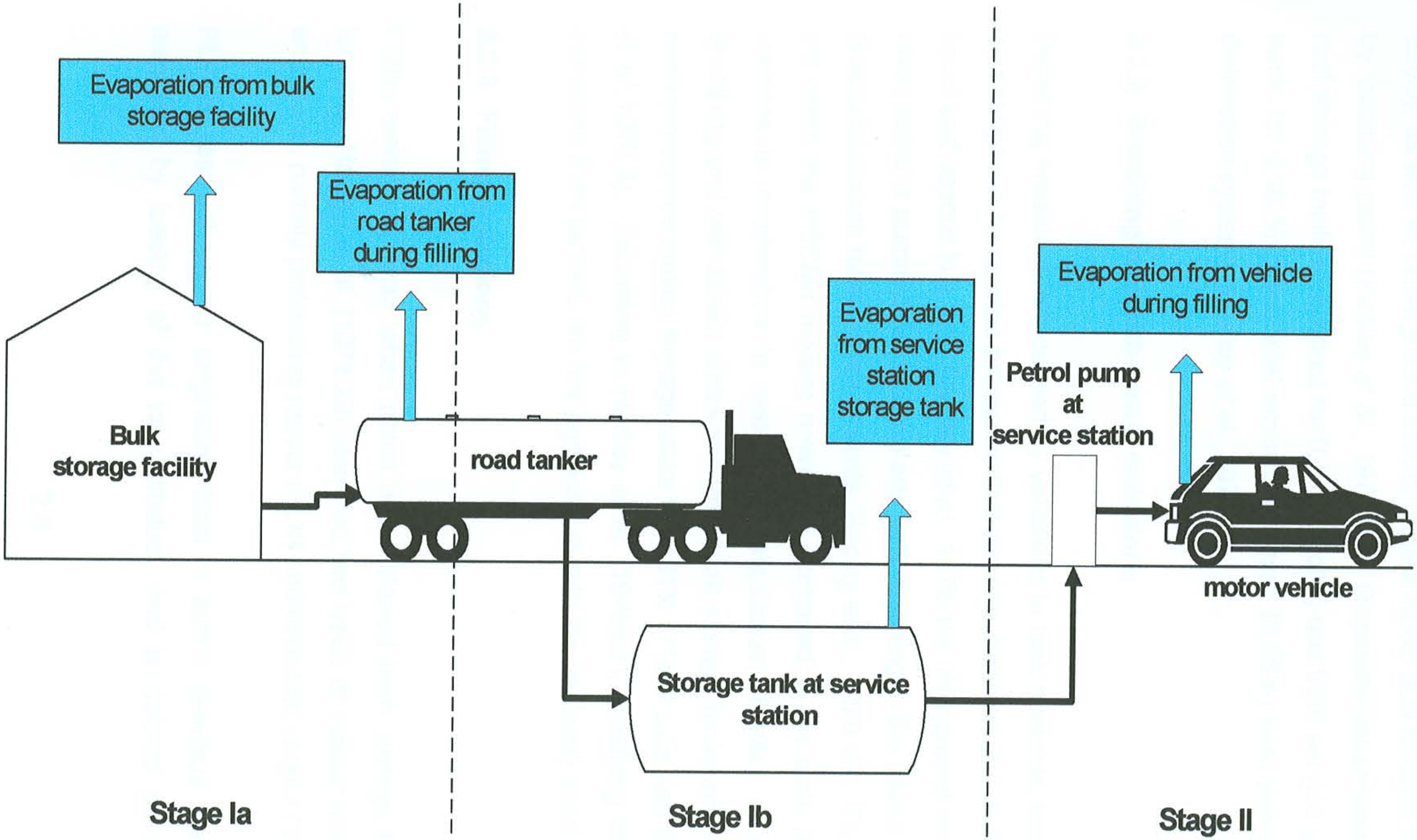

Figure 2.2 Evaporative emissions from petrol storage and distribution systems.

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2.2.1 Displacement emissions

Displacement emissions occur from fixed roof storage facilities (bulk storage tanks), as well as underground service station tanks due to vapour displacement by incoming petrol (Hadley *et al.*, 1978:16). Displacement emissions from fixed roof storage facilities account for 0,14 % (vol%) and from service station storage tanks for 0,16 % of the total emissions losses (0,56%) from petrol storage and distribution systems (Hadley *et al.*, 1978:8).

2.2.2 Breathing and withdrawal emissions

Breathing emissions are caused by variations in tank contents, temperature and by changes in barometric pressures that cause expansion and contraction of the liquid and vapour in a tank (Hadley *et al.*, 1978:16). Withdrawal emissions occur when petrol is pumped out of a storage tank resulting in the intake of air through pressure/vacuum relief valves or vents (Hadley *et al.*, 1978:16). The incoming air will dilute the VOC/air mixture previously contained in the tank, resulting in an increase in evaporation to restore the equilibrium (Hadley *et al.*, 1978:16). Breathing and withdrawal emissions from bulk storage tanks account for 0,02% and from service station storage tanks for 0,01% of total emission losses (Hadley *et al.*, 1978:8). According to Hadley *et al.* (1978:27), breathing and withdrawal emissions from tankers are not significant due to the relatively short transit times.

2.2.3 Filling emissions

Filling emissions occur when petrol is transferred from storage tanks to road tankers. Hadley *et al.* (1978:23) identified two types of vapour making up filling emissions, namely preloading vapour (PLV) and evolution vapour (V_e).

PLV is residual vapour originating from a tank's previous contents, being displaced by loading of the new product, and is defined as a fraction or percentage of full saturation, C_p. According to Hadley *et al.* (1978:24), typical C_p values are:

- C_p less than 1% ($C_p < 0{,}01$) when the previous contents of a road tanker were a non-volatile product;
- C_p between 10% and 20% ($0{,}1 < C_p < 0{,}2$) when the previous contents of a tanker were discharged completely at one point;
- C_p between 30% and 50% ($0{,}3 < C_p < 0{,}5$) when the previous contents were discharged at several occasions; and
- C_p between 90% and 100% ($0{,}9 < C_p < 1{,}0$) when the contents of a tanker were discharged at a service station tank that allows for vapour return.

Evolution vapour (V_e) evaporates from the product itself when it is being loaded. Petrol can be loaded into a road tanker via top splash loading, submerged top loading or bottom loading. Most V_e evaporation takes place during splash loading when the turbulence in a tank is at its peak. In order to estimate V_e, a parameter V_B is used to represent the amount of splashing in a tanker during filling. V_B is equal to the fraction of the original tank atmosphere that is assumed to be completely saturated during loading. Typical values for V_B are (Hadley *et al.*, 1978:25):

- $V_B = 0{,}4$ for top splash loading,
- $V_B = 0{,}15$ for submerged top loading, and
- $V_B = 0{,}13$ for bottom loading.

Hadley *et al.* (1978:26) derived Equation 1 for the calculation of tanker filling emission (E_f) as a percentage of the petrol loaded:

$$E_f = f \times C_s \left[C_p + V_B \left(\frac{1 - C_p}{1 - C_s} \right) \right] \qquad [1]$$

where: E_f = filling emission (liquid equivalent) expressed as a percentage of the volume of liquid loaded;

f = liquid to vapour volume equivalence factor (f = 0,45 under European conditions, as derived in Appendix A);

C_s = concentration of petrol vapour under equilibrium conditions (fully saturated), equal to the petrol true vapour pressure in bars (see Section 2.3, Hadley *et al.*, 1978:42);

C_p = the average preloading vapour concentration expressed as a fraction of full saturation; and

V_B = parameter representing the amount of splashing.

Hadley *et al.* (1978:48) calculated the values for emissions during tanker filling shown in Table 2.2, assuming that petrol from the tanker was discharged at one point only.

Table 2.2 Filling emissions from road tanker loading.

Activity	C_p	V_B	E_f (%)
Top splash loading	0,15	0,40	0,105
Top submerged loading	0,15	0,15	0,055
Bottom loading	0,15	0,13	0,050

2.2.4 Emissions from vehicle refuelling

When a motor vehicle is being refuelled at a service station the incoming petrol displaces the petrol vapour in the fuel tank, causing it to escape into the atmosphere. These emissions contribute to 0,18 volume % of the total emissions from petrol storage and distribution systems (Hadley *et* al., 1978:28).

2.3 FACTORS AFFECTING EVAPORATION

The main factors affecting evaporation are product (liquid petrol) properties, liquid/vapour interface areas and turbulence in the relevant liquid and vapour. Product properties that play a role during evaporation are vapour pressure and temperature. The higher either the vapour pressure and/or the temperature of a liquid, the higher the expected rate of evaporation. The vapour pressure of a petroleum product can be determined by using the Reid vapour pressure (RVP) method where RVP is also a generic term used for petrol volatility (EPA, 2003a). RVP is a standard laboratory method that measures the Reid vapour pressure of a substance at a temperature of 100ºF, or 37,8 °C (Hadley *et al.*, 1978:13). According to Hadley *et al.* (1978:14), the RVP is about 10% less than the true vapour pressure. Figure B.1 in Appendix B shows a nomogram for the determination of true vapour pressure from RVP at any temperature for different petroleum products (Hadley *et al.*, 1978:29).

The rate of evaporation is also proportional to the area of the liquid/vapour interface (Hadley *et al.*, 1978). By decreasing the liquid/vapour interface area, the amount of evaporation will decrease due to the limited amount of vapour space above the liquid (Hadley *et al.*, 1978:15).

Turbulence in the liquid and/or vapour will increase the rate of evaporation and reduces the time necessary to reach 100 % saturation in the vapour space via two mechanisms (Hadley *et al.*, 1978:15). When light hydrocarbons evaporate, the thin liquid surface layer becomes momentarily deficient in these molecules, slowing the rate of evaporation. However, when fresh petrol is loaded, the light hydrocarbons move to this region via diffusion and evaporation continues. This process is accelerated by mixing and/or turbulence in the liquid.

In the vapour space above the liquid, the hydrocarbon molecules are heavier than air and tend to accumulate as a layer just above the liquid surface, suppressing further evaporation (Hadley *et al.*, 1978:15). Turbulent movements in the vapour space caused by thermal convection currents or pressure vacuum valve air intakes accelerate evaporation.

2.4 CONTROL OF EMISSIONS

Emissions from petrol storage and distribution systems can be controlled in accordance to the hierarchy of methods presented in Figure 2.3. The hierarchy of these methods, namely prevention, minimisation, recovery and finally treatment; represents the ideal hierarchical order of managing emissions from petrol storage and distribution systems.

2.4.1 Emission prevention and minimisation

The same techniques are followed in both the prevention and minimisation of emissions. These include decreasing the volatility of petrol (by lowering RVP or introducing RVP limits) and its temperature, vapour balancing, minimising the liquid/vapour interface area and reducing turbulence.

It is common practice in large parts of Europe and North America to blend petrol to a predetermined RVP limit, depending on the season (Kojima and Mayorga-Alba, 1998). For summers the RVP of petrol is typically limited to between 48 kPa to 55 kPa and for winters between 70 kPa to 90 kPa, resulting in reduced emissions (Kojima and Mayorga-Alba, 1998). Although there has been a move in lowering the RVP limits generally, lower limits exist to avoid combustion problems in motor vehicles (Hansen, 1996).

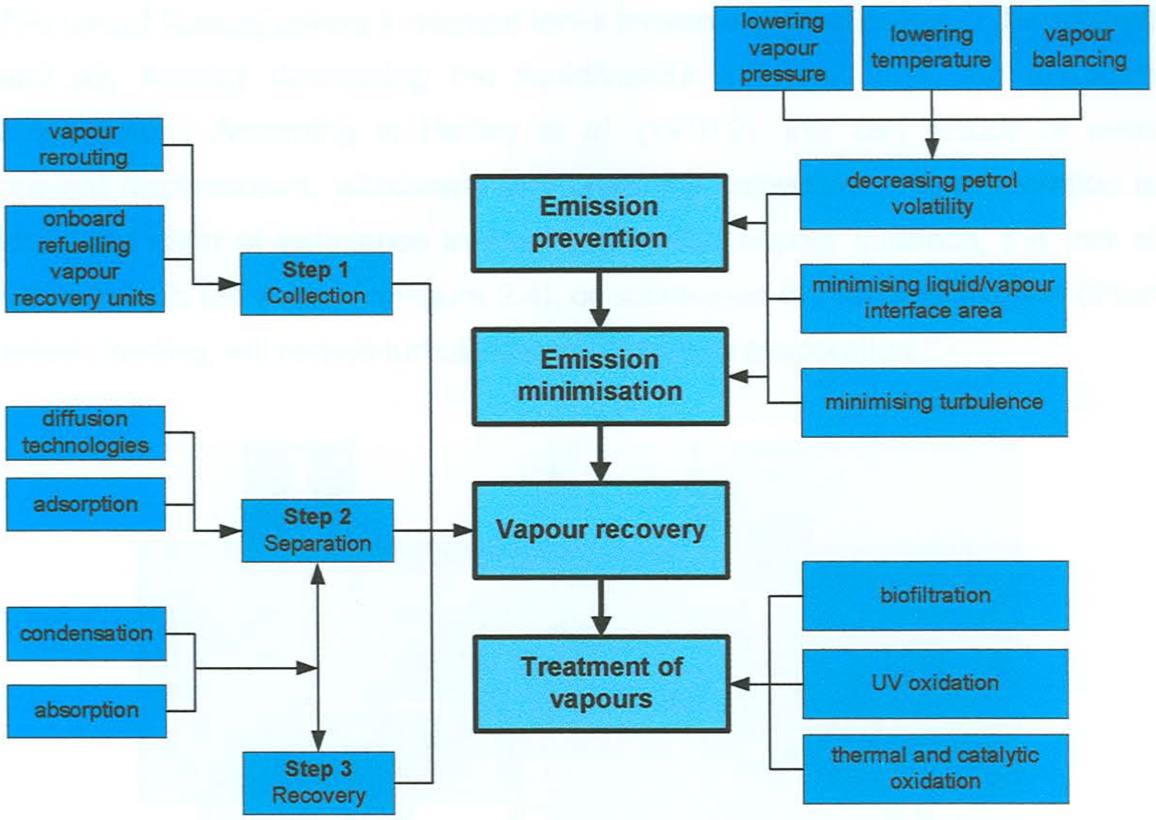

Figure 2.3 Hierarchy of vapour emission control.

Lowering the temperature that petrol is stored at will decrease the true vapour pressure and therefore decrease the amount of evaporation. Methods in reducing petrol temperature include painting of storage tanks in sun reflecting colours (for example, silver and white) and the use of underground storage tanks.

Vapour balancing involves a vapour retrieval system whereby vapour displaced from tanks/tankers receiving petrol is returned to the tanks/tankers delivering petrol. For example, vapour formed during vehicle refuelling is rerouted back to the service station storage tank. The liquid inside the service station storage tank will only evaporate until the vapour in the air space above the liquid reaches a certain pressure, therefore less evaporation will occur due to the returned vapour (Jeffery, 1998).

The use of floating covers in storage tanks prevents contact between the product and air, thereby decreasing the liquid/vapour interface area and therefore evaporation. According to Hadley *et al.* (1978:2), this can reduce or even prevent displacement, withdrawal and breathing emissions. As evaporation is also a function of turbulence in the liquid and/or vapour interface, the use of either bottom (as shown in Figure 2.4), or submerged top loading, instead of top splash loading; will reduce turbulence and therefore evaporation.

Figure 2.4 Bottom loading.

2.4.2 Vapour recovery

Vapour recovery is a broad term for a process where petrol vapour, which would normally escape into the atmosphere, is recaptured and recovered into the liquid state. It involves the:

Step 1 collection of VOCs/air mixture,
Step 2 separation of VOCs from air, and
Step 3 the recovery of the separated VOCs into liquid state.

Recovery systems generally consist of vapour collection or balancing systems; using either condensation, absorption, diffusion and/or adsorption technologies to recovery vapour emissions.

Collection of vapour

Vapour collection (Step 1) can take place during either or all of the three stages of the petrol storage and distribution system identified in Section 2.1. Stage I collection involves the collection of vapour formed during road tanker loading at terminals (Stage Ia) and unloading at service stations (Stage Ib). Road tankers are modified to allow for the collection/rerouting of vapour from the road tanker to a vapour recovery unit (VRU) (Stage Ia) and from the service station storage tank to the road tanker (Stage Ib). Modifications involve the closing of vents on a road tanker and service station storage tank and the addition of piping and equipment to allow for vapour collection/rerouting.

The collection of vapour during Stage II involves vapour formed during vehicle refuelling. Two methods can be used. The first method involves the return of vapour to the service station storage tank when refuelling by using a specially modified petrol-filling nozzle, as shown in Figure 2.5. The second method is when the emissions are captured on the vehicle itself by Onboard Refuelling Vapour Recovery (ORVR) units, usually consisting of carbon canisters (Jeffery, 1998).

Once the vapour has been collected, various processes or combinations of processes can be used to separate and recover the vapour (Steps 2 and 3). These include condensation, absorption, diffusion and adsorption.

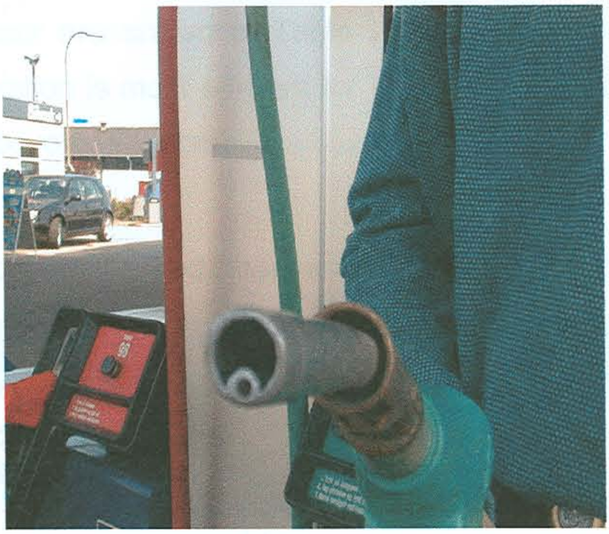

Figure 2.5 Petrol nozzle at service station adapted for the collection of vapour.

Condensation

Condensation of a vapour into liquid can be achieved by compression (increase in pressure) or cooling (decrease in temperature), with separation and re-condensation taking place in a single process as shown in Figure 2.6. However, compression is normally ruled out due to risk of explosion (Jeffery, 1998). Cooling can be achieved by either mechanical refrigeration or using liquid nitrogen (cryogenic condensation) as the cooling medium (Jeffery, 1998).

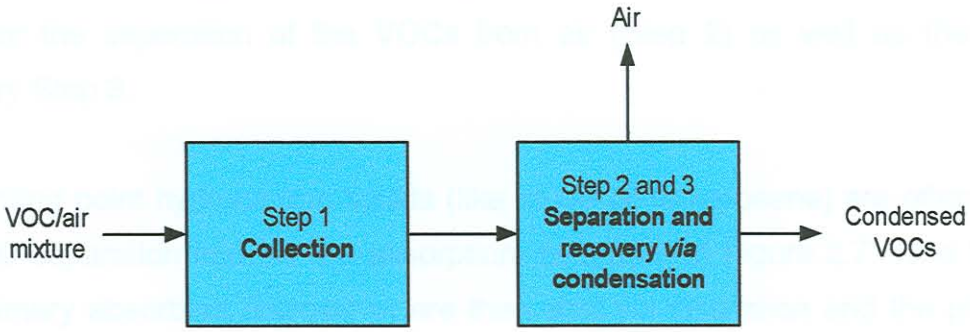

Figure 2.6 Flowdiagram for condensation as vapour recovery process.

The advantages and disadvantages of using condensation for separation and recovery of petrol vapour are shown in Table 2.3. According to Ruddy and Carroll (1993), condensation is most efficient for VOC recovery at relatively high VOC concentrations (above 5 000 ppm).

Table 2.3 Advantages and disadvantages of condensation.

Advantages	Disadvantages
Moderate efficiencies, 50-90% (Ruddy and Carroll, 1993).	Energy requirements of mechanical refrigeration are high (Jeffery, 1998).
Simple, flexible, safe process (Jeffery, 1998).	Nitrogen source needed for cryogenic condensation.
Can handle wide range of products (Jeffery, 1998).	May result in the generation of a wastewater stream (Dunn and El-Halwagi, 1996).

Absorption

The application of absorption is well known in the chemical process industry. When a vapour stream containing VOCs is brought in contact with a hydrocarbon liquid, the VOCs in the vapour will be absorbed into the liquid due to molecular forces. The absorption of the VOCs in the vapour depends on the vapour pressure and the temperature of the absorbent, as well as the liquid-vapour equilibrium. In the case of absorption as vapour recovery method, absorption is used for the separation of the VOCs from air (Step 2) as well as the final, recovery Step 3.

Low boiling point hydrocarbon liquids (like crude oil or kerosene) are often used for VOC separation from air via absorption, as shown in Figure 2.7. The VOCs and primary absorbent (kerosene) are then split via distillation and the primary absorbent recycled and used again (see Figure 2.7). The VOCs is then absorbed into petrol (secondary absorbent) and thereby recovered into the liquid state. Absorption is also used for recovery after separation methods like adsorption or with the use of membranes.

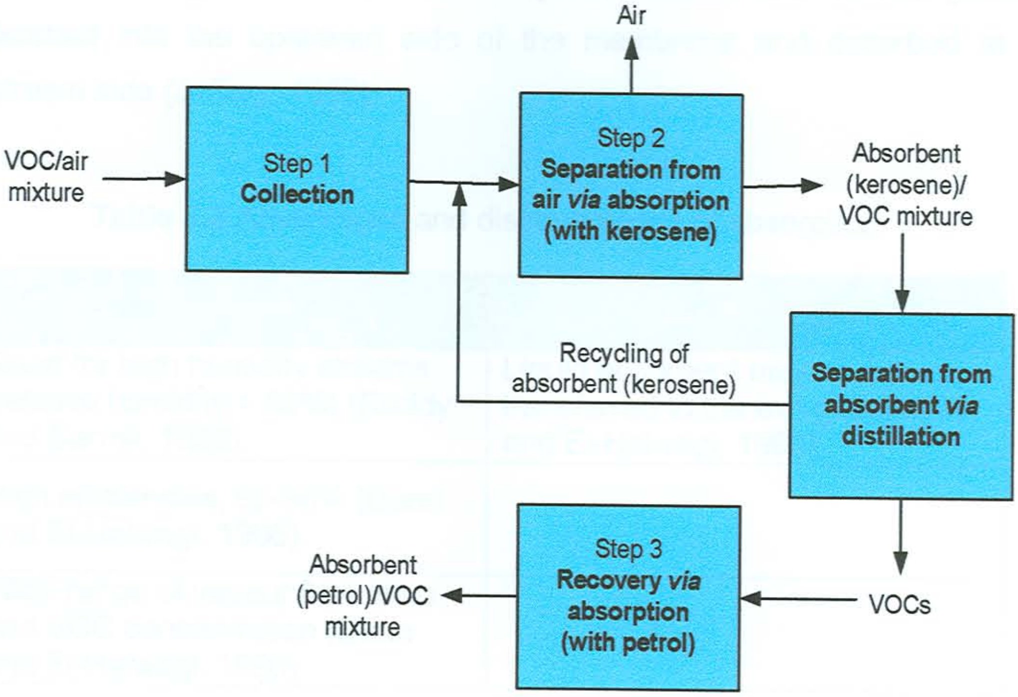

Figure 2.7 Flowdiagram for absorption vapour recovery process using kerosene and petrol as primary and secondary absorbents respectively.

Advantages and disadvantages of absorption as a vapour separation and recovery method are shown in Table 2.4. Absorption can be used for high vapour flows and VOC concentrations ranging between 500 ppm to 5 000 ppm (Ruddy and Carroll, 1993).

Diffusion technologies

The application of diffusion technologies such as membranes for the control of petrol vapour is relatively new. The membranes separate VOCs from the air that can then be recovered by absorption or condensation, as shown in Figure 2.8. There are currently two types of membranes used for the separation of VOCs

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from air, namely diffusion membranes and solubility membranes (Jeffery, 1998). Diffusion membranes act like a sieve where the molecules in the vapour are separated according to their size. Solubility membranes allow certain gases to be adsorbed into the upstream side of the membrane and desorbed at the downstream side (Jeffery, 1998).

Table 2.4 Advantages and disadvantages of absorption.

Advantages	Disadvantages
Good for high humidity streams (relative humidity > 50%) (Ruddy and Carroll, 1993).	Liquid absorbent may be transferred to the exit gas (Dunn and El-Halwagi, 1996).
High efficiencies, 95-98% (Dunn and El-Halwagi, 1996).	
Wide range of vapour flow rates and VOC concentration (Dunn and El-Halwagi, 1996).	

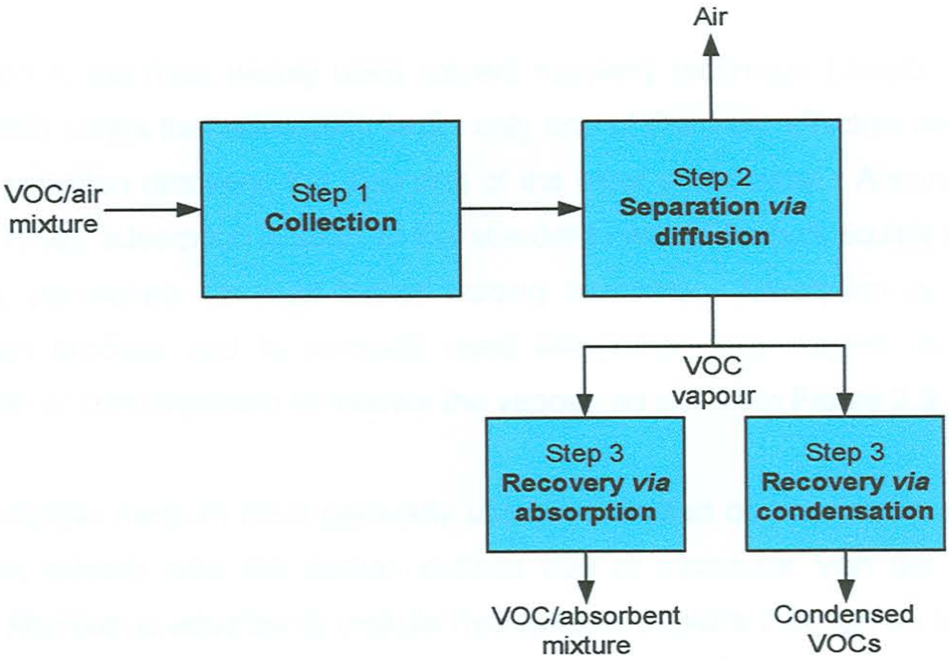

Figure 2.8 Flowdiagram for using diffusion technology as vapour recovery process.

Advantages and disadvantages of using membranes for VOC/air separation are shown in Table 2.5.

Table 2.5 Advantages and disadvantages of diffusion technologies.

Advantages	Disadvantages
Recovery of between 95 and 99% (Ohlrogge, Peinemann, Wind and Behling, 1990).	Constant vapour flow rates are necessary, but buffer tanks are a major safety concern.
Safe process and operational flexibility (Jeffery, 1998).	High power consumption (Jeffery, 1998).
Very wide range of product handling, for example, hydrogen sulphide, acetone, methyl tertiary butyl ether (MTBE), ethyl acetate.	Post treatment system needed in the case of very high emission standards (Ohlrogge *et al.*, 1990).

Adsorption

Adsorption is the most widely used solvent recovery technique (Jacob, 1991). Ruhl (1993) states that adsorption is not only one of the most effective methods of VOC emission recovery, but also one of the most economical. According to Jeffery (1998), adsorption is seen as the standard method for bulk liquids vapour recovery, particularly for road tanker loading terminals. Adsorption is only a separation process and is normally used with other technologies (such as absorption or condensation) to recover the vapour, as shown in Figure 2.9.

The adsorption medium most generally used is activated carbon, where certain molecules adsorb onto the carbon surface due to molecular Van der Waals forces. Alternative adsorbents include hydrophobic zeolites that can be used at higher humidity levels than activated carbon, but at a higher cost (Ruhl, 1993). The VOCs are recovered by regeneration or desorption of the adsorption medium. Two regeneration technologies are currently in use, namely:

- Thermal regeneration

Steam, hot nitrogen and hot flue gases are some of the heat sources used for this type of regeneration. According to Young and Tuttle (1997), thermal regeneration has been the traditional method for maintaining the effective working capacity of activated carbon in many vapour phase applications. *In situ* thermal systems usually have at least three carbon adsorber vessels, one on-stream receiving the vapour, the second being heated for regeneration and the third being cooled before being used again (Young and Tuttle, 1997). The major advantage of thermal regeneration is the large effective working capacity that is created by this regeneration process (Young and Tuttle, 1997). The process is used in applications where the contaminant concentration is low and with high gas temperatures. Disadvantages of thermal regeneration are the time required to heat and cool the carbon; and mechanical damage to the activated carbon because of heating and cooling cycles resulting in more frequent replacement of the carbon.

- Pressure swing and purge regeneration

Pressure swing regeneration involves the decrease in system pressure to desorb the VOCs and a purge stream aids in the removal of VOCs from the carbon bed. This system only requires two carbon beds, the one being on-stream receiving contaminated gas while the second is being regenerated. Two types of pressure swing methods have been used, firstly where adsorption takes place at elevated pressure and the pressure is lowered to regenerate the carbon. Secondly where adsorption takes place at or near atmospheric pressure and during regeneration the pressure is reduced by mechanical means (vacuum pump). According to Young and Tuttle (1997), the benefits of pressure swing regeneration is the longevity of the carbon (up to 12 years), the flexibility of the system, simplicity of the system (only two carbon beds) and the fact that no contaminated condensate has to be treated.

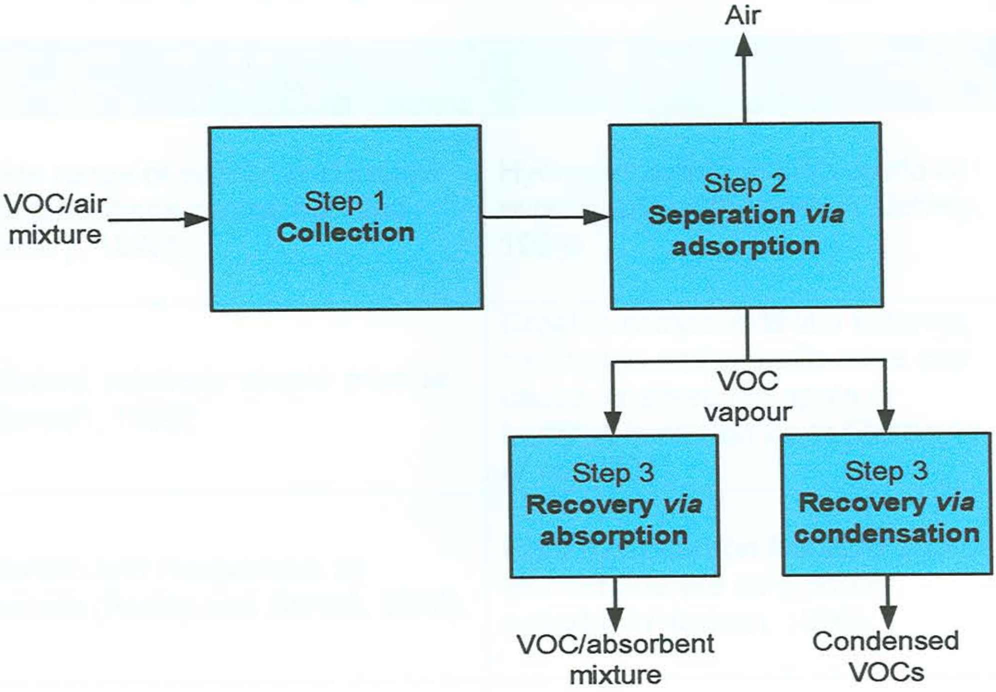

Figure 2.9 Flowdiagram for using adsorption as vapour recovery process.

Advantages and disadvantages of adsorption as a separation method are shown in Table 2.6.

2.4.3 Treatment of vapour

Technologies such as biofiltration, UV oxidation, thermal and catalytic oxidation are some of the methods that could be used to treat vapour containing VOCs. These methods are destructive but in some cases remain the only viable option. Destructive methods have been losing ground with legislative agencies because of the formation of carbon dioxide (a greenhouse gas) and the loss of useful product. According to Moretti and Mukhopadhyay (1993), the selection of destruction versus recovery technologies is usually based on the economic benefit of recovering the VOCs in the waste stream.

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Table 2.6 Advantages and disadvantages of adsorption.

Advantages	Disadvantages
Wide range of vapour and vapour concentrations can be handled (Jeffery, 1998).	Hydrogen sulphide from crude oil vapour poison the carbon (Jeffery, 1998).
Efficient, relatively simple process (Hansen, 1996).	Organic compounds like ketones, aldehydes and organic acids can cause localised hot spots or bedfires in carbon beds (Zerbonia *et al.*, 2001).
Flexible and inexpensive to operate (Ruddy and Carroll, 1993).	Light hydrocarbon fractions such as methane are very poorly adsorbed (Hansen, 1996).
	Carbon performance decreases with high humidity vapour streams (relative humidity > 50%).

Aizpuru *et al.* (2001) concluded that the use of biofiltration is an attractive process for VOC treatment, with a high removal efficiency, that could be improved. It involves the use of a packed column that is seeded with microorganisms that allow for the biodegradation of the VOC to water and carbon dioxide. Packing materials include peat, compost, soil, heather branches, bark and more recently sludge from sewage treatment plants (Aizpure *et al.*, 2001).

UV oxidation uses oxygen-based oxidants (ozone and peroxide) to convert VOCs into carbon dioxide and water in the presence of UV light (Moretti and Mukhopadhyay, 1993).

According to Jacob (1991), thermal oxidation (incineration) is one of the most popular methods of dealing with VOCs in industrial exhaust streams. Thermal oxidizers can achieve efficiencies between 95 and 99%, operating at temperatures between 700 and 1 000 °C (Ruddy and Carroll, 1993). Catalytic oxidizers operate at lower temperatures (370 – 490 °C) due to the use of catalysts, achieving a removal efficiency of between 90 and 95% (Rudy and Carroll, 1993). Thermal and catalytic oxidizers are the most popular VOC treatment methods in use today, because of their broad applicability to a wide range of VOC emission streams (Moretti and Mukhopadhyay, 1993). These methods are technically simpler than vapour recovery, but require a high level of safety considerations (Jeffery, 1998).

2.5 LEGISLATION REGARDING EVAPORATIVE EMISSIONS

In November 1991, the Protocol to the Convention on Long-range Transboundary Air Pollution on the Control of Emissions of VOCs (shortened VOC protocol) was adopted and became effective on 29 September 1997 (UNECE, 2002). It forms part of the Geneva Convention on Long-range, Transboundary Air Pollution that was established and undersigned in 1979 by the United Nations Economic Commission for Europe (UNECE) (Fenger, 1999). UNECE includes countries in North America, Europe and Central Asia. The VOC protocol specified three options for emission reduction targets of which one had to be selected by a country, either upon signature or upon ratification. These options were:

Option 1	30% reduction in emissions of VOCs by 1999, using a year between 1984 and 1990 as basis.
Option 2	The same reduction as for Option 1 within a Tropospheric Ozone Management Area (TOMA), ensuring that by 1999 total national emissions do not exceed 1988 levels.

Option 3 Where emissions in 1988 were low enough not to exceed certain specified levels, countries may opt for a stabilisation at that level of emission by 1999.

Table 2.7 shows the options selected by the various member countries of UNECE.

Table 2.7 Options selected by countries regarding 1991 VOC Protocol.

Option	Base year	Countries
1	1984	Liechtenstein, Switzerland, United States of America.
	1985	Denmark.
	1988	Austria, Belgium, Estonia, Finland, France, Germany, Netherlands, Portugal, Spain, Sweden, United Kingdom.
	1990	Czechoslovakia, Italy, Luxembourg, Monaco, Slovakia.
2	-	There are TOMAs in Norway and Canada.
3	-	Bulgaria, Greece and Hungary.

Legislation in Europe and the USA aimed at reducing the emissions from petrol storage and distribution facilities, to comply with the above mentioned VOC protocol, are limiting VOC emissions by the gradual extension of controls down the fuels distribution chain (Munn and Kornelius, 2002). VOC legislation and regulations for Europe and the United States of America are summarised in Sections 2.5.1 and 2.5.2. An overview of air pollution legislation in South Africa is given in Section 2.5.3.

2.5.1 Overview of VOC emission legislation in Europe

Although minimum standards of emission control have been agreed between countries in Europe, the method of application is left to individual countries and differences do occur (Munn and Kornelius, 2002). The European directive on Integrated Pollution Prevention and Control (IPPC) (Directive 96/61/EC) governs pollution prevention in the industrial sector. The basis for the directive is the use of best available technology (BAT). The first major legislation in Europe regarding VOC emissions was under the German TA Luft 1981 legislation where VOC emissions could not exceed 150 mg/m^3 vented (Sangster, 1991). This remains the most stringent legislation regarding allowed VOC emissions.

In some European countries (Sweden, Denmark) the oil industry voluntarily installed Stage Ia and Ib control facilities to pre-emp perceived legislation at that time (Sangster, 1991). The EU 94/63/EC Directive of 1995 requires the control of VOC emissions resulting from the storage and distribution of petrol from bulk storage facilities to service stations (Stage I). Countries within the EC were required to make the directive law by December 1995 (Jeffery, 1998). According to the Institute of Petroleum (2002), Directive EU 94/63/EC made vapour recovery a requirement from December 1998 for existing terminals loading more than 150 000 ton per annum and for service stations handling more than 1 000 m^3 per annum.

2.5.2 Overview of VOC emission legislation in the USA

The regulatory environment in the USA is highly structured and a combination of regulations and permits are used to achieve results (Munn and Kornelius, 2002). The Environmental Protection Acency (EPA) enacted the first control measures dealing with Stage I operations in 1970 (Sangster, 1991). Stringent controls are applied in certain areas of petrol distribution, such as road tanker loading and unloading, and vehicle refuelling (Jeffery, 1998). The EPA also established national ambient air quality standards (NAAQSs) to limit levels of criteria pollutants. The criteria pollutants are particulate matter, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide and lead. Geographical areas that meet NAAQSs are classified as attainment areas, and the others as non-attainment areas. The classification of these areas determines the type and the severity of emission control that has to be used.

The Clean Air Act (CAA) of 1990 has six titles that, *inter alia*, direct the implementation, maintenance and enforcement of the NAAQSs through a variety of mechanisms. For example, Title I requires the reduction of VOC emissions in areas that exceed the NAAQS for ozone of 0,08 ppm as an 8 hour average (Fenger, 1999) and Title III addresses the reduction of hazardous pollutants.

The Code of Federal Regulations (CFR) contains regulations for the achievement of the CAA and its amendments objectives and is divided into 50 titles. Almost all environmental regulations appear in Title 40 (EPA, 2003b). For example, Regulation 40CFR63 (CFR, 2001), Subpart XX (Standards of Performance for Bulk Gasoline Terminals) stipulates that emissions from vapour collections systems may not exceed 35 mg total organic compound (TOC) per litre of petrol loaded.

2.5.3 South African air pollution legislation

Currently South Africa does not have legislation regarding the use of vapour recovery systems for VOC emission control *per se*. In addition, the country does not have established ambient air quality standards or an overall approach that includes ambient air monitoring and emission inventories to enhance the level of air quality on a country-wide basis (Lents and Nikkila, 2000). The Atmospheric Pollution Prevention Act (No 45 of 1965), as amended, is the primary mechanism in South Africa for the management and control of air pollution. Although part of this act deals with the control of emissions from motor vehicles (only diesel), the bulk storage of liquid petroleum products (scheduled process, no 14(b)) and hydrocarbon gas is classified as an noxious or offensive gas, it does not specifically include the control of VOC emissions from the evaporation of petrol during loading, unloading or vehicle refuelling by the mandatory use of vapour recovery processes. However, the guidelines used by the Chief Air Pollution Control Officer (CAPCO) for the issue of permits to operators of such processes states, *inter alia*, that a fugitive emission monitoring and maintenance programme must be implemented at all plants. This should also include positive identification of all sources of VOCs, estimation of the emission rate, as well a programme of preventative maintenance to minimise such emissions (CAPCO, *s.a.*). Fugitive emissions include the release of gases from anthropogenic activities, such as the storage and transportation of fuel, and therefore the emissions from the storage and distribution of petrol falls under the guidelines discussed above.

Apart from the present drafting of new air legislation, namely the Air Quality Bill (SA Bill, 2003), that makes transitional provision for ambient ozone (O_3) concentrations; VOC emissions are only addressed (partly, together with other pollutants) via the Refinery Managers Environmental Forum (RMEF), which was formed in 2000 by representatives of the major oil fuels manufacturing facilities (Caltex, Engen, Natref, Petro SA, Sapref and Sasol). The forum encourages the sharing of ideas and practices with the aim of promoting a standard of environmental governance in the refineries (Lents and Nikkila, 2000). Due to the formation of the RMEF the refinery industry has become involved in Good Neighbour Agreements (GNAs) and Environmental Management Co-operation Agreements (EMCAs) that have the potential to reduce VOC and other emissions. However, Lents and Nikkila (2000) state that this is a short term solution as these agreements only focus on air quality issues on a localised scale.

Notwithstanding the present state of legislation with regard to VOC emission control, South Africa also struggles with all the environmental constraints associated with a developing country. These include insufficient resources, both manpower and financial, for the effective enforcement of environmental legislation (Friend, 2001). This view is confirmed by Munn and Kornelius (2002), who stated that the biggest difference between South Africa and other countries is the local lack of capacity and resources available, to the government, in order to manage air quality issues. It is unlikely that South Africa will provide the level of resources available elsewhere so it is important that South Africa learn from other countries those measures that can be adopted that are the most successful and require the least resources to implement (Munn and Kornelius, 2002).

CHAPTER 3

Process description and experimental setup

3.1 INTRODUCTION

The Engen refinery in South Africa is located next to the Wentworth residential area in Durban (Figure 3.1). It is the second largest refinery in South Africa, processing 20 million litres of crude oil per day. The products from the refinery are distributed by the Engen logistics and supply division, which has a network of 79 depots throughout Southern Africa, *via* the bulk storage and loading facility situated next to the refinery. The facility provides petrol to service stations by using road tankers as transport method; loading approximately 1,2 million m^3 petrol per year (Cool Sorption, 2001).

Figure 3.1 The Engen (Wentworth) refinery with the bulk storage and loading facility at the foreground.

A vapour recovery unit (VRU) was constructed and installed during 2001 in order to collect the vapour at the facility for processing at the recovery unit. This VRU was used for the experimental work conducted in this dissertation. In this chapter an overview of the unit and associated modifications to road tankers and loading facilities, as well as the carbon vacuum adsorption (CVA) process used to recover the collected vapour, is given. Thereafter the actual experimental setup is described.

3.2 PROCESS DESCRIPTION

3.2.1 Facility and road tanker set-up

There are 9 loading bays at the Engen loading facility for the loading of road tankers. Bays 1 to 2 are used for the loading of other products (like paraffin) and bays 3 to 9 for mainly petrol loading. A vapour header, as shown in Figure 3.2, has been added to the facility for the rerouting of the vapour from the road tankers to the VRU. At each of bays 3-9, vapour return hoses have been installed with adaptors to connect to the road tankers (Figure 3.3). The hoses are connected to vapour return lines (Figure 3.3), which in turn are connected to the vapour header.

Figure 3.2 Loading racks and vapour header leading to VRU.

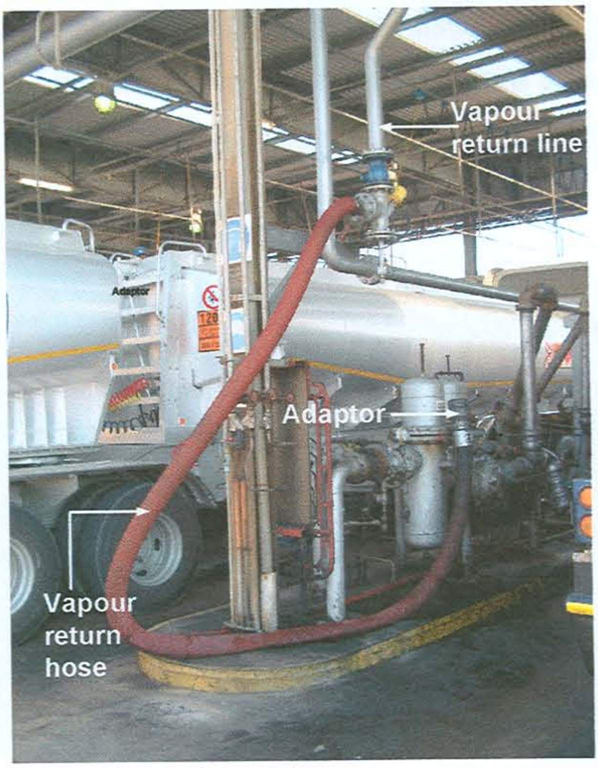

Figure 3.3 Vapour return hose for the transfer of vapour from a tanker to the VRU.

For the recovery of petrol vapour from road tankers to the VRU, certain modifications are required to existing tankers. Normally large road tankers can have up to 4 separate compartments, where each compartment has a pressure relief vent on top. For use at the Engen facility, tankers are adapted to allow for vapour collection/vapour balancing by connecting these vents to an existing manifold and extending it with additional piping, as shown in Figures 3.4 and 3.5.

During loading at the facility, a vapour return hose is connected to the tanker *via* a vapour return adaptor, connecting the tanker and the vapour return line (Figure 3.3). As a tanker is being loaded by using bottom loading (as shown in Figure 2.4), the petrol displaces the vapour in the compartment into the vapour return line. Due to the use of bottom loading, all the tankers must also be fitted with sensors to avoid overfilling. If overfilling occurs, liquid product will accumulate in the vapour return hose, which will prevent the discharge of vapour to the VRU through the vapour return line and vapour header (Figure 3.2).

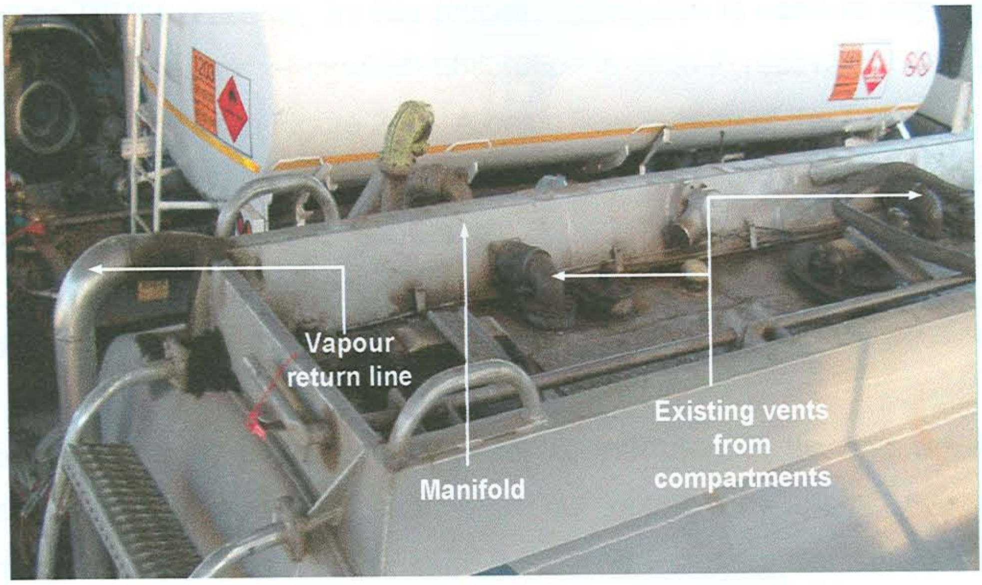

Figure 3.4 Top view of modified road tanker.

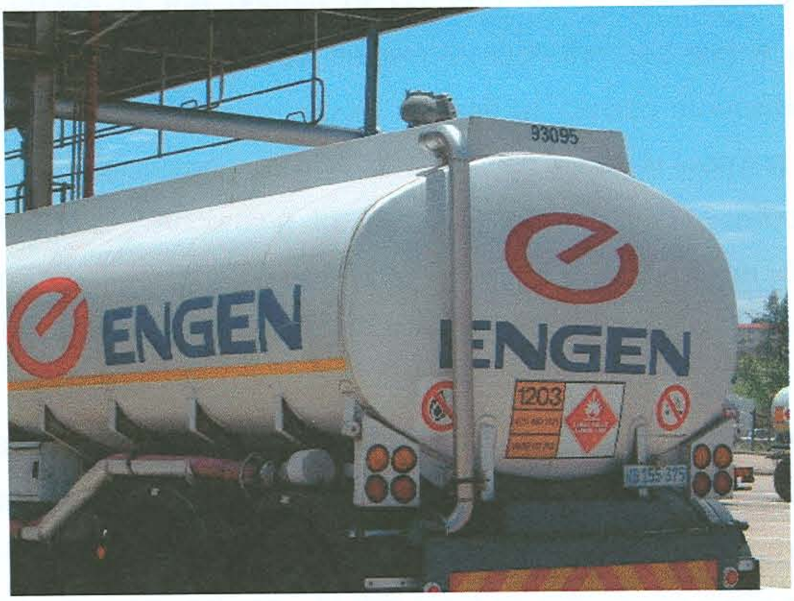

Figure 3.5 Modified road tanker to allow for vapour recovery.

3.2.2 Carbon vacuum adsorption process

After vapour collection, VOCs are recovered by using the carbon vacuum adsorption (CVA) process. In this process adsorption is used to separate the collected VOCs and air, after which absorption is used to recover the VOCs in a liquid state (as shown in Figure 2.9). A basic flowdiagram of the CVA process at the Engen facility can be seen in Figure 3.6, with Figures 3.7 and 3.8 giving the top and front view of the VRU respectively.

Adsorption

The first step for the recovery of petrol at the VRU is through adsorption. Collected vapour flows through a knock-out pot to one of the two carbon adsorption beds, (C1 and C2 in Figure 3.6). The two beds allow for continuous operation of the VRU, with the one bed adsorbing and the other being regenerated. For the purpose of this discussion bed C1 is in adsorption mode. The vapour enters at the bottom of C1 and VOCs are adsorbed onto the activated carbon. The cleaned air passes through the bed and is vented. This air is analysed for VOC (hydrocarbon) as well as carbon monoxide to give an indication of the effectiveness of the unit, as well as early warning of hot spots forming in the bed. According to Zerbonia *et al.* (2001), carbon monoxide concentration monitoring provides the necessary information for the safe operation of the carbon bed.

After a certain time of adsorption the bed can be divided into three zones: the inlet zone, mass transfer zone and the outlet zone. If the mass transfer zone reaches the top of the bed, breakthrough will occur and some of the inlet VOCs will escape into the atmosphere. At this plant an adsorption cycle of 15 minutes ensures that the breakthrough of VOC vapour does not occur. After the adsorption step in bed C1 ends (15 minutes), bed C2 is placed in adsorption mode and bed C1 is regenerated.

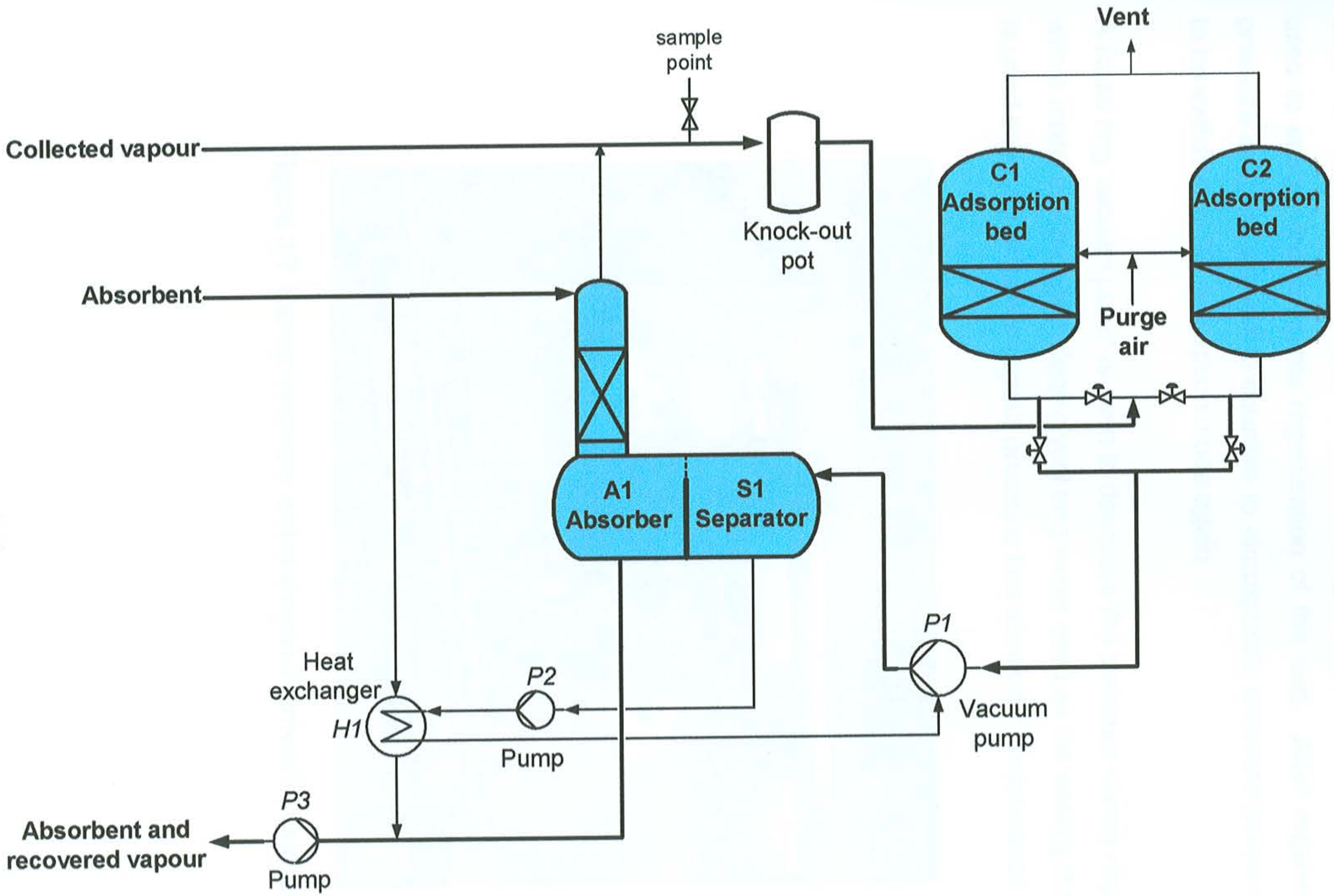

Figure 3.6 Carbon vacuum adsorption (CVA) process.

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Regeneration

Regeneration of these adsorption beds takes place in two stages. For the first stage pressure is decreased by the use of a vacuum pump (P1) and most of the VOCs are desorbed. During the second stage a small amount of purge air is used to ensure the complete regeneration of the bed. After regeneration the pressure in C1 is allowed to equalise to atmospheric pressure before it is ready to be switched to the adsorption mode again.

A liquid ring vacuum pump is used to decrease the pressure during regeneration, with a mixture of monoethylene glycol and water used as the sealing fluid. Glycol is used because of its low vapour pressure that allows for an increased vacuum.

Figure 3.7 Vapour recovery unit at Engen-Wentworth, Durban.

Figure 3.8 Vapour recovery unit (front view).

Separation

During the second step of petrol recovery at the Engen VRU, the glycol and VOC vapour mixture are separated in the separator (S1, first part of the vessel in Figure 3.8). The concentrated VOC vapour flows from the separator to an absorber column, A1, where it is recovered. The sealing fluid, in this case glycol, is pumped (with P2) from the separator through a heat exchanger, H1 to remove the heat of compression from the glycol. The glycol is then recycled back to the vacuum pump. The coolant used in the heat exchanger is fresh petrol from a daily storage tank.

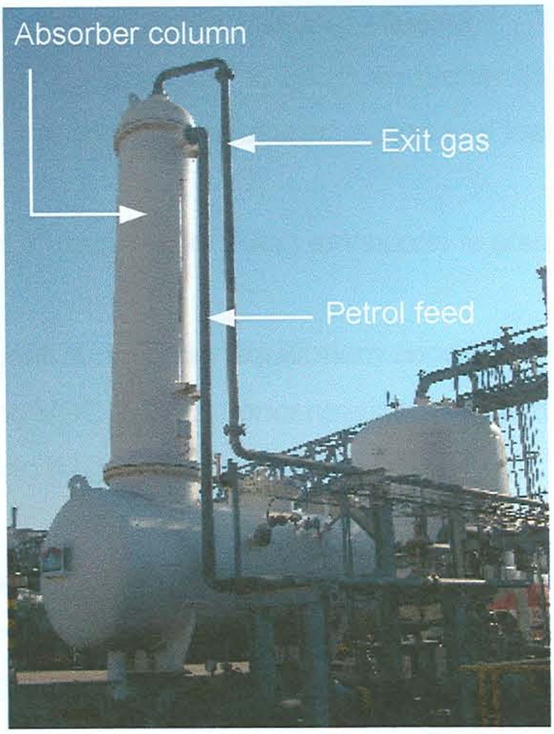

Figure 3.9 Separator and absorber column.

Absorption

The VOC rich vapour from the separator (S1) moves up into the absorber column (A1, shown in Figure 3.9) where petrol from the daily storage tank is used as absorbent. Any vapour that is not absorbed is recycled back to the carbon beds. The petrol product (containing the recovered vapour) from the absorber is pumped (P3) back to the daily storage tank.

3.3 THEORETICAL FILLING EMISSION CALCULATION

Equation 1 introduced in Chapter 2 was used for the calculation of the theoretical filling emission for the conditions at the Engen facility. In this equation a factor f (liquid to vapour volume equivalence factor) is used. This factor was derived (as shown in Appendix A) for typical European product properties and conditions and had to be adapted for the South African situation. The average product temperature in Durban was expected to be much higher than the temperature of 15°C used in Appendix A and was measured during fuel loading

As shown in Equation 1, road tanker filling emissions is also a function of the:

- VOC vapour concentration under equilibrium conditions (fully saturated, C_s),
- average preloading VOC vapour concentration (C_p), and
- amount of splashing (V_B).

The average preloading vapour concentration (C_s) was determined from the nomogram in Appendix B. As shown in Table 3.1, the average RVP at the Engen facility for 2002 varied within a certain range during the year (Kemp, 2003). There is, however, a maximum allowable RVP of 75 kPa for leaded and unleaded petrol, according to standards by the South African Bureau of Standards (SABS, 1995 and SABS, 2001). As the RVP and the temperature do not remain constant and varied within a certain range, different C_s values were determined at different values within the range.

The preloading vapour concentration (C_p) was determined by assuming that all the tankers discharged completely at only one point.

The amount of splashing (V_B) could be quantified by knowing the type of loading method that was used. All the tankers at the Engen-Wentworth facility load *via* bottom loading, therefore the value of V_B was known.

Table 3.1 Average RVP (in kPa) values at Engen, Wentworth for 2002.

Month	Average RVP values (kPa)	
	Engen 95 Unleaded	Engen 97 Leaded
January	60,0	65,9
February	65,4	67,9
March	60,5	67,2
April	71,2	66,9
May	64,7	65,0
June	62,5	59,6
July	58,1	67,2
August	57,0	62,4
September	70,7	69,5
October	66,7	68,7
November	58,8	61,8
December	60,9	65,0

3.4 EXPERIMENTAL METHOD AND SETUP

Vapour from road tankers is a mixture of VOCs and air and therefore the VOC concentration in these mixtures had to be determined for calculation of experimental filling emissions. For the conversion of the VOC vapour to a liquid equivalent value, the factor f specified in Equation 1 had to be calculated for South African product properties and conditions. Data was obtained from the Fuel-Facs^{+}® information management system employed at the Engen facility (CSI, 2002). This system records the following data (see Appendix C) automatically when a road tanker is loading any product at the facility:

- road tanker name and number,
- type of product loaded,
- start and stop time,

- gross (measured at ambient temperature) and net (measured at 20ºC) product quantity loaded, and
- product temperature.

All the tankers that load at the Engen facility are recorded and no notification of the tankers that connect to the VRU is made by the Fuel Facs$^{+}_{®}$ system, although all tankers loading petrol and diesel have to connect to the system according to facility management. To ensure that only the tankers that did connect to the system was taken into consideration for calculation purposes; the numbers of the tankers that did connect to the system was noted manually. Tankers not connecting, even though they have been adapted for this purpose, and incorrect operating practices were also noted.

As shown in Appendix C, the product loading data was only available as total volume loaded over a known time period and therefore the product flow rate had to be calculated.

An ultrasonic flow meter (Panametrics, Model GM 686) was installed in the vapour header (ID 250 mm) connecting the loading racks with the VRU. The ultrasonic flow meter measures the vapour flow (VOC/air mixture) from the road tankers that are connected with the VRU *via* the various connection hoses described in Section 3.2.1. According to McCarthy (1999), ultrasonic flow meters are increasingly gaining acceptance from measuring gas flow because of the following advantages:

- high accuracy,
- high repeatability,
- negligible pressure drop, and
- low maintenance.

There are two main types of ultrasonic flow meters, namely transit time and Doppler. The meter installed at the Engen facility is of the transit time type where the flow velocity is measured by measuring the time difference for sound to travel a fixed distance with and against the direction of flow by transducers. Figure 3.10 shows a simplified schematic representation of such a meter, with the transducers mounted in diagonal mode, and Figure 3.11 the installation at the Engen facility.

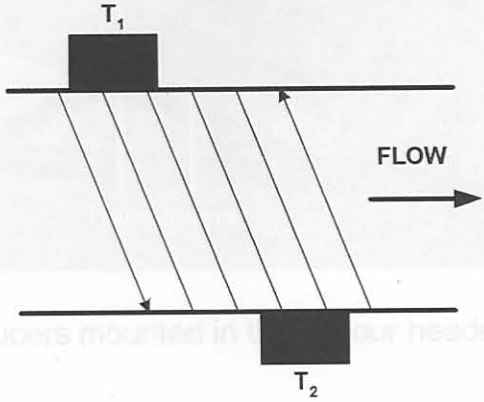

Figure 3.10 Ultrasonic flow meter with transducers (T_1 and T_2) in diagonal mode.

From Figure 3.10; the transit time (t_{12}) of an ultrasonic signal travelling with the flow is measured from transducer 1 (T_1) to transducer 2 (T_2). When this measurement is completed, the transit time (t_{21}) of an ultrasonic signal travelling against the flow is measured from T_2 to T_1. As the dimensions of the internal piping and the distance between the transducers are known, the gas velocity can therefore be determined.

The ultrasonic flow meter measures the vapour flow through the vapour header continuously but the data can only be recorded at specified time intervals (ranging from a few seconds up to 3 minutes). For the comparison of petrol loading data with the vapour flow data, the same time interval had to be used. The shortest interval used to record the product data was 1 minute and could not be changed. The vapour flow data was therefore recorded every ten seconds and converted to one minute averaged values by the multiplication of the velocity by the internal area of the vapour header (ID = 250 mm).

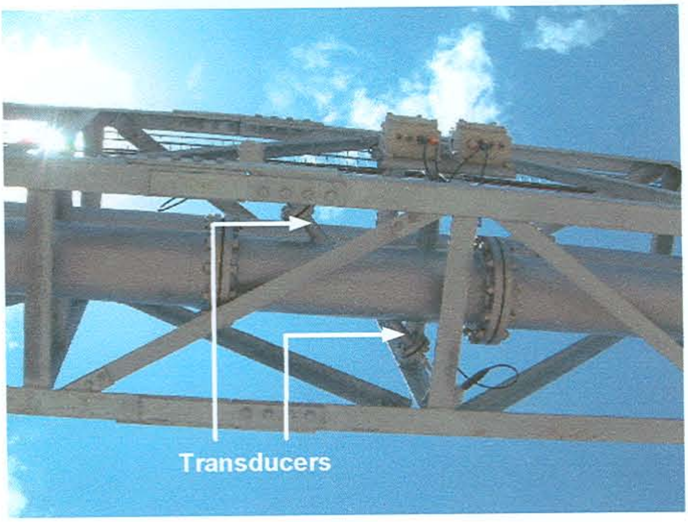

Figure 3.11 Transducers mounted in the vapour header at the Engen facility.

The ultrasonic flow meter measures the velocity of the VOC/air mixture through the vapour header, and because only the flow rate of the VOCs were of importance; the concentration of the VOC/air mixture at the Engen-Wentworth facility had to be known. Appendix D shows the volumetric concentration of vapour at different temperatures for petrol with an RVP of 70 kPa and 90 kPa, respectively. This was used in conjunction with grab samples of the vapour from the vapour header to verify the vapour concentration.

Vapour samples were taken upstream of the VRU at the sampling point in the vapour header (see Figure 3.6). Thermal tubes and glass samplers were used for taking vapour samples during different days, an hour apart each time. For the thermal tube sampling a syringe was used whereby a fixed, known volume of the VOC/air mixture was drawn into the tubes filled with various adsorbents. Using the glass sampler, the VOC/air mixture was allowed to flow into the sampler over some time without any external pressure. Gas chromatography and flame ionization spectroscopy was used to analyse the VOC concentration in both types of samples and analysed by two independent laboratories to determine the organic content.

CHAPTER 4

Results and discussion

4.1 INTRODUCTION

This chapter is structured in five parts. Firstly experimental results from this research and theoretical filling emission calculations, using South African product (petrol) data, are presented. Thereafter experimental filling emissions for the Engen-Wentworth facility are calculated, based on the data collected. Finally observations made during data collection and the effective inclusion into future legislation for VOC emission control in South Africa are discussed.

4.2 EXPERIMENTAL RESULTS

Only the tankers that connected to the vapour recovery system during the time when data was collected (October 2002 and May 2003) are presented in Appendix E and will be used in determining experimental filling emissions (Section 4.4). The petrol loading data from Appendix E were converted to volumetric flows, as the volume loaded over a certain time was known. As the temperature of the fuel that was loaded was also known, an average product temperature for all the available data (that was used in the calculation of the theoretical and experimental filling emission calculations) was determined as 26,2ºC.

The vapour flow (in m/s, measured by the ultrasonic flow meter), being a mixture of VOCs and air, was converted to one minute averaged volumetric flow values in Appendix F (only part of the measured data, the rest of the converted data is shown in Appendix G).

The typical vapour VOC concentration at the Engen facility had to be known before the experimental filling emission could be determined (the ultrasonic flow meter measures the velocity of the VOC/air mixture in the vapour header and the filling emission calculations are based on the VOC quantity). There were 2 paths through which the VOC concentration could be determined:

i) experimentally *via* analysis of vapour samples from the Engen facility, and
ii) theoretically, by using vapour pressure data.

Although direct measurement of the VOC concentration would be preferable, this option was too costly for this research and therefore grab vapour samples (using thermal tubes and glass samplers) were analysed to determine the VOC concentration. The analytical VOC concentration results for the grab samples taken from the vapour header at the Engen facility are shown in Appendix H.

The VOC concentration results of samples 1 to 4 (thermal tubes) were very low compared to the VOC concentration of 40 vol% value stated in Section 2.1 for European conditions. The highest VOC concentration was in sample 4 and was equal to 6497,32 ppm or 0,65 vol%; as shown in Table H.1 in Appendix H. According to Carr (2003), there could have been a breakthrough of the thermal tubes explaining the low results. So, even if the VOC concentration could have been high, the thermal tubes are only able to sample a limited amount and therefore the use of another sampling method had to be investigated.

Further research revealed that glass samplers, where a larger volume of vapour could be sampled, were a better alternative than the thermal tubes (Mey, 2003). Thermal tubes are more commonly used for ambient air samples and are designed for the adsorption of heavier hydrocarbons (VOCs) in low concentrations. Glass samplers will tend to understate the lighter hydrocarbons (VOCs), but a larger sample can be taken. Four samples were taken with glass samplers on the same day, a few minutes apart. As shown in Table H.3 the results of samples 5 to 8 are higher than those of samples 1 to 4. The highest VOC concentration was for sample 5 and was equal to 11,07 vol %.

From the analysis the average molecular weight was also determined. For samples 1 to 4 (81,1 g/mol, Table 4.1) it was much higher than the European value of 64 g/mol, whereas the average result from samples 5 to 7 (59,5 g/mol) was in the same range as the European value. The average molecular weight of all eight samples was 70,3 g/mol.

Table 4.1 Comparison of average molecular weights of vapour samples (only VOC part) taken at Engen facility.

Samples 1-4 (thermal tubes)		Samples 5-8 (glas samplers)	
Component	Molecular weight %	Component	Molecular weight %
Methane	0,06	Methane	0,11
		Ethane and ethylene	0,36
Propane	1,16	Propane and propylene	6,36
Butane	8,44	Iso-butane	13,17
		1-butene	3,06
		n-butane	11,93
		t-butene-2	1,86
		c-butene-2	1,52
Pentane	11,11	Iso-pentane	0,03
		n-pentane	15,03
		1-pentene	0,39
		Pentane	4,35
Hexane	47,93	Iso-hexane	0,39
		n-hexane	0,29
Heptane	5,52	Iso-heptane	0,51
		n-heptane	0,03
Octane	3,36	Iso-octane	0,09
		n-octane	0,00
Nonane	2,49	Iso-nonane	0,01
		n-nonane	0,00
Decane	0,54	Iso-decane	0,00
Undecane	0,23	n-decane	0,00
Average molecular weight (VOCs only) g/mol	81,1		59,5

There could be various reasons for the low VOC concentration results. Every effort was made to ensure that mostly petrol was being loaded at the times when the samples were taken, but it is possible that other products could also have been loaded at this time, as the previous contents of the road tankers were unknown. It is thus possible that vapour originating from other product (for example diesel, resulting in very low VOC concentrations) could have been sampled, even though petrol was loaded. All the samples were taken as grab samples and this could also explain the low results if the samples were taken at times when the VOC concentration was low. All of the samples were taken at times when there were numerous tankers loading simultaneously.

Due to the low VOC concentration results from the analyses, it was decided to investigate the calculation of the VOC concentration theoretically. Assuming a state of equilibrium in the vapour space in the road tanker, it is known that the mixture of petrol vapour and air will be present at a constant ratio and the concentration of the petrol (VOC) vapour is proportional to the true vapour pressure (TVP) of the liquid petrol at its storage temperature (Hadley *et al.*, 1978:14). The petrol vapour displaces air, creating a partial pressure equal to the TVP, the balance of the partial pressure, assuming atmospheric pressure of 101,325 kPa, is due to the remaining air.

Using the nomogram (Figure B.1) in Appendix B, the TVP can be determined if the Reid vapour pressure (RVP) and the storage temperature of the petrol is known. For example, petrol with an RVP of 65 kPa at 37,8°C (100°F) will exert a TVP of 47 kPa at a storage temperature of 25°C (Figure B.1, Appendix B). The VOC concentration in the vapour space is then given by Equation 2 (assuming the vapour is 100% saturated at the conditions stated):

$$\text{VOC vapour} = \frac{47\text{kPa}}{101{,}325\text{kPa}} = 46\ \text{vol\%} \qquad [2]$$

If the vapour is not fully saturated (as an example, only 40% saturated), the concentration will be given by Equation 3:

$$\text{VOC vapour} = 46\ \text{vol\%} \times 0{,}4 = 18\ \text{vol\%} \qquad [3]$$

Using the nomogram in Appendix B and an S value (see Figure B.1 in Appendix B) of 3 for petrol (shown as motor gasoline in Figure B.1), values for TVP was determined for known RVP and temperature values. Figure 4.1 shows the resultant TVP values at different RVP and temperature values (with a linear relationship between TVP and RVP).

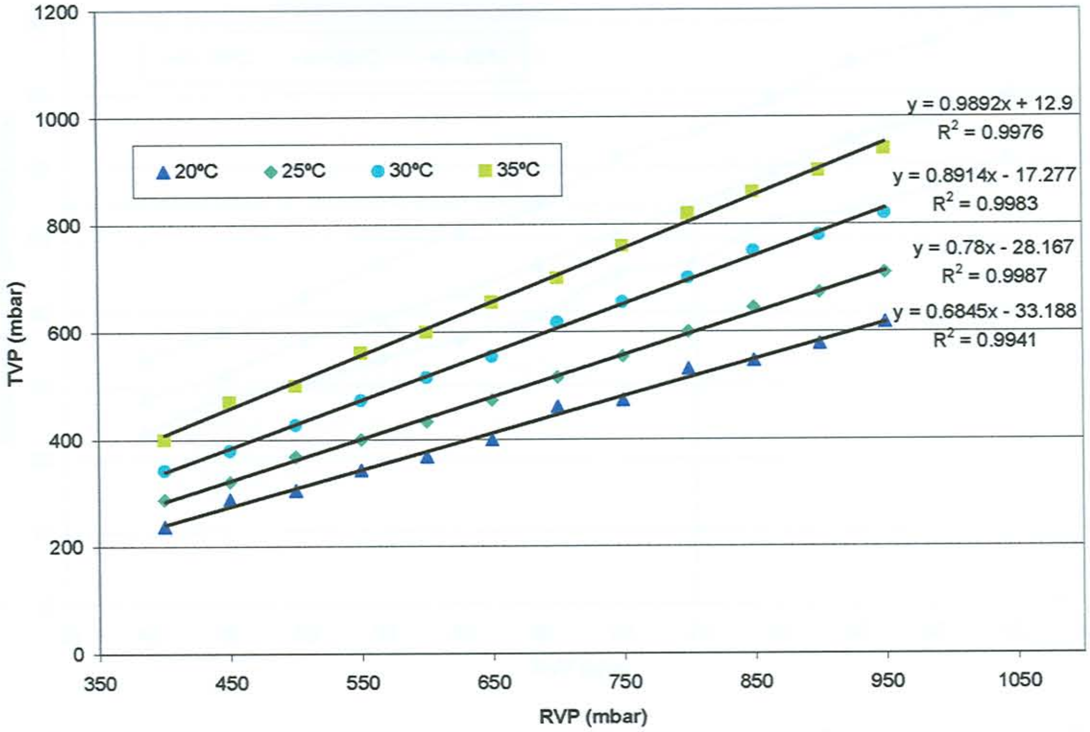

Figure 4.1 TVP versus RVP at temperatures from 20°C to 35°C.

Using Equation 2 and the TVP values determined for Figure 4.1, VOC concentrations were calculated for different RVP and temperature values. Figure 4.2 shows the theoretical VOC concentration of petrol vapour as a function of RVP and temperature, assuming the vapour is 100% saturated.

From Figure 4.2 the VOC concentration in the vapour increases with an increase in RVP, as well as temperature. As it cannot be assumed that the petrol vapour in the road tankers is saturated, Figure 4.2 can only give an indication of the relationship between RVP, temperature and concentration; and cannot be used to determine an average concentration at the Engen facility. It does, however, show the maximum possible concentration if the RVP and storage temperature of liquid petrol is known. At an RVP of 75 kPa (maximum allowable RVP in South Africa) and 25°C (typical storage temperature), the maximum possible VOC concentration will be in the order of 55 vol% (see Figure 4.2).

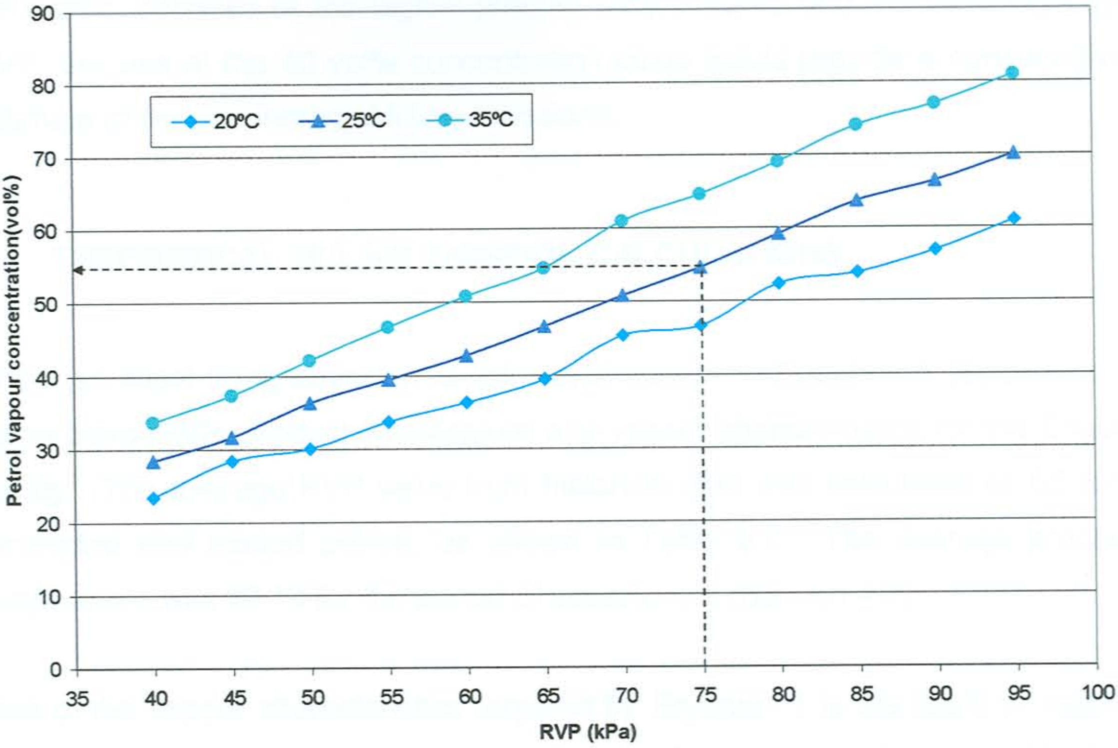

Figure 4.2 Theoretical VOC vapour concentration (vol%), assuming 100% saturation, as a function of RVP (kPa) and temperature.

Figure D.1 in Appendix D shows typical VOC concentration data at various temperatures for European summers (RVP = 70 kPa) and winters (RVP = 90 kPa) petrol. These are results from analysis on vapour samples taken by Cool Sorption (2001) in Europe. From Figure D.1 it can be shown that the typical

European VOC concentration is between 30 vol% and 40 vol% at a temperature of 15ºC for petrol with a RVP of 70 kPa and 90 kPa, respectively. At a temperature of 25ºC and using winter petrol data (RVP = 70 kPa), which is comparable to the RVP at the Engen facility, the VOC concentration is 40 vol% and at 30ºC the concentration can be as high as 50 vol%.

Due to the low VOC concentration results it was decided to use the value of 40 vol% for further calculations (Section 2.1). This value is a good approximation of the VOC concentration and has been proven to be correct under European conditions. As the VOC concentration in petrol vapour at the Engen facility would be higher, because of the higher product temperatures and the relatively high RVP, the use of the 40 vol% concentration value would provide a conservative estimate of the experimental filling emissions.

4.3 THEORETICAL FILLING EMISSION CALCULATIONS

The theoretical filling emission is calculated based on Equation 1 (Section 2.2) using petrol RVP, product temperature and vapour characteristics for the Engen facility. The average RVP value from historical data was calculated as 65 kPa (unleaded and leaded petrol), as shown in Table 3.1. The average product temperature was 26 ºC for the period of assessment (Section 4.2).

One of the vapour characteristics required for Equation 1 is the liquid to vapour equivalence factor f, derived in Appendix A for European conditions, and had to be adapted for the conditions at the Engen facility. Calculation of f required the average VOC molecular weight, liquid vapour density, product temperature and pressure at the Engen facility.

From Section 4.2 the average VOC molecular weight was 81,1 g/mol and 59,5 g/mol for samples 1 to 4 and 5 to 8 respectively. The liquid vapour density was not determined experimentally and therefore the same value as in Appendix A was used. According to Hadley *et al.* (1978:43), the liquid vapour density (only VOCs) is 600 kg/m^3 at 15°C and 101,325 kPa. Average product temperature for the period of assessment was 26°C and an atmospheric pressure of 101,325 kPa was used in calculations.

Table 4.2 shows a comparison of factor f determined for the two sets of samples. The value of f determined with a molecular weight of 81,1 g/mol at 26°C is higher than the European value of 0,0045 at 15°C. The molecular weight of the second group of samples provided a lower value for f. Due to the large discrepancy between the experimental VOC concentration results, it was decided to use the f value from samples 5 to 8 (namely 0,0041 or 0,41%) for further calculations. Although this is slightly lower that the value derived for European data, it is expected that this represents a minimum value at the Engen facility, indicating the most conservative estimate of filling emissions.

Table 4.2 Comparison of factor f determined for the two sets of samples.

Variable	Results for samples 1 to 4	Results for samples 5 to 8
Molecular weight of vapour	81,1 g/mol	59,5 g/mol
Vapour density (in liquid form)	600 kg/m^3	600 kg/m^3
Storage temperature	26 °C (299 K)	26 °C (299 K)
Atmospheric pressure	101,325 kPa	101,325 kPa
f	0,0055	0,0041
V/L ratio	182	247

The other variables used in Equation 1 were C_s, C_p and V_B. C_s is the VOC vapour concentration at 100% saturation and is equal to the petrol TVP (Section 2.2). It can be determined from Figure B.1 in Appendix B, if the RVP and product temperature is known. Cp is the preloading VOC concentration and is dependent on the amount of product discharges that were made until a tanker was loaded again. For calculation purposes it was decided to assume that a road tanker will only discharge its contents at one point, and therefore C_p equals 0,15. The type of loading method also has an influence on the amount of evaporation that would occur and because all the tankers at the Engen facility use bottom loading, a V_B value of 0,13 will be used for calculations (the average value for bottom loading, as explained in Section 2.2).

As the RVP and temperature of the product may vary, thereby influencing the amount of VOCs that evaporate, it was decided to determine filling emissions within an RVP range, rather than using the average value of 65 kPa (Section 3.3). As 75 kPa is the maximum allowable RVP for leaded and unleaded petrol, and because the RVP is almost always above 60 kPa (Section 3.3); a range of between 60 kPa to 75 kPa was used. The product temperature of the fuel can also vary between 20ºC to 35ºC (see Appendix E), and was therefore used as the product storage temperature range.

Figure 4.3 shows the theoretical filling emission (E_f) results for RVPs from 60 kPa to 75 kPa and for product temperatures from 25ºC to 35ºC. As expected, filling emissions increase with an increase in RVP and temperature. At an RVP of 65 kPa and 26ºC, typical conditions at the Engen facility, the theoretical filling emission is approximately 0,08%. The results in Figure 4.3 give a good indication of the approximate amount of filling emissions that may occur and shows that the expected filling emissions at the Engen facility will be higher than the value of 0,05% stated by Hadley *et al.* (1978:48), for typical filling emissions under European conditions. As filling emissions are expressed as a percentage (Section 2.2), this means that for every 1 000 litres of petrol that is loaded at the Engen facility, 0,8 litres will evaporate.

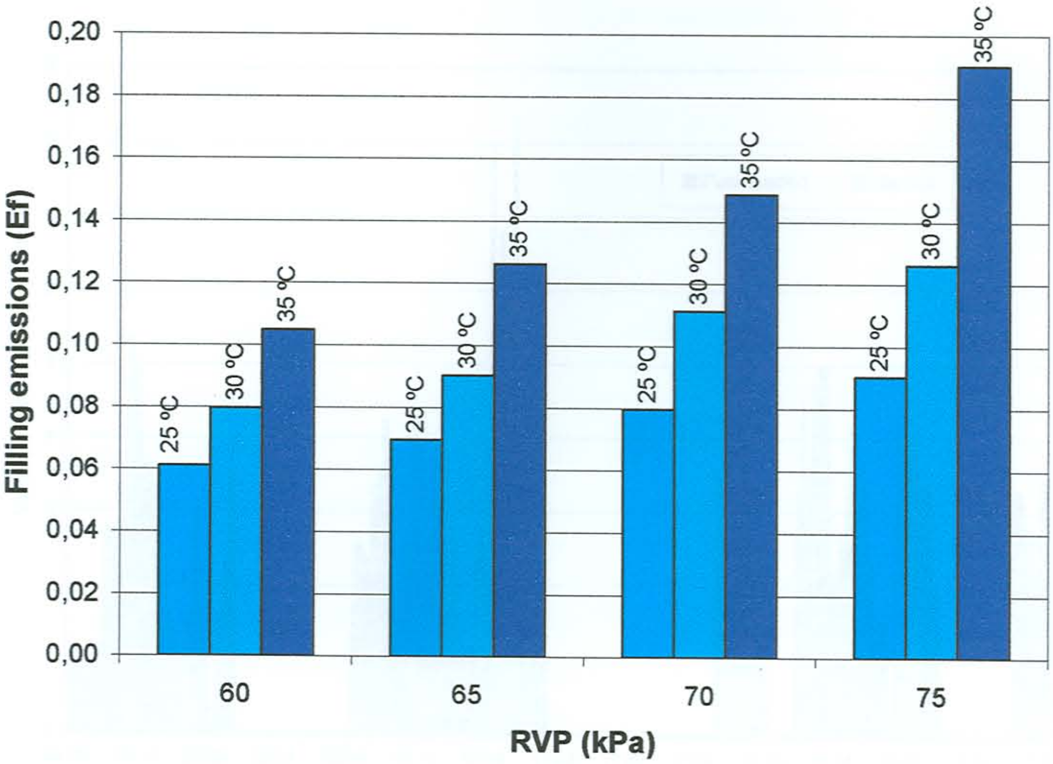

Figure 4.3 Filling emissions (E_f) for the typical range of RVPs and temperatures at the Engen, Wentworth facility (E_f is the liquid equivalent volume of VOCs in the vapour divided by the volume of petrol loaded, expressed as a percentage).

4.4 EXPERIMENTAL FILLING EMISSIONS

The petrol loading data (Appendix E) and the vapour flowrate data (Appendix F and G) were used to determine the experimental filling emission. As an example of the actual data collected, the fuel flow (petrol and diesel) and the corresponding vapour flow for tankers 28 to 44 during the period 08:09 to 14:01 on 6 May 2003 are presented in Figure 4.4. (Appendix I show similar examples during different days). Although some form of visual correlation does exist (apart from data for the first hour due to operational problems, see Section 4.5), the following aspects may impact on obtaining good correlations between loading and emission rates.

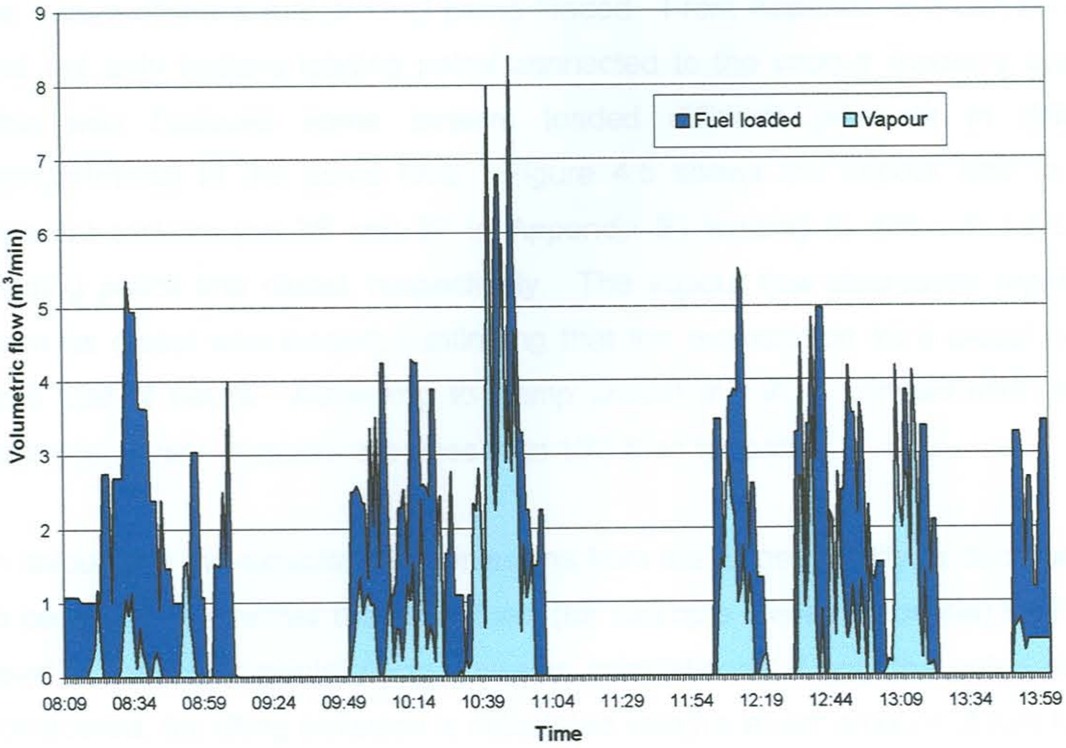

Figure 4.4 Comparison between fuel loading data and vapour flow through the vapour header for the period 08:09 to 14:01 on 6 May 2003.

As the actual vapour flowrate through the vapour header will be dependent on the overall loading rates at all the loading bays, loading characteristics will impact on final vapour flowrates. For example, when fuel is loaded, the first and last hundred litres of a loading start and finish slow, to prevent overfilling (Hamilton, 2002). This then results in plug flows through the vapour header, which would explain the numerous peaks in Figure 4.4. The design of road tankers will also determine the rate at which fuel is loaded (for example, some tankers are capable to load at about 2 200 litres per minute; while others may only load at 1 600 litres per minute). The number of tankers loading at the same time will also result in changing flowrates due to overall loss of pressure over the loading bays (Hamilton, 2002).

The other aspect that impacts on the VOC concentration and vapour flowrate is the nature of the actual product being loaded. From Appendix E it can be seen that not only tankers loading petrol connected to the vapour recovery system. This was because some tankers loaded different products in different compartments at the same time. Figure 4.5 shows the vapour flow for two different tankers (no 36 and 37 in Appendix E) loading at different bays and loading petrol and diesel, respectively. The vapour flow decreases rapidly as soon as diesel was loaded, confirming that the evaporation from diesel is less than that of petrol. According to Kemp (2003) the VOC concentration in, for example, diesel, is much less (less than 1%) than for petrol.

In calculating the experimental emissions from the Engen facility, a decision had to be made on whether the other fuels (for example diesel, kerosene) had to be used in the experimental filling emission calculations. If only the petrol data is considered, the filling emission is calculated using a lesser amount of fuel for the same vapour data and it is then assumed that all the vapour is petrol vapour with a VOC concentration of 40 vol%, which in the case of diesel vapour, is not true. Therefore, by using the total amount of fuel loaded, the effect of the vapour that may have originated from diesel (therefore, very low VOC concentration) is compensated for. On the other hand, the previous tanker contents could have been petrol, therefore contributing to the VOCs in the vapour, but the other fuels only contributed to a small percentage of the total fuel loaded during this time. There will be a VOC/air flow from trucks loading diesel, but most of the vapour measured were from tankers loading petrol. It was therefore decided to show the experimental filling emission calculation for both situations. The calculation used to determine the experimental filling emission follows as an example.

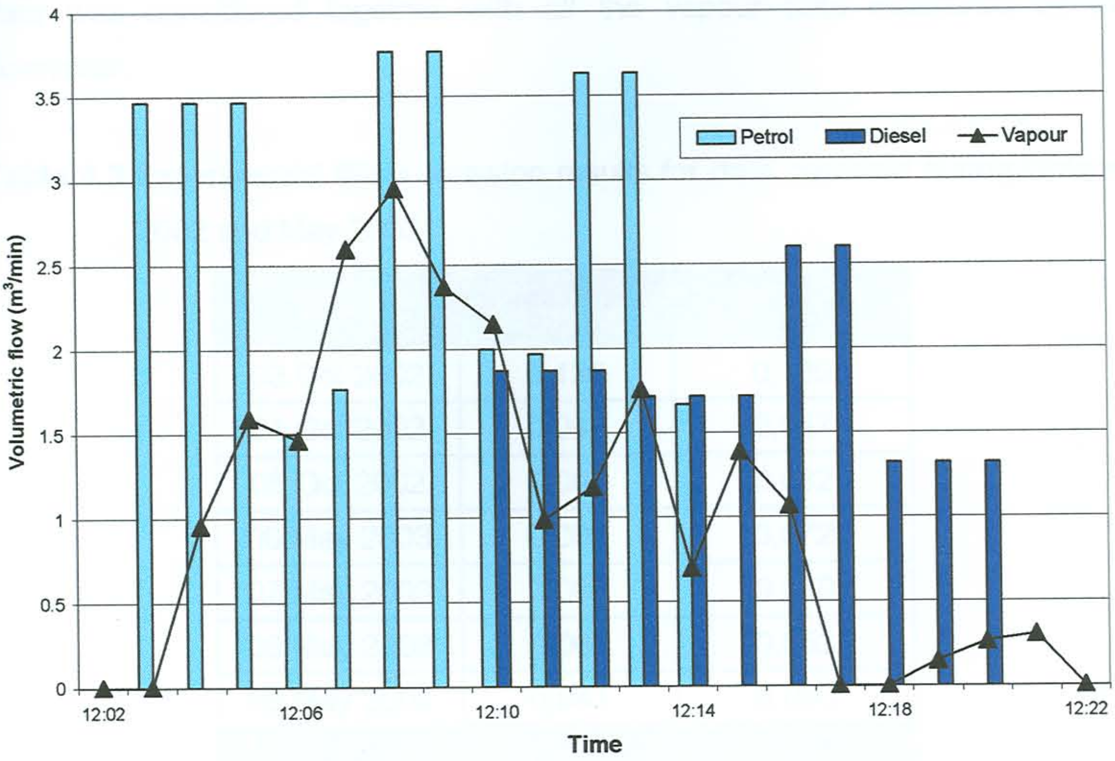

Figure 4.5 Vapour flow over a time period where petrol and diesel were loaded into two different tankers.

Say there is P m^3 petrol that is loaded and V m^3 vapour evaporates, where the vapour is a mixture of VOCs and air and the VOC concentration is 40 vol % (Section 4.2). The liquid to vapour volume equivalence value, f, for petrol was determined at the Engen facility as 0,0041 (Table 4.2). The actual emission E_f can then be calculated using Equation 4.

$$E_f = \frac{0{,}4 \times V \times f}{P} \times 100 \qquad [4]$$

The results from the data collected during different days in October 2002 and May 2003 are shown in Table 4.3. In the first column only the petrol loading data and all the vapour data was considered and it was assumed that all the vapour measured by the ultrasonic flowmeter was from petrol. All the other fuel loaded was ignored. The second column is the filling emission if all the fuel's loading data was considered together with all the vapour data measured by the flowmeter.

Table 4.3 Experimental filling emission results for data collected during October 2002 and May 2003.

Date	Filling emission	
	Petrol	Total Fuel
03 Oct 2002	0,139	0,139
04 Oct 2002	0,047	0,047
05 Oct 2002	0,082	0,082
06 May 2003	0,089	0,072
07 May 2003	0,094	0,070
08 May 2003	0,062	0,052
09 May 2003	0,041	0,030
Average	**0,079**	**0,069**

As shown in Table 4.3, when all the fuel loaded was taken into consideration, the average experimental filling emission from all the collected data was approximately 0,07%. Therefore for every 1 000 litres of petrol that is loaded into road tankers, 0,7 litres evaporate. When only petrol is considered the filling emission is higher (0,08%). As most of the fuel loaded during the time of this research was petrol the experimental filling emission was taken as 0,08%. This value is much higher compared to the value of 0,05% for European conditions.

The theoretical and the experimental filling emission results compare well although many assumptions were made in the calculation of the experimental filling emission calculations. The analytical results to determine the molecular weight from petrol vapour and the VOC concentration was the largest obstacle in the determination of the experimental filling emission, together with the fact that different fuels were loaded at the facility during data collection.

4.5 GENERAL OBSERVATIONS

During the time when the experimental data was collected, the general use of the vapour recovery equipment by the road tanker drivers was observed to assess any possible operational problems. Table 4.4 shows a list of the tankers where problems with vapour collection did occur.

At the Engen facility all tankers loading petrol must be adapted (as explained in Chapter 2) to allow for vapour return from the tankers to the VRU. Almost all the tankers loading at the Engen facility have been adapted and only one tanker (Tanker 2) out of over 100 tankers assessed, were not adapted for vapour collection.

At some stages during experimental data collection it was found that the vapour return hoses were filled with product (liquid petrol). This occurs when the overfill sensor on the tanker does not work properly and liquid petrol is pushed through the vapour return piping into the hoses when a compartment is full. This petrol is wasted as it is emptied into the drains on the facility. The tankers responsible for the overfilling were not known as the hoses were not checked after each tanker loaded.

In the case of tankers 28 and 62 in Table 4.4 the road tanker drivers were aware that their tanker's overfill sensors were not working. They then observed the level in a specific compartment through the manholes on top of the tankers. This involved the driver standing on the top of the tanker in order to stop the loading of fuel whenever a compartment is full. Even though these tankers were still connected to the vapour return system, it defeated the purpose as all the vapour escaped into the atmosphere through the open manholes.

Table 4.4 List of road tankers where problems with vapour collection did occur at the Engen facility.

Number (as indicated in Appendix E)	Tanker name and number	Observation
28	Unitrans (686)	Manhole on top of tanker is open, even though the tanker is connected to the vapour return system.
62	Bulktrans (24271)	Did not connect from the start of loading. Manhole on top of tanker is open even though tanker is connected to the vapour recovery system.
*	Freight Dynamics (372)	Not adapted for vapour return.
*	Engen Transport (96091)	Did not connect to vapour return system, although the tanker has been adapted for vapour recovery.

* Not shown in Appendix E because tanker did not connect to vapour return system, and was therefore not considered in calculations.

The effect on the vapour flow is illustrated in Figure 4.4, where from 08:09 to 08:20 there was no vapour through the vapour header and only Tanker 28 was connected to the system. After 08:20 there was a small amount of vapour measured, this was because the manholes were closed for a while during loading after instruction by the facility manager. At 08:31 Tanker 29 started loading petrol and the increased vapour flow can be seen in Figure 4.4.

4.6 INCLUSION IN SOUTH AFRICAN LEGISLATION

The newly proposed air pollution legislation, namely the Air Quality Bill (SA Bill, 2003) is aimed at replacing the Air Pollution Prevention Act (No 45 of 1965). The new legislation proposes the establishment of national norms and standards; a framework for air quality management planning and reporting; and regulatory instruments for the control of air pollution and compliance and enforcement. The Air Quality Bill sets ambient air quality standards rather than emission standards. The draft bill also addresses various regulatory tools available to government for achieving acceptable ambient air quality, for example:

- *priority areas* may be identified for focussed attention;
- *listed activities* will have to require a licence before operation; and
- *controlled emitters*, where emission standards will be set for identified emitters.

The bulk storage of liquid petroleum products in storage facilities with individual tank capacities of at least 1 000 m^3 is included as a scheduled process in the Atmospheric Pollution Prevention Act (No 45 of 1965). Although the CAPCO guidelines for hydrocarbon emission control requires that a programme of preventative maintenance must be implemented at all plants to minimise such emissions (CAPCO, *s.a.*), in practice these guidelines never resulted in the implementation of suitable vapour recovery systems. An example being that the Engen Wentworth vapour recovery system was the first of its kind to be installed in South Africa, and this only came into operation during 2001.

The draft bill on Air Quality does not mention the specific activities or areas that will be regulated, and therefore only the possible regulation of certain processes and areas can be discussed. The storage of petrol (and other petroleum products) could be extended to include smaller volumes as part of the new legislation, and then service stations storage tanks will also be included. The guidelines could also be altered to include the minimisation of VOC emissions during the distribution of petrol *via* recovery.

Transitional provision for ambient ozone and nitrogen oxide (NO_x) concentrations are made in the draft bill, but not for VOCs. As ozone is a secondary pollutant formed when VOCs and nitrogen oxides (NO_x) react, VOCs will be regulated indirectly by the enforcement of the ozone standards.

As discussed in Chapter 2, some European countries pre-empted the possibility of future legislation by installing vapour recovery systems before they were obligated to do so. This was also the case at the Engen-Wentworth facility. Internationally the control of VOCs from the storage and distribution of petrol (Stage I) has been applied for years and currently the focus is on the recovery of vapour from vehicle refuelling (Stage II). It is expected that the control of VOCs from petrol storage, distribution and refuelling in South Africa will be phased in over time, as was the case internationally.

Public pressure with regard to air pollution control will also play an important role in the application of vapour recovery in the future. In South Africa, communities are situated close to bulk storage facilities and public participation and awareness with regard to environmental matters, such as air quality, is increasing. An added advantage in the use of vapour recovery systems is the monetary value of the recovered VOCs, which makes this an attractive control option for the oil companies. The application of vapour recovery systems will also be easier to implement in South Africa, as the technologies have been proven and have been known internationally for some time.

For these reasons it is believed that an increase in the application of vapour recovery systems in South Africa will occur over a shorter period of time.

CHAPTER 5

Conclusions and recommendations

VOC controls can take many forms and the type of control method used will be determined by the characteristics of the VOC emissions. Minimisation techniques, such as the lowering of RVP, can be implemented but only to a certain degree, as there is a lower limit with regard to petrol volatility. Vapour recovery is the preferred technique for the control of VOC emissions from petrol storage and distribution systems. This also has the added advantage of monetary savings from recovered petrol vapour. There are various VOC treatment techniques, but this must only be used in situations were other control options are not viable.

The analytical VOC concentration results obtained from samples 1 to 4 were very low compared to literature values, but the average molecular weight for these samples were high compared to the European value. This was because the thermal tubes used for sampling were good at adsorping heavier hydrocarbons (VOCs) but not as effective for lower molecular weight VOCs. Thermal tubes are also commonly used to sample ambient air samples, therefore at much lower concentrations, and it was found that the breakthrough of these tubes could explain the low results.

The VOC concentration results from the analysis on the glass samples (samples 5 to 8) were higher, but still low compared to literature values. The average molecular weight of these samples were, however, in the same range as the European value. The VOC concentration could not be determined accurately as the samples were taken from the vapour header where the relevant composite sample of different vapours from the different tankers were measured and the preloading vapour specifics (petrol, diesel or kerosene) were unknown. The results from the sample analysis were much lower than expected and it was concluded that the vapour samples contained mixtures of petrol and other fuel vapour (such as diesel), where the VOC concentration of the diesel vapour were known to be much lower.

The theoretical and experimental results in Chapter 4 show that the filling emission (expressed as a percentage of the volume petrol loaded) from the Engen facility was in the order of 0,08% compared to the value of 0,05% derived for European conditions. This can mainly be ascribed to the higher temperatures of the petrol loaded at the Engen facility and the relatively high RVP.

The main operational problem was the overfilling of the road tankers due to overfill sensors not working. This resulted in the wastage of liquid product. For vapour recovery to work effectively and efficiently, the equipment supporting it, must also be in good working order. The use of the vapour collection equipment by the road tanker drivers was generally good. The control of VOC emissions must be approached holistically and the people using the collection equipment must be informed of the benefits of the system. As the road tankers are not usually the property of the facilities, in this case the Engen facility, the owners of these tankers must ensure that they are in good working order. This must be enforced by the management of the facility.

Although there are guidelines with regard to fugitive VOC emissions, that includes emissions from the storage and distribution of petrol in South Africa, there is no legislation governing the control measures that must be implemented to minimise these emissions. Air pollution issues are, however, becoming more important with the possibility of new air pollution legislation. Internationally vapour recovery has been included in legislation, and it is expected that this will also be the case in South Africa in the future. Bulk storage and loading facilities are coming under increased pressure to control emissions as they are situated close to communities. When the new air quality legislation comes into force, the standards set out in the legislation will determine the emission control measures that will be taken by various industries. The degree of enforcement of the new legislation will also determine the rate at which control measures, such as vapour recovery systems, will be implemented.

The VOC emissions from the filling of road tankers only form part of emissions from the total storage and distribution system. As stated in Chapter 2 the total emissions are equal to 0,56% under European conditions. The results in Chapter 4 show that the filling emission was higher than the European value and therefore it can be concluded that VOC emissions at all the other stages of storage and distribution will also be higher, and therefore the total emission will be higher than the 0,56% stated for Europe.

It is recommended that additional vapour samples from the road tankers loading petrol and diesel respectively, must be analysed to determine the VOC concentrations of both. Other recommendations with regard to future studies are as follows:

- determine the experimental VOC emissions from Stage Ib operations;
- compare VOC vapour concentrations for vapour from diesel and other heavier fuels with that of petrol;
- determine the vapour collection efficiency at the facility and the possibility of improvements that could be made; and
- investigate the development of regulations to enforce the use of vapour recovery systems.

The following actions are recommended for the general control of VOC emissions at the Engen facility:

- ensure that the overfill sensors on the road tankers are in working order and enforce this by not allowing tankers to load if this is not the case;
- train road tanker driver and facility personnel on the benefits of the vapour recovery system with regard to their health and wellbeing; and
- lower the RVP during the warmer months in South Africa to minimise VOC emissions.

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APPENDIX A

Petrol liquid/vapour volume equivalence

According to the ideal gas law, 1 kg of hydrocarbon (VOC) vapour at atmospheric pressure and a temperature of 15° C (European conditions) occupy a volume as shown in Equation A1.

$$\text{Volume of vapour(V)} = 22{,}4 \times \frac{288}{273} \times \frac{1}{M} = \frac{23{,}6}{M} m^3 \qquad [A1]$$

where M = mean molecular weight of the hydrocarbon (VOC) vapours and the 22,4 term is in m^3/kmol at standard conditions (0 °C and 101,325 kPa), according to Avogadro's law.

Also, according to Hadley *et al.* (1978), 1kg of the same vapour in liquid form occupies the volume shown in Equation A2.

$$\text{Volume of liquid(L)} = \frac{1}{d} m^3 \qquad [A2]$$

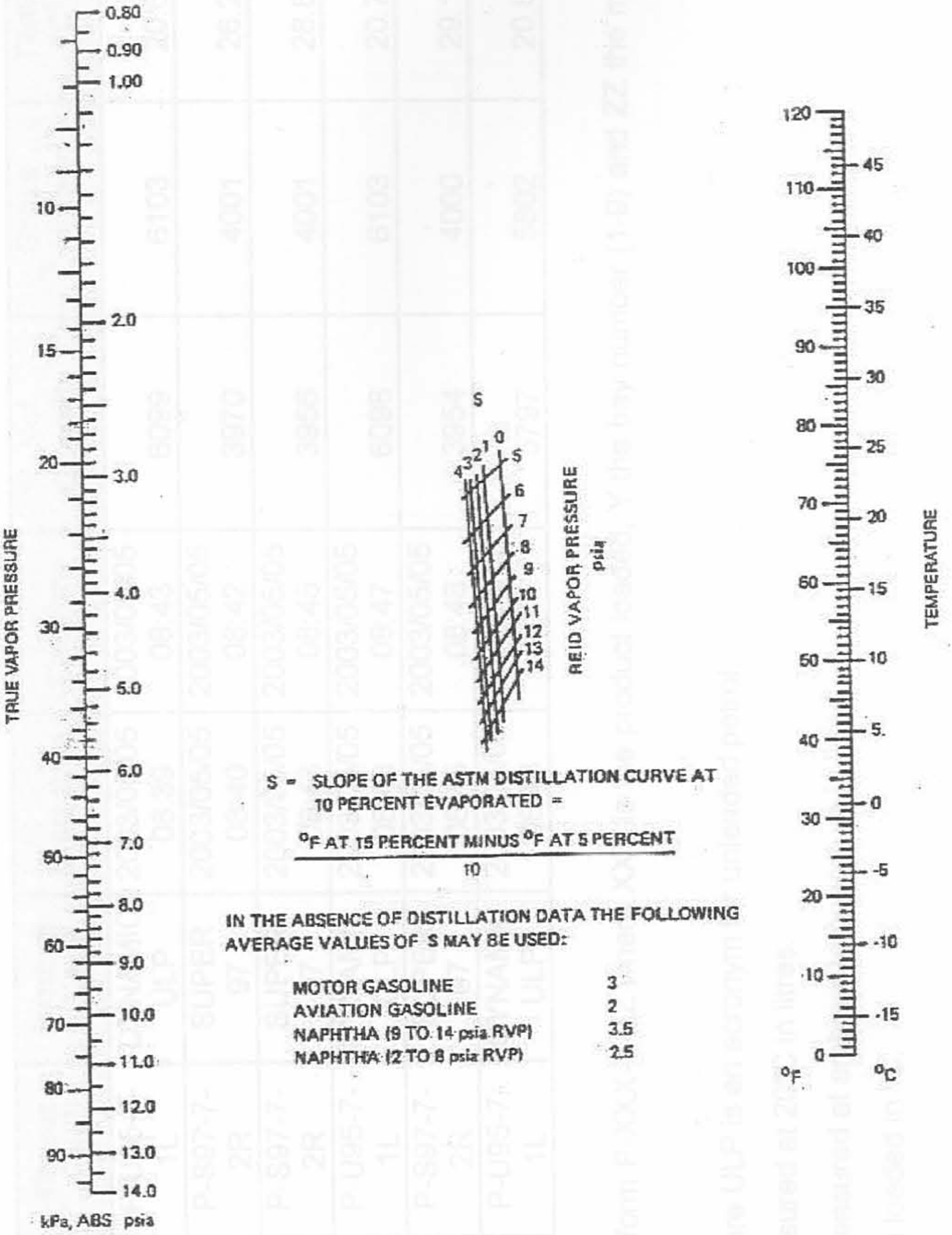
where d = liquid density of the hydrocarbon (VOC) vapours in kg/m^3.

Therefore, by combining Equations A1 with A2, the vapour/liquid volume ratio (V/L) at atmospheric pressure and 15°C, is:

$$\frac{V}{L} = \frac{23{,}6 \times d}{M} \qquad [A3]$$

According to Hadley *et al.* (1978) the typical mean molecular weight for hydrocarbon (VOC) vapour at European conditions is 64 g/gmol and the condensed vapour density is approximately 600 kg/m^3 at 15ºC and 101,325 kPa. By substituting these values into Equation A3, V/L = 220 m^3. The inverse, L/V = 0,0045 or 0,45%; is known as the liquid to vapour equivalence factor (f), used in calculating the volume liquid equivalent contained in a given volume of petrol vapour (Hadley *et al.*, 1978).

APPENDIX B



S = SLOPE OF THE ASTM DISTILLATION CURVE AT 10 PERCENT EVAPORATED =

$$\frac{°F \text{ AT 15 PERCENT MINUS } °F \text{ AT 5 PERCENT}}{10}$$

IN THE ABSENCE OF DISTILLATION DATA THE FOLLOWING AVERAGE VALUES OF S MAY BE USED:

MOTOR GASOLINE	3
AVIATION GASOLINE	2
NAPHTHA (9 TO 14 psia RVP)	3.5
NAPHTHA (2 TO 8 psia RVP)	2.5

Figure B.1 Nomogram for the determination of true vapour pressure (TVP) from RVP and temperature (Hadley *et al.*,1978).

APPENDIX C

Table C.1 Product loading data from Fuel Facs⁺® system.

Tanker name	Number	Preset code[1]	Product loaded[2]	Start time	End time	Net Quantity[3]	Gross Quantity[4]	Temp °C[5]
Engen transport	92062	P-U95-7-1L	DYNAMIC ULP	2003/05/05 08:39	2003/05/05 08:43	6099	6103	20.6
Engen transport	92062	P-S97-7-2R	SUPER 97	2003/05/05 08:40	2003/05/05 08:42	3970	4001	26.2
Engen transport	92062	P-S97-7-2R	SUPER 97	2003/05/05 08:43	2003/05/05 08:45	3956	4001	28.8
Engen transport	92062	P-U95-7-1L	DYNAMIC ULP	2003/05/05 08:43	2003/05/05 08:47	6098	6103	20.7
Engen transport	92062	P-S97-7-2R	SUPER 97	2003/05/05 08:45	2003/05/05 08:48	3954	4000	29.1
Engen transport	92062	P-U95-7-1L	DYNAMIC ULP	2003/05/05 08:48	2003/05/05 08:51	5797	5802	20.8

1 Preset code in the form P-XXX-Y-ZZ where XXX is the product loaded, Y the bay number (1-9) and ZZ the meter position.

2 Product loaded where ULP is an acronym for unleaded petrol.

3 Net quantity is measured at 20°C in litres.

4 Gross quantity is measured at ambient temperature in litres.

5 Temperature of fuel loaded in °C.

APPENDIX D

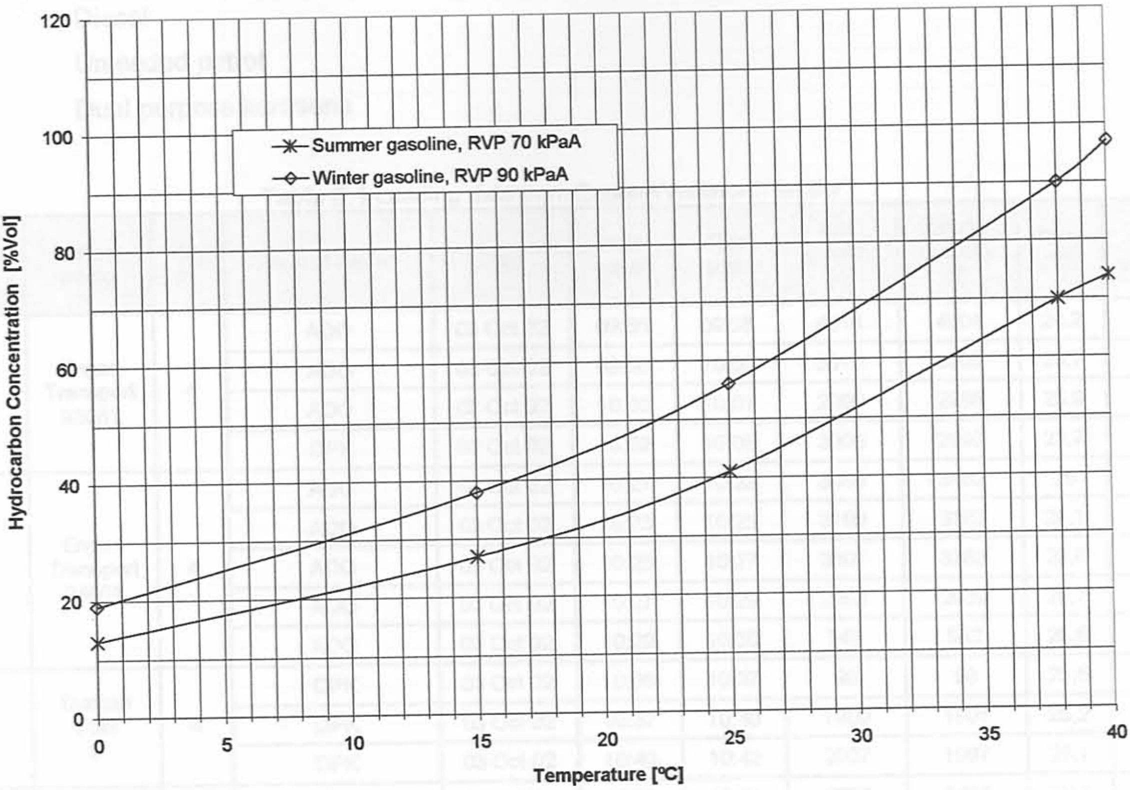


Figure D.1 Hydrocarbon (VOC) concentration (vol%) as a function of temperature for petrol with RVP values of 70 kPa and 90 kPa, respectively (Cool Sorption, 2001).

APPENDIX E

ADO	Diesel
ULP	Unleaded petrol
DPK	Dual purpose kerosene

Table E.1 Loading data from Engen-Wentworth facility*.

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
1	Engen Transport 93061	4	ADO	03 Oct 02	09:56	09:58	4018	4004	24,2	2
			ADO	03 Oct 02	09:58	10:00	3016	3002	25,7	2
			ADO	03 Oct 02	10:00	10:01	2999	2985	25,9	1
			DPK	03 Oct 02	10:02	10:05	3006	2997	23,7	3
2	Engen Transport 94001	4	ADO	03 Oct 02	10:21	10:23	3499	3482	26	2
			ADO	03 Oct 02	10:23	10:25	3199	3183	26,1	2
			ADO	03 Oct 02	10:25	10:27	3801	3783	25,8	2
			ADO	03 Oct 02	10:27	10:29	2953	2939	25,7	2
			ADO	03 Oct 02	10:29	10:30	545	542	25,6	1
3	Durban Fuel 5	4	DPK	03 Oct 02	10:36	10:37	98	98	25,5	1
			DPK	03 Oct 02	10:37	10:40	1909	1901	25,2	3
			DPK	03 Oct 02	10:40	10:42	2007	1997	26,1	2
4	Engen Transport 86052	6	ADO	03 Oct 02	12:32	12:34	5502	5458	29,8	2
			ADO	03 Oct 02	12:36	12:38	6001	5955	29,4	2
			ADO	03 Oct 02	12:39	12:42	5500	5460	29	3
			ADO	03 Oct 02	12:44	12:47	6001	5957	29	3
			ADO	03 Oct 02	12:56	12:59	6000	5955	29,2	3
5	Engen Transport 92072	5	ADO	03 Oct 02	12:34	12:36	3800	3776	27,4	2
			ADO	03 Oct 02	12:37	12:39	3800	3776	27,7	2
			ADO	03 Oct 02	12:39	12:41	3902	3878	27,6	2
			ADO	03 Oct 02	12:41	12:44	4601	4573	27,5	3
6	Engen Transport 200163	7	ADO	03 Oct 02	12:20	12:23	3761	3745	25,4	3
			ADO	03 Oct 02	12:24	12:27	5332	5295	28,3	3
			ADO	03 Oct 02	12:28	12:31	5301	5264	28,5	3
			ADO	03 Oct 02	12:32	12:32	9	9	28,5	1
			ADO	03 Oct 02	12:35	12:38	4894	4861	28,4	3
			ADO	03 Oct 02	12:38	12:42	5300	5264	28,5	4
			ADO	03 Oct 02	12:43	12:46	5300	5263	28,5	3

* as provided by Fuel Facs^{+}® system.

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (ºC)	Time (min)
7	Engen Transport 95061	7	ADO	03 Oct 02	12:45	12:48	5001	4975	26,3	3
			SUPER 97	03 Oct 02	12:45	12:47	6003	5958	25,9	2
			SUPER 97	03 Oct 02	12:48	12:50	5303	5260	26,4	2
			ADO	03 Oct 02	12:49	12:53	5000	4971	27	4
			SUPER 97	03 Oct 02	12:51	12:54	5302	5261	26,1	3
			ADO	03 Oct 02	12:53	12:57	5000	4970	27,3	4
			ADO	03 Oct 02	12:59	13:01	1258	1250	27,3	2
			ADO	03 Oct 02	13:02	13:05	3743	3720	27,3	3
8	Engen Transport 200163	8	ADO	03 Oct 02	13:06	13:08	4999	4969	27,1	2
			ADO	03 Oct 02	13:10	13:12	5000	4969	27,3	2
			ADO	03 Oct 02	13:13	13:15	4999	4967	27,5	2
			ADO	03 Oct 02	13:17	13:19	5499	5464	27,6	2
			ADO	03 Oct 02	13:21	13:23	5799	5762	27,7	2
9	Caltex Transport 518	6	SUPER 97	03 Oct 02	13:07	13:10	3999	3974	25	3
			SUPER 97	03 Oct 02	13:10	13:13	3999	3971	25,6	3
			SUPER 97	03 Oct 02	13:13	13:16	3999	3969	26	3
			ADO	03 Oct 02	13:19	13:21	3994	3964	29,2	2
10	Engen Transport 99062	7	ADO	03 Oct 02	13:27	13:29	4001	3978	27	2
			ADO	03 Oct 02	13:30	13:33	4001	3975	27,8	3
			ADO	03 Oct 02	13:35	13:38	4001	3975	28	3
			ADO	03 Oct 02	13:38	13:42	4000	3974	28,1	4
11	Unitrans Lesotho 690	8	PREMIUM 93	04 Oct 02	10:55	10:59	6495	6442	26,4	4
			PREMIUM 93	04 Oct 02	10:59	11:04	6094	6026	28,8	5
			PREMIUM 93	04 Oct 02	11:04	11:08	6093	6044	26,3	4
			PREMIUM 93	04 Oct 02	11:08	11:13	6096	6043	26,7	5
			PREMIUM 93	04 Oct 02	11:13	11:17	6095	6046	26,3	5
			PREMIUM 93	04 Oct 02	11:17	11:21	5495	5445	27,1	4
			PREMIUM 93	04 Oct 02	11:25	11:29	5995	5941	27	4
			PREMIUM 93	04 Oct 02	11:29	11:34	6499	6441	26,9	5
12	Engen Transport 200014	8	ADO	04 Oct 02	11:45	11:52	3199	3184	25,6	7
			ADO	04 Oct 02	11:52	12:02	5300	5269	26,9	10
			ADO	04 Oct 02	12:03	12:10	3499	3481	26,2	7
			ADO	04 Oct 02	12:10	12:18	3999	3979	26,2	18
13	Engen Transport 96091	8	ADO	04 Oct 02	12:24	12:26	5199	5172	26,3	2
			ADO	04 Oct 02	12:26	12:29	5200	5173	26,4	3
			ADO	04 Oct 02	12:29	12:31	5199	5173	26	2
			ADO	04 Oct 02	12:31	12:34	5200	5174	25,9	3
			ADO	04 Oct 02	12:34	12:36	5200	5174	25,9	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
14	Unitrans Botswana 102	8	PREMIUM 93	04 Oct 02	13:13	13:17	4494	4457	26,5	5
			PREMIUM 93	04 Oct 02	13:17	13:21	4495	4433	30,8	4
			PREMIUM 93	04 Oct 02	13:21	13:24	4495	4442	29,1	3
			PREMIUM 93	04 Oct 02	13:25	13:28	4494	4443	28,9	3
			PREMIUM 93	04 Oct 02	13:33	13:33	0	0	0	0
			PREMIUM 93	04 Oct 02	13:33	13:36	3498	3456	29,4	3
			PREMIUM 93	04 Oct 02	13:36	13:39	3798	3750	29,9	3
			PREMIUM 93	04 Oct 02	13:39	13:43	4494	4443	28,9	4
			PREMIUM 93	04 Oct 02	13:43	13:46	4494	4442	29	3
			PREMIUM 93	04 Oct 02	13:47	13:50	4494	4441	29,3	3
			PREMIUM 93	04 Oct 02	13:51	13:54	4494	4443	28,7	3
			PREMIUM 93	04 Oct 02	13:55	13:58	4499	4450	28,5	3
15	Roan 899	6	SUPER 97	04 Oct 02	15:13	15:04	3481	3450	27,3	3
			SUPER 97	04 Oct 02	15:04	15:08	5530	5471	28,6	4
			SUPER 97	04 Oct 02	15:10	15:13	3102	3069	28,5	3
			SUPER 97	04 Oct 02	15:13	15:16	4391	4342	28,8	3
16	Roan 47	6	SUPER 97	04 Oct 02	15:21	15:25	5942	5877	28,7	4
			SUPER 97	04 Oct 02	15:26	15:28	1554	1537	28,8	2
			DYNAMIC ULP	04 Oct 02	15:30	15:34	5972	5938	24,7	4
			DYNAMIC ULP	04 Oct 02	15:35	15:39	6084	6049	24,8	4
17	Engen Transport 86051	7	SUPER 97	05 Oct 02	07:25	07:28	6002	5962	25,3	3
			SUPER 97	05 Oct 02	07:29	07:33	6002	5961	25,4	4
			SUPER 97	05 Oct 02	07:33	07:37	5801	5762	25,4	4
			SUPER 97	05 Oct 02	07:37	07:40	5902	5862	25,5	3
			SUPER 97	05 Oct 02	07:40	07:43	6300	6256	25,5	3
18	Engen Transport 200163	7	SUPER 97	05 Oct 02	07:28	07:32	3000	2985	24,1	4
			DYNAMIC ULP	05 Oct 02	07:30	07:33	6003	6016	18,3	3
			SUPER 97	05 Oct 02	07:42	07:44	5002	4969	25,3	2
			DYNAMIC ULP	05 Oct 02	07:44	07:48	6003	6013	18,5	4
			SUPER 97	05 Oct 02	07:45	07:48	5001	4967	25,3	3
			SUPER 97	05 Oct 02	07:48	07:50	5001	4967	25,4	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
19	Unitrans Lesotho 691	8	PREMIUM 93	05 Oct 02	09:26	09:32	6494	6450	25,3	6
			PREMIUM 93	05 Oct 02	09:32	09:37	6094	6045	26,3	5
			PREMIUM 93	05 Oct 02	09:37	09:42	6098	6060	24,9	5
			PREMIUM 93	05 Oct 02	09:42	09:46	6094	6052	25,4	4
			PREMIUM 93	05 Oct 02	09:47	09:51	6093	6053	25,1	4
			PREMIUM 93	05 Oct 02	09:52	09:56	5495	5456	25,6	4
			PREMIUM 93	05 Oct 02	09:59	10:04	5996	5950	26,1	5
			PREMIUM 93	05 Oct 02	10:04	10:09	6498	6444	26,5	5
20	Engen Transport 95061	7	SUPER 97	05 Oct 02	11:06	11:08	5002	4961	26,6	2
			DYNAMIC ULP	05 Oct 02	11:07	11:10	5002	4984	23,1	3
			SUPER 97	05 Oct 02	11:09	11:11	5001	4956	27,2	2
			SUPER 97	05 Oct 02	11:12	11:14	5000	4956	27	2
			SUPER 97	05 Oct 02	11:15	11:17	5002	4957	27,1	2
			SUPER 97	05 Oct 02	11:17	11:20	5000	4956	27	3
			ADO	05 Oct 02	11:20	11:21	0	0	0	1
			ADO	05 Oct 02	11:22	11:23	35	35	24,8	1
			ADO	05 Oct 02	11:23	11:24	0	0	0	1
			ADO	05 Oct 02	11:25	11:27	1776	1770	24,7	2
			ADO	05 Oct 02	11:29	11:30	379	378	24,7	1
			ADO	05 Oct 02	11:31	11:31	0	0	24,9	0
			ADO	05 Oct 02	11:31	11:32	9	9	25	1
			ADO	05 Oct 02	11:35	11:35	0	0	0	0
21	Caltex Transport 221	5	ULP 95	05 Oct 02	12:05	12:05	0	0	0	0
			ULP 95	05 Oct 02	12:06	12:09	6000	5986	22	3
			ULP 95	05 Oct 02	12:09	12:11	6150	6134	22,2	3
			SUPER 97	05 Oct 02	12:12	12:15	6004	5978	23,4	3
			SUPER 97	05 Oct 02	12:15	12:19	6103	6075	23,7	4
22	Caltex Transport 292	7	SUPER 97	05 Oct 02	13:12	13:14	5701	5669	24,6	2
			SUPER 97	05 Oct 02	13:15	13:17	5701	5666	24,9	2
			SUPER 97	05 Oct 02	13:19	13:21	5803	5767	24,9	2
			SUPER 97	05 Oct 02	13:22	13:25	5801	5765	24,9	3
23	Engen Transport 200014	5	SUPER 97	05 Oct 02	13:30	13:31	51	50	25,3	1
			SUPER 97	05 Oct 02	13:31	13:34	6044	5996	26,3	3
			ADO	05 Oct 02	13:37	13:39	3001	2982	27,8	2
			ADO	05 Oct 02	13:39	13:41	3002	2982	28,4	2
			ADO	05 Oct 02	13:41	13:43	4001	3972	28,7	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
24	Caltex Transport 215	5	ADO	05 Oct 02	14:11	14:13	3103	3080	28,8	2
			ADO	05 Oct 02	14:13	14:23	5351	5312	29	10
			ADO	05 Oct 02	14:23	14:26	5652	5609	29,2	3
			SUPER 97	05 Oct 02	14:35	14:37	4302	4267	26,6	2
			SUPER 97	05 Oct 02	14:38	14:40	5003	4955	27,6	2
			ULP 95	05 Oct 02	14:42	14:45	5001	4966	25,8	3
			ULP 95	05 Oct 02	14:45	14:47	4208	4183	25	2
25	Caltex Transport 549	5	ADO	05 Oct 02	15:04	15:06	3501	3475	29,2	2
			ADO	05 Oct 02	15:06	15:08	1151	1141	29,8	2
			ADO	05 Oct 02	15:09	15:10	2351	2332	30	1
			ADO	05 Oct 02	15:10	15:12	3501	3472	29,9	2
			ADO	05 Oct 02	15:13	15:15	3500	3473	29,6	2
26	Caltex Transport 252	5	ADO	05 Oct 02	15:20	15:23	5201	5161	29,4	3
			ADO	05 Oct 02	15:24	15:26	5203	5163	29,3	2
			ADO	05 Oct 02	15:26	15:29	5301	5260	29,3	3
			ADO	05 Oct 02	15:29	15:32	5301	5261	29,3	3
27	Caltex Transport 222	5	SUPER 97	05 Oct 02	15:35	15:38	5101	5055	27,2	3
			SUPER 97	05 Oct 02	15:38	15:41	5001	4958	26,9	3
			SUPER 97	05 Oct 02	15:41	15:44	5001	4959	26,8	3
			ULP 95	05 Oct 02	15:45	15:48	6013	5975	25,3	3
			ULP 95	05 Oct 02	15:48	15:51	6151	6120	24,1	3
28	Unitrans Lesotho 686	8	PREMIUM 93	06 May 03	08:09	08:15	6513	6511	19,7	6
			PREMIUM 93	06 May 03	08:15	08:21	6111	6110	19,9	6
			PREMIUM 93	06 May 03	08:21	08:27	6107	6107	20	6
			PREMIUM 93	06 May 03	08:27	08:33	6115	6107	19	6
			PREMIUM 93	06 May 03	08:33	08:39	6118	6110	19	6
			PREMIUM 93	06 May 03	08:39	08:45	5500	5501	20,2	6
			PREMIUM 93	06 May 03	08:48	08:54	5994	6006	21,6	6
			PREMIUM 93	06 May 03	08:54	09:00	6482	6498	21,9	6
29	Caltex Transport 293	6	SUPER 97	06 May 03	08:31	08:35	5454	5499	26,5	4
			ULP 95	06 May 03	08:32	08:36	5183	5201	22,9	4
			SUPER 97	06 May 03	08:35	08:39	5443	5500	28,2	4
			SUPER 97	06 May 03	08:39	08:43	5835	5899	28,7	4
			SUPER 97	06 May 03	08:44	08:48	5835	5899	28,7	4
			SUPER 97	06 May 03	08:55	08:58	5836	5899	28,5	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
30	Engen Transport 86052	7	ADO	06 May 03	08:23	08:26	5174	5201	26,2	3
			ADO	06 May 03	08:27	08:30	4996	5028	27,8	3
			ADO	06 May 03	08:30	08:33	4979	5012	27,9	3
			ADO	06 May 03	08:33	08:37	4981	5014	28	4
			ADO	06 May 03	08:37	08:40	3683	3708	28,1	3
			ADO	06 May 03	09:03	09:03	0	0	0	0
			ADO	06 May 03	09:03	09:04	37	37	27,2	1
			DYNAMIC ULP	06 May 03	09:03	09:06	4501	4503	20,4	3
			ADO	06 May 03	09:04	09:05	0	0	27,2	1
			SUPER 97	06 May 03	09:06	09:07	2480	2501	26,5	1
			DYNAMIC ULP	06 May 03	09:07	09:10	4493	4504	22,1	3
			SUPER 97	06 May 03	09:08	09:09	2471	2501	29,5	1
			ADO	06 May 03	09:10	09:10	54	54	27,1	1
			ADO	06 May 03	09:11	09:11	1	1	27,1	1
			ADO	06 May 03	09:18	09:19	0	0	26,9	1
			ADO	06 May 03	09:20	09:21	0	0	0	1
			ADO	06 May 03	09:48	09:48	0	0	0	0
			ADO	06 May 03	09:54	09:54	81	82	26	1
			ADO	06 May 03	09:54	09:55	3	3	26,2	1
			ADO	06 May 03	10:08	10:11	3800	3823	27,4	3
31	Engen Transport 92062	6	SUPER 97	06 May 03	09:52	09:56	5842	5900	27,8	4
			DYNAMIC ULP	06 May 03	09:52	09:58	6071	6100	23,9	6
			SUPER 97	06 May 03	09:56	10:00	5239	5299	29,1	4
			DYNAMIC ULP	06 May 03	09:59	10:02	6072	6099	23,7	3
			SUPER 97	06 May 03	10:01	10:05	5831	5899	29,2	4
			ADO	06 May 03	10:03	10:06	4968	5000	27,7	3
32	Engen Transport 92061	6	SUPER 97	06 May 03	10:11	10:15	6030	6099	29	4
			ADO	06 May 03	10:14	10:17	4958	4999	30	3
			SUPER 97	06 May 03	10:15	10:19	5831	5899	29,3	4
			DYNAMIC ULP	06 May 03	10:18	10:18	22	22	23,5	1
			SUPER 97	06 May 03	10:19	10:23	5238	5299	29,3	4
			DYNAMIC ULP	06 May 03	10:19	10:20	128	129	23,5	1
			DYNAMIC ULP	06 May 03	10:21	10:25	5818	5848	24,3	4
			ADO	06 May 03	10:26	10:29	4958	4999	30,1	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (ºC)	Time (min)
33	Engen Transport 93095	4	ADO	06 May 03	10:50	10:52	4464	4499	29,5	2
			ADO	06 May 03	10:52	10:55	3966	3997	29,5	3
			ADO	06 May 03	10:55	10:57	4462	4497	29,5	2
			ADO	06 May 03	10:57	11:00	4464	4499	29,5	3
			ADO	06 May 03	11:00	11:02	4464	4499	29,5	2
34	Caltex Transport 297	5	ADO	06 May 03	10:44	10:47	4963	4999	28,8	3
			ULP 95	06 May 03	10:44	10:47	5971	6000	24	3
			SUPER 97	06 May 03	10:44	10:47	5570	5608	25,5	3
			ULP 95	06 May 03	10:49	10:52	5980	6000	22,7	3
			SUPER 97	06 May 03	10:49	10:51	5547	5609	28,8	2
			SUPER 97	06 May 03	10:52	10:55	5841	5907	28,9	3
35	Bulktrans 24531	8	PREMIUM 93	06 May 03	10:03	10:08	5468	5501	24,7	5
			PREMIUM 93	06 May 03	10:09	10:12	2986	3011	26,4	3
			PREMIUM 93	06 May 03	10:13	10:18	5457	5500	26,2	5
			PREMIUM 93	06 May 03	10:18	10:23	5462	5505	26,1	5
			PREMIUM 93	06 May 03	10:28	10:33	5453	5500	26,7	5
			PREMIUM 93	06 May 03	10:34	10:39	5455	5506	27,2	5
			PREMIUM 93	06 May 03	10:39	10:44	5448	5499	27,2	5
			PREMIUM 93	06 May 03	10:45	10:49	4954	5002	27,5	4
			PREMIUM 93	06 May 03	10:50	10:53	3969	4008	27,5	3
36	Engen Transport 92062	7	SUPER 97	06 May 03	12:03	12:06	5824	5901	30,4	3
			DYNAMIC ULP	06 May 03	12:03	12:07	5966	6002	25	4
			SUPER 97	06 May 03	12:07	12:10	5226	5299	31	3
			DYNAMIC ULP	06 May 03	12:08	12:11	5973	6002	24	3
			SUPER 97	06 May 03	12:11	12:14	5821	5902	30,9	3
			ADO	06 May 03	12:12	12:15	4967	5000	28,1	3
37	Unitrans Natal 1519	4	ADO	06 May 03	12:10	12:13	5573	5619	30,1	3
			ADO	06 May 03	12:13	12:16	5103	5148	30,5	3
			ADO	06 May 03	12:16	12:18	5151	5197	30,6	2
			ADO	06 May 03	12:18	12:21	3932	3966	30,7	3
			ADO	06 May 03	12:33	12:33	23	23	30	1
			ADO	06 May 03	12:34	12:35	1200	1210	30,3	1
			ADO	06 May 03	12:45	12:46	117	118	30,1	1
			ADO	06 May 03	12:50	12:54	5288	5336	31,1	4
			ADO	06 May 03	12:55	12:55	407	410	31,1	1
			ADO	06 May 03	12:56	12:56	54	55	31,1	1
			ADO	06 May 03	12:56	12:57	116	117	31,1	1
			ADO	06 May 03	12:57	12:58	996	1005	31	1
			ADO	06 May 03	12:59	12:59	46	46	31,1	1

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
38	Engen Transport 200163	7	ADO	06 May 03	12:32	12:36	4963	5000	29	4
			SUPER 97	06 May 03	12:32	12:35	6018	6099	30,6	3
			SUPER 97	06 May 03	12:36	12:39	5620	5700	31,2	3
			DYNAMIC ULP	06 May 03	12:36	12:40	5967	6002	24,9	4
			SUPER 97	06 May 03	12:40	12:43	6015	6100	31,2	3
			DYNAMIC ULP	06 May 03	12:40	12:44	5974	6003	24,1	4
39	Caltex Transport 518	8	ADO	06 May 03	12:50	12:52	3771	3801	29,4	2
			ADO	06 May 03	12:52	12:55	3770	3801	30	3
			ADO	06 May 03	12:55	12:57	3978	4011	30	2
40	Engen Transport 92033	5	SUPER 97	06 May 03	12:38	12:41	4263	4306	27,9	3
			SUPER 97	06 May 03	12:42	12:45	4256	4308	29,5	3
			SUPER 97	06 May 03	12:45	12:46	1391	1408	29,7	1
			SUPER 97	06 May 03	12:48	12:50	4946	5007	29,7	2
41	Engen Transport 92027	7	ADO	06 May 03	12:51	12:55	3771	3801	29,6	4
			ADO	06 May 03	12:55	12:58	3769	3801	30	3
			ADO	06 May 03	12:58	13:01	3869	3901	30,1	3
			ADO	06 May 03	13:01	13:04	4562	4600	30,1	3
42	Unitrans Natal 1519	8	ADO	06 May 03	13:11	13:13	3670	3700	29,8	2
			ADO	06 May 03	13:14	13:17	5258	5302	30,1	3
			ADO	06 May 03	13:17	13:21	5454	5500	30	4
43	Caltex Transport 250	5	SUPER 97	06 May 03	13:11	13:14	5937	6008	29,4	3
			SUPER 97	06 May 03	13:17	13:20	5933	6006	29,7	3
			ULP 95	06 May 03	13:21	13:23	4171	4199	25,5	2
44	Engen Transport 92062	6	SUPER 97	06 May 03	13:50	13:53	5238	5299	29,2	3
			DYNAMIC ULP	06 May 03	13:50	13:54	6069	6099	24,2	4
			SUPER 97	06 May 03	13:54	13:58	5820	5899	30,7	4
			DYNAMIC ULP	06 May 03	13:55	14:00	5971	6000	24	5
			SUPER 97	06 May 03	13:59	14:03	5819	5899	30,8	4
			DYNAMIC ULP	06 May 03	14:00	14:03	5870	5899	24,1	3
45	Engen Transport 200163	6	ADO	07 May 03	08:22	08:25	5914	5953	28	3
			SUPER 97	07 May 03	08:26	08:30	5980	6019	25,3	4
			DYNAMIC ULP	07 May 03	08:27	08:31	6104	6099	19,2	4
			SUPER 97	07 May 03	08:30	08:34	5661	5699	25,4	4
			DYNAMIC ULP	07 May 03	08:31	08:34	5903	5898	19,4	3
			SUPER 97	07 May 03	08:34	08:38	6030	6072	25,6	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (ºC)	Time (min)
46	Engen Transport 200014	7	ADO	07 May 03	08:31	08:33	2979	3001	28,7	2
			ADO	07 May 03	08:33	08:36	3973	4001	28,5	3
			ADO	07 May 03	08:36	08:39	2982	3001	27,7	3
			ADO	07 May 03	08:39	08:42	3977	4001	27,4	3
47	Caltex Transport 297	6	ADO	07 May 03	08:44	08:44	0	0	0	1
			ULP 95	07 May 03	08:44	08:47	5970	6000	24,2	3
			SUPER 97	07 May 03	08:44	08:44	0	0	0	1
			SUPER 97	07 May 03	08:44	08:48	5559	5599	25,7	4
			ADO	07 May 03	08:45	08:48	5162	5199	28,7	3
			ADO	07 May 03	08:49	08:52	5165	5203	28,7	3
			SUPER 97	07 May 03	08:49	08:53	5558	5599	25,9	4
			SUPER 97	07 May 03	08:54	08:57	5854	5900	26,1	3
48	Engen Transport 92033	7	ADO	07 May 03	09:07	09:10	3878	3901	27,2	3
			ADO	07 May 03	09:10	09:13	4074	4102	28,2	3
			SUPER 97	07 May 03	09:14	09:16	3965	4000	27	2
			ULP 95	07 May 03	09:17	09:17	0	0	0	1
			ULP 95	07 May 03	09:18	09:21	2686	2695	23	3
49	Engen Transport 96022	5	ADO	07 May 03	09:10	09:12	2985	3005	28,1	2
			ADO	07 May 03	09:12	09:15	4964	5000	28,9	3
			ADO	07 May 03	09:15	09:17	1986	2001	29	2
			ADO	07 May 03	09:17	09:19	3969	4000	29,2	2
50	Engen Transport 93095	5	ADO	07 May 03	09:24	09:26	3970	4000	29,1	2
			ADO	07 May 03	09:26	09:28	3972	4003	29,4	2
			ADO	07 May 03	09:29	09:31	3968	3999	29,5	2
			ADO	07 May 03	09:31	09:33	3968	4000	29,6	2
51	Engen Transport 92062	6	SUPER 97	07 May 03	09:29	09:33	5854	5899	26,2	4
			ULP 95	07 May 03	09:30	09:32	4972	5000	24,5	2
			ADO	07 May 03	09:33	09:36	4959	5000	29,8	3
			SUPER 97	07 May 03	09:34	09:38	6004	6054	26,6	4
			SUPER 97	07 May 03	09:38	09:42	5803	5852	26,6	4
			SUPER 97	07 May 03	09:42	09:44	2082	2099	26,7	2
			ADO	07 May 03	09:57	09:57	0	0	0	1
			SUPER 97	07 May 03	09:57	09:58	14	14	26,5	1
			SUPER 97	07 May 03	10:00	10:04	5241	5285	26,7	4
			ADO	07 May 03	10:01	10:01	0	0	0	1
			ADO	07 May 03	10:02	10:05	5947	6001	31,1	3
			SUPER 97	07 May 03	10:05	10:08	5253	5299	26,9	3
			SUPER 97	07 May 03	10:09	10:09	0	0	0	1
			SUPER 97	07 May 03	10:10	10:13	4955	4999	27	3
			SUPER 97	07 May 03	10:39	10:43	5946	5999	27,1	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
52	Unitrans Natal 672	4	SUPER 97	07 May 03	09:40	09:44	5961	5997	24,8	4
			SUPER 97	07 May 03	09:44	09:47	4957	4997	26,3	3
			SUPER 97	07 May 03	09:47	09:50	5453	5497	26,4	3
			SUPER 97	07 May 03	09:51	09:54	5552	5597	26,5	3
			SUPER 97	07 May 03	09:55	09:58	5452	5497	26,5	3
			SUPER 97	07 May 03	09:58	10:01	5551	5597	26,5	3
			SUPER 97	07 May 03	10:02	10:05	5055	5097	26,6	3
			SUPER 97	07 May 03	10:08	10:10	4758	4797	26,6	2
			SUPER 97	07 May 03	10:10	10:13	5847	5897	26,7	3
53	Engen Transport 86051	7	ULP 95	07 May 03	09:42	09:47	5869	5895	23,7	5
			SUPER 97	07 May 03	09:42	09:45	5946	6002	27,4	3
			SUPER 97	07 May 03	09:45	09:48	5747	5803	27,6	3
			DYNAMIC ULP	07 May 03	09:47	09:49	3331	3344	23,1	2
			ADO	07 May 03	09:48	09:51	5959	6002	28,7	3
			DYNAMIC ULP	07 May 03	09:50	09:51	963	967	22,8	1
			DYNAMIC ULP	07 May 03	09:51	09:53	1454	1457	21,7	2
			DYNAMIC ULP	07 May 03	09:53	09:53	236	236	21,1	1
54	Engen Transport 98062	8	ADO	07 May 03	09:49	09:52	5466	5509	29,4	3
			ADO	07 May 03	09:52	09:55	5465	5509	29,6	3
			ADO	07 May 03	09:55	09:57	5460	5504	29,7	2
			ADO	07 May 03	09:57	10:00	5270	5312	29,7	3
			ADO	07 May 03	10:04	10:06	5357	5401	29,8	2
			ADO	07 May 03	10:07	10:09	4468	4505	29,9	2
			ADO	07 May 03	10:09	10:10	1496	1508	29,9	1
			ADO	07 May 03	10:10	10:13	4468	4505	30	3
			ADO	07 May 03	10:13	10:16	4361	4398	30	3
55	Engen Transport 99062	6	ADO	07 May 03	09:57	09:57	0	0	0	1
			SUPER 97	07 May 03	09:57	09:58	14	14	26,5	1
			SUPER 97	07 May 03	10:00	10:04	5241	5285	26,7	4
			ADO	07 May 03	10:01	10:01	0	0	0	1
			ADO	07 May 03	10:02	10:05	5947	6001	31,1	3
			SUPER 97	07 May 03	10:05	10:08	5253	5299	26,9	3
			SUPER 97	07 May 03	10:09	10:09	0	0	0	1
			SUPER 97	07 May 03	10:10	10:13	4955	4999	27	3
			SUPER 97	07 May 03	10:39	10:43	5946	5999	27,1	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
56	Caltex Transport 550	7	SUPER 97	07 May 03	10:13	10:15	4455	4499	27,7	2
			SUPER 97	07 May 03	10:15	10:18	4198	4241	28	3
			SUPER 97	07 May 03	10:18	10:21	4454	4499	28	3
			SUPER 97	07 May 03	10:21	10:23	4255	4299	28,1	2
			SUPER 97	07 May 03	10:29	10:32	6088	6150	28,1	3
			SUPER 97	07 May 03	10:32	10:35	6236	6300	28,2	3
			ULP 95	07 May 03	10:36	10:41	6162	6196	24,5	5
			ADO	07 May 03	10:42	10:45	5160	5201	29,6	3
57	Caltex Transport 293	4	DPK	07 May 03	10:19	10:24	4788	4807	24,5	5
			DPK	07 May 03	10:24	10:28	4789	4808	24,4	4
			DPK	07 May 03	10:28	10:34	5087	5109	25	6
			DPK	07 May 03	10:35	10:40	5083	5108	25,5	5
			DPK	07 May 03	10:40	10:45	5081	5107	25,8	5
			DPK	07 May 03	10:45	10:50	5080	5108	26,2	5
58	Caltex Transport 442	5	ADO	07 May 03	10:38	10:38	76	77	29,8	1
			ADO	07 May 03	10:40	10:41	42	42	29,9	1
			ADO	07 May 03	10:41	10:42	2	2	30	1
			ADO	07 May 03	10:42	10:44	3300	3329	30,6	2
			ADO	07 May 03	10:45	10:46	31	32	31,1	1
			ADO	07 May 03	10:47	10:49	3435	3467	31,1	2
			ADO	07 May 03	10:50	10:52	3765	3801	31,3	2
			ADO	07 May 03	10:52	10:54	3765	3800	31,3	2
59	Caltex Transport 245	3	SUPER 97	07 May 03	10:45	10:48	3771	3799	25,9	3
			ULP 95	07 May 03	10:46	10:48	4627	4647	23,6	2
			SUPER 97	07 May 03	10:49	10:52	3963	3999	27,2	3
			SUPER 97	07 May 03	10:52	10:55	3914	3949	27,1	3
			SUPER 97	07 May 03	10:55	10:58	5252	5299	27,2	3
			SUPER 97	07 May 03	10:58	11:00	2378	2400	27,2	2
60	Engen Transport 95061	7	DYNAMIC ULP	07 May 03	10:51	10:56	5971	5998	23,7	5
			ADO	07 May 03	10:52	10:55	4872	4915	30,5	3
			SUPER 97	07 May 03	10:55	10:58	5244	5299	28,2	3
			DYNAMIC ULP	07 May 03	10:56	11:00	5789	5803	22,1	4
			SUPER 97	07 May 03	10:58	11:01	5280	5337	28,4	3
			DYNAMIC ULP	07 May 03	11:00	11:01	14	14	22,1	1
			DYNAMIC ULP	07 May 03	11:01	11:05	5240	5255	22,3	4
			DYNAMIC ULP	07 May 03	11:05	11:08	4888	4903	22,4	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
61	Engen Transport 92061	6	SUPER 97	07 May 03	10:48	10:52	5969	6025	27,4	4
			SUPER 97	07 May 03	10:52	10:56	5982	6038	27,5	4
			SUPER 97	07 May 03	10:56	10:58	1976	1995	27,4	2
			SUPER 97	07 May 03	11:00	11:03	3801	3837	27,5	3
			SUPER 97	07 May 03	11:03	11:06	5180	5230	27,5	3
			SUPER 97	07 May 03	11:07	11:10	5593	5647	27,6	3
			SUPER 97	07 May 03	11:11	11:14	5760	5816	27,7	3
62	Bulktrans 24271	8	PREMIUM 93	07 May 03	10:45	10:45	0	0	0	1
			PREMIUM 93	07 May 03	10:45	10:50	4969	5002	25,2	5
			PREMIUM 93	07 May 03	10:51	10:56	4962	5009	27,2	5
			PREMIUM 93	07 May 03	10:56	11:01	4969	5005	25,7	5
			PREMIUM 93	07 May 03	11:01	11:06	4973	5011	26,1	5
			PREMIUM 93	07 May 03	11:08	11:13	4966	5012	27,2	5
			PREMIUM 93	07 May 03	11:14	11:19	4960	5011	27,8	5
			PREMIUM 93	07 May 03	11:19	11:20	309	312	27,9	1
			PREMIUM 93	07 May 03	11:20	11:25	4646	4695	28,2	5
			PREMIUM 93	07 May 03	11:26	11:31	4943	5000	28,9	5
			PREMIUM 93	07 May 03	11:31	11:36	4954	5010	28,7	5
63	Caltex Transport 222	7	SUPER 97	07 May 03	11:13	11:16	5938	6001	28,5	3
			SUPER 97	07 May 03	11:16	11:18	3118	3152	28,5	2
			SUPER 97	07 May 03	11:18	11:21	6281	6350	28,7	3
			SUPER 97	07 May 03	11:21	11:24	6084	6151	28,7	3
			SUPER 97	07 May 03	11:25	11:28	6132	6199	28,7	3
			ULP 95	07 May 03	11:28	11:33	6113	6145	24,3	5
64	Unitrans Natal 42201	5	ADO	07 May 03	11:31	11:33	3368	3399	31,4	2
			ADO	07 May 03	11:33	11:35	4356	4399	31,8	2
			ADO	07 May 03	11:36	11:38	3367	3400	31,9	2
			ADO	07 May 03	11:38	11:40	3762	3799	31,9	2
			SUPER 97	07 May 03	11:44	11:47	5956	6006	26,7	3
			SUPER 97	07 May 03	11:47	11:50	5951	6007	27,4	3
			SUPER 97	07 May 03	11:50	11:53	5952	6007	27,4	3
			DYNAMIC ULP	07 May 03	11:55	11:59	4976	5002	24,2	4
			DYNAMIC ULP	07 May 03	12:00	12:04	4980	5003	23,7	4
65	Engen Transport 92062	7	SUPER 97	07 May 03	11:39	11:42	6032	6099	28,8	3
			SUPER 97	07 May 03	11:43	11:46	6031	6099	28,9	3
			SUPER 97	07 May 03	11:46	11:49	5833	5899	28,9	3
			SUPER 97	07 May 03	11:51	11:54	5833	5899	28,9	3
			SUPER 97	07 May 03	11:55	11:58	5833	5899	29	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
66	Engen Transport 86052	6	SUPER 97	07 May 03	11:34	11:38	6040	6099	27,7	4
			SUPER 97	07 May 03	11:39	11:43	5940	6000	27,9	4
			ULP 95	07 May 03	11:41	11:43	4373	4401	25,2	2
			SUPER 97	07 May 03	11:43	11:47	5841	5899	27,9	4
			SUPER 97	07 May 03	11:47	11:51	5940	5999	27,9	4
67	Engen Transport 86051	6	SUPER 97	07 May 03	11:54	11:57	5741	5799	28	3
			DYNAMIC ULP	07 May 03	11:55	11:59	5971	6001	24,2	4
			SUPER 97	07 May 03	11:58	12:01	5543	5599	28	3
			DYNAMIC ULP	07 May 03	11:59	12:04	5978	6003	23,5	5
			ADO	07 May 03	12:02	12:05	4947	5000	33,1	3
68	Engen Transport 92033	7	ADO	07 May 03	12:06	12:09	3768	3801	30,4	3
			ADO	07 May 03	12:10	12:13	3765	3801	31,6	3
			ADO	07 May 03	12:13	12:15	2181	2202	31,6	2
			ADO	07 May 03	12:15	12:18	3765	3801	31,6	3
69	Caltex Transport 221	6	SUPER 97	07 May 03	12:09	12:13	5938	5999	28,2	4
			SUPER 97	07 May 03	12:13	12:17	6085	6149	28,3	4
			SUPER 97	07 May 03	12:18	12:21	5937	5999	28,3	3
			SUPER 97	07 May 03	12:22	12:26	5936	5999	28,3	4
			ULP 95	07 May 03	12:28	12:30	3128	3150	25,8	2
			ULP 95	07 May 03	12:30	12:33	6301	6350	26,4	3
70	Unitrans Natal 683	5	ADO	07 May 03	12:09	12:13	5943	6001	31,6	4
			ADO	07 May 03	12:13	12:16	4950	5000	32,1	3
			ADO	07 May 03	12:16	12:19	5939	5999	32,2	3
			ADO	07 May 03	12:19	12:22	5939	6000	32,3	3
			ADO	07 May 03	12:22	12:24	4457	4502	32,3	2
			ADO	07 May 03	12:25	12:27	2972	3002	32,2	2
			ADO	07 May 03	12:30	12:33	5944	6004	32,2	3
			ADO	07 May 03	12:33	12:37	5945	6005	32,3	4
71	Engen Transport 98062	7	ADO	07 May 03	12:23	12:27	5548	5601	31,6	4
			ADO	07 May 03	12:27	12:31	5547	5601	31,8	4
			ADO	07 May 03	12:31	12:34	2971	3000	31,8	3
			ADO	07 May 03	12:34	12:38	5251	5302	31,8	4
			ADO	07 May 03	12:41	12:45	5349	5401	31,8	4
			ADO	07 May 03	12:45	12:49	5001	5050	31,9	4
			ADO	07 May 03	12:49	12:51	2477	2501	31,9	2
			ADO	07 May 03	12:52	12:55	4459	4503	31,9	3
			ADO	07 May 03	12:55	12:59	5003	5052	31,9	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
72	Engen Transport 96022	3	ADO	07 May 03	12:33	12:37	3694	3727	30,8	4
			ADO	07 May 03	12:37	12:41	4305	4346	31,5	4
			SUPER 97	07 May 03	12:38	12:38	45	46	26,4	1
			SUPER 97	07 May 03	12:41	12:44	4906	4953	27,7	3
73	Engen Transport 200014	6	ADO	07 May 03	12:39	12:41	2968	3000	32,9	2
			ADO	07 May 03	12:42	12:45	4947	5003	33,7	3
			ADO	07 May 03	12:45	12:48	2970	3003	33,7	3
			ADO	07 May 03	12:48	12:50	3955	4001	33,8	2
74	Berg Gasoline 5	5	SUPER 97	07 May 03	12:42	12:43	1495	1508	27	1
			ADO	07 May 03	12:51	12:54	3965	4005	32	3
			ADO	07 May 03	12:54	12:57	4359	4404	32,4	3
			ADO	07 May 03	12:58	13:01	4552	4599	32,4	3
			ADO	07 May 03	13:04	13:08	5744	5803	32,5	4
			ADO	07 May 03	13:08	13:12	5744	5804	32,5	4
			ADO	07 May 03	13:12	13:15	3761	3800	32,5	3
			ADO	07 May 03	13:15	13:19	5740	5800	32,5	4
			ADO	07 May 03	13:19	13:23	5740	5800	32,6	4
75	Engen Transport 92027	7	ULP 95	07 May 03	15:02	15:06	4966	4996	24,8	4
			SUPER 97	07 May 03	15:07	15:07	0	0	29,4	1
			SUPER 97	07 May 03	15:08	15:10	3161	3199	29,5	2
			SUPER 97	07 May 03	15:10	15:12	4347	4401	29,8	2
			SUPER 97	07 May 03	15:12	15:15	4347	4401	29,7	3
76	Uniswazi 4506	4	SUPER 97	07 May 03	15:00	15:03	4351	4398	28,4	3
			SUPER 97	07 May 03	15:04	15:07	4350	4398	28,6	3
			SUPER 97	07 May 03	15:07	15:10	4351	4398	28,6	3
			SUPER 97	07 May 03	15:10	15:13	4351	4398	28,5	3
			SUPER 97	07 May 03	15:16	15:21	6329	6397	28,5	5
			SUPER 97	07 May 03	15:21	15:26	6330	6397	28,4	5
			SUPER 97	07 May 03	15:26	15:31	6329	6397	28,4	5
			SUPER 97	07 May 03	15:31	15:35	6329	6396	28,4	4
			SUPER 97	07 May 03	15:35	15:40	5834	5896	28,5	5
77	Caltex Transport 221	6	SUPER 97	07 May 03	15:13	15:17	5934	5999	28,7	4
			SUPER 97	07 May 03	15:17	15:21	5933	5999	28,8	4
			SUPER 97	07 May 03	15:21	15:25	5933	5999	28,8	4
			SUPER 97	07 May 03	15:25	15:29	5933	5999	28,7	4
78	Engen Transport 92033	8	ADO	07 May 03	15:35	15:38	3869	3907	31,6	3
			ADO	07 May 03	15:38	15:39	3176	3208	32,1	1
			ADO	07 May 03	15:40	15:42	3862	3901	32,1	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
79	Caltex Transport 442	6	SUPER 97	07 May 03	15:36	15:39	3906	3949	28,6	3
			SUPER 97	07 May 03	15:39	15:42	4005	4049	28,7	3
			SUPER 97	07 May 03	15:42	15:46	4351	4399	28,7	4
			SUPER 97	07 May 03	15:46	15:49	4351	4399	28,7	3
80	Caltex Transport 222	6	SUPER 97	08 May 03	09:44	09:48	5948	5999	26,8	4
			SUPER 97	08 May 03	09:48	09:51	3123	3149	26,7	3
			SUPER 97	08 May 03	09:51	09:55	6295	6350	26,8	4
			SUPER 97	08 May 03	09:55	10:00	6097	6149	26,8	5
			SUPER 97	08 May 03	10:00	10:04	6145	6199	27	4
			ULP 95	08 May 03	10:05	10:08	6107	6150	25,8	3
81	Engen Transport 95061	7	DYNAMIC ULP	08 May 03	09:40	09:43	5271	5277	20,8	3
			ADO	08 May 03	09:41	09:43	3528	3556	29,8	1
			ADO	08 May 03	09:45	09:47	1433	1445	30	1
			DYNAMIC ULP	08 May 03	09:45	09:45	10	10	20,5	1
			DYNAMIC ULP	08 May 03	09:50	09:53	4697	4702	20,9	3
			SUPER 97	08 May 03	09:52	09:55	5301	5343	26,2	3
			DYNAMIC ULP	08 May 03	09:54	09:55	317	317	20,7	1
			DYNAMIC ULP	08 May 03	09:56	09:59	4671	4676	20,8	3
			SUPER 97	08 May 03	10:00	10:03	5811	5868	27,7	3
			SUPER 97	08 May 03	10:05	10:08	5718	5776	28	3
			SUPER 97	08 May 03	10:11	10:11	0	0	28	1
82	Engen Transport 0213	3	ADO	08 May 03	09:52	09:56	5461	5504	29,7	4
			ADO	08 May 03	09:57	09:59	3518	3546	29,9	2
			SUPER 97	08 May 03	10:01	10:04	3719	3749	26,5	3
			SUPER 97	08 May 03	10:04	10:07	4214	4250	26,7	3
83	Caltex Transport 548	5	SUPER 97	08 May 03	10:07	10:08	0	0	0	1
			SUPER 97	08 May 03	10:09	10:11	3975	4005	26	2
			SUPER 97	08 May 03	10:11	10:14	4470	4508	26,6	3
			SUPER 97	08 May 03	10:14	10:16	4470	4508	26,7	2
			SUPER 97	08 May 03	10:16	10:19	3973	4006	26,7	3
84	Caltex Transport 518	6	SUPER 97	08 May 03	10:25	10:28	4360	4399	27,1	3
			SUPER 97	08 May 03	10:29	10:32	4358	4399	27,5	3
			SUPER 97	08 May 03	10:33	10:37	4606	4649	27,5	4
			ULP 95	08 May 03	10:38	10:41	4381	4413	26,1	3
85	Caltex Transport 221	7	SUPER 97	08 May 03	10:45	10:48	5938	6000	28,2	3
			SUPER 97	08 May 03	10:48	10:50	3115	3149	28,7	2
			SUPER 97	08 May 03	10:50	10:53	6279	6349	28,7	3
			SUPER 97	08 May 03	10:53	10:56	6083	6150	28,7	3
			SUPER 97	08 May 03	10:57	11:00	6131	6199	28,7	3
			ULP 95	08 May 03	11:00	11:05	6112	6146	24,6	5

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
86	Engen Transport 200014	6	ADO	08 May 03	10:49	10:51	1985	02	30,2	2
			ADO	08 May 03	10:51	10:54	3963	4002	31,9	3
87	Engen Transport 86051	6	SUPER 97	08 May 03	10:59	11:00	52	53	27,3	1
			ADO	08 May 03	11:00	11:03	5943	6002	32	3
			SUPER 97	08 May 03	11:00	11:04	5889	5946	27,7	4
			SUPER 97	08 May 03	11:04	11:07	4686	4734	28	3
			DYNAMIC ULP	08 May 03	11:04	11:07	4905	4933	24,7	3
			SUPER 97	08 May 03	11:07	11:09	1055	1065	28	2
			DYNAMIC ULP	08 May 03	11:07	11:09	1042	1045	22,3	2
			SUPER 97	08 May 03	11:09	11:13	5840	5899	28	4
88	Uniswazi 4507	8	ADO	08 May 03	11:05	11:06	9	10	29,3	1
			ADO	08 May 03	11:06	11:07	0	0	0	1
			ADO	08 May 03	11:17	11:19	3418	3447	30	2
			ADO	08 May 03	11:20	11:22	3420	3450	30,5	2
			ADO	08 May 03	11:22	11:25	3519	3550	30,5	3
			ADO	08 May 03	11:25	11:28	3519	3551	30,5	3
			ADO	08 May 03	11:56	12:00	5906	5958	30,6	4
			ADO	08 May 03	12:01	12:04	5906	5960	30,9	3
			ADO	08 May 03	12:05	12:08	5850	5904	31	3
			ADO	08 May 03	12:09	12:12	5707	5760	31,1	3
			ADO	08 May 03	12:12	12:16	5205	5253	31,1	4
89	Engen Transport 200163	6	SUPER 97	08 May 03	11:22	11:26	4950	4999	27,9	4
			DYNAMIC ULP	08 May 03	11:23	11:27	6078	6099	22,8	4
			SUPER 97	08 May 03	11:27	11:29	2902	2932	28,2	2
			DYNAMIC ULP	08 May 03	11:28	11:31	5885	5900	22,1	3
			SUPER 97	08 May 03	11:30	11:33	4866	4916	28,2	3
			SUPER 97	08 May 03	11:33	11:36	4869	4919	28,2	3
90	Engen Transport 99062	7	ADO	08 May 03	11:16	11:19	4565	4601	29,4	3
			ADO	08 May 03	11:19	11:22	4562	4602	30,5	3
			ADO	08 May 03	11:23	11:26	4266	4303	30,6	3
			ADO	08 May 03	11:27	11:30	5453	5501	30,7	3
			ADO	08 May 03	11:31	11:32	565	570	30,7	1
			ADO	08 May 03	11:33	11:36	4888	4931	30,7	3
91	Engen Transport 92061	6	SUPER 97	08 May 03	11:40	11:44	5839	5899	28,1	4
			ADO	08 May 03	11:41	11:44	4957	5007	32,2	3
			DYNAMIC ULP	08 May 03	11:44	11:47	6077	6100	23,1	3
			SUPER 97	08 May 03	11:45	11:48	5176	5230	28,2	3
			DYNAMIC ULP	08 May 03	11:48	11:51	5880	5899	22,6	3
			SUPER 97	08 May 03	11:49	11:52	5768	5827	28,2	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
92	Bulktrans 24261	8	PREMIUM 93	08 May 03	12:21	12:26	4950	5003	28,2	5
			PREMIUM 93	08 May 03	12:26	12:31	4935	5004	30,7	5
			PREMIUM 93	08 May 03	12:31	12:35	5446	5503	28	4
			PREMIUM 93	08 May 03	12:36	12:41	5927	6000	29,4	5
			PREMIUM 93	08 May 03	12:43	12:47	4935	5002	30,4	4
			PREMIUM 93	08 May 03	12:47	12:52	4939	5004	30	5
			PREMIUM 93	08 May 03	12:52	12:57	5431	5506	30,6	5
			PREMIUM 93	08 May 03	12:57	13:02	4930	5001	31,1	5
			PREMIUM 93	08 May 03	13:02	13:07	5430	5502	30,2	5
93	Engen Transport 95061	6	ADO	08 May 03	12:30	12:32	4562	4610	32,6	2
			ADO	08 May 03	12:33	12:36	4559	4609	33,3	3
			ADO	08 May 03	12:36	12:39	4559	4609	33,3	3
			ADO	08 May 03	12:39	12:40	0	0	0	1
			ADO	08 May 03	12:40	12:42	4559	4610	33,3	2
			ADO	08 May 03	12:43	12:46	4559	4609	33,3	3
			ADO	08 May 03	12:48	12:51	4945	4999	33,4	3
			ADO	08 May 03	12:52	12:55	5143	5200	33,4	3
94	Caltex Transport 518	7	ADO	08 May 03	12:43	12:45	3968	4002	30,2	2
			SUPER 97	08 May 03	12:50	12:53	4354	4400	28,4	3
			SUPER 97	08 May 03	12:53	12:56	4344	4400	30,2	3
			ULP 95	08 May 03	12:58	13:02	4614	4645	25,6	4
95	Caltex Transport 297	5	ULP 95	08 May 03	12:56	12:59	5953	5999	26,3	3
			SUPER 97	08 May 03	12:56	12:58	5556	5607	27,3	2
			ADO	08 May 03	12:59	13:02	5148	5199	32	3
			SUPER 97	08 May 03	12:59	13:02	5555	5610	27,8	3
			SUPER 97	08 May 03	13:03	13:05	5852	5910	27,7	2
			SUPER 97	08 May 03	13:07	13:10	5952	6010	27,7	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
96	Bulktrans 24601	8	ADO	08 May 03	13:19	13:22	4460	4501	31	3
			PREMIUM 93	08 May 03	13:19	13:19	3	3	29,3	1
			PREMIUM 93	08 May 03	13:20	13:20	0	0	0	1
			PREMIUM 93	08 May 03	13:20	13:21	0	0	0	1
			PREMIUM 93	08 May 03	13:21	13:21	0	0	0	1
			PREMIUM 93	08 May 03	13:21	13:22	0	0	0	1
			ADO	08 May 03	13:22	13:24	4961	5009	31,6	2
			PREMIUM 93	08 May 03	13:23	13:23	0	0	0	1
			PREMIUM 93	08 May 03	13:24	13:24	0	0	0	1
			ADO	08 May 03	13:25	13:28	4962	5011	31,6	3
			PREMIUM 93	08 May 03	13:27	13:27	0	0	0	1
			ADO	08 May 03	13:29	13:32	4958	5006	31,6	3
			ADO	08 May 03	13:32	13:34	3969	4008	31,7	2
			PREMIUM 93	08 May 03	13:35	13:35	0	0	0	1
			PREMIUM 93	08 May 03	13:36	13:41	5929	6002	29,4	5
			PREMIUM 93	08 May 03	13:41	13:45	3960	4005	28,8	4
			PREMIUM 93	08 May 03	13:45	13:50	5942	6005	28,3	5
			PREMIUM 93	08 May 03	13:51	13:56	5938	6003	28,5	5
97	Engen Transport 200163	7	ADO	08 May 03	13:19	13:22	4919	4964	31	3
			SUPER 97	08 May 03	13:20	13:23	5955	6025	29,2	3
			ULP 95	08 May 03	13:23	13:27	4889	4923	25,6	4
			SUPER 97	08 May 03	13:24	13:27	6127	6200	29,3	3
			SUPER 97	08 May 03	13:29	13:32	5963	6033	29,2	3
			SUPER 97	08 May 03	13:32	13:35	5559	5623	29,2	3
98	Bulktrans 24311	5	SUPER 97	08 May 03	13:41	13:44	4960	5007	27,5	3
			SUPER 97	08 May 03	13:44	13:47	4958	5007	27,8	3
			SUPER 97	08 May 03	13:47	13:50	4959	5008	27,7	3
			SUPER 97	08 May 03	13:50	13:52	4959	5007	27,7	2
			SUPER 97	08 May 03	13:58	14:01	4957	5006	27,7	3
			SUPER 97	08 May 03	14:02	14:05	4958	5007	27,8	3
			SUPER 97	08 May 03	14:05	14:06	1987	2006	27,7	1
99	Caltex Transport 293	6	SUPER 97	08 May 03	13:46	13:47	0	0	0	1
			ULP 95	08 May 03	13:47	13:50	5849	5900	27,2	3
			SUPER 97	08 May 03	13:47	13:51	5493	5549	28,1	4
			SUPER 97	08 May 03	13:51	13:55	5492	5549	28,2	4
			ADO	08 May 03	13:52	13:55	5043	5099	33,4	3
			SUPER 97	08 May 03	13:55	13:59	5838	5899	28,3	4
			SUPER 97	08 May 03	13:59	14:03	5838	5899	28,3	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
100	Engen Transport 92061	7	SUPER 97	08 May 03	13:59	14:02	4898	4954	29,1	3
			SUPER 97	08 May 03	14:02	14:05	4911	4969	29,3	3
			ULP 95	08 May 03	14:04	14:07	4883	4918	25,9	3
			SUPER 97	08 May 03	14:05	14:08	4877	4934	29,2	3
			SUPER 97	08 May 03	14:08	14:11	4870	4927	29,2	3
			SUPER 97	08 May 03	14:11	14:14	4866	4923	29,2	3
101	Engen Transport 0213	5	ADO	09 May 03	08:26	08:28	3970	3999	28,8	2
			ULP 95	09 May 03	08:28	08:31	3985	4000	23,2	3
			SUPER 97	09 May 03	08:32	08:34	3490	3505	23,4	2
			SUPER 97	09 May 03	08:34	08:37	4485	4507	23,8	3
102	Engen Transport 96091	5	ADO	09 May 03	08:39	08:42	4965	5000	28,5	3
			ADO	09 May 03	08:42	08:45	4170	4199	28,6	3
			ADO	09 May 03	08:45	08:47	4963	4999	28,7	2
			ADO	09 May 03	08:48	08:50	4964	5000	28,8	2
103	Caltex Transport 221	7	ULP 95	09 May 03	08:26	08:30	4600	4624	24,3	4
			SUPER 97	09 May 03	08:31	08:31	105	105	24,2	1
			SUPER 97	09 May 03	08:32	08:35	5856	5895	25,3	3
			SUPER 97	09 May 03	08:35	08:36	1490	1500	25,3	1
			SUPER 97	09 May 03	08:36	08:39	5959	6000	25,4	3
			SUPER 97	09 May 03	08:39	08:42	5961	6002	25,4	3
104	Engen Transport 92061	6	DYNAMIC ULP	09 May 03	08:47	08:50	6092	6099	20,9	3
			ADO	09 May 03	08:48	08:51	4958	4999	30	3
			SUPER 97	09 May 03	08:48	08:48	13	13	22,9	1
			SUPER 97	09 May 03	08:49	08:50	7	7	22,9	1
			SUPER 97	09 May 03	08:50	08:50	4	4	22,9	1
			SUPER 97	09 May 03	08:50	08:51	0	0	0	1
			SUPER 97	09 May 03	08:51	08:52	2	2	22,9	1
			SUPER 97	09 May 03	08:52	08:53	0	0	0	1
			DYNAMIC ULP	09 May 03	08:52	08:55	5899	5899	19,9	3
			SUPER 97	09 May 03	08:53	08:57	5843	5873	24,1	4
			SUPER 97	09 May 03	08:58	09:01	5269	5299	24,6	3
			SUPER 97	09 May 03	09:02	09:06	5865	5899	24,6	4
105	Engen Transport 99062	7	ADO	09 May 03	08:46	08:46	0	0	0	1
			ADO	09 May 03	08:47	08:50	4576	4601	26,7	3
			ADO	09 May 03	08:50	08:53	4569	4601	28,5	3
			ADO	09 May 03	08:54	08:57	3773	3800	28,7	3
			ADO	09 May 03	08:57	09:01	5460	5500	28,9	4
			ADO	09 May 03	09:01	09:05	5460	5500	29,1	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
106	Unitrans Lesotho 684	8	PREMIUM 93	09 May 03	08:45	08:55	6484	6498	21,7	10
			PREMIUM 93	09 May 03	08:55	09:01	6091	6104	21,6	6
			PREMIUM 93	09 May 03	09:01	09:07	6087	6103	22	6
			PREMIUM 93	09 May 03	09:07	09:13	5989	6001	21,6	6
			PREMIUM 93	09 May 03	09:13	09:19	6089	6102	21,6	6
			PREMIUM 93	09 May 03	09:19	09:25	5480	5500	22,8	6
			PREMIUM 93	09 May 03	09:28	09:30	834	838	23,6	2
			PREMIUM 93	09 May 03	09:30	09:36	5235	5264	24,3	6
			PREMIUM 93	09 May 03	09:36	09:42	6467	6504	24,4	6
107	Engen Transport 200014	5	ADO	09 May 03	09:03	09:04	0	0	0	1
			SUPER 97	09 May 03	09:03	09:04	0	0	0	1
			ADO	09 May 03	09:34	09:36	3475	3500	28,8	2
			SUPER 97	09 May 03	09:34	09:36	4985	5008	23,7	2
			ADO	09 May 03	09:36	09:38	3470	3499	30,1	2
			ADO	09 May 03	09:38	09:41	4362	4399	30,3	3
108	Engen Transport 85053	7	ULP 95	09 May 03	09:10	09:14	5782	5813	24,5	4
			SUPER 97	09 May 03	09:10	09:13	5790	5831	25,6	3
			SUPER 97	09 May 03	09:13	09:17	5886	5927	25,6	4
			ADO	09 May 03	09:17	09:21	5877	5920	28,9	4
			SUPER 97	09 May 03	09:17	09:20	5462	5499	25,5	3
109	Unitrans Natal 122	3	ADO	09 May 03	09:19	09:24	5856	5898	28,7	5
			ADO	09 May 03	09:24	09:28	5455	5498	29,5	4
			ADO	09 May 03	09:28	09:32	5456	5500	29,6	4
			ADO	09 May 03	09:33	09:37	5461	5504	29,6	4
			ADO	09 May 03	09:40	09:44	3573	3601	29,6	4
			ADO	09 May 03	09:44	09:48	5657	5702	29,7	4
			ADO	09 May 03	09:48	09:52	5856	5904	29,9	4
			ADO	09 May 03	09:52	09:56	5558	5603	29,9	4
110	Caltex Transport 245	7	SUPER 97	09 May 03	10:24	10:27	3972	4000	25,7	3
			ULP 95	09 May 03	10:25	10:29	3772	3796	25,1	4
			SUPER 97	09 May 03	10:27	10:30	4961	5000	26,2	3
			ULP 95	09 May 03	10:29	10:33	3973	3995	24,8	4
			SUPER 97	09 May 03	10:30	10:32	4964	5000	25,8	2
			SUPER 97	09 May 03	10:33	10:35	3972	4001	25,8	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
111	Caltex Transport 221	5	ULP 95	09 May 03	10:24	10:28	5966	6002	24,9	4
			ULP 95	09 May 03	10:28	10:31	6117	6150	24,5	3
			SUPER 97	09 May 03	10:32	10:34	3141	3157	24,2	2
			SUPER 97	09 May 03	10:34	10:37	6322	6356	24,3	3
			SUPER 97	09 May 03	10:37	10:41	6124	6158	24,3	4
			SUPER 97	09 May 03	10:41	10:44	6176	6210	24,3	3
112	Engen Transport 86051	7	SUPER 97	09 May 03	10:41	10:43	4269	4301	25,8	2
			DYNAMIC ULP	09 May 03	10:42	10:46	5975	6003	23,8	4
			SUPER 97	09 May 03	10:44	10:47	5420	5459	25,7	3
			SUPER 97	09 May 03	11:00	11:01	339	341	26	1
			SUPER 97	09 May 03	11:03	11:07	5856	5900	26	4
			SUPER 97	09 May 03	11:13	11:17	5889	5933	25,9	4
113	Uniswazi 4506	4	SUPER 97	09 May 03	10:49	10:52	4372	4397	24,5	3
			SUPER 97	09 May 03	10:53	10:56	4372	4397	24,7	3
			SUPER 97	09 May 03	10:56	10:59	4371	4397	24,7	3
			SUPER 97	09 May 03	10:59	11:03	4370	4396	24,7	4
			SUPER 97	09 May 03	11:07	11:11	6362	6398	24,5	4
			SUPER 97	09 May 03	11:12	11:16	6359	6397	24,6	4
			SUPER 97	09 May 03	11:16	11:21	6360	6397	24,6	5
			SUPER 97	09 May 03	11:21	11:26	6359	6397	24,7	5
			SUPER 97	09 May 03	11:26	11:30	5862	5897	24,7	4
114	Caltex Transport 518	6	ADO	09 May 03	10:49	10:52	3760	3799	32,6	3
			ADO	09 May 03	10:52	10:54	3760	3800	32,9	2
			ADO	09 May 03	10:55	10:57	3958	4000	32,9	2
			ADO	09 May 03	10:57	11:00	3957	3999	33	3
115	Bulktrans 24361	5	SUPER 97	09 May 03	10:59	11:02	5973	6007	24,5	3
			SUPER 97	09 May 03	11:02	11:03	1995	2007	24,5	1
			SUPER 97	09 May 03	11:03	11:07	5972	6006	24,5	4
			SUPER 97	09 May 03	11:07	11:11	5974	6006	24,3	4
			SUPER 97	09 May 03	11:14	11:14	0	0	0	1
			SUPER 97	09 May 03	11:15	11:18	5576	5607	24,4	3
			SUPER 97	09 May 03	11:18	11:21	5575	5605	24,4	3
			SUPER 97	09 May 03	11:21	11:24	5574	5606	24,5	3
			SUPER 97	09 May 03	11:24	11:27	5572	5604	24,6	3
			SUPER 97	09 May 03	11:27	11:30	5576	5607	24,5	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
116	Engen Transport 85053	6	ADO	09 May 03	11:06	11:09	5936	6000	32,9	3
			SUPER 97	09 May 03	11:06	11:10	5410	5444	24,9	4
			ULP 95	09 May 03	11:10	11:13	5856	5901	26,3	3
			SUPER 97	09 May 03	11:10	11:14	5890	5926	24,9	4
			SUPER 97	09 May 03	11:14	11:18	5814	5850	25	4
117	Engen Transport 92061	7	ULP 95	09 May 03	11:23	11:24	22	22	25,4	1
			SUPER 97	09 May 03	11:23	11:24	0	0	0	1
			DYNAMIC ULP	09 May 03	11:23	11:28	6089	6106	22,4	5
			ULP 95	09 May 03	11:24	11:25	3	4	25,4	1
			SUPER 97	09 May 03	11:24	11:26	4175	4207	26	2
			ULP 95	09 May 03	11:25	11:26	4	4	25,4	1
			SUPER 97	09 May 03	11:26	11:27	0	0	0	1
			SUPER 97	09 May 03	11:27	11:29	1680	1693	26,1	2
			ULP 95	09 May 03	11:28	11:28	6	6	25,6	1
			DYNAMIC ULP	09 May 03	11:29	11:29	22	22	20,8	1
			SUPER 97	09 May 03	11:30	11:31	8	8	26,1	1
			DYNAMIC ULP	09 May 03	11:30	11:32	2127	2130	21,1	2
			ULP 95	09 May 03	11:31	11:35	5819	5859	25,8	4
			SUPER 97	09 May 03	11:31	11:32	0	0	0	1
			SUPER 97	09 May 03	11:32	11:33	0	0	0	1
			DYNAMIC ULP	09 May 03	11:33	11:33	0	0	0	1
			DYNAMIC ULP	09 May 03	11:33	11:36	3749	3754	21,3	3
			SUPER 97	09 May 03	11:34	11:34	0	0	0	1
			SUPER 97	09 May 03	11:34	11:35	0	0	0	1
			SUPER 97	09 May 03	11:35	11:36	0	0	0	1
			SUPER 97	09 May 03	11:36	11:37	0	0	0	1
			SUPER 97	09 May 03	11:38	11:40	2535	2555	26,2	2
			SUPER 97	09 May 03	11:41	11:42	717	723	26,2	1
			SUPER 97	09 May 03	11:44	11:45	899	906	26,2	1
			SUPER 97	09 May 03	11:46	11:49	5249	5291	26,3	3
			SUPER 97	09 May 03	11:49	11:51	1702	1716	26,5	2
118	Engen Transport 86052	6	DYNAMIC ULP	09 May 03	11:23	11:28	6085	6100	22,1	5
			SUPER 97	09 May 03	11:27	11:30	4669	4699	25,1	3
			DYNAMIC ULP	09 May 03	11:29	11:32	5995	6002	20,9	3
			SUPER 97	09 May 03	11:34	11:38	5959	5999	25,4	4
			DYNAMIC ULP	09 May 03	11:34	11:38	4893	4899	21,2	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
119	Caltex Transport 443	4	DPK	09 May 03	11:37	11:41	3879	3897	25,4	4
			DPK	09 May 03	11:41	11:44	3980	3999	25,2	3
			DPK	09 May 03	11:44	11:47	4181	4200	25,1	3
			DPK	09 May 03	11:48	11:51	4186	4206	25,1	3
120	Engen Transport 99062	6	SUPER 97	09 May 03	12:27	12:31	5262	5299	25,6	4
			ADO	09 May 03	12:28	12:30	1979	2000	32,4	2
			SUPER 97	09 May 03	12:31	12:35	5259	5299	26,2	4
			SUPER 97	09 May 03	12:36	12:40	5757	5799	25,8	4
			SUPER 97	09 May 03	12:40	12:44	5956	5999	25,7	4
121	Unitrans Natal 42202	8	ADO	09 May 03	12:35	12:38	3371	3402	30,8	3
			ADO	09 May 03	12:38	12:41	4364	4407	31,7	3
			ADO	09 May 03	12:41	12:44	3368	3401	31,7	3
			ADO	09 May 03	12:44	12:46	3862	3900	31,6	2
			ADO	09 May 03	12:50	12:53	5747	5803	31,5	3
			ADO	09 May 03	12:53	12:56	5749	5805	31,6	3
			ADO	09 May 03	12:56	12:58	5745	5801	31,5	2
			ADO	09 May 03	12:59	13:01	5746	5802	31,4	2
			ADO	09 May 03	13:01	13:03	4658	4703	31,4	2
122	Engen Transport 85053	7	SUPER 97	09 May 03	12:48	12:51	5795	5844	26,7	3
			DYNAMIC ULP	09 May 03	12:49	12:51	3981	4006	25,1	2
			SUPER 97	09 May 03	12:51	12:53	1521	1534	26,6	2
			DYNAMIC ULP	09 May 03	12:52	12:52	9	9	25,5	1
			DYNAMIC ULP	09 May 03	12:53	12:54	1740	1751	25,3	1
			SUPER 97	09 May 03	12:55	12:58	6179	6232	26,7	3
			DYNAMIC ULP	09 May 03	12:55	12:58	4216	4242	25,2	3
			SUPER 97	09 May 03	12:58	13:01	4229	4265	26,8	3
			DYNAMIC ULP	09 May 03	13:02	13:04	1428	1437	25,2	2
123	Caltex Transport 518	5	ADO	09 May 03	13:03	13:05	2776	2801	30,9	2
			ADO	09 May 03	13:06	13:07	988	998	31,8	1
			ADO	09 May 03	13:07	13:09	3762	3799	32	2
			ADO	09 May 03	13:09	13:11	3960	4000	32	2
			ADO	09 May 03	13:12	13:14	3465	3500	32	2
124	Engen Transport 92033	4	ADO	09 May 03	13:23	13:23	198	200	30,5	1
			ADO	09 May 03	13:24	13:24	104	105	31,2	1
			DPK	09 May 03	13:26	13:29	2812	2826	25,7	3

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
125	Unitrans Natal 674	5	SUPER 97	09 May 03	13:53	13:56	4970	5005	25,6	3
			SUPER 97	09 May 03	13:56	13:58	3978	4006	25,5	2
			SUPER 97	09 May 03	13:58	14:00	3978	4006	25,5	2
			SUPER 97	09 May 03	14:00	14:03	4973	5008	25,5	3
			SUPER 97	09 May 03	14:03	14:06	4573	4604	25,5	3
			SUPER 97	09 May 03	14:06	14:09	5270	5306	25,5	3
			SUPER 97	09 May 03	14:09	14:11	3981	4009	25,5	2
			SUPER 97	09 May 03	14:15	14:18	4774	4808	25,6	3
			SUPER 97	09 May 03	14:18	14:20	4872	4907	25,6	2
			SUPER 97	09 May 03	14:29	14:30	928	934	25,6	1
			SUPER 97	09 May 03	14:34	14:35	999	1006	25,5	1
			SUPER 97	09 May 03	14:35	14:36	1001	1008	25,5	1
			SUPER 97	09 May 03	14:36	14:38	1495	1506	25,5	2
			SUPER 97	09 May 03	14:38	14:39	1484	1494	25,5	1
			SUPER 97	09 May 03	14:40	14:41	115	116	25,5	1
			SUPER 97	09 May 03	14:42	14:44	900	907	25,6	2
			SUPER 97	09 May 03	14:44	14:45	304	306	25,6	1
			SUPER 97	09 May 03	14:45	14:46	1099	1106	25,6	1
126	Engen Transport 86052	6	DYNAMIC ULP	09 May 03	13:58	14:02	5948	5999	27,1	4
			SUPER 97	09 May 03	13:59	14:03	5854	5899	26,1	4
			DYNAMIC ULP	09 May 03	14:02	14:06	5953	5998	26,3	4
			SUPER 97	09 May 03	14:03	14:07	5955	6000	26	4
			SUPER 97	09 May 03	14:07	14:11	4366	4399	26	4
127	Engen Transport 92061	6	SUPER 97	09 May 03	14:17	14:21	5854	5899	26,1	4
			DYNAMIC ULP	09 May 03	14:17	14:21	6050	6102	27	4
			SUPER 97	09 May 03	14:22	14:26	5259	5299	26	4
			DYNAMIC ULP	09 May 03	14:22	14:25	3866	3899	27	3
			SUPER 97	09 May 03	14:26	14:30	5855	5899	26	4
			SUPER 97	09 May 03	14:31	14:35	5855	5899	26	4
128	Berg Gasoline 7	3	ADO	09 May 03	14:00	14:04	5449	5500	31,2	4
			ADO	09 May 03	14:04	14:08	3715	3750	31,4	4
			ADO	09 May 03	14:08	14:12	5448	5499	31,3	4
			ADO	09 May 03	14:12	14:16	3716	3751	31,3	4
			ADO	09 May 03	14:18	14:22	4954	5000	31,4	4
			ADO	09 May 03	14:22	14:26	4953	5000	31,5	4
			ADO	09 May 03	14:26	14:30	4956	5003	31,4	4
			ADO	09 May 03	14:30	14:34	4955	5002	31,4	4
			ADO	09 May 03	14:34	14:38	4954	5001	31,4	4

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
129	Engen Transport 200163	7	SUPER 97	09 May 03	14:20	14:23	6049	6103	27,1	3
			DYNAMIC ULP	09 May 03	14:20	14:23	4964	5007	27,1	3
			SUPER 97	09 May 03	14:23	14:26	5649	5699	27	3
			SUPER 97	09 May 03	14:27	14:29	5571	5620	27	2
			SUPER 97	09 May 03	14:30	14:33	6047	6100	27	3
			SUPER 97	09 May 03	14:33	14:36	6028	6081	27	3
130	Engen Transport 200014	8	ADO	09 May 03	14:37	14:39	3566	3600	31,4	2
			ADO	09 May 03	14:39	14:41	3973	4012	31,5	2
			ADO	09 May 03	14:41	14:43	2977	3006	31,4	2
			ADO	09 May 03	14:43	14:45	3864	3901	31,5	2
131	Caltex Transport 245	4	SUPER 97	09 May 03	14:40	14:41	475	479	26	1
			SUPER 97	09 May 03	14:44	14:46	3293	3318	26	2
			ULP 95	09 May 03	14:46	14:46	44	44	26,8	1
			ULP 95	09 May 03	14:47	14:50	5108	5153	27,2	3
			SUPER 97	09 May 03	14:47	14:49	3967	3997	26,1	2
			SUPER 97	09 May 03	14:49	14:52	3968	3997	25,9	3
			SUPER 97	09 May 03	14:52	14:55	5259	5297	25,8	3
			SUPER 97	09 May 03	14:55	14:58	5656	5697	25,8	3
132	Caltex Transport 293	5	ADO	09 May 03	15:14	15:17	4755	4799	31,1	3
			ADO	09 May 03	15:17	15:20	4201	4243	32,2	3
			ADO	09 May 03	15:20	15:21	551	556	32,3	1
			ADO	09 May 03	15:21	15:24	5049	5100	32,3	3
			ADO	09 May 03	15:24	15:27	5048	5100	32,4	3
			ADO	09 May 03	15:27	15:30	5048	5100	32,4	3
			ADO	09 May 03	15:30	15:33	5047	5099	32,4	3
133	Engen Transport 95061	7	SUPER 97	09 May 03	15:02	15:06	5733	5784	27,1	4
			DYNAMIC ULP	09 May 03	15:02	15:05	1578	1591	26,7	3
			SUPER 97	09 May 03	15:06	15:09	5203	5250	27,1	3
			DYNAMIC ULP	09 May 03	15:06	15:07	1307	1318	27,2	1
			ADO	09 May 03	15:08	15:09	244	246	29,8	1
			ADO	09 May 03	15:09	15:12	4710	4754	31,3	3
			SUPER 97	09 May 03	15:09	15:12	5253	5300	27	3
			SUPER 97	09 May 03	15:12	15:15	5253	5300	27	3
			DYNAMIC ULP	09 May 03	15:13	15:14	2074	2093	27,5	1
			SUPER 97	09 May 03	15:16	15:18	5075	5120	27,1	2

Table E.1 Loading data from Engen-Wentworth facility (continued).

Series No	Tanker name	Bay no	Product loaded	Date	Start time	Stop time	Net quantity (ℓ)	Gross quantity (ℓ)	Temp (°C)	Time (min)
134	Bulktrans 24331	8	ADO	09 May 03	15:00	15:01	636	641	30,6	1
			ADO	09 May 03	15:02	15:04	5308	5359	31,4	2
			ADO	09 May 03	15:05	15:07	4952	5001	31,6	2
			ADO	09 May 03	15:08	15:10	5951	6010	31,8	2
			ADO	09 May 03	15:12	15:15	4951	5000	31,8	3
			ADO	09 May 03	15:15	15:18	4958	5007	31,7	3
			ADO	09 May 03	15:18	15:20	4962	5011	31,7	2
			ADO	09 May 03	15:21	15:23	4957	5006	31,7	2
			ADO	09 May 03	15:24	15:26	4958	5007	31,8	2
Average product temperature									**26,2**	

APPENDIX F

Table F.1 Extract of experimental vapour data (for 6 May 2003).

Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min	Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min
08:08:05	0,00	0,00	0,00	08:35:05	0,00	0,00	0,13
08:08:15	0,00	0,00		08:35:15	0,00	0,00	
08:08:25	0,00	0,00		08:35:25	0,00	0,00	
08:08:35	0,00	0,00		08:35:35	0,00	0,00	
08:08:45	0,00	0,00		08:35:45	0,00	0,00	
08:08:55	0,00	0,00		08:35:55	0,25	0,76	
08:09:05	0,00	0,00	0,00	08:36:05	0,26	0,79	0,66
08:09:15	0,00	0,00		08:36:15	0,25	0,76	
08:09:25	0,00	0,00		08:36:25	0,24	0,73	
08:09:35	0,00	0,00		08:36:35	0,16	0,49	
08:09:45	0,00	0,00		08:36:45	0,2	0,61	
08:09:55	0,00	0,00		08:36:55	0,19	0,58	
08:10:05	0,00	0,00	0,00	08:37:05	0,13	0,40	0,34
08:10:15	0,00	0,00		08:37:15	0,12	0,37	
08:10:25	0,00	0,00		08:37:25	0,11	0,34	
08:10:35	0,00	0,00		08:37:35	0,11	0,34	
08:10:45	0,00	0,00		08:37:45	0,1	0,31	
08:10:55	0,00	0,00		08:37:55	0,09	0,27	
08:11:05	0,00	0,00	0,00	08:38:05	0,09	0,27	0,20
08:11:15	0,00	0,00		08:38:15	0,08	0,24	
08:11:25	0,00	0,00		08:38:25	0,08	0,24	
08:11:35	0,00	0,00		08:38:35	0,08	0,24	
08:11:45	0,00	0,00		08:38:45	0,07	0,21	
08:11:55	0,00	0,00		08:38:55	0,00	0,00	
08:12:05	0,00	0,00	0,00	08:39:05	0,00	0,00	0,00
08:12:15	0,00	0,00		08:39:15	0,00	0,00	
08:12:25	0,00	0,00		08:39:25	0,00	0,00	
08:12:35	0,00	0,00		08:39:35	0,00	0,00	
08:12:45	0,00	0,00		08:39:45	0,00	0,00	
08:12:55	0,00	0,00		08:39:55	0,00	0,00	
08:13:05	0,00	0,00	0,00	08:40:05	0,00	0,00	0,00
08:13:15	0,00	0,00		08:40:15	0,00	0,00	
08:13:25	0,00	0,00		08:40:25	0,00	0,00	
08:13:35	0,00	0,00		08:40:35	0,00	0,00	
08:13:45	0,00	0,00		08:40:45	0,00	0,00	
08:13:55	0,00	0,00		08:40:55	0,00	0,00	

Table F.1 Experimental vapour data (continued).

Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min	Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min
08:14:05	0,00	0,00	0,00	08:41:05	0,00	0,00	0,22
08:14:15	0,00	0,00		08:41:15	0,00	0,00	
08:14:25	0,00	0,00		08:41:25	0,10	0,31	
08:14:35	0,00	0,00		08:41:35	0,11	0,34	
08:14:45	0,00	0,00		08:41:45	0,11	0,34	
08:14:55	0,00	0,00		08:41:55	0,12	0,37	
08:15:05	0,00	0,00	0,00	08:42:05	0,12	0,37	0,35
08:15:15	0,00	0,00		08:42:15	0,12	0,37	
08:15:25	0,00	0,00		08:42:25	0,11	0,34	
08:15:35	0,00	0,00		08:42:35	0,11	0,34	
08:15:45	0,00	0,00		08:42:45	0,11	0,34	
08:15:55	0,00	0,00		08:42:55	0,11	0,34	
08:16:05	0,00	0,00	0,00	08:43:05	0,11	0,34	0,21
08:16:15	0,00	0,00		08:43:15	0,11	0,34	
08:16:25	0,00	0,00		08:43:25	0,11	0,34	
08:16:35	0,00	0,00		08:43:35	0,08	0,24	
08:16:45	0,00	0,00		08:43:45	0,00	0,00	
08:16:55	0,00	0,00		08:43:55	0,00	0,00	
08:17:05	0,00	0,00	0,00	08:44:05	0,00	0,00	0,00
08:17:15	0,00	0,00		08:44:15	0,00	0,00	
08:17:25	0,00	0,00		08:44:25	0,00	0,00	
08:17:35	0,00	0,00		08:44:35	0,00	0,00	
08:17:45	0,00	0,00		08:44:45	0,00	0,00	
08:17:55	0,00	0,00		08:44:55	0,00	0,00	
08:18:05	0,00	0,00	0,12	08:45:05	0,00	0,00	0,00
08:18:15	0,06	0,18		08:45:15	0,00	0,00	
08:18:25	0,05	0,15		08:45:25	0,00	0,00	
08:18:35	0,04	0,12		08:45:35	0,00	0,00	
08:18:45	0,04	0,12		08:45:45	0,00	0,00	
08:18:55	0,05	0,15		08:45:55	0,00	0,00	
08:19:05	0,05	0,15	0,24	08:46:05	0,00	0,00	0,00
08:19:15	0,05	0,15		08:46:15	0,00	0,00	
08:19:25	0,05	0,15		08:46:25	0,00	0,00	
08:19:35	0,06	0,18		08:46:35	0,00	0,00	
08:19:45	0,12	0,37		08:46:45	0,00	0,00	
08:19:55	0,14	0,43		08:46:55	0,00	0,00	
08:20:05	0,13	0,40	0,40	08:47:05	0,00	0,00	0,00
08:20:15	0,13	0,40		08:47:15	0,00	0,00	
08:20:25	0,13	0,40		08:47:25	0,00	0,00	
08:20:35	0,15	0,46		08:47:35	0,00	0,00	
08:20:45	0,10	0,31		08:47:45	0,00	0,00	
08:20:55	0,15	0,46		08:47:55	0,00	0,00	

Table F.1 Experimental vapour data (continued).

Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min	Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min
08:21:05	0,44	1,34	1,18	08:48:05	0,00	0,00	0,00
08:21:15	0,45	1,37		08:48:15	0,00	0,00	
08:21:25	0,43	1,31		08:48:25	0,00	0,00	
08:21:35	0,39	1,19		08:48:35	0,00	0,00	
08:21:45	0,30	0,92		08:48:45	0,00	0,00	
08:21:55	0,30	0,92		08:48:55	0,00	0,00	
08:22:05	0,23	0,70	0,53	08:49:05	0,00	0,00	0,00
08:22:15	0,20	0,61		08:49:15	0,00	0,00	
08:22:25	0,19	0,58		08:49:25	0,00	0,00	
08:22:35	0,18	0,55		08:49:35	0,00	0,00	
08:22:45	0,13	0,40		08:49:45	0,00	0,00	
08:22:55	0,11	0,34		08:49:55	0,00	0,00	
08:23:05	0,00	0,00	0,00	08:50:05	0,00	0,00	0,04
08:23:15	0,00	0,00		08:50:15	0,00	0,00	
08:23:25	0,00	0,00		08:50:25	0,00	0,00	
08:23:35	0,00	0,00		08:50:35	0,00	0,00	
08:23:45	0,00	0,00		08:50:45	0,00	0,00	
08:23:55	0,00	0,00		08:50:55	0,07	0,21	
08:24:05	0,00	0,00	0,00	08:51:05	0,16	0,49	0,57
08:24:15	0,00	0,00		08:51:15	0,22	0,67	
08:24:25	0,00	0,00		08:51:25	0,21	0,64	
08:24:35	0,00	0,00		08:51:35	0,11	0,34	
08:24:45	0,00	0,00		08:51:45	0,2	0,61	
08:24:55	0,00	0,00		08:51:55	0,23	0,70	
08:25:05	0,00	0,00	0,02	08:52:05	0,54	1,65	1,51
08:25:15	0,00	0,00		08:52:15	0,59	1,80	
08:25:25	0,03	0,09		08:52:25	0,44	1,34	
08:25:35	0,00	0,00		08:52:35	0,45	1,37	
08:25:45	0,00	0,00		08:52:45	0,45	1,37	
08:25:55	0,00	0,00		08:52:55	0,49	1,50	
08:26:05	0,00	0,00	0,00	08:53:05	0,54	1,65	1,56
08:26:15	0,00	0,00		08:53:15	0,56	1,71	
08:26:25	0,00	0,00		08:53:25	0,5	1,53	
08:26:35	0,00	0,00		08:53:35	0,49	1,50	
08:26:45	0,00	0,00		08:53:45	0,49	1,50	
08:26:55	0,00	0,00		08:53:55	0,49	1,50	
08:27:05	0,00	0,00	0,00	08:54:05	0,49	1,50	0,71
08:27:15	0,00	0,00		08:54:15	0,29	0,89	
08:27:25	0,00	0,00		08:54:25	0,14	0,43	
08:27:35	0,00	0,00		08:54:35	0,16	0,49	
08:27:45	0,00	0,00		08:54:45	0,16	0,49	
08:27:55	0,00	0,00		08:54:55	0,16	0,49	

Table F.1 Experimental vapour data (continued).

Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min	Time	Velocity m/s	Vol flow m^3/min	Ave flow m^3/min
08:28:05	0,00	0,00	0,00	08:55:05	0,16	0,49	0,48
08:28:15	0,00	0,00		08:55:15	0,16	0,49	
08:28:25	0,00	0,00		08:55:25	0,16	0,49	
08:28:35	0,00	0,00		08:55:35	0,16	0,49	
08:28:45	0,00	0,00		08:55:45	0,16	0,49	
08:28:55	0,00	0,00		08:55:55	0,15	0,46	
08:29:05	0,00	0,00	0,09	08:56:05	0,14	0,43	0,07
08:29:15	0,00	0,00		08:56:15	0,00	0,00	
08:29:25	0,00	0,00		08:56:25	0,00	0,00	
08:29:35	0,00	0,00		08:56:35	0,00	0,00	
08:29:45	0,00	0,00		08:56:45	0,00	0,00	
08:29:55	0,17	0,52		08:56:55	0,00	0,00	
08:30:05	0,18	0,55	0,65	08:57:05	0,00	0,00	0,00
08:30:15	0,23	0,70		08:57:15	0,00	0,00	
08:30:25	0,23	0,70		08:57:25	0,00	0,00	
08:30:35	0,23	0,70		08:57:35	0,00	0,00	
08:30:45	0,22	0,67		08:57:45	0,00	0,00	
08:30:55	0,19	0,58		08:57:55	0,00	0,00	
08:31:05	0,30	0,92	1,05	08:58:05	0,00	0,00	0,00
08:31:15	0,31	0,95		08:58:15	0,00	0,00	
08:31:25	0,33	1,01		08:58:25	0,00	0,00	
08:31:35	0,49	1,50		08:58:35	0,00	0,00	
08:31:45	0,46	1,40		08:58:45	0,00	0,00	
08:31:55	0,18	0,55		08:58:55	0,00	0,00	
08:32:05	0,17	0,52	0,84	08:59:05	0,00	0,00	0,02
08:32:15	0,17	0,52		08:59:15	0,00	0,00	
08:32:25	0,17	0,52		08:59:25	0,00	0,00	
08:32:35	0,4	1,22		08:59:35	0,00	0,00	
08:32:45	0,38	1,16		08:59:45	0,00	0,00	
08:32:55	0,36	1,10		08:59:55	0,03	0,09	
08:33:05	0,32	0,98	1,13	09:00:05	0,03	0,09	0,02
08:33:15	0,32	0,98		09:00:15	0,00	0,00	
08:33:25	0,34	1,04		09:00:25	0,00	0,00	
08:33:35	0,42	1,28		09:00:35	0,00	0,00	
08:33:45	0,41	1,25		09:00:45	0,00	0,00	
08:33:55	0,42	1,28		09:00:55	0,00	0,00	
08:34:05	0,40	1,22	0,54	09:01:05	0,00	0,00	0,00
08:34:15	0,32	0,98		09:01:15	0,00	0,00	
08:34:25	0,35	1,07		09:01:25	0,00	0,00	
08:34:35	0,00	0,00		09:01:35	0,00	0,00	
08:34:45	0,00	0,00		09:01:45	0,00	0,00	
08:34:55	0,00	0,00		09:01:55	0,00	0,00	

APPENDIX G

Table G.1 One minute averaged vapour flow values.

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
07:32	NA	NA	0,09	NA	NA	NA	NA
07:33	NA	NA	1,47	NA	NA	NA	NA
07:34	NA	NA	1,07	NA	NA	NA	NA
07:35	NA	NA	0,76	NA	NA	NA	NA
07:36	NA	NA	1,68	NA	NA	NA	NA
07:37	NA	NA	0,00	NA	NA	NA	NA
07:38	NA	NA	1,01	NA	NA	NA	NA
07:39	NA	NA	0,21	NA	NA	NA	NA
07:40	NA	NA	0,00	NA	NA	NA	NA
07:41	NA	NA	0,00	NA	NA	NA	NA
07:42	NA	NA	1,34	NA	NA	NA	NA
07:43	NA	NA	0,00	NA	NA	NA	NA
07:44	NA	NA	1,10	NA	NA	NA	NA
07:45	NA	NA	1,22	NA	NA	NA	NA
07:46	NA	NA	4,40	NA	NA	NA	NA
07:47	NA	NA	2,01	NA	NA	NA	NA
07:48	NA	NA	0,00	NA	NA	NA	NA
07:49	NA	NA	2,17	NA	NA	NA	NA
07:50	NA	NA	2,20	NA	NA	NA	NA
07:51	NA	NA	0,00	NA	NA	NA	NA
07:52	NA	NA	0,00	NA	NA	NA	NA
07:53	NA	NA	0,00	NA	NA	NA	NA
07:54	NA	NA	0,00	NA	NA	NA	NA
07:55	NA	NA	0,00	NA	NA	NA	NA
07:56	NA	NA	0,00	NA	NA	NA	NA
07:57	NA	NA	0,00	NA	NA	NA	NA
07:58	NA	NA	0,00	NA	NA	NA	NA
07:59	NA	NA	0,00	NA	NA	NA	NA
08:00	NA	NA	0,00	NA	NA	NA	NA
08:01	NA	NA	0,00	NA	NA	NA	NA
08:02	NA	NA	0,00	NA	NA	NA	NA
08:03	NA	NA	0,00	NA	NA	NA	NA
08:04	NA	NA	0,00	NA	NA	NA	NA
08:05	NA	NA	0,00	NA	NA	NA	NA
08:06	NA	NA	0,00	NA	NA	NA	NA
08:07	NA	NA	0,00	0,00	NA	NA	NA

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
08:08	NA	NA	NA	0,00*	NA	NA	NA
08:09	NA	NA	NA	0,00*	NA	NA	NA
08:10	NA	NA	NA	0,00*	NA	NA	NA
08:11	NA	NA	NA	0,00*	NA	NA	NA
08:12	NA	NA	NA	0,00*	NA	NA	NA
08:13	NA	NA	NA	0,00*	NA	NA	NA
08:14	NA	NA	NA	0,00*	NA	NA	NA
08:15	NA	NA	NA	0,00*	NA	NA	NA
08:16	NA	NA	NA	0,00*	NA	NA	NA
08:17	NA	NA	NA	0,00*	NA	NA	NA
08:18	NA	NA	NA	0,12*	NA	NA	NA
08:19	NA	NA	NA	0,24*	NA	NA	NA
08:20	NA	NA	NA	0,40*	NA	NA	NA
08:21	NA	NA	NA	1,18*	NA	NA	NA
08:22	NA	NA	NA	0,53*	NA	NA	NA
08:23	NA	NA	NA	0,00*	NA	NA	NA
08:24	NA	NA	NA	0,00*	NA	NA	NA
08:25	NA	NA	NA	0,02*	NA	NA	NA
08:26	NA	NA	NA	0,00*	NA	NA	0,75
08:27	NA	NA	NA	0,00*	0,03	NA	0,16
08:28	NA	NA	NA	0,00*	0,10	NA	0,12
08:29	NA	NA	NA	0,09*	0,12	NA	1,03
08:30	NA	NA	NA	0,65*	0,56	NA	0,72
08:31	NA	NA	NA	1,06*	3,06	NA	0,46
08:32	NA	NA	NA	0,84*	1,00	NA	0,55
08:33	NA	NA	NA	1,14*	0,62	NA	0,17
08:34	NA	NA	NA	0,55*	1,41	NA	0,21
08:35	NA	NA	NA	0,13*	0,41	NA	0,08
08:36	NA	NA	NA	0,66*	0,69	NA	0,49
08:37	NA	NA	NA	0,34*	1,09	NA	1,17
08:38	NA	NA	NA	0,20*	0,00	NA	0,47
08:39	NA	NA	NA	0,00*	0,00	NA	0,4
08:40	NA	NA	NA	0,00*	0,15	NA	0,75
08:41	NA	NA	NA	0,22*	1,01	NA	0,19
08:42	NA	NA	NA	0,35*	2,18	NA	0,67
08:43	NA	NA	NA	0,21*	1,32	NA	0,67
08:44	NA	NA	NA	0,00*	0,00	NA	0,85
08:45	NA	NA	NA	0,00*	0,00	NA	1,83

NA: Data in Appendix E not available for this time period.
* One minute averaged flow values calculated for the data presented in Appendix F.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
08:46	NA	NA	NA	0,00*	0,42	NA	1,05
08:47	NA	NA	NA	0,00*	1,17	NA	0,04
08:48	NA	NA	NA	0,00*	0,65	NA	0,45
08:49	NA	NA	NA	0,00*	0,00	NA	0,8
08:50	NA	NA	NA	0,04*	0,14	NA	0,67
08:51	NA	NA	NA	0,58*	0,48	NA	1,13
08:52	NA	NA	NA	1,51*	0,49	NA	1,23
08:53	NA	NA	NA	1,56*	0,08	NA	0,44
08:54	NA	NA	NA	0,71*	0,00	NA	0,7
08:55	NA	NA	NA	0,48*	0,00	NA	1,47
08:56	NA	NA	NA	0,07*	0,00	NA	1,23
08:57	NA	NA	NA	0,00*	0,07	NA	0,21
08:58	NA	NA	NA	0,00*	0,12	NA	0,32
08:59	NA	NA	NA	0,02*	0,12	NA	1,29
09:00	NA	NA	NA	0,02*	0,14	NA	1,17
09:01	NA	NA	NA	0,00*	0,17	NA	0,8
09:02	NA	NA	NA	0,02	0,16	NA	0,35
09:03	NA	NA	NA	0,00	0,22	NA	0,11
09:04	NA	NA	NA	0,00	2,69	NA	0
09:05	NA	NA	NA	0,00	2,70	NA	0,28
09:06	NA	NA	NA	0,00	0,09	NA	0,38
09:07	NA	NA	NA	0,00	0,65	NA	0,89
09:08	NA	NA	NA	0,00	1,13	NA	1,17
09:09	NA	NA	NA	0,00	0,61	NA	0,49
09:10	NA	NA	NA	0,00	0,08	NA	0,28
09:11	NA	NA	NA	0,00	2,12	NA	0,77
09:12	NA	NA	NA	0,00	1,96	NA	0,76
09:13	NA	NA	NA	0,00	0,66	NA	0,23
09:14	NA	NA	NA	0,00	1,31	NA	0,9
09:15	NA	NA	NA	0,00	1,22	NA	1,18
09:16	NA	NA	NA	0,00	0,95	NA	0,68
09:17	NA	NA	NA	0,00	1,00	NA	0,56
09:18	NA	NA	NA	0,00	0,10	NA	0,79
09:19	NA	NA	NA	0,00	0,21	NA	0,56
09:20	NA	NA	NA	0,00	0,57	NA	0,47
09:21	NA	NA	NA	0,00	1,35	NA	0,06
09:22	NA	NA	NA	0,00	0,22	NA	0,81
09:23	NA	NA	NA	0,00	0,83	NA	0,67

NA: Data in Appendix E not available for this time period.
* One minute averaged flow values calculated for the data presented in Appendix F.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
09:24	NA	NA	NA	0,00	0,56	NA	0,00
09:25	NA	NA	NA	0,00	0,56	NA	0,13
09:26	NA	NA	NA	0,00	1,50	NA	0,41
09:27	NA	NA	NA	0,00	0,98	NA	0,67
09:28	NA	NA	NA	0,00	1,80	NA	0,64
09:29	NA	NA	NA	0,00	0,60	NA	0,30
09:30	NA	NA	NA	0,00	0,00	NA	0,74
09:31	NA	NA	NA	0,00	0,22	NA	2,67
09:32	NA	NA	NA	0,00	0,00	NA	1,48
09:33	NA	NA	NA	0,00	0,00	NA	0,88
09:34	NA	NA	NA	0,00	0,04	NA	0,55
09:35	NA	NA	NA	0,00	0,26	NA	0,55
09:36	NA	NA	NA	0,00	0,07	NA	1,12
09:37	NA	NA	NA	0,00	1,50	NA	0,18
09:38	NA	NA	NA	0,00	1,20	NA	0,44
09:39	NA	NA	NA	0,00	2,12	NA	0,29
09:40	NA	NA	NA	0,00	4,52	0,38	0,00
09:41	NA	NA	NA	0,00	3,11	0,00	0,44
09:42	NA	NA	NA	0,00	2,63	0,56	0,71
09:43	NA	NA	0,31	0,00	1,67	0,35	0,50
09:44	NA	NA	1,71	0,00	4,36	0,00	0,03
09:45	NA	NA	1,77	0,00	2,82	0,00	0,22
09:46	NA	NA	1,56	0,00	3,22	0,38	0,59
09:47	NA	NA	0,00	0,00	3,79	0,33	0,61
09:48	NA	NA	0,00	0,00	2,69	0,98	0,15
09:49	NA	NA	1,53	0,00	2,92	2,09	0,00
09:50	NA	NA	0,00	0,00	1,87	2,31	0,59
09:51	NA	NA	0,00	0,00	2,26	1,00	0,63
09:52	NA	NA	1,37	0,30	3,89	0,35	0,17
09:53	NA	NA	1,65	0,58	1,82	0,76	0,00
09:54	NA	NA	0,00	1,06	3,03	2,09	0,00
09:55	0,09	NA	0,00	1,35	3,35	1,95	0,00
09:56	1,47	NA	0,00	0,85	1,59	0,00	0,00
09:57	1,07	NA	0,00	1,03	0,70	0,85	0,00
09:58	0,76	NA	0,00	1,13	1,27	2,42	0,00
09:59	1,68	NA	0,00	0,97	1,77	3,20	0,00
10:00	0,00	NA	0,00	0,98	1,01	0,00	0,00
10:01	1,01	NA	0,00	0,28	0,00	2,37	0,00

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
10:02	0,21	NA	0,00	0,00	0,14	3,56	0,00
10:03	0,00	NA	0,00	0,00	0,07	1,55	0,00
10:04	0,00	NA	0,00	0,23	0,06	0,23	0,00
10:05	1,34	NA	0,00	0,90	0,36	0,76	0,00
10:06	0,00	NA	0,00	1,16	0,68	1,80	0,00
10:07	1,10	NA	0,00	0,19	1,49	0,43	0,00
10:08	1,22	NA	0,00	0,65	1,36	1,89	0,00
10:09	4,40	NA	0,00	0,64	1,34	1,91	0,00
10:10	2,01	NA	NA	0,22	2,29	0,85	0,00
10:11	0,00	NA	NA	0,58	1,39	2,55	0,00
10:12	2,17	NA	NA	1,26	1,02	0,62	0,00
10:13	2,20	NA	NA	1,03	0,92	1,29	0,00
10:14	0,00	NA	NA	1,54	0,06	2,37	0,00
10:15	0,00	NA	NA	0,11	1,17	0,00	0,00
10:16	0,00	NA	NA	1,04	1,68	0,00	0,00
10:17	0,00	NA	NA	2,40	1,03	0,09	0,00
10:18	0,00	NA	NA	1,08	2,02	0,13	0,00
10:19	0,00	NA	NA	0,38	1,05	0,11	0,00
10:20	0,00	NA	NA	0,69	0,67	0,03	0,00
10:21	0,00	NA	NA	0,57	0,86	0,00	0,33
10:22	0,00	NA	NA	0,2	0,54	0,22	0,78
10:23	0,00	NA	NA	2,06	0,45	0,54	0,79
10:24	0,00	NA	NA	2,44	0,37	0,00	1,14
10:25	0,00	NA	NA	0,14	1,02	0,00	1,03
10:26	0,00	NA	NA	0,00	3,24	0,00	0,66
10:27	0,00	NA	NA	0,00	2,78	0,00	0,93
10:28	0,00	NA	NA	0,00	1,03	0,02	1,37
10:29	0,00	NA	NA	0,00	3,42	0,03	0,73
10:30	0,00	NA	NA	0,00	2,18	0,11	0,63
10:31	0,00	NA	NA	0,08	1,38	0,70	0,51
10:32	0,31	NA	NA	0,03	0,64	0,29	0,17
10:33	1,71	NA	NA	0,26	1,55	0,00	0,09
10:34	1,77	NA	NA	0,12	4,06	0,13	0,12
10:35	1,56	NA	NA	0,22	2,71	0,00	0,21
10:36	0,00	NA	NA	2,33	0,94	0,00	0,14
10:37	0,00	NA	NA	2,24	1,14	0,00	0,04
10:38	1,53	NA	NA	2,81	1,68	0,00	0,2
10:39	0,00	NA	NA	1,86	4,18	0,00	0,19

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
10:40	0,00	NA	NA	0,66	3,27	0,00	0,03
10:41	1,37	NA	NA	4,25	0,25	0,23	0,15
10:42	1,65	NA	NA	7,99	0,67	0,59	0,39
10:43	0,00	NA	NA	2,81	0,78	0,49	0,09
10:44	0,00	NA	NA	2,25	2,56	0,00	0,0
10:45	0,00	NA	NA	3,03	2,34	0,47	0,00
10:46	0,00	NA	NA	4,67	3,20	0,00	0,81
10:47	0,00	NA	NA	5,85	1,83	0,43	0,69
10:48	0,00	NA	NA	2,89	0,80	0,44	0,31
10:49	0,00	NA	NA	3,71	4,24	0,56	0,21
10:50	0,00	NA	NA	2,77	3,05	0,31	0,43
10:51	0,00	NA	NA	4,66	1,22	0,47	0,47
10:52	0,00	NA	NA	2,82	1,43	0,16	0,52
10:53	0,00	NA	NA	0,61	1,89	0,00	0,89
10:54	0,00	NA	NA	1,78	0,93	0,38	0,33
10:55	0,00	NA	NA	1,07	1,86	0,40	0,23
10:56	0,00	NA	NA	1,30	0,70	0,00	0,36
10:57	0,00	NA	NA	1,72	0,14	0,16	0,49
10:58	0,00	NA	NA	0,00	0,37	0,67	0,4
10:59	0,00	NA	NA	0,00	0,77	0,41	0,07
11:00	0,00	0,31	NA	0,00	0,72	0,00	0,17
11:01	0,00	0,27	NA	0,02	0,21	0,00	0,15
11:02	0,00	0,27	NA	0,00	0,77	0,03	0,16
11:03	0,00	0,18	NA	0,00	0,70	0,00	0,31
11:04	0,00	0,00	NA	0,00	0,02	0,26	0,53
11:05	0,00	0,24	NA	0,00	0,50	0,00	0,25
11:06	0,00	0,18	NA	0,00	0,29	0,00	0,18
11:07	0,00	0,00	NA	0,00	0,15	0,13	0,19
11:08	0,00	0,00	0,45	0,00	0,35	0,02	0,39
11:09	0,00	0,00	0,00	0,00	0,48	0,00	0,82
11:10	0,00	0,00	0,00	0,00	0,54	0,09	0,63
11:11	0,00	0,18	0,00	0,00	0,52	0,02	0,68
11:12	0,00	0,15	0,00	0,00	0,07	0,06	0,61
11:13	0,00	0,00	0,00	0,00	0,64	1,21	0,23
11:14	0,00	0,00	1,88	0,00	0,18	2,47	0,21
11:15	0,00	0,34	0,00	0,00	0,70	0,74	0,18
11:16	0,00	0,00	0,00	0,00	0,69	1,08	0,17
11:17	0,00	0,12	0,41	0,00	0,12	1,43	0,05

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m³/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
11:18	0,00	0,00	0,71	0,00	1,04	1,10	0,16
11:19	0,00	0,00	0,53	0,00	1,25	0,90	0,16
11:20	0,00	0,00	0,00	0,00	0,91	1,97	0,45
11:21	0,00	0,64	0,00	0,00	0,43	1,13	0,93
11:22	0,00	0,70	0,48	0,00	0,62	0,99	0,58
11:23	0,00	0,00	0,00	0,00	0,74	0,44	0,74
11:24	0,00	0,00	0,00	0,00	0,04	1,21	1,32
11:25	0,00	0,00	0,00	0,00	0,30	0,81	0,65
11:26	0,00	0,00	NA	0,00	0,87	0,13	0,24
11:27	0,00	0,00	NA	0,00	1,09	0,00	0,53
11:28	0,00	0,00	NA	0,00	1,80	0,00	0,97
11:29	0,00	0,00	NA	0,00	0,59	0,00	0,58
11:30	0,00	0,00	NA	0,00	1,87	0,39	0,58
11:31	0,00	0,40	NA	0,00	1,24	0,47	0,74
11:32	0,00	0,00	NA	0,00	1,02	0,09	1,04
11:33	0,00	0,00	NA	0,00	1,13	0,00	0,39
11:34	0,00	0,00	NA	0,00	0,77	0,00	0,30
11:35	0,00	0,00	NA	0,00	1,64	0,00	1,08
11:36	0,00	0,00	NA	0,00	1,18	0,00	0,27
11:37	0,00	0,37	NA	0,00	1,08	0,00	0,12
11:38	0,00	0,55	NA	0,00	0,62	0,00	0,23
11:39	0,00	0,49	NA	0,00	0,44	0,00	0,20
11:40	0,00	0,00	NA	0,00	1,38	0,00	0,03
11:41	0,00	0,00	NA	0,00	2,40	0,00	0,21
11:42	0,00	0,00	NA	0,00	2,15	0,00	0,16
11:43	0,00	0,00	NA	0,00	1,55	0,00	0,85
11:44	0,00	0,43	NA	0,00	3,30	0,00	1,11
11:45	0,00	2,38	NA	0,00	2,40	0,02	0,60
11:46	0,00	3,72	NA	0,00	0,87	0,02	0,84
11:47	0,00	3,72	NA	0,00	2,07	0,00	0,20
11:48	0,00	1,28	NA	0,00	2,80	0,25	0,00
11:49	0,00	0,34	NA	0,00	2,45	0,66	0,00
11:50	0,00	2,20	NA	0,00	1,13	0,74	0,00
11:51	0,00	1,86	NA	0,00	0,77	0,74	0,00
11:52	0,00	2,17	NA	0,00	2,38	1,51	0,00
11:53	0,00	1,37	NA	0,00	2,14	1,85	0,00
11:54	0,00	0,00	NA	0,00	1,14	1,59	0,00
11:55	0,00	0,00	NA	0,00	0,85	2,22	0,00

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
11:56	0,00	0,00	NA	0,00	0,71	1,81	0,00
11:57	0,00	0,00	NA	0,00	1,28	0,90	0,00
11:58	0,00	0,00	NA	0,00	1,38	2,26	0,14
11:59	0,00	3,91	NA	0,00	1,54	1,94	0,75
12:00	0,00	0,00	NA	0,00	0,08	0,61	0,59
12:01	0,00	0,00	NA	0,00	0,00	0,29	0,04
12:02	0,00	2,75	NA	0,00	0,00	0,78	0,84
12:03	0,00	2,47	NA	0,00	0,78	0,75	0,49
12:04	0,00	0,00	NA	0,96	3,07	0,43	0,37
12:05	0,00	4,18	NA	1,59	0,94	0,40	0,13
12:06	0,00	2,81	NA	1,46	1,13	0,89	0,83
12:07	0,00	0,00	NA	2,59	1,69	0,84	0,50
12:08	0,00	0,61	0,09	2,95	1,68	0,34	0,37
12:09	0,00	2,5	1,47	2,37	0,65	0,43	0,43
12:10	0,00	2,59	1,07	2,15	4,21	0,71	0,88
12:11	0,00	0,00	0,76	0,99	2,03	0,78	0,57
12:12	0,00	0,52	1,68	1,18	1,45	0,00	0,23
12:13	0,00	2,56	0,00	1,76	3,50	0,00	0,78
12:14	0,00	2,62	1,01	0,70	2,45	0,00	0,54
12:15	0,00	0,00	0,21	1,39	0,61	0,00	0,00
12:16	0,00	0,00	0,00	1,07	1,93	0,00	0,00
12:17	0,00	0,12	0,00	0,00	1,88	0,00	0,00
12:18	0,00	0,00	1,34	0,00	0,55	0,07	0,00
12:19	0,00	0,12	0,00	0,15	2,09	0,92	0,00
12:20	0,00	0,00	1,10	0,27	2,31	0,91	0,00
12:21	0,00	0,00	1,22	0,31	2,16	0,69	0,00
12:22	0,00	0,00	4,40	0,00	1,96	0,00	0,00
12:23	0,00	0,00	2,01	0,00	0,29	0,48	0,00
12:24	0,00	0,00	0,00	0,00	1,06	1,33	0,16
12:25	0,00	0,24	2,17	0,00	1,80	1,01	0,59
12:26	0,00	0,15	NA	0,00	1,86	0,39	0,24
12:27	0,00	0,00	NA	0,00	1,40	0,00	0,00
12:28	0,00	0,00	NA	0,00	2,16	0,25	0,21
12:29	0,00	0,00	NA	0,00	1,34	0,74	0,35
12:30	0,00	0,00	NA	0,00	1,34	0,72	0,19
12:31	0,00	0,46	NA	0,00	1,34	0,33	0,00
12:32	0,00	0,27	NA	0,11	1,52	0,27	0,34
12:33	2,98	0,00	NA	2,69	1,47	0,38	0,64

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
12:34	2,98	0,27	NA	2,69	0,73	0,71	0,39
12:35	0,00	1,59	NA	0,93	1,58	0,72	0,84
12:36	1,98	1,68	NA	1,41	0,91	0,63	0,62
12:37	1,98	0,00	NA	3,05	0,08	0,06	0,29
12:38	1,98	1,92	NA	3,5	1,22	0,06	0,67
12:39	0,00	1,34	NA	0,56	1,54	0,11	0,85
12:40	2,23	0,82	NA	0,00	1,11	0,90	0,00
12:41	2,23	2,32	NA	0,89	0,00	0,75	0,72
12:42	0,00	5,43	NA	0,00	0,00	0,36	0,93
12:43	0,00	1,22	NA	0,00	0,00	0,05	0,00
12:44	2,73	0,46	NA	2,22	0,00	0,00	0,00
12:45	2,73	4,12	NA	2,10	0,17	0,38	0,45
12:46	0,00	2,75	NA	0,55	0,72	0,48	0,59
12:47	1,98	1,47	NA	2,74	1,06	0,98	0,83
12:48	1,98	0,00	NA	1,50	1,16	2,11	0,96
12:49	1,98	1,28	NA	0,98	2,04	0,24	0,30
12:50	0,00	1,43	NA	0,5	1,62	0,4	0,95
12:51	0,00	0,00	NA	0,66	1,23	0,28	0,80
12:52	0,00	0,00	NA	1,22	1,46	1,08	0,96
12:53	0,00	0,00	NA	0,73	1,68	3,83	2,04
12:54	0,00	2,44	NA	0,28	1,65	2,66	1,32
12:55	0,00	1,16	NA	1,29	0,98	1,24	0,42
12:56	0,00	0,00	NA	0,81	0,88	3,58	1,02
12:57	0,00	1,77	NA	0,00	0,07	3,64	0,59
12:58	0,00	1,22	NA	1,46	0,00	1,02	0,3
12:59	0,00	1,65	NA	1,20	0,00	1,33	0,45
13:00	0,00	0,00	NA	0,00	0,91	2,97	0,13
13:01	0,00	0,00	NA	0,00	1,06	1,60	0,09
13:02	0,00	0,00	NA	0,00	1,07	0,38	0,02
13:03	0,04	0,00	NA	0,03	0,89	0,43	0,02
13:04	0,00	0,00	NA	0,12	0,81	1,97	0,00
13:05	0,14	0,00	NA	0,22	1,77	1,50	0,00
13:06	0,00	0,00	NA	0,18	1,19	0,42	0,2
13:07	0,00	0,00	NA	1,00	1,00	0,00	0,24
13:08	0,00	0,00	NA	4,18	0,14	0,00	0,02
13:09	2,90	0,00	NA	2,29	1,27	0,00	0,02
13:10	2,90	0,00	NA	2,00	1,25	0,00	0,00

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
13:11	2,90	0,31	NA	2,77	0,23	0,00	0,00
13:12	2,90	0,27	NA	2,68	0,88	0,00	0,00
13:13	2,90	0,27	NA	1,47	1,08	0,00	0,00
13:14	1,35	0,18	0,31	4,12	1,10	0,00	0,00
13:15	1,37	0,00	1,71	3,37	0,24	0,00	0,00
13:16	1,37	0,24	1,77	0,86	1,15	0,25	0,00
13:17	1,30	0,18	1,56	0,24	1,28	1,41	0,00
13:18	0,00	0,00	0,00	1,42	1,32	1,37	0,00
13:19	1,52	0,00	0,00	0,14	0,55	1,12	0,00
13:20	1,52	0,00	1,53	0,15	0,54	1,00	0,00
13:21	1,52	0,00	0,00	0,19	2,15	1,02	0,00
13:22	1,52	0,18	0,00	0,00	1,02	1,65	0,00
13:23	2,11	0,15	1,37	0,00	0,39	0,38	0,28
13:24	2,11	0,00	1,65	0,00	2,29	0,05	0,31
13:25	2,11	0,00	0,00	0,00	0,87	0,13	0,10
13:26	2,11	0,34	0,00	0,00	0,00	0,81	0,00
13:27	2,11	0,00	0,00	0,00	0,00	1,21	0,00
13:28	2,11	0,12	0,00	0,00	0,00	0,31	0,00
13:29	2,11	0,00	0,00	0,00	0,00	1,51	0,00
13:30	2,11	0,00	0,00	0,00	0,00	1,21	0,00
13:31	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13:32	0,00	0,64	0,00	0,00	0,00	0,00	0,00
13:33	0,00	0,70	0,00	0,00	0,00	0,00	0,00
13:34	0,00	0,00	0,00	0,00	0,00	0,03	0,00
13:35	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13:36	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13:37	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13:38	0,00	0,00	0,00	0,00	0,00	0,52	0,00
13:39	0,00	0,00	0,00	0,00	0,00	0,42	0,00
13:40	0,00	0,00	NA	0,00	0,00	0,11	0,00
13:41	0,00	0,00	NA	0,00	0,00	0,26	0,00
13:42	0,00	0,4	NA	0,00	0,00	0,83	0,00
13:43	0,00	0,00	NA	0,00	0,00	0,06	0,00
13:44	0,00	0,00	NA	0,00	0,00	0,89	0,00
13:45	0,00	0,00	NA	0,00	0,00	0,84	0,00
13:46	0,00	0,00	NA	0,00	0,00	0,69	0,00
13:47	0,00	0,00	NA	0,00	0,00	0,95	0,00
13:48	0,00	0,37	NA	0,00	0,00	0,82	0,00

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
13:49	NA	0,55	NA	0,00	0,00	0,64	0,00
13:50	NA	0,49	NA	0,64	0,00	0,68	0,73
13:51	NA	0,00	NA	0,70	0,00	0,05	0,73
13:52	NA	0,00	NA	0,77	0,00	0,31	0,33
13:53	NA	0,00	NA	0,58	0,00	0,28	0,51
13:54	NA	0,00	NA	0,34	0,00	0,1	0,62
13:55	NA	0,43	NA	0,49	0,00	1,87	2,96
13:56	NA	2,38	NA	0,49	0,00	1,62	1,73
13:57	NA	NA	NA	0,49	0,00	1,03	1,25
13:58	NA	NA	NA	0,49	0,00	0,15	1,43
13:59	NA	NA	NA	0,49	0,00	1,80	0,80
14:00	NA	NA	NA	0,49	0,00	1,32	1,90
14:01	NA	NA	NA	0,49	0,00	0,94	1,90
14:02	NA	NA	NA	0,49	0,00	2,14	0,62
14:03	NA	NA	NA	0,49	0,00	0,93	0,95
14:04	NA	NA	NA	NA	0,00	0,00	0,97
14:05	NA	NA	NA	NA	0,00	0,39	0,47
14:06	NA	NA	NA	NA	0,00	0,41	1,13
14:07	NA	NA	NA	NA	0,00	0,00	0,70
14:08	NA	NA	NA	NA	0,00	0,42	0,19
14:09	NA	NA	NA	NA	0,00	0,48	0,02
14:10	NA	NA	NA	NA	0,00	0,16	0,00
14:11	NA	NA	NA	NA	0,00	0,26	0,00
14:12	NA	NA	NA	NA	0,00	0,41	0,39
14:13	NA	NA	NA	NA	0,00	0,76	0,81
14:14	NA	NA	NA	NA	0,00	0,4	0,40
14:15	NA	NA	NA	NA	0,00	0,62	1,15
14:16	NA	NA	NA	NA	0,00	0,89	0,87
14:17	NA	0,00	NA	NA	0,00	0,00	0,13
14:18	NA	0,00	NA	NA	0,00	0,00	0,00
14:19	NA	0,00	NA	NA	0,00	0,00	0,00
14:20	NA	3,91	NA	NA	0,00	0,00	0,27
14:21	NA	0,00	NA	NA	0,00	0,00	0,30
14:22	NA	0,00	NA	NA	0,00	0,00	0,07
14:23	NA	2,75	NA	NA	0,00	0,00	0,00
14:24	NA	2,47	NA	NA	0,00	0,00	0,72
14:25	NA	0,00	NA	NA	0,00	0,00	0,62
14:26	NA	4,18	NA	NA	0,00	0,00	0,41

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m³/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
14:27	NA	2,81	0,00	NA	0,00	NA	0,39
14:28	NA	0,00	0,00	NA	0,00	NA	0,40
14:29	NA	0,61	0,00	NA	0,00	NA	0,39
14:30	NA	2,5	0,00	NA	0,00	NA	0,49
14:31	NA	2,59	0,00	NA	0,00	NA	0,48
14:32	NA	0,00	0,00	NA	0,00	NA	0,54
14:33	NA	0,52	0,00	NA	0,00	NA	0,33
14:34	NA	2,56	0,00	NA	0,00	NA	0,46
14:35	NA	2,62	0,00	NA	0,00	NA	0,20
14:36	NA	0,00	0,00	NA	0,00	NA	0,91
14:37	NA	0,00	0,00	NA	0,00	NA	0,78
14:38	NA	NA	0,00	NA	0,00	NA	0,16
14:39	NA	NA	0,00	NA	0,00	NA	0,30
14:40	NA	NA	0,00	NA	0,00	NA	0,93
14:41	NA	NA	0,00	NA	0,00	NA	0,87
14:42	NA	NA	0,12	NA	0,00	NA	1,04
14:43	NA	NA	0,00	NA	0,00	NA	0,24
14:44	NA	NA	0,12	NA	0,00	NA	1,00
14:45	NA	NA	0,00	NA	0,00	NA	1,04
14:46	NA	NA	0,00	NA	0,00	NA	0,55
14:47	NA	NA	0,00	NA	0,00	NA	0,47
14:48	NA	NA	0,00	NA	0,00	NA	0,15
14:49	NA	NA	0,00	NA	0,00	NA	0,46
14:50	NA	NA	0,24	NA	0,00	NA	0,62
14:51	NA	NA	0,15	NA	0,00	NA	0,21
14:52	NA	NA	0,00	NA	0,00	NA	0,19
14:53	NA	NA	0,00	NA	0,00	NA	0,59
14:54	NA	NA	0,00	NA	0,00	NA	0,48
14:55	NA	NA	0,00	NA	0,00	NA	0,00
14:56	NA	NA	0,46	NA	0,00	NA	0,00
14:57	NA	NA	0,27	NA	0,00	NA	0,00
14:58	NA	NA	0,00	NA	0,00	NA	0,00
14:59	NA	NA	0,27	NA	0,00	NA	0,00
15:00	NA	2,02	1,59	NA	0,00	NA	0,00
15:01	NA	2,02	1,68	NA	0,00	NA	0,00
15:02	NA	2,02	0,00	NA	0,00	NA	0,00
15:03	NA	2,02	1,92	NA	0,63	NA	0,00
15:04	NA	0,12	1,34	NA	2,25	NA	0,00

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
15:05	NA	0,00	0,82	NA	2,63	NA	0,00
15:06	NA	0,00	2,32	NA	1,29	NA	0,00
15:07	NA	0,00	5,43	NA	2,97	NA	0,00
15:08	NA	1,95	1,22	NA	1,64	NA	0,00
15:09	NA	3,94	0,46	NA	0,91	NA	0,00
15:10	NA	3,94	4,12	NA	0,57	NA	0,00
15:11	NA	3,94	2,75	NA	0,23	NA	0,26
15:12	NA	3,74	1,47	NA	0,10	NA	0,44
15:13	NA	1,75	0,00	NA	0,57	NA	0,43
15:14	NA	1,75	1,28	NA	1,07	NA	0,98
15:15	NA	1,75	1,43	NA	1,23	NA	0,73
15:16	NA	3,72	0,00	NA	1,84	NA	0,42
15:17	NA	3,72	0,00	NA	1,91	NA	0,19
15:18	NA	1,28	0,00	NA	1,68	NA	0,79
15:19	NA	0,34	2,44	NA	1,66	NA	0,85
15:20	NA	2,20	1,16	NA	2,68	NA	0,3
15:21	NA	1,86	0,00	NA	1,74	NA	0,53
15:22	NA	2,17	1,77	NA	0,5	NA	0,79
15:23	NA	1,37	1,22	NA	2,45	NA	0,27
15:24	NA	0,52	1,65	NA	2,77	NA	0,00
15:25	NA	2,56	0,00	NA	1,32	NA	NA
15:26	NA	2,62	0,00	NA	0,83	NA	NA
15:27	NA	0,00	0,00	NA	1,83	NA	NA
15:28	NA	0,00	0,00	NA	1,65	NA	NA
15:29	NA	3,91	0,00	NA	0,73	NA	NA
15:30	NA	0,00	0,00	NA	0,68	NA	NA
15:31	NA	0,00	0,00	NA	0,22	NA	NA
15:32	NA	2,75	0,00	NA	2,39	NA	NA
15:33	NA	2,47	0,00	NA	2,12	NA	NA
15:34	NA	0,00	0,00	NA	1,95	NA	NA
15:35	NA	4,18	0,00	NA	1,18	NA	NA
15:36	NA	2,81	0,31	NA	0,39	NA	NA
15:37	NA	0,00	0,27	NA	1,86	NA	NA
15:38	NA	0,61	0,27	NA	0,48	NA	NA
15:39	NA	2,50	0,18	NA	0,00	NA	NA
15:40	NA	2,59	0,00	NA	NA	NA	NA
15:41	NA	0,00	0,24	NA	NA	NA	NA
15:42	NA	0,00	0,18	NA	NA	NA	NA

NA: Data in Appendix E not available for this time period.

Table G.1 One minute averaged vapour flow values (continued).

Time	Average flow, m^3/min						
	03 Oct 2002	04 Oct 2002	05 Oct 2002	06 May 2003	07 May 2003	08 May 2003	09 May 2003
15:43	NA	NA	0,00	NA	NA	NA	NA
15:44	NA	NA	0,18	NA	NA	NA	NA
15:45	NA	NA	0,15	NA	NA	NA	NA
15:46	NA	NA	0,00	NA	NA	NA	NA
15:47	NA	NA	0,00	NA	NA	NA	NA
15:48	NA	NA	0,34	NA	NA	NA	NA
15:49	NA	NA	0,00	NA	NA	NA	NA
15:50	NA	NA	0,12	NA	NA	NA	NA
15:51	NA	NA	NA	NA	NA	NA	NA
15:52	NA	NA	NA	NA	NA	NA	NA
15:53	NA	NA	NA	NA	NA	NA	NA

NA: Data in Appendix E not available for this time period.

APPENDIX H

Table H.1 Concentration of the individual thermal tube samples (1 to 4)*.

Sample no	mg/m^3	ppm (at 25°C, 101,325 kPa)	Vol %
1	7135	2140,55	0,21
2	530	159,11	0,16
3	17249	5174,66	0,52
4	21658	6497,32	0,65

*as supplied by Langet Laboratories (2003)

Table H.2 Average results based on the analysis from the four thermal tube samples*.

Identity	Quantity	Vol % (v)	Cumulative %	Molecular weight (m)	Molecular weight % (mv)
C1-C2	12,0466	0,21	0,21	30	0,06
Propane	187,4232	2,63	2,38	44	1,16
Butane	1037,7458	14,54	17,38	58	8,44
Pentane	1101,3727	15,44	32,81	72	11,11
Hexane	618,8492	55,73	88,55	86	47,93
Heptane	18,1921	5,52	94,07	100	5,52
Octane	0,0000	3,18	97,25	114	3,36
Nonane	43,8101	1,95	99,2	128	2,49
Decane	11,6211	0,38	99,58	142	0,54
Undecane	0,2101	0,15	99,72	156	0,23
Dodecane	1,0306	0,06	99,79	170	-
Tretradecane	0,1969	0,05	99,83	198	-
Pentadecane	0,2075	0,02	99,85	212	-
Hexadecane	0,2374	0,01	99,86	226	-
Heptadecane	0,3735	0,02	99,88	240	-
Octadecane	0,1877	0,01	99,89	254	-
Eisosane	0,5647	0,05	99,94	282	-
Tetracosane	0,1994	0,04	99,98	338	-
Average molecular weight (only VOCs)	-	-	-	-	81,1
TOTAL	-	-	100	-	-

*as supplied by Langet Laboratories (2003)

Table H.3 Results of analysis from the four gas samples*.

Component	Molecular Weight (m)	Sample 5		Sample 6		Sample 7		Sample 8	
		Volume% (v)	Molecular weight % (mv)	Volume% (v)	Molecular weight % (mv)	Volume% (v)	Molecular weight % (mv)	Volume% (v)	Molecular weight % (mv)
Methane	16	0,06	0,91	0,07	1,04	0,04	0,58	0,01	0,14
Ethane and ethylene	30	0,12	3,57	0,15	4,60	0,05	1,58	0,01	0,34
Propane and propylene	44	1,46	64,46	1,58	69,44	0,63	27,86	0,18	7,88
Iso-butane	58	2,31	133,84	2,25	130,39	0,98	57,10	0,32	18,33
1-butene	56	0,60	33,64	0,55	30,74	0,21	11,82	0,08	4,38
n-butane	58	2,26	131,14	2,06	119,39	0,79	45,79	0,30	17,38
t-butene-2	56	0,41	22,68	0,35	19,50	0,11	6,13	0,05	2,70
c-butene-2	56	0,32	18,17	0,28	15,73	0,09	5,09	0,04	2,22
Iso-pentane	72	0,01	0,39	0,00	0,30	0,00	0,07	0,00	0,05
n-pentane	72	2,41	173,43	2,10	151,04	0,72	52,20	0,32	22,80
1-pentene	70	0,07	5,14	0,06	4,15	0,01	1,03	0,01	0,60
Pentane	72	0,81	58,19	0,66	47,76	0,15	11,08	0,09	6,53
Iso-hexane	86	0,07	6,40	0,05	4,60	0,01	0,45	0,01	0,56
n-hexane	86	0,05	4,68	0,04	3,30	0,00	0,33	0,01	0,47
Iso-heptane	100	0,09	8,83	0,06	5,86	0,01	0,56	0,01	0,74
n-heptane	100	0,00	0,45	0,00	0,31	0,00	0,00	0,00	0,04
Iso-octane	114	0,01	1,54	0,01	0,98	0,00	0,00	0,00	0,16
n-octane	114	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Iso-nonane	128	0,00	0,22	0,00	0,08	0,00	0,00	0,00	0,00
n-nonane	128	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Iso-decane	142	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
n-decane	142	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total VOCs (vol %)	-	11,07	-	10,27	-	3,82	-	1,42	-
Air	28,8	88,93	2561,11	89,73	2584,26	96,18	2770,07	98,58	2839,15
Average molecular weigth (only VOCs)			60,30		59,33		58,08		60,15
TOTAL	-	100,00	-	100,00	-	100,00	-	100,00	-

*as supplied by SCI Laboratories (2003)

APPENDIX I

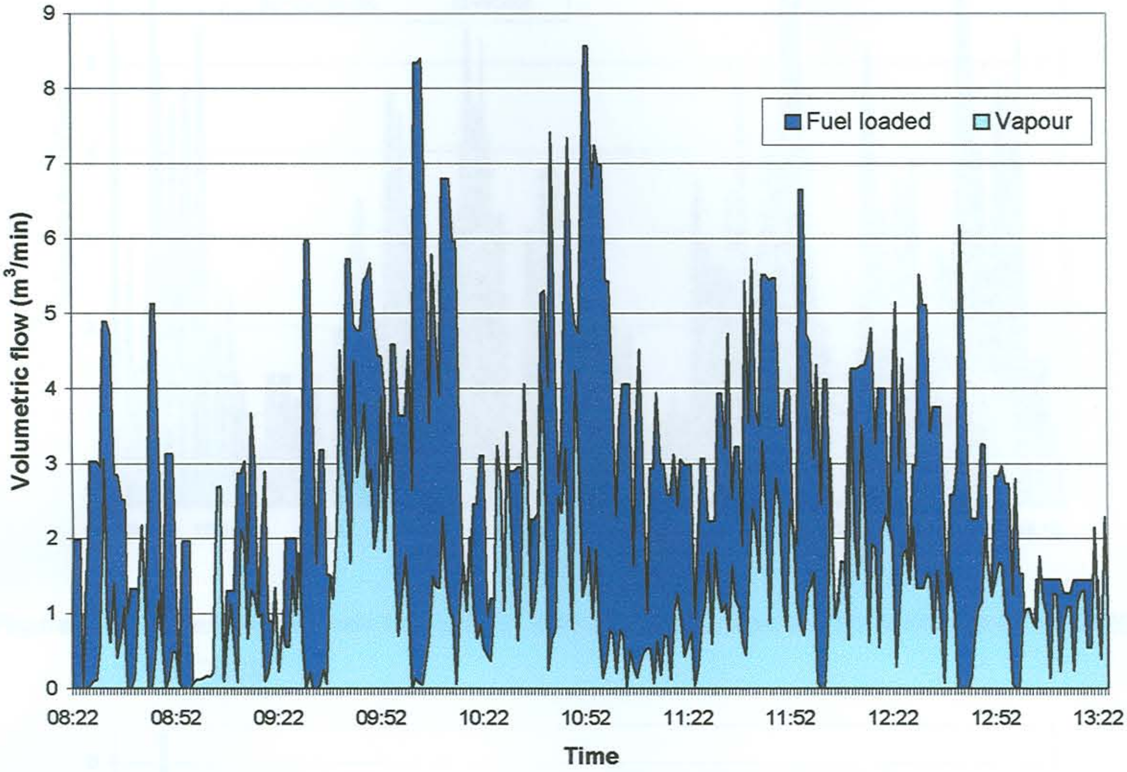


Figure I.1 Comparison between fuel loading data and vapour flow for the period 08:22 to 13:22 on 7 May 2003.

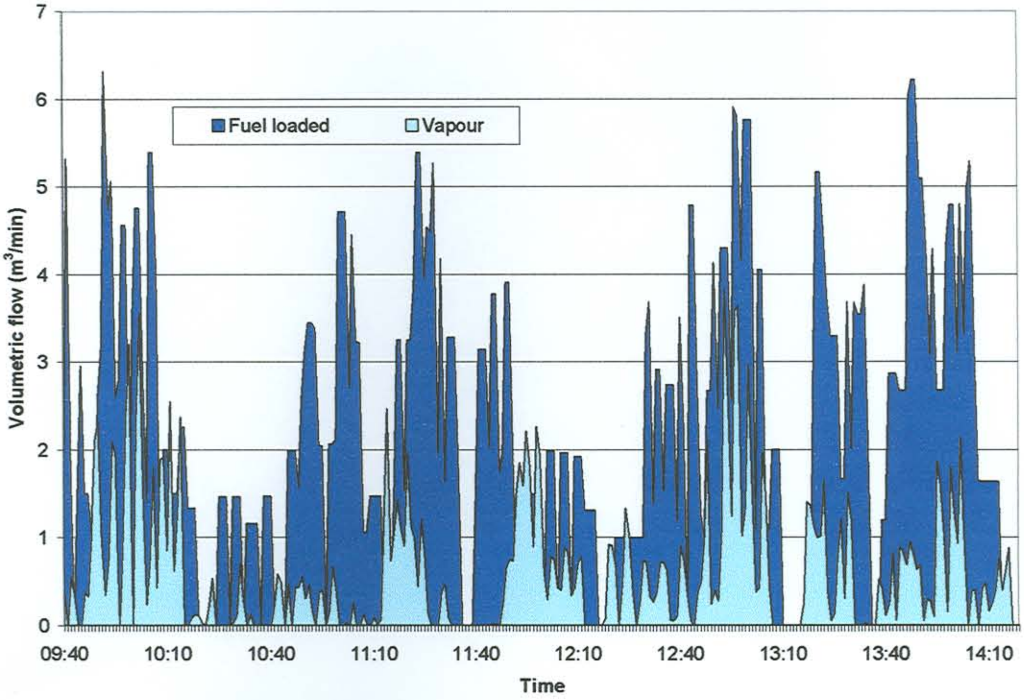


Figure I.2 Comparison between fuel loading data and vapour flow for the period 09:40 to 14:20 on 8 May 2003.

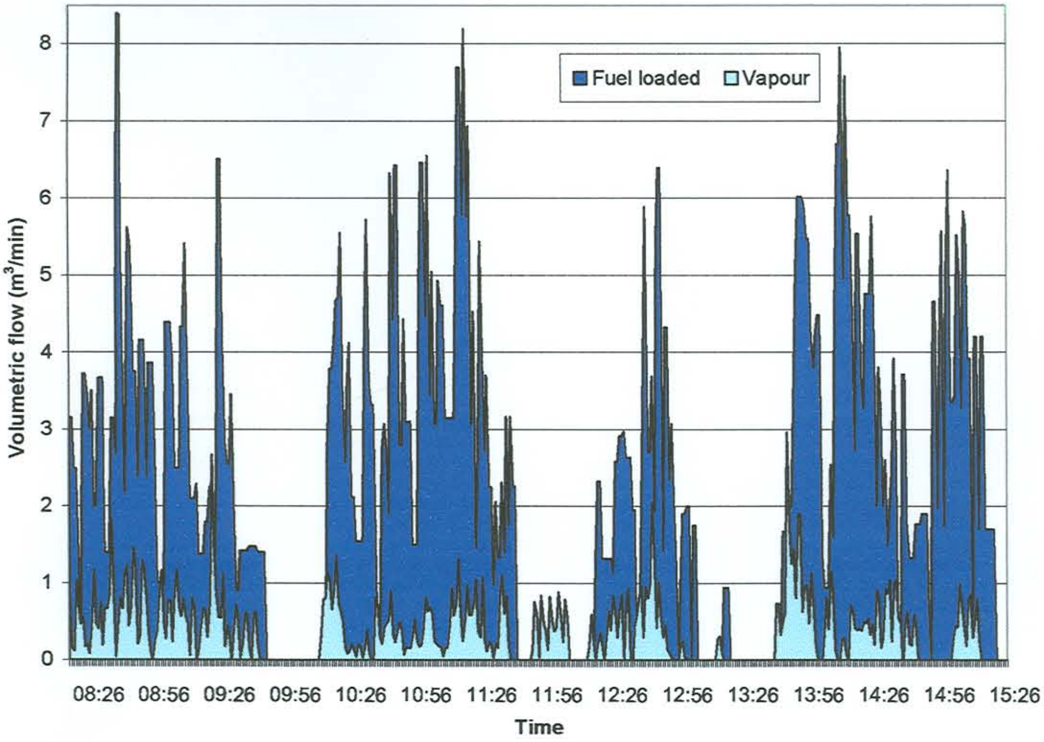


Figure I.3 Comparison between fuel loading data and vapour flow for the period 08:26 to 15:30 on 9 May 2003.